RECLAMATION
Managing Water in the West

TECHNICAL MEMORANDUM

Submitted to the Cherokee Nation and Adair County Rural Water District No. 1, Oklahoma
Prepared by the Bureau of Reclamation, Oklahoma-Texas Area Office, Native American Technical Assistance Program

Hydraulic Assessment of Adair County Rural Water District No. 1

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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ACRONYMS

BOD	biochemical oxygen demand
CBOD	carbonaceous biochemical oxygen demand
CIEUW	Commercial and Institutional End Uses of Water
DEQ	Department of Environmental Quality
DO	dissolved oxygen
EPA	United States Environmental Protection Agency
EQ	equalization
FAC	Project Planning and Facility Operations, Maintenance, and Rehabilitation
ft	feet
gal/ft	gallons per foot
GPCD	Gallons per Capita Day
GPM	Gallons per Minute
gpd	gallons per day
MOR	Monthly Operations Reports
mgd	million gallons per day
MGY	million gallons per year
CNRA	Chickasaw National Recreation Area
O&M	Operations and Maintenance
OCWP	Oklahoma Comprehensive Water Plan
OWRB	Oklahoma Water Resources Board
%	percent
POE	Point-of-Entry
RWD	Rural Water District
SBR	sequencing batch reactor
TM	Technical Memorandum
TSS	total suspended solids
USGS	United States Geologic Survey
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

The Cherokee Nation partnered with Adair County Rural Water District No. 1 (Cherry Tree) and was awarded funding for Fiscal Year 2015 under Reclamation's Native American Technical Assistance Program to evaluate alternatives to address water losses and inefficiencies associated with Cherry Tree's distribution system, such as pipeline breaks and leaks, undersized pipe, storage inefficiencies, or undocumented water losses. Many problems appear to stem from water pressures that do not meet Oklahoma Administrative Code (OAC) requirements.

Cherry Tree's distribution system was evaluated using EPANET software to simulate existing conditions associated with reported pressure and operational challenges. Hydraulic simulations confirmed water losses, high and low pressure zones, and other operational challenges reported by the Cherokee Nation and Cherry Tree.

Several infrastructure improvements were evaluated and recommended with the objective of maintaining pressures above 25 psi and below 85 psi per OAC standards. Certain exceptions were allowed in cases where higher pressure may be needed to reduce water age. Potential improvements consist of installing 13 pressure reducing valves, 11,900-ft of new pipe, a tank automation/valve control, and two booster pumps. Although the high pressures were greatly reduced by improvements, these areas should still be closely monitored for potential leaks resulting from the high pressure. Improvements are also proposed to the operational settings of the Oak Ridge Pump Station to reduce water age in the Oak Ridge Tank.

Preliminary costs were developed to assist in planning future infrastructure improvements. The preliminary costs total approximately $420,000 and are divided among several "areas" with in Cherry Tree. Numerous funding opportunities exist at the state and federal level to leverage local resources for infrastructure improvements.

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INTRODUCTION

Adair County Rural Water District No. 1 (Cherry Tree) serves a population of roughly 2,000 customers and covers over 60,000 acres of southern Adair County in the Cookson Hills of the Ozark Plateau of Northeastern Oklahoma (Figure 1). Cherry Tree purchases treated surface water from the City of Stilwell, Oklahoma. The distribution system construction began in the late sixties and has been expanded several times and as recently as the early 2000's. A hydraulic assessment to look at the distribution system as a whole has not been conducted since construction was completed. Several water meters are from the seventies and with the assistance of the Cherokee Nation, the older meters are in the process of being replaced with automated meter reading (AMR). Cherry Tree serves a very high population of Cherokee Nation Tribal members (>75%) and has been cooperating with the Cherokee Nation to seek assistance with an evaluation of the distribution system and eventual implementation of improvements.

Authority

This assessment was conducted under Reclamation's Native American Affairs Technical Assistance Program (http://www.usbr.gov/native/programs/techasst_activities_tap.html). This program supports a broad range of activities, including, but not limited to: water needs assessments; evaluations of municipal, industrial, and rural water systems; recommendations on improved water management strategies; or other planning and engineering studies. Work is typically performed by Reclamation staff through cooperative working relationships with the tribes to provide the tribes with opportunities to benefit from Reclamation's technical expertise and resources. Funding is awarded on a competitive basis through solicitations that are advertised each year, contingent upon appropriations.

The Cherokee Nation partnered with Cherry Tree and was awarded $55,000 in program funding for Fiscal Year 2015 to evaluate the infrastructure issues facing Cherry Tree. The Cherokee Nation asked Reclamation to conduct the analysis and to develop solutions to address their needs.

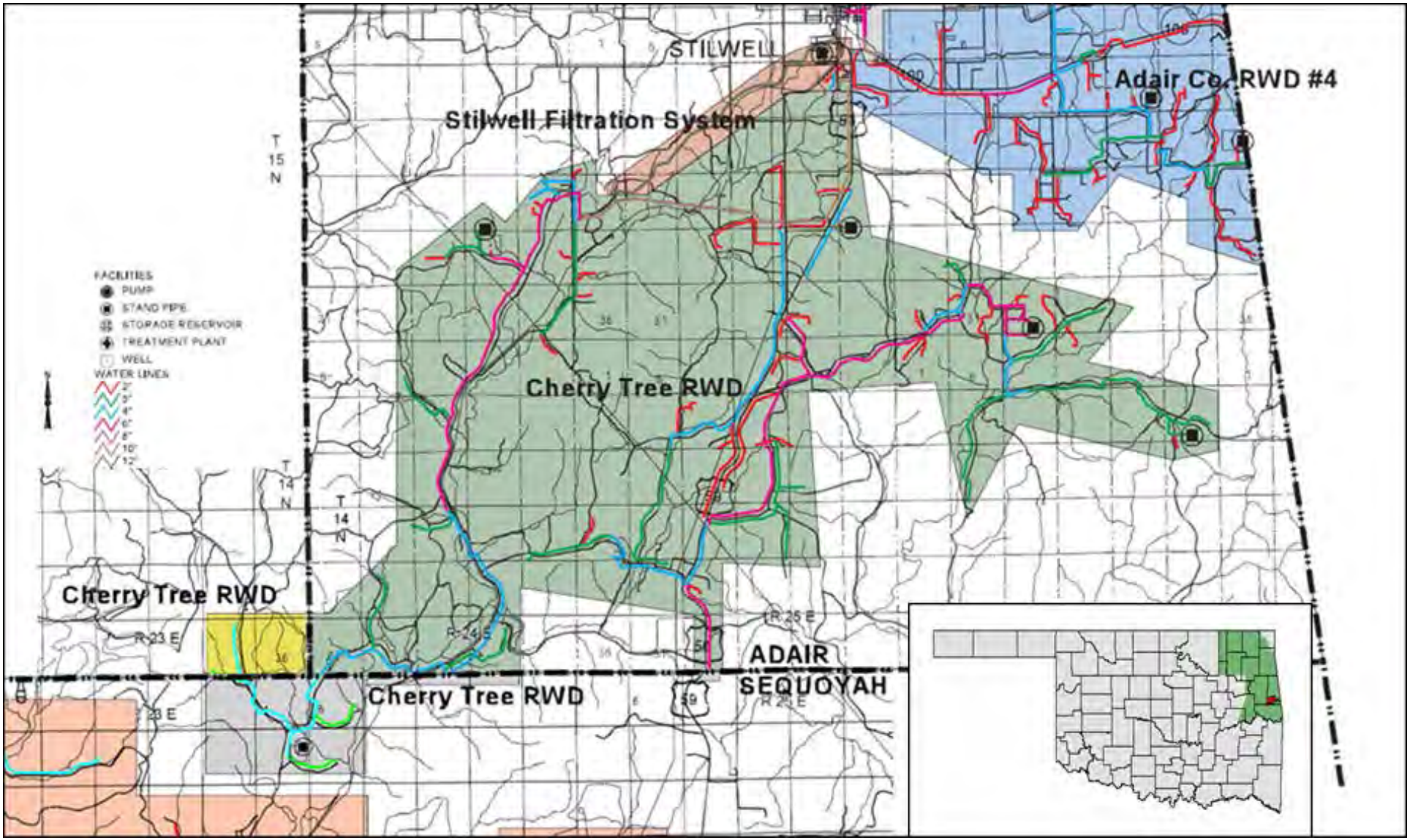

Figure 1: Cherry Tree's boundaries and Oklahoma reference map to the Cherokee Nation (green) and Cherry Tree (red).

Problems and Needs

Cherry Tree's issues in the distribution system stem from aging infrastructure and from operational changes associated with various expansions that have prevented the system from being operated as originally designed. Specifically, Cherry Tree is experiencing water losses and inefficiencies due to pipeline breaks and leaks, undersized pipe, storage inefficiencies, and undocumented water losses. Many problems appear to stem from water pressures that do not meet OAC requirements. The extreme changes in elevation exasperate this problem. The Cherokee Nation has assisted with several emergency repairs and is concerned about the reliability distribution system and wishes to examine alternatives/solutions for improvements. An assessment of the distribution system could allow the Cherokee Nation to focus on high priority needs as well as apply for specific funding from Indian Health Service and other funding agencies.

The tasks identified are:

- Perform cursory analysis of water supplies versus demands.
- Evaluate system wide hydraulics and water losses.
- Identify alternatives for upgrading the distribution system.
- Develop preliminary cost estimates for the implementation of these improvements.

EXISTING AND PROJECTED SUPPLIES AND DEMANDS

Supply

Cherry Tree and three other rural water districts in Adair County purchase treated water from the City of Stilwell. Stilwell has three sources of water. Stilwell's primary water right is Stilwell City Lake (Carson Lake) at 2,000 acre-feet per year (AFY). Stilwell also uses Evansville Creek and Star Springs as water sources with permitted amounts of 420-AFY and 710-AFY respectively. Stilwell's combined water rights are 3,130 AFY.

Demand

Water demands are based on both population growth rate and water usage. The Lower Arkansas Watershed Planning Report for the 2012 Oklahoma Comprehensive Water Plan (OCWP) Update provides an estimate for Cherry Tree's 2010 population, water use, and projected growth.

Table 1: Population projections from 2012 OCWP Update

Public Water Systems:	**Retail GPD**	**Population**						Annual Change (%)
		2010	2020	2030	2040	2050	2060	
Stilwell	455	3462	4028	4604	5179	5764	6357	1.67
Adair Co. RWD No. 1 (Cherry Tree)	148	2097	2445	2793	3141	3497	3854	1.68
Adair Co. RWD No. 2	154	912	1063	1215	1366	1521	1677	1.68
Adair Co. RWD No. 3	70	3984	4645	5307	5968	6644	7323	1.68
Adair Co. RWD No. 4	72	1075	1253	1431	1610	1792	1975	1.67
Total population		*11530*	*13434*	*15350*	*17264*	*19218*	*21186*	1.67

Table 2 compares Stilwell and its customers' water rights and projected demands as documented in the OCWP. If growth in the area's water demands is consistent with these projections, Stilwell and its customers would expect to see supply shortages as early as 2030.

Table 2: Water rights and demand information from the 2012 OCWP Update.

Public Water Systems:	**Water Rights** (AFY)	**Demand (AFY)** 2010	2020	2030	2040	2050	2060
Stilwell	3,130	1,763	2,051	2,344	2,637	2,935	3,237
Adair Co. RWD No. 1 (Cherry Tree)	-	347	404	462	520	579	638
Adair Co. RWD No. 2	-	157	183	209	236	262	289
Adair Co. RWD No. 3	-	313	365	417	469	522	575
Adair Co. RWD No. 4	-	87	101	116	130	145	160
Total Supplies & Demands	***3,130***	*2,667*	*3,104*	*3,548*	*3,992*	*4,443*	***4,899***
Supply Surplus/(Deficit)	**-**	463	26	(418)	(862)	(1,313)	(1,769)

Population Growth

The OCWP projected the population for 2010 and the data did not reflect actual 2010 census data. Recent U.S. Census Bureau data was gathered for Adair County, Stilwell, Bell Census-Designated Place (CDP), Cherry Tree CDP, Flute Springs CDP, and Greasy CDP. Cherry Tree CDP does not align with the rural water district's boundary and only includes the town of Cherry Tree's population and excludes the other communities that are served by the rural water district as shown in Figure 2.

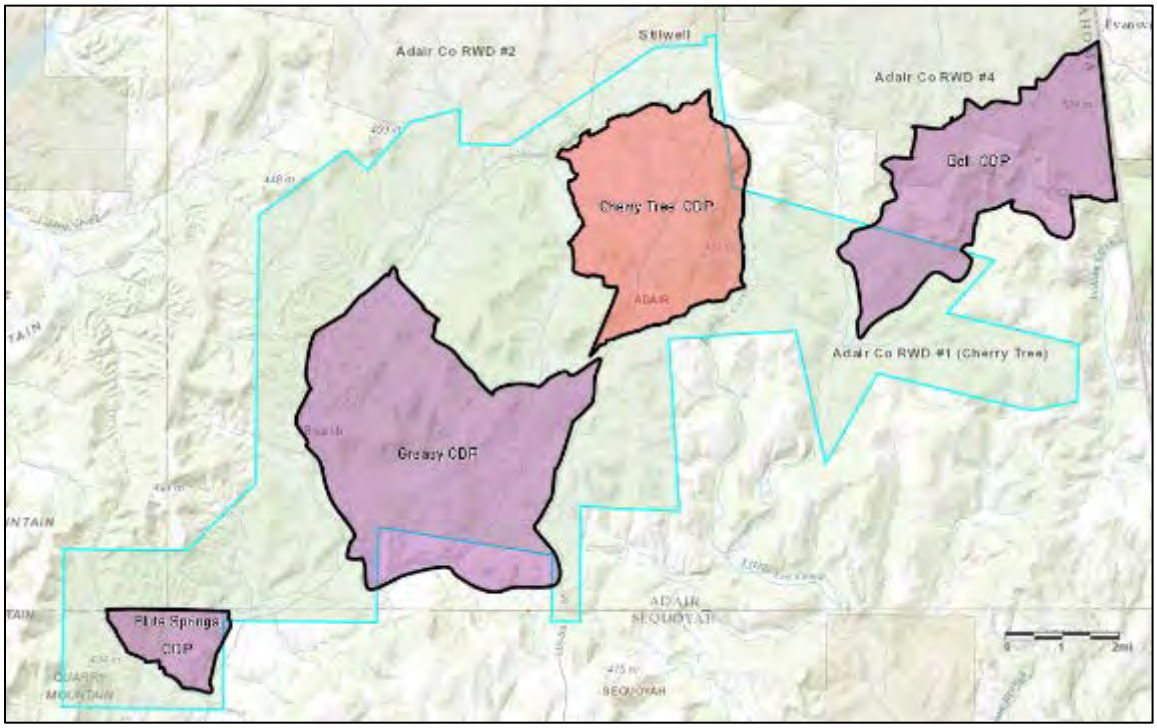

Figure 2: Map of Cherry Tree and the census tract for Cherry Tree CDP, Bell CDP, Greasy CDP, and Flute Springs CDP.

Table 3 lists the 2000 and 2010 census data and the 2014 estimated population for the four CDPs that overlap with portions of Cherry Tree and also shows Stilwell and Adair County census data for comparison.

Table 3: 2000 and 2010 census data for four CDPs that overlap with Cherry Tree, Stilwell, and Adair County and the calculated population per customer.

Local Communities:	**Zip Code**	**Census Population**		**2000 to 2010**	**2014 Population**	**2000 to 2014**
		2000	2010	% Change		% Change
Bell CDP	74960	602	535	-11.1296	522	0.95
Cherry Tree CDP	74960	1,202	883	-26.5391	970	1.38
Flute Springs CDP	74931	182	130	-28.5714	51	5.14
Greasy CDP	74931	387	372	-3.87597	300	1.61
Total		*2,373*	*1,920*	-19.0898	*1843*	1.60
Stilwell		3,276	3,949	20.54335	3974	1.52
Adair County		21,038	22,683	7.819184	22380	0.46

The Population projections and demand projections for Cherry Tree and other rural water systems supplied by the Stilwell were developed in the OCWP as increasing approximately 1.6% annually over a 50 year period. The population for the rural area around Stilwell has decreased, while the population of Stilwell and Adair County has increased. Overall population growth is occurring at less than the 2012 OCWP Update; therefore the demand growth will lag well behind the demand indicated in the 2012 OCWP update. Availability of supply does not appear to be an issue and will not be further developed in this report.

INFRASTRUCTURE ASSESSMENT

Existing Infrastructure

Cherry Tree purchases water from the City of Stilwell through a 6-inch compound meter, which has a high water level of 1240 feet above sea level (ft). The master meter is located south of Stilwell along Highway (HWY) 59. Cherry Tree uses five water storage tanks (Bell, Henderson, Killer Mountain, Oak Ridge, and Sanders Flat), three pressure reducing stations, and four pump stations (Killer Mountain, Kirk Mountain, Oak Ridge, and Star Killer Hollow).

Design or as-built drawings for Cherry Tree's distribution system were not available. As previously described, the distribution system has been extended several times since it began operations in the late sixties. It was reported that it is unlikely that a map was ever created of the entire distribution system since the last expansion in 2000. The Cherokee Nation created the distribution map included in Appendix A. This map and Oklahoma Water Resource Board's Interactive Maps and GIS Data were used to determine general locations and elevations throughout the distribution system. The Cherokee Nation map was used if discrepancies existed between maps (i.e., primarily along the southern border of Adair County). Figure 3 illustrates the distribution system's existing features and pipe network labeled by pipe diameter size.

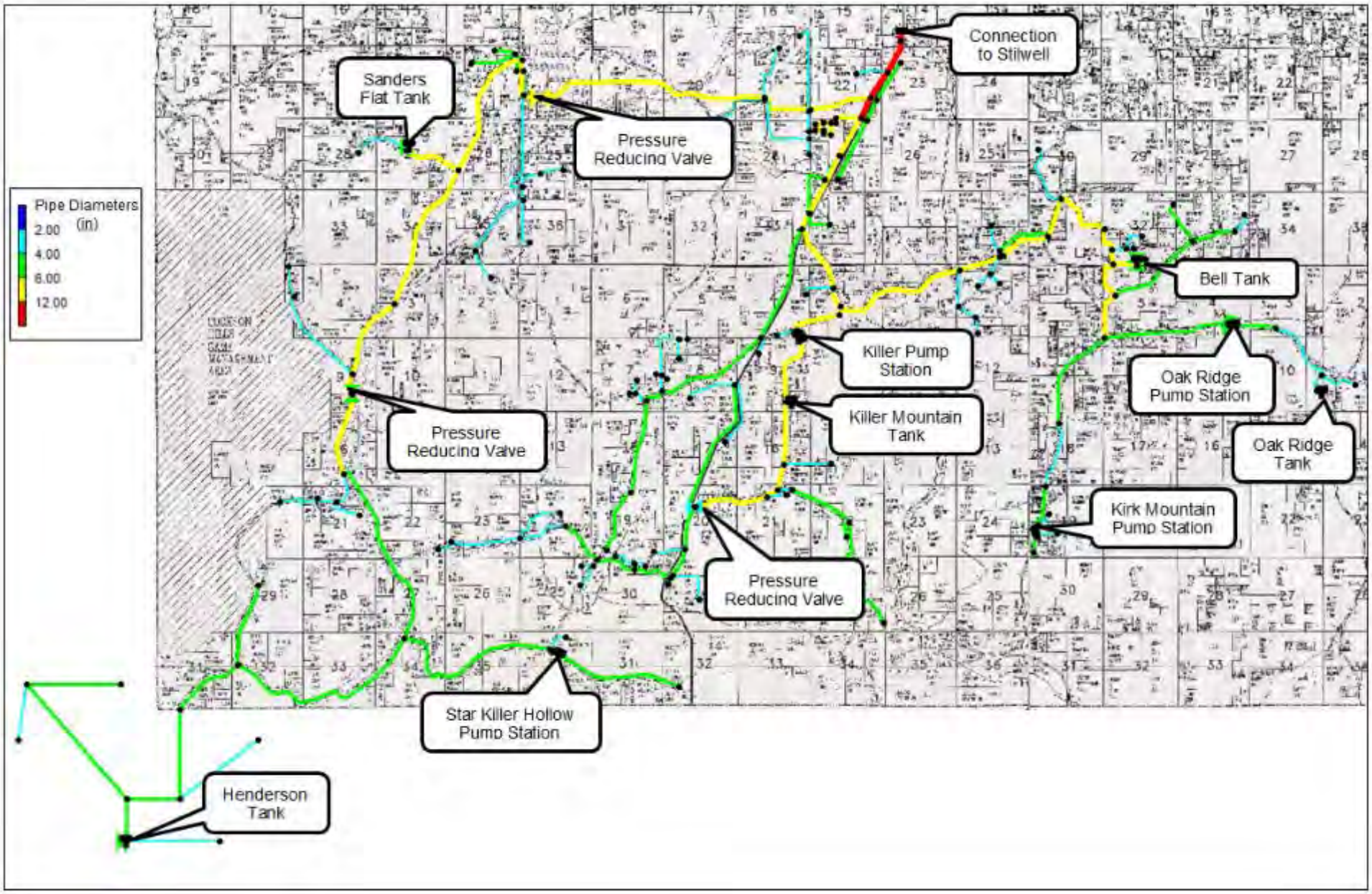

Figure 3: Pipe network for Cherry Tree's distribution system shown on a portion of an Adair County map. Note the distribution system in also part of Sequoyah and Cherokee County as shown in the lower left corner of that map near Flute Springs, Oklahoma.

The distribution system splits into two main pipelines (shown in yellow) from the Cherry Tree area. One main pipeline conveys water to Killer Mountain which then splits off into smaller lines to Bell and Greasy in the eastern portion of the distribution system. The other main pipeline conveys water to Lyons/Bunch, which then splits off into smaller lines to Flute Springs and Star Killer Hollow in the western portion of the distribution system.

The distribution system pipelines vary by age and type. The original lines from 1968 still remain in some areas near Cherry Tree. The main line from Stilwell is a 12-inch transite (asbestos cement) pipe. A large portion of this line has been transferred to Stilwell, and the District only retained a short segment of the transite pipeline. Some lines have recently been replaced with PVC in this and other areas of the distribution system during maintenance for breaks. The original east and central section of the distribution system was fed by wells. Cherry Tree decided to purchase water from Stilwell because the wells had insufficient capacity for the growing district due to the system expansions.

The eastern portion of the distribution system near Bell, Killer Mountain, and Greasy was installed in the late 1980s. The pipe in the Bell area is John Manville plastic blue pipe installed in 1985. This pipe was manufactured with a dividing seam that has cracked in many areas under the high pressures. Portions of this section have been replaced when leaks are found. Similarly, PVC pipe from two to eight inches were used to further extend other portions of the distribution system. The western portion of the distribution system was extended to Lyons, Bunch, and Flute Springs in the 1990s through the early 2000s with the final extension along Star Killer Hollow. Gate valves are installed throughout the system. In the Bell area valves were installed every quarter of a mile, but this varies in other portions of the system.

Water Use

Three years of previous water billing data were provided by Cherry Tree to assess water usage and identify high water users for the hydraulic simulations. Cherry Tree provides water to several high usage customers, including industrial users and schools. The ten largest water users account for approximately 14% of the total Districts usage. Some of the large water use is cyclical in nature; however some customers showed abnormally high uses for few months during the three year time frame.

The distribution system has had an average of 823 customers over the past three years, with over 1,010 different customers purchasing water during that time period. Figure 4 shows the fluctuation in Cherry Tree's customers during this time. Although the number of customers fluctuates, Cherry Tree has experienced only slight growth by increasing from 820 customers in December 2011 to 825 customers in February 2015.

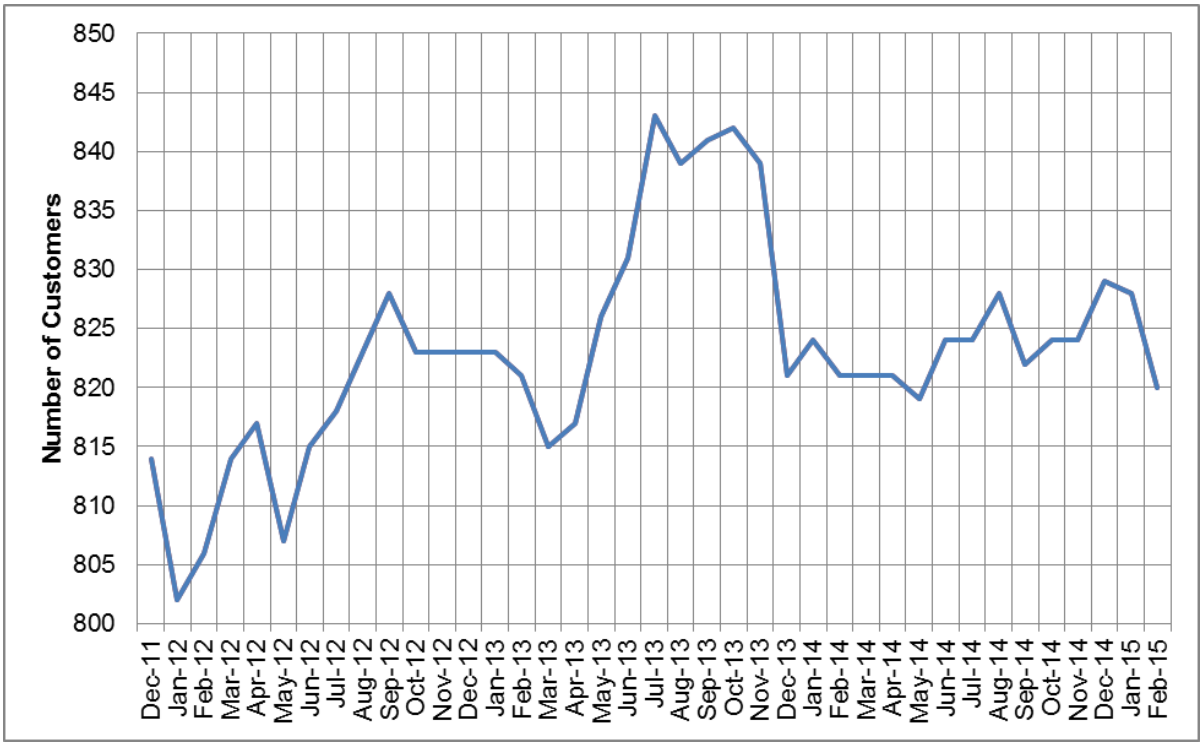

Figure 4: Number of Cherry Tree customers during the three-year time period evaluated.

Figure 5 shows the water purchased each month during the three-year time period compared to the average annual usage of 341 AF. The lowest monthly usage was 243 AF in October 2013 and the largest was 615 AF in December of 2013. Water purchased does not necessarily equate to water use, but rather the billing information only shows the water purchased/billed to each customer. Several of the large users and smaller users show substantial increase in usage November and December of 2013. It is unknown what caused the spike in usage in for this time frame. The increase could be attributed to several factors:

- Pipe breaks,
- Meter malfunctions,
- Misreading meters, or
- Increased usage from high volume customers

Cherry Tree's average monthly usage volume for the three year time period were as follows:

- 2012 - 356AF
- 2013 – 343AF
- 2014 – 318AF

A decline in usage occurred in 2014, and the number of customers using less than 25,000 gallons per month had minor fluctuations. This could suggest these variations are due to pipe breaks or other undocumented water losses and not seasonal variations in water use. This could be significantly effecting Cherry Tree's operations, especially during winter months when the largest peaks are shown in the figure.

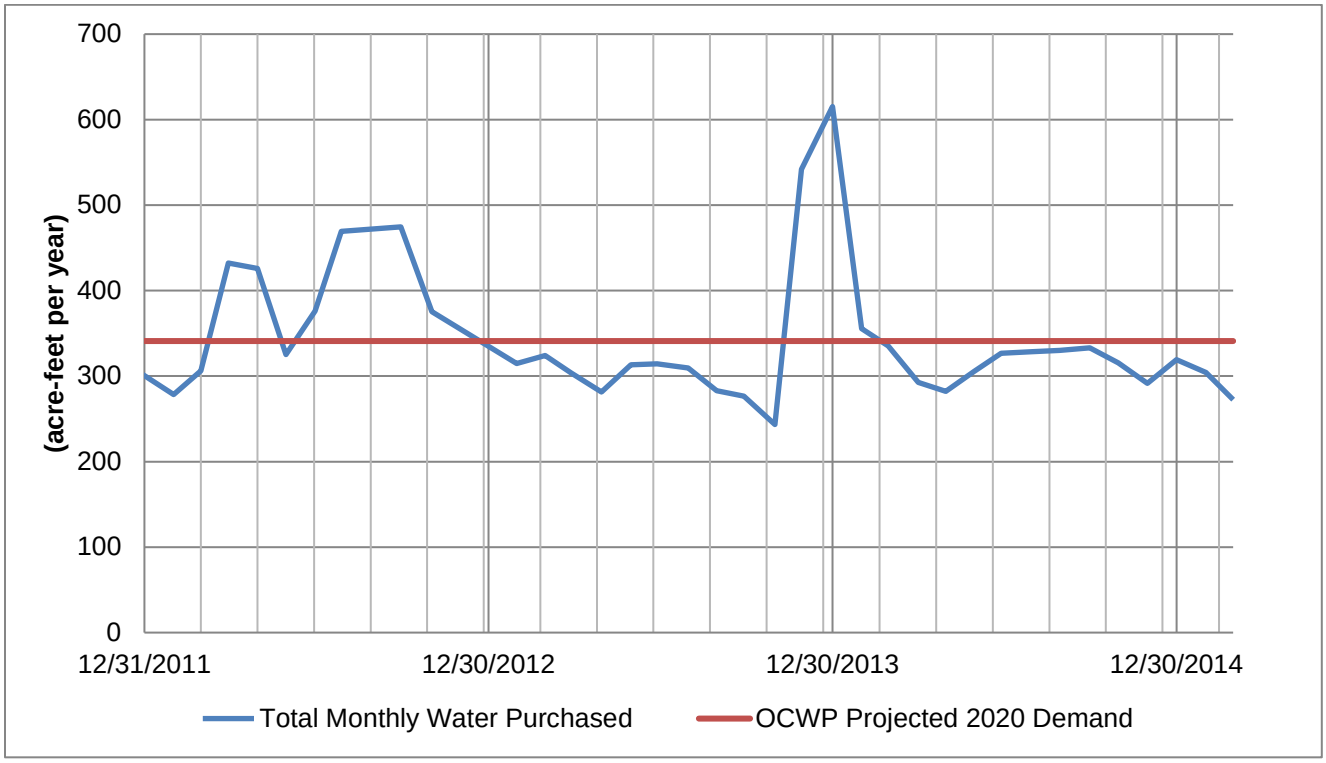

Figure 5: Total monthly water purchased by Cherry Tree based on billing data compared to the OCWP's projected 2020 demands (404 AFY).

Assuming a population per customer of 3.07, the calculated gallons per capita (gpcd) usage for the three years of billing data ranges from 55 to 270 gpcd, with an average of 120 gpcd. This average is less than the 148 gpcd reported in the OCWP for Cherry Tree; however many of these are industrial users and schools.

Figure 6 shows the percentage of customers purchasing: 25,000 gallons per month, 20,000 gallons per month, 15,000 gallons per month, 10,000 gallons per month, and 5,000 gallons per month. The billing data show that a majority of Cherry Tree's customers use less than 10,000 gallons per month. Slight seasonal variations can be observed from this figure for the summer months in 2012 and 2014, but data inconsistencies such as abnormally high usage for only a few months in 2013 prevents any conclusions from being made to determine growth rates or peaking factors.

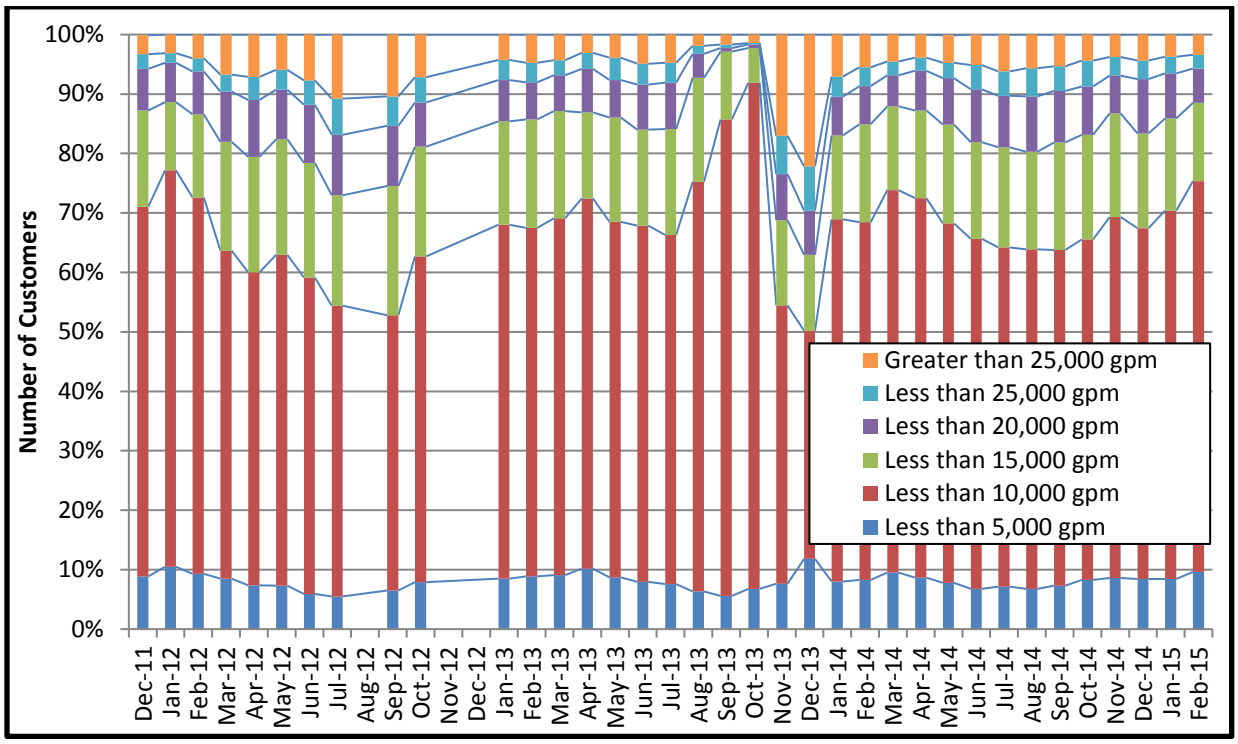

Figure 6: Water use each month and estimated number of customers based on ranges from greater than 25,000 gallons per month to less than 5,000 gallons per month.

Four months of water usage were compared. These four months include: highest month of water purchased total (December 2013), average month of water purchased total (February 2014), highest month of water purchased in 2014 (January 2014), and average month of water purchased in 2014 (October 2014). The usage show that water use of some customers were inconsistent especially in the high usage month.

Figure 7 shows each of these four months by purchased amount in escalating order verses the percentage of customers with at least that amount. This figure shows that even in months with atypical water use, a majority (over 75% percent) of the customers use less than 25,000-gallons per month; although the previous figures showed the customers with this use varied. This data indicates that the water usage could be reduced for customers if water loss is decreased, thus extending their water supply to address needs despite potential growth.

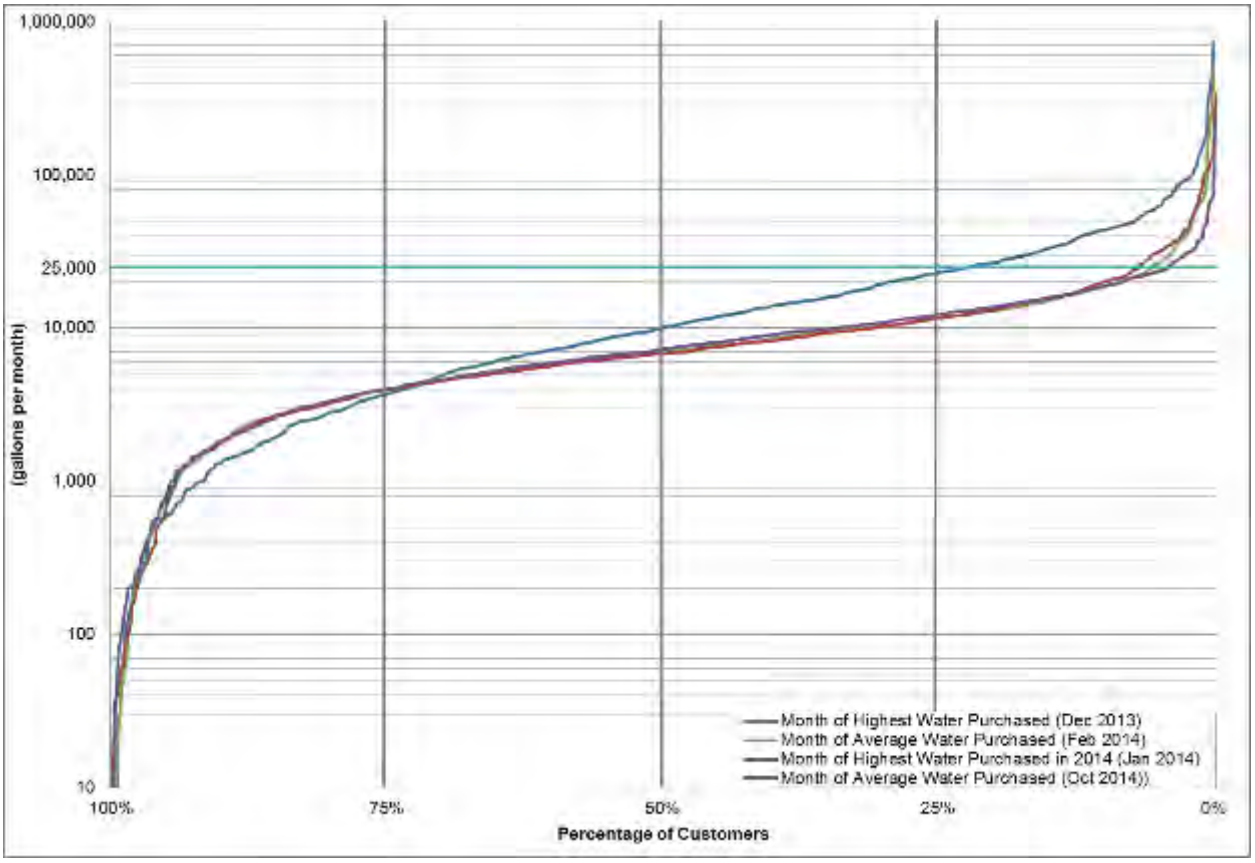

Figure 7: Monthly purchased amount in escalating order verse percentage of customers with at least that amount.

Hydraulic Simulations

EPANET software was utilized to model and conduct hydraulic simulations of Cherry Tree's distribution system as part of this analysis. EPANET is public domain software that models water distribution piping and was developed by the Environmental Protection Agency (EPA) in 2000. The program performs extended period simulations of hydraulic and water quality behavior within pressurized pipe networks. Proposed improvements were identified using the hydraulic simulations to address pressure problems and operational challenges that were reported and identified through the hydraulic simulations.

Several assumptions and limitations exist for the hydraulic simulations. First, discrepancies existed between pipe locations and diameters identified by the OWRB's network maps versus the map drawn by the Cherokee Nation. Utilizing GPS data would help resolve these discrepancies but was beyond the scope of this study. Water meter malfunctions could be contributing to unbilled water for Cherry Tree and billing data inconsistencies. Some of the water meters are from the 1970s; with the assistance of the Cherokee Nation, these older meters are in the process of being replaced with automated meter reading (AMR). Using improved billing data from the AMRs could reduce incorrect assumptions used in the hydraulic simulation. Additionally, specific pump manufacturer information, such as pump curves and settings, could also improve the hydraulic simulations.

Cherry Tree covers an area of over 60,000 acres in the Cookson Hills of the Ozark Plateau. Customers are at elevations that vary from 655 ft to 1,436 ft as shown in Figure 8. The drastic elevation shifts create the pressure challenges found throughout the distribution system. Each of the five existing tanks are at elevations to provide sufficient pressure to the customers in the respective areas. Star Killer Hollow and Kirk Mountain are the only areas that are constantly pressurized using pumps. These two areas have few customers so it is unlikely that there is enough economic benefit to installing a standpipe in these areas; however, potential energy recovery or renewable energy options exist that could help Cherry Tree offset the energy use to maintain the pressure in these areas.

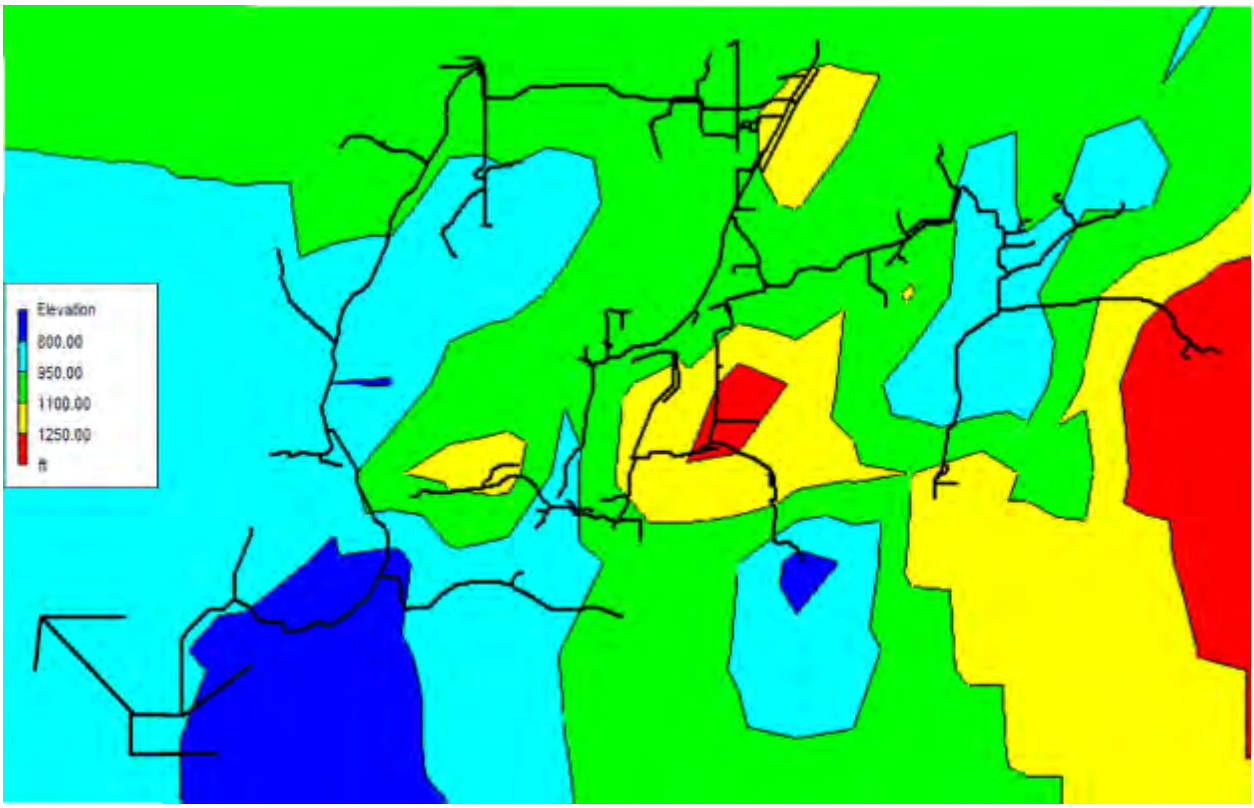

Figure 8: Contours plot of the elevation variations within Cherry Tree and the distribution system outlined in black from EPANET.

Several sources of data were used for the hydraulic simulations including: Policy and Procedure for Cherry Tree (as amended January 29, 1987), distribution system map created by the Cherokee Nation for this project, billing data, and elevations from Topographic maps/Google Earth. Table 4 lists the conditions for tanks, pressure reducing valves, and pumps used in the network model.

For the purposes of this assessment, the system was divided into nine areas labeled as Bell, Bunch (Cave Springs), Cherry Tree, Flute Springs (Henderson), Greasy, Killer Mountain, Lyons (Sanders Flat), Oak Ridge, and Star Killer Hollow.

The four months of water usage data described in the Water Purchased Section were used for the hydraulic simulations as recorded in Table 5. It was decided that these four demand scenarios would best model the actual range of flows that Cherry Tree experiences. These four demand scenarios used for hydraulic simulations were:
Scenario 1-Highest month of water purchased total (December 2013),
Scenario 2-Average month of water purchased total (January 2013),
Scenario 3-Highest month of water purchased in 2014 (February 2014), and
Scenario 4-Average month of water purchased in 2014 (October 2014).

This data was used to develop the network operations and functions, as well as to develop proposed improvements. The 35 largest customers were identified during the four months and applied to their respective location in the network model. All additional demands were

distributed equally over the system except in low population areas, where only the average customer use was applied. Demand patterns for the simulations were applied in 24-hr cycles with a peaking factor of 2.4 for ten consecutive hours during each cycle and no peaking factor for the remaining hours.

Table 4: Tanks, pressure reducing valves, and pumps condition identified in the Policy and Procedure for Cherry Tree and control conditions to operate during all four demand scenarios. Note not all three pumps at Killer Mountain are 7.5-hp motors, but were adjusted to such for the network model operations.

Tank Conditions:	**Bell**	**Henderson**	**Killer Mountain**	**Oak Ridge**	**Sanders Flat**
Elevation (ft)	1,140	900	1,350	1,400	1,105
Diameter (ft)	12	15	14	7	14
Height (ft)	70	70	70	70	70
Volume (gallons)	59,000	92,000	80,000	20,000	80,000
Initial Level (ft)	40	50	50	25	50
Minimum Level (ft)	0	30	10	10	0
Maximum Level (ft)	70	70	70	70	70
Level Controls	-	-	10	15	-
	-	-	70	50	-

Pressure Reducing Valve Conditions:	**Cave Springs**	**Cave Springs (bypass line)**	**HWY 59**	**Lyons Community**
Diameter (in)	2	4	2	2.5
Adjustable Range (psi)	15-75	50-150	15-75	15-75
Specified Setting (psi)	75	120	53	67

Pump Conditions:	**Killer Mountain**	**Kirk Mountain**	**Oak Ridge**	**Star Killer Hollow**
Latitude	35°42'46.37"N	35°40'25.05"N	35°42'46.66"N	35°38'50.14"N
Longitude	94°38'56.72"W	94°35'41.41"W	94°32'47.26"W	94°42'30.82"W
Elevation (ft)	980	1,090	1,065	860
Pumps in Parallel	3	1	2	1
Motor (hp)	7.5	3	3	3
Flow (gpm)	10	18	18	18
Head (ft)	385	258	258	258

Table 5: Demands scenarios used for the network simulations based on the four highlighted months.

Demands:	**Scenarios for Water Purchased** (gallons per day)			
	Scenario 1: Highest Month (Dec 2013)	Scenario 2: Average Month (Jan 2014)	Scenario 3: Highest Month in 2014 (Feb)	Scenario 4: Average Month in 2014 (Oct)
Total	531,213	306,924	320,625	281,378
Average	647	372	391	341
Distribution of other demands	2,954	1,682	1,939	1,755
Largest Tap Users:				
109	4,588	2,784	471	397
133	5,618	380	170	11
213	3,715	4,388	814	228
282	3,635	565	364	361
308	4,355	99	112	111
340	2,728	597	850	727
375	14,216	10,926	9,946	11,913
400	836	326	462	497
424	2,978	4,042	2,309	106
435	2,965	3,387	921	849
450	2,533	12,170	921	305
~~508~~	302	220	189	293
516	9,457	1,052	286	249
522	674	1,956	1,273	243
531	478	512	607	378
570	483	340	326	680
655	3,209	3,234	1,388	772
658	2,220	1,739	2,363	2,258
700	2,753	3,293	1,771	451
705	4,999	889	1,003	722
710	-	-	-	882
771	1,296	347	758	2,467
773	4,432	4,001	6,243	5,374
774	1,498	558	943	1,867
775	2,335	1,987	2,529	2,313
776	10,914	13,017	17,871	8,613
778	11,752	3,417	381	564
837	1,797	3,640	2,147	1,121
844	5,172	921	1,337	1,547
848	24,039	721	720	-
859	745	388	489	451
866	1,318	313	399	388
924	310	204	166	145
1238	-	853	1,119	696
1255	-	-	1,054	-

Existing Conditions

The distribution system was evaluated under the four Demand Scenarios to simulate and compare to the reported pressures and operational challenges. Oklahoma Administrative Code (OAC) 252:626-19-1 requires that a hydraulic analysis of the system must demonstrate that a minimum of 25 psi should be maintained throughout the distribution system during peak demands. Pressures over 85-psi are considered excessive and harmful to infrastructure. Sustained pressure that exceeds 85-psi can damage residential plumbing systems that are designed for lower pressures and may affect the Cherry Tree's water fixtures, pipe connections, and valves. Therefore 25 to 85-psi is considered the ideal range of pressure for this analysis.

The hydraulic simulations identified high and low pressure areas throughout the distribution system under all four demand scenarios. Figure 9 shows the modeled pipe network when Bell, Lyons, and Greasy's water pressures are the highest under Demand Scenario 2 – Average Month. Similar results were found under the other three demand scenarios where these areas experience particularly high pressures.

The Henderson Tank was reported as unable to fill and being under-utilized. This was confirmed through the network simulations, as shown in Figure 10 and Figure 11. The Henderson Tank is hydraulically tied to the Sanders Flat Tank. The Sanders Flat Tank is unable to empty and fill more than a few feet due to high pressures which are limiting the tank's use. This restricts the Henderson Tank's ability to fill as well. Based on the existing conditions and assumptions used as part of the hydraulic simulations, the Sanders Flat Tank remains between 89 to 96% full at all times. The model indicates that the water in the Sanders Flat Tank is not cycling through the tank is stored with minor mixing for long periods of time.

Water age is a general indicator of water quality, and lower water age indicates better water quality. When chlorine reacts with organic material in water on the pipe walls, the residual disinfectant concentration diminishes as water remains in a distribution system. If treated water stays in the system a long time before it reaches consumers, disinfectant concentration may not be strong enough to control microorganisms. Longer travel times also mean more reaction time for disinfection by-product formation, an additional health concern. This long storage time increases health concerns and the Sanders Flat Tank should be investigated further to determine whether the tank is storing excess water and increasing the water age for the entire section of the distribution system past Lyons.

A similar concern potentially exist at the Oak Ridge Tank. The Oak Ridge Tank serves only a few customers. The network simulations indicated the tank is storing water for extended periods of time, thereby; increasing the water age by over 2¼ days for its customers. The tanks size allows it to store more water than the minimal customer demands in the area. The Oak Ridge Tank is controlled by a water level sensor at the Oak Ridge Pump Station which can be easily adjusted to alleviate this concern. OAC 252:626-17-4 Distribution Storage states that "the maximum design variation between high and low levels in storage structures providing pressure to distribution system is 30 feet"; for this tank and the few customers the design variation should be further limited.

The hydraulic simulation under the existing conditions confirmed the water loss, high and low pressures, water age and operational challenges reported by the Cherokee Nation and Cherry Tree.

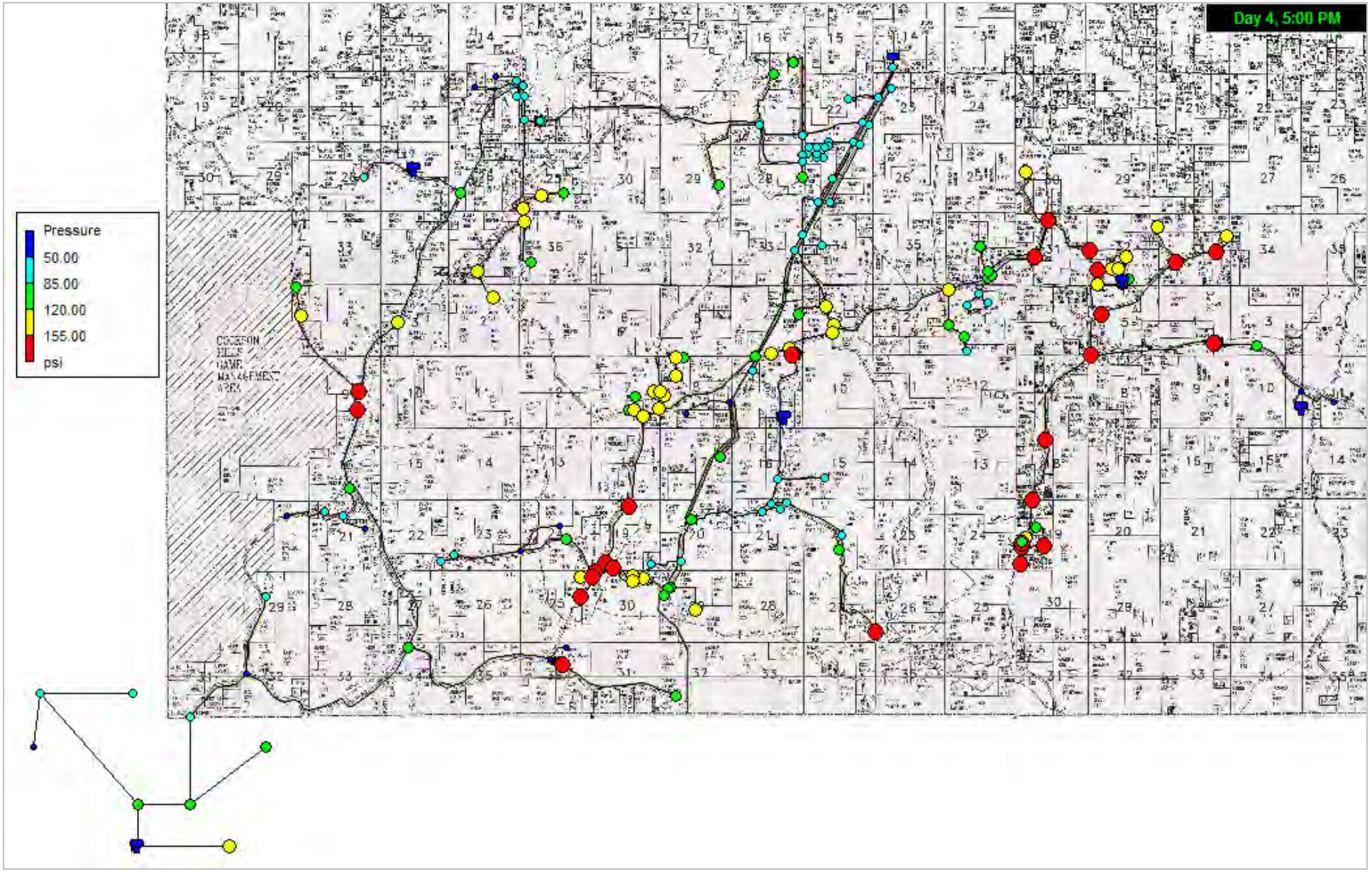

Figure 9: Modeled pipe network showing the pressure range when Bell, Lyons, and Greasy's water pressures are the highest for existing conditions under Scenario 2 – Average Month.

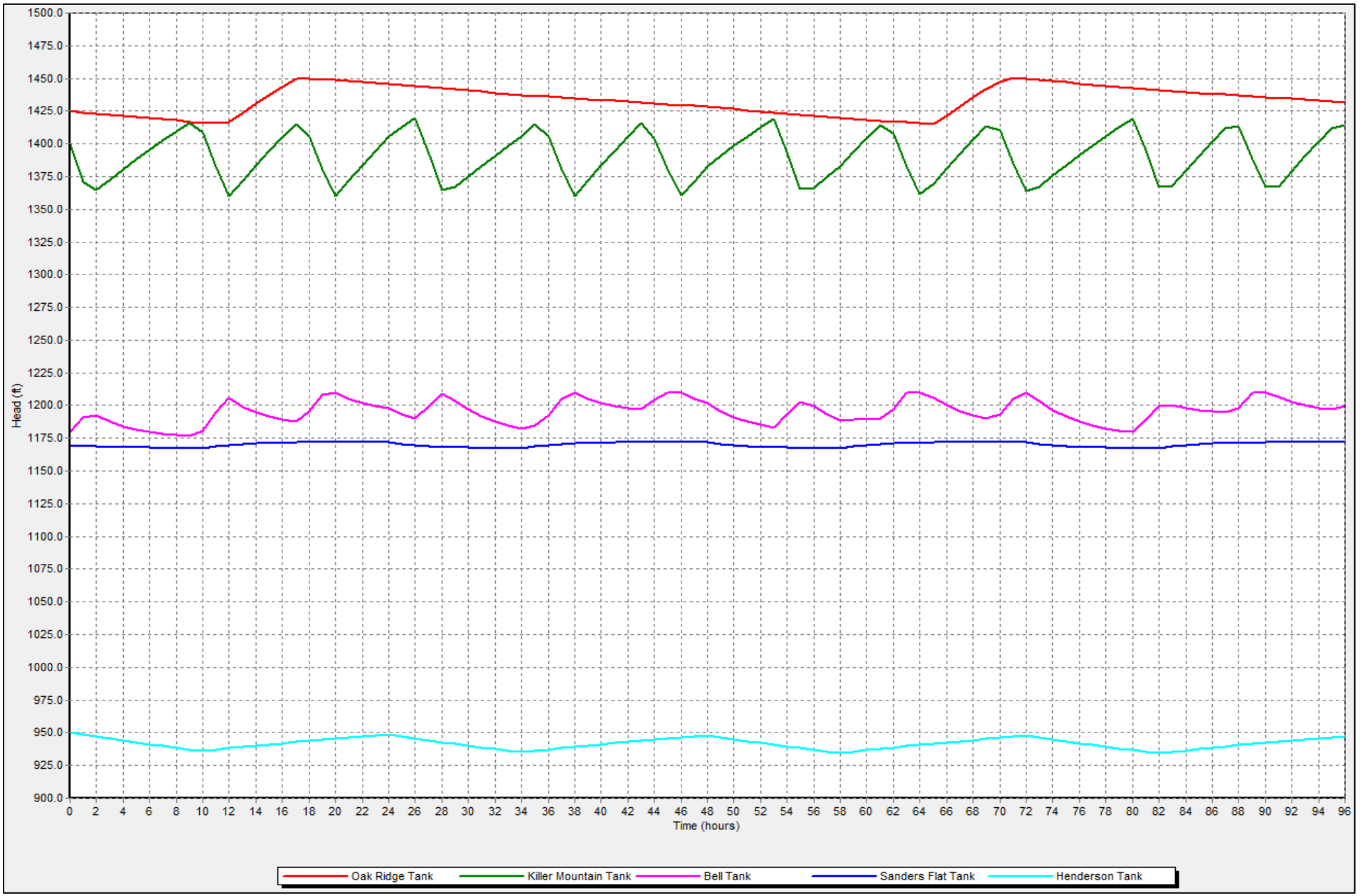

Figure 10: Graph of tank elevations for the modeled pipe network over a 96-hr period for existing conditions under Scenario 2 - Average Monthly Use. Note the Sanders Flat Tank is only being used for approximately 5-ft of elevation for storage. Conversely, the Oak Ridge Tank, which provides water to a relatively small number of customers, is being used for approximately 45-ft of storage, increasing the water age to its few customers by over 2¼ days.

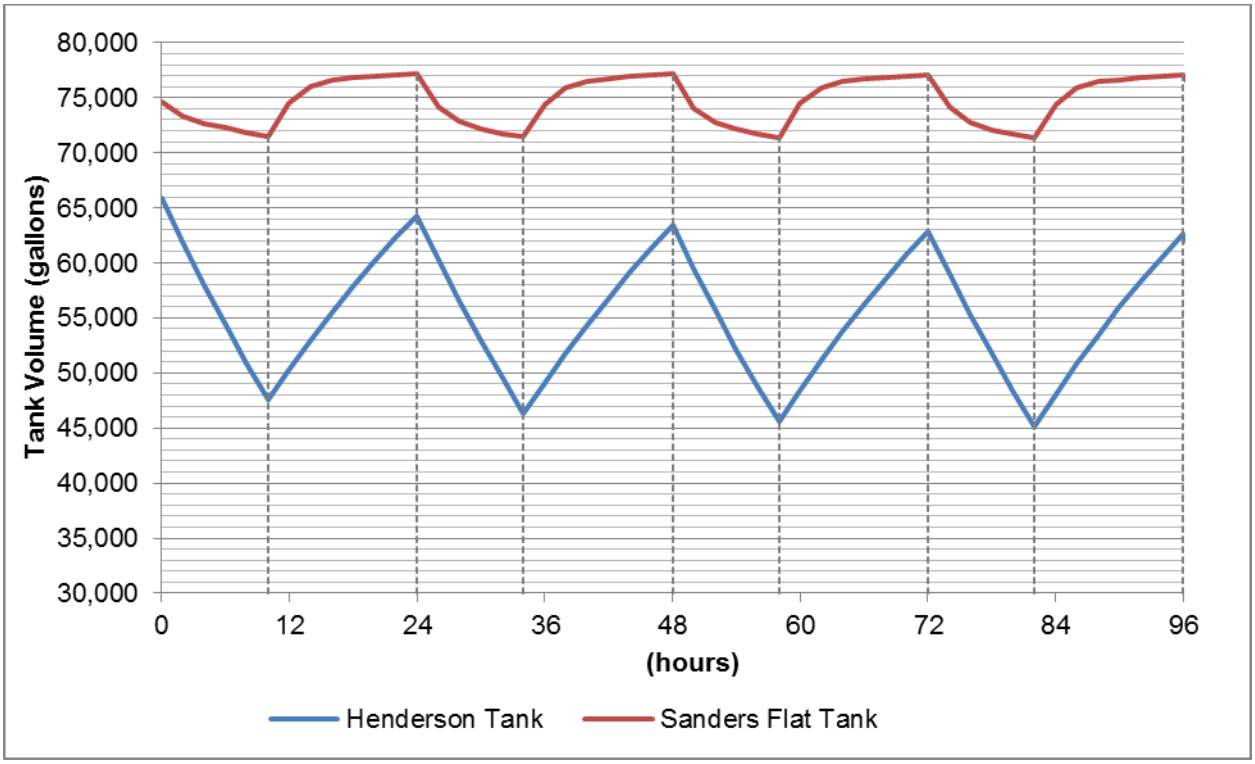

Figure 11: Henderson and Sanders Flat Tank Volumes over a modeled 96-hr period for existing conditions under Demand Scenario 2 - Average Monthly Use to show the connectivity limiting a full recovery in the Henderson Tank and the active volume of the Sanders Flat Tank.

Pressure exceed 100-psi and go up to 160-psi in some locations, in particular the area South of Lyons and north of Bunch along Bunch Rd. If the pressure were reduced in this area to an acceptable range it would prevent the Sanders Flat Tank from filling as needed and it would reduce the pressure for the customers in the relatively high elevation area of Cherokee County along E0950 Rd (northwest of Flute Springs). The area northwest of Flute Springs is close to the minimal pressure of 25-psi. The pressure should be monitored around this location at the highest customer on the line to determine if the pressure does drop below 25-psi as shown in the model results.

Similarly, Vanderheiden Mountain between Killer Mountain and Bell, southwest of the intersection of E0890 Rd/D4723 Rd has a higher elevation resulting in low water pressures that fluctuate between 12 and 62-psi. The pressure in this area is impacted by the operations the Bell and Killer Mountain Tanks; however, more dramatically by the Killer Mountain Tank because the area is at a higher elevation than the Bell Tank. These two tanks are hydraulically connected, along with the Oak Ridge Tank. As each of the tanks fill and empty, the pressure in the mainline changes and causes the flow and pressure to vary tremendously. The pressure should be monitored near this location and at the highest customer on the line to determine if the pressure does drop below 25-psi as shown in the model results.

Proposed Improvements

1. Proposed improvements were identified to address the following issues and in the order listed: Low Pressure-In locations with low pressure, simulated improvements include a) increasing pressure allowances in existing pressure reducing valves, b) increasing water level elevations in tanks, or c) installing a booster pump station. Installing booster pump stations would result in an increase in monthly energy and maintenance costs for Cherry Tree that could not be covered as part of a grant or loan. Therefore, booster pump stations are only proposed in locations where no other alternatives to increase pressure were identified. For example, a booster pump station was not identified for the area northwest of Flute Springs because operational improvements to allow the Henderson Tank to maintain higher water level elevations could increase pressure to the area.
2. Long Water Age-In locations with long water age, simulated improvements include a) modifying existing tank controls or b) installing new tank water level control sensor and actuated valve.
3. High Pressure-In locations with high pressure, simulated improvements include a) installing new pressure reducing valves, b) disconnecting lines in looped connections to isolate areas from high pressure, or c) installing new pipelines. Installing new pipelines were only considered where no other alternative to decrease pressure could be identified.

The hydraulic simulations were adjusted by adding the proposed improvements. These proposed improvements were found to reduce high pressure zones while maintaining a minimum of 25-psi throughout the system and allowing each tank to store and release water to minimize water age.

Improvements added consisted of installing 13 pressure reducing valves, 11,900-ft of new pipe, a tank automation/valve control, and two booster pumps. These proposed improvements are labeled in red on the distribution system map on Figure 12. Improvements are also proposed to the operational settings of the Oak Ridge Pump Station to reduce water age in the Oak Ridge Tank.

Figure 12 shows the modeled pipe network with the proposed improvements when Bell, Lyons, and Greasy's water pressures are the highest, which is under Scenario 2 – Average Month. This can be compared with the pressures shown in Figure 9. Note even with the proposed improvements, some locations still have pressures above 85-psi as necessary to maintain a minimum pressure of 25-psi at all locations. Although the high pressures at these locations were greatly reduced by the proposed improvement, these areas should still be closely monitored for potential leaks resulting from the high pressure.

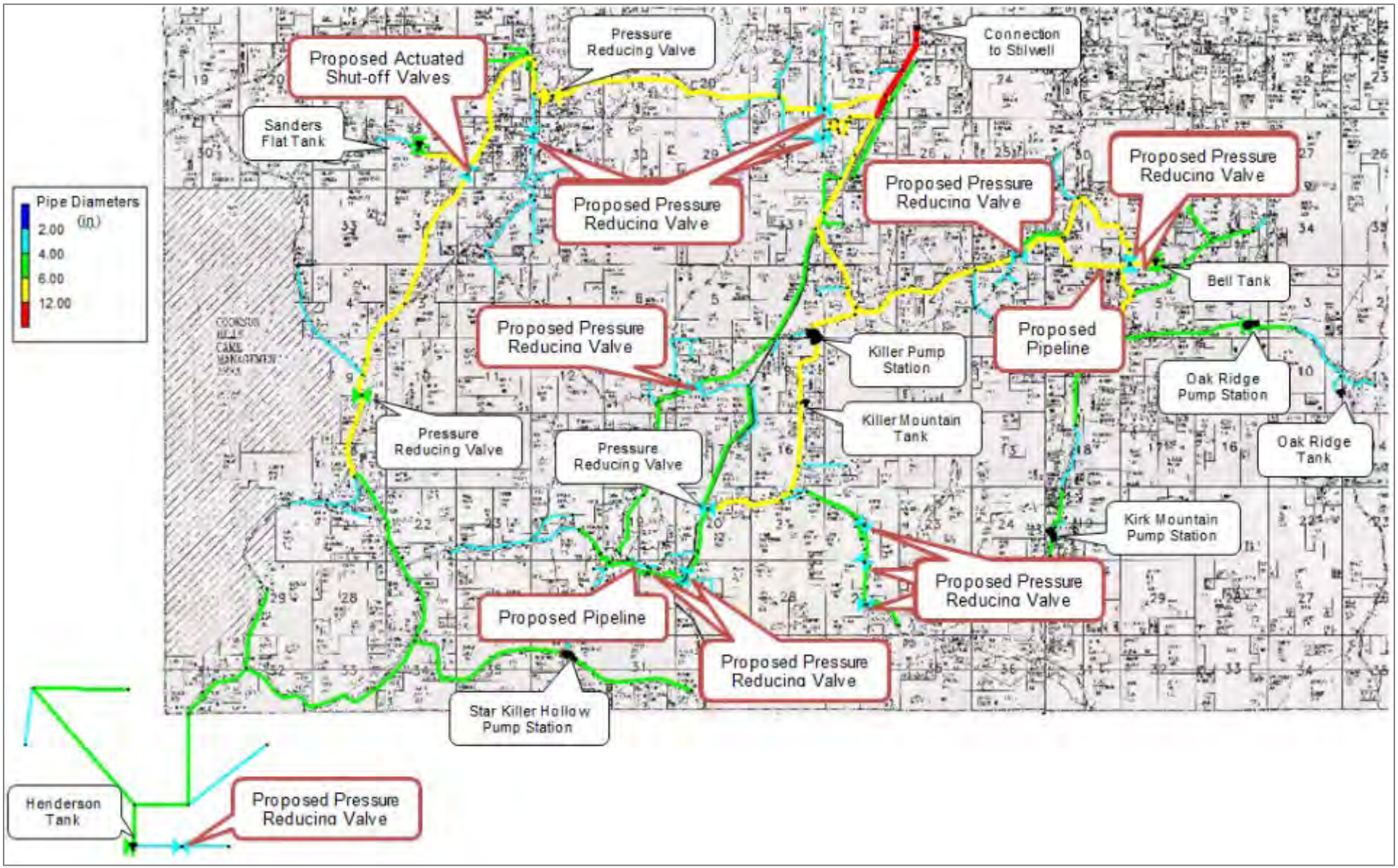

Figure 12: EPANET pipe network for Cherry Tree's distribution system shown on a portion of an Adair County map. Note the distribution system in also part of Sequoyah and Cherokee County as shown in the lower left corner of that map near Flute Springs, Oklahoma.

Figure 13: Modeled pipe network showing the pressure range with proposed improvements under Scenario 2 - Average Monthly Use. (Compare with Figure 9).

With the proposed improvements, the Sanders Flat Tank could be used for 30-ft of active storage, as shown in Figure 14, about 28,000-gallons more than existing conditions. This proposed improvement could also allow the Henderson Tank to fill to meet demands regardless of the Sanders Flat Tank activity.

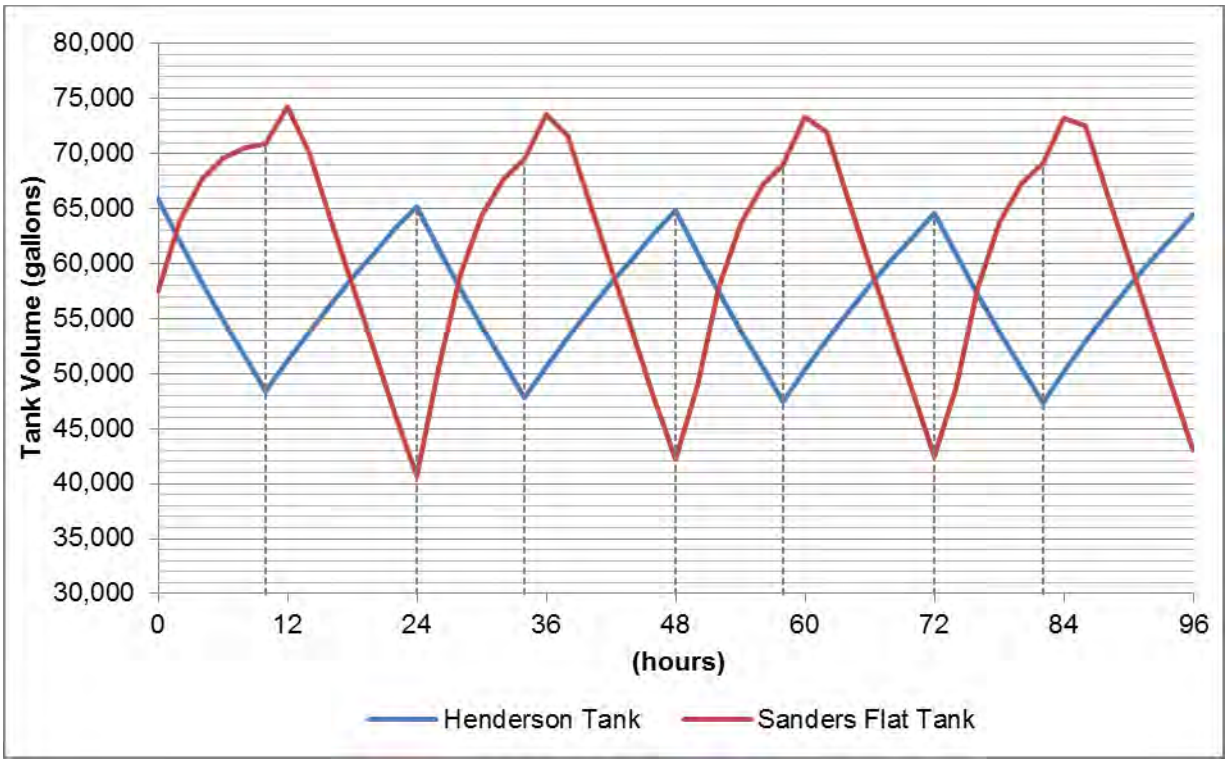

Figure 14: Henderson and Sanders Flat Tank Volumes over a modeled 96-hr period with proposed improvements under Demand Scenario 2 - Average Monthly Use to show an increase in the active volume of the Sanders Flat Tank and connectivity no longer limiting the Henderson Tank from filling.

Details for each of the proposed improvements are described for each area below and illustrated in Figure 15-Figure 20. Preliminary cost estimates were developed for each of the proposed improvement as described in Appendix B and shown in Table 6-8. Other potential Alternatives to the proposed improvements do exist, but the proposed improvements were evaluated to minimize capital and operational costs as part of this preliminary analysis utilizing technology Cherry already maintains. Table 6 summarizes all of these changes and a comparison of the cost estimates for each area's proposed improvements.

Table 6: Summary table of the proposed improvements by each area and estimated costs.

Proposed Improvement by Area:	**Subtotal**	**Contingencies**	**Total**
Cherry Tree Area	$2,324	$2,700	$5,000
Lyons Area	$18,007	$22,000	$40,000
Flute Springs area	$775	$1,200	$2,000
Greasy area	$41,350	$49,600	$91,000
Killer Mountain area	$2,324	$2,700	$5,000
Bell area	$121,912	$147,100	$269,000
Total	**$186,692**	**$225,300**	**$412,000**

Proposed improvements for the Cherry Tree area:

The proposed improvements in the Cherry Tree Area consist of three pressure reducing valves:

1. Near Dahlonegah School the pressure increases to over 80-psi and up to 110-psi in some locations. Installing a pressure reducing valve would limit the pressure on the north side of N4700 Rd and Dahlonegah School Rd to 35-psi and control the pressure for customers on the downstream lines to an acceptable range (between 25 to 85-psi).
2. Near the airport along N4700 Rd the pressure increases to almost 120-psi. Installing a pressure reducing valve would limit the pressure on the north side of N4700 Rd and Industrial Park Rd to 35-psi and control the pressure for customers on the downstream lines to an acceptable range.
3. South of Cherry Tree along Greasy School Rd the pressure increases to over 100-psi and up to 160-psi in some locations. Installing a pressure reducing valve would limit the pressure south of Cherry Tree along Greasy School Rd where the elevation is approximately 980-ft to 40-psi. This could control the pressure for customers on the lines south of Cherry down to Greasy to an acceptable range.

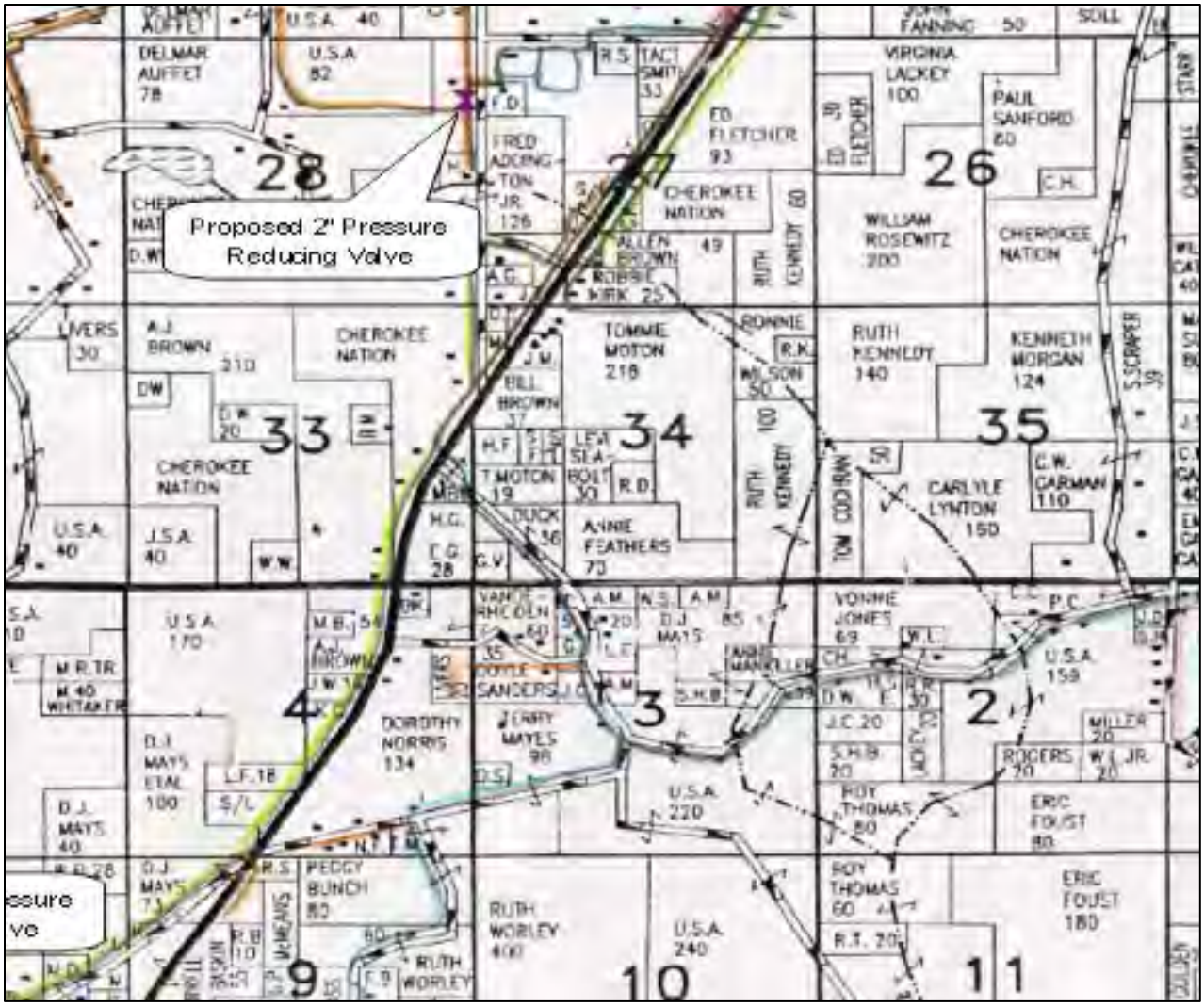

Figure 15: Approximate location of three pressure reducing valves proposed in the Cherry Tree area.

Proposed improvements for the Lyons area:

Improvements in the Lyons Area will consist of two pressure reducing valves and tank control/automation valve:

1. South of Lyons along N4660 Rd the pressure ranges from over 85-psi and up to 145-psi. Installing a pressure reducing valve would limit the pressure at approximately 1,500-ft north of the intersections of N4660 Rd D0885 Rd, where the elevation drops to 980-ft, to 25-psi. This would control the pressure for customers on the lines south of Lyons to an acceptable range except southwest of the intersection of D0885 Rd and N4660 Rd. At this location the pressure could only be brought down to about 89-psi from over 140-psi to maintain a minimum pressure of 25-psi at all other locations on the line.
2. When the Sanders Flat Tank, southwest of Lyons, was modeled it showed that even with the pressure reducing valve (above) in Lyons the tank's operations are still limited by high pressures to between 62 and 67-ft of storage and the 70-ft tank is being utilized for 5-ft of water storage. As previously described the limited mixing of water stored (over

70,000 gallons) has the potential to create public health concerns. Modifying the operations of this tank by basing its operation on water level elevation changes rather than relative pressure changes and by automating a valve to close off the pipe segment north of the intersection of Sanders Flat Rd and Bunch Rd when the tank has filled would allow this tank to be further utilized and reduce the water age in the system. An actuated valve connected to a water level control system would provide the divide in the distribution system so the tank can release stored flows below 62-ft to fully operate and feed the distribution system south of Lyons. As previously described if a pressure reducing valve in Lyons is used to further reduce the pressure in the line south of the Sanders Flat Tank, the Henderson Tank would be unable to fill enough to provide a minimum pressure of 25-psi to all customers in the area and would not improve its operational constraints.

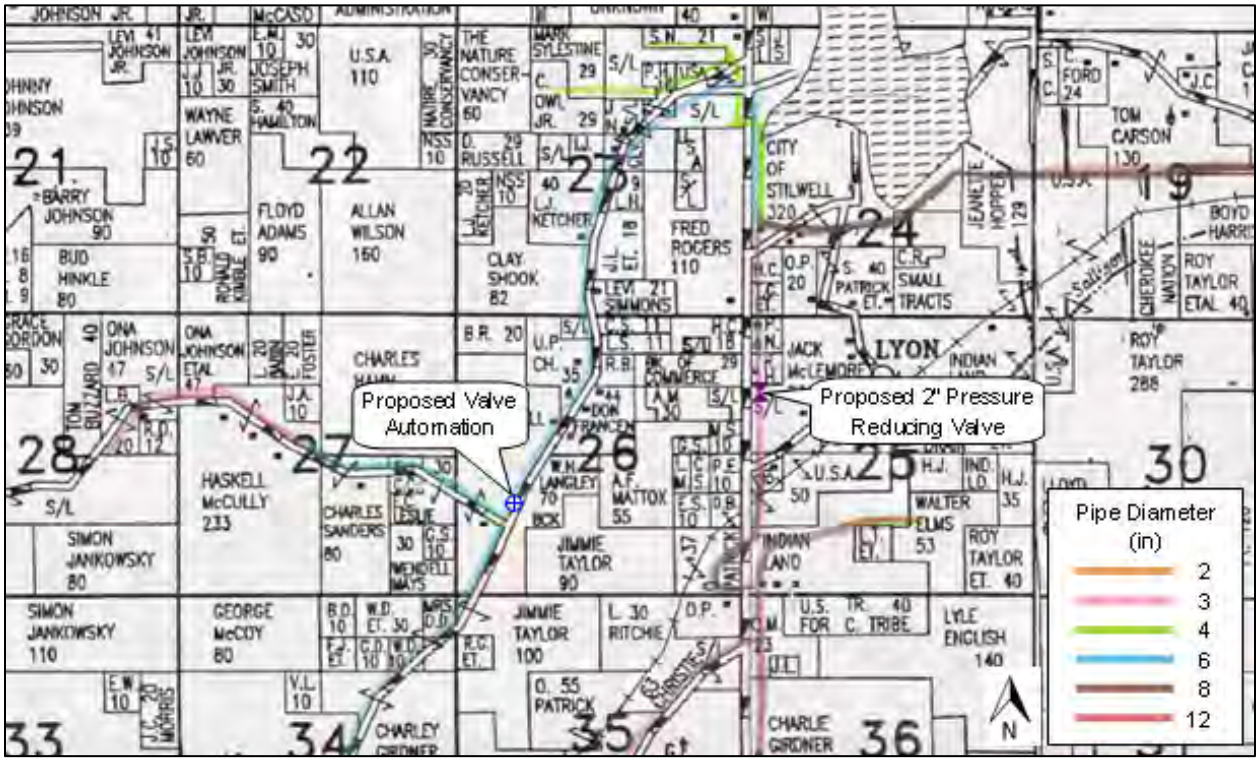

Figure 16: Approximate location of one pressure reducing valves and tank controls/valve automation proposed in the Lyons area.

Proposed improvements for the Flute Springs area:

The proposed improvements in the Flute Springs Area consist of the addition of one pressure reducing valve:

1. East of the Henderson Tank along E0965 Rd the pressure increases to almost 130-psi. The installation of a pressure reducing valve would limit the pressure east of the Henderson Tank along E0965 Rd, where the elevation drops to 780-ft, to 25-psi. This could control the pressure for customers on the line to an acceptable range.

Proposed improvements for the Greasy area:

Proposed improvements for the Greasy Area consist of one pressure reducing valve and 6800 feet of 4" pipe with two pressure reducing valves:

1. The Killer Mountain Tank provides water to customers at elevations of 1,215-ft in the area along E0912 Rd northwest of Greasy. The model shows that the customers along this road have pressures as low as 14-psi. The pressure should be monitored near the highest elevation on the line to determine if the pressure does drop below 25-psi as indicated in the modeling results. Increasing the on the existing pressure reducing valve along HWY-59 from 53-psi to 63-psi would provide the minimum pressure of 25-psi to the customers along E0912 Rd. Increasing the pressure at this valve would impact the area of lower elevations in Greasy, which are already dangerously high. The next proposed improvement would address this concern whether the pressure is increased in the pressure reducing valve or not.
2. The installation of 6,800-ft of 4 inch pipe and two new pressure reducing valves to separate the higher and lower sections of Greasy would allow both areas to have pressure within an acceptable range. The elevation in Greasy varies from approximate elevation 870-ft on the east side, and rises to approximate elevation of 1,215-ft on the west side. The high elevations on the west side of Greasy limit Cherry Tree's ability to install pressure reducing valves in the area.

   The distribution system would tee near the intersection of HWY 59 and Maxwell Mountain Rd where the approximate elevation is 1,035-ft. The installation of two 2-inch pressure reducing valves in the existing line; one at the intersection of HWY 59 and Maxwell Mountain Rd where the elevation is 1,000-ft to control the pressure to 25-psi and one on Maxwell Mountain Rd where the elevation is 940-ft to further control the pressure to 35-psi. The new pipeline would run parallel to the existing line and connect directly with those on the western edge. Pressure in the new pipeline would be allowed to stay high through Greasy to supply adequate pressure on the western edge. Where Maxwell Mountain Rd reaches an elevation of approximately 940-ft, split and cap the existing line and connect the western edge to the new pipeline. This improvement will limit the pressure in Greasy to an acceptable range, and also allow the customers at higher elevations to benefit of the high pressure provided by the Killer Mountain Tank.

   - This proposed improvement was identified to utilize the existing infrastructure as much as possible; however, Cherry Tree has other alternatives to mitigate these pressure challenges. The construction of a booster pump station on the existing line with the two pressure reducing valves previously described would also provide pressure to all customers in the area pressure within an acceptable range. This option would require at least two pumps, one for operation and one standby, a building and utility hookups. Annual energy expenses were estimated to be approximately $900 per year for 16,480 kWh.

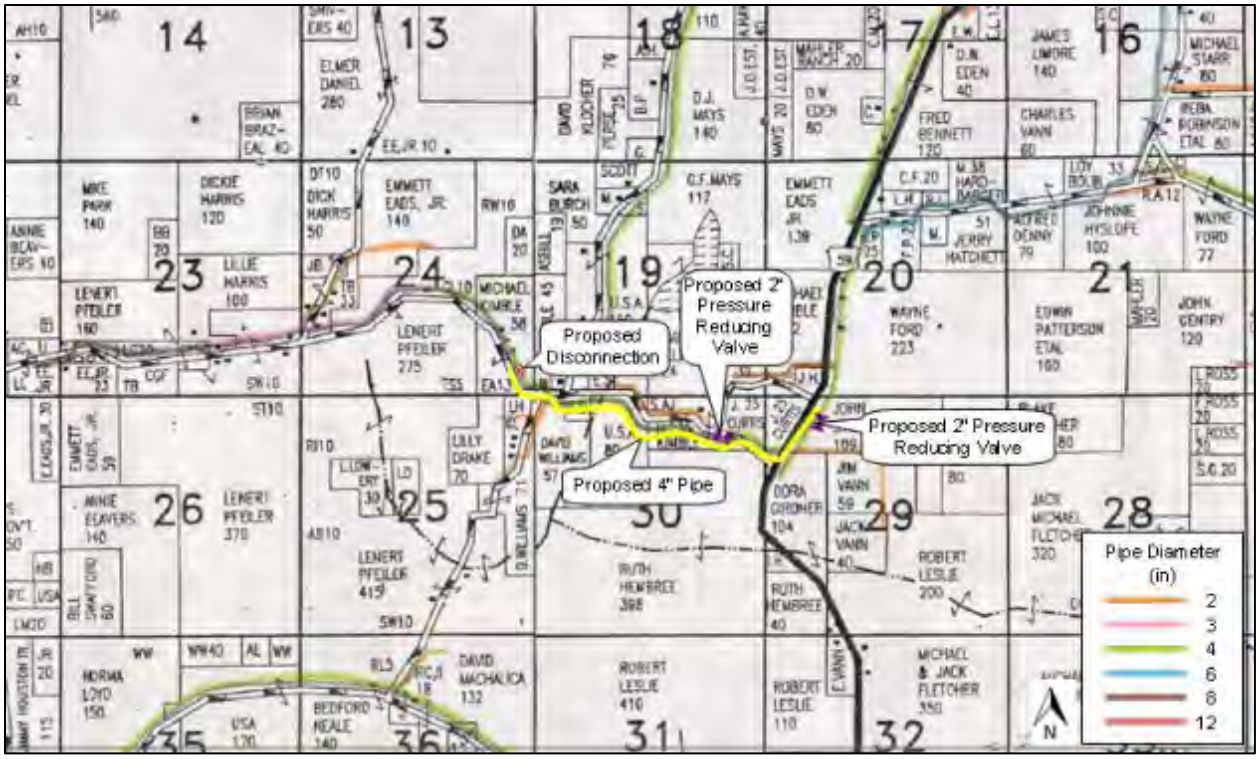

Figure 17: Approximate location of one pressure reducing valve, 6,800-ft of additional pipe (shown in yellow), and disconnection proposed to reconnect the western edge to the new pipe in the Greasy area.

Proposed improvements for the Killer Mountain area:

The proposed improvements in the Killer Mountain Area would consist of the installation of three pressure reducing valves:

1. The pressure reducing valves would be located along D4712 Rd Southeast of Killer Mountain. The elevation in this area drops from approximately 1,250-ft to 890-ft, which results in pressures over 275-psi. The approximate locations of the pressure reducing valves would be where at elevations of 1,190-ft, at 1,120-ft, and at 990-ft, reducing to 55-psi initially then to 25-psi at the next two valves. This would substantially reduce the pressure along this line to an acceptable range. Figure 19 shows a conceptual figure of how the three proposed pressure reducing valves would mitigate the excessive pressure along this line.

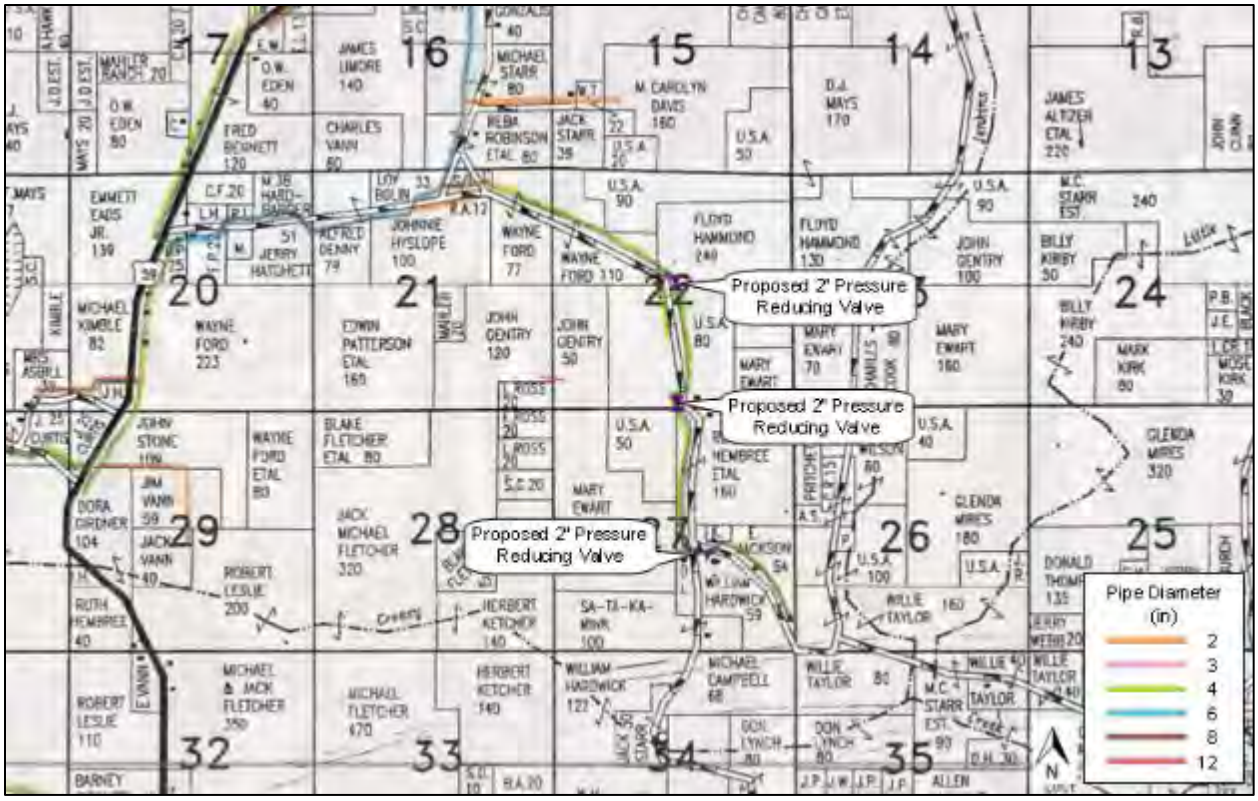

Figure 18: Approximate location of three pressure reducing valves proposed in the Killer Mountain area.

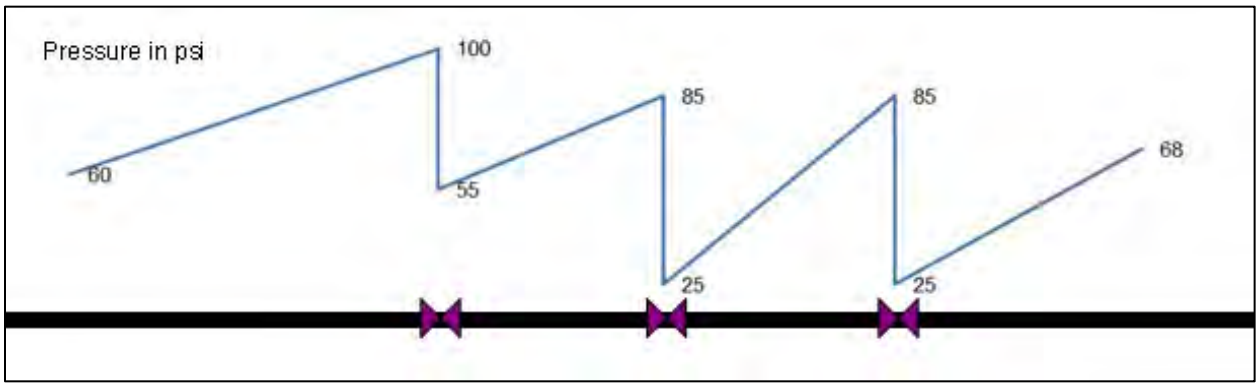

Figure 19: Conceptual diagram of pressure peaks along D4712 Rd south of Killer Mountain that could be mitigated by installing three pressure reducing valves in series.

Proposed improvements for the Bell area:

The improvements in the Bell area will consist of three pressure reducing valves and 5,100 feet of 6 inch pipe

1. The model indicated that the area along Salem Rd/E0890 Rd/D4723 Rd as having pressures lower than 25 PSI. Vanderheiden Mountain Pump Station is described in Cherry Tree's Policy and Operation document last amended in January 28, 1987, but is no longer in operation. This pump station was described as maintaining sufficient pressure to customers in this area with elevations around 1,180-ft. The function of the pump station were identified as necessary a part of the hydraulic assessment to maintain a minimum pressure of 25-psi to this area. Pressure should be monitored along this line to

determine if a booster pump station is still necessary. No cost estimate was included for building rehabilitation due to the uncertainty of the existing facility and monitoring need; however, costs were included for two new pumps to provide the minimum pressure.

2. The model indicated that the Bell and Vanderheiden Mountain area along E0890 Rd/D4723 Rd has pressures over 85-psi and up to 175-psi at some locations. The installation of a pressure reducing valve would limit the pressure on the southwest side of the intersection of E0890 Rd/D4723 Rd and Meecher Ln to 65-psi going both directions that split northeast and northwest. If the pressure is reduced to less than 65-psi at this junction the Bell Tank will be unable to fill, however a pressure reducing valve could benefit the system by preventing pressure spikes in this area when the Bell Tank and Oak Ridge Tank are filling at the same time.

3. The Bell area is in a valley with high surrounding elevations. These high elevations require Bell Tank to maintain certain pressures to provide for demands. This prevents pressure reducing valves from being the sole alternative to decrease the high pressures reaching 200-psi. Therefore to continue to utilize the Killer Mountain Tank to fill the Bell and Oak Ridge Tanks, the proposed improvements do not include options for pressure reducing valves and a new pump station for this area.

   The installation of 5,100-ft of 6 inch pipe and two pressure reducing valves would separate the higher and lower sections of Bell to allow the area to have pressure within the acceptable range. To minimize the amount of new pipe required, the proposed 5,100-ft pipeline would run parallel along E0890 Rd from the intersection with D4723 Rd to the intersection with N4740 Rd and to the east of the school and would require crossing Little Lee Creek. An alternative alignment that would increase the pipe length from 5,100 to 9,750-ft but eliminate the need for new right of way and would be to follow the existing pipeline to Bell along E0885 Rd.

   The pipe at the junction of the new pipeline at the intersection of E0890 Rd and D4723 Rd would be disconnected and capped on the existing line so water is moved from the lower Elevation at Bell back to this area. This would substantially decrease the pressure to this area. The installation of two pressure reducing valves at the junction of the new pipeline and N4740 Rd on the North and South pipe junction would limit the pressure to 50-psi and 65-psi respectively. This improvement would utilize the high pressure from the Killer Mountain Tank to fill the Bell Tank and reach customers at higher elevations, while decreasing the pressure at lower elevations to an acceptable range.

Figure 20: Approximate location of three pressure reducing valves, 5,100-ft of additional pipe (shown in yellow), and disconnection proposed in the Bell area.

Proposed improvements for the Oak Ridge area

The proposed changes to the oak Ridge Area consist of modifying the operations of the Oak Ridge Tank

1. The operations would be modified by limiting the tank elevation changes to 5-ft of storage (from 25 to 30-ft or 10 to 13-psi). This would decrease the water age to the few customers by 40-hours to 12-hr cycles. Figure 21 shows all the tanks head changes over a 96-hr period of operations under Demand Scenario 2 - Average Monthly with the proposed improvements.

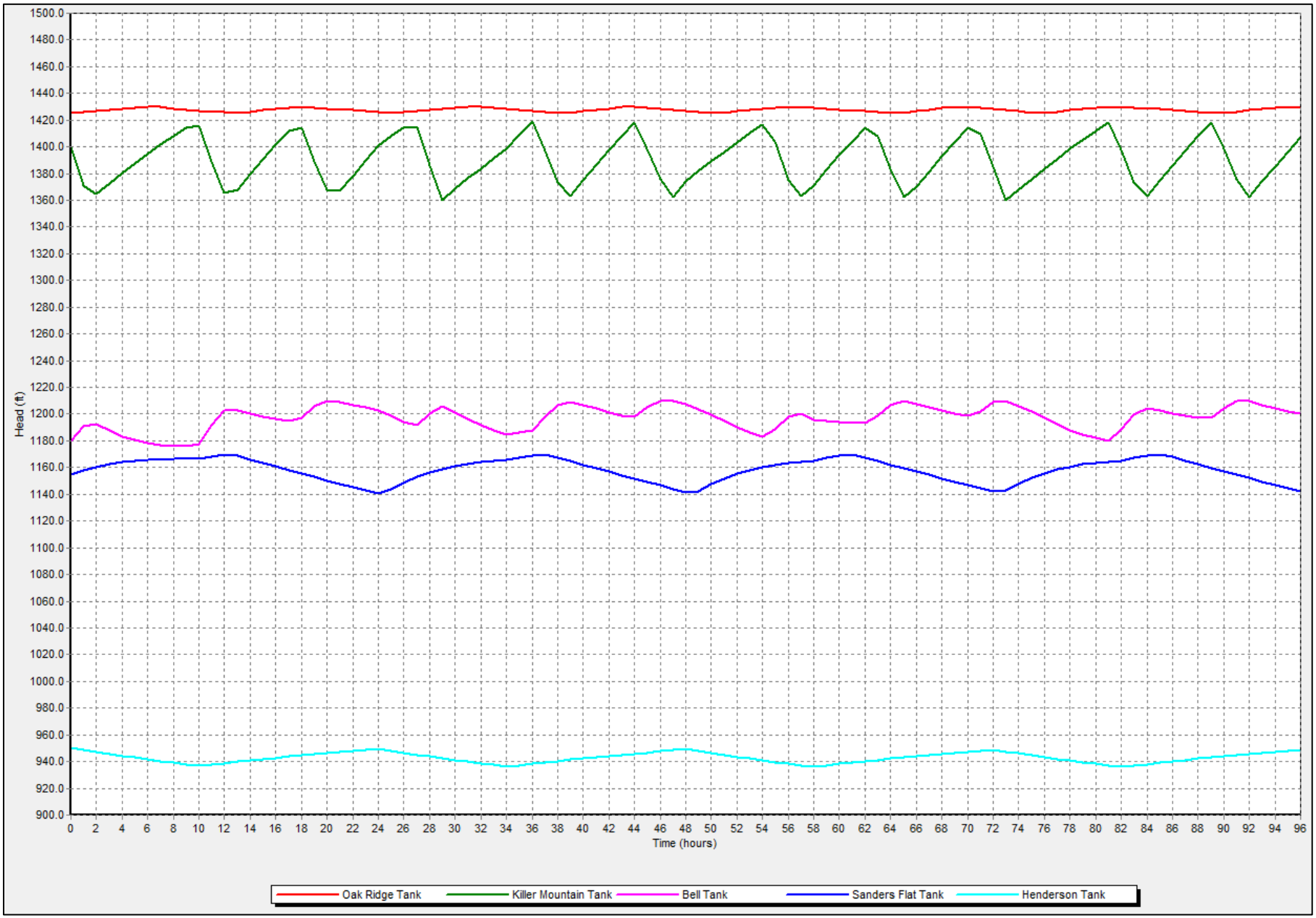

Figure 21: Graph of tank elevations for the modeled pipe network with proposed improvements over a 96-hr period under Scenario 2 - Average Monthly Use. Note with the proposed improvements the Sanders Flat Tank could be used for over 35-ft of elevation for storage. Conversely, the Oak Ridge Tank, which provides water to a relatively small number of customers, could be used for only 5-ft of storage, decreasing the water age to its few customers by 40-hours.

Table 7: Estimate worksheet for proposed improvements (page 1 of 3).

BUREAU OF RECLAMATION **ESTIMATE WORKSHEET** **Sheet __1__ of __3___**

FEATURE:
Proposed Distribution System Improvements
Cost estimate includes proposed modifications for the following areas surrounding for Cherry Tree, Lyons, Flute Springs, Greasy, Killer Mountain, and Bell. Pay items correspond to order listed in the report. Contingencies are not embedded within the individual amounts shown for Pay-items 1-17.

PROJECT:
Cherokee Nation - Adair County Rural Water District No. 1
Proposed Distribution System Improvements
Construction Cost Estimate

WOID: **ESTIMATE LEVEL:** **Preliminary**
REGION: GP **UNIT PRICE LEVEL:** **Jan-16**
FILE:

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Cherry Tree area					
	1	Pressure Reducing Valve (PRV),					
		max 80-psi reduced to 35-psi		1	each	$775	$775
		Installation		1	L.S.	$300	$300
	2	PRV, maximum 65-psi reduced to 35-psi		1	each	$775	$775
		Installation		1	L.S.	$300	$300
	3	PRV, maximum 115-psi reduced to 40-psi		1	each	$775	$775
		Installation		1	L.S.	$300	$300
		Lyons area					
	4	Tank/Valve Automation					
		Tank Elevation Sensor & Automation		1	L.S.	$1,182	$1,182
		4" Actuated Valve		1	each	$1,321	$1,321
		Electrical hookups		3,200	L.F.	$3	$9,536
		Excavation for connection		1,422	B.C.Y.	$4	$5,194
	5	PRV, maximum 85-psi reduced to 25-psi		1	each	$775	$775
		Installation		1	L.S.	$300	$300
		Flute Springs area					
	6	PRV, maximum 70-psi reduced to 25-psi		1	each	$775	$775
		Installation		1	L.S.	$300	$300
		Greasy area					
	7	PRV, maximum 115-psi reduced to 25-psi		1	each	$775	$775
		Installation		1	L.S.	$300	$300
	8	PRV, maximum 65-psi reduced to 35-psi		1	each	$775	$775
		Installation		1	L.S.	$300	$300
	9	4-inch PVC Pipe		6,800	L.F.	$3	$21,522
		Backfill		1,778	L.C.Y.	$2	$3,800
		Road Crossings					
		Excavation		3	each	$224	$672
		Boring		1	each	$2,974	$2,974
		Greasy Creek Crossings		1	each	$10,833	$10,833
		Sheet 1 Subtotal					$64,556

QUANTITIES **PRICES**

BY **Anna Hoag**	**CHECKED** **TMichalewicz**	**BY AHoag**	**CHECKED** **TMichalewicz**	**REVIEWED**
DATE PREPARED **Jan-2016**	**REVIEWED**	**DATE** **Jan-2016**	**PRICE LEVEL** **Jan-2016**	

Table 8: Estimate worksheet for proposed improvements (page 2 of 3).

BUREAU OF RECLAMATION **ESTIMATE WORKSHEET** **Sheet __2__ of __3___**

FEATURE: **Proposed Distribution System Improvements** Cost estimate includes proposed modifications for the following areas surrounding for Cherry Tree, Lyons, Flute Springs, Greasy, Killer Mountain, and Bell. Pay items correspond to order listed in the report. Contingencies are not embedded within the individual amounts shown for Pay-items 1-17.	**PROJECT:** **Cherokee Nation - Adair County Rural Water District No. 1** **Proposed Distribution System Improvements** **Construction Cost Estimate**
	WOID: **ESTIMATE LEVEL: Preliminary**
	REGION: GP **UNIT PRICE LEVEL: Jan-15**
	FILE:

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Killer Mountain area					
	10	PRV, maximum 100-psi reduced to 65-psi		1	each	$775	$775
		Installation		1	L.S.	$300	$300
	11	PRV, maximum 95-psi reduced to 25-psi		1	each	$775	$775
		Installation		1	L.S.	$300	$300
	12	PRV, maximum 85-psi reduced to 25-psi		1	each	$775	$775
		Installation		1	L.S.	$300	$300
		Bell area					
	13	Booster Pump Station					
		Grundfos MQ		2	each	$500.00	$1,000
		Building and Electrical Rehabilitation					To Be Determined
	14	PRV, maximum 100-psi reduced to 65-psi		1	each	$775	$775
		Installation		1	L.S.	$300	$300
	15	PRV, maximum 120-psi reduced to 65-psi		1	each	$775	$775
		Installation		1	L.S.	$300	$300
	16	PRV, maximum 120-psi reduced to 50-psi		1	each	$775	$775
		Installation		1	L.S.	$300	$300
	17	6-inch PVC Pip		5,100	L.F.	$14.50	$73,947
		Excavation		2,267	B.C.Y.	$3.65	$8,280
		Backfill		2,834	L.C.Y.	$2.14	$6,057
		Road Crossings					
		Boring		2	each	$2,974	$5,948
		Little Lee Creek Crossings		1	each	$10,833	$10,833
		Right of Way		1.0	mi	$14,000	$13,523
		Sheet 2 Subtotal					$126,036

QUANTITIES		PRICES		
BY AHoag	**CHECKED TMichalewicz**	**BY AHoag**	**CHECKED Tmichalewicz**	**REVIEWED**
DATE PREPARED Jan-2016	**REVIEWED**	**DATE Jan-2016**	**PRICE LEVEL Jan-2016**	

Table 9: Estimate worksheet for proposed improvements (page 3 of 3).

BUREAU OF RECLAMATION **ESTIMATE WORKSHEET** **Sheet __3__ of __3___**

FEATURE: **Proposed Distribution System Improvements** Cost estimate includes proposed modifications for the following areas surrounding for Cherry Tree, Lyons, Flute Springs, Greasy, Killer Mountain, and Bell. Pay items correspond to order listed in the report. Contingencies are not embedded within the individual amounts shown for Pay-items 1-17.	**PROJECT:** **Cherokee Nation - Adair County Rural Water District No. 1** **Proposed Distribution System Improvements** **Construction Cost Estimate** **WOID:** **ESTIMATE LEVEL:** **Preliminary** **REGION: GP** **UNIT PRICE LEVEL:** **Jan-15** **FILE:**

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Sheet 1 Subtotal					$64,556
		Sheet 2 Subtotal					$126,036
		Subtotal					$190,592
		Mobilization	5%	+/-			$9,528
		Subtotal with Mobilization					$200,120
		Contract Cost Allowances (sum of):	20%	+/-			$40,020
		Design Contingencies, 15% (+/-)					
		APS, 5% (+/-). Type of					
		Procurement: Request for Proposal					
		CONTRACT COST					$240,140
		Construction Contingencies	25%	+/-			$60,060
		FIELD COST					**$300,200**
		Escalation Notice to Proceed (NTP)				See Detailed Cost Table	
		FIELD COST (with Escalation to NTxP)					
		Non-Contract Costs	40%	+/-			$120,000
		CONSTRUCTION COST					**$420,000**
		Sheet 2 Subtotal					$126,036

QUANTITIES		PRICES		
BY	**CHECKED**	**BY**	**CHECKED**	**REVIEWED**
DATE PREPARED **Jan-2015**	**REVIEWED**	**DATE** **Jan-2015**	**PRICE LEVEL** **Jan-2015**	

FUNDING OPPORTUNITIES

Through the Cherokee Nation, State, and Federal sources, funding opportunities are available to support efforts to make improvements that can help reduce water loss and hydraulic challenges for Cherry Tree. Numerous funding opportunities exist at the state and federal level to leverage local resources for infrastructure improvements. Fifteen funding programs are described below that aim to facilitate water and wastewater infrastructure improvements. The Oklahoma Water Resources Board (OWRB) administers the funds for the state program, which are the first five listed below. Additional information for each OWRB financing opportunity can be found at on OWRB's Website at http://www.owrb.ok.gov/financing/.

1. The State Revenue Bond Issue (1985) is a low-interest public water and sewer loan Revenue Bond Loan Program that offers a variable interest rate with a fixed rate conversion option.
2. The Clean Water State Revolving Fund (CWSRF) loan program was established by the 1987 Clean Water Act amendments to provide a renewable financing source for statewide wastewater infrastructure and polluted runoff control needs while protecting the State's surface and groundwater. The CWSRF is funded by EPA capitalization grants, State matching funds, and bonds. During fiscal year 2013, OWRB would continue offering financing at approximately 40% below market rate.
3. The Drinking Water State Revolving Fund loan program (1997) is funded by EPA capitalization grants, State matching funds, loan repayments, investment earnings, and bonds. The low-interest loan program is administered cooperatively by OWRB and ODEQ) to assist communities with public water supply infrastructure construction projects.
4. The Emergency Grants Program (1983) is point-based designed to assist communities facing crises that threaten life, health, or property. The maximum grant available is $100,000; and the applicant must contribute a minimum of 15% of the total project cost.
5. The Rural Economic Action Plan (REAP) Grants (1996) is a point-based program designed to assist smaller communities that lack sufficient fiscal capacity. REAP grants are match-free with a maximum grant amount of $150,000. Cities, towns, and municipalities with a population less than 7,000 can apply; but populations less than 1,750 are given priority.
6. U.S. Department of Agriculture (USDA) Water and Wastewater Disposal Systems for Rural Communities offer grants and loans for communities and tribes with a population less than 10,000.
7. USDA Technical Assistance and Training Grants may be a source of funding if a private nonprofit organization with expertise in water and wastewater issues is willing to work on the project.
8. USDA Water and Waste Disposal Loans and Grants provide water and waste disposal to residents in counties where the per capita income does not exceed 70% of the national average.

9. Department of Housing and Urban Development (HUD) States Program provides funding to the states to distribute to low & moderate income communities to develop housing including water and wastewater.
10. HUD Indian Community Development Block Grant Program provides grants to develop water & wastewater in low and moderate-income families. This funding is strictly for tribal projects.
11. EPA State Revolving Loan Program provides construction funds for municipal wastewater treatment facilities.
12. Economic Development Administration Public Works and Development has funding available for construction of public works facilities to create development opportunities in areas experiencing severe economic distress.
13. Department of Indian Health Services provides funding for water supply and sewage treatment facilities for Indian tribes.
14. U.S. Department of the Interior – Bureau of Reclamation – WaterSMART: Water and Energy Efficiency Grants seeks to conserve and use water more efficiently, increase the use of renewable energy, improve energy efficiency, benefit endangered and threatened species, facilitate water markets, carry out activities to address climate-related impacts on water or prevent any water-related crisis or conflict.
15. U.S. Department of the Interior – Bureau of Reclamation – Drought Resiliency Project Grants seek to increase the reliability of water supply; improve water management; implement systems to facilitate the voluntary sale, transfer, or exchange of water; and provide benefits for fish, wildlife, and the environment to mitigate impacts caused by drought.

Additional information for the following three grant programs could be used to provide technical or financial assistance to Cherry Tree to implement the proposed improvements.

Emergency Grants

Through the Emergency Grants, OWRB offers up to $100,000 project grants for emergency situations (defined as a life, health, or property threatening situation). This program can provide funding for applicants that cannot reasonably finance the project without assistance from the OWRB and the eligible entities include rural water districts. Cherry Tree could apply for funding through this program to complete a portion of the improvements in Bell or Greasy, where the high pressure causes frequent breaks that result in the area's water being shut-off during repairs. This program requires a 15-percent cost share by Cherry Tree and is awarded based on a point-based system. The Grant Priority Evaluation Policy (120 points maximum) is used to determine points each applicant, using the following criteria:

- Nature of emergency (50 points maximum)
    - Documentation of the excessive water loss and a past record of breaks in the Bell and Greasy area could be used to address this evaluation criterion.
- Water and sewer rates (13 points maximum)
    - This criteria requires documentation of the current rate structure.
- Monthly debt payment (10 points maximum)
    - This criteria requires documentation of current monthly debt payment.

- Local contribution (10 points maximum)
    - If Cherry Tree or other funding sources contribute to a portion greater than 15 percent of the cost share for the proposed improvements this could be documented to address this evaluation criteria.
- Median household income (10 points maximum)
    - Table 10 provides a summary for the median household income for the four CDP's that overlap with portions of Cherry Tree for this criteria.

Table 10: Summary of U.S. Census Bureau, 2009-2013 5-Year American Community Survey for Median Household Income.

Communities that are Part of Cherry Tree:	Zip Code	Household Estimate	Median Household Income
Bell CDP	74931	150	$34,167
Cherry Tree CDP	74931	286	$30,385
Flute Springs CDP	74931	32	$16,250
Greasy CDP	74931	106	$34,286
	Total	574	-
	Minimum	-	*$16,250*
	Average	-	*$28,772*

- Applicant's ability to finance the project (12 points maximum)
    - This criteria requires documentation of the ability to finance the project.
- Amount of grant requested (varies from 5 points for amounts more than $94,999 to 10 points for $25,000 or less)
    - Table 11 provides an estimate of the proposed improvements divided to meet this program's requirements. Note if less funding is requested more points could be awarded.

Table 11: Summary table of the proposed improvements by each area and estimated costs divided for as a potential cost share for this grant program.

Proposed Improvement by Area:	Total	OWRB (85% up to $100,000)	Matching Funds
Cherry Tree Area	$7,100	$0	$7,100
Lyons Area	$40,400	$0	$40,400
Flute Springs area	$2,400	$0	$2,400
Greasy area	$92,500	$50,000	$42,500
Killer Mountain area	$7,100	$0	$7,100
Bell area	$270,800	$50,000	$220,800
Total	**$420,300**	**$100,000**	**$320,300**

- Benefit to other systems (5 points maximum)
    - A case could be made describing that the excessive water loss by Cherry Tree impacts Stilwell and the other three rural water districts that rely on the same water source. Improvements to Cherry Tree to reduce water loss would ultimately benefit all water systems in southern Adair County.
- Application number (up to 14 point deduction)

Applications that receive 60 or more points are placed on the grant Priority List. Applications are then recommended for approval to the Board when all other funding sources are secured and adequate grant funds are available for obligation.

Rural Economic Action Plan (REAP) Grants

Through the REAP Grants, OWRB offers up to $150,000 project grants for water line construction or repair to communities with a populations of 7,000 people or less, with priority given to less than 1,750. This program can provide funding for applicants that cannot reasonably finance the project without assistance from the OWRB and the eligible entities include rural water districts. Cherry Tree could apply for funding through this program to complete any combination of the proposed improvements. This program requires a 40-percent cost share by Cherry Tree and is awarded based on a point-based system. The REAP Grant Priority Evaluation Policy (115 points maximum) is used to distribute REAP grant funds using the following criteria:

- Population (55 points)
    - As previously documented the exact population of Cherry is unknown. In the OWCP it was estimated that Cherry Tree has a population of 2,097 in 2010, but census data does not match the rural water boundaries by zip code or census tract so this number cannot be confirmed. The four census tracks that overlap with Cherry Tree have a combined population of 1,920 in 2010, but large portions of these areas are not included in Cherry Tree while other parts of the boundaries are excluded. Cherry Tree could survey their customers to determine a more accurate population to see if they are below the 1,750 population threshold for this grant program to receive maximum points in this category or use the census/OWCP estimates.
- Water and sewer rates (13 points maximum)
    - Increasing block water rate structures are given preference through this point category. This criteria requires documentation of the current rate structure.
- Indebtedness per customer (10 points maximum)
    - This criteria requires documentation of current debt and number of customers.
- Median household income (10 points maximum)
    - Table 10 provides a summary for the median household income for the four CDP's that overlap with portions of Cherry Tree for this criteria.
- Applicant's ability to finance the project (12 points maximum)
    - This criteria requires documentation of the ability to finance the project.
- Amount of grant requested (points vary from -5 for over $140K, to +5 for less than $20K. Maximum amount that can be requested is $150K.)
- Previous grant assistance (points vary from -8 for 1 prior grant to -14 for 5 or more prior grants)
    - Cherry Tree has only received a $10,000 Emergency Grant in 1984 from OWRB.
- Enforcement order with a project construction start date on or before June 30 of the Board's current fiscal year for funding REAP grants (5 points maximum)
    - No enforcement orders have been placed on Cherry Tree to require this urgency.

    - Table 12 provides an estimate of the proposed improvements divided to meet this program's requirements. Note if less funding is requested more points could be awarded.
- Previous grant assistance (points vary from -8 for 1 prior grant to -14 for 5 or more prior grants)
    - Cherry Tree has only received a $10,000 Emergency Grant in 1984 from OWRB.
- Enforcement order with a project construction start date on or before June 30 of the Board's current fiscal year for funding REAP grants (5 points maximum)
    - No enforcement orders have been placed on Cherry Tree to require this urgency.

Table 12: Summary table of the proposed improvements by each area and estimated costs divided for as a potential cost share for this grant program.

Proposed Improvement by Area:	**Total**	**OWRB (40% up to $150,000)**	**Matching Funds**
Cherry Tree Area	$7,100	$0	$7,100
Lyons Area	$40,400	$16,000	$24,400
Flute Springs area	$2,400	$0	$2,400
Greasy area	$92,500	$26,000	$66,500
Killer Mountain area	$7,100	$0	$7,100
Bell area	$270,800	$108,000	$162,800
Total	**$420,300**	**$150,000**	**$270,300**

- Benefit of project to other systems (5 points maximum)
    - Similarly, a case could be made describing that the excessive water loss by Cherry Tree impacts Stilwell and the other three rural water districts that rely on the same water source. Improvements to Cherry Tree to reduce water loss would ultimately benefit all water systems in southern Adair County.

Applications that receive 40 or more points are placed on the REAP Grant Priority List. Completed REAP applications must be received by the OWRB by 5:00 p.m. on the first business day of September for potential funding from the following Fiscal Year appropriations. REAP applications are then recommended for approval to the Board when all other funding sources are secured and adequate REAP grant funds are available for obligation.

CONCLUSIONS

Census data and population projections for southern Adair County show that Cherry Tree CDP's population is decreasing consistently through the U.S. Census Bureau's 2013 survey and 2014 estimate, however; the county as a whole is projected to grow during this period. This growth could increase Cherry Tree's customer base in certain locations. The census data growth is not consistent with the OCWP projections in the area. Additional data is required to determine if Stilwell and its' customers would to see supply shortages as early as 2030.

Cherry Tree's total water purchased decreased in 2014, and the number of customers using less than 25,000 gallons per month remained stable, suggesting these variations are due to pipe breaks or other undocumented water losses and not seasonal variations in water use. This could be significantly effecting Cherry Tree's operations, especially during winter months when the largest peaks occurred.

The billing data showed that a majority of Cherry Tree's customers use less than 10,000 gallons per month. Slight seasonal variations can be observed for the summer months in 2012 and 2014, but data inconsistencies in 2013 prevent any conclusions from being made to determine growth rates or peaking factors. Even in months with atypical water use 75% percent of the customers use less than 25,000-gallons per month; although the customers with this use varied. This data indicates that the water usage could be reduced for customers if water loss is decreased, thus extending their water supply to address needs despite potential growth.

Water demands could be further reduced for Cherry Tree if the excessively high water pressure is controlled. This high water pressure produces more wasted water with minimal benefits for each customer. Cherry Tree has areas with pressures over 200-psi and customers of those areas cannot avoid wasting water due to their high water pressure resulting in higher water bills. This high water pressure does not allow customers to easily cut back their water use and reduce their water bill.

This assessment proposes infrastructure improvements to reduce pressure and minimize the risk of line breaks, but additional conservation measures could also further enhance the water and operational cost savings by Cherry Tree. All of the measures described in the OCWP could be considered by Cherry Tree to reduce the amount of water purchased from Stilwell.

Cherry Tree has several challenges with their existing distribution system such as high and low pressure zones, under sized lines, and unquantified water loss (although this cannot be verified due to faulty meters). Distribution system construction started in the late sixties and sections have been extended several times and as recently as the early two thousands. Due to all these additions, the distribution system is no longer operating as originally designed. Network simulations confirmed these challenges and high pressure areas throughout the distribution system. It also identified low pressure areas and long water age as potential health concerns for Cherry Tree.

It was reported that the Henderson Tank is unable to fill and is being under-utilized. This was confirmed through the network simulations. The Henderson Tank is hydraulically tied to the Sanders Flat Tank. This long storage time increases health concerns and the Sanders Flat Tank

should be investigated further to determine whether the tank is storing excess water and increasing the water age for the entire section of the distribution system past Lyons.

A similar health concern could exist at the Oak Ridge Tank which serves only a few customers. When simulated the tank was storing large amounts of water for extended periods of time; increasing the water age by over 2¼ days for its customers. This is due to the tank size being able to store more volume than the minimal customer demands in the area. However, because the Oak Ridge Tank is controlled by a water level sensor at the Oak Ridge Pump Station, this can be easily adjusted to alleviate this concern. OAC 252:626-17-4 Distribution Storage states that "the maximum design variation between high and low levels in storage structures providing pressure to distribution system is 30 feet"; for this tank and the few customers the design variation should be further limited.

By systematically adjusting the hydraulic simulations, the proposed improvements were found to reduce high pressure zones while maintaining a minimum of 25-psi throughout the system and allowing each tank to store and release water to minimize water age. Proposed improvements consist of installing:

- 13 pressure reducing valves,
- 11,900-ft of new pipe,
- a tank automation/valve control, and
- two booster pumps.

Even with the proposed improvements, some locations will still require pressures above 85-psi in order to maintain a minimum pressure of 25-psi at all locations (in accordance with OAC 252:626-19-1). This occurs especially in the Bell area where Cherry Tree reported frequent line breaks due to high water pressure. The high pressures at these locations were greatly reduced by the proposed improvement; however these areas should still be closely monitored for potential leaks resulting from the high pressure.

Preliminary cost estimates were developed for each of the proposed improvement as described in Appendix B and shown in Table 6-8. Additional alternatives to the listed proposed improvements exist, but they were evaluated to minimize capital and operational costs as part of this preliminary analysis utilizing technology Cherry Tree already maintains.

Through the Cherokee Nation, State, and Federal sources, funding opportunities are available to support efforts to make improvements that can help reduce water loss and hydraulic challenges for Cherry Tree. Numerous funding opportunities exist at the state and federal level to leverage local resources for infrastructure improvements. Fifteen funding programs were identified that aim to facilitate water and wastewater infrastructure improvements. Additional information for the two grant programs were highlighted in more detail that could provide technical or financial assistance to Cherry Tree to implement the proposed improvements.

Water Conservation Limitations due to High Water Pressure

Water conservation can produce economic savings by reducing the amount of water purchased and extending the life of existing infrastructure. One necessary water conservation opportunity for Cherry Tree is to reduce high water pressure. High water pressure increases pipe breaks and

water lost during repairs. Additionally, high water pressure increases the amount of water that is wasted by each customer during every-day activities when compared to the same use at more moderate pressures. Figure 22 illustrates how higher water pressure and water flow can increase the water wasted for the same amount of water use. The figure shows that water flow through a distribution system almost doubles from 50-psi to 150-psi. The high water pressure produces more wasted water with minimal benefits for each customer. In comparison, Cherry Tree has areas with pressures over 200-psi and customers of those areas cannot avoid wasting water due to their high water pressure resulting in higher water bills. This high water pressure does not allow customers to easily cut back their water use and reduce their water bill. In turn it requires Cherry Tree to purchase additional water from Stilwell each month that is not being used by customers, increasing monthly operational expenses, and therefore increasing distribution system wide loss.

Figure 22: Conceptual illustration of water use at higher pressures and flows increases wasted water for the same amount of use (http://www.watts.com/pages/learnAbout/reducingValves.asp?catId=64).

The 2012 OCWP Update discussed several other ways to implement water conservation measures. These include, but are not limited to, (1) volumetric pricing (i.e., conservation-based rate structure) where water rates are allocated based on volume used[1]; (2) developing a drought contingency plan that includes restrictions on outdoor water use during drought conditions; (3) installing/updating water meters to better account for water use and improve leak detection; (4) maintaining conveyance infrastructure to improve water delivery efficiency; (5) mandating or providing incentives for installation of high water efficiency fixtures in residential/commercial developments; (6) increasing public awareness through education. This assessment will only propose infrastructure improvements to reduce pressure and minimize line breaks, but additional conservation measures could further enhance the water and operational cost savings by Cherry Tree. All of these measures could be considered by Cherry Tree to reduce the amount of water purchased from Stilwell.

[1] Generally, the first rate block should include the average usage per residential meter per month, with 25 – 50 percent rate increases for each subsequent block, with no more than three blocks.

REFERENCES

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APPENDIX A: DISTRIBUTION MAP

APPENDIX B: BASIS OF COST ESTIMATES

Purpose and Intended Use of the Cost Estimates

The cost estimates are considered "preliminary-level", as defined by Reclamation's Directives and Standards FAC 09-01, which states: "preliminary cost estimates developed and produced to document a very preliminary analysis performed to look at a given problem, need, or opportunity utilizing readily available data. The estimates do not meet the criteria used for preparation of either Appraisal or Feasibility cost estimates." Table B.1 below identifies the project development timeline and level of cost estimates produced.

Table B.1 Types of cost estimates produced for each project planning stage (D&S FAC 09-01).

PROJECT STATUS	PROJECT STAGE	LEVEL OF COST ESTIMATE PRODUCED
Planning	Planning	***Preliminary***
		Appraisal
		Feasibility
Construction	Design	Percent Design [Updated feasibility]
		Prevalidation of Funds
	Solicitation	Independent Government Cost Estimate [Award]
	Construction	Independent Government Cost Estimate for Contract Improvements
Operation and Maintenance	Operations	One or more of the previously identified estimates

Basis of Cost Estimate

The cost estimates were prepared by Reclamation staff and are in 2015 dollars. Details are provided in Appendix D. The unit costs were derived for each quantity using the construction cost data that has been compiled in the RSMeans Heavy Construction Cost Data and market values provided by various distributors near Cherry Tree. A location factor was used to adjust only the unit cost data provide by RSMeans Heavy Construction Cost Data (Reed Construction, 2012) to Muskogee, Oklahoma, which is 71.4% of the national average. The cost estimates are divided into the following key elements:

- Contract Costs: estimated cost of the contract at the time of bid or award.
  - Mobilization: A value of 5 +/- % was utilized for mobilization. This includes costs of contractor bonds, and mobilizing contractor personnel and equipment to the project site during initial project t-up. The assumed 5 +/- % value in the cost estimate is based upon past experience of similar projects.
  - Design Contingency: For packaged systems a value of 20 +/- % was used for (i) unlisted items, (ii) design and scope changes; and (iii) cost estimating refinements.
- Construction Contingency: A value of 25 +/- % was used for construction contingencies based upon the completeness and reliability of: the engineering design data, geological information, projected quantities, and the general knowledge of the conditions at the site.

It covers minor differences in actual and estimated quantities, unforeseeable difficulties at the site, changed site conditions, possible minor changes in plans, and other uncertainties.

- Non-Contract Costs: A value of 40 % was used for noncontract costs such as soil surveys, water quality testing, environmental compliance, engineering designs, and construction management.