

INTEGRATED WATER RESOURCE PLAN

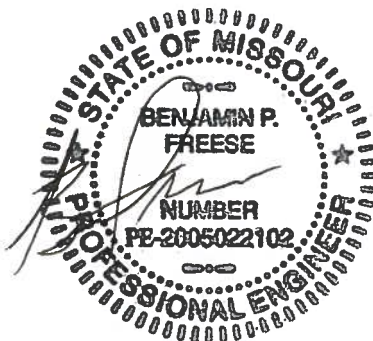
Final Report

B&V PROJECT NO. 191263

PREPARED FOR

Columbia, Missouri Water & Light
Department

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LIST OF ACRONYMS

ADD - Average Daily Demand
AF - Acre-foot
AF/YR – Acre-feet per year
AMI - Advanced Metering Infrastructure
ASR - Aquifer Storage and Recovery
ASTM – American Standards of Testing Methods
AWWA - American Water Works Association
BMP – Best Management Practice
BOD – Biochemical Oxygen Demand
CATSO - Columbia Area Transportation Study Organization
CBOD – Carbonaceous Biochemical Oxygen Demand
CCF – Hundred cubic feet
CEE – Consortium of Energy Efficiency
CFU – Colony Forming Units
CT - Concentration Time
CW&L - Columbia Water & Light
DMA – District metered area
DO – Dissolved Oxygen
DWR – Department of Water Resources (California)
EPA – Environmental Protection Agency
ETo - Evapotranspiration
Gal - Gallon
Gal/Day – Gallons per day
GPCD - Gallons per capita per day
GPF - Gallons per flush
GPM - Gallons per minute
GWUDI - Groundwater Under the Direct Influence of Surface
ILI – Infrastructure Leakage Index
IWA – International Water Association
IWRP - Integrated Water Resources Plan
LRWSS - Long Range Water System Study
mA – milli amp
MBR – Membrane Bio-Reactor
MDD - Maximum Daily Demand
MDNR - Missouri Department of Natural Resources
MGD - Million gallons per day
MG/L - Milligrams per liter
MG/YR – Million gallons per year
mL - milliliters
MORs – Monthly operation reports
N - Nitrogen

NPDES - National Pollution Discharge Elimination System
NPW – Non Potable Water
NRW – Non Revenue Water
NSF – National Sanitation Federation
NTU - Nephelometric Turbidity Unit
NYC – New York City
O&M - Operation and maintenance
OAC – Oklahoma Administrative Code
ODEQ – Oklahoma Department of Environmental Quality
P - Phosphorus
POE – Point of entry
PPM – Parts per million
PSI – Pounds per square inch
REU – Residential End User
REUWS – Residential End Users of Water Study
SAWS – San Antonio Water System
SCC - Solids Contact Clarifier
TCEQ – Texas Commission on Environmental Quality
TOC - Total Organic Carbon
TWDB – Texas Water Development Board
UARL – Unavoidable annual real losses
USGS – United States Geological Survey
UV – Ultraviolet
WADI – Water Audit Data Initiative
WET – Water education for teachers
WF – Water Factor
WRF – Water Research Foundation
WTP – Water Treatment Plant
WWTP - Wastewater Treatment Plant

1.0 Executive Summary

Columbia is a vibrant, growing community that prides itself on maintaining a safe, reliable and efficient water system. Customers have benefited from clean, reliable drinking water for the past 100 years, and have continually invested in the system since that time. Columbia Water & Light (CW&L) provides potable water service to domestic, commercial, institutional and industrial customers throughout the City of Columbia and select adjacent properties.

To continue to assure a safe and reliable supply, the CW&L embarked in an Integrated Water Resource Plan (IWRP) to take a holistic approach to managing water resource requirements. The IWRP includes evaluation of water supply, water demand, water quality, environmental protection and enhancement, and public participation. The plan provides a sustainable approach that is environmentally conscious, cost-effective, defensible, meets regulatory guidelines, and provides a reliable supply to meet future needs.

Ultimately, the IWRP serves as a guide for program development, budget preparation and capital improvements planning for Columbia's water system. The IWRP considers many aspects of the City's water resources and their interactions with one another, including, but not limited to the following:

- The City's current water source and supply capacity,
- Projected population growth and water needs,
- Potential future sources of water,
- Development of water alternatives considering:
 - Water Demand Trends
 - Water Conservation
 - Potable Water Supply
 - Non-Potable Water Supply
 - Regulatory Requirements
 - Community Involvement

The IWRP incorporates inputs from these components in a model which explore different ways to meet supply needs through the year 2040. Figure 1-1 provides a graphical representation on how these inputs are correlated into an overall plan.

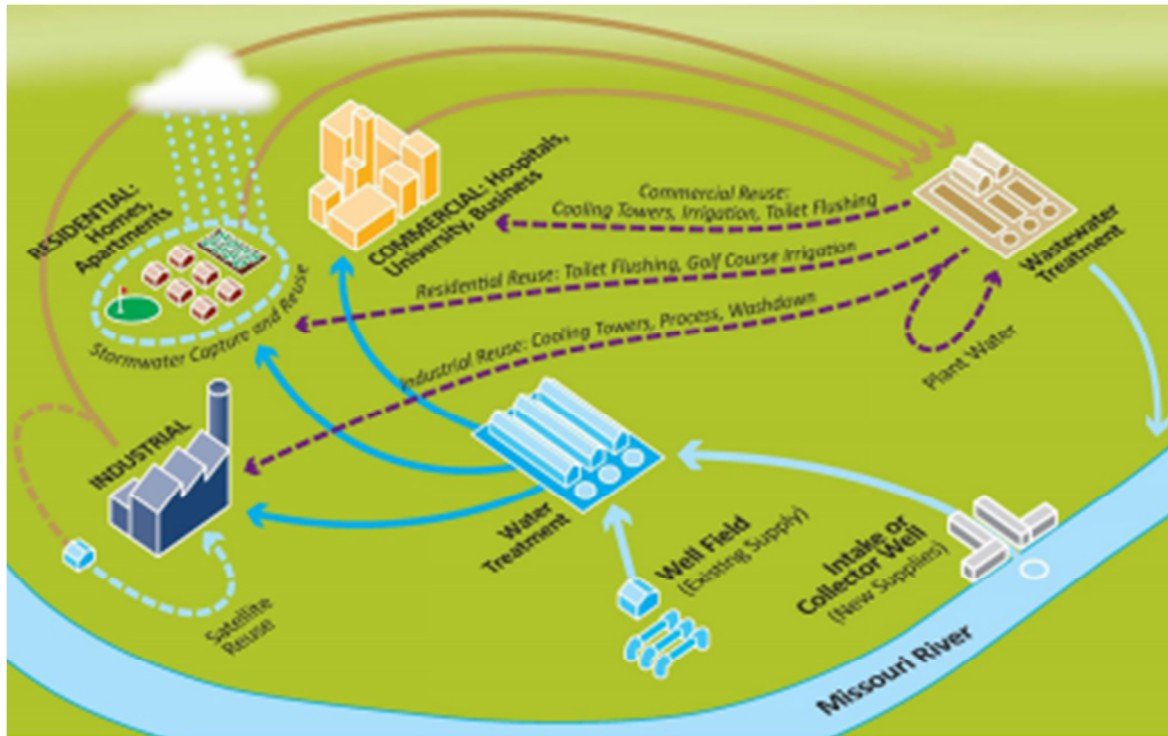


Figure 1-1 Available Sources of Supply for Columbia

The model estimates the cost and reliability of various solutions to the City's water resource needs. The IWRP uses the model results and stakeholder input to identify a recommended approach to meet minimum supply requirements. The IWRP concludes with discussion about the recommendations and how they will provide value to CW&L's customers.

The Integrated Water Resource Plan has been developed to act as a guide for prudent development of a reliable cost-effective water supply for the next 30 years and beyond. Through a long-term planning process, the City can be good stewards of a valuable natural resource, better prepare for potential challenges, evaluate new alternatives to ensure a safe and reliable water supply, and meet the demands of a changing community. The water resource plan is not intended to be a preliminary design report used to select specific treatment processes, target water quality goals, and exact locations of non-potable infrastructure, but it is intended to serve as a means to develop an overall path forward for an approach the City should take in addressing future water supply requirements. As projects move forward, further evaluation and refinement of the concepts presented will need to occur in order to optimize the overall plan and assure all factors are considered.

EXISTING SYSTEM

The City's water system currently serves approximately 48,000 customers in 89 square miles with a historical peak demand of 23.3 million gallons per day (MGD). The Water System consists of alluvial ground water wells and a production facility in the Missouri River flood plain, two water transmission mains into Columbia, four pump stations, three ground storage reservoirs, three elevated storage tanks and 671 miles of water mains.

The system serves residential, commercial, industrial, and institutional customers within the City limits, as well as small areas adjacent to the City. The University of Missouri campus is within the City limits, but utilizes its own deep well water supply and is not served by CW&L. The McBaine Water Treatment Plant supplies the CW&L system and treats water from groundwater wells in an alluvial aquifer in the McBaine Bottoms near the Missouri River.

The McBaine Water Treatment Plant is a groundwater softening plant consisting of aeration, 2-stage precipitative softening, filtration, and disinfection facilities. Originally constructed in 1970, the facility has seen two major 8 MGD expansions throughout its service life. These improvements have increased capacity from 16 MGD to its current rated capacity of 32 MGD, while continuing to provide quality water to its customers. However, replacement and upgrades to existing equipment and structures are necessary, especially for a facility in operation for more than 45 years. Over time, deterioration of assets affects performance, operator flexibility, and reliability, which limit the overall capacity of the facility. The “McBaine Water Treatment Plant and West Ash Condition Assessment”, Black & Veatch (2016), summarized the condition of the existing plant and costs to rehabilitate the plant to continue to provide reliable supply to the City. It is estimated that \$18 million dollars are required to improve operation, replaced deteriorated equipment, and increase reliability of the treatment plant. These costs are not dependent upon expansion of the facility. As discussed in the Condition Assessment, without rehabilitation of the plant, specifically replacement of the original 1970s process equipment and electrical gear, the reliable capacity of the plant should currently be considered 24 MGD.

HISTORICAL WATER DEMAND

Historical average and peak day demands from 1972 to 2016 are shown in Figure 1-2 alongside the Peak Factor (the ratio of average to peak day demands).

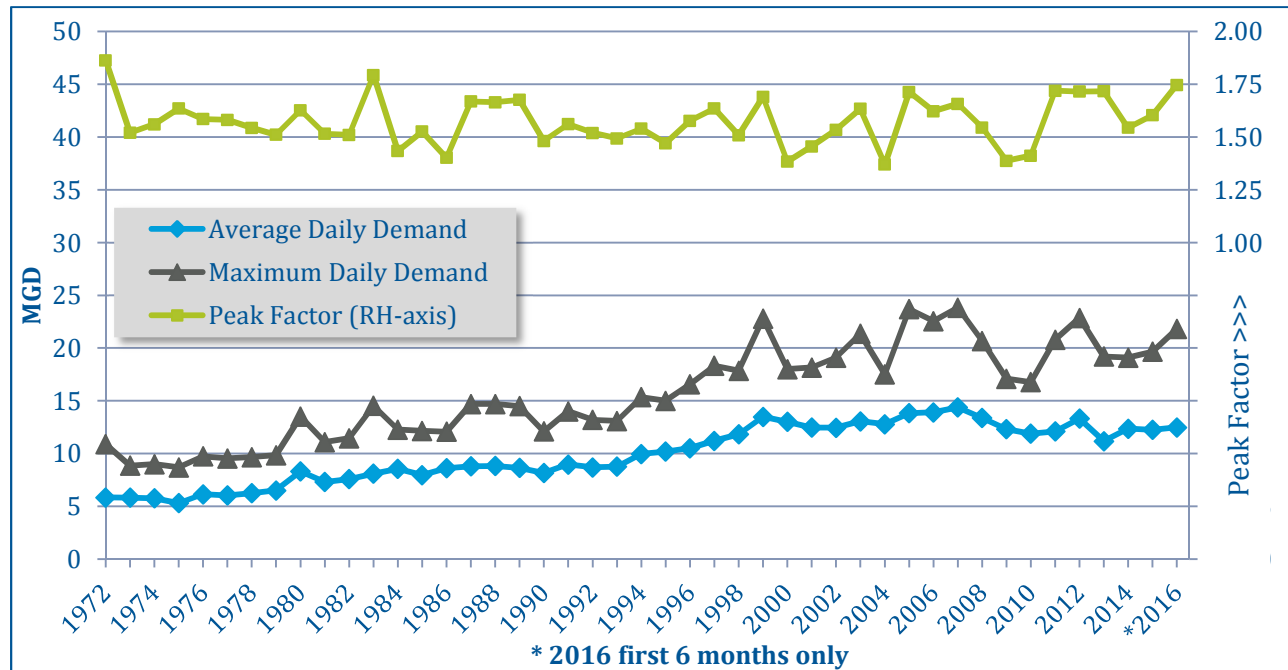


Figure 1-2 Average and Peak Demand and Resultant Peak Factor

Maximum daily demand is measured as the maximum 24-hour water demand in a given year. Based on the data shown in Figure 1-2, a maximum day (or peak day) factor of 1.8 would be applied to the annual average consumption forecast, as this represents a reasonable upper bound of the peak day factor over the past 20 years.

POPULATION PROJECTIONS

Future population projections were obtained from Mizzou Show Me and Columbia Area Transportation Study Organization (CATSO) sources, with projected population to 2030. The project’s planning horizon is 2040 so the two population projections were extended using the observed annual growth rates for the respective forecasts to 2040, and an average forecast of the two population projections was used as a means of creating possible scenarios of future population for planning purposes. In all years, the CATSO population projection represented the highest forecasted values. Table 4-4 summarizes the population projections.

Table 1-1 City of Columbia Historic and Projected Population

YEAR	CATSO POPULATION (POP _C)	MU SHOW ME POPULATION (POP _B)	BLENDED MIDPOINT POPULATION (POP _A +POP _B)/2
2015	116,285	114,296	115,300
2020	125,919	120,677	123,300
2025	135,650	126,701	131,175
2030	146,134	131,797	139,000
Equivalent Annual Growth Rate	1.53%	0.95%	1.25%
2035*	157,689	138,207	147,893
2040*	170,178	144,929	157,393
*Extrapolated values using annual growth rates 2015-2030			

DEMAND PROJECTIONS

A review of the current drinking water demand was completed to establish water supply requirements for the IWRP planning period. The review included data compiled from the 2015 Long Range Water System Study (LRWSS), prepared by Jacobs (2015), which was an update from the 2008 Long Range Planning Study. The IWRP planning period extended beyond the limits of these studies so additional analysis was required to estimate the future demand requirements. Specific demand projections were established by user class, which included residential, commercial, large commercial, and irrigation user to better understand the impact if alternative water supply or conservation measures were implemented in the City. While drinking water demand projection is not an exact science, this evaluation included review of known historical data and expected growths typical of this type of community to establish supply requirements to year 2040.

Demand information was assembled into a final set of demand forecast scenarios as follows.

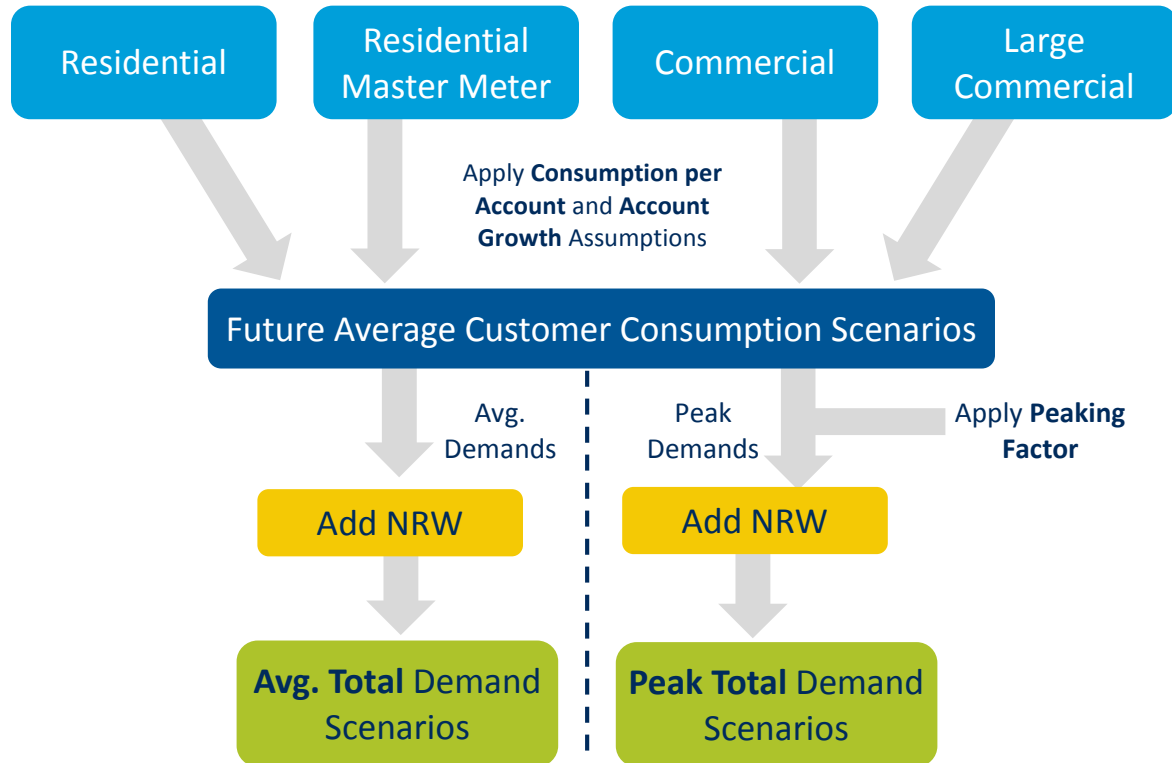


Figure 1-3 Flow Chart of Demand Forecast Scenario Development

Based on these inputs, the total average and maximum day required production for the baseline scenario is presented in Figure 1-4. The graph shows the revised projections derived from this evaluation along with previous projections from the Long Range Water System Study (LRWSS), Jacobs (2015), for comparison.

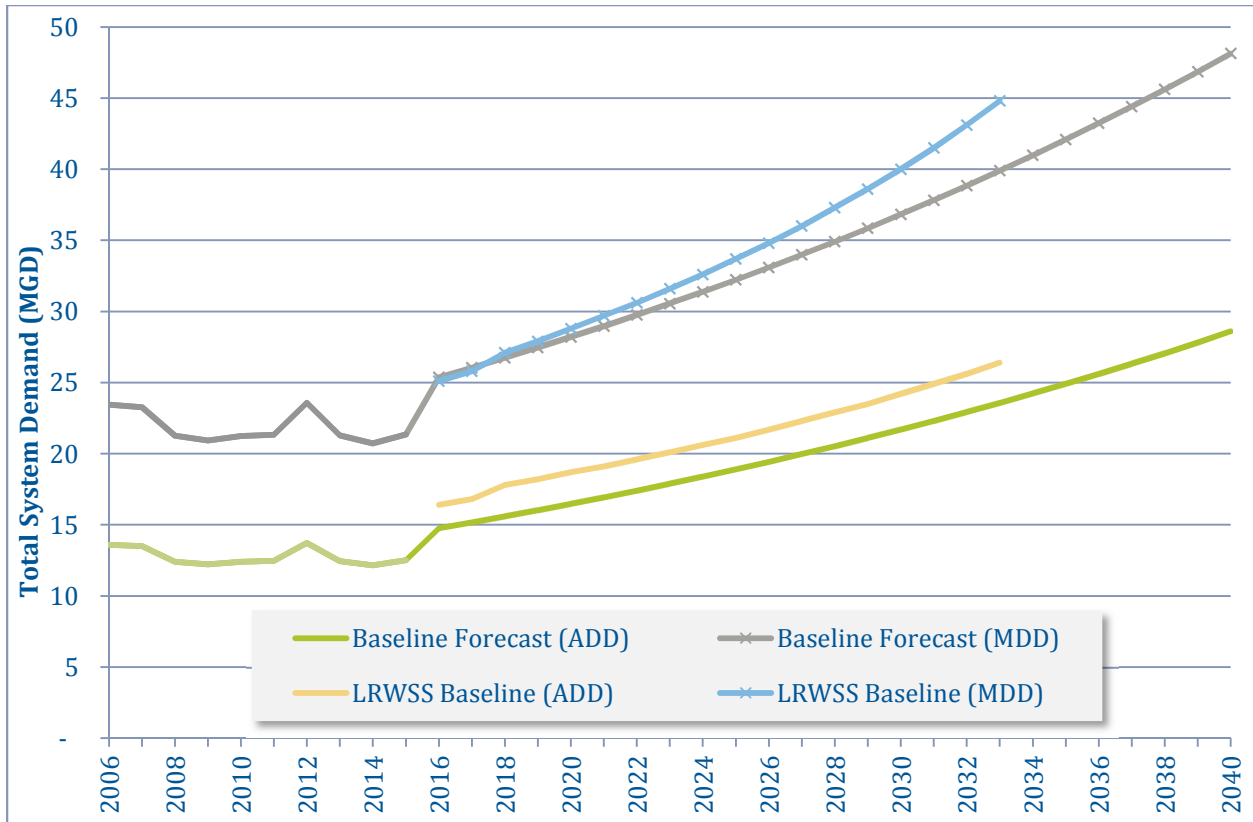


Figure 1-4 Average Daily and Maximum Daily Demand Forecasts, including comparison to LRWSS Baseline

WATER SUPPLY SOURCES

The evaluation of current and potential future water sources includes both sources for potable use and non-potable use. The sources were each evaluated in their ability to meet future demands reliably and sustainably.

The potable alternatives evaluated include the continued use of the McBaine Bottoms Aquifer using vertical wells, installation of horizontal collector wells along the Missouri River bank, and the potential use of the Missouri River as a supply source.

These alternatives address supply to the existing McBaine Water Treatment Plant site for treatment and potable use. Evaluation of potable water supplies beyond the general vicinity of the plant were not considered as any alternative supply would require a new treatment facility and additional transmission piping that would result in higher overall costs than those included in the evaluation.

A conceptual model of the alluvial aquifer that supplies the McBaine Treatment Plant concluded that the aquifer will yield a total of 65 MGD with 32 wells for 30 days with groundwater levels at each well approaching, but not dropping below the tops of the well screens. These conceptual findings agree with previous evaluations which found that a well spacing of around 1,300 feet should be feasible, as well as confirm that the alluvial aquifer can yield at least 52 MGD from approximately 28 wells, provided that the wells are adequately maintained over time.

Non-potable water may be used in place of potable supply for specific applications such as irrigation, industrial use, and other applications that aren't for human consumption. Some level of treatment and/or monitoring would be required to meet all regulatory requirements for non-potable use. Non-potable supply alternatives include recycled water from the existing Columbia Regional Wastewater Treatment Plant, recycled water from smaller satellite treatment plants, collected stormwater, and untreated or minimally treated groundwater. Whereas potable water supplies can be delivered predominantly with the existing distribution system, the non-potable supplies require a separate distribution system and separate administration, the costs for which can be significant for the overall project. These sources of non-potable water were evaluated for irrigation and industrial use, depending on the supply.

WATER CONSERVATION

Conserving and using water more efficiently can reduce the amount of water treated to drinking water standards. Reducing the amount of treated water used by the community adds resilience to and eases demands on the drinking water system. In order to estimate the potential of the City to reduce water demand, historical water demand trends were evaluated and projected over the planning horizon, benchmarks were established for water use by customer class, and a range of conservation measures were evaluated.

To determine interest in conservation, the city conducted a survey of its customers in May 2016. One goal of the survey was to improve understanding of customers' actions and perceptions of water conservation. A total of 730 survey responses were received to the survey, of which 380 were from residential customers and 350 were from commercial customers. Figure 1-5 summarizes the results of the survey.

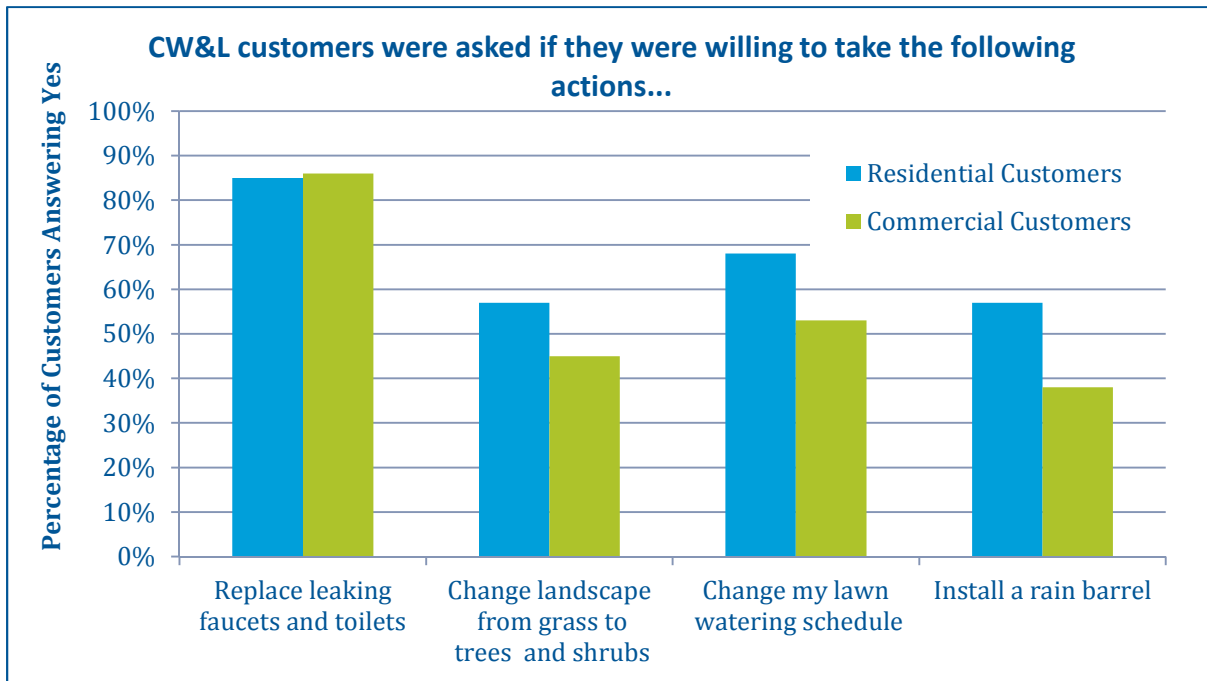


Figure 1-5 CW&L Customer Responses to 2016 Water Conservation Survey Questions

In general, the results show a very positive response by CW&L customers towards potential conservation actions. Residential customers appear slightly more willing to undertake additional conservation measures compared to commercial customers.

Water conservation can be achieved using a variety of strategies. Selecting the appropriate suite of strategies for the individual utility will depend on the goals of the program, available funding, a thorough understating of the baseline conditions, and should include input from customers. This assessment of water conservation potential for CW&L examined multiple areas of action including those best management practices listed in Table 1-2.

Table 1-2 Potential Water Conservation Strategies

CONSERVATION PROGRAM	CONSERVATION ACTIVITY
Conservation Analysis and Planning	Conservation Coordinator
	Customer Surveys
	Customer Audits
Financial Incentives	Water Conservation Pricing
Supply-Side Conservation & Water Loss Control	AWWA Water Audit and Water Loss Control
Landscaping	Landscape Irrigation Conservation and Incentives
	Residential Landscape Irrigation Evaluation
Education & Public Awareness	Public Information
	School Education
Rebate, Retrofit, and Incentive Programs	Audit Programs for Commercial and Large Commercial Accounts
	Residential Toilet and / or Clothes Washer Incentive Program
	Showerhead, Aerator, and Toilet Flapper Retrofit
Conservation Technology	New Construction Graywater
	Rainwater Harvesting and Condensate Reuse
Regulatory & Enforcement	Prohibition on Wasting Water
	Landscape Irrigation Scheduling Ordinance
	New Construction or Retrofit Ordinance

In addition to these conservation strategies, a significant measure to conserve water use is to reduce the amount of unaccounted for or lost water in the distribution system. Many utilities, including Columbia, track unaccounted for water in their systems. Figure 1-6 shows performance of Columbia relative to other utilities.

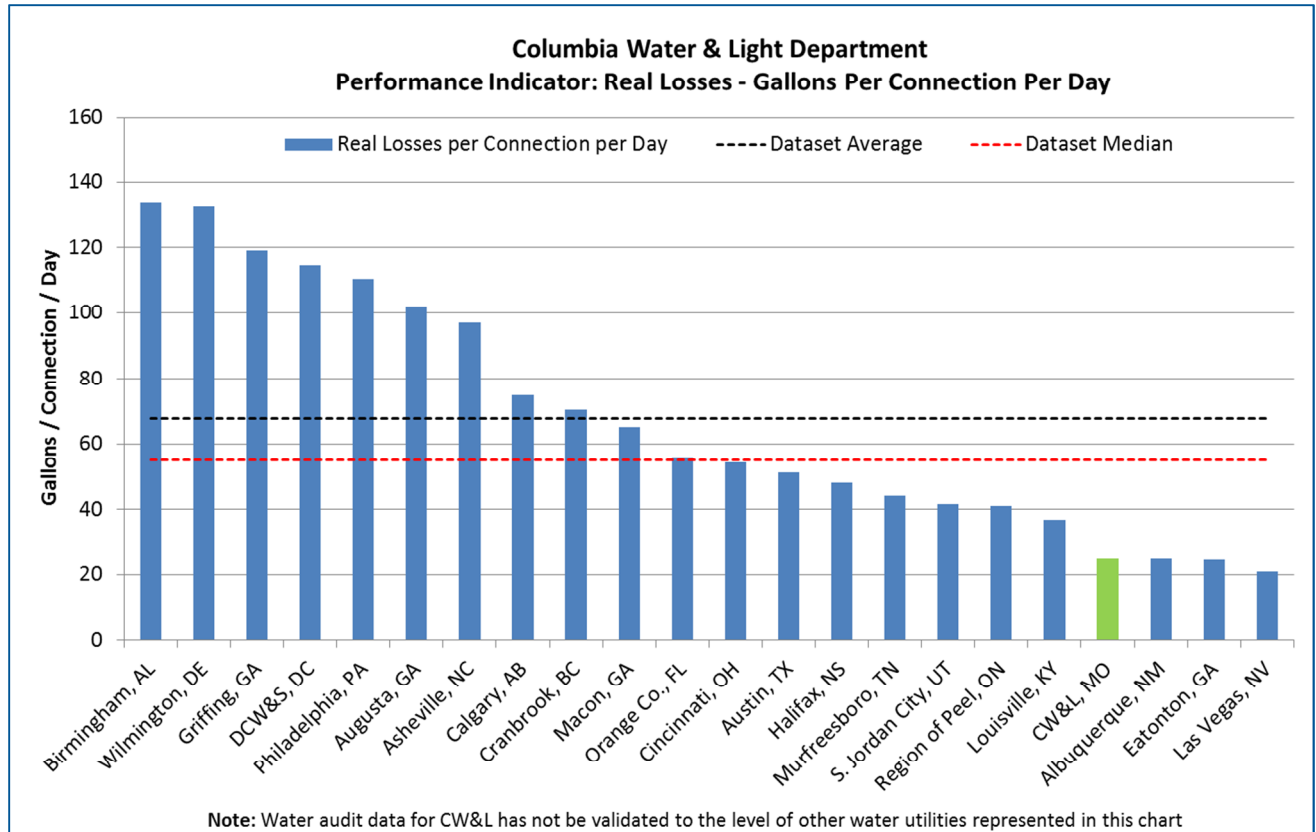


Figure 1-6 Published Water Audit Data (AWWA). Real Losses per Connection per Day

The data shows that Columbia is performing well compared to other utilities in relation to water loss.

There are many directions a conservation program can proceed. Based on a review of the available data and information, the following recommendations are provided regarding the implementation of a CW&L water conservation program.

- **Data-Driven.** Prior to implementing any of the aforementioned water conservation strategies, it is recommended that additional data is gathered from customers (via more detailed surveys or customer liaison groups) in order to ensure the programs are tailored to the specific needs of CW&L customers.
- **Water-Energy Nexus.** As CW&L already has energy efficiency programs, there may be an opportunity to leverage these existing programs to include water efficiency measures; such opportunities are not typically available to many utilities.
- **Irrigation Focus.** Five different strategies have been identified to address irrigation demands on the system. Based on the available data, there appears to be significant potential to address irrigation demand and these approaches could be among the most cost effective. CW&L could adopt a tiered approach to irrigation strategies that move from education, through specific outreach efforts, to enforced irrigation ordinances.

- **Pilot Programs.** The conservation programs outlined can all be adopted initially as pilot programs. This is a sensible strategy as each utility’s customer base is unique and the response to customer incentive program can vary for a multitude of reasons. A pilot strategy can limit the cost of the programs while real data is gathered to evaluate program savings. Pilot programs can be limited in scope (a subset of customers) or duration.
- **Monitoring & Evaluation.** Monitoring and frequent evaluation of the conservation program’s effectiveness will be essential to verify the impact of the program and to ensure it is responsive to customers’ needs. Water savings can be estimated based on adoption rates of water efficient products and validated by examining water use records (i.e., billing data) to help verify savings. The overall water conservation program involves a number of individual components, and program priorities may change in response to customer feedback and the results of program evaluations.

Implementing a combination of these conservation measures can have a significant impact on average day and peak day water use for a community. An effective conservation program can reduce or delay expansion of treatment facilities and help assure adequate water supply is available. The essential elements of the conservation program recommended for Columbia along with annual costs of the program through 2026 and estimated water savings are shown in Table 1-3. An important consideration is that the greatest potential reduction in demands, and the most cost-effective reduction, is achieved by focusing on reducing demands for lawn irrigation.

Table 1-3 Estimated Annual Costs for CW&L Water Conservation Program

CONSERVATION ACTIVITY	ANNUAL COST 2017-2026 (2016 DOLLARS)	ESTIMATED WATER SAVINGS 2026 (MGD)
Conservation Coordinator & Program Admin	\$110,000	N/A
AWWA Water Audit	\$50,000	N/A
Public Information & Customer Surveys	\$140,000	N/A
School Education	\$37,500	N/A
Audit Programs for Commercial and Large Commercial Accounts	\$142,806	0.095
Residential Toilet Incentive Program	\$178,863	0.176
Commercial Toilet Incentive Program	\$47,602	0.019
Residential Clothes Washer Incentive Program	\$115,999	0.101
Residential Showerhead / Aerator Retrofit	\$35,773	0.101
Landscape Irrigation Scheduling Ordinance & Enforcement	\$80,000	0.534
TOTAL PROGRAM	\$938,542	1.027

The effectiveness of a fully implemented conservation program was evaluated for Columbia to estimate the potential reduction in average day and peak day usage through the planning period. A number of factors were included in the development of this estimate, including remaining number of

old fixtures and demand reductions seen in other similar communities. Based on this, a realistic decrease for 2015 would be 1 MGD for average daily demands and 3 MGD for maximum daily demands. By 2040, the estimated decrease in water usage would be 1.5 MGD for average daily demands and 5 MGD in maximum daily demands as shown in Table 1-4. While these conservation measures can contribute significantly in reducing demands and thereby delaying the need for expansion of some elements of the water supply system, ongoing monitoring and evaluation is required to determine the magnitude and reliability of the reductions in water demand achieved by the conservation program.

Table 1-4 Demand Projections for CW&L for Baseline and Conservation Scenarios (ADD and MDD)

		2020	2025	2030	2035	2040
Average Daily Demand	Baseline (MGD)	16.47	18.90	21.69	24.90	28.59
	Conservation (MGD)	16.11	17.98	20.54	23.61	27.14
Maximum Daily Demand	Baseline (MGD)	28.20	32.22	36.82	42.09	48.13
	Conservation (MGD)	27.19	29.19	32.98	37.75	43.21

PUBLIC ENGAGEMENT

Early and continuous public involvement brought diverse perspectives and values into the planning process. Desired outcomes of the public engagement effort included:

- *Developing* an informed group of stakeholders that understand the benefits and tradeoffs of implementing available water management strategies.
- *Informing* the stakeholders by providing balanced and objective information to assist them in understanding the problems, alternatives, opportunities, and solutions.
- *Consulting* the stakeholders by obtaining feedback on analysis and alternatives.
- *Involving* the stakeholders by working directly with them throughout the process to ensure that concerns and aspirations are consistently understood and considered, ensuring stakeholder groups are included and consulted.
- *Building* partnerships with other agencies and stakeholders, recognizing the effect this effort has on the community and other sustainable infrastructure initiatives.

Information on water supply alternatives, non-potable water uses, and conservation practices were presented to stakeholders so that they understood the benefits and trade-offs of implementing available water management strategies. Stakeholders were consulted on the developed options and recommendations so that the Integrated Water Resource Plan represents the best balance for the community.

The outreach helped to understand the concerns of the public and get an idea of customers' willingness to participate in conservation programs. The summer 2016 survey of Columbia water users showed that customers are active participants in water conservation and are willing to do their part to conserve water. A final presentation was delivered to the public on February 15, 2017 which summarized the results of the report.

COST ESTIMATION

Cost estimates were developed for all of the alternatives. These include the capital costs and the cost to operate and maintain facilities. Estimates are based on existing cost models and recent bid or project data. Additional allowances for general requirements (permitting, contingencies) and engineering, legal, and administrative costs were combined to obtain a total estimated capital cost for the project. Quantities for structures, building, process components, pipeline lengths, and basin sizes were developed based on preliminary process sizing of the treatment components, preliminary site layout, and similar regional plant facilities. Costs for distribution systems for non-potable irrigation usages were also incorporated.

Although there would be slight variations in the potable distribution system depending on the supply source, in general the overall capacity and extent of the potable supply system would essentially be the same for each supply source as the potable system would still be required to meet maximum day and fire flow requirements. Therefore, for the basis of this analysis, the potable supply distribution costs were considered the same for all the supply alternatives, as any variations would be minimal and not impact the evaluation results in this study.

The costs developed as part of this project are to be used as a basis of comparison between the alternatives. They are not to be interpolated for future customer rate increases as a number of other factors would need to be considered to determine the impact per customer.

All cost estimates are planning-level, and any further work requires a more detailed and locally-specific evaluation of cost. Figure 1-7 shows the annualized cost for each supply alternative over a 30 year period at interest rate of 5 percent.

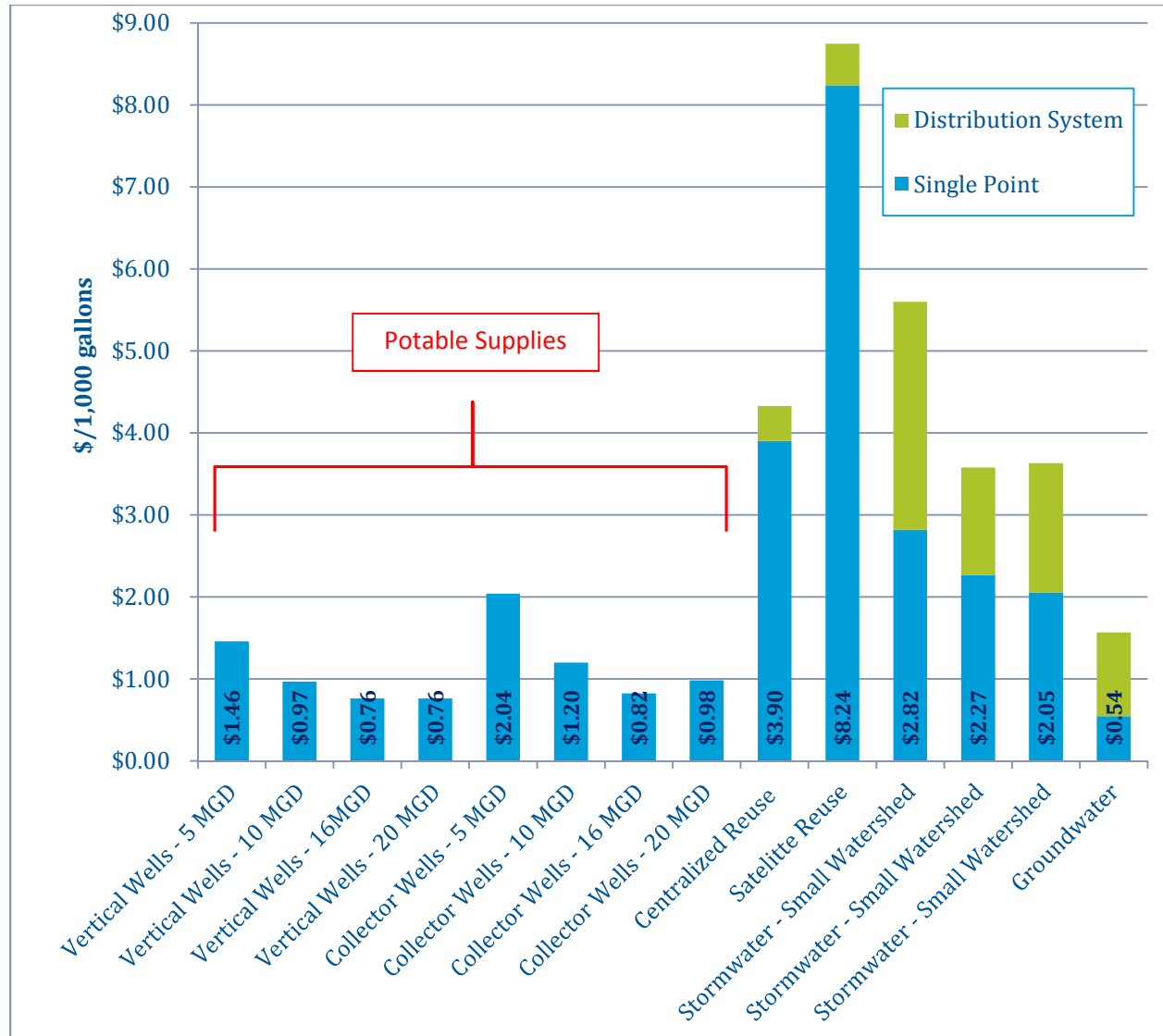


Figure 1-7 Annualized Costs (Based on Average Demand)

MODEL DEVELOPMENT AND SCENARIO EVALUATION

An integrated demand and supply model was constructed in GoldSim, which allows the user to select various supply and demand scenarios for evaluation and comparison. The model can help to estimate the cost and reliability of various approaches to meeting the City’s water resource needs. Nine scenarios were evaluated in this report which represents combinations of conservation and supply alternatives. These scenarios included:

- **Scenario 1:** 16 MGD potable water treatment expansion
- **Scenario 2:** 10 MGD potable water treatment expansion plus conservation
- **Scenario 3:** Partial 16 MGD potable water treatment expansion, limited well field expansion, and conservation

- **Scenario 4:** 10 MGD potable water treatment expansion, non-potable groundwater wells, and conservation
- **Scenario 5:** 10 MGD potable water treatment expansion, non-potable groundwater wells
- **Scenario 6:** 10 MGD potable water treatment expansion, stormwater ponds,
- **Scenario 7:** 10 MGD potable water treatment expansion, stormwater ponds, conservation
- **Scenario 8:** 10 MGD potable water treatment expansion, centralized reuse, conservation
- **Scenario 9:** 10 MGD potable water treatment expansion, satellite reuse, conservation

For each scenario, annualized costs were developed for comparison and summarized in Figure 1-8.

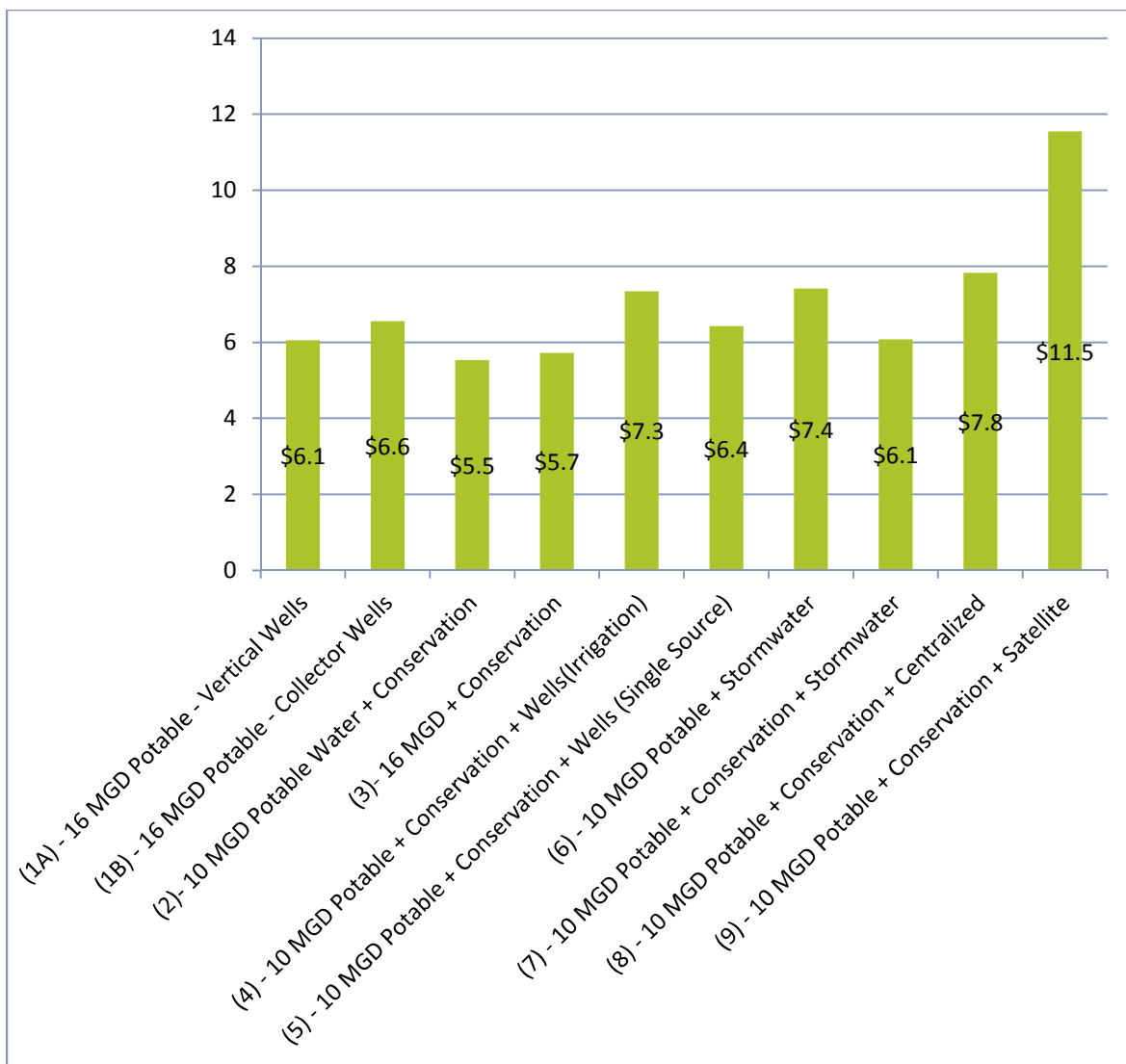


Figure 1-8 Annualized Cost for Each Scenario (in Millions of Dollars)

The lowest cost scenario does not necessarily result in the best long term solution to satisfy the City's needs for water supply. Non-economic factors such as reliability of the selected plan, how the plan would be perceived and accepted by residents, and environmental and safety aspects all should be considered in the selection process. In addition, the costs presented above relate to only capital and operations costs to implement the improvements. These do not capture the overall costs to the customer for these improvements. Many other factors will go into the costs to customers that are not included as part of this study. Therefore, these costs are to be used only as a comparison between the alternatives.

To incorporate both economic and non-economic factors into the evaluation, a scoring system was created that assigns a weight for each criteria based on level of priority. The criteria and weighting factor for the economic and non-economic comparisons are shown in Table 1-5.

Table 1-5 Economic and Non-Economic Evaluation Criteria

NON-ECONOMIC EVALUATION CRITERIA	
Criteria	Weighting Factor
Annualized Costs	30%
Reliability	25%
Social	15%
Environmental	30%
Summary	100%

After establishing the weighting factor, each alternative was considered with regard to the criteria, and a score was assigned to each alternative on scale of 1 to 10, with 10 indicating the best performing alternative in the respective criteria category. For example, the lowest capital cost received a 10 in regards to the annualized cost criteria, and the other alternatives were assigned a score based on a ratio of the cost with respect to the lowest cost. Based on the importance factors of the criteria and the individual criteria scores for each alternative, a total score was calculated. The higher the total score indicates that the alternative better met the criteria. Figure 1-9 summarizes the results.

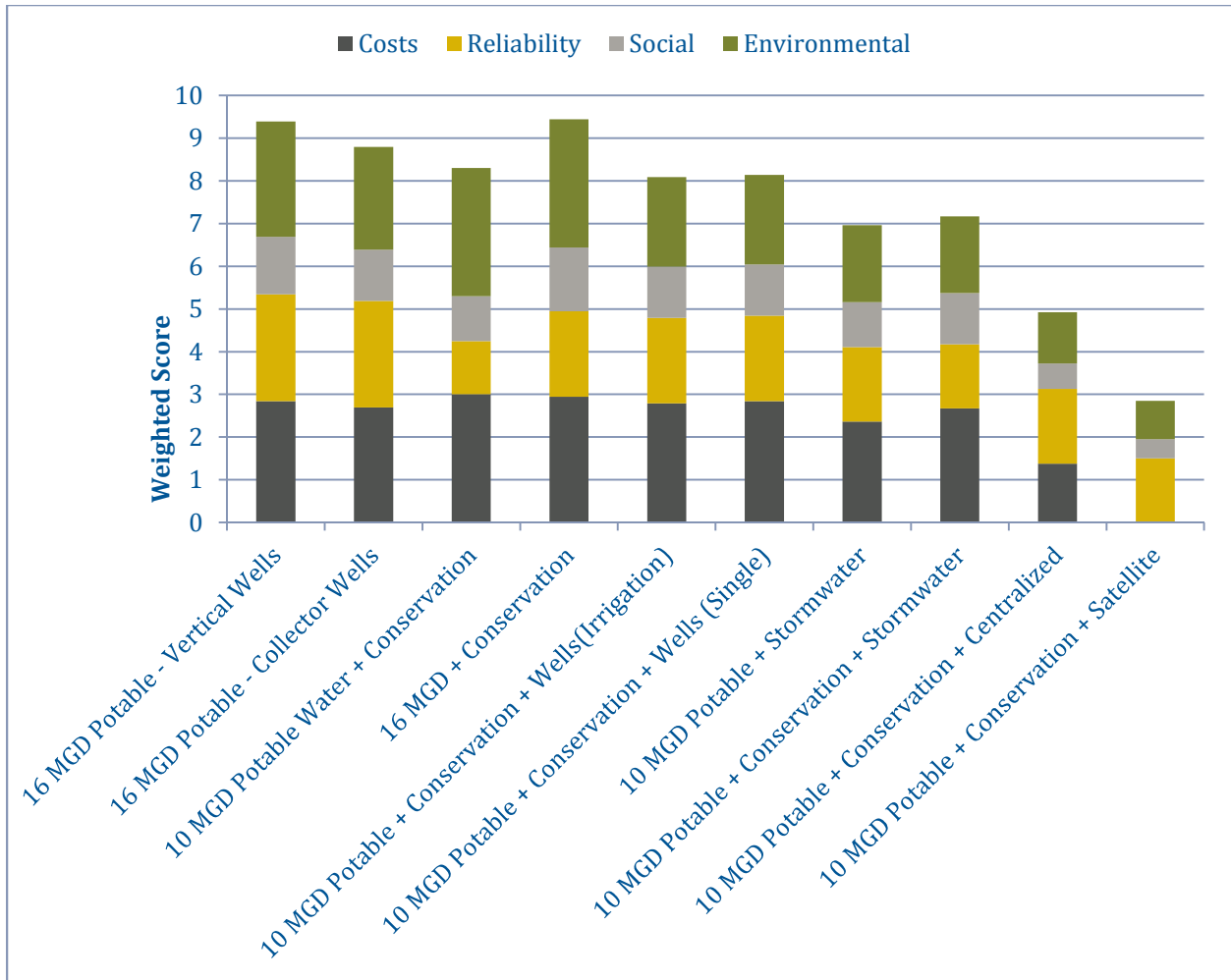


Figure 1-9 Evaluation of Scenarios

CONCLUSIONS AND RECOMMENDATIONS

Based on the evaluation completed including economic and non-economic factors the following recommendations have been developed:

Scenarios that incorporate non-potable supplies were generally slightly more costly than the potable supply alternatives, and also scored lower on the non-economic factors. A significant cost component of non-potable systems is the distribution system required for irrigation purposes. Non-potable supplies can be a viable source of water supply if used for single point users where large distribution networks aren't required and flow demands are relatively constant. However, the location of the user relative to the source of supply will impact costs and be the primary driver relative to feasibility.

For the four non-potable sources evaluated, the centralized wastewater and satellite wastewater reuse supplies were extremely costly to construct, and did not score high in non-economic criteria, especially public perception. Therefore, these supply sources should not be considered in the overall supply plan for the City, especially given the availability of other water sources in the region.

Deep groundwater wells were the lowest cost non-potable supply alternative. When deep wells are installed to supply a single user they provided the lowest supply cost of any of the potable or non-potable alternatives. Therefore, the continued use of deep groundwater wells to serve industries, golf courses, and parks should continue, which can help delay installation of new supply wells required for expansion at the water treatment plant.

Implementing deep groundwater wells are not as effective for residential irrigation due to the patterns of extremely high peaks. Wells are generally sized for a specific capacity and do not have the ability to meet peak day or hour conditions unless extremely oversized for the area it serves, multiple wells are installed, and/or ample storage is provided. The distribution piping also needs to be sized for sufficient flow to handle the peak hour demands when a large percentage of the area is watering at one time. Furthermore, installation of a non-potable distribution system for irrigation doesn't significantly reduce the size of the piping for the potable system as most areas fire flow dictates the potable system pipe sizing.

Stormwater ponds used for non-potable supply would generally be more expensive to implement than potable supply expansion. In addition to being more costly, environmental aspects and finding optimal locations for the ponds further diminish the viability of this source of supply. Similar to deep groundwater wells, there may be some small scale instances where a pond could be utilized for a single point user or small residential area. However, these would be site specific and difficult to implement at a large scale by the City. For residential irrigation, stormwater ponds have the same distribution costs as groundwater wells, but are more flexible for peak demands. Ponds are impacted more by drought conditions so they are also not as reliable as other sources of supply. The City is currently conducting an Integrated Stormwater Management Plan (IMP) that may consider large stormwater retention basins. Additional volume could be incorporated into these basins to serve as non-potable supply. However, any volume built into the basin for non-potable use would be in addition to volume required for stormwater detention, making the basin larger. Therefore, utilizing a combination of stormwater detention and non-potable water storage in basin is not real feasible as they serve different purposes.

For all the non-potable supply alternatives the City could require developers to provide the source water and distribution network as part of their development. This would burden these costs onto the developer and ultimately the home owners. By implementing this approach the potable supply capacity could be reduced, thus delaying installation of additional wells and expansion costs at the plant. However, this approach would not have a major impact on overall costs to the City as the infrastructure to supply the area with potable supply would still be required. This approach may also detrimentally impact development and growth within the City, which should also be considered.

Generally, other City's move forward with non-potable supplies when there is a shortage of available potable supply to serve the future growth. This is not the case for Columbia as there is abundance of supply, either with the existing vertical well field, collector wells located along Missouri River, or even the Missouri River itself.

Therefore, the most reliable, cost effective approach for the City to address future water supply needs is to expand the potable supply, which consideration of implementing conservation to reduce overall supply needs. Three potable supply expansion concepts were considered and listed below:

Alternative 1 – 16 MGD Water Treatment Expansion

Alternative 2 – 10 MGD Water Treatment Plant Expansion and Conservation

Alternative 3 – Partial 16 MGD Treatment Plant Expansion and Conservation

Alternative 1, 16 MGD Treatment Plant Expansion, would meet the projected future maximum day demands through year 2040 without impacting current water usage. Expanding a treatment facility to meet anticipated water needs is a traditional approach taken by many communities, especially for those with ample water supply such as Columbia. This also is a similar approach to what Columbia has done in the past, both in the 1990's and 2000's, when the plant was expanded by 8 MGD on two separate occasions to meet projected demands. The major difference is that in lieu of two smaller expansions, this alternative recommends one larger expansion to cover a longer timeframe to lower the overall cost to meet water supply for the planning period. The estimated annualized cost for comparison of this alternative is \$6.1 million dollars.

If capital and operational costs were the only factors to consider, then the recommended approach would be to upgrade the water treatment plant with a 10 MGD expansion and implement the conservation program. However, this alternative (Alternative No. 2) would require significant changes to the standard irrigation practices currently in place, including ordinances, replacement of high flow toilets, inefficient washers and showerheads, new rate structures, and aggressive education on conservation. Even with implementing these measures, it is estimated based on similar programs around the country that have already implemented conservation that the peak day demand reduction from conservation would not be sufficient to offset your demand needs by the end of the evaluation period, year 2040. Therefore, to meet the system demands for the full planning period, either additional conservation restrictions beyond what has been identified in this study, lower expected population growth, or another plant expansion, would have to occur before 2040. The estimated annualized cost for this alternative is \$5.5 million dollars, which is approximately \$0.6 million dollars per year less than Alternative No. 1. However, if conservation was not successful in offsetting future water requirements and another plant expansion would be required, the overall cost of this alternative would be more than Alternative 1. Therefore, this alternative scored lower on reliability to meet supply needs throughout the planning period.

Alternative No. 3 includes a partial 16 MGD expansion and conservation. The partial 16 MGD expansion would include initially constructing the process train (basins, filters, clearwell, pump station) able to treat a capacity of 16 MGD, but the remaining treatment components, such as well field, pipelines, aerators, chemical feed systems, to generally be expanded only when needed based on supply needs. Many of these facilities, such as the well and aerators, can be increased in capacity incrementally over time with minimal impact in operations.

Conservation would still play a critical component to this plan as it will allow the expansion of the remaining facilities to be delayed, and the overall peak day of the capacity of the plant to be reduced. The effectiveness of conservation measures could be re-evaluated in 5-7 years, at which point demand projections could be adjusted and its impact on overall implementation of the remaining improvements. The essential elements and approach for implementing a conservation plan are outlined in Section 6 of this report.

Based on this evaluation, the recommendation is to proceed with Alternative No. 3, partial 16 MGD expansion. Expanding a portion of the facilities to 16 MGD versus the 10 MGD included in Alternative No. 2 will reduce the potential risk of a future plant expansion within the planning period. Furthermore, the 16 MGD process train provides additional flexibility at the plant to incorporate the necessary improvements to the existing plant and a more reliable treated water supply. If the conservation program is as effective as estimated, or even more effective, the additional wells and remaining plant expansion costs could be pushed out further in the implementation schedule. It is possible that the full 16 MGD plant expansion could not be required until beyond the 2040 planning period with an effective conservation plan. Based on a partial plant expansion the estimated annualized cost for this alternative is \$5.7 million, which is approximately \$0.2 million more per year than Alternative No. 2.

Unless the City desires to enforce strict irrigation ordinances, it will take time for the conservation program to impact the overall water usage. Therefore, implementation of conservation program should not delay the expansion of the treatment facility. Some conservation measures could help to limit localized supply issues, specifically education regarding irrigation practices. However, it should be noted that there is sufficient supply in the existing well field to meet all demands through at least year 2040 whether or not conservation is implemented. Therefore, conservation should be decision the community makes related to environmental impact and social behaviors.

As indicated, there is approximately \$18M in plant improvements required whether or not the plant is expanded. By building the infrastructure in place at the plant for the partial 16 MGD expansion in conjunction with the rehabilitation, some of these costs associated with the existing plant could be deferred, along with delaying the well field expansion until the supply is needed. This approach provides the most cost efficient and reliable method to meeting the city's water supply needs.

Implementation

Based on current demand projections, the peak day of 32 MGD will be exceeded in year 2023. It is recommended that at least 3 years be included from start of the preliminary design to project completion for the expansion project. Therefore, the partial plant expansion should start by mid-2019 at the latest to assure completion before end of 2022. However, it is recommended that the project start in year 2018 to assure completion and satisfactory operation before peak capacity is exceeded. It is recommended the initial capacity of the plant be increased by at least 5 MGD. However, additional evaluation should be completed to determine the most cost effective approach for incremental expansion.

The historical peak day capacity of 23.8 MGD essentially matches the current 24 MGD reliable capacity of the water treatment plant. City staff have already implemented some of the rehabilitation improvements and continue to proceed on specific components as funding is available. The City should proceed with critical rehabilitation components in the near term, but consideration should be given to combining the plant rehabilitation into the expansion project to incorporate as many aspects as possible into one project for efficiency in construction. The sooner these improvements are started the more reliable the overall system will become.

2.0 Program Overview

The City of Columbia, Missouri, Water and Light Department (CW&L) requested development of an Integrated Water Resource Plan (IWRP) that provides an implementable plan to meet the water resource needs for its current and future customers until year 2040. The IWRP takes a holistic approach to managing water resource requirements that includes evaluation of water supply, water demand, water quality, environmental protection and enhancement, and public participation. The plan provides a sustainable approach that is environmentally conscious, cost-effective, defensible, meets all regulatory guidelines, and provides a reliable supply to meet future needs.

The water resource plan is not intended to be preliminary design report used to select specific treatment processes, target water quality goals, and exact locations of non-potable infrastructure, but it is to serve as means to develop an overall path forward the City should take in addressing future water supply requirements. As projects move forward further evaluation and refinement of the concepts presented to address water supply will need to occur to optimize the overall plan and assure all factors are considered.

2.1 INTEGRATED WATER RESOURCE PLAN PROCESS

The IWRP process included development of technical options to meet the City's water needs by evaluating the feasibility and costs for expanded potable water supply, conservation, and non-potable supplies. Throughout the process, public meetings were held and information was presented to an IWRP Advisory Board which included diverse representatives from the public and CW&L board members to provide input and direction as to important items to include in the IWRP. The IWRP committee included,

- Terry Merritt
- Benjamin Ross
- Robert Roper, Jr.
- John Clark
- Jack Clark (Water and Light Advisory Board Member)
- John Conway (Water and Light Advisory Board Member)
- Robert Hasheider (Water and Light Advisory Board Member)
- Henry Ottinger (Water and Light Advisory Board Member)
- Dick Parker (Water and Light Advisory Board Member)
- Barbara Buffaloe (Sustainability Manager)

Additional public engagement, including distribution of fact sheets, surveys, and public open houses further integrated the public and stakeholders into the overall IWRP process. This process identified options and cumulative alternatives to meet the agreed upon goals and objectives of the IWRP.

Ultimately, the IWRP will serve as a guide for program development, budget preparation and capital improvements planning for Columbia's water system. The guide considered many aspects of the City's water resources and their interactions with one another, including, but not limited to the following:

- City's current water source and supply capacity
- Projected population growth and water needs
- Potential future sources of water
- Development of water alternatives considering
 - Water Demand Trends
 - Water Conservation
 - Potable Water Supply
 - Non-Potable Water Supply
 - Regulatory Requirements
- Community Involvement

The IWRP will conclude with recommendations that meet minimum requirements, discussion on why those recommendations are being made, and how they will provide value to CW&L's customers.

2.2 REPORT STRUCTURE

This report summarizes the information included in the integrated water resources planning and evaluation. The report is divided into the following chapters:

- **Chapter 1: Executive Summary**
- **Chapter 2: Program Overview** – Provides the program background, purpose, and approach.
- **Chapter 3: Existing System** – Describes the water supply infrastructure in use in the CW&L system.
- **Chapter 4: Demand Projections** – Update of previous demand estimates with current data and projections to 30 years.
- **Chapter 5: Water Supply Sources** – Describes potential sources for potable and non-potable supplies in the Columbia area.
- **Chapter 6: Water Conservation** – Detailed evaluation of the potential for water savings through conservation.
- **Chapter 7: Public Engagement** – Discussion of how stakeholder engagement informs the IWRP.
- **Chapter 8: Cost Estimation Development** – Planning-level estimate of capital and O&M costs for the alternatives presented.
- **Chapter 9: Model Development** – Explanation of the model platform, inputs, and capabilities.
- **Chapter 10: Scenario Definitions** – Description of the nine scenarios evaluated using the model.
- **Chapter 11: Model Results** – Costs, implementation schedule, and discussion of impacts for each of the nine scenarios.
- **Chapter 12: Evaluation of Scenarios** – Discussion of the scenario evaluation results in terms of feasibility in meeting the needs of CP&W.
- **Chapter 13: Conclusion and Recommendations** – Discussion of the scenarios which provide the most sustainable, reliable, and cost-efficient means toward meeting Columbia's demands for the planning horizon.

3.0 Existing System

3.1 SERVICE AREA DESCRIPTION

The City’s water system currently serves approximately 48,000 customers in 89 square miles with a historical peak demand of 23.3 million gallons per day (MGD). The Water System consists of ground water wells and a production facility in the Missouri River flood plain, two water transmission mains into Columbia, four pump stations, three ground storage reservoirs, three elevated storage tanks and 671 miles of water mains. Figure 2-1 shows the general service boundary for the system.

The system serves residential, commercial, industrial, and institutional customers within the City limits as well as small areas adjacent to the City. Within the City limits but not served by CW&L is the University of Missouri campus, which has its own deep well water supply. Treatment occurs at the McBaine Water Treatment Plant, which is a groundwater softening plant.

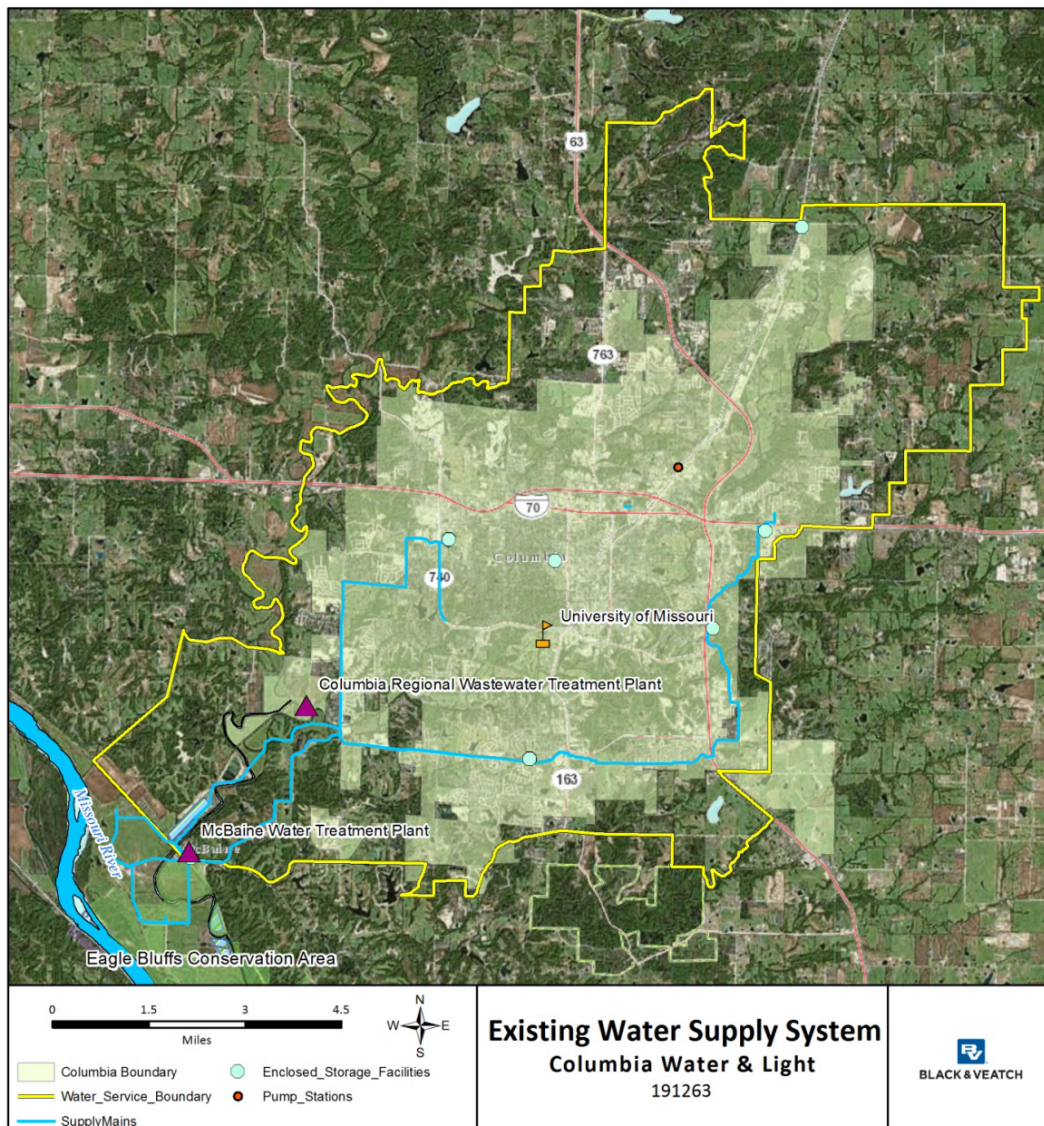


Figure 3-1 CW&L Service Area

3.2 EXISTING WATER SUPPLY

Since 1904, the City of Columbia has been using groundwater for their drinking water supply. Originally, deep bedrock wells located within City limits pulled water from the Ozark Aquifer with depths ranging 500 to 1200 feet below ground surface. As a result of concerns about the declining water levels in the deep wells and the long term capacity of the Ozark Aquifer, the City began research on the McBaine Bottoms Aquifer along the Missouri River in the 1960s as a new water source for the City. The study, conducted by Layne Western Company, determined the McBaine Bottoms Aquifer was a viable drinking water source with sufficient capacity to meet the City's needs well into the future. The City began using the McBaine Bottoms Aquifer as their water source in the early 1970s in conjunction with the construction of the McBaine Water Treatment Plant (WTP).

The McBaine Bottoms Aquifer is a prolific alluvial aquifer located beneath the flood plain of the Missouri River about seven miles southwest of downtown Columbia. The alluvial fill consists of fine grain clay and silts near the ground surface, fine to medium sand in the middle of the aquifer, and coarser sand and gravel above bedrock. The water quality in the aquifer is generally very high but does exhibit concentrations of hardness, alkalinity, carbon dioxide and dissolved iron. The McBaine Bottoms Aquifer is highly transmissive and receives sufficient recharge to replace the City's production of around five billion gallons of groundwater per year.

The City currently has 15 high-capacity vertical wells in the McBaine Bottoms Aquifer that serve as the City's source of supply. Three additional wells, completed by spring 2017, will bring the total number of wells to 18. The well field has a network of piping that is connected to two raw water transmission mains leading to the McBaine Water Treatment Plant. The locations of the wells are shown in Figure 3-3.

The McBaine Bottoms Alluvial Aquifer has the ability to yield a significant quantity of water for the City for the foreseeable future. In 2012, Black & Veatch worked with the City to complete the McBaine Well Field Study which evaluated the capacity of the aquifer along with the capacity of the existing 15 wells. The evaluation indicated that the well field could produce approximately 28 million gallons per day (MGD) with all 15 wells in operation, considering the effects of recharge and interference between adjacent wells when all wells are operating at the same time.

To confirm well field production capabilities had not diminished significantly over time, a performance test was conducted with all 15 wells in operation on September 15, 2015. The test confirmed that the well field could produce 28.5 MGD with all 15 wells in operation.



Figure 3-2 Existing Well

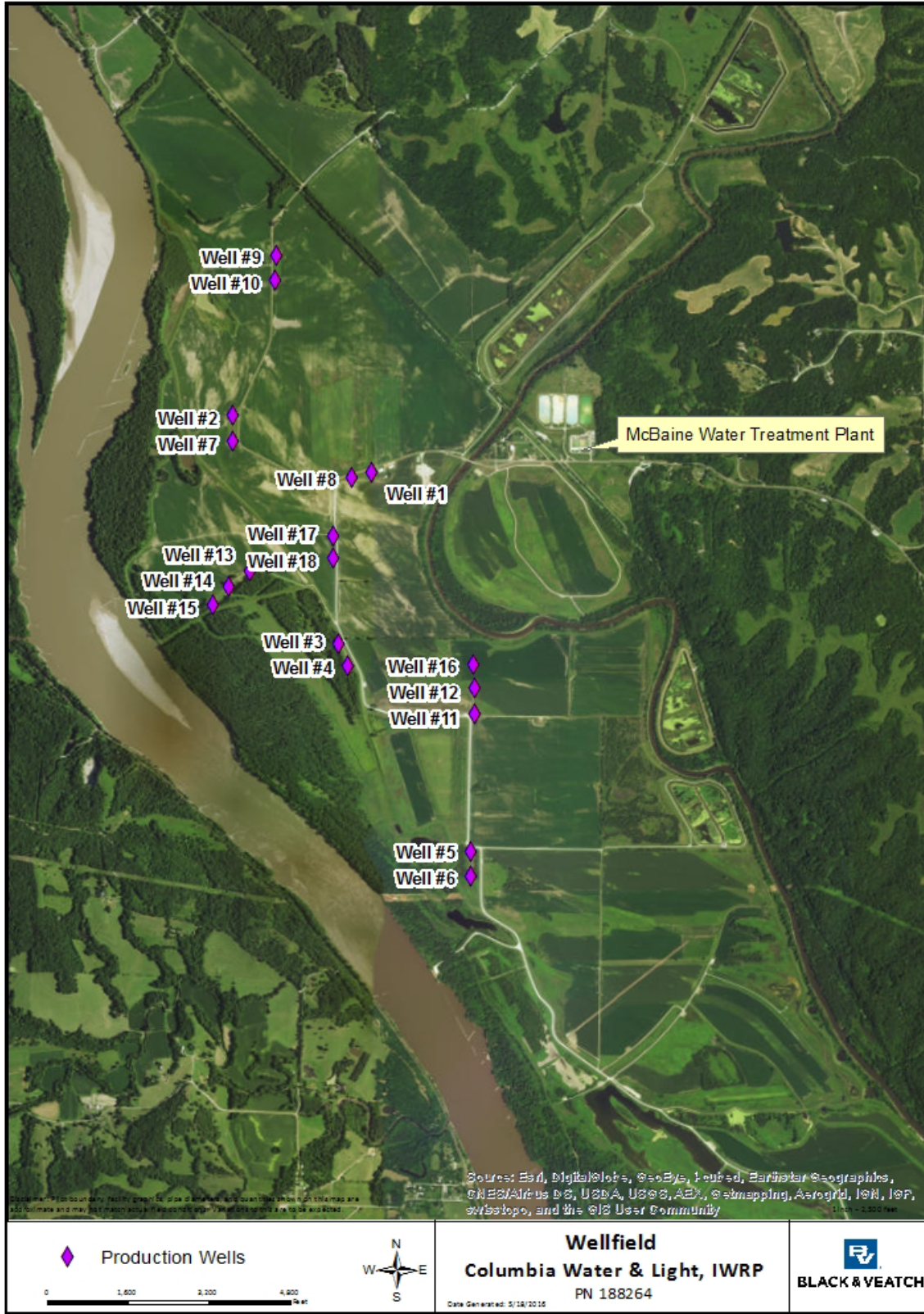


Figure 3-3 McBaine Well Field and Water Treatment Plant

To provide redundancy and increase reliability, three wells are scheduled to be installed by spring 2017 that will provide an estimated additional 6 MGD of well capacity. After installation of the three new wells the firm capacity of the existing well field is approximately 29.6 MGD with 17 of the 18 wells operating (with one reserved as a standby well). The capacity of the well field is variable over time based on a number of factors, including climate conditions, river conditions, condition of each well as it ages, effectiveness of periodic well maintenance activities, and pump and motor conditions.

As discussed in the McBaine Water Treatment Plant and West Ash Condition Assessment, Black & Veatch (2016), replacement of the lower head pumps at the wells would increase the firm capacity of the well field to meet the existing plant capacity of 32 MGD. The raw water capacity would also increase if modifications are made to the plant to minimize flow restrictions at the inlet.

Table 3-1 summarizes the total well field and WTP capacity based on interference and piping losses for both existing and future conditions following construction of the three new wells.

Table 3-1 McBaine Well Field and WTP Capacities

CONDITION	TOTAL INSTALLED CAPACITY (MAXIMUM)	FIRM INSTALLED CAPACITY (SAFE YIELD)
Existing Wellfield (15 Wells) ^{1,2}	26.9	23.6
Expanded Wellfield (18 Wells) ^{1,2}	32.9	29.6
McBaine WTP Capacity after Rehabilitation ^{1,2,3}	34.5	31.2
1. The three future well capacities were estimated at 2 MGD each. 2. Well capacities include pipe losses. 3. Rehabilitation includes modifications to aerator influent piping.		

3.3 MCBAIN WATER TREATMENT PLANT

The McBaine Water Treatment Plant is a groundwater softening plant consisting of aeration, 2-stage precipitative softening, filtration, and disinfection facilities. Originally constructed in 1970, the facility has seen two major 8 MGD expansions throughout its service life. These improvements have increased capacity from 16 MGD to its current rated capacity of 32 MGD, while continuing to provide quality water to its customers. However, replacement and upgrades to existing equipment and structures are necessary, especially for a facility in operation for more than 45 years, to continue to produce quality water. Over time, deterioration of assets affects performance, operator flexibility, and reliability, which limit the overall capacity of the facility to 24 MGD. The “McBaine Water Treatment Plant and West Ash Condition Assessment”, Black & Veatch 2016, summarized the condition of the existing plant and costs to rehabilitate the plant to continue to provide reliable supply to the City.

3.3.1 Plant Description

Raw groundwater is conveyed from the well field to the plant through a network of piping, and upon entering the plant, flows through a single 36-inch diameter flow meter prior to being divided between four 8 MGD induced-draft aerators. These aerators initiate the oxidation of iron and remove carbon dioxide and hydrogen sulfide. The aerated water discharges to a common wet well from which it flows via concrete flumes to four 8 MGD primary/secondary softening basin trains. The two original basin

trains are equipped with upflow solids contact clarifier (SCC) equipment in the primary basins and flocculating clarifier equipment in the secondary basins. The first and second plant expansion basin trains have SCC equipment in both the primary and secondary basins. Lime is added at each of the primary basins to reduce the hardness of the raw water to approximately 150 mg/L as CaCO₃. Chlorine is added between the primary and secondary basins to maintain 2 to 3 mg/L free chlorine residual in the water within the secondary basins and the downstream filters to achieve compliance with the virus inactivation CT requirements of the Ground Water Rule and provide the desired chlorine residual in the finished water leaving the plant. Provisions for reduction of softened water pH through addition of carbon dioxide are not currently available.



Figure 3-4 McBaine Water Treatment Plant

Settled water from basin trains 1 and 2 and from basin trains 3 and 4 flows by gravity to two respective effluent drop boxes, where fluoride is added prior to discharge to a common filter influent pipe. Eight multimedia (anthracite / sand / garnet) filters remove suspended solids and turbidity from the settled water. Each filter is equipped with a hydraulic surface wash system to enhance removal of solids from the upper portion of the bed during backwashing. Effluent turbidity from individual filters is continuously monitored. The filters are backwashed by gravity flow from an elevated wash water storage tank. There is no finished water clearwell or storage facility at the existing plant site. Water from individual filters discharges to a common 24-inch diameter effluent pipe header, from which it is conveyed to the distribution system via 8 vertical turbine high service pumps through two 36-inch diameter transmission mains. The finished water is pumped to the West Ash Pump Station Reservoir and the South Pump Station and Reservoir. Water from these two pump stations is then pumped to the distribution system.

As there are no rate control valves for individual filters in use, the filters operate in declining rate mode, with cleaner filters operating at higher throughput rates than filters with higher levels of solids

deposition. Additional chlorine can be fed to each of the finished water transmission lines if required, along with ammonia seasonally to convert the free chlorine residual to chloramine to halt further formation of regulated chlorine-based disinfection byproducts.

Settled solids from the primary and secondary basins discharge to four onsite holding/dewatering lagoons. Filter backwash is discharged to a reclaim basin.

3.3.2 Water Quality

Table 3-2 summarizes raw and finished water quality characteristics for the McBaine Water Treatment Plant. The information presented in Table 3-2 is based on monthly average data provided by the plant staff for January 2008 through mid-2011. While the information presented in Table 3-2 is based on monthly average values, and therefore does not reflect short-term variations in concentrations, plant operators indicate that both raw and finished water quality parameters typically do not exhibit significant variations, and that overall water quality has not changed appreciably since the period for which data were provided.

Table 3-2 Water Quality Data (January 2008 – June 2011)

PARAMETER / SAMPLE LOCATION	AVERAGE	RANGE
Turbidity, NTU		
Raw Water	1.26	0.24 – 5.65
Primary Basin Discharge	8.5	2.3 – 26.6
Plant Discharge	0.48	0.22 – 1.48
pH, units		
Raw Water	7.18	7.08 – 7.36
Aerated Water	7.51	7.36 – 7.76
Primary Basin Discharge	8.96	8.61 – 9.38
Plant Discharge	8.57	8.17 – 8.93
Total Alkalinity, mg/L as CaCO ₃		
Raw Water	300	280 – 319
Aerated Water	291	265 – 313
Primary Basin Discharge	127	106 – 140
Plant Discharge	121	97 – 137
P Alkalinity, mg/L as CaCO ₃		
Raw Water	0	-
Aerated Water	0	-
Primary Basin Discharge	22	5 – 31
Plant Discharge	14	6 – 22
Total Hardness, mg/L as CaCO ₃		
Raw Water	325	306 – 348
Aerated Water	315	293 – 337
Primary Basin Discharge	151	144 – 160
Plant Discharge	154	143 – 163
Calcium Hardness, mg/L as CaCO ₃		
Raw Water	236	216 – 256
Aerated Water	230	209 – 253
Primary Basin Discharge	82	73 – 94
Plant Discharge	85	74 – 94

PARAMETER / SAMPLE LOCATION	AVERAGE	RANGE
Magnesium Hardness, mg/L as CaCO ₃		
Raw Water	88	80 – 95
Aerated Water	85	76 – 101
Primary Basin Discharge	69	59 – 77
Plant Discharge	68	60 – 79
Iron, mg/L		
Raw Water	6.00	5.01 – 7.62
Aerated Water	5.77	5.14 – 6.57
Primary Basin Discharge	1.07	0.74 – 4.66
Plant Discharge	0.08	0.01 – 1.10
Carbon Dioxide (calculated), mg/L as CO ₂		
Raw Water	50	30 – 59
Aerated Water	24	11 – 38
Free Chlorine Residual, mg/L		
Plant Discharge	2.05	1.50 – 2.65
Total Chlorine Residual, mg/L		
Plant Discharge	1.71	1.60 – 2.01

3.3.3 Existing Plant Capacity

McBaine WTP has a rated design capacity of 32 MGD. To achieve 32 MGD, all major components of the treatment plant would be in operation and operating effectively. The historical maximum day of production is 23.3 MGD. The plant has the capability to process higher flows, up to about 32 MGD. However, the stress on the plant components, and potential water quality impacts considering the condition of the existing facilities, 32 MGD should not be considered a reliable capacity. As discussed in the Condition Assessment, without rehabilitation of the plant, specifically replacement of the original 1970s process equipment and electrical gear, the reliable capacity should be considered as 24 MGD.

The preliminary estimated cost to rehabilitate the plant and provide a more reliable capacity to match the current raw water supply capacity is about \$18 million dollars. The required improvements to the plant and schedule to implement these changes are summarized in the Condition Assessment report.

3.4 AQUIFER STORAGE AND RECOVERY (ASR) WELLS

3.4.1 Background

In the early 2000s, the City converted deep bedrock wells to Aquifer Storage and Recovery (ASR) wells. ASR wells are operated in a similar fashion to a large storage reservoir, whereby surplus water is injected and stored throughout the year and then used to supplement supply during periods of peak demand. ASR technology provides drought prone regions with an alternative solution to meet peak water demands. The City began using ASR #10 in 2003 and ASR #8 in 2008. When needed during periods of peak demand, each well was capable of supplying 2 MGD to the City's water system.

ASR #10 was used extensively from 2005 to 2007 because the City was expanding the water treatment plant and construction restricted plant capacity. Since that time, the ASR wells have been used infrequently. In 2009 the City began using chloramines as their secondary disinfectant for the distribution system which required the wells to be re-permitted. The permits for ASR #10 and ASR #8

expired on June 9, 2016 and July 10, 2016, respectively. In order to receive permit renewal, the City will have to conduct geochemical studies with an estimated cost of approximately \$300,000.

3.4.2 Future ASR usage

CW&L staff recommended that the City not renew their permits for ASR #8 and #10 for a number of reasons including:

- The cost of renewing the permits for the ASR wells, along with the cost of operating and maintaining the wells, is high when compared to the amount of water supply benefit to the City.
- Future use of the ASRs may be limited due to the planned improvements and expansion of the WTP and well field.
- Treated water which is injected into the ASR quickly loses chlorine residual. Additional chlorination equipment would need to be installed to treat the recovered water from the bedrock aquifer to avoid a boil order when ASR water is used.
- CW&L does consider the ASR wells as available for water supply in the event of an extreme emergency.

Therefore, as part of this evaluation, the ASR capacity is not considered part of the overall reliable supply to the system. However, use of the ASR wells to provide for non-potable water sources are included in the non-potable water supply alternatives.

4.0 Demand Projections

A review of the current drinking water demand and population data was completed to establish water supply requirements for the IWRP planning period. The review included data compiled from the 2015 Long Range Water System Study (LRWSS), prepared by Jacobs (2015), which was an update from the 2008 Long Range Planning Study. The IWRP planning period extended beyond the limits of these studies so additional analysis was required to estimate the future demand requirements. Specific demand projections were established by user class, which included residential, commercial, large commercial, and irrigation user to better understand the impact if alternative water supply or conservation measures were implemented in the City. While drinking water demand projection is not an exact science, this evaluation included review of known historical data and expected growths typical of this type of community to establish supply requirements to year 2040.

4.1 COLUMBIA'S HISTORICAL POPULATION GROWTH

The City of Columbia has seen steady population growth over the years. In 1970, when the treatment plant was originally constructed, the City had a population of about 58,000 residents. The City's growth has been increasing at varying rates throughout its history, with a more rapid rate since the late 2000's. The most recent 2015 population estimate indicated 119,108 residents based on the U.S. Census Bureau. The population increase between 2010 and 2015 was about 10,600 residents, a 9 percent increase over that time. Figure 4-1 summarizes the historical population growth rate for the City.

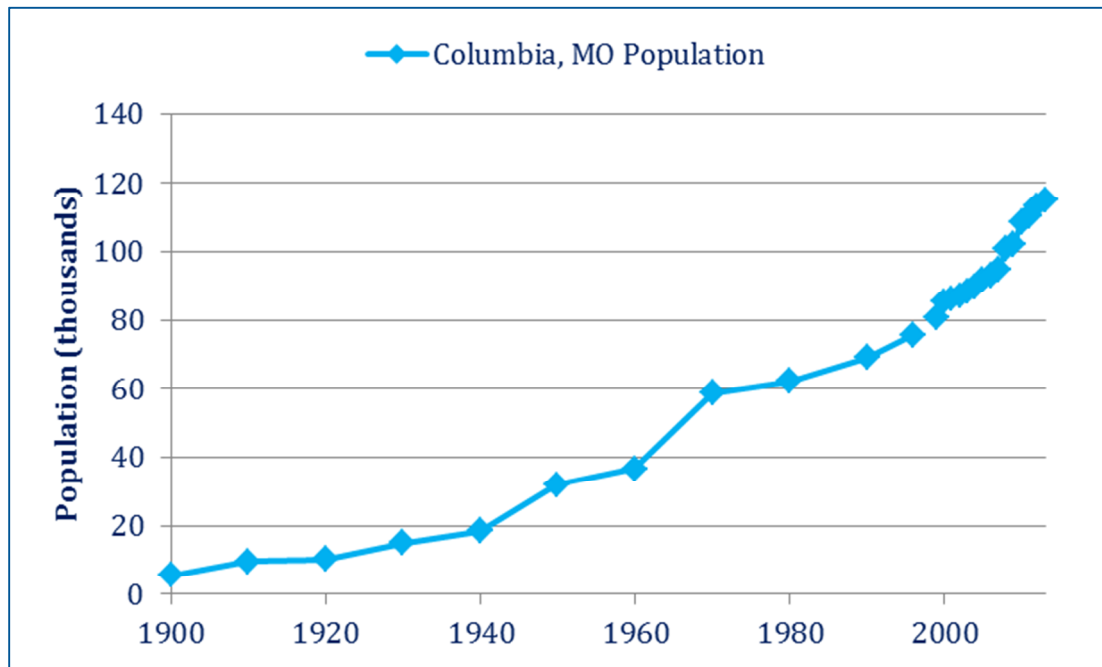


Figure 4-1 Columbia, MO Historical Population Growth

4.2 HISTORICAL CUSTOMER GROWTH

Table 4-1 summarizes the historical water customer growth since 1997 and the percent change in customers.

Table 4-1 Total CW&L Customers (LWRSS data ending August 2014)

YEAR	TOTAL WATER CUSTOMERS	% CHANGE IN CUSTOMERS
1997	30,618	-
1998	32,488	6.1
1999	33,476	3.0
2000	34,367	2.7
2001	35,174	2.3
2002	36,082	2.6
2003	37,614	4.2
2004	39,246	4.3
2005	40,557	3.3
2006	41,815	3.1
2007	43,034	2.9
2008	43,554	1.2
2009	43,911	0.8
2010	44,360	1.0
2011	44,755	0.9
2012	45,263	1.1
2013	46,195	2.1
2014	46,441	0.5
Average		2.5%

Population growth is not necessarily a direct correlation to water demands and customer accounts. Different customer classes grow at varying rates which impact supply requirements, and these classes are impacted differently based on the types of conservation or water supply measures implemented by the City. Therefore, it is important to have the historical basis of growth per customer class to better project future water supply demands. The city currently separates accounts by the following classes:

- Residential
- Small Commercial
- Large Commercial
- Irrigation

Table 4-2 summarizes the historical growth per class for each of these customer classes.

Table 4-2 Customer Classes (LRWSS data ending August 2014)

YEAR	RESIDENTIAL WATER CUSTOMERS	% CHANGE IN CUSTOMERS	COMMERCIAL WATER CUSTOMERS	% CHANGE IN CUSTOMERS	LARGE COMMERCIAL WATER CUSTOMERS	% CHANGE IN CUSTOMERS	IRRIGATION WATER CUSTOMERS	% CHANGE IN CUSTOMERS
1997	27,873		2,713		32		254	
1998	29,424	5.6	3,026	11.5	38	18.8	300	18.1
1999	30,066	2.2	3,375	11.5	35	-7.9	357	19
2000	31,033	3.2	3,297	-2.3	37	5.7	380	6.4
2001	31,731	2.2	3,405	3.3	38	2.7	378	-0.5
2002	32,534	2.5	3,511	3.1	37	-2.6	382	1.1
2003	33,568	3.2	4,017	14.4	29	-21.6	407	6.5
2004	34,944	4.1	4,273	6.4	29	0	439	7.9
2005	36,121	3.4	4,406	3.1	30	3.4	516	17.5
2006	37,395	3.5	4,389	-0.4	31	3.3	696	34.9
2007	38,365	2.6	4,638	5.7	31	0	627	-9.9
2008	39,304	2.4	4,220	-9	30	-3.2	633	0.9
2009	40,313	2.6	3,568	-15.5	30	0	647	2.2
2010	40,822	1.3	3,518	-1.4	20	-33.3	673	4
2011	41,236	1	3,496	-0.6	23	15	700	4.1
2012	41,731	1.2	3,509	0.4	23	0	780	11.3
2013	42,706	2.3	3,463	-1.3	26	13	883	13.3
2014	42,923	0.5	3,492	0.8	26	0	1,046	18.4
Average		2.60%		1.70%		-0.40%		9.10%

4.3 HISTORICAL WATER CONSUMPTION

Historical average to peak day water demands are in Table 4-3. It shows historical average daily water consumption demands ranging from 10.8-12.35 MGD with maximum daily demands between 12.5-19.7MGD. Peaking factor is calculated by dividing the maximum daily water consumption by average daily water consumption. This peaking factor can then be used to easily relate average and maximum daily demand scenarios for the system.

Table 4-3 Average to Peak Water Consumption (LRWSS data ending August 2014)

YEAR	AVERAGE DAILY WATER CONSUMPTION (GALLONS)	MAXIMUM DAILY WATER CONSUMPTION (GALLONS)	PEAKING FACTOR
2002	11,045,284	13,596,179	1.2
2003	11,385,531	15,803,720	1.4
2004	10,946,968	12,474,710	1.1
2005	12,615,487	18,793,355	1.5
2006	12,346,902	17,250,738	1.4
2007	12,238,759	17,183,429	1.4
2008	11,048,650	13,702,574	1.2
2009	10,849,309	12,610,636	1.2
2010	11,048,781	13,741,340	1.2
2011	11,088,679	16,332,797	1.5
2012	12,323,412	19,671,015	1.6
2013	11,052,736	14,537,835	1.3
2014	10,756,882	13,204,513	1.2

4.4 HISTORICAL PEAK TO AVERAGE DAY PRODUCTION

A review of peak and average demand was conducted based on production data from the plant. The available peak and average demand data is shown in Figure 4-2.

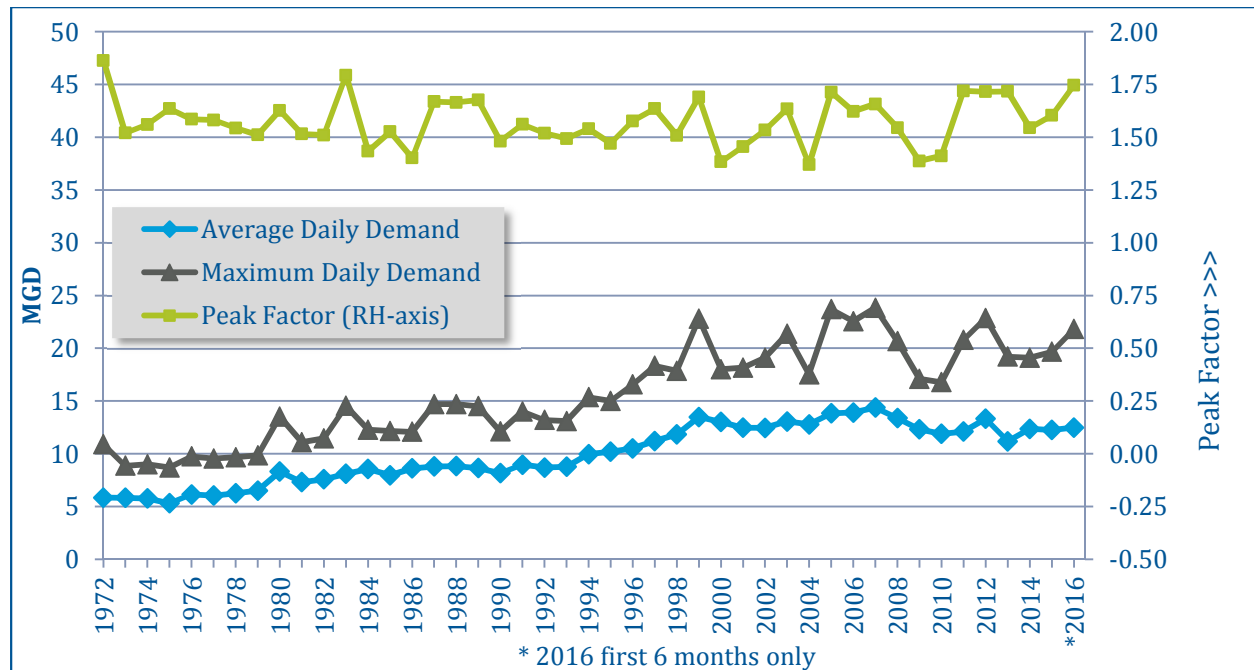


Figure 4-2 Average and Peak Demand and Resultant Peak Factor

Maximum daily demand is measured as the *maximum 24-hour water demand in a given year*. Based on the data shown in Figure 4-2, a maximum day (or peak day) factor of 1.8 will be applied to the annual average consumption forecast as this represents a reasonable upper bound of the peak day factor over the past 20 years.

4.5 POPULATION PROJECTIONS

Future population projections were obtained from Mizzou Show Me and Columbia Area Transportation Study Organization (CATSO) sources, with projected population to 2030. The project’s planning horizon is 2040 so the two population projections were extended using the observed annual growth rates for the respective forecasts to 2040, and an average forecast of the two population projections was used as a means of creating possible scenarios of future population for planning purposes. In all years, the CATSO population projection represented the highest forecasted values. Table 4-4 summarizes the population projections.

Table 4-4 City of Columbia Historic and Projected Population

YEAR	CATSO POPULATION (POP _C)	MU SHOW ME POPULATION (POP _B)	BLENDED MIDPOINT POPULATION (POP _A +POP _B)/2
2015	116,285	114,296	115,300
2020	125,919	120,677	123,300
2025	135,650	126,701	131,175
2030	146,134	131,797	139,000
Equivalent Annual Growth Rate	1.53%	0.95%	1.25%
2035*	157,689	138,207	147,893
2040*	170,178	144,929	157,393
*Extrapolated values using annual growth rates 2015-2030			

As indicated in Section 4.1, the actual population of the City in 2015 was estimated at 119,108 residents, which is about 3,800 more residents than listed as the blended population. Although the number of residents appear to be higher than what is included in either population study, for the basis of this study and future population projections this report will continue to use the blended population projections indicated above. However, as milestone years are met the population projections should be compared to actual population numbers and the lifespan of the project adjusted accordingly.

4.6 PREVIOUS DEMAND ESTIMATES

The 2015 Long Range Water System Study (LRWSS) developed future water demands, utilizing a similar approach from the 2008 study. To create future water demands the LRWSS included a baseline growth scenario, a worst-case growth and a best-case growth scenario. The LRWSS used these future growth scenarios and multiplied them by the respective demands as noted below.

- Residential – 185 gallons /customer/day for average and 1.5 times that for peak
- Commercial – 630 gallons/ customer / day for average and 1.4 times that for peak
- Large Commercial – 70,000 gallons / customer / day for average and peak
- Master Meter - 770 gallons / customer / day for average and 1.1 times that for peak
- Irrigation only – 1,100 gallons / customer / day for average and 3 times that for peak

Based on the above method, Table 4-5 presents the projected future demands included in the LRWSS. This information was used to identify proposed system improvements. The LRWSS divided the CW&L service area into five sections and looked at past and potential future growth to plan future system improvements.

Table 4-5 LRWSS future water demand projections

YEAR	AVERAGE DAILY WATER PRODUCTION (MGD)	MAXIMUM DAILY WATER PRODUCTION (MGD)
2013	15.4	23.1
2014	15.7	23.7
2015	16.1	24.4
2016	16.4	25.1
2017	16.8	25.8
2018	17.8	27.1
2019	18.2	27.9
2020	18.7	28.8
2021	19.1	29.7
2022	19.6	30.6
2023	20.1	31.6
2024	20.6	32.6
2025	21.1	33.7
2026	21.7	34.8
2027	22.3	36.0
2028	22.9	37.3
2029	23.5	38.6
2030	24.2	40.0
2031	24.9	41.5
2032	25.6	43.1
2033	26.4	44.8

4.7 POPULATION RELATION TO WATER DEMAND

The relationship between increasing population and increasing water demand appears logical; however the relationship is more complex than is often assumed. In projecting water demand it can be instructive to examine historic trends to identify key factors that have influenced demand and examine the likely trends of these influences in order to create accurate projections of future water demand.

Figure 4-3 shows historic population data for the City of Columbia based on U.S. Census information, projected population trends¹ and historic water demand, based on average daily water production.

¹ Population projections for the City of Columbia were obtained from CATSO and MU Show Me

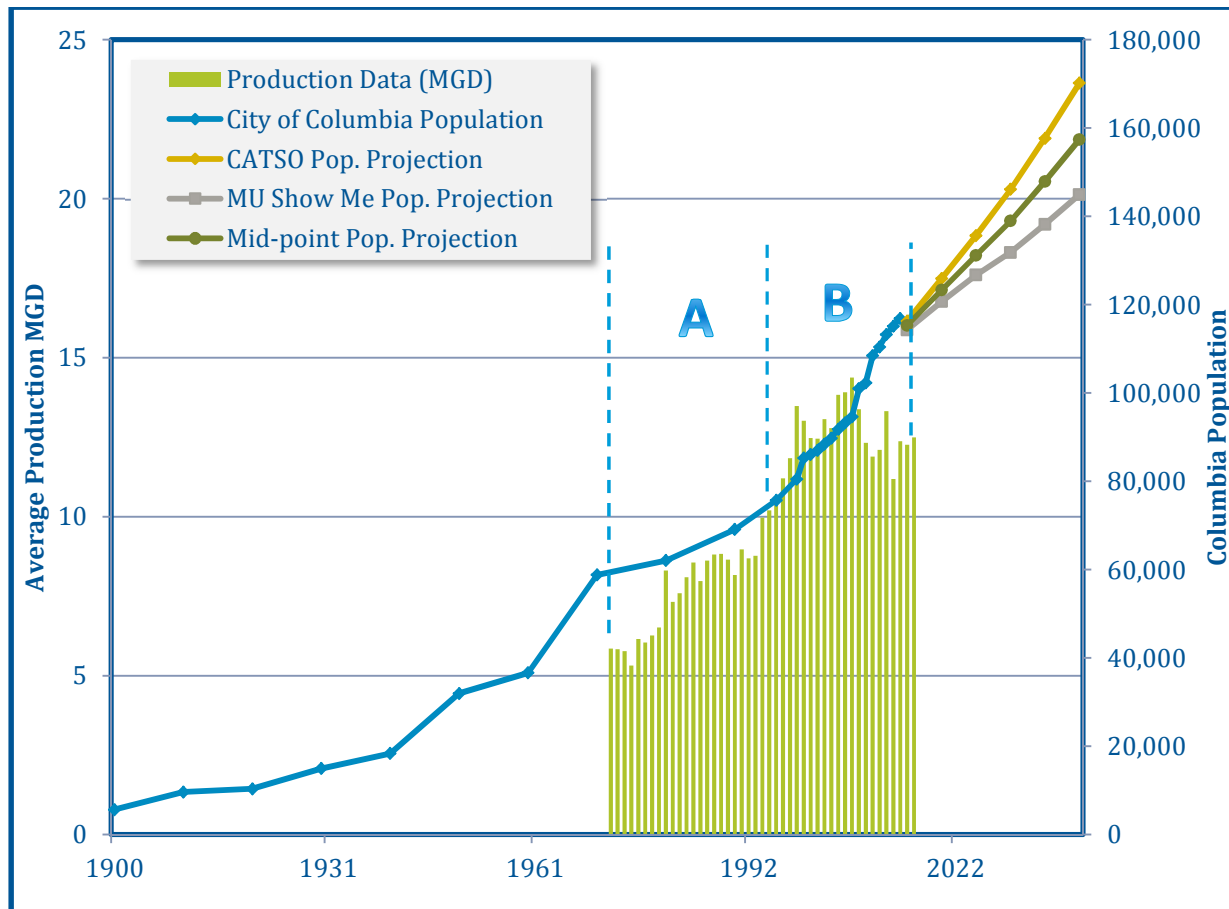


Figure 4-3 Population Growth and Water Demand for the City of Columbia

Water production data is shown here (rather than customer billing data) as it is available back to 1992 and provides a longer term perspective. Figure 4-3 shows that the population growth rate has been variable and is not the only factor influencing customer water demand. Period A in Figure 4-3 represents a time of relatively slow population growth but rapid water demand expansion; whereas period B indicates that a rapidly increasing population did not lead to an increase in water demand.

4.8 CUSTOMER ACCOUNTS AND DEMAND TRENDS

In order to understand water demand trends, seasonal influences and better identify factors that significantly impact demand, customer consumption (sales) data was examined and trended. The review included the consumption volume and number of accounts on a monthly basis for the period inclusive of October 2005 – September 2015.

To gain further insight into customer trends, a disaggregated approach was used. The source data for customer consumption for CW&L originally had 25 classifications, breaking down consumption by factors such as customer class, consumption inside the city limits and outside the city limits, and by water accounts and irrigation only accounts. Based on a review of the data and the relative proportion of use by the different customer classifications, demand was aggregated into four key customer classes, shown in Table 4-64, that are typical for most water systems.

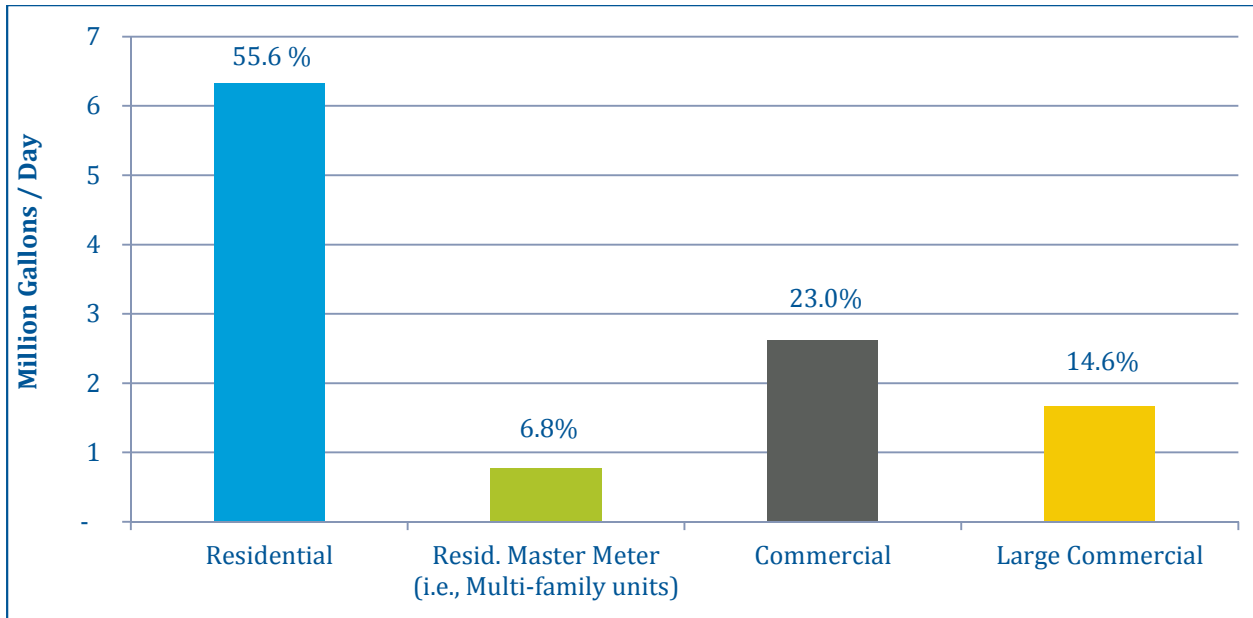


Figure 4-4 Customer Consumption (Sales) by Customer Class

Figure 4-5 shows the total number of accounts and total customer consumption for the available time period. The trends generally align with area B in Figure 4-3 in that the total number of accounts increased during the period (by approximately 16%), while the customer demand can be characterized as flat-to-slightly-declining.

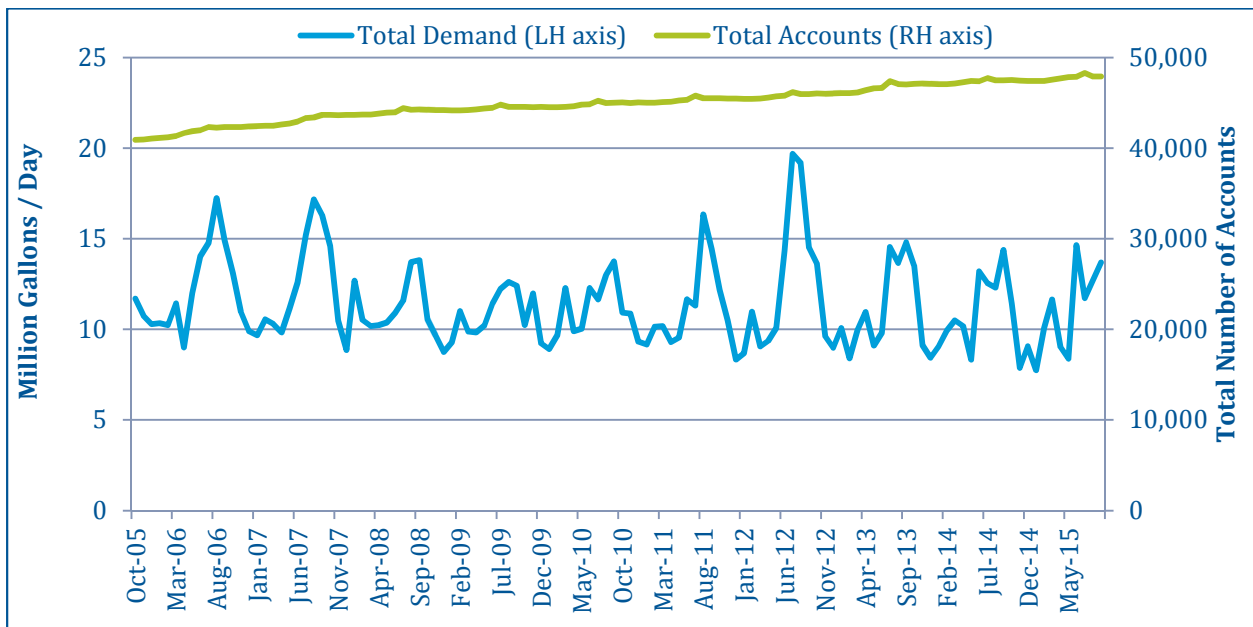


Figure 4-5 Total Customer Consumption and Total Accounts

The peaks shown in Figure 4-5 indicate increased water consumption in the summer months associated with irrigation and other outdoor water uses. Precipitation data was obtained for Sanborn Field at the

University of Missouri² from the Missouri Historical Agricultural Weather Database. The average monthly summer precipitation is shown in Figure 4-6 and, in general, the periods of highest summer demand coincides with lowest average precipitation in the summer months.

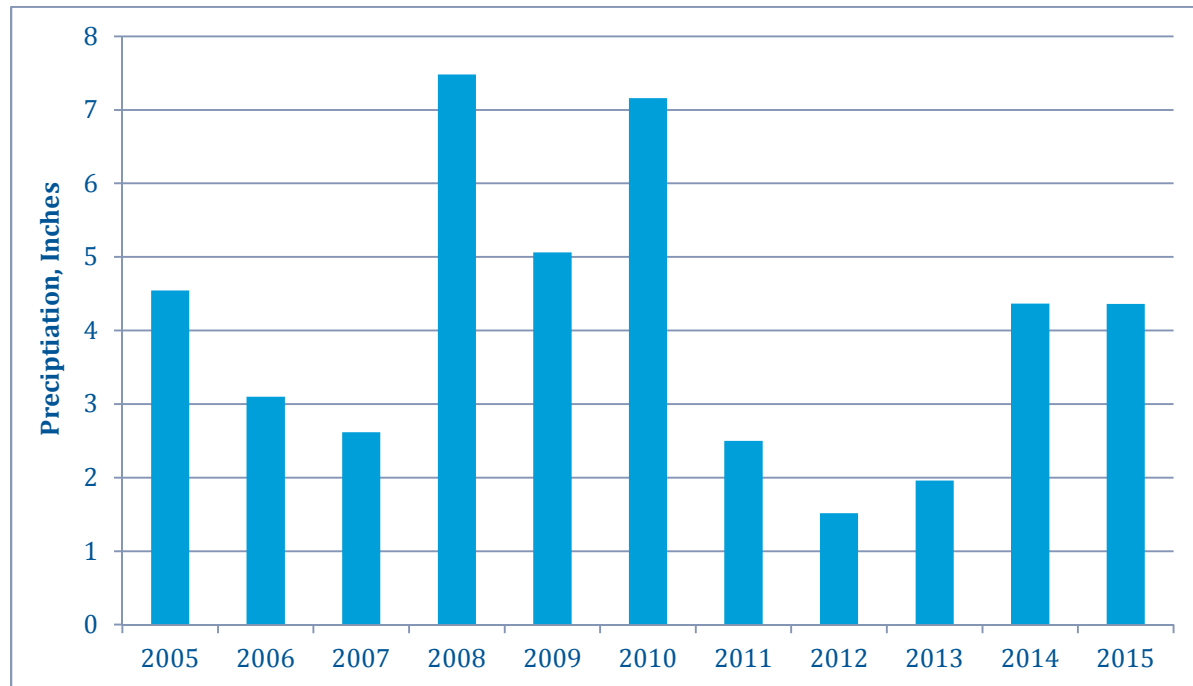


Figure 4-6 Average Monthly Precipitation June - September (Sanborn Field)

4.8.1 Residential Customers Trends

Residential customer demand represents over 55% of total customer demand and is the largest customer class by both volume and number of accounts. The data for these accounts primarily represents single-family customers. According to the U.S. Census³, the average number of residents per household in the City of Columbia is 2.34.

The average residential customer demand (using an average of the most recent three years of data) is 145.3⁴ gallons per day with a resultant per capita consumption of (145.3/2.34) 62.1 gallons per capita per day (gpcd). Calculation of the per capita metric helps in benchmarking water use by CW&L customers against other water systems and helps to indicate the potential scope for water conservation savings. A per capita consumption of 62.1 gpcd represents an annual average value and therefore includes both indoor and outdoor use. As a conservative water supply planning assumption, the 2012 average residential customer demand was utilized as a base value from which to project future demand as this represents a recent hot, dry year (174.6 gallons per household per day or 74.6 gallons per capita per day).

² http://agebb.missouri.edu/weather/history/report.asp?station_prefix=san&start_month=1&end_month=1&start_day=1&end_day=1&start_year=2005&end_year=2016&period_type=1&convert=1&field_elements=70

³ <http://www.census.gov/quickfacts/table/RHI105210/2915670>

⁴ An additional calculation was performed using the total *volume* of all residential accounts, but excluding the *number* of irrigation accounts (assuming that these customers also have a regular water account); the resulting value was 146.1 gallons per account and 62.5 gpcd.

As seen from the residential data in Figure 4-7, an increase in the number of customer accounts has not led to an upward trend in consumption. This means that the use per account has trended downwards and implies that customers have become more water efficient over time.

This is a trend that has been witnessed in most water systems around the U.S. One of the significant drivers of this trend has been the Energy Policy Act of 1992. This legislation set minimum efficiency standards for all toilets, shower, urinals and faucets manufactured in the United States after 1994. As new houses are constructed, and older homes remodeled, the water efficiency of residential fixtures has increased. In addition, appliances such as clothes washers have also become more efficient – in both water and energy use – further increasing water efficiency. The residential customer data trends indicate that these changes have influenced consumption patterns and are important to understand in order to forecast future demand. However, the extent to which these fixture and appliance changes have occurred, and the potential for future efficiency savings, for CW&L customers is unknown but will be evaluated further in Section 6 Water Conservation.

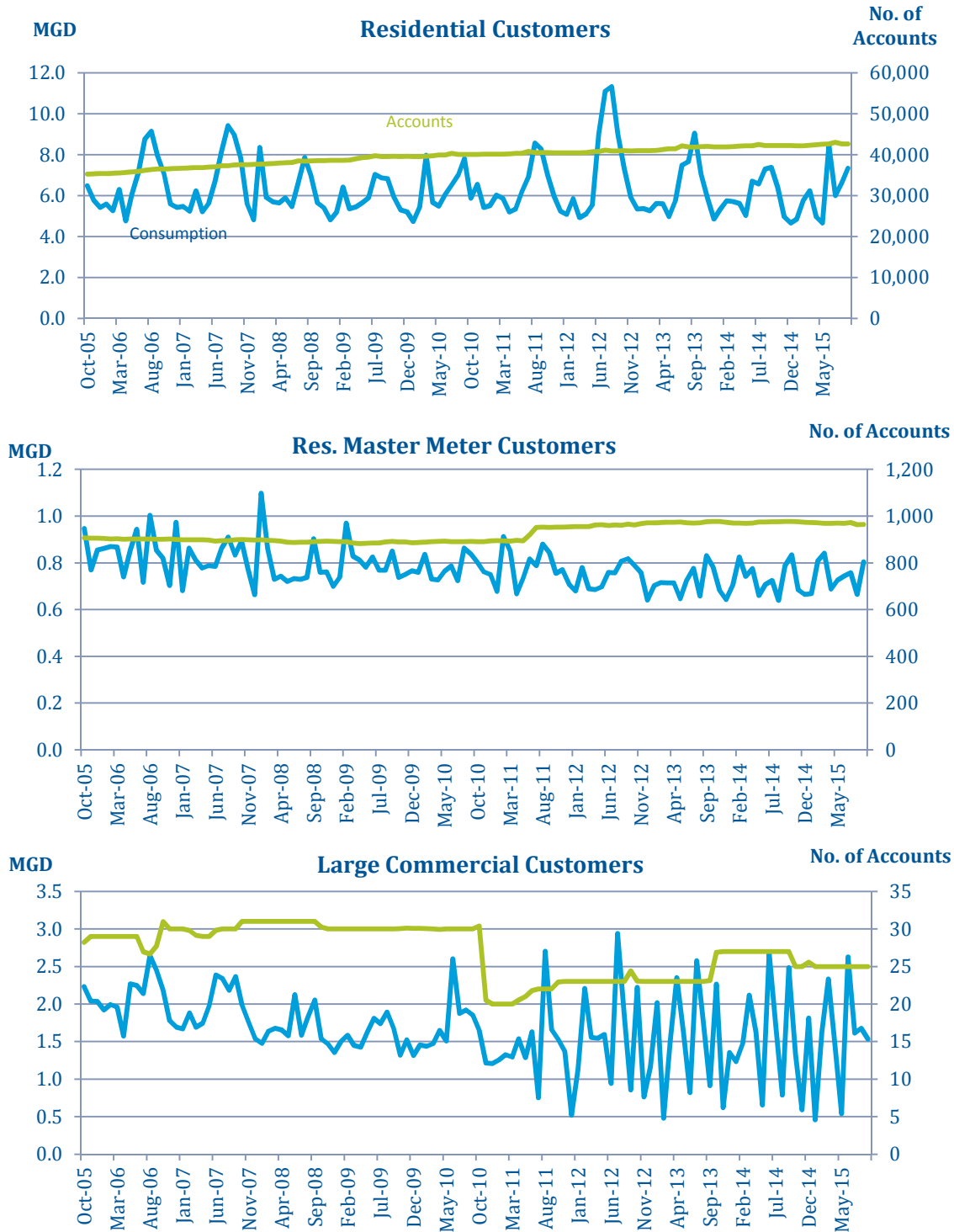


Figure 4-7 Customer Consumption (Sales) and Account Trends 2005-2015

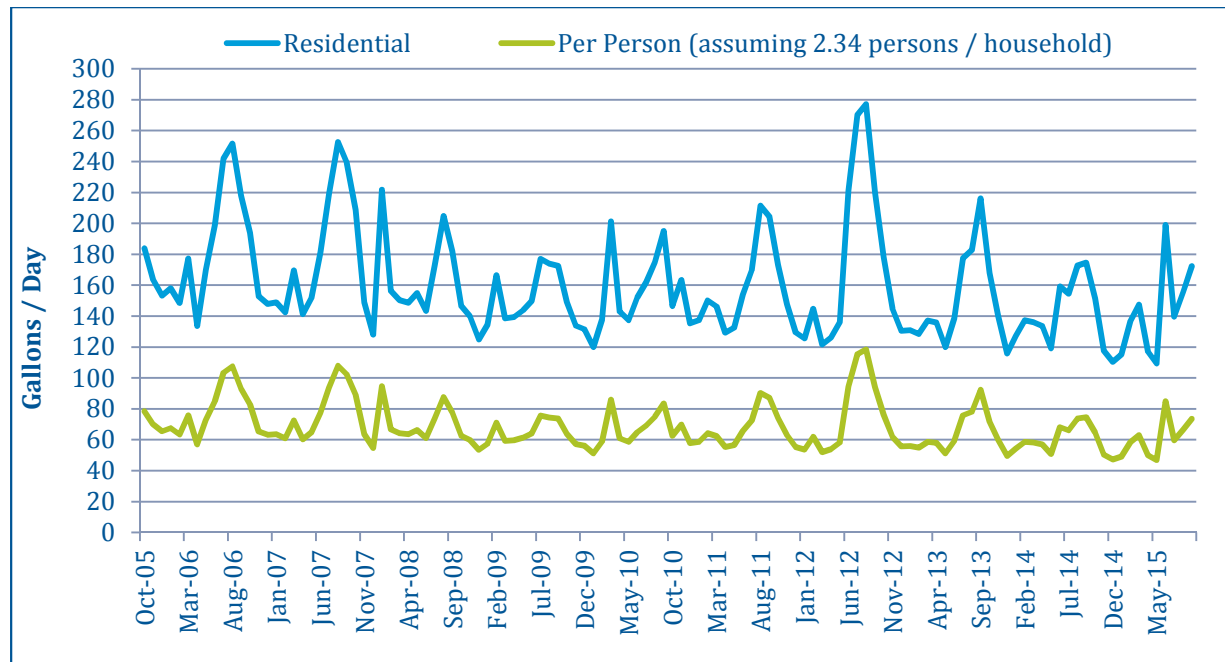


Figure 4-8 Residential and Per-Capita Consumption Trends 2005 - 2015

4.8.2 Residential Master Meter Customer Trends

Residential master meter demand represents approximately 7% of total customer demand. The number of accounts has remained fairly constant over the period except for a step-change in June 2011. Consumption patterns appear to have trended downwards, likely for similar reasons to those described in 4.8.1 for residential customers. Seasonal peaks are far less evident within this customer class, which makes sense as the majority of these customers include apartments and other multi-family units, trailer parks and rental units with more limited irrigation opportunities and associated outdoor water uses.

4.8.3 Commercial Customer Trends

Commercial demand represents approximately 23% of total customer demand and represents the second largest customer class. The overall trend in consumption within this customer class is flat. Although there was a noticeable decrease in the number of accounts, coinciding with the start of the economic recession in 2008, there was not a discernable impact on overall demand. The ways in which water is used by customers in this class varies significantly. The data shows that seasonal trends are evident in the commercial sector indicating that outdoor irrigation and general level of business activity (e.g., hotels and restaurants) contribute to the summer peak demand.

4.8.4 Large Commercial Customer Trends

Large commercial customer demand represents approximately 15% of total customer demand. Water use by large commercial customers can vary greatly depending on the type of business activity and economic conditions and this is evidenced in Figure 4-7. Consumption for this customer class shows a steady decline in the first five years followed by a leveling out of demand, but with highly variable monthly use. The peak consumption value has not changed significantly, but appears to have been temporarily depressed during the recession years of 2008-2009.

4.8.5 Summary of Observed Trends

Table 4-6 shows a summary of trends in *consumption per account* and trends in the *number of accounts* for each of the customer classes detailed above, over the period of 2006 to 2015. The values represent the average rate of annual change.

Table 4-6 Summary of Trends in Consumption per Account and Number of Accounts, by Customer Class

ANNUAL AVERAGE RATE OF CHANGE 2006-2015*	RESIDENTIAL	RESIDENTIAL MASTER METER	COMMERCIAL	LARGE COMMERCIAL
Consumption Per Account	-2.4%	-2.2%	1.7%	-1.3%
Number of Accounts	1.9%	0.8%	-1.5%	-1.1%
City of Columbia Population	2.7%			
*2005 was excluded from the annual analysis because only three months of data were available				

4.9 REVISED CUSTOMER CLASS FORECASTS

Water demand forecasts were created for the period 2016 to 2040. The water demand forecast will consider the following components to provide an estimate of future water production requirements:

- Customer consumption forecasts by sector
- Average Day vs Maximum (Peak) Day Demand
- Non-Revenue Water (i.e., the difference between water produced and water sales to customers)

For each customer class, a baseline demand forecast was created. The baseline scenario represents a recommended water supply planning scenario.

4.9.1 Residential Forecasts

Baseline Scenario: The number of residential accounts was grown at 2.7% annually based on the observed population growth rate over the past 10 years. This is considered a conservative assumption (i.e., higher growth) as it is higher than the observed rate of increase in account growth over the same period (1.9% / year), and higher than the projected rate of population increase. Per capita consumption was held constant at the 2012 (most recent dry year demand) level which assumes no additional water efficiency savings per customer throughout the forecast period. The projected trend line for residential consumption is shown in Figure 4-9.

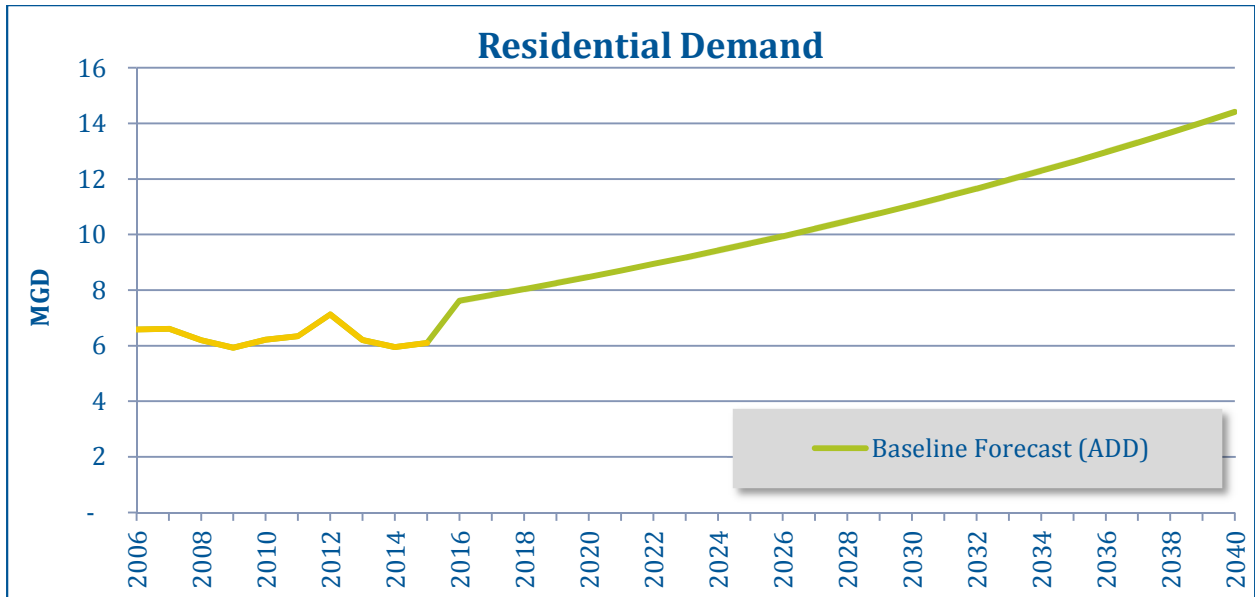


Figure 4-9 Historic and Projected Residential Consumption (Sales)

4.9.2 Residential Master Meter Forecasts

Baseline Scenario: The number of residential master meter accounts was grown at 1.0% annually, which is marginally higher than the 10-year observed rate of 0.8% / year as shown in Figure 4-9. Although this customer class has observed a decrease in consumption per account, no further efficiency gains are forecasted and water consumption per account is held constant at the 2015 value of 769 gallons / account (this value was chosen as it was higher, and therefore represents a more conservative assumption, than the 2012 value). The projected trend line for residential master meter consumption is shown in Figure 4-10.

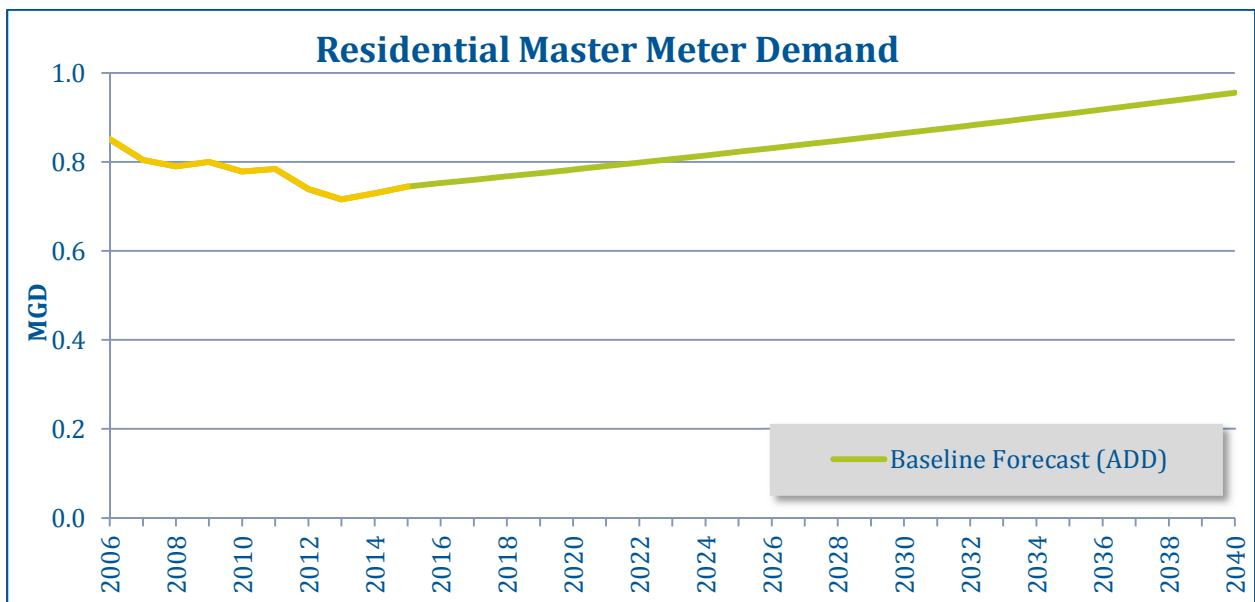


Figure 4-10 Historic and Projected Residential Master Meter Consumption (Sales)

4.9.3 Commercial Forecasts

A base year value of 717 gallons per account was chosen as the initial value from which to project demand; this is the 2012 value which reflects dry-year demand and is higher than the observed 2015 value of 627 gallons per account.

Baseline Scenario: The observed 10 year annual change in accounts is -1.5% per year, however the average for the most recent 5-year period is 1.2% growth per year. For the baseline scenario an annual growth rate of 1.0% per year was assumed for the entire forecast period. The 10 year trend in consumption per account is an annual increase of 1.7% and this value was continued through the forecast period. The projected trend line for commercial consumption is shown in Figure 4-11.

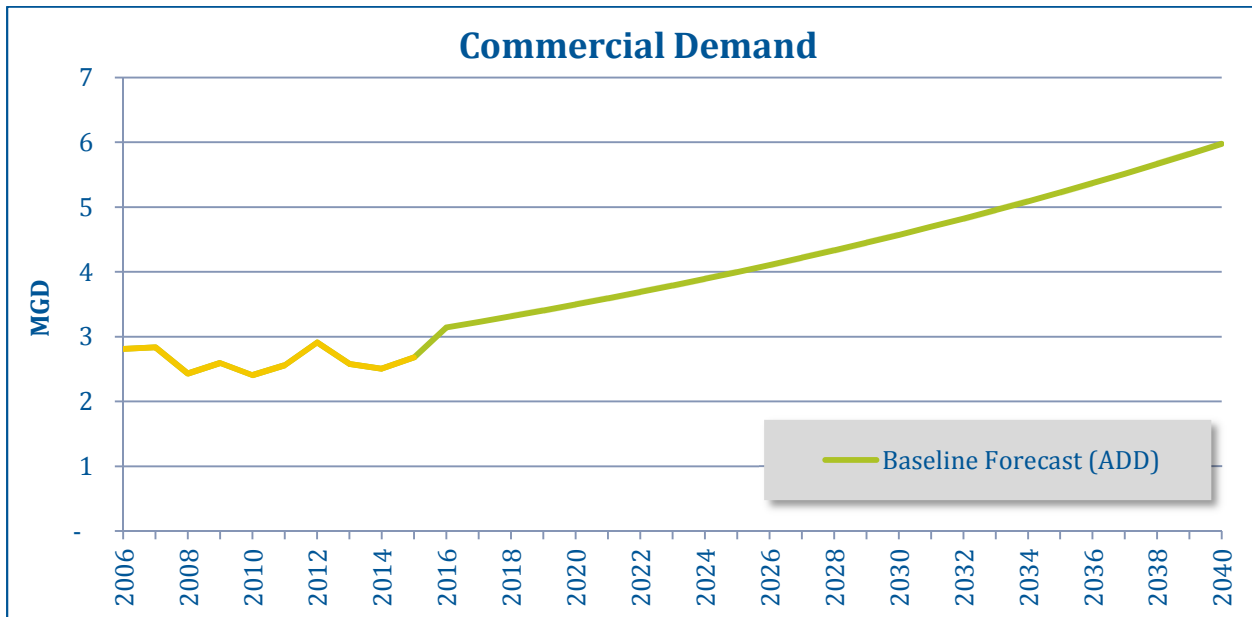


Figure 4-11 Historic and Projected Commercial Consumption (Sales)

4.9.4 Large Commercial Forecasts

A base year value 67,800 gallons per account was chosen as the initial value from which to project demand; this is the 2012 value which reflects dry-year demand and is higher than the observed 2015 value of 61,700 gallons per account.

Baseline Scenario: The number of large commercial accounts was grown at an annual rate of 1.0%. This is different from the observed 10-year average which was -1.1%. A more conservative (higher growth) assumption was selected recognizing that large commercial water demand is more unpredictable and variable compared to residential demand and that the observed 10-year trend includes a significant economic recession and that future growth could return quickly. Consumption per account has declined at an annual rate of -1.3% over the past 10 years, although it has increased by 1.4% per year over the past 5 years. A 1.4% annual growth rate in consumption per account was assumed and continued through the forecast period. The projected trend line for large commercial consumption is shown in Figure 4-12.

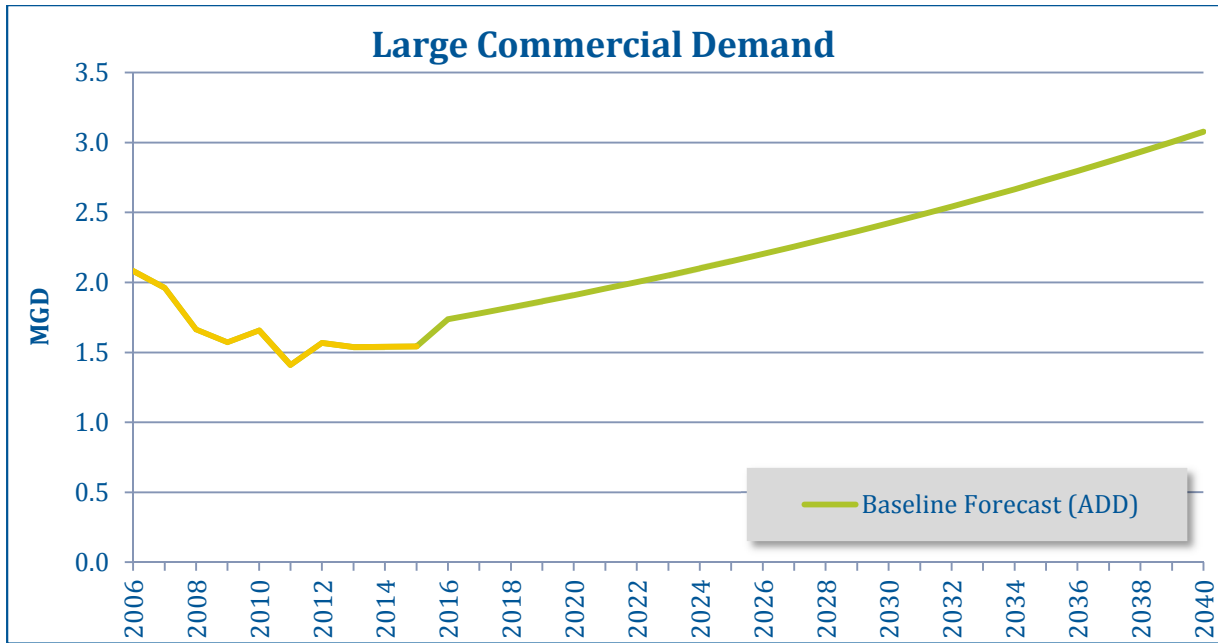


Figure 4-12 Historic and Projected Large Commercial Consumption (Sales)

4.9.5 Composite Customer Consumption Forecast

Figure 4-13 shows the projected composite customer consumption forecast through 2040. However, this projection only includes the demand attributable directly to average annual customer consumption, and does not include system demand due to non-revenue water and an estimate of peak consumption. These two items are addressed in the following sections.

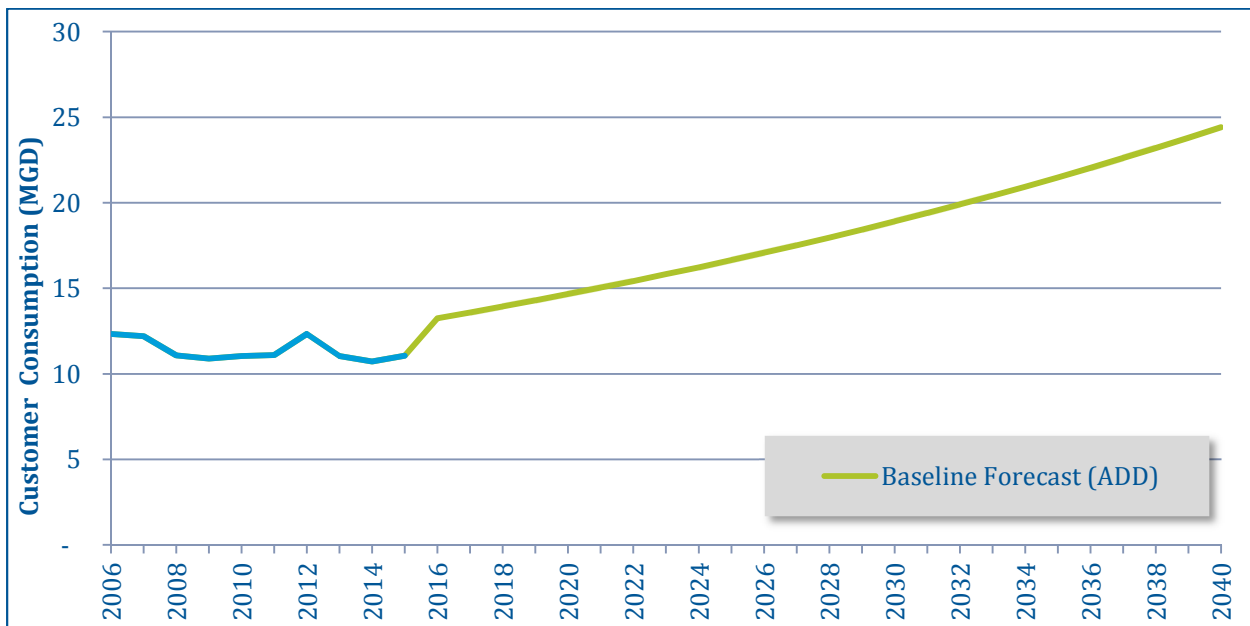


Figure 4-13 Total (Average) Customer Consumption (Sales)

4.9.6 Non-Revenue Water

Available, annual customer consumption data and annual production data overlapped for the 9-year period 2006 – 2014. The difference between the average daily water produced and the average daily customer demand was calculated and is shown graphically in Figure 4-14. This volume can be classified as Non-Revenue Water⁵. This volume of water may comprise physical losses from the distribution system, which includes leaks, breaks and other real losses, and apparent losses, which includes unauthorized consumption, customer metering inaccuracies and other forms of measurement or data error. Based on the information provided in Figure 4-14, the average value for non-revenue water of 1.4 MGD was chosen, which is equivalent to 30 gallons per account per day. The median value of real losses published in a dataset by American Water Works Association (AWWA)⁶ is 47 gallons per account per day. Depending on future levels of water loss control, non-revenue water may increase, decrease, or remain relatively constant. It should also be noted that the volume of non-revenue water does not vary proportionally to consumption, so the same value for non-revenue water was applied to average and peak demand.

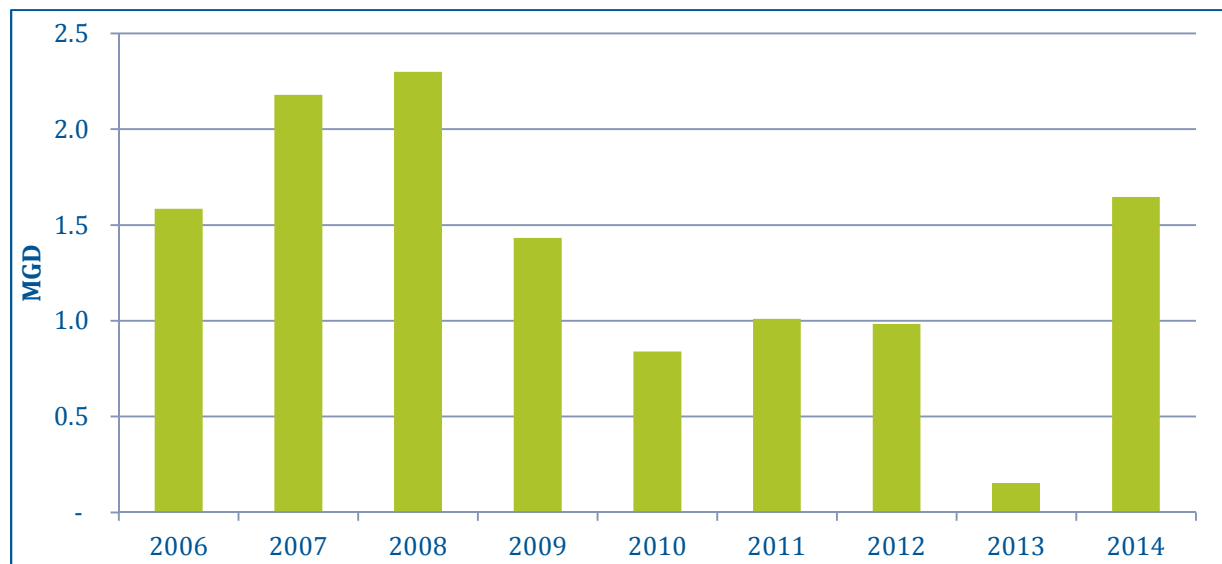


Figure 4-14 Estimated Non-Revenue Water Volume

4.10 IRRIGATION TRENDS

In the above analysis irrigation accounts have been included within the data for the customer classification to which they belong. During the review of data, trends in the number of dedicated irrigation accounts and associated consumption volume were analyzed.

Figure 4-15 and Figure 4-16 show the annual and monthly irrigation trends respectively. It should be noted that the 2015 data point is the average of January through September, so the value may appear higher than a true annualized value that would include the months of October through December (and the lower irrigation demand expected for these months).

⁵ A best practice for determining non-revenue water is to perform a Water System Audit following the approach described in AWWA's manual: Water Audits and Loss Control Programs (M36).

⁶ <http://www.awwa.org/Portals/0/files/resources/water%20knowledge/water%20loss%20control/2015-Validated-Water-Audit-Data.xlsm>

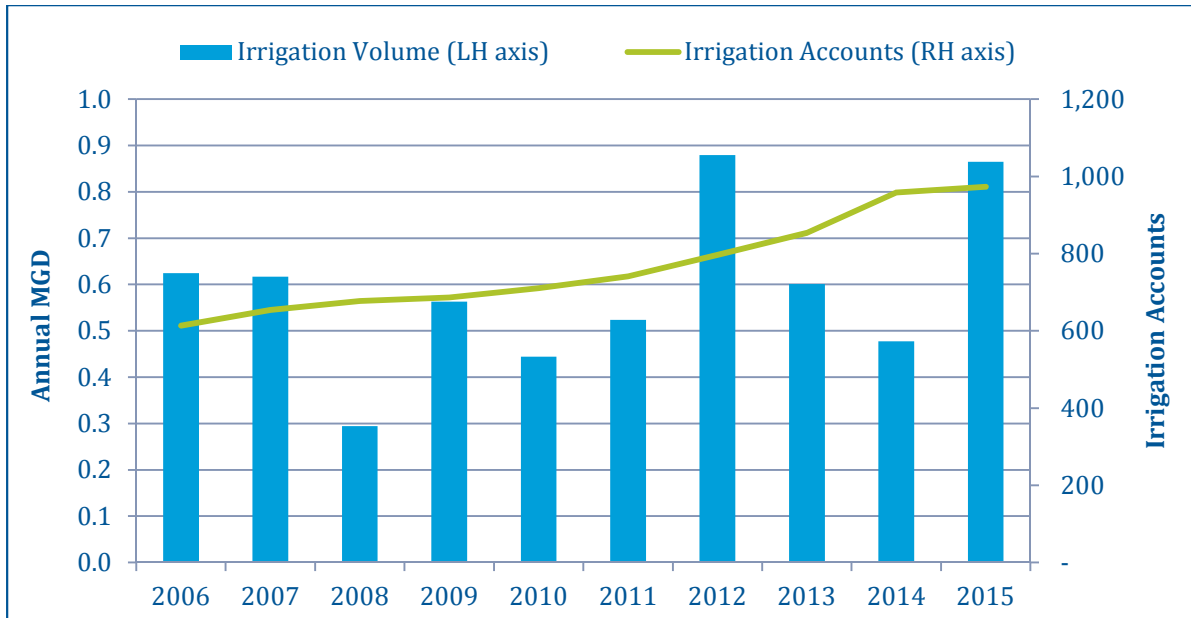


Figure 4-15 Annual Trends in Irrigation Accounts and Consumption

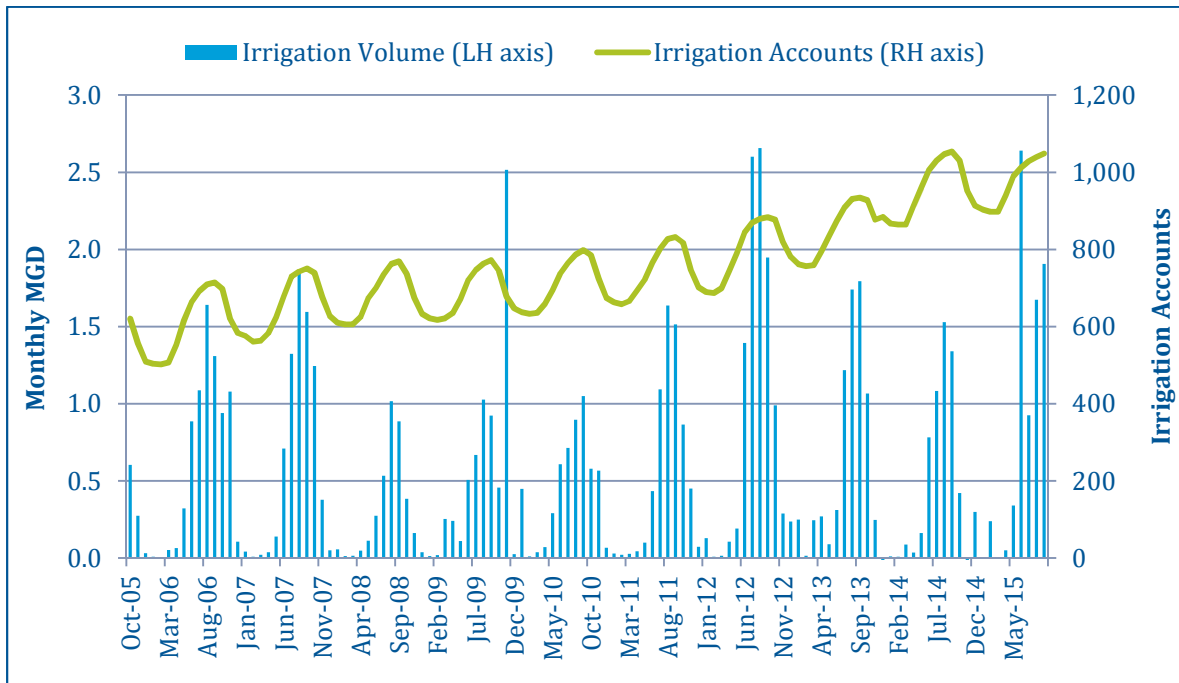


Figure 4-16 Monthly Trends in Irrigation Accounts and Consumption

Although the number of irrigation accounts has increased significantly during the review period, the volume of irrigation consumption has not increased similarly. A more detailed review may be needed to fully understand how much true additional demand is being added to the system versus transfer of demand from regular water service accounts to irrigation accounts by customers in order to avoid incurring a sewerage cost.

4.11 DEMAND SCENARIO SUMMARY & RECOMMENDATIONS

The information generated and described above was assembled into a final set of demand forecast scenarios as follows.

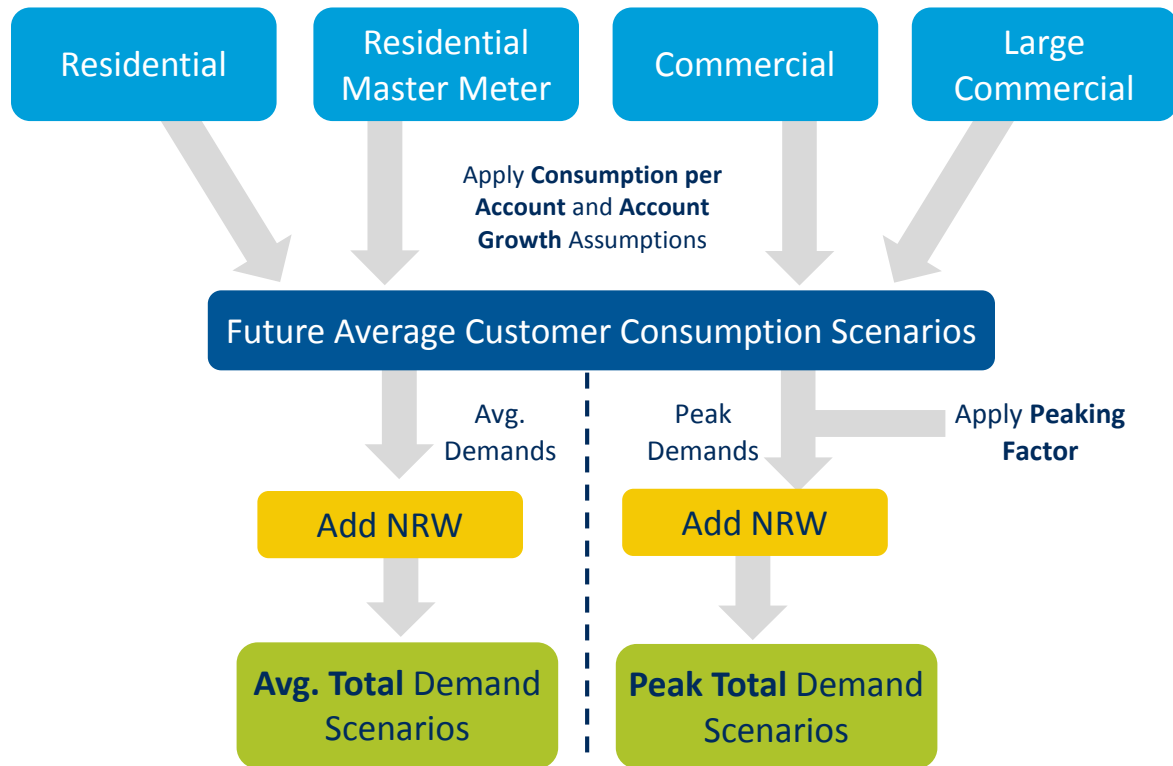


Figure 4-17 Flow Chart of Demand Forecast Scenario Development

The total average and max day required production for the baseline scenario is presented in figure 4-18. In addition, the LRWSS baseline demand projections were plotted on the same figure for comparison.

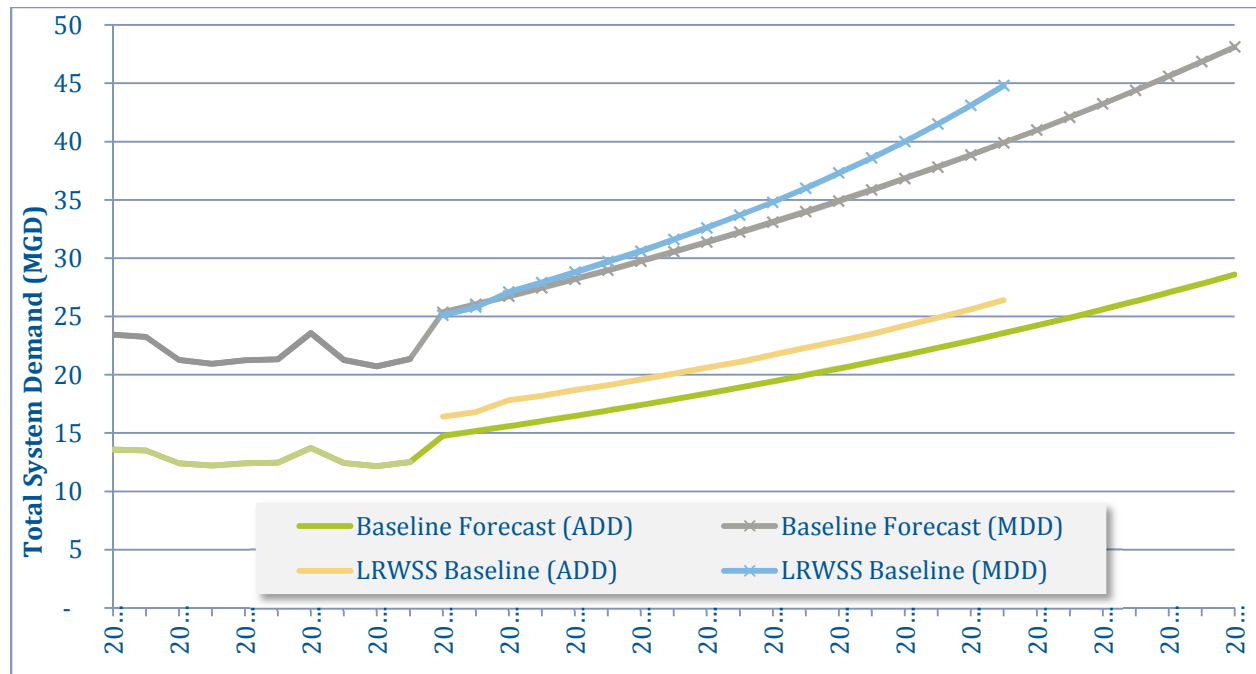


Figure 4-18 Demand Forecasts, including comparison to LRWSS Baseline

4.12 POTABLE WATER DEMAND CONCLUSION

The LRWSS projections completed in 2015 appear to slightly overestimate the water production requirements for both average and max day demands for the CW&L system. The differences in average day demand are relatively consistent, but the differences in peak day demand increase with time. A low-demand scenario, with potential costs and savings, will be further developed in the conservation section. The Baseline demands as presented in Figure 4-18 will be used within this analysis for the initial water demand projections for this study.

4.13 NON-POTABLE DEMANDS

Alternative non-potable water supply sources including groundwater, wastewater, and storm water may be used to offset potable demands by either reclamation or reuse. These systems are typically built in targeted development areas to meet either industrial or residential irrigation demands. The portion of total demands which may be met by non-potable water is highly variable among cities where a ‘purple pipe’ system has been implemented. Non-potable sources may be developed which met or exceed the demands for non-potable water, but it is important not to overestimate the impact this has on the demand for drinking water in the planning process.

Demands for non-potable reuse water can be estimated using a range of percentages of the total demand. For reference, the San Antonio Water Supply has implemented a reuse program that has been able to meet 5% of the city’s demands, but has not been able to exceed that. Other ‘purple-pipe’ programs in Clearwater and St. Petersburg, Florida and across California meet a portion of demands ranging from 2% to 20% with non-potable water. A representative range of non-potable demands is shown in Table 4-7 for a general estimate of the volumes that may be feasible based on Columbia’s water demands.

Table 4-7 Demand Projections and Potential Non-Potable Demands

	2020	2025	2030
Average Daily Demand (MGD) ⁷	18.70	21.10	24.20
2.5% of Demand (MGD)	0.47	0.53	0.61
5% of Demand (MGD)	0.94	1.06	1.21
10% of Demand (MGD)	1.87	2.11	2.42
15% of Demand (MGD)	2.81	3.17	3.63

Although the City of Columbia meets golf-course irrigation demands with on-site water systems, other irrigation uses like parks, schools, and new residential developments may be feasible. Installation of dedicated reclaimed water lines in residential or industrial developments requires political initiative, but can provide an opportunity for conservation.

The largest 50 water users in 2015, as provided by Columbia Water & Light, are shown on Figure 4-19. These values are based on total, combined annual use, and the table indicates whether a portion of that total annual value is used for irrigation. The demands shown are total demand, and only a portion of that demand may be met by reuse water, but the map does help to identify locations where industrial demands are high and what range of demands should be expected in localized areas.

4.13.1 Industrial Users

Through the evaluation of the database of large users, a number of large industrial users can be identified and ranked broadly according to business type and likelihood that non potable water (NPW) may be a feasible alternative water source. As a preliminary evaluation, the top 50 customers are shown and listed in Table 4-8. Some of the listed users have multiple meters but are listed as one a single customer. The users can be categorized as high, medium, or low likelihood of their ability to use recycled water based on business type.

Table 4-8 Overview of the Major Business Types According to Feasibility of Reuse

FEASIBILITY OF REUSE	BUSINESS TYPES	NUMBER OF ENTITIES	TOTAL USE (AF/YR)
High	Concrete or cement manufacturing, pipe manufacturing, car wash, power plant	11	319.3
Medium	Retail, university or school campus, hotel, office campus, assisted living facility	28	663.7
Low	Food, beverage, and brewing	5	1,006.2

⁷ Long Range Water System Study, Jacobs, 2015.

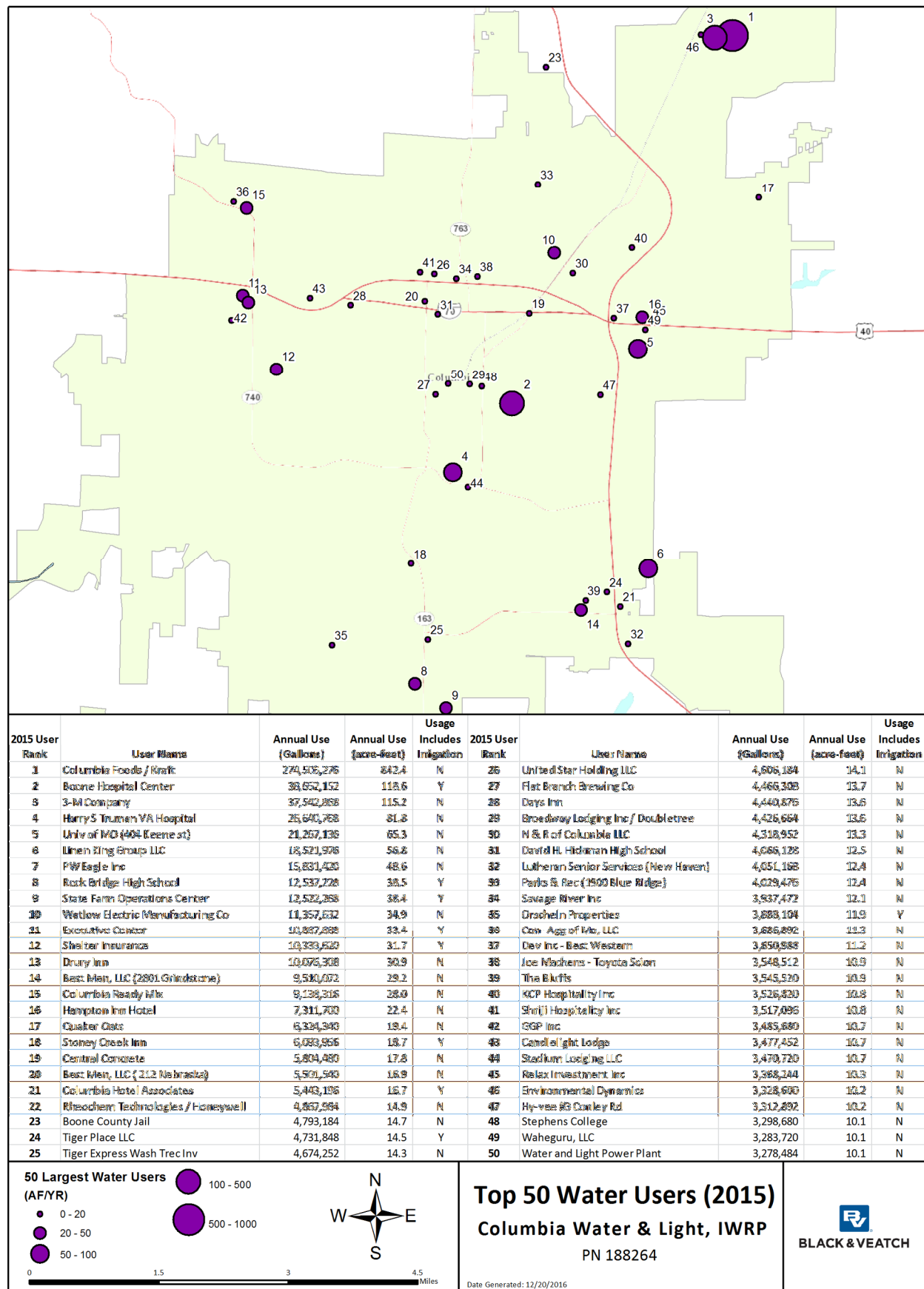


Figure 4-19 The 50 largest water users in 2015, as provided by Columbia Water & Light

If reuse is selected as an alternative for further consideration, industrial users would need to be contacted to identify specific water quality requirements and to identify what portion of overall demands could be met with NPW supplies. Larger industrial users typically provide one of the best core users for NPW systems due to their generally higher usage and typically more stable usage seasonally. Some industrial users can require additional onsite treatment, and any waste stream impacts to the sewer system would also need to be considered.

4.13.2 Irrigation Users

Review of available irrigation use data for a ten-year period (2006-2015) indicates that peak monthly irrigation use (August) is on average 2.77 times greater than the annual average irrigation use. A monthly irrigation demand distribution for non-potable water has been developed, based on the average monthly water use from the City's irrigation metering program data (Figure 4-20).

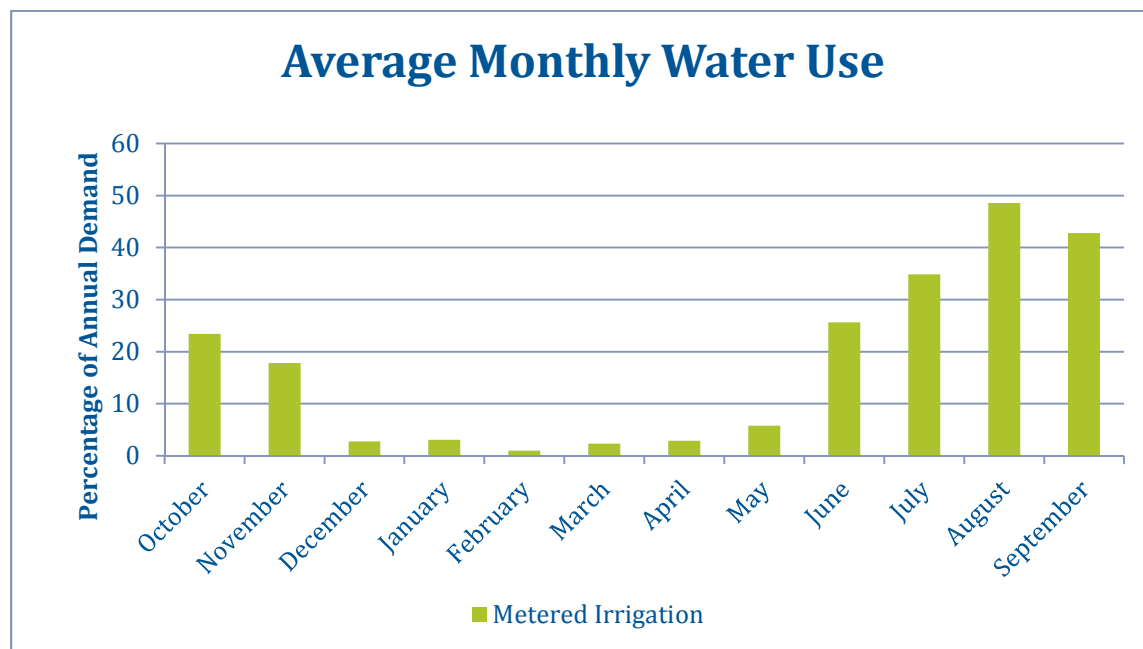


Figure 4-20 Average Monthly Metered Irrigation Water Use, Columbia Water and Light (2005-2015)

A non-potable distribution network is required to deliver water to customers, and for irrigation customers the cost of the distribution system may limit the feasible extent of the system. Irrigation in a residential subdivision, for instance, is limited to lawn areas and gardens, and the distribution system must reach each home. Additionally, the distribution system must be capable of handling all of the demands in peak months, which requires a larger capacity than a constant-demand system. Implementation and costs for installation of non-potable irrigation systems are further discussed in scenario development section.

4.13.3 Impact on Demand for Potable Water

The goal of a non-potable system is to reduce the demand for drinking water by meeting some of those demands with reclaimed or reuse water. Industrial customers may be able to reduce their demands for potable water significantly, and a system which provides a consistent supply will have a greater impact and be more economical to construct. Using non-potable supplies for irrigation has the benefit of

impacting the peak demands, but typically the demands are somewhat limited, and the cost of distribution is significantly higher.

In either case, but especially for an irrigation system, administration of the system is required. Separate metering, rates, and billing would be required, and real-time management of usage may be necessary, especially in times of drought. A significant public education program is required to ensure that the community understands the limitations of using non-potable water.

5.0 Water Supply Sources

Population growth will require the City to look for expanded sources of water to adequately supply the City of Columbia through 2040. The goal of the IWRP is develop a plan using a combination of sources that will meet these long term water supply needs.

Water is used for drinking, bathing, cooking, watering, flushing, irrigation, industrial, and many more applications. Not all these uses require identical sources and quality of water. Because of this distinction, potential water supply alternatives can be broken down into two distinct categories: potable and non-potable supplies.

Potable supply would meet the needs of drinking, bathing, and other uses that may result in human consumption. Expansion of potable water sources would require new or expanded infrastructure for supply of raw water (wells) and treatment, but can utilize existing infrastructure to distribute the water to customers.

Non-potable water may be used in place of potable supply for specific applications such as irrigation, industrial use, and other applications that aren't for human consumption. Some level of treatment and/or monitoring is required to meet regulatory requirements for non-potable use. Non-potable supply alternatives include recycled water from the existing Columbia Regional Wastewater Treatment Plant, recycled water from smaller satellite treatment plants, collected stormwater, and untreated or minimally treated groundwater. These sources of non-potable water will be evaluated at a treatment level suitable for applications where human contact is expected, consistent with neighboring state regulations.

This chapter includes a planning-level evaluation of potential sources of potable and non-potable water which could be used to meet the City's demand.

5.1 POTABLE WATER SUPPLY ALTERNATIVES

This section presents water supply alternatives to meet future demands for the CW&L service area. The alternatives evaluated include the continued use of the McBaine Bottoms Aquifer using vertical wells, installation of horizontal collector wells along the Missouri River bank, and the potential use of the Missouri River as a supply source.

These alternatives address supply to the existing McBaine Water Treatment Plant site for treatment and potable use. Evaluation of potable water supplies beyond the general vicinity of the plant were not considered as any alternative supply would require a new treatment facility and additional transmission piping that would result in higher overall costs than those included in the evaluation.

Past studies, including "Evaluation of Future Water Supply Sources", by CH2M Hill, 1996, included evaluation of potential groundwater supplies from the Eagle Bluff Conservation Area, groundwater from the Overton Bottom, and groundwater from the Ozark Bedrock Aquifer. The evaluation concluded that expansion into the Eagle Bluffs Conservation Area was not recommended due water quality concerns, access, and additional treatment requirements. Expansion into the Overton Bottom, which is on the west side of the Missouri River, may be feasible, however would be significantly more expensive as it would require a pipeline across the Missouri River. The rehabilitation and use of the original two deep

wells located in the City limits, or additional deep wells, that pull from the Ozark Aquifer had also been evaluated are not considered a long term alternative for potable water supply for the system. However, these wells will be considered for non-potable water applications and potentially for emergency connections to the distribution system.

5.1.1 Plant Rehabilitation

As discussed in Section 3.2, the current firm raw water supply to the treatment plant after installation of the three new wells scheduled in fall 2016 will be about 30 MGD. The current reliable capacity of the treatment plant is 24 MGD. To increase the reliable capacity of the plant to match the plant rated capacity of 32 MGD the preliminary estimated costs of plant rehabilitation improvements are approximately \$18M. Therefore, for the alternatives that utilize the existing plant the rehabilitation cost are included to reliably provide the 32 MGD capacity.

Future plant capacity will be dependent on a number of factors including population growth, conservation, and potential non-potable water usage. To provide a full range of potential water supply expansion alternatives till year 2040, each alternative was evaluated at approximately 5 MGD increments up to 20 MGD of expansion. This would result in a maximum total plant capacity of 52 MGD.

Significant upgrades to the existing facility are required to improve the reliability of the plant and to feasibly meet the rated plant capacity of 32 MGD. Any peak flows in excess of 32 MGD would require additional modifications and new facilities.

The plant improvements associated with this evaluation include maintaining current treatment performance meeting all current state and federal water quality regulations. This evaluation did not evaluate advanced treatment processes to exceed any current regulations or alter distribution characteristics. The improvements do include, when applicable, costs for treating varying source water, including groundwater influenced by surface water, but still providing only the necessary treatment to meet current regulations.

It is recommended that prior to proceeding with a capital project for plant improvements or expansion that decisions on what water quality requirements and treatment methods should be employed at the plant to meet the City's water quality goals.

5.1.2 Potable Alternative No. 1: Expand Existing Well field in McBaine Bottoms

This alternative includes installation of additional vertical wells to meet projected future average day and maximum day water demand of up to 52 MGD.

5.1.2.1 Vertical Well Expansion

A detailed hydrogeologic evaluation of the potential maximum yield of the McBaine Bottoms Aquifer was not performed as part of this study. However, based on available information about the existing wellfield and previous desktop studies, the McBaine Bottoms Aquifer is a prolific aquifer that is constantly recharged and would provide more than enough groundwater supply for future expansion with wells. As pointed out in the desktop well field study (Black & Veatch, 2012), maximum well field yield is more limited by well siting issues (e.g., available land for wells, proximity to wetlands, proximity to the river) than by the ability of the aquifer to yield the desired quantity of groundwater. As discussed

previously, a performance test conducted in 2015 indicated 15 existing well were capable of producing 26.9 MGD, or an average of about 1.8 MGD per well. Although new wells pumping individually may have a capacity of between 2.0 and 2.5 MGD each, this performance test is a good indication of what older wells are capable of producing after they have deteriorated somewhat with age while also accounting for interference with adjacent wells and hydraulic capacity of the system.

To accommodate new well sites in this portion of the river valley, the current spacing between well pairs (approximately 2300 to 2900 feet) would need to be reduced to approximately 1300 feet, which previous work concluded would be feasible since the added drawdown from the additional well interference would amount to only several feet at each well (Metcalf & Eddy, 1990). Figure 5-1 displays a 1300 feet buffer around the well pairs as well as a 200 feet buffer around any significant surface water body. To help provide some confirmation of this, the conceptual model of McBaine well field prepared during the desktop study (Black & Veatch, 2012) was used to simulate additional well sites to estimate what the alluvial aquifer might yield in the future. To be conservative, the Missouri River was set to a lower than average river elevation of 550 feet. The results from the conceptual model, illustrated on Figure 5-2, suggest that the aquifer will yield a total of 65 MGD with 32 wells for 30 days with groundwater levels at each well approaching but not dropping below the tops of the well screens. Using an average value of 1.8 MGD as determined by the 2015 well field performance test (to account for reduced well capacity over time, interference, and system hydraulics), for a total of nearly 58 MGD from 32 wells, the model shows slightly less drawdown surrounding the wellfield. These conceptual findings agree with the 1990 evaluation that a well spacing of around 1300 feet should be feasible and confirm that the alluvial aquifer can yield at least 52 MGD from approximately 28 wells provided that the wells are adequately maintained over time. It is recommended that at least 2 additional wells be provided as standby wells for firm capacity, for a total of 30 wells, if the full 52 MGD capacity is desired.



Figure 5-1 Existing well field with surface water and well field spacing buffers applied.

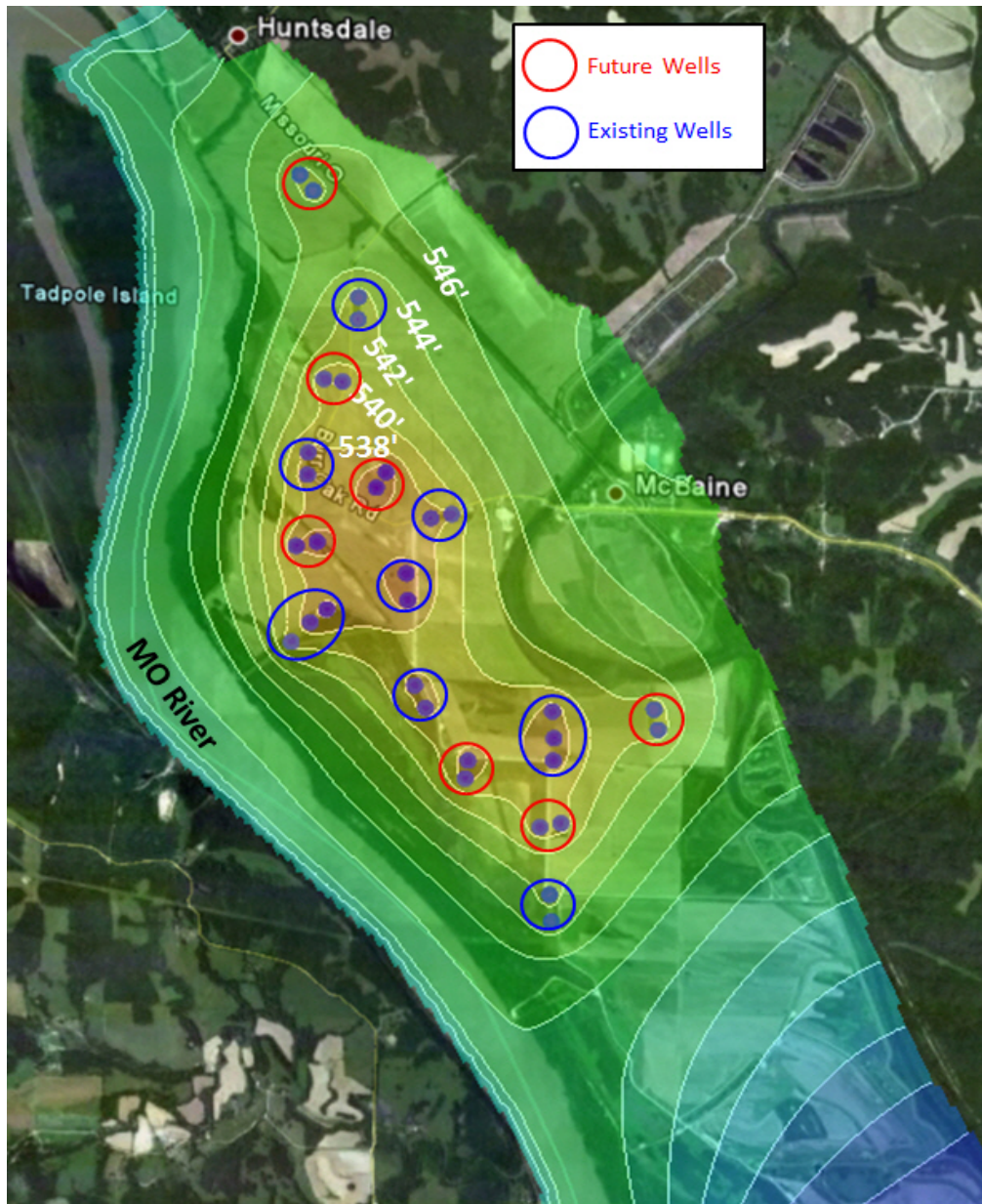


Figure 5-2 Conceptual Modeling of up to 32 wells with below average river groundwater elevation contours in feet

5.1.2.2 Water Quality

Although a water quality review of the aquifer was not part of this evaluation, the location of the new wells should be sufficient distance away from the Missouri River, the wetlands, and the Eagle Bluffs Conservation Area where those sources would have minimal impact on the water supply quantity and quality. However, additional analysis and monitoring should occur and final determination of the treatment requirements for the aquifer will be established by Missouri Department of Natural Resources.

During drought conditions in 2012 chloride concentrations increased in the water produced by several of the wells in the wellfield, including Wells 5, 6, 11, and 12 which are near the Eagle Bluffs Conservation Area and Well 1 which is near the constructed wetlands. The chloride concentrations measured during

the drought conditions at the nearby wells were typically in the order of 20 milligrams per liter (mg/L) which is well below the Environmental Protection Agency's secondary maximum containment limit of 250 mg/L.

As well field withdrawal rates increase over time, continued monitoring of the chloride levels in the USGS monitoring wells and supply wells should occur to confirm that the chloride concentrations and other contaminants remain below the maximum containment limit. Several operational procedures could be implemented to minimize the migration of chlorides to the wells, which include:

- With multiple wells there would be much more flexibility in the raw water supply. Therefore, the wells nearest the higher chloride levels would be operated only for peak conditions.
- Provide pumping combinations that paired wells with lowest chloride concentrations with wells with potentially higher concentrations to keep the overall concentration into the plant low
- If chloride concentrations did continue to show signs of migrating towards the well field, a cut-off well could be installed that would prevent any further migration.

If concerns did arise in the future from potential contamination of the well field, additional wells would be located further from Eagle Bluffs Conservation Area and the Wetlands and closer to the river, where water quality is impacted more by the Missouri River than other sources. Vertical wells near the river would have high capacity, however they would be most likely be considered under the influent of surface water. Reclassification of the water supply as groundwater under the direct influence of surface water would require additional treatment modifications; however would still provide a safe and reliable water supply.

5.1.2.3 Impact on Treatment Plant

The plant's current reliable capacity is approximately 24 MGD. As indicated in the "McBaine Water Treatment Plant and West Ash Condition Assessment", Black & Veatch 2016, significant upgrades to the existing facility are required to improve the reliability of the plant and to feasibly meet the rated plant capacity of 32 MGD. Any peak flows in excess of 32 MGD would require additional modifications and new facilities.

The Condition Assessment evaluated several alternatives for plant expansion to 45 MGD and 60 MGD. The assessment recommended that expansion should consist of a new process train located north of the existing plant in the current lime lagoon area. The existing levee would be expanded so that the new process train remained protected from flooding.

The new process train would consist of:

- Two induced draft aerators, each sized for half the basin flow
- One circular solids contact unit
- One recarbonation basin sized for 20 minutes of contact time
- Four filters, sized to allow full treatment train capacity to be met with one in backwash
- A post-filter baffled clearwell sized to provide wet-well volume for pump operation (approx. 250,000 gallons) and filter backwash. The clearwell would be configured to be expandable to

increase capacity if source water was reclassified as groundwater under the influence and additional disinfection contact time was required in clearwell.

- Three high service pumps located above the clearwell to pump finished water to the south high service line
- A new backwash tank, or dedicated backwash pumps, to serve the new filters.
- Modifications to the existing chemical feed systems to feed the new process train.
- Provisions for future addition of advanced treatment such as granular activated carbon deep beds or other determine advanced treatment measures.

The new process train would generally have the same configuration for any expansion of 10 MGD or more, resulting in a total treatment capacity between 42 and 52 MGD, with only the process components varying in size to match specific capacity. If the desired plant expansion was less than 10 MGD, then the number of aerators would be reduced to one, but the other components would remain the same.

The addition of a new process train was recommended over re-rating the existing plant, or converting the existing basins to single stage softening because it provides significantly more flexibility within the plant, increases reliability of the overall system by separating the process trains, and is the best cost value for expansion. Making any significant changes to the existing plant within the same footprint would be challenging based on space availability and constructability issues associated with keeping the plant in service throughout construction. The new treatment train could be built with minimal interruptions to existing operations. As recommended in the Condition Assessment, if the new process train has sufficient capacity to handle winter month flow conditions, then large portions of the existing plant could be taken offline for rehabilitation. This would reduce the overall construction costs for rehabilitation, and delay some of the more costly rehabilitation costs until higher flows were required to meet system demand.

5.1.3 Potable Alternative No. 2: Horizontal Collector Wells

This alternative includes installation of horizontal collector well(s) along the Missouri River for the additional raw water supply to the treatment plant. Horizontal collector wells are relatively common along the Missouri River and have the ability to produce 5 times or more capacity than a vertical well.

A collector well would be constructed by sinking a cast-in-place concrete caisson (approximately 20 feet in diameter) from the ground surface, through the alluvium, until it reaches bedrock or a confining impervious layer below the aquifer. The bottom of the caisson would be sealed and the interior dewatered. Well screens would then be installed horizontally from the interior of the caisson into the most desirable portion of the aquifer. The screens would usually be near the bottom of the aquifer where the larger aggregate would normally be located, and where there is the greatest thickness of saturated aquifer. To increase the capacity, the screens could be directed toward surface water to allow the surface water to more rapidly recharge the aquifer. Vertical diffusion vane pumps would be installed in a pumping station constructed above the caisson to convey groundwater from the horizontal collector well to the plant. For planning purposes, a horizontal collector well would likely produce 10 to 15 MGD, possibly more depending on the hydraulic connection with the river. Figure 5-3 illustrates a typical horizontal collector well.

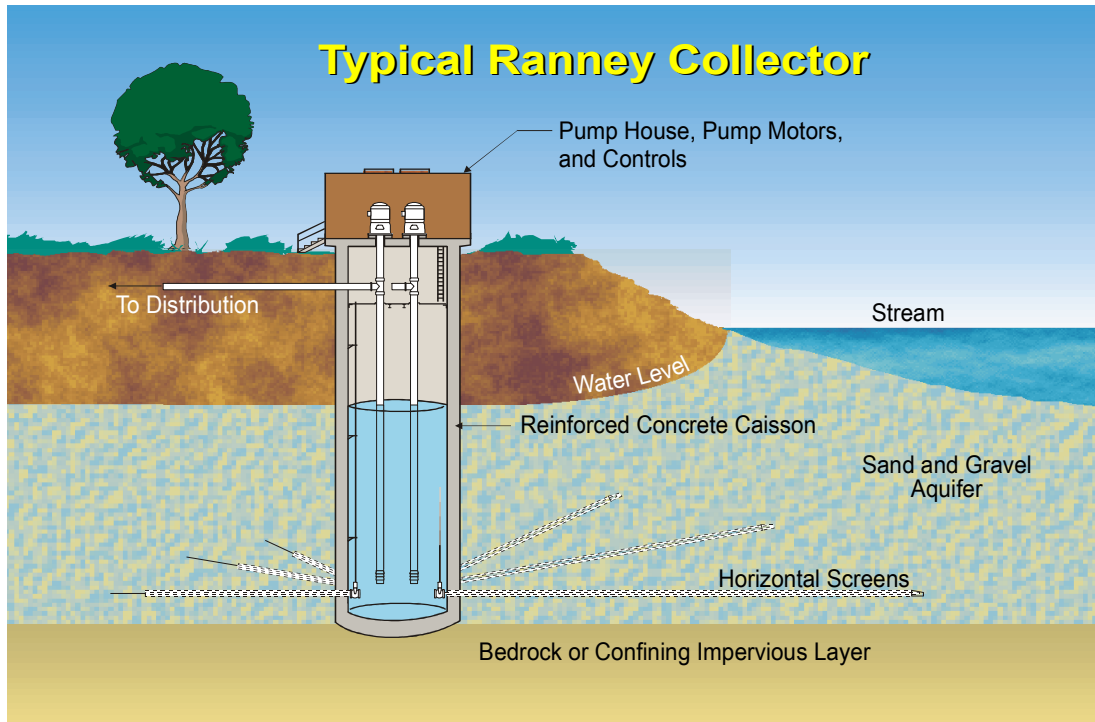


Figure 5-3 Typical collector well.

The initial capital costs for a horizontal collector well are typically higher as compared to a number of vertical wells with an equivalent capacity. However, if used to replace a number of vertical wells, the City would have fewer wells to operate and maintain, and this reduction in operations and maintenance (O&M) cost would help to offset the relatively high capital cost of collector wells. Collector well water would likely be considered Groundwater under the Direct Influence of Surface Water (GWUDI), requiring treatment modifications. However, since most of the water produced by a collector well comes from the river and these wells would be located farther from the wetland areas, there may be fewer concerns about any migration of chlorides in the future.

5.1.3.1 Water Quality

There are collector wells in Missouri that are classified as groundwater only, with no direct surface water influence. These are typically located farther away from a surface water source, but at the expense of well yield. Prior to selecting collector wells, additional testing and discussions with Missouri Department of Natural Resources (MDNR) should occur to determine the likelihood of being classified as GWUDI. If any future horizontal collector well is located near the Missouri River to maximize groundwater production, it would be classified as GWUDI and would require upgrades at the water treatment plant to meet new regulations.

Another concern with collector wells is that unlike multiple vertical wells, they present a single point for contamination. If the collector well would become contaminated a larger percentage of the plant water supply would be unusable. Therefore, this alternative includes collector wells to meet the expansion requirements, while keeping the remaining vertical wells in operation. As existing vertical wells become damaged or costly to repair, the decision to replace the existing wells with new vertical wells or collector wells would be determined.

5.1.3.2 Impact on Treatment Plant

If the collector well does draw from the Missouri River, there is the potential to notice the following changes in water quality:

- Increase in turbidity,
- varying temperatures based on the season,
- higher Total Organic Carbon (TOC),
- change in pH,
- change in hardness and alkalinity, and
- Increase in potential disinfection byproduct formation.

These changes can all have an impact on the treatment process, and there will be new regulatory requirements for treating the water. Modifications in addition to those required to rehabilitate the existing plant would be required, with the most costly being the addition of a clearwell and new pumping station downstream of the existing filters. The clearwell would allow the plant to meet the required disinfection requirements for GWUDI, and allow the flow to be controlled through the filters to prevent turbidity excursions.

To avoid the costly modifications to the existing plant, the new basin train would be designed to effectively treat source water that was classified as GWUDI. The process train would provide sufficient pH control, disinfection time, and a filter operating scheme to assure the regulatory requirements are met for source water classified as GWUDI. All the flow from the collector well would be pumped directly to the new process train. The new train would be designed to accept flow from either the collector well or existing groundwater wells, whereas the existing plant would only accept flow from the vertical wells classified as groundwater only. Therefore, no additional modifications to the plant, other than the rehabilitation costs, are required for this alternative.

5.1.4 Potable Alternative No. 3: Surface Water Intake

Another alternative which was considered is supplementing the water supply treated at McBaine WTP with surface water from the Missouri River. The Missouri River is the supply source for many communities and has sufficient capacity to meet the future demands of the City. However, treating and supplying Missouri River water will present new challenges. New treatment processes, including pre-sedimentation basins to remove the heavy river silts, and coagulation, flocculation, and sedimentation, followed by filtration would be required to remove turbidity, oxidized iron and manganese, color, organics, viruses, bacteria, Giardia, and Cryptosporidium. The costs to construct the facilities to treat river water, and the long term operational and maintenance costs to treat is significantly more than the continued use of groundwater or a new collector well supply. Therefore, although a very reliable and viable supply source, surface water supply is not recommended to meet the future demand period included in this evaluation.

5.2 NON-POTABLE WATER SUPPLY ALTERNATIVES

Non-potable water supply sources including surface water, groundwater, wastewater, and storm water may be used to offset potable demands by either reclamation or reuse. By treating the source water to meet specific needs, rather than treating all water to potable or drinking water standards, non-potable

systems may save on costs and resources. Non-potable supplies have the greatest impact when they reduce the demand for potable supplies, so the location and type of demand is critical to understanding the role that non-potable water could play in a water supply strategy.

Both Rain Barrels and Greywater systems are typically single lot-scale non-potable recapture and reuse alternatives that may help to decrease demands from residential, commercial, or industrial properties. These single point recapture systems are discussed in the water conservation section of this report and are not included as part of the large scale non-potable water supplies.

In order to implement a non-potable water supply system, source water must be collected, treated, and delivered to the user, often with a ‘purple pipe’ system (dedicated non-potable water delivery system). In many cases, this system would also need to be metered and managed by the water utility separately from the potable water system. Two typical uses of non-potable water are irrigation and industrial processes, which were considered in this evaluation, which require different supply and distribution infrastructure.

Purple pipe systems could deliver non-potable water for irrigation in new residential developments or landscaped areas like city parks or golf courses. Many parks and golf courses within Columbia’s service area supply irrigation water for most golf courses and parks with on-site wells, so there is no need for non-potable water at existing parks. Irrigation demands are seasonal, so supply and distribution systems must be sized to handle peak demands but are likely to be off-line for a few months of the year. Irrigation metering records were used to estimate how annual demands for irrigation water would be distributed on a monthly basis, which results in a peaking factor of 2.77.

Industrial users of non-potable water may use it for irrigation, dust control, process, cooling, or wash water. Depending on the type of industry and the application, there may be specific quality and quantity demands. If there were a large industrial user that had a year-round demand, the potential to develop non-potable supplies could be cost effective and could have a significant supply impact. The ideal ways to implement industrial reuse could include reaching out to large industrial water users and development of purple pipe systems in any new industrial park development.

This section evaluates the non-potable supply alternatives described in Table 5-1.

Table 5-1 Non-Potable Alternatives

ALTERNATIVE	FACILITY TYPE	SOURCE	TREATMENT REQUIRED
1.	Centralized Wastewater Reuse	Treated Wastewater Effluent	Disinfection and Filtration
2.	Satellite Wastewater Treatment Plants	Wastewater	Advanced Treatment
3.	Stormwater Catchment	Stormwater runoff	Disinfection and Aeration
4.	Groundwater Wells	Groundwater	Disinfection

5.2.1 Types of Water Reuse

Water reuse is generally classified by the treatment configuration (direct or indirect) and the supplied water quality (potable or non-potable). Direct reuse is defined as the use of reclaimed water that is piped directly from the wastewater treatment plant to the place where it is utilized. Indirect reuse is defined as discharging reclaimed water to a water supply source, such as a surface water body or groundwater, where it blends with the water supply before being removed for non-potable or potable uses. It is important to note that the difference between direct and indirect can be slight if the environmental barrier is limited. Potable water is suitable for direct consumption, and non-potable is used to meet a range of other demands. This gives four classes of reuse:

1. Direct Potable – typically additional treatment at a wastewater treatment facility and conveyance to a water treatment plant, where it is treated with other raw water sources
2. Direct Non-potable - typically additional treatment at a wastewater treatment facility and conveyance to an end user for industrial, irrigation, or other uses that do not require drinking water quality
3. Indirect Potable – treated wastewater effluent that discharges to a surface or groundwater supply, blends with the supply, and may undergo natural purification processes before being treated to drinking water standards
4. Indirect Non-potable – treated wastewater effluent that returns to the environment and is used to meet demands that do not require drinking water quality

Many forms of indirect reuse have been implemented through the years as discharges from one water user contribute to streamflow or groundwater recharge and are then diverted by a downstream water user. Direct non-potable reuse is most commonly used for irrigation or industrial uses, and is regulated according to how much human contact is expected, which is discussed further in Reuse Water Treatment Regulations section.

5.2.2 Central Wastewater Reuse

This non-potable alternative includes treating effluent from the City's WWTP to acceptable water quality requirements for reuse.

The Columbia Regional Wastewater Treatment Plant (WWTP) is operated by Columbia Water and Light Department, and is located at 4900 West Gillespie Bridge Road, Columbia, MO 65203 (). The WWTP was built in 1983 with an initial capacity of 13 MGD, replacing over 75 small facilities throughout the City of Columbia. In 2013, improvements were completed to allow the WWTP to treat up to 25.2 MGD through the mechanical treatment facilities and remove ammonia to meet the new effluent limit of 6 mg/L of ammonia required by the NPDES permit prior to discharge to the wetlands. The Columbia WWTP uses a complete-mix activated sludge process to treat an average of 16 MGD of municipal wastewater.

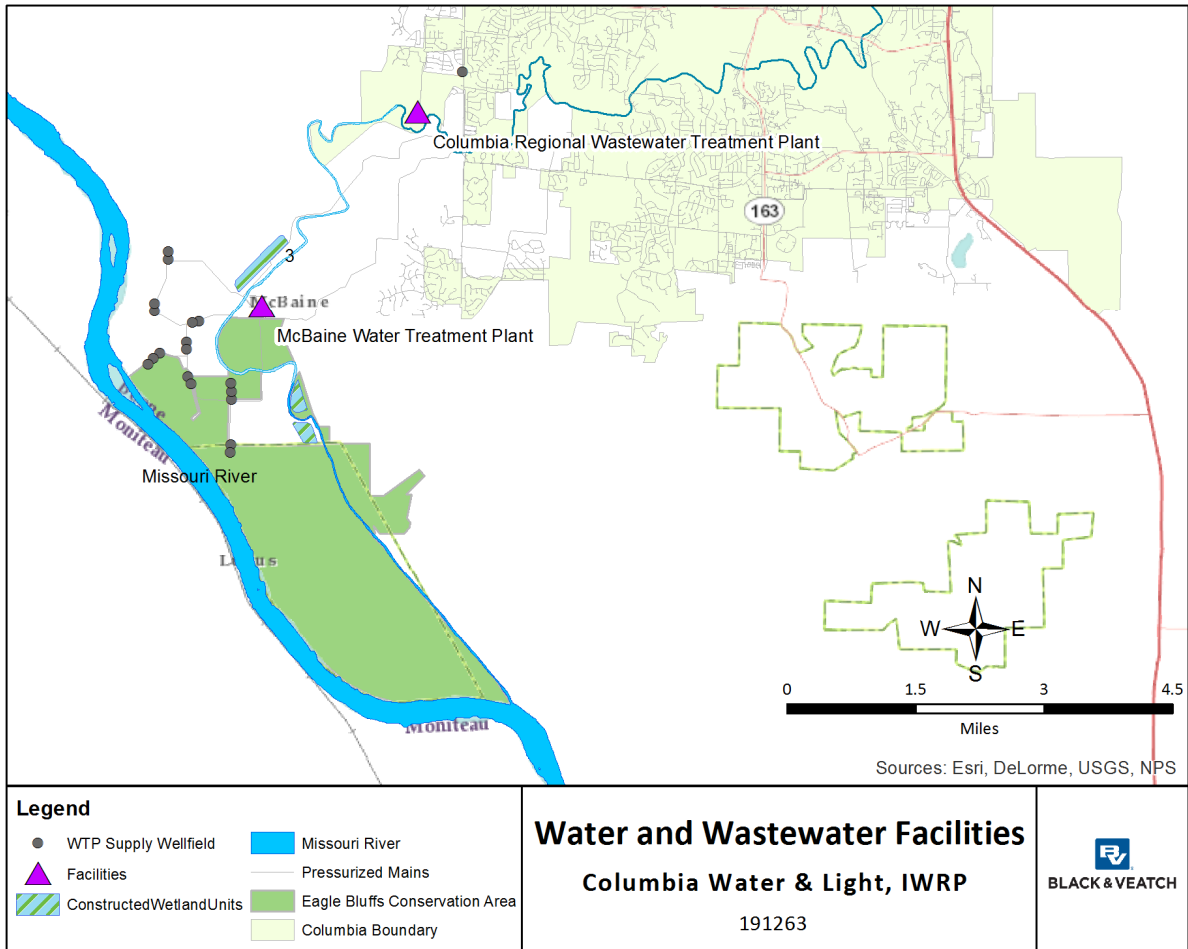


Figure 5-4 Columbia Water & Light Water and Wastewater Facilities

Effluent is discharged to 130 acres of constructed wetlands after treatment in the WWTP and then flows to the Missouri Department of Conservation’s Eagle Bluff Conservation Area on the Missouri River. The treated effluent is used to help maintain the wetland as habitat for birds and other wildlife. The wastewater is gravity-fed through Eagle Bluff via a series of channels and gates, which eliminates the need for Eagle Bluff to pump freshwater and the associated costs (either from a well or from the Missouri River). One of the primary objectives for the City’s wastewater treatment improvement strategy is to continue to supply Eagle Bluffs with effluent.

5.2.2.1 Treatment Requirements

Effluent from the wastewater plant meets water quality requirements for discharging into the conservation area. At a minimum, disinfection would be required to re-use the effluent for non-potable use. Tertiary filtration or membrane filtration would also be recommended and is included in the reuse process stream to remove remaining particles prior for distribution. The facilities would be built on the existing treatment plant.

5.2.2.2 Supply Capabilities

To be consistent with the City's desire to continue supplying water to Eagle Bluffs, a centralized wastewater effluent reuse alternative would need to allow the current volume of treated effluent from the Regional Wastewater Treatment Plant to travel through the Eagle Bluff Conservation Area. Keeping this goal in mind, two approaches were considered.

One approach would be to divert the effluent at the far south end of the Conservation Area, after it has passed through Eagle Bluffs. At this point, the water could be considered comparable to raw surface water from the Missouri River, but the collection point would be further away from potential non-potable demand centers than other raw surface water alternatives, and therefore more costly to pipe and pump.

The other approach is to divert effluent at the treatment plant outflow, limited to only additional effluent as the Regional Wastewater Treatment Plant capacity increases, in order to protect the existing supply to Eagle Bluffs. Columbia's average daily demand for water is projected to increase from current rate of 15 MGD to 28 by 2040, with an average rate increase of 0.3 MGD to 0.5 MGD per year. Therefore, the theoretical supply available from the plant for non-potable use is 13 MGD by year 2040, which far exceeds any estimate of demand for non-potable water.

5.2.3 Satellite Wastewater Reuse

New satellite wastewater treatment plants could be considered to serve new non-potable demands in areas with a high density of demand. A satellite plant could be a packaged wastewater treatment system capable of producing recycled water for non-potable reuse. Satellite plants are considered decentralized systems where wastewater is diverted from a nearby sanitary sewer line and treated for use in nearby areas. A decentralized system can reduce the pumping and conveyance infrastructure needed. However, the need for new satellite treatment plants more than offsets any gains from producing water near a demand. These plants require additional O&M, tend to cost more per unit of water produced, and require a means for solids disposal or treatment.

The Satellite treatment facilities would need to be located on a main wastewater supply line, and would require sufficient space available to house the water treatment plant. Figure 5-5 shows locations of major trunk lines in the collection system. The package satellite system would need to be located near one of the major collector sewers.

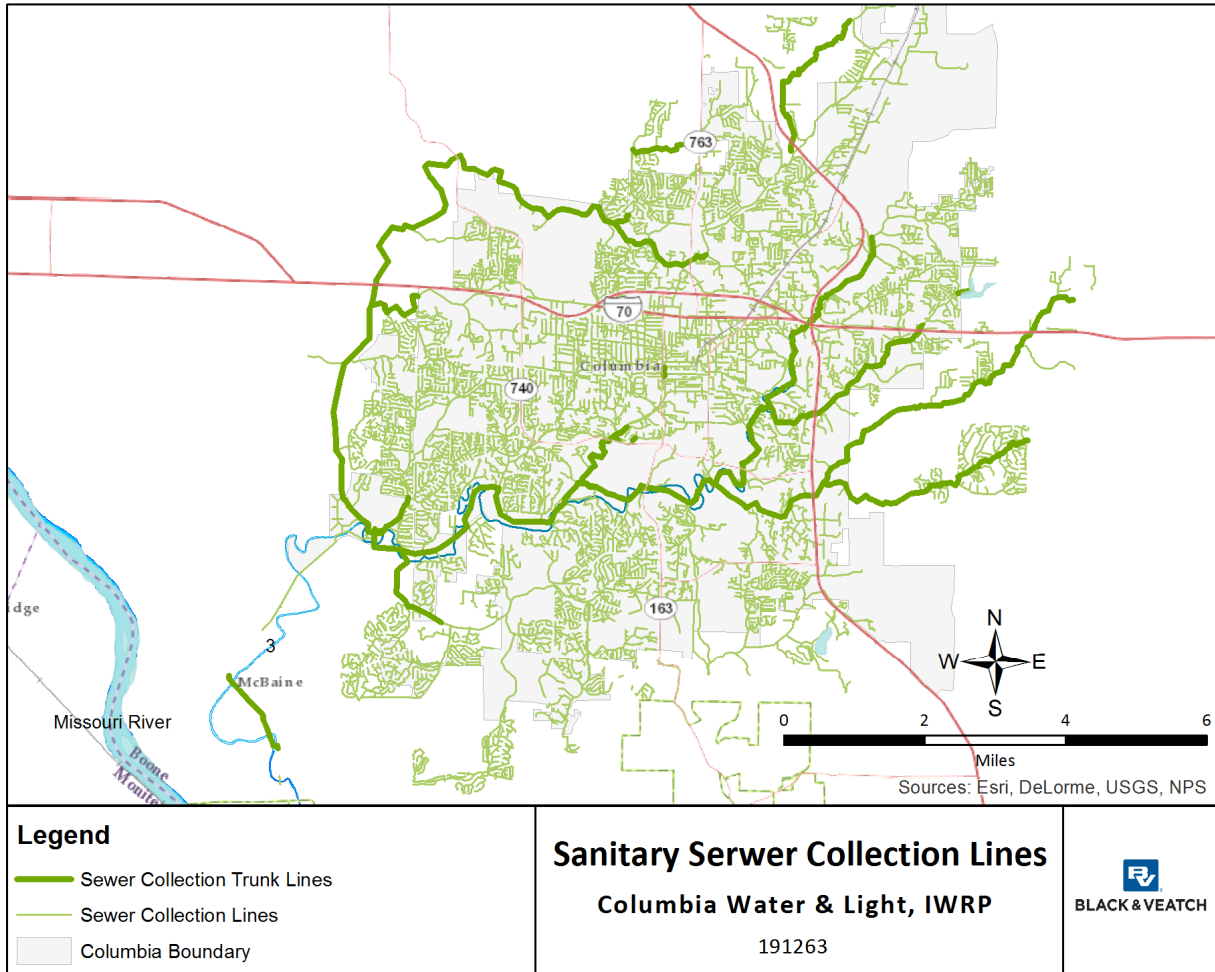


Figure 5-5 CW&L Sanitary Sewer Collection System

5.2.3.1 Treatment Requirements

Effluent from major sewers would have to be directed through screening, advanced Membrane Bioreactor or Ultrafiltration, followed by disinfection and pumping to the system. , An equalization tank will be required to store treated water prior to distribution in the non-potable system because of the diurnal flows in the sewers. The tank would have to be sufficiently sized to handle changes in flow and meet the intended needs of the system. A system used for irrigation would need a larger tank to provide sufficient capacity to meet peak demand conditions.

5.2.3.2 Supply Capabilities

Supplies for the satellite treatment plants are limited by the City’s desire to maintain supplies of wastewater effluent to Eagle Bluffs Conservation Area, as with the centralized wastewater reuse alternative. In order to maintain current flows, only increases in wastewater effluent would be available for treatment, which may require a later implementation for this alternative.

The location of the facilities and capacity of nearby sewers may diminish the actual capacity available for satellite reuse. A site specific evaluation for any selected location would be required to determine actual capacities.

5.2.4 Stormwater Catchment

Stormwater retention ponds can be used to catch and store rainwater and runoff, which may then be used for irrigation with minimal treatment. The amount of supply can be estimated using the area of selected watersheds in Columbia and rainfall records for the area. Six watersheds were used to estimate the yield for stormwater catchment ponds designed for water supply.

Stormwater retention ponds can be designed and operated for two different purposes: provide a water supply, and to manage floodwater and runoff quality. The way that a pond is designed and operated for stormwater management and flood mitigation is different than a pond that is solely used for supply purposes. For instance, a supply pond has the highest yield when it is operated to remain as full as possible, whereas a pond used for flood control requires some portion of the capacity to remain empty (freeboard) to accept incoming flood water.

For a pond to perform both flood control and supply functions, a larger pond would be needed to provide the same amount of supply, and the associated costs would increase. In coordination with the City's Stormwater Integrated Management Plan, any selected locations for stormwater ponds could be evaluated to also serve as non-potable supply.

This evaluation assumes stormwater catchment ponds are designed and operated solely as supply ponds. This concept is used to estimate the maximum amount of supply one could expect from a pond with the drainage area and capacity available. Sizing and costs do not include capacity or components required for flood control.

5.2.4.1 Treatment Requirements

The stormwater in any potential pond site would need to be tested to avoid water quality issues, but it is assumed that all stormwater would meet quality requirements for 'contact' applications with the use of pond aerators or fountains and disinfection.

5.2.4.2 Supply Capabilities and Sizing

Stormwater retention ponds would need to be sized based on the demands being served, the size of the watershed, and any limitations on the storage capacity due to the proposed pond site. The National Hydrography Dataset (NHD 2+) was utilized in ArcGIS to delineate watersheds that may be feasible for stormwater pond development in and around the city limits. These potentially feasible watersheds were compared with areas that were identified for new development or redevelopment in the City's 2013 document, 'Columbia Imagined.' The watersheds that have the capacity to provide a sufficient amount of runoff and are near growth areas were further evaluated for estimated yields.

Yields at each location were estimated using the area of the contributing watershed, drought year rainfall estimates based on historical records (assumed constant throughout the city), and the size of the pond. Figure 5-6 shows how firm yield estimates vary based on a range of drainage area and retention capacity combinations.

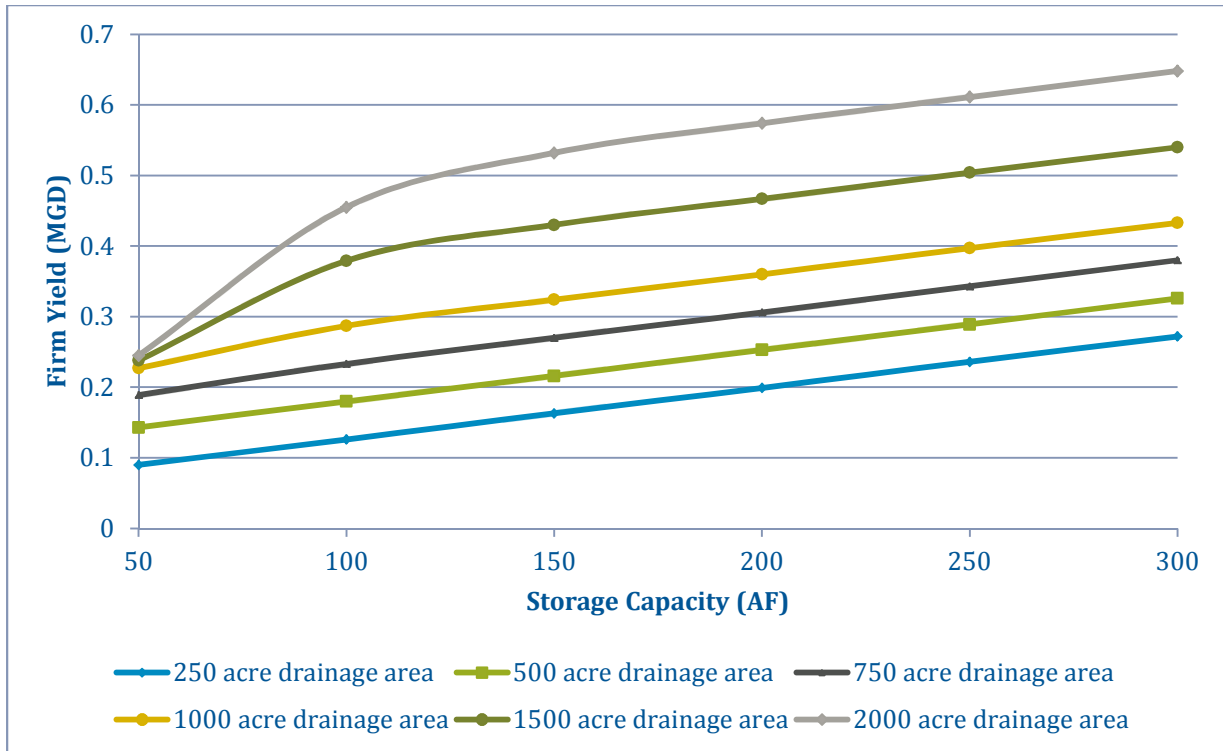


Figure 5-6 Firm Yield Estimates Based on Drought Year Climate Data, Watershed Characteristics, and Storage Capacity

Pond inflows were modeled assuming drought-year rainfall, an estimate of free surface evaporation (based on evapotranspiration values⁸), and the drainage area of the watershed. The runoff coefficient was estimated at 0.7 which is representative of perviousness in a semi-urban area.

Daily demands for irrigation water from the pond were modeled on the monthly distribution of demand in irrigation meter records from the City of Columbia’s voluntary irrigation metering program. These demands were estimated based on monthly distribution, (i.e. the percentage of annual demands that occur in each month). Historical irrigation demands were not evaluated on an hourly basis, but the distribution system was designed to accommodate 15% of the demands at any point in time. A simplified estimate of pond geometry was used (5-foot deep, rectangular ponds), and the pond area was varied to produce different firm yield values. Figure 5-7 shows the watershed areas that were evaluated.

⁸ University of Missouri Commercial Agriculture Extension Service

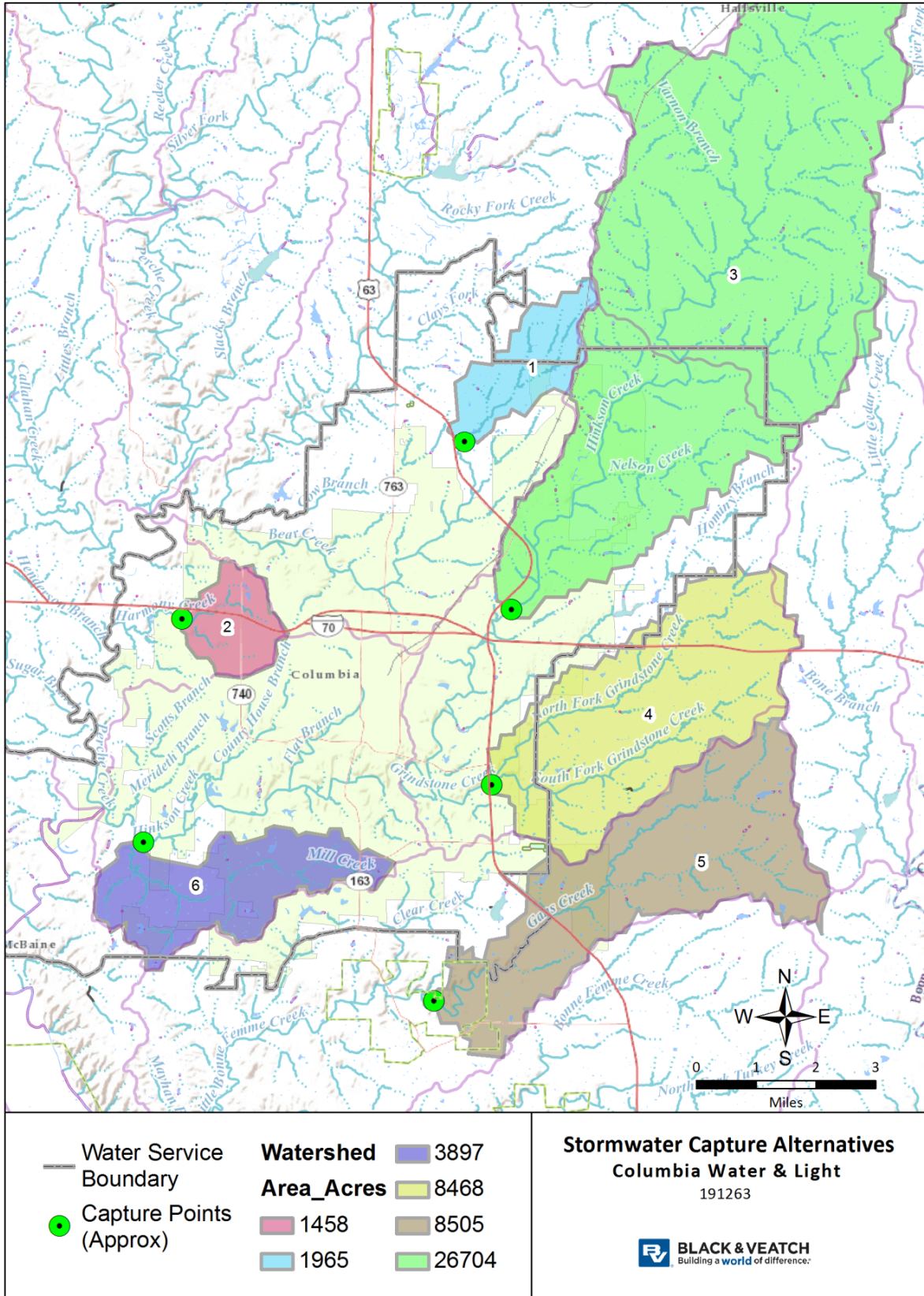


Figure 5-7 Potentially feasible drainage areas for stormwater capture ponds.

For each of the six approximate pond locations shown in Table 5-2, a range of feasible pond sizes and their associated yields were calculated based on the contributing area.

Table 5-2 Stormwater Pond Model Alternatives

POND #1					
Watershed size (acres)	1,900				
Average Yield, MGD	0.25	0.50	1.00		
Max Day Capacity, MGD	0.69	1.39	2.77		
Pond Capacity Required (AF)	61	171	500		
POND #2					
Watershed size (acres)	1,400				
Average Yield, MGD	0.25	0.50	0.88		
Max Day Capacity, MGD	0.69	1.39	2.44		
Pond Capacity Required (AF)	64	211	500		
POND #3					
Watershed size (acres)	26,700				
Average Yield, MGD	0.25	0.50	1.00	2.00	2.33
Max Day Capacity, MGD	0.69	1.39	2.77	5.54	6.45
Pond Capacity Required (AF)	31	61	134	403	500
POND #4					
Watershed size (acres)	8,400				
Average Yield, MGD	0.25	0.50	1.00	1.76	
Max Day Capacity, MGD	0.69	1.39	2.77	4.88	
Pond Capacity Required (AF)	32	89	236	500	
POND #5					
Watershed size (acres)	8,500				
Average Yield, MGD	0.25	0.50	1.00	1.78	
Max Day Capacity, MGD	0.69	1.39	2.77	4.92	
Pond Capacity Required (AF)	32	88	236	500	
POND #6					
Watershed size (acres)	3,800				
Average Yield, MGD	0.25	0.50	1.00	1.25	
Max Day Capacity, MGD	0.69	1.39	2.77	3.45	
Pond Capacity Required (AF)	48	121	342	500	

5.2.5 Groundwater Wells

5.2.5.1 Existing Deep Rock Wells

The City of Columbia used deep bedrock wells located throughout the city as a primary supply until 1972. As a result of concerns about the declining water levels in the deep wells and the long term capacity of the Ozark Aquifer, the City began to research the McBaine Bottoms Aquifer along the Missouri River in the 1960s as a new water resource for the City. The McBaine wellfield and water treatment plant were completed in 1972.

The City maintains one of the deep wells to serve as an emergency backup during peak demands or prolonged drought. Two of the other deep wells were converted to Aquifer Storage and Recovery (ASR) facilities which were able to produce up to 2 MGD each, but the cost to re-permit continued ASR has been prohibitive with recent changes in regulations. Within the City of Columbia, at least 20 industrial and commercial users pump water from the Ozark Aquifer, including the University of Missouri; wells in this area vary from 300 to 1500 feet deep, with well capacities between 360 and 1,000 gpm. Supply Capabilities

Groundwater from deep bedrock wells could potentially be used to offset potable demands with minimal treatment. The water quality is generally adequate for 'contact' NPW use, requiring simple disinfection for treatment. One concern, however, is declining groundwater levels in the area that could make O&M costs increase in future as mining of the groundwater continues. An evaluation of the available yield in the Ozark aquifer was not completed as part of this project, but it is assumed to have sufficient capacity to provide adequate supply for non-potable demands. However, any development of groundwater will require exploratory test wells and pumping tests to estimate a yield for each well.

5.2.5.1.1 Concerns and Limitations

The locations of existing wells are shown in Figure 5-8 . The Fairview and Scott Blvd. wells will be considered for conversion from ASR to production, and the West Ash well could be evaluated based on location of non-potable customers. If the area of use is not immediately adjacent to the existing wells, costs could be significantly impacted by the trunk pipeline construction and new well construction may be more cost effective.

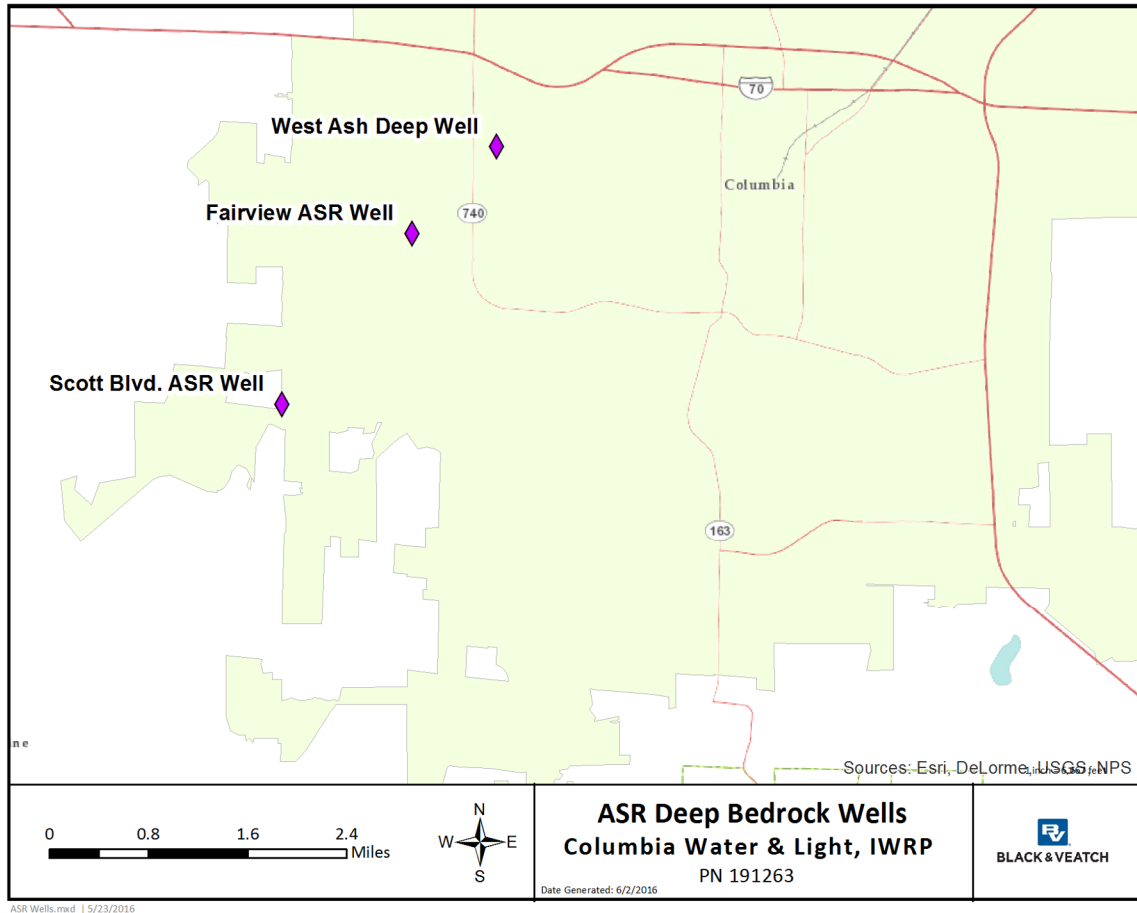


Figure 5-5-8 Location of Existing Deep Bedrock Wells

In order to further pursue groundwater from these wells as a potential supply, pumping tests may be necessary to assess the performance of the wells. This may help to determine the state of the wells and pumps currently installed and help to evaluate the cost and feasibility of using these wells as a supply.

An alternative to using the existing deep bedrock wells, new wells could be drilled which tap into the same aquifer.

5.2.6 Distribution System

Whereas potable water can largely use the distribution pipes in place to get water to individual water users, non-potable water requires a separate distribution system. This can represent a significant portion of the cost of any non-potable water supply system.

New residential developments, industrial parks, or other clustered major water users are the most common sites for non-potable development, which limits cost and traffic disruption. (Retrofitting an existing residential neighborhood with purple pipe is typically cost-prohibitive.) There is a significant difference in cost and effort between supplying a point source (like an industrial user) and 400-1500 acres of residential homes. It may be possible to require the developer of a subdivision to include purple pipe, and shift the costs to the developer, but the requirements of the system are still the same.

The distribution system required to deliver non-potable supplies used for irrigation can be approximated by assuming an average lot size, the amount of water required to irrigate typical lawn or turf, and the supply volume. The following assumptions were used to estimate the costs for a residential irrigation system for non-potable water:

- Lots are 1 Acre on average
- 30% of the area is irrigated
- Demand is 2.17 ft./year on irrigated areas, based on best practices for lawn irrigation
- One out of every eight lots are irrigated at any given time (assuming a demand scheduling program)
- A one mile main trunk pipeline to serve the distribution area
- Each lot watering utilizing

With these assumptions, a high-level service areas and distribution piping networks can be generated for various yields (Table 3-1).

Table 5-3 Estimated Non-Potable Irrigation Distribution System Service Area

AVERAGE ANNUAL YIELD	1 MGD	0.5 MGD	0.25 MGD
Max Day Capacity (MGD)	2.77	1.39	0.69
Total Area Served by System (acres)	1,720	860	430
Peak Instantaneous Demand (gpm)	3,871	1,935	968
Distribution Pipe Length (miles)	34.0	17.0	8.5
Trunk Pipeline Size (inches)	16	12	8

The service area shown in Figure 5-9 is the extent that the irrigation ‘purple pipe’ system would need to cover in order to deliver irrigation supplies.

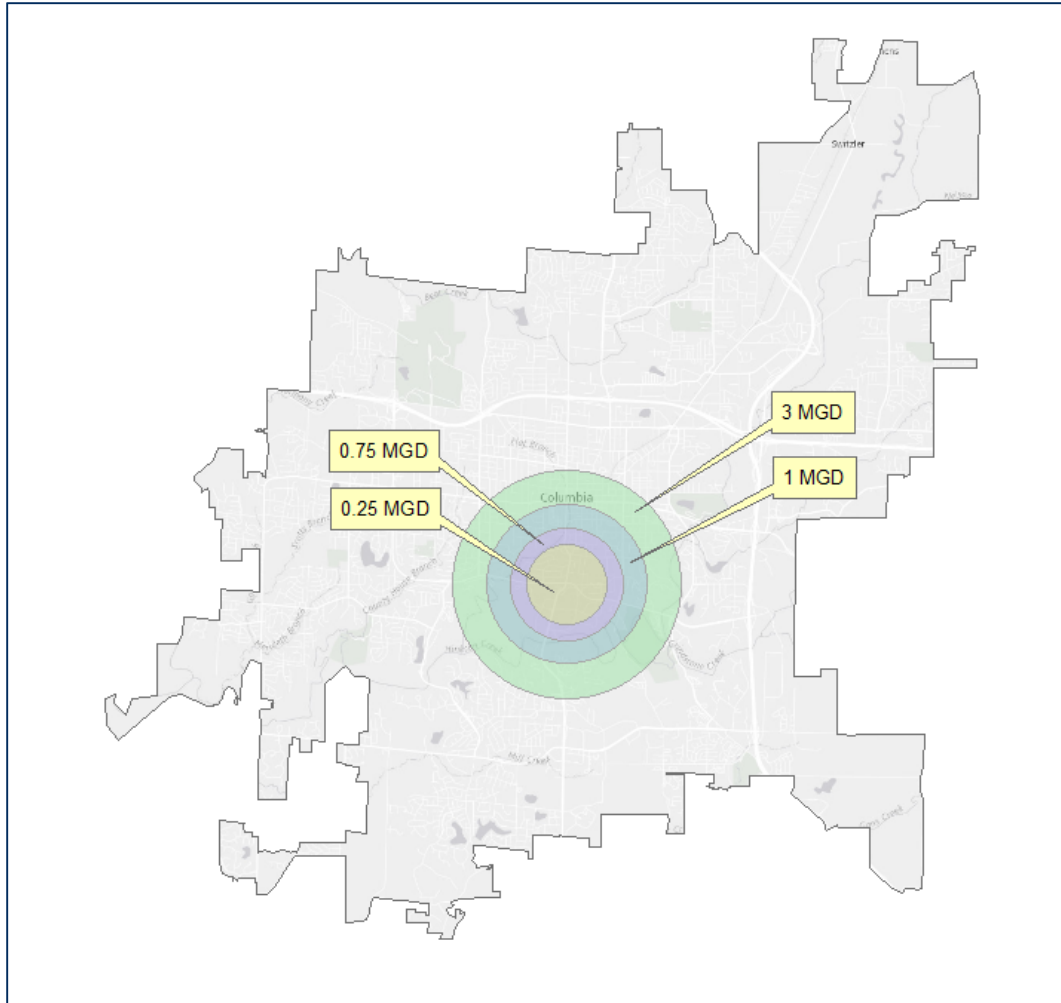


Figure 5-5-9 Approximate service area for irrigation distribution systems at various annual yields

A distribution system required for an industrial user was approximated as a single trunk line. An industrial park system would likely fall between the irrigation and single-point of use models.

In addition to the construction and O&M costs, there is a cost for administration and management of a non-potable system. Metering, billing, and any demand management (coordinating the timing of users and management of the supply) would all be required in order to implement a non-potable supply system. Some of the alternatives would require significantly more oversight than others: stormwater ponds as an irrigation supply would require regular pond level monitoring and public communication and oversight, whereas a constant-demand industrial user of wastewater treatment plant effluent would require less administration and communication.

5.2.7 Reuse Water Treatment Regulations

The State of Missouri does not have explicit non-potable reuse water guidance, but the environmental regulatory entities in Oklahoma and Texas have created guidelines, which are included here for reference. Any reuse program should be developed in close coordination with the Missouri Department of Natural Resources, as well as any other local and state entities involved in water supply, stormwater, wastewater, or watershed protection.

5.2.7.1 Texas Reuse Regulations

Texas Commission on Environmental Quality (TCEQ) 30 TAC §210 describes the uses and water quality standards for two categories of recycled water.

Type I Reclaimed Water Use. This type of use includes irrigation or other uses in areas where the public may be present during the time when irrigation takes place or other uses where the public may come in contact with the reclaimed water. The following types of uses would be considered Type I uses:

- A. Residential irrigation, including landscape irrigation at individual homes;
- B. Urban uses, including irrigation of public parks, golf courses with unrestricted public access, school yards, or athletic fields;
- C. Use of reclaimed water for fire protection, either in internal sprinkler systems or external fire hydrants;
- D. Irrigation of food crops where the applied reclaimed water may have direct contact with the edible part of the crop;
- E. Irrigation of pastures for milking animals;
- F. Maintenance of impoundments or natural water bodies where recreational activities, such as wading or fishing, are anticipated even though the water body was not specifically designed for such a use;
- G. Toilet or urinal flush water; and
- H. Other similar activities where the potential for unintentional human exposure may occur.

For Type I water uses, reclaimed water should meet the quality metrics presented in Table 5-4 on a 30-day average, sampled twice per week.

Table 5-4 Texas Type 1 Water Quality Requirements

PARAMETER	LIMIT
BOD5 or CBOD5	5 mg/L
Turbidity	3 NTU
Fecal coliform or E. coli	20 CFU /100 ml *
Fecal coliform or E. coli	75 CFU /100 ml **
Enterococci	4 CFU /100 ml *
Enterococci	9 CFU /100 ml **
BOD5 – Biochemical oxygen demand, 5-day test CBOD5 – carbonaceous biochemical oxygen demand, 5-day test CFU – colony forming units mg/L – milligrams per liter	ml - milliliters NTU – Nephelometric turbidity units *30-day geometric mean **maximum single grab sample

Type II Reclaimed Water Use. This type of use includes irrigation or other uses in areas where the public is not present during the time when irrigation activities occur or other uses where the public would not come in contact with the reclaimed water. The following are examples of uses that would be considered Type II uses.

- A. Irrigation of sod farms, silviculture, limited access highway rights of way, and other areas where human access is restricted or unlikely to occur. The restriction of access to areas under irrigation with reclaimed water could include the following:
 - i. The irrigation site is considered to be remote.
 - ii. The irrigation site is bordered by walls or fences and access to the site is controlled by the owner/operator of the irrigation site.
 - iii. The irrigation site is not used by the public during the times when irrigation operations are in progress. Such sites may include golf courses, cemeteries, and landscaped areas surrounding commercial or industrial complexes.
 - iv. The irrigation site is restricted from public access by local ordinance or law with specific standards to achieve such a purpose.
- B. Irrigation of food crops where the reclaimed water is not likely to have direct contact with the edible part of the crop, or where the food crop undergoes pasteurization prior to distribution for consumption.
- C. Irrigation of animal feed crops other than pasture for milking animals.
- D. Maintenance of natural water bodies where direct human contact is not likely.
- E. Soil compaction or dust control in construction areas where application procedures minimize aerosol drift to public areas.
- F. Cooling tower makeup water. Use for cooling towers which produce significant aerosols adjacent to public access areas may have special requirements.
- G. Irrigation or other non-potable uses of reclaimed water at a wastewater treatment facility.

For Type II water uses, reclaimed water must meet the criteria based on a 30-day average, sampled once per week. Water that is treated through methods other than a pond system should meet the quality metrics shown in Table 5-5, and systems with a pond system should meet the metrics in

Table 5-6.

Table 5-5 Texas Type 2 Water Quality Requirements for Systems Other Than a Pond System

PARAMETER	LIMIT
BOD5	20 mg/L
or CBOD5	15 mg/L
Fecal coliform or E. coli	200 CFU /100 ml *
Fecal coliform or E. coli	800 CFU /100 ml **
Enterococci	35 CFU /100 ml *
Enterococci	89 CFU /100 ml **
BOD5 – Biochemical oxygen demand, 5-day test CBOD5 – carbonaceous biochemical oxygen demand, 5-day test CFU – colony forming units	mg/L – milligrams per liter ml - milliliters *30-day geometric mean **maximum single grab sample

Table 5-6 Texas Type 2 Water Quality Requirements for a Pond System

PARAMETER	LIMIT
BOD5	30 mg/L
Fecal coliform or E. coli	200 CFU/100 ml *
Fecal coliform or E. coli	800 CFU /100 ml **
Enterococci	35 CFU/100 ml *
Enterococci	89 CFU/100 ml **
BOD5 – Biochemical oxygen demand, 5-day test CBOD5 – carbonaceous biochemical oxygen demand, 5-day test CFU – colony forming units	mg/L – milligrams per liter ml - milliliters *30-day geometric mean **maximum single grab sample

5.2.7.2 Oklahoma Reuse Regulations

Oklahoma may have the most relevant water reuse regulations of any state to that may be applicable in Missouri. Their regulations have been developed in the past 2 years to address both recent acute shortages and long range water supply planning issues, as well as localized needs for non-potable water (NPW) reuse. The regulations are very comprehensive and look at all aspects related to water reuse including storage and operations and maintenance requirements. Summarized in Oklahoma’s new regulations for reference are some items that may be future requirements if Columbia utilizes water reuse in its’ long term water resources plan. This includes summaries of Oklahoma’s guidelines for:

- Categories of reclaimed water uses and the treatment, sampling, record keeping and reporting requirements specific to each category
- Storage and requirements of reclaimed water
- Permit requirements
- General requirements for reclaimed water systems and O&M requirements
- Distribution system requirements and O&M requirements

Information for this discussion comes from Oklahoma’s’ water reuse regulations (Oklahoma Administrative Code (OAC), Title 252. These regulations are for reclaimed water used for irrigation and other non-potable water uses.

- Chapter 627 Water Reuse
- Chapter 656 Water Pollution Control Facilities Construction Standards

5.2.7.2.1 Categories of Reclaimed Water (OAC 252:656-27-1 and OAC 252:627-1-6)

States like Oklahoma typically group the various uses of reclaimed water into four categories as shown in Table 5-7. Each category is subject to specific treatment and sampling requirements.

Table 5-7 Categories of Reclaimed Water in Oklahoma

CATAGORY	USE(S) ⁽¹⁾	MINIMUM TREATMENT ⁽²⁾	TESTING FREQUENCY ⁽³⁾	LIMITS ⁽³⁾	MORS ⁽³⁾
1	Indirect Potable Reuse / Aquifer Recharge	Reserved	Reserved	Reserved	Reserved
2	<ul style="list-style-type: none"> • Drip irrigation on orchards or vineyards • Schoolyard spray/drip irrigation • Public access landscapes spray/drip irrigation • Toilet and urinal flushing • Fire protection systems • Commercial closed loop air conditioning systems • Vehicle and equipment washing (excluding self-serve car washes) • Dust control • Aggregate washing and sieving • Range cattle watering 	<ul style="list-style-type: none"> • Secondary/Suspended Growth mechanical treatment • Coagulation (chemicals and/or polymers) • Filtration • Nutrient removal based on final use • Disinfection with Cl then UV 	Turbidity: Continuous (Recorded at least once every 15 minutes)	<ul style="list-style-type: none"> • Daily average ≤ 2 NTUs • Always ≤ 3 NTUs 	Submit MORs to ODEQ
			Cl disinfection at POE: Continuous	<ul style="list-style-type: none"> • Free available Cl always ≥1 ppm at POE to distribution system • Free available Cl at end-of-pipe always ≥0.50ppm 	
			Total Coliform: Daily	Non detect in four of the last seven daily samples, single sample max ≤23 cfu/100mL	
			Nitrogen/Phosphorous: Monthly	≤ most stringent agronomic rate	
3	<ul style="list-style-type: none"> • Subsurface irrigation of orchards or vineyards • Restricted access landscape irrigation • Restricted access landscape impoundment • Irrigation of livestock pasture • Concrete mixing • Restricted irrigation of sod farms 	<ul style="list-style-type: none"> • Secondary/Suspended Growth mechanical treatment • Nutrient removal based on final use • Disinfection chlorination by 	Cl disinfection: Every 12 hours	Free available Cl always ≥1 ppm at POE to distribution system	Submit MORs to ODEQ
			Fecal coliform: 3 per week	<ul style="list-style-type: none"> • Monthly geometric mean of < 200 coli/100 ml • Single sample maximum < 400 coli/100 ml 	
			Nitrogen/Phosphorous: Monthly	≤ most stringent agronomic rate	
			BOD5 or CBOD5: Weekly	< 20 mg/L	
4	<ul style="list-style-type: none"> • Soil compaction and similar construction activities • Restricted golf course irrigation 	<ul style="list-style-type: none"> • Primary treatment through wastewater treatment lagoons • Cl Disinfection • Storage Detention Time 	Fecal coliform: Weekly	<ul style="list-style-type: none"> • Monthly geometric mean of < 200 coli/100 mL • Single sample maximum < 800 coli/100 mL 	Submit MORs to ODEQ
			Cl disinfection: Daily	Free available Cl always ≥1 ppm at POE to distribution system	
			DO: Weekly	>2.0 mg/L	
5	<ul style="list-style-type: none"> • Pasture irrigation for range cattle • Irrigation of fiber, seed, forage and similar crops • Irrigation 	<ul style="list-style-type: none"> • Primary treatment through wastewater treatment lagoons 	None		Maintain MORs On-Site

1. 252:627-1-6 Permitted Uses of Reclaimed Water
 252:656-27-1 Categories of Reclaimed Water
 2. 252:656-27-3 Treatment
 3. Appendix A: Testing Frequency and Limits for Reclaimed Water Systems

5.2.7.2.2 Storage and Retreatment of Reclaimed Water (OAC 252:656-27-5)

Oklahoma allows for storage of reclaimed water in tanks, open storage basins, or lagoons. Most states have permitting and construction requirements for lagoons and other types of open storage basins (refer to Oklahoma's OAC 252:656-11-3). Furthermore, Oklahoma adds the following storage requirement for reclaimed water in alignment with the various classifications of Reclaimed water shown in Table 5-7:

- Storage tanks – Categories 2-5 reclaimed water may be stored in tanks that meet NSF or ASTM standards for public water supply. If stored, Category 2 reclaimed water will be filtered and chlorinated prior to distribution.
- Open storage basins – Categories 2 and 3 reuse water may be stored in open storage basins. If stored in an open storage basin, Category 2 reuse water will be filtered and chlorinated prior to distribution.
- Lagoons – Categories 4 and 5 reclaimed water may be stored in lagoons or ponds.

5.2.7.2.3 Permit Requirements

As with all other water and wastewater facilities, Oklahoma permits the construction and operations of water and wastewater system infrastructure. These include:

- Permit to Construct and a Permit to Supply.
- Applications for Operating a Supply or System of Reclaimed water

Permitting in Oklahoma usually takes 6-9 months and operating permits are valid for up to 5 years and require the operator to operate and maintain the system (this is typical of most states). In Oklahoma there are additional requirements that operation and maintenance be accomplished in accordance with specific rules for reclaimed water storage, delivery and distribution. Thus, Oklahoma requires an operations permit that is valid for specific water reuse uses by a reclaimed water operator.

5.2.7.2.4 General Requirements Operating Reclaimed Water Systems

Permits typically outline various general requirements and operating standards for reclaimed water systems. Some of the typical general requirements for operating a reclaimed water system include:

- No unauthorized wastes, hazardous substances, or chemicals are introduced into the water;
- No cross-connections between wastewater, reclaimed water, and potable water supplies;
- No unpermitted bypasses or discharges of wastewater or reclaimed water from the system;
- Suppliers must have a certified operator;
- All violations or requirements are to be reported to the regulatory agency;
- The regulatory agency reserves the right to inspect a reclaimed water users' storage and distribution systems at any time;
- The regulator has the right to inspect reclaimed water users' facilities also;
- Suppliers are required to use accredited laboratories for all analyses;
- Flow measuring devices must be used to measure the amount of reclaimed water being generated and distributed; and

- Reclaimed water systems must be designed to ensure that direct and wind-blown spray from irrigation systems cannot be uncontrolled and should be confined to the designated irrigation area. This typically requires minimum buffer zones and setback distances to organized human activity, recreation facilities, wells, waters of the state, and property lines.

5.2.7.2.5 Operation and Maintenance Requirements for Reclaimed Water Systems (OAC 252:627-3-2 – 3-4)

Table 5-8 lists the O&M requirements and restrictions that suppliers are required to enforce at areas where reclaimed water is used.

Table 5-8 Operation and Maintenance Requirements and Use Restrictions

CATEGORY	SUPPLIER O&M REQUIREMENTS	RESTRICTIONS
2	<p>OAC 252:627-3-2</p> <ul style="list-style-type: none"> • Suppliers will have legal access to sites where reclaimed water is used • Ensure that all distribution and irrigation equipment is maintained 	<p><i>Category 2 reclaimed water is not to be used:</i></p> <ul style="list-style-type: none"> • On any food crop that may be consumed raw • On processed food crops less than 30 days before harvest • For spray irrigation on orchards or vineyards • At rates that allow discharge from irrigation sites; at rates that exceed the N and P uptake rates for the crop; at rates that result in phytotoxicity • During periods of precipitation or while soil is either saturated or frozen • On land having a slope greater than 5% • Where there are berms that would cause pooling of reclaimed water • On public use areas that have a high potential for skin to ground contact, including sports field, playgrounds, etc. • At any location unauthorized by the state in the permit

CATEGORY	SUPPLIER O&M REQUIREMENTS	RESTRICTIONS
3 & 4	<p>OAC 252:627-3-3</p> <ul style="list-style-type: none"> Suppliers will have legal access to sites where reclaimed water is used Ensure that all distribution and irrigation equipment is maintained 	<p><i>Categories 3 and 4 reclaimed water is not to be used:</i></p> <ul style="list-style-type: none"> From a lagoon cell that receives raw sewage On public use areas that have a high potential for skin to ground contact, including sports field, playgrounds, etc. On golf courses, unless irrigation takes place when closed to the public On any food crop that may be consumed raw For spray irrigation on orchards or vineyards At rates that allow discharge from irrigation sites; at rates that exceed the N and P uptake rates for the crop; at rates that result in phytotoxicity Within 100 feet of the permitted boundary of the site When the DO concentration is less than 2.0 mg/L During periods of precipitation or while soil is either saturated or frozen On land having a slope greater than 5% Where there are berms that would cause pooling of reclaimed water On public use areas during times of use On sod farms unless a period of 30 days has elapsed between the last application of reclaimed water and harvesting sod
5	<p>OAC 252:627-3-4</p> <ul style="list-style-type: none"> Ensure that fencing is maintained to prevent unauthorized access to the site Ensure signs are posted on or near the fence on each side of the reclaimed water site describing the nature of the facility and advise against trespassing Suppliers will have legal access to sites where reclaimed water is used Ensure that Cat. 5 reclaimed water is not applied in public use areas Ensure that all distribution and irrigation equipment is maintained 	<p><i>Category 5 reclaimed water is not to be used:</i></p> <ul style="list-style-type: none"> From a lagoon cell that receives raw sewage From any lagoon cell other than the one specified in the permit On any food crop that may be consumed raw On grain crops less than 30 days before harvest At rates that allow discharge from irrigation sites; at rates that exceed the N and P uptake rates for the crop; at rates that result in phytotoxicity Within 100 feet of the permitted boundary of the site When the DO concentration is less than 2.0 mg/L During periods of precipitation or while soil is either saturated or frozen On land having a slope greater than 5% Where there are berms that would cause pooling of reclaimed water

5.2.7.2.6 Distribution System Requirements (OAC 252:656-27-4)

ODEQ requirements for the design of reclaimed water distribution systems include the following:

- Piping – all reclaimed water piping, valves, outlets and appurtenances shall be colored purple (Pantone 522) and are to be stamped with a warning that includes the following:
 - The word “CAUTION”
 - Specifies the category number of the reclaimed water

- The words “DO NOT DRINK”
- Hose Bibs – hose bibs, hydrants, and/or similar outlets are to be equipped with warning signs that indicate the water is not safe to drink. Hose bibs must be located in a locked, vault or box.
- Gravity Pipes – designed and constructed to meet the requirements of OAC 252:656-5-2 through 5.
- Pumping Stations and Force Mains – designed and constructed to meet the requirements of OAC 252:656-7-1 through 4 with the following exceptions:
 - Pump openings less than three inches may be allowed when stormwater, settled or filtered reclaimed water is pumped.
- Reclaimed Water Flushing System – a flushing system is required to prevent slime growth and the regrowth of pathogens. All flushing systems shall include the following at a minimum:
 - Provisions for disposal of flushed water
 - Air gaps designed to meet the requirements of OAC 252:656-9-2

5.2.7.2.7 Operation and Maintenance Requirements for Distribution Systems (OAC 252:627-3-1)

The ODEQ requires the following O&M to be done on the distribution systems:

- Structural integrity of all parts of the distribution system must be maintained by the supplier and kept in good working order.
- All connections must be inspected on a routine basis to ensure that the integrity of the distribution system is maintained.
- Erosion control shall be provided by the supplier for all parts of the distribution system located in or near waterways or flood plains.
- Pump stations shall be properly maintained and operated by:
 - Securing pump stations to prevent unauthorized access
 - Maintaining the pumps in working condition
 - Cleaning debris from the screens to prevent clogging
 - Maintaining the alarms
 - Maintaining the back-up generators or portable engine driven pumps
 - Maintaining a complete set of operational instructions, emergency procedures and maintenance schedules
- Suppliers shall maintain a “Flushing Plan” in their O&M manual.

6.0 Water Conservation

Conserving and using water more efficiently can reduce the amount of water treated to drinking water standards. Reducing the amount of treated water used by the community adds resilience to and eases demands on the drinking water system. In order to estimate the potential of the City to reduce water demand by conservation, the following factors were considered:

- Historical Water Demand Trends
- Benchmarking Water Use
- Water Conservation Potential

6.1 HISTORICAL WATER DEMAND TRENDS

To develop an assessment of water conservation potential for any community – and to design effective strategies to achieve it – it is first necessary to understand historic and current water use patterns. Population projections and customer consumption data was analyzed in order to understand water demand trends, seasonal influences and to identify factors that significantly impact water use. The review included the consumption volume and number of accounts on a monthly basis for the period inclusive of October 2005 – September 2015.

To gain further insight into customer trends, a disaggregated approach was used. The source data for customer consumption for CW&L originally had 25 classifications, breaking down consumption by factors such as customer class, consumption inside the city limits and outside the city limits, and by water accounts and irrigation only accounts. Based on a review of the data and the relative proportion of use by the different customer classifications, demand was aggregated into the four sectors shown in Figure 6-1.. Conservation program for CW&L will consider approaches relevant to each of these customer classes.

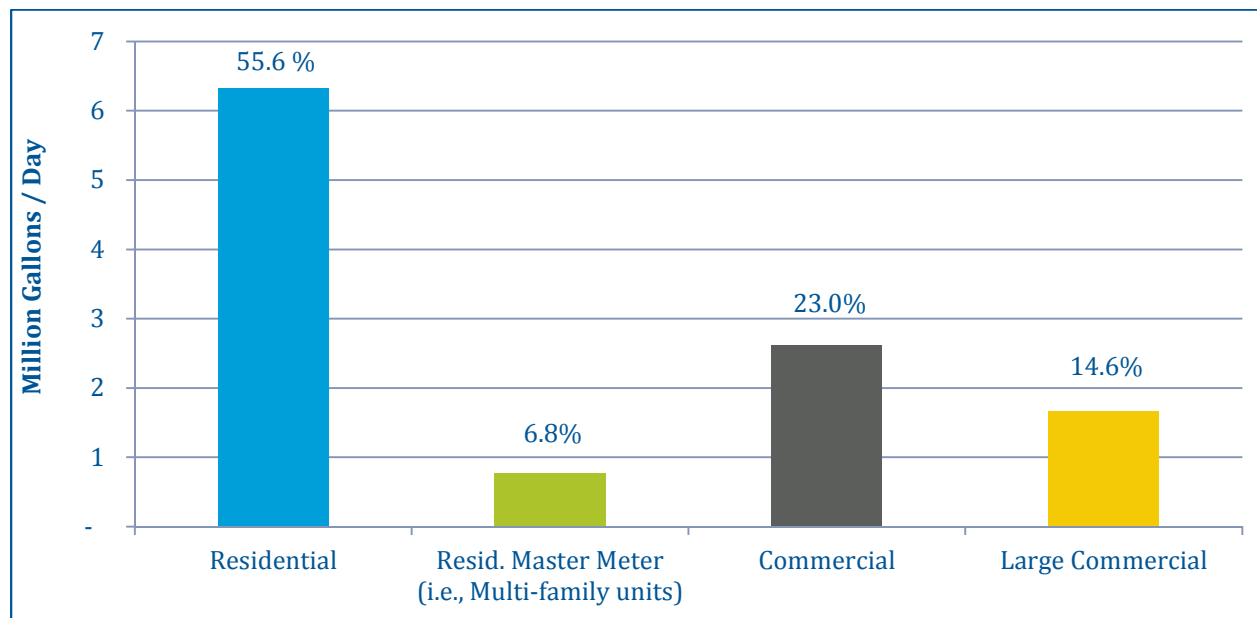


Figure 6-1 Customer Demand by Customer Class

6.2 BENCHMARKING WATER USE

Comparisons of water use efficiency typically use a per capita approach to normalize the data. Although this makes logical sense, as the number of residents in a house is the most important variable and its value varies from home to home (DeOreo, 2011), it does not always result in a meaningful comparison. Care should be taken when comparing per capita numbers as the number may be generated from a broad, top-down approach (i.e., dividing total water use by population), or by studies that specifically look at water use by the end-user (e.g., DeOreo, 2011), or other variations in assessment methodology. If a utility is primarily interested in tracking customer consumption using a per capita approach over time in order to evaluate trends, the particular methodology is not as important as using a *consistent* methodology from year-to-year.

6.2.1 Residential Customer Benchmarking

Using available census data, a per capita consumption value can be estimated for CW&L residential customers. Residential customer demand represents over 55% of total customer demand (see Figure 6-2) and is the largest customer class by both volume and number of accounts. The data for these accounts primarily represents single-family customers. According to the U.S. Census⁹, the average number of residents per household in the City of Columbia is 2.34. The average residential customer demand (using an average of the most recent three years of data) is 145.3 gallons per day¹⁰ with a resultant per capita consumption of $(145.3/2.34)$ 62.1 gallons per capita per day (gpcd). Calculation of the per capita metric helps in benchmarking water use by CW&L customers against other water systems and helps to identify the potential scope for water conservation savings. A per capita consumption of 62.1 gpcd represents an annual average value and therefore includes both indoor and outdoor use. As a point of comparison, the 2012 average residential customer demand was 174.6 gallons per household per day, or 74.6 gallons per capita per day (2012 represents a hot, dry summer for the City of Columbia).

Figure 6-2 shows available consumption data on a monthly basis for CW&L for the period October 2005 – September 2015. As expected, a clear seasonal pattern in water use is evident driven primarily by an increase in outdoor water use during the months of June through October, and most evidently during the hot and dry summer of 2012. There is no universally accepted method for estimating outdoor water use from monthly consumption data, as outdoor use will be driven by regional climatic differences¹¹. A typical approach is to determine an indoor baseline value, with all usage above that baseline estimated to be outdoor use; this provides a simplified approach in the absence of more detailed data. A trend line has been added to the winter baseline portion of the per capita line as this helps to illustrate what appears to be a fairly continuous increase in indoor water efficiency between 2005 and 2015.

⁹ <http://www.census.gov/quickfacts/table/RHI105210/2915670>

¹⁰ An additional calculation was performed using the total *volume* of all residential accounts, but excluding the *number* of irrigation accounts (assuming that these customers also have a regular water account); the resulting value was 146.1 gallons per account and 62.5 gpcd.

¹¹ http://www.pacinst.org/wp-content/uploads/sites/21/2013/02/appendix_b3.pdf

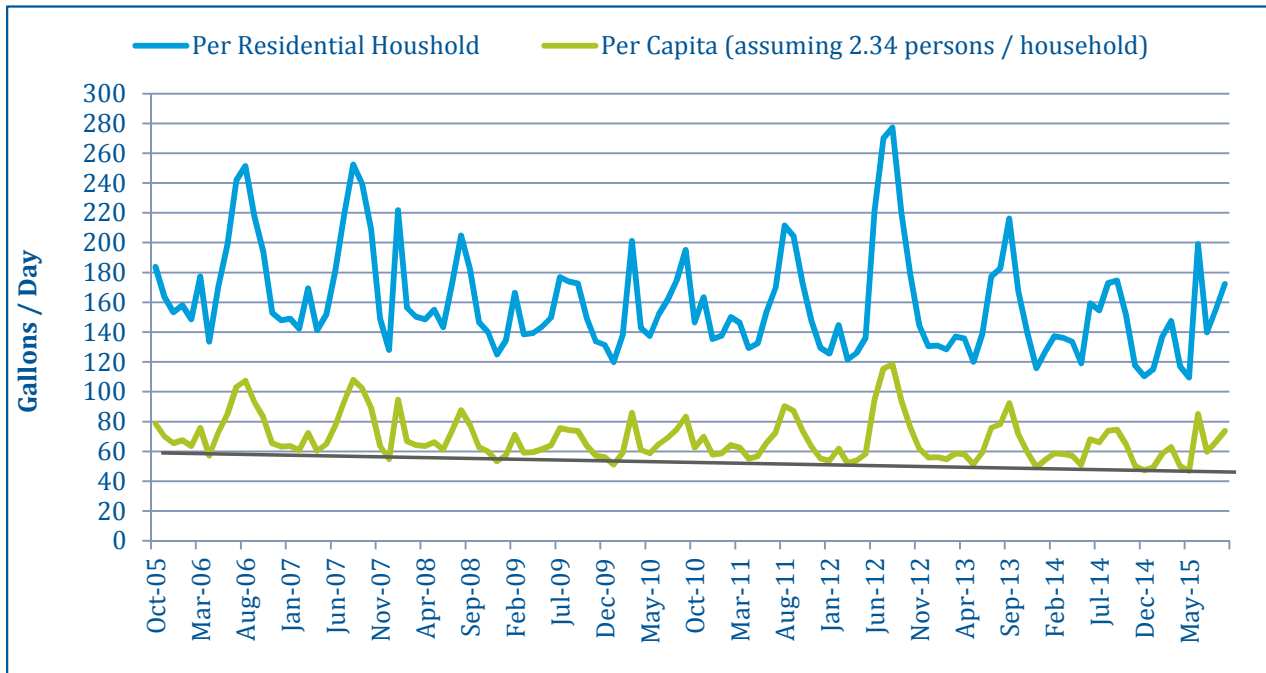


Figure 6-2 Residential Household and Per Capita Trends

The trends seen in Figure 6-2 are reflective of trends seen by many water utilities across the nation. The current federal plumbing efficiency standards, which were established by the U.S. Energy Policy Act of 1992 (Section 123: Energy Conservation Requirements for Plumbing Products), are significant in explaining the increased (indoor) water efficiency of U.S. homes. The federal legislation set minimum efficiency standards for all toilets, showers, urinals and faucets manufactured in the United States after 1994, with standards specified as follows:

- Toilets: 1.6 gallons per flush (gpf)
- Urinals: 1.0 gpf
- Showerheads: 2.5 gallons per minute (gpm) at 80 psi; 2.2 gpm at 60 psi
- Faucets: 2.5 gpm at 80 psi; 2.2 gpm at 60 psi

Although the Energy Policy Act was passed in 1992, its effective date was 1994. The Energy Policy Act has delivered significant savings in water efficiency relative to homes using fixtures and fittings from the pre-Energy Policy Act period¹².

6.2.2 Multi-Family and Non-Residential Customer Benchmarking

As the number of dwelling units per residential master meter connection is not known, it is not possible to estimate a per capita consumption value for this customer class. Benchmarking was also not possible for commercial and large commercial customers as studies have shown that it is difficult to identify metrics that can be used consistently to analyze and compare water demand in these sectors¹³. Factors

¹² Analysis of Water Use in New Single Family Homes, Prepared by William B. DeOreo of Aquacraft Water Engineering & Management for The Salt Lake City Corporation and the U.S. Environmental Protection Agency, 2011.

¹³ Frost, D., Sversvold, D., Wilcut, E., & Keen, D.J. Journal AWWA 108:3:64 March 2016

such as the number of employees, the square feet of the building and the NAICS code for the particular facility can be of some use to help group similar customers and compare usage, but this level of data is currently not available for CW&L commercial and large commercial customers. CW&L may wish to consider collecting this information in order to better understand water use within these customer classifications.

6.2.3 National Perspective

A study of residential water use (DeOreo, 2011) quantified the savings in water use that can be expected from modern homes.

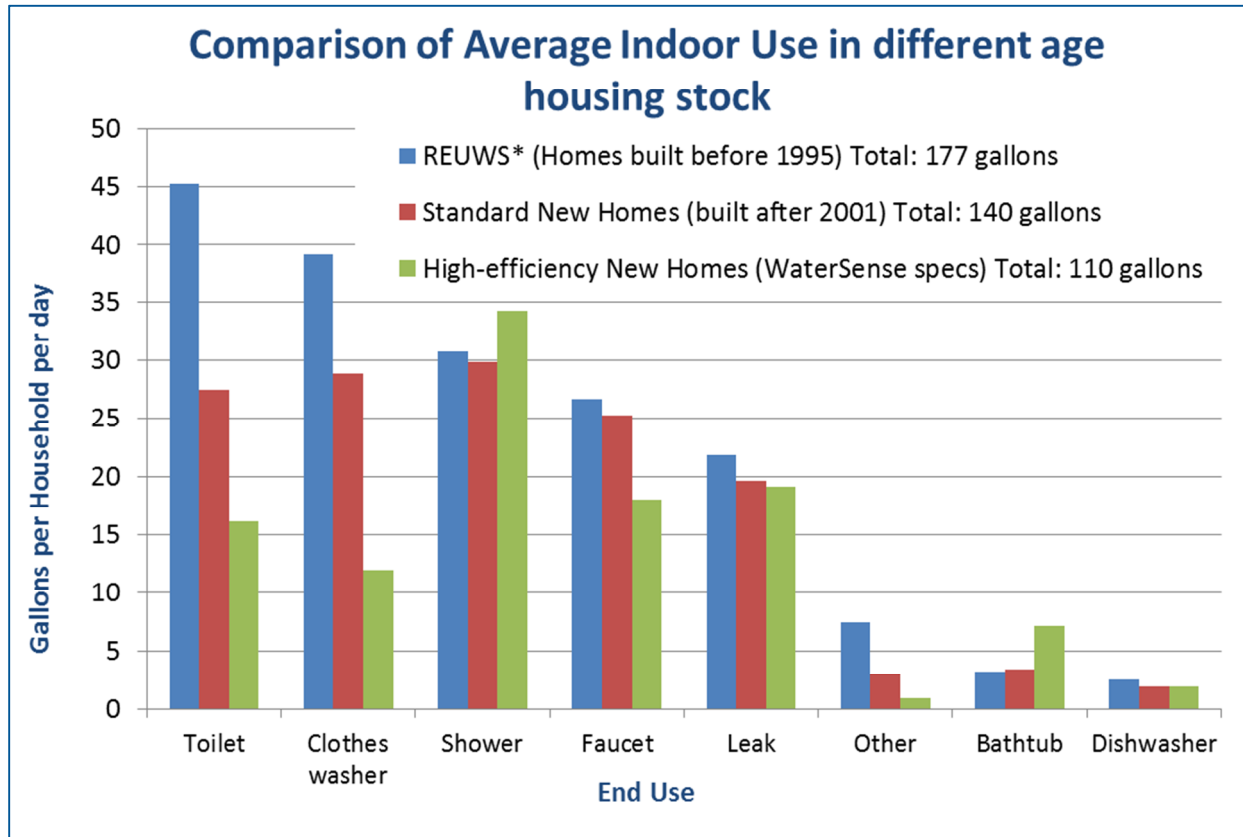


Figure 6-3 Comparison of Average Indoor Use in Different Age Housing Stock¹⁴

The study concluded that “there are no technical reasons for not moving single family demands lower. The technologies for the key indoor fixtures and appliances are now available in the form of high-efficiency toilets, showers and clothes washers.” It should be noted that the water use volumes shown in Figure 6-3 are household numbers and not per capita numbers, however the important message conveyed in the figure is that significant water savings are possible through the introduction and retrofitting of more water efficient fixtures and fittings with the average total indoor use potentially declining from 177 gallons *per household* to 110 gallons *per household* as reported by the study data.

¹⁴ Mayer, Peter et al.. Residential End Uses of Water Study. AWWA Research Foundation. 1998. Chart adapted from: Analysis of Water Use in New Single Family Homes, Prepared by William B. DeOreo of Aquacraft Water Engineering & Management for The Salt Lake City Corporation and the U.S. Environmental Protection Agency, 2011.

6.3 WATER CONSERVATION POTENTIAL

Water conservation can be achieved using a variety of strategies. Selecting the appropriate suite of strategies for the individual utility will depend on the goals of the program, available funding, a thorough understating of the baseline conditions, and should include input from customers.

6.3.1 Indoor Water Use

There are several studies that can provide valuable information to aid in the understanding of water conservation potential. For example, the Water Research Foundation commissioned studies designed to provide insight into how water is used with residential settings. Two studies of Residential End Uses of Water (REU1999¹⁶ and REU2016¹⁷) have been published and provide information that can help identify water conservation potential. The publication of the updated study in 2016 also provides a means of understanding the changes that have occurred in residential water uses. The following summary is taken from the REU2016 Executive Report:

Residential indoor water use in single-family homes has decreased. The average per household daily water use has decreased 22 percent, from 177 gphd (REU1999) to 138 gphd (REU2016). Per capita average water use has decreased 15 percent, from 69.3 gpcd (REU1999) to 58.6 gpcd (REU2016). In REU1999, a household averaged 2.77 people and in REU2016, a household averaged 2.65 people. The improved water efficiency of clothes washers and toilets accounts for most of the decreases in indoor use.

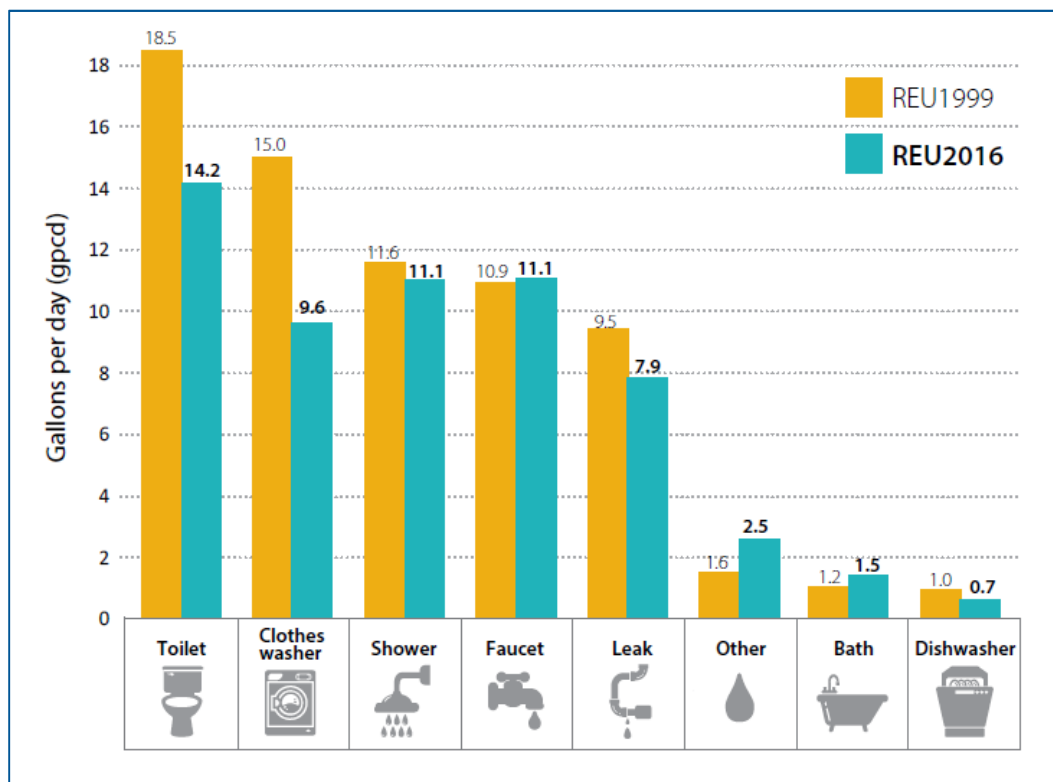


Figure 6-4 Average daily indoor per capita water use REU1999 and REU2016¹⁸

¹⁶ Water Research Foundation. 1999. Residential End Uses of Water Study (REUWS 1999)

¹⁷ Water Research Foundation. 2016. Residential End Uses of Water, Version 2 (REUWS 2016)

¹⁸ Water Research Foundation. 2016. Residential End Uses of Water, Version 2 (REUWS 2016)

Figure 6-4 is taken directly from the REU2016 Executive Report and shows that the majority of savings have arisen from greater efficiency in toilets and clothes washers. These items, plus showers, and faucets, comprise the four largest components of indoor water use and are obvious targets for increased efficiency.

6.3.2 EPA WaterSense

In the period of time between the two Residential End Use studies, another significant development occurred that has helped to increase residential water efficiency nationwide. In 2006, the U.S. Environmental Protection Agency (EPA) created the WaterSense Program. WaterSense labeled products have been certified to be at least 20% more efficient than standard products without sacrificing performance. WaterSense toilets now operate at or below 1.28 gallons per flush, bathroom faucets can now use 1.5 gallons per minute and new high efficiency flush urinals use 0.5 gallons per flush. When new plumbing fixtures are installed, they are required to meet or exceed the current National Plumbing Efficiency Standards. WaterSense products are backed by independent third-party testing and certification so that water efficiency can be achieved without compromising performance. As an indication of the growing acceptance of WaterSense products, the WaterSense specifications have become mandatory for new construction in several jurisdictions including in New York City (July 2012)¹⁹, the states of Georgia (January 2012)²⁰ and Texas²¹ and California²² (both January 2014).

6.3.3 ENERGY STAR Clothes Washers

A review of the market for residential clothes washers indicates that there are currently no WaterSense labeled models available. However the ENERGY STAR program features a water use component that is measured through a Water Factor (WF) that specifies the gallons of water used per cubic foot of laundry and so allows a comparison between washers of different sizes. The average American family washes about 300 loads of laundry each year and therefore an ENERGY STAR clothes washer can help families cut their related energy and water costs. ENERGY STAR certified clothes washers use about 25% less energy and 40% less water than regular washers²³. The most water efficient models on the market are Consortium for Energy Efficiency (CEE) Tier 2 and Tier 3 washers which have WFs of 4.5 gallons and 4.0 gallons respectively.

6.3.4 Irrigation and other Outdoor Water Use

Irrigation and other outdoor water uses can drive peak demand for water at the same time that available resources are the most limited. There are a number of approaches that can be used to tackle this issue including the following general areas which will be explored in more detail in later sections:

¹⁹ See NYC Local Law 57 of 2010, available at <http://www.nyc.gov/html/dob/downloads/pdf/l157of2010.pdf>.

²⁰ Georgia State Amendments to the International Plumbing Code (Revised Jan. 1, 2012), available at <http://www.dca.state.ga.us/development/constructioncodes/programs/documents/2012effective/effective/IPC-2012-effective.pdf>; Georgia Code § 8-2-3, available at <http://statutes.laws.com/georgia/title-8/chapter-2/article-1/part-1/8-2-3>;

²¹ California Health and Safety Code § 17921.3, available at <http://codes.lp.findlaw.com/cacode/HSC/1/d13/1.5/2/s17921.3>

²² Texas Health and Safety Code, Title 5 Chapter 372, available at <http://www.statutes.legis.state.tx.us/Docs/HS/htm/HS.372.htm>

²³ https://www.energystar.gov/products/appliances/clothes_washers

- **Education and Outreach.** This can be focused on individual home owners and also landscapers who many homeowners use to set up and maintain their irrigation equipment.
- **Irrigation Audits.** For customers with the highest summer water use, irrigation audits could be offered by CW&L or a third party contractor to ensure that the homeowners are following good irrigation practices regarding watering frequency, timing and rates of application
- **Pricing.** Pricing signals can be sent to customers through water rates. A summer / winter price differential, or an inclining block rates structure (or both) can be used to send a signal to customers that discretionary uses of water (e.g., lawn watering) will be charged at a higher per unit volume rate.
- **Irrigation Ordinances.** Limiting lawn watering to specific days per week or times of the day can reduce demand. However an ordinance requires government willingness and action to implement and enforce.

6.3.5 Non-Residential Water Conservation

Commercial and large commercial customers can also increase their water use efficiency by replacing the types of water using fixtures and appliances described above. The WaterSense program also endorses toilets, urinals, pre-rinse spray valves, faucets and aerators that are designed to achieve water savings for non-residential applications. Depending on the type of facility, these types of end use of water may account for a large or small proportion of the overall water use. For non-residential customers a specific water efficiency audit may be required to determine the potential for water efficiency savings. A portion of non-residential water use will be for irrigation uses and should not be overlooked in a non-residential water audit.

6.3.6 Supply-Side Conservation

Traditionally, water conservation has focused on the end-user or customer. While this is still an important area of focus, it has become increasingly recognized that efficiencies, and utility cost savings, can be gained by focusing on the distribution and delivery of water to the customer. Additionally, the conservation message will be better received by the utilities' customers if the utility itself is engaging in and showing leadership by improving water supply efficiency.

A best practice approach is for retail public utilities to perform a water loss audit in accordance with the American Water Works Association (AWWA) M36 Methodology. The water loss audit provides a framework for gathering and understanding the accuracy of data, calculating performance measures, and identifying costs of water losses. The AWWA offers products that can assist a utility in performing a water audit. They have published the M36 Manual, which can provide additional guidance on implementing this best management practice, and offer free water loss audit software that allows utilities to compile a water loss audit²⁴.

6.3.7 Data-Driven Approach

Water use depends on various factors such as population, climate, land use, condition of the water distribution infrastructure and socioeconomic characteristics (e.g., cost of water relative to income level

²⁴ <http://www.awwa.org/resources-tools/water-knowledge/water-loss-control.aspx>

of residents). In order to design an effective water conservation strategy, it is important to gather adequate and accurate information on the factors listed above. It is also important to accurately track water use so that the impact of water conservation can be monitored and evaluated, including the assessment of progress against any targets or goal. To support data driven planning it is important to have an accurate assessment of the following aspects of water use:

- **Source metering.** It is important to accurately measure water withdrawals in order to provide accurate information to state and other agencies that have the responsibility of assessing water resource impacts and planning for future growth.
- **Production metering.** Water gains economic value when it is purified and pressurized and sent into the distribution system. To understand the efficiency of water distribution systems and track losses through a water system audit, it is vital to have an accurate measurement of water production through metering at the water treatment plant.
- **Customer metering.** Customer meters are the ‘cash registers’ for the water utility operations and a metered system is the best way to equitably spread the cost of water service. Therefore it is important to ensure that the meters are functioning accurately to not only recover revenues owed to the utility but also to ensure customer equity and the effectiveness of pricing signals to encourage water conservation.
- **Customer end use.** Beyond the customer meter, water use patterns will be influenced by regional, local and customer-specific characteristics of use. Effective water conservation planning will need to understand these characteristics and employ strategies that target specific end uses.

With appropriate tracking of water use – which integrates the impact of conservation strategies - future decision making can be improved and plans adjusted as required.

6.3.8 Customer Use Data Analysis

To aid in the understanding of water conservation potential, an analysis of customer data was undertaken. This analysis focuses on the residential customer class as this is the largest single customer class and customers all use water for similar purposes (compared to the more highly variable commercial uses of water). Individual customer account data was reviewed to provide an understanding of the distribution of water consumption. This is shown in Figure 6-5 which shows different residential consumption levels and the number of customers and use volume associated with each level of water use.

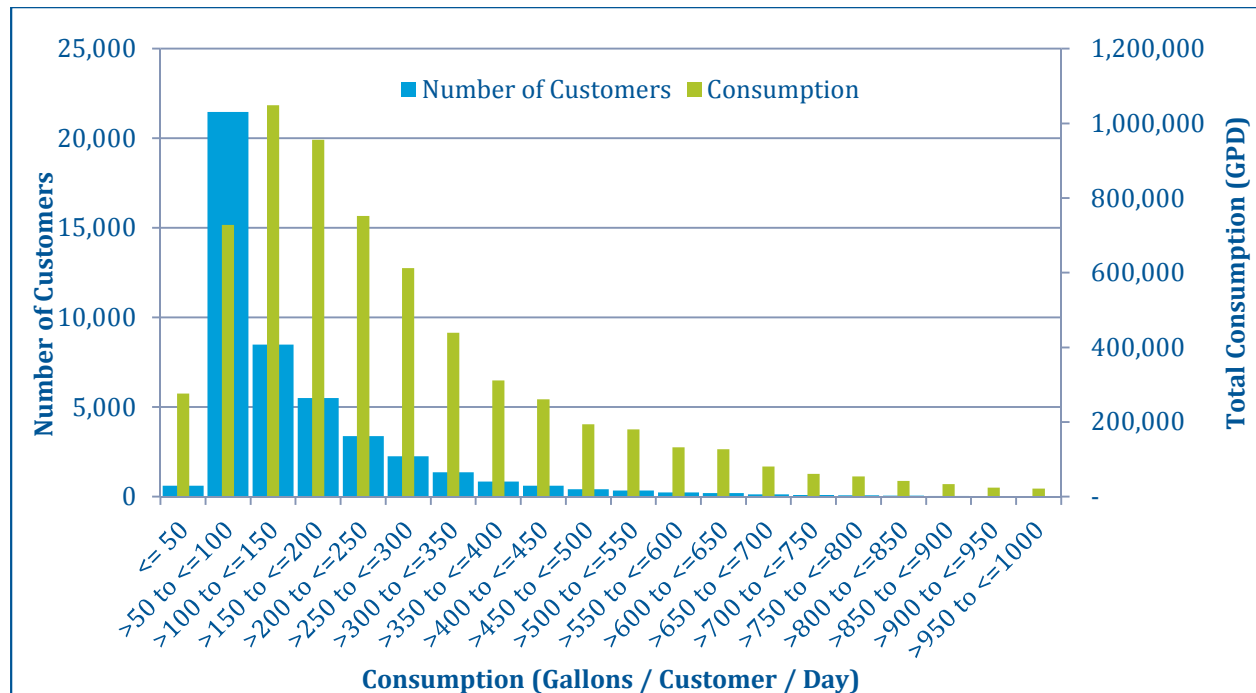


Figure 6-5 Residential Water Consumption across a range of Use Levels

Figure 6-5 shows a typical distribution of consumption, common to many water utilities, with the majority of customers - and the majority of consumption - from households consuming less than 250 gallons per day. As an example of how to interpret Figure 6-5 is approximately 8,000 customers (left y-axis) consume an average of 100 to 150 gallons per day, with the total consumption of those users equal to approximately 1 MGD (right y-axis). It should be noted that the data presented are from 2012 which represents dry year demand so the use values presented are higher than during a typical year; however the consumption is gallons per day averaged over the entire year so the graphic will not change significantly year-to-year and the profile of the chart will look the same. There are a small number of accounts in the residential customer class that have average use above 1,000 gallons per day but these are not shown in the graphic.

6.4 WATER CONSERVATION BEST MANAGEMENT PRACTICES

Water conservation can be achieved using a variety of strategies. Selecting the appropriate suite of strategies for the individual utility will depend on the goals of the program, available funding, a thorough understating of the baseline conditions, and should include input from customers. This assessment of water conservation potential for CW&L will examine multiple areas of action including those best management practices listed in Table 6-1.

Table 6-1 Potential Water Conservation Strategies

CONSERVATION PROGRAM	CONSERVATION ACTIVITY
Conservation Analysis and Planning	Conservation Coordinator
	Customer Surveys
	Customer Audits
Financial Incentives	Water Conservation Pricing
Supply-Side Conservation & Water Loss Control	AWWA Water Audit and Water Loss Control
Landscaping	Landscape Irrigation Conservation and Incentives
	Residential Landscape Irrigation Evaluation
Education & Public Awareness	Public Information
	School Education
Rebate, Retrofit, and Incentive Programs	Audit Programs for Commercial and Large Commercial Accounts
	Residential Toilet and / or Clothes Washer Incentive Program
	Showerhead, Aerator, and Toilet Flapper Retrofit
Conservation Technology	New Construction Graywater
	Rainwater Harvesting and Condensate Reuse
Regulatory & Enforcement	Prohibition on Wasting Water
	Landscape Irrigation Scheduling Ordinance
	New Construction or Retrofit Ordinance

6.4.1 Conservation Analysis and Planning

The following discussion describes a broad array of potential best practice approaches to water conservation that can be considered by CW&L for inclusion in a water conservation plan. Several of these water conservation options will be evaluated in more detail using specific CW&L data to provide a provisional estimate of the potential costs and savings of a water conservation program.

6.4.1.1 Water Conservation Coordinator

A successful water conservation program will require a champion and this is usually enabled through a dedicated water conservation coordinator position. This staff person would be dedicated to the overall administration of the conservation program. This position would have responsibility for the implementation of the various components of the plan and would be the main point of contact for stakeholders in the program. This position would also be involved in education and outreach efforts, case study development and program evaluation and reporting. This position would also be involved in evaluating the program on an annual basis and developing recommendations for program modifications.

6.4.1.2 Customer Surveys

The city conducted a survey of its customers in May 2016 and one goal of the survey was to improve understanding of customers’ actions and perceptions around water conservation. A total of 730

responses were received to the survey, of which 380 were from residential customers and 350 were from commercial customers.

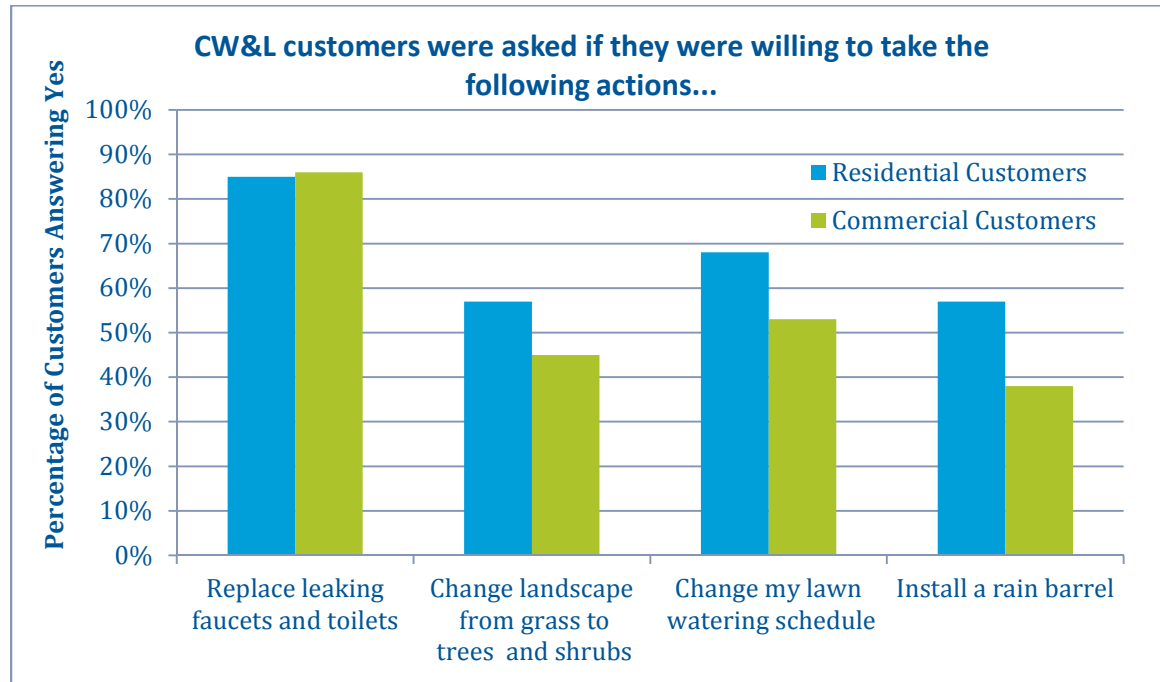


Figure 6-6 CW&L Customer Responses to 2016 Water Conservation Survey Questions

In general, Figure 6-6 shows a very positive response by CW&L customers towards potential conservation actions. Residential customers appear slightly more willing to undertake additional conservation measures compared to commercial customers. A more detailed set of questions could be developed in order to gain more insight into current customer behavior and the existing level of water efficiency to provide greater confidence in the estimate of potential savings.

Customer engagement is key to ensuring a successful water conservation program and CW&L should develop robust data on its customer base. This should go beyond the basic understanding of customer types (i.e., residential versus commercial) to include an assessment of indoor versus outdoor water use in order to target water conservation initiatives most effectively. This type of information could be developed by looking at water use profiles from actual customer data, or it could be estimated from individual parcel level data including attributes such as lot sizes.

For example CW&L should develop a reasonable understanding of the number, or percentage, of customers using automated irrigation systems across the service area. Surveys can be conducted on a sample of customers to develop an estimate of how many have automatic systems. This information may also be obtained from discussions with landscape and irrigation contractors. However a number of surveys may be required as there will likely be significant geographic variation as housing age and value are two factors that may influence the prevalence of automatic irrigation equipment. Some information for southwest Columbia has been obtained as a result of an issue that developed during the summer of 2016; A number of sprinkler systems were activating at the same time causing a localized pressure drop in the system. This led to an investigation by the city and a request for staggered irrigation scheduling to help alleviate pressure drops.

An important driver for many water conservation strategies is the incentive for the end user to reduce costs by saving water. This price signal relies on the appropriate rate structure but more fundamentally it relies on all customers being metered and billed accordingly. As is typical of many large utilities, there are some CW&L customers who do not pay a water bill directly (e.g., those in apartments and other multi-family units, trailer parks and rental units) however these customers represent a small fraction of overall use and the opportunities for discretionary use are not usually significant.

Desk-based research can also be helpful and potentially more cost effective than an on-the-ground survey. For example, the United States Census Bureau publishes the American FactFinder website (www.factfinder.census.gov) which allows detailed information to be queried for the study area. Information can be retrieved on household and demographic information, including the following):

- Household size
- Age of housing construction
- Occupancy / vacancy rates
- Ownership / rental rates
- Household value
- Household / disposable income

Specific knowledge of the customer base will help determine the focus of water conservation strategies. To enhance information on customers' water use habits, a water use survey for single-family and multi-family customers can be conducted. A Water Use Survey Program can be an effective method of reducing both indoor and outdoor water usage. Surveys should be offered based on water use starting with the highest single-family and multi-family accounts, respectively. Using this approach, the utility conducts a survey of single-family and multi-family customers and uses the information gathered to provide information to them about methods to reduce indoor water use through replacement of inefficient showerheads, toilets, aerators, clothes washers, and dishwashers (TWDB, 2013). There are typically three options for conducting the survey:

- Train utility staff to conduct an onsite survey;
- Hire an outside contractor to conduct the onsite surveys; or
- Provide a printed or online survey for customers to complete on their own.

6.4.1.3 Customer Audits

For non-residential customers, an onsite water audit will likely be more effective than a survey, due to the often highly specific nature of the water use. Some non-residential customers can be aggregated into common sub-sectors such as hotels and restaurants, and water conservation information can be provided specifically for these types of customers. There are many sources of valuable information that have been developed for non-residential water uses. One example is WaterSense at Work²⁵, published by the EPA WaterSense program, which includes a compilation of water efficiency best management practices to help commercial and institutional facilities understand and better manage their water use. This helps facilities to establish an effective water management program and identify projects and

²⁵ https://www3.epa.gov/watersense/commercial/docs/watersense_at_work/

practices that can reduce facility water use²⁶. By implementing water-efficient best management practices, commercial and institutional facilities have an opportunity to:

- Achieve cost savings
- Increase competitive advantage
- Reduced risks associated with water scarcity
- Demonstrate leadership
- Access opportunities in the green building marketplace

As the City of Columbia already has a Commercial Efficiency Program that focuses on energy efficiency, it could consider expanding the program to include water use efficiency.

6.4.2 Water Efficiency Rebate programs

Many water utilities have used rebate programs to incentivize the adoption of more water efficient products. This is also true of energy utilities with many having advanced customer engagement and incentive programs. The City of Columbia already has energy rebate offerings for residential and commercial customers and could consider expanding these program to water using devices, especially as many fixtures and appliances use both water and energy and therefore provide an opportunity for dual savings.

6.4.2.1 Example Rebate Programs

A rebate program can be an effective means of encouraging customers to replace older, less efficient water using products with newer, more efficient models. It also helps engage the utility with its customers and gain a greater understanding of customer needs. Many water utilities have implemented rebate programs and several programs were reviewed as part of this study. As noted, three significant areas of indoor residential water use are showers, toilets and clothes washers. It is therefore not surprising to see that these are among the qualifying products offered through many water utility rebate programs. There is also potential overlap beyond the single family residential sector as these products are found in many multi-family, commercial, institutional and industrial facilities, although the particular models may vary depending on the end use application.

6.4.2.2 Rebate Program Goals

Rebate programs are designed to incentivize customers to take an action that they would not otherwise have taken. In regard to water conservation incentives, rebates can work in the following ways:

- Accelerate the penetration rates of water efficient devices. For example, a customer uses the rebate to purchase a WaterSense toilet – something that they were not planning to do prior to the rebate becoming available. Essentially this encourages the customer to ‘act now’, accelerating water conservation.
- Incentivize customers to purchase a more efficient version of a product. A customer may have been planning to purchase a clothes washer, but a rebate available for only the most efficient machines may encourage the customer to purchase a more water efficient model.

²⁶ <https://www3.epa.gov/watersense/commercial/bmps.html>

- Overcome reluctance to water efficiency. It should be acknowledged that there is an element of skepticism regarding water saving devices such as low flow shower heads. The low cost of shower heads and the performance improvements associated with the WaterSense-labeled products provides an opportunity for customers to adopt these products at little to no cost once a rebate is applied.

6.4.3 School Outreach Programs

As part of an outreach and education program, schools and educational facilities could be good candidates for water efficiency programs. These programs can combine a specific educational component in addition to an audit program. Project WET²⁷ (Water Education for Teachers) develops water education resources and works with local partners to implement water education programs. One example could be to develop material to support a math curriculum that has students estimate and calculate water savings associated with the implementation of efficient fixtures and fittings retrofitted to their school building.

6.4.4 Water Rates and Pricing Signals

Retail water bills typically include two parts: fixed charges and variable charges that are based on the amount of water used by the customer. Water billing that includes a relatively small fixed portion and a significant volumetric component that increases with volume of water use provides a financial incentive to the consumer to reduce water use. The installation of water meters and billing by volume of use can reduce water use by ten percent.

Flat rates (generally used by suppliers that do not yet meter water use) and rate structures that reduce the per-gallon price for increased usage (declining block rates) are not considered to be conservation pricing structures and are not recommended.

While increasing block rates is generally the most effective for promoting water conservation, there may be little additional cost incentive to the customer compared to uniform rates if the increase in per-gallon cost is small. More frequent billing, that is, monthly, also can be more effective. Water rates that encourage conservation can be powerful tools to reduce per capita use. Three effective conservation rate structures include:

- **Increasing block rates.** Increasing block rates charge a higher amount per gallon as usage increases, which provide an incentive to keep use low. The number of blocks, the volumetric block levels, and the variation in price per unit volume determine the effectiveness of the price signal.
- **Seasonal pricing.** Seasonal rates charge a higher amount per gallon during the irrigation season when the water supplier's demands are highest, because the peak demands are generally most expensive for the supplier to meet.
- **Allocation-based rates.** Allocation-based rates include higher per-gallon costs for usage exceeding base usage established for each customer according to customer characteristics, such as number of occupants or size of irrigated landscape.

²⁷ <http://www.projectwet.org/>

CW&L has a fairly sophisticated rate schedule that uses a combination of all three types of rates described above. Additionally, there are differentials in rates for customers inside and outside of the city limits; however the overall structure of the rates is the same.

For residential customers inside the city limits, the base volumetric price for water is \$2.79 per CCF (hundred cubic feet). In the months October through May this price is constant for all consumption volumes. In the summer months (designated as June through September) the price is \$2.79 for the first two CCF and then \$3.91 per CCF for all remaining consumption.

For commercial customers inside the city limits, all non-summer month usage is \$2.60 per CCF. In the summer months, all water usage that does not exceed seventy percent of the customer's average monthly water use during the immediate preceding billing periods of January, February, and March is charged at \$2.60 per CCF. All remaining consumption is charged at \$3.91 CCF.

For large commercial customers inside the city limits, all non-summer month usage is \$2.43 per CCF. In the summer months, all water usage that does not exceed seventy percent of the customer's average monthly water use during the immediate preceding billing periods of January, February, and March is charged at \$2.43 per CCF. All remaining consumption is charged at \$3.91 CCF.

CW&L already uses price signals in its rates to provide customers with a water conservation incentive. According to the FY2014, Comprehensive Annual Financial Report, the city implemented a 5% rate increase in 2014. Columbia continues to have very competitive utility rates for the region. Based on Black & Veatch's extensive experience with municipal water rates, CW&L's rates are comparable to national averages and a more aggressive pricing signal could be established (e.g. a third tier of pricing) to further incentivize water conservation.

6.4.5 Water System Audits

The AWWA water audit provides a framework for gathering data, calculating performance measures, and assessing the financial cost of water losses. Thousands of utilities in the U.S. have used the AWWA water audit methodology and software in order to quantify water losses. Several regulatory agencies have also recognized the advantages of the AWWA methodology and require water utilities to complete the audit on an annual basis. An overview of the key elements required for a successful water audit strategy is provided below. It is recommended that CW&L pursue a water audit as many utilities discover system efficiencies and cost savings are possible.

6.4.5.1 Standardized Water Audit Approach

Water loss reduction strategies are best built upon calibrated and standardized models built on a foundation of accurate data. There are two kinds of audits that can be performed: a top-down water audit (such as the AWWA approach), and a bottom-up water audit. The difference between the two approaches primarily reflects the way data are gathered and derived.

The first step of the Top-Down Water Audit is to identify a group of stakeholders within the utility to aid with gathering the required data for a first look at the utility performance. Data is gathered and entered initially into a simple water balance model. The water balance model provides the level of detail for

which data is currently available at this desktop analysis (top-down) level. Figure 6-7 shows the major components of the most current AWWA/IWA standard water balance model.

Real Losses are the annual volumes lost through all types of leaks and breaks in water mains and service connections, up to the point of customer metering. Real losses also include overflows from treated water storage tanks or reservoirs.

Apparent Losses occur due to errors generated while collecting and storing customer usage data. The three categories of apparent losses include: Unauthorized Consumption, Customer Metering Inaccuracies, and Systematic Data Handling Errors.

This is an important distinction as these two categories of losses have different revenue implications for the water utility, with real losses having a more direct impact on water resources.

Own Sources	Corrected System Input Volume	Water Export	Billed Water Exported			Revenue Water
		Water Supply	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue Water
				Billed Un-metered Consumption		
Water Losses			Unbilled Authorized Consumption	Unbilled Metered Consumption	Non-Revenue Water (NRW)	
				Unbilled Un-metered Consumption		
Water Imported		Apparent Losses	Unauthorized Consumption			
	Customer Metering Inaccuracies and Data Handling Errors					
	Real Losses		Leakage on Transmission and/or Distribution Mains			
Leakage and Overflows at Utility's Storage Tanks						
		Leakage on Service Connections up to point of Customer metering				

Figure 6-7 Standard IWA/AWWA Water Balance

The AWWA water audit utilizes a grading scheme to rate the confidence of each input audit components. Once the audit has been completed, a water audit data validity score will be generated. It is important to recognize the significance of the water audit data validity score and evaluate both the output metrics and the audit score together. For the initial audit generated by the utility, it is likely that some components of the required data are either not available or were originally derived from estimates or engineering judgments. During the top-down auditing process, these components are assigned the appropriate data grading score by reviewing a standardized *Grading Matrix* (incorporated within the AWWA software). Once an aggregate confidence level is obtained by satisfying all the audit inputs, the utility can identify the components that will have the largest impact on improving the

aggregated confidence of either the apparent loss volume or the real loss volume. These input components are then typically prioritized for further verification.

It should be noted that it will likely require several years of conducting water audits to generate a high level of confidence in audit inputs. Once this level of confidence is reached, it is more realistic to base data-driven investment decisions on the water audit data and performance metrics. To generate this level of confidence in the data will require bottom-up activities and field studies that supplement the desk-top data used as entries into the audit spreadsheet.

One typical place to begin field validation is usually with the assessment of the accuracy of the supply meters. After investigation of the supply meters, the next step is an assessment of the accuracy of various categories of consumer meters. Consumer meter accuracy validation is usually done on statistically representative batches of meters. Both these items are discussed in more detail below.

6.4.5.2 Production Meter Testing

One of the most critical measurements in the audit is the accurate measurement of water leaving the water treatment plant recorded through the production meters. Production master meters should be flow verified and calibrated annually at a minimum. It should be noted that there is an important distinction between ‘flow verification’ and ‘calibration’. *Flow verification* is the act of confirming the accuracy of the primary metering device – the measuring element. Flow verification requires an independent measurement, typically by a second meter in series with the first, to provide comparative readings from which to quantify any discrepancy or error.

Calibration is the act of making modifications to the secondary electronic device – the output device where the flowmeter’s measured values are converted and communicated. Typically this can be a differential pressure transducer or cell that converts the flowmeter measurement into a common electronic signal (i.e., 4-20 mA) used in the telemetry or SCADA system.

Both flow verification and calibration are vital in providing the highest degree of confidence in the water supplied volume within the water balance as this is perhaps the most important input value to the audit calculation²⁸.

6.4.5.3 Customer / Retail Meter Testing

Customer meters can be thought of as the “cash registers” for a utility. This means that it is critical for customer meters to be as accurate as possible to ensure that utilities capture (and then charge for) the water that a customer receives. Similarly, for the purposes of developing an accurate water balance and understanding of supply efficiency, customer meter accuracy is an important factor. Furthermore, getting an accurate picture of water use (and measuring the impact of water conservation) will depend on accurate customer metering. Due to these drivers, customer meters should be considered one of the most vital assets within the utilities’ overall infrastructure and a robust program to monitor meter accuracy and repair and replace where necessary should be established. That said, attending to the accuracy of customer meters will not, *per se*, impact water conservation, but it will support accurate assessment and data driven decision making.

²⁸ Georgia Water System Audits and Water Loss Control Manual, Georgia Department of Natural Resources, Jan. 2015

In order to assure water is being accounted for accurately, meters need to be selected, installed, operated and maintained using generally accepted industry standards. Meters should be regularly calibrated and tested in accordance with the manufacturer’s recommendations or the guidelines issued by the American Water Works Association (AWWA), Manual for Water Meters-Selection, Installation, Testing, and Maintenance (AWWA M6).

6.4.5.4 Water Audit Data for CW&L

A preliminary AWWA water audit was developed for CW&L using 2014 data. Table 6-2 shows a summary of the water audit inputs and calculated performance indicators. This information will be used to estimate potential efficiency savings related to water losses from the distribution system.

Table 6-2 Preliminary Water Audit for CW&L System (2014 data)

AUDIT COMPONENT / INDICATOR	VALUE	UNITS
Volume From Own Sources	4,515.050	M. Gal. / Year
Volume From Own Sources MMEA	No Data	
Billed Metered	3,917.730	M. Gal. / Year
Billed Unmetered	No Data	
Unbilled Metered	No Data	
Unbilled Unmetered	56.438	M. Gal. / Year
Unbilled Unmetered Default Used	Yes	
Authorized Consumption	3,974.168	M. Gal. / Year
Unauthorized Consumption	11.288	M. Gal. / Year
Unauthorized Consumption Default Used	Yes	
Customer Metering Inaccuracies	79.954	M. Gal. / Year
Systematic Data Handling Errors	9.794	M. Gal. / Year
Systematic Data Handling Errors Default Used	Yes	
Length of Mains	689.0	Miles
Number of Active and Inactive Service Connections	48,281	
Service Connection Density	70	Conn./Mile
Customer meters located at the Curbstop / property line	Yes	
Average Operating Pressure	45.0	PSI
Apparent Losses	101.036	M. Gal. / Year
Real Losses	439.846	M. Gal. / Year
Water Losses	540.882	M. Gal. / Year
Non-Revenue Water	597.320	M. Gal. / Year
Non-Revenue Water as % by Volume of Water Supplied	13.2%	

AUDIT COMPONENT / INDICATOR	VALUE	UNITS
Non-Revenue Water as % by Cost of Operating System	5.1%	
Apparent Losses per service connection per day	5.73	Gal. / Day
Real Losses per service connection per day	24.96	Gal. / Day
Infrastructure Leakage Index (ILI)	2.44	Unit-less Ratio

6.4.5.5 Tracking and Benchmarking Performance

Another reason that utilities should adopt the AWWA water audit methodology is that it generates more meaningful performance indicators than traditional water loss approaches and helps to identify areas where reductions in water use can be made. Real and Apparent losses are typically expressed in terms of gallons / connection / day (for rural systems real losses are expressed in gallons / mile of main /day). These are more reliable indicators than simplistic percentage approaches. An additional important indicator is the Infrastructure Leakage Index (ILI). The index is a ratio of actual real losses (as reported through the audit) compared to the theoretical lowest level of leakage (Unavoidable Annual Real Loss, or UARL). A calculated ILI value of 1.0 would indicate that a utility has reached a real loss level that reflects the successful application of today's best real loss control technology. As such, ILI values of 1.0 are rare within the industry and this level is often not economically achievable, unless water is very scarce, very expensive, or both. A significant advantage of the ILI approach is that it considers utility specific factors such as the number of connections, the average system pressure and the length of the customer service line, in the calculation of the system's UARL. As long as it is based on reliable data, the ILI can be a useful planning tool for benchmarking system performance. Validated water audit data has been published by AWWA on an annual basis for several years. The most recent published dataset is the 2015 Water Audit Data Initiative²⁹ which contains audit information from 26 North American water utilities. Figure 6-8 shows performance of these utilities expressed as real losses per connection per day. Water utilities performing a water audit can benchmark their performance against this dataset.

²⁹ AWWA 2015 Validated Water Audit Data <http://www.awwa.org/resources-tools/water-knowledge/water-loss-control.aspx>

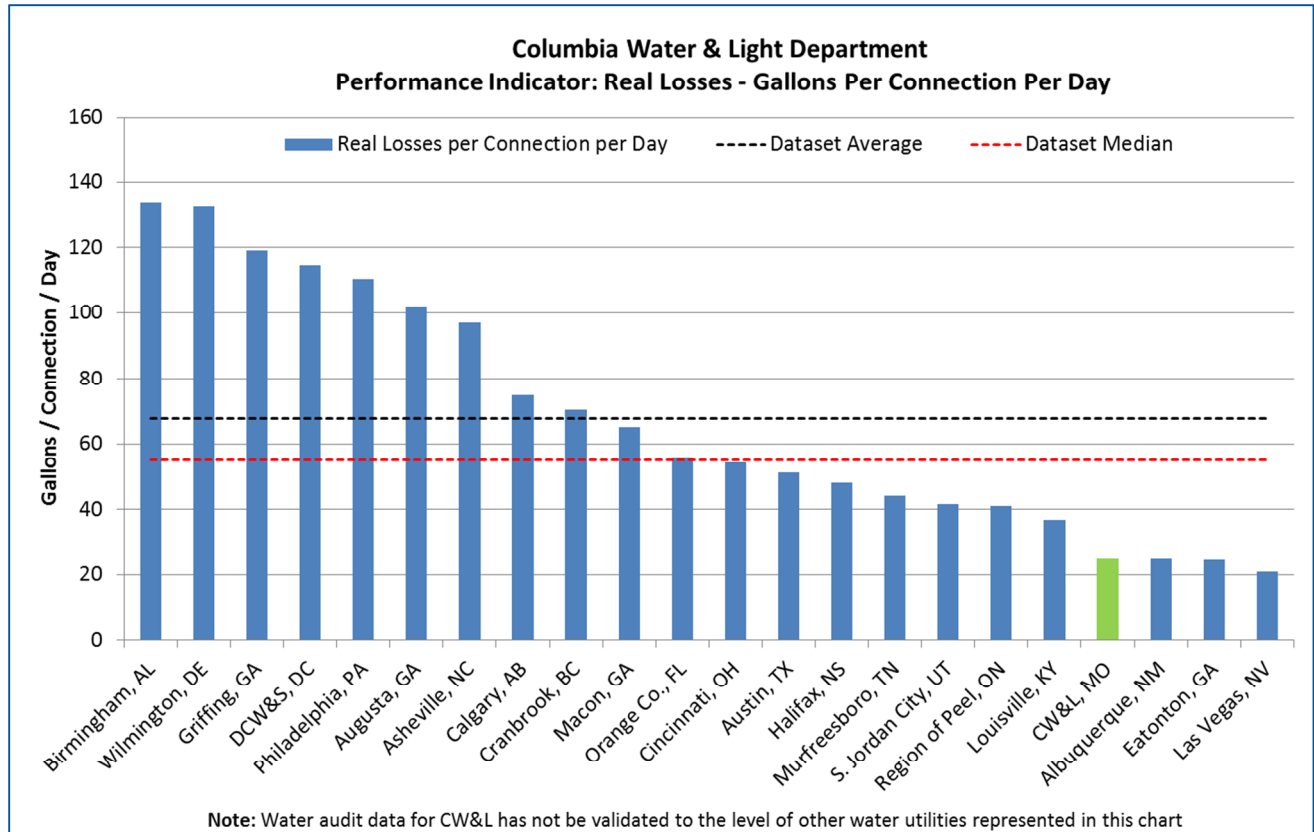


Figure 6-8 Published Water Audit Data (AWWA). Real Losses per Connection per Day

It is important to recognize that trying to achieve a water loss of zero isn't a practical or a realistic expectation. Understanding that water losses are broken down into two categories, real losses and apparent losses, is important and central to the water audit framework.

6.4.5.6 Developing a Water Loss Management Plan

A water loss management plan should recognize the different drivers behind real losses and apparent losses and also their financial and water resources implications. Once this is understood, the appropriate management strategies can be selected and implemented. For the purposes of developing an advanced water conservation plan, the focus here is on real loss management as reducing real losses directly benefits water resources.

A real loss management plan will encompass both the need for additional standardization and record keeping and an increased implementation of leakage detection surveying. There are several types of leakage detection survey options that a utility should consider. Regardless of the type or scope of the water leak survey, it is important that the utility carefully record the leak report data in electronic format and begin tracking the water lines surveyed along with all leak data through the repair process. It is to be expected that there are areas within the distribution network that are more susceptible to unreported leakage and as the program progresses, these suspect areas will be better defined and can be surveyed more frequently, thus making the leak detection survey more targeted, efficient and cost effective.

For larger utilities, the setting up of smaller zones to analyze demand and water loss variations more actively such as pressure zones, or District Metered Areas (DMAs) should be considered. DMA sizes will vary but typically may cover 1,000 – 3,000 connections. This will allow the distribution system to be discretized so that problem areas can be more easily identified and leak detection technologies applied with greater confidence.

Although apparent loss management is not a focus area for water conservation, the importance of the issue to a utility should not be overlooked. As retail water meters tend to deteriorate with age and use, resulting in under-registration of actual flow, this has two immediate negative impacts to the utility that may indirectly impact water conservation:

1. Utilities will lose revenue as not all the water delivered to the customer is registered through the meter unit. The lost revenue could be used to fund water conservation programs
2. If utilities mistakenly trust the data generated by under-registering customer meters, they may erroneously conclude that end-users use less water than they actually get through their meter. Additionally, these losses may be assumed to be real loss (physical leakage from the distribution system) and a utility may mistakenly prioritize leak detection efforts when they should first focus on meter calibration and maintenance efforts.

Unauthorized consumption and systematic data handling errors are other areas within the water balance that may be addressed through a water loss plan. Although these two items are very different in their underlying causes, a review of billing data to identify trends and outliers may indicate potential accounts where these items are generating errors and impacting revenue. Although detailed analyses of billing data may require advanced data management and application of statistical techniques, it may be possible to identify some issues by starting with a more simplified analysis.

6.4.6 Water Reuse and Conservation

Although the IWRP considers the use of non-potable reuse water, it is important that use of reuse water should not relieve the customer of their ongoing water conservation responsibilities. Doing so would undermine the effects and gains of the water conservation program. For example, if a customer sees reuse water supplied by the City being used either outside of the daily watering restrictions, a climate of misunderstanding will result, even if there are notices that potable water is not being used. Reuse water should also be used responsibly.

The availability of reuse water certainly does improve the supply situation, but this alone will not reduce overall demand and the localized demands that this will bring. In fact, allowing reuse water to be used at any time without restrictions will exacerbate the situation. Using water wisely should be encouraged and applied across the entire supply system not just in the potable water system. This is critical to the successful development of a combined conservation and reuse program.

6.4.6.1 Rainwater Harvesting

Rainwater harvesting conservation programs can reduce potable water usage and can also reduce problems related to excessive run-off. At the smallest scale these program can take the form of rain-barrels, but can be expanded to more elaborate building-specific or watershed level systems that may be applicable for both residential and commercial properties. Potential savings will depend upon

regional climate patterns and can be highly variable. Although rainwater is recommended for all irrigation uses, it is most appropriate for use with drip or micro irrigation systems as the rainwater can be distributed using gravity if the collection tank is at a suitable elevation.

CW&L may wish to consider a demonstration rainwater project which can be useful to help educate the utility and interested customers on these types of projects. Prior to advancing any rainwater harvesting projects or programs CW&L should ensure that system specifications concur with local building and plumbing codes.

6.4.6.2 Greywater Collection (New Construction)

The definition of graywater can vary between jurisdictions, but it is typically defined as wastewater from clothes washers, showers, bathtubs, and hand sinks not used for the disposal of hazardous or toxic ingredients³⁰. In some locations (e.g., Texas) builders of new homes are encouraged to install dual piping that provides the capacity to collect graywater from allowable sources and to use the water for landscaping near to the property. An interesting outcome of the trend towards increased indoor water efficiency is that it reduces the quantity of graywater generated from the fixtures and appliances in the home. Due to the increased plumbing requirements, graywater collection systems are generally expensive and, except in specific circumstances, they will generally not be a cost effective approach to water conservation for CW&L.

6.4.7 Landscape Irrigation and Lawn Watering

Landscape irrigation and lawn watering are important areas for focus in a water conservation plan. As observed during the summer of 2016 in southwest Columbia, lawn watering can become an operational issue (i.e., may trigger system pressure issues). Customer surveys or sampling will help inform the utility on the extent of irrigation by utility customers and potentially provide insight on where issues may arise if multiple irrigation systems operate on a similar schedule. This is an important, and complex, water management issue for CW&L as individual best practice irrigation scheduling may result in multiple irrigation systems activating simultaneously. For example, based on an investigation by the City, it appears that 5am was a typical time for irrigation to begin. This is consistent with lawn watering best practice advice which recommends watering lawns in the early morning hours. If customers have automatic irrigation systems, a more detailed survey should include an evaluation of the schedule currently used and recommend any equipment repairs or changes to increase the efficiency of the irrigation system. The irrigation component of a single-family survey should target single-family customers using more than a certain amount of water per billing period that could be considered excessive for the particular geographic area and other characteristics of the service area. For CW&L, this may be around 20,000 gallons per month (27 CCF) in summer since that could represent an outdoor use of more than 12,000 gallons per month. Surveying outdoor water use in homes with water use below 20,000 gallons per month is less likely to provide as significant an opportunity for water reductions. When conducting an onsite survey for a customer with an automatic irrigation system that is managed by an irrigation or maintenance contractor, it is beneficial to have the contractor present for the irrigation system survey (TWDB, 2013).

³⁰ <http://www.twdb.texas.gov/conservation/BMPs/Mun/doc/8.1.pdf>

Studies by the California Department of Water Resources (DWR) have shown that landscape irrigation is frequently inefficient and, in some cases, a high percentage of residential landscape irrigation is wasted as a result of overwatering, poor design and poor maintenance³¹. Therefore, the survey of automatic irrigation systems should include a check of the entire system for broken, misdirected or misting heads and pipe or valve leaks. The customer's service line and meter box should also be checked for leaks. Head spacing should be checked to determine if proper heads are installed. The schedule on the irrigation controller should be checked and the customer queried about how the schedule is adjusted during the year. A schedule should be provided based on evapotranspiration ("ET_o") based water-use budgets equal to no more than 80 percent of reference ET_o per square foot of irrigated landscape. The customer should be provided a written report on the system repairs and equipment changes needed and the appropriate efficient irrigation schedule by month. The controller should be reset with the efficient schedule. If the system does not have a rain sensor, it should be installed as part of the survey if feasible or provided to the customer to be installed by a contractor. Information should be provided on the installation of dedicated landscape meters for multi-family customers if offered by the utility (TWDB, 2013).

There are many actions that may be taken to improve landscape water use efficiency. Professional landscape and irrigation design, proper installation, careful maintenance and management of the site and the selection of high quality irrigation equipment are some of the factors that can influence the efficient use of water on the landscape. Dedicated landscape meters, establishment of landscape water budgets and associated budget-based rate structures, the performance of irrigation audits, public information programs, technical training for landscape professionals, the use of alternative sources of water on the landscape, and a multitude of rebate programs to support conversion from lawns to water-smart plants and irrigation equipment are examples of actions that can be taken along with, or in place of, irrigation restrictions.

Irrigation restrictions can be useful in reducing water use, especially in the high demand summer months. In many areas, water use increases dramatically when customers start to irrigate their landscapes. Many utilities use irrigation restrictions during a prolonged drought or when available resources run low and are typically implemented through municipal ordinances. To increase the effectiveness of these programs, a set of enforcement actions may need to be developed, communicated to the public and implemented. An outreach program will be required to carefully communicate the necessity of water use restrictions and what end users should expect.

Voluntary elements of a comprehensive landscape irrigation program should include the following (DWR, 2010):

- Widespread training programs for professional landscape maintenance contractors on water use efficiency, system maintenance and improvements
- Educational websites for consumers on landscape design, plant selection, irrigation system installation and repair
- Installation of separate landscape meters for better information and water management (some CW&L customers already have these)

³¹ California Department of Water Resources (DWR). 20x2020 Water Conservation Plan, February 2010

- More irrigation auditor training programs, and more irrigation audit programs provided by local water suppliers
- Support for rebate programs that fund upgrades to irrigation systems and controllers. Some utilities provide rebates for improved landscape plantings and reduction of turf areas
- Use of public building landscapes as local examples of good design, installation, and maintenance
- Strong local and regional programs to encourage efficient new landscapes, replacement of older inefficient landscapes, and better management of high-water-using plantings such as turf

6.4.8 Ordinances

The cheapest but most politically sensitive way to reduce demand is by legislating actions that results in water conservation. This could be achieved through the actions of the City government. A number of potential ordinances are possible; some of the more common approaches, covering both indoor and outdoor water use, are described below:

- **Water Waste Ordinances:** Typically these ordinances address poor practices such as allowing water to escape from the owner's property due to broken sprinkler heads or automatic sprinkler systems that are not set up correctly. They may also restrict or prohibit washing of driveways, sidewalks and other impervious surfaces. Some water waste ordinances require a rain sensor on automated sprinkler systems to ensure that watering does not occur during rain events.
- **Irrigation Ordinances.** These typically dictate the time of day and frequency per week of watering. These types of ordinances often have variances for establishing new lawns. One important aspect of these ordinances is that if lawn watering is restricted to certain days of the week it should be implemented so as not to exacerbate peak water use as occurred in southwest Columbia in the summer of 2016. In some cases, lawn irrigation is allowed on the same day as trash pickup, which balances demand across the system and also helps residents remember the watering schedule and reduces confusion.
- **Retrofit on Resale Ordinances.** These direct property owners to replace inefficient fixtures and fittings at the time of sale; if this type of ordinance is implemented it is often accompanied by a rebate offer to help offset any financial impacts.
- **Local Construction Standards.** These ordinances require highly water efficient fixtures and fittings – above and beyond standard plumbing codes. For example, Texas, Georgia and Colorado have passed statewide building codes that restrict the sale of plumbing products to WaterSense certified products. New York City, Miami-Dade County, Chicago and other jurisdictions have modified local plumbing codes to require that fixtures and fittings meet WaterSense specifications.

6.4.8.1 Limit Number of Days Allowed Per Week for Lawn Watering

Limiting lawn watering to two or three days per week can reduce demand, especially during the summer months. This also allows further restrictions in cases of a severe drought or if an emergency arises and demand needs to be reduced further. Since the city has a reasonably abundant source of water it is expected that three day per week watering will be sufficient to manage irrigation conservation.

Data from a Colorado-based study³² shows the potential mandatory restrictions to provide water savings during drought. The study found that during periods of mandatory restrictions savings in per capita use range from 18 – 56 percent, compared to 4 to 12 percent during periods of voluntary restrictions; communities with the most stringent restrictions achieved the greatest savings. Although this study is based in a region where outdoor irrigation is very large component of summer water use, it provides a reference point to show how ordinances can affect irrigation practices in the community. It would be prudent to add requirements to any water conservation ordinance for working rain sensors, annual back-up battery replacement, and new and replacement sensors and irrigation systems.

6.4.8.2 Review of Other Possible Actions or Ordinances

In June 2016, the city saw high demand spikes from a community of roughly 700 single-family homes in the south part of the city. This spike appears to be driven by residents irrigating their lawns between 4-6am. This is a good practice in terms of timing the application of water as it reduces evaporation that occurs compared to irrigating during late morning and early afternoon hours. However, when much of the irrigation coincides during these hours it can place a significant strain on the distribution system and can lead to reduced pressure. Therefore, coordination of education and outreach efforts is necessary in order to ensure that restrictions do not have unintended consequences.

It is recommended that prior to adoption of ordinances that include water use conservation measures, local government should embark on a 1-2 year public information campaign to promote awareness and empower residents with knowledge of specific actions to be taken for insuring reduction in water demand. The public information campaign will be most successful if it continues even after the ordinance has been adopted to increase compliance and to maintain a presence of the need for water conservation in the community. It is important that the customer is informed about the enforcement program that will be employed³³.

One of the key findings of the Colorado study³⁴ was that water managers noted the potential for customer confusion if the water restriction programs are too complex. A simple and consistent message for all customers can take advantage of broad media to remind customers of water restrictions, however the problem noted above of coincident lawn watering causing spikes demand needs to be avoided. This could provide an important lesson for the implementation of a program for the City of Columbia.

6.5 WATER CONSERVATION PLANNING

6.5.1 Demand Projection Methodology

In Section 4, water demand forecasts were created for the period 2016 to 2040. The water demand forecast considers the following components to provide an estimate of future water production requirements:

³² Kenney, D.S., Klein, R.A., and Clark, M.P. Use and Effectiveness of Municipal Watering Restrictions During Drought in Colorado. Journal of the American Water Resources Association, February 2004, pp. 77-87

³³ Chicago Metropolitan Agency for Planning. 2010. Model Water Use Conservation Ordinance.

³⁴ Kenney, D.S., Klein, R.A., and Clark, M.P. Use and Effectiveness of Municipal Watering Restrictions During Drought in Colorado. Journal of the American Water Resources Association, February 2004, pp. 77-87

- Customer consumption forecasts by sector, driven by assumptions regarding:
 - Average consumption per account
 - Growth in the number of accounts
- Average Day vs Maximum (Peak) Day Demand
- Non-Revenue Water (i.e., the difference between water produced and water sales to customers)

For each customer class, a baseline forecast was created. The baseline scenario represents a recommended water supply planning scenario and is explained in Section 4. Based on the information and analysis in this technical memo, a low-demand, or conservation, forecast was created that represents a potential lower demand due to the impact of increased levels of water efficiency implemented through technology changes, or behavioral changes. In developing the conservation forecast, the growth in the number of accounts was modeled using the same assumptions as in the baseline forecast to allow a direct comparison between the two scenarios.

The approach used for modeling the individual contribution of various water conservation measures was to project a 10-year water savings estimate which would have the effect of reducing the average consumption per account. As a conservative assumption, no additional efficiency savings are included beyond the 10 year projection as uncertainty increases with an extended forecast. If trends seen in the past 20 years continue, technology improvements may lead to greater levels of water efficiency and additional savings as water using fixtures, appliances and processes become more efficient. However, these future (additional) savings are not included in this approach due to high levels of uncertainty. As water conservation and efficiency programs are generally more nimble than infrastructure projects less lead time is required. Therefore these programs can typically be implemented and reevaluated on a five-to-ten year basis, or more frequently if desired. Due to the relatively nimble nature of these programs, pilot programs can also be implemented if CW&L does not wish to engage in a full scale program. Due to the multiple individual strategies that are available within an overall water conservation program, a tiered approach is also possible and this implementation strategy is described in more detail below.

6.5.2 Estimating Conservation Potential for CW&L

Based on a review of the water conservation approaches in Section 4 and the data available for CW&L, the following water conservation program components were evaluated for water savings and associated costs in the water conservation forecast scenario:

- Water Conservation Coordinator
- Public Education & Outreach
- Water Conservation Rebate Programs:
 - Toilet Replacement Rebate Programs
 - Showerhead / Aerator Replacement Rebate Programs
 - Clothes Washer Replacement Rebate Programs
- Lawn watering scheduling restrictions (ordinances)
- Commercial Water Efficiency Audits
- Water Loss Reduction

6.5.2.1 Water Conservation Coordinator

If CW&L intends to expand its water conservation efforts then a staff or management position should be assigned responsibility for the program. This would not have to be a full-time position initially, although if all the program elements were implemented (as outlined below) then a full-time, dedicated position would be required. As CW&L already has some experience of conservation and efficiency program within the energy functions of the utility then there could be some potential for overlap, or accelerated learning, for the water conservation program. There is also a potential for CW&L to combine water and energy efficiency programs as some efficiency measures have the potential to save both water and energy.

Although there is no direct water conservation benefit assigned to the water conservation coordinator position, it is a necessary role to ensure the program is adequately resourced and to provide accountability to the program by assigning water conservation responsibilities. Initial roles of the water conservation coordinator would be to:

- Identify customer survey opportunities that would lead to more targeted water conservation efforts
- Research the customer base (e.g., demographic and economic data) and analyze available data

Both these activities would help develop a greater understanding of the customer base which could be useful for other aspects of the utility (e.g., customer service) and to design more effective water conservation efforts.

The cost of the water conservation coordinator position is equivalent to the salary costs associated with the position.

6.5.2.2 Public Education & Outreach

A focused effort to educate customers will help to build support for the actionable aspects of the CW&L water conservation plan (e.g., rebate programs and good irrigation practices). The outreach effort should begin by engaging customers and raising awareness of the aims of the water conservation program. Customers often need to be made aware that a water conservation program can result in overall financial savings for the utility and the customer, as water conservation programs may defer investment in more expensive supply-side options.

Water conservation savings attributable to outreach and education efforts are difficult to accurately identify and quantify. Several water utilities, such as the San Antonio Water System (SAWS), TX do not include any estimated savings from public education efforts, although they do track the number of customers that they reach through workshops and outreach programs³⁵. Using a similar conservative approach for this analysis, no specific water conservation savings were estimated as a direct result of education and outreach efforts alone; however these are important aspects of an overall water conservation program and can lead to behavioral changes that result in water conservation. A conservation coordinator would have the primary responsibility for developing education and outreach content. Some examples of ways in which to communicate to customers are included below:

³⁵ Water Conservation Savings Quantification Study, TWDB. 2012.

- **Bill Inserts.** Bill inserts are a good way to reach all customers and the transition to monthly billing for all customers allows for timely messages to be communicated, such as specific advice and reminders as customers enter the irrigation season.
- **CW&L Website (www.como.gov/WaterandLight/).** The CW&L website is currently used to disseminate water conservation information to its customers, but could be expanded to add more water conservation content, or additional links to outside resources. Furthermore, customer engagement can be improved by providing customers with access to their data through a web-based interface where customers can view their water usage profile, compare to benchmarks, and allow calculation of potential water conservation savings through retrofits and behavioral change (see Section 4.2.2.1).
- **Email.** Email can provide a flexible and low cost means of communication to customers and can be used to provide timely updates on water conservation. A focused effort is generally required to gather the necessary information as it is typical of water utilities to have only have 10-20% of their customers' email addresses.
- **Social Media.** Social media accounts such as Twitter and Facebook can be used to publicize and promote the water conservation plan. As with email, not all customers have these accounts, but the flexibility of social media means timely messages and updates can be communicated quickly and at low cost and these messages are likely to reach more customers over time.
- **Schools Program.** As part of an outreach and education program, schools and educational facilities are typically good candidates for water efficiency programs. The facilities themselves may provide opportunities for water (and energy) efficiency upgrades with associated educational opportunities for students through programs such as Project WET³⁶ and online resources for educators³⁷.

6.5.2.3 AMI and Customer Engagement

Advanced Metering Infrastructure (AMI) is being evaluated and implemented by many water utilities in the U.S. AMI provides the enabling technology to achieve numerous operational efficiencies and also allows the utility to engage with customers by providing an enhanced level of service related to water consumption and water conservation. This can provide customers with the tools and information they need in order to effectively manage their water use. AMI systems can translate more frequent meter readings (daily, or even hourly) into value-added information for customers. Through the use of dashboards, or similar customer engagement portals, the following services can be provided to customers and are likely to result in water conservation:

- **Timely Information and Awareness:** Through a web-based interface driven by AMI data, customers can gain significant insight into their water use patterns. Daily updates are usually sufficient to provide valuable information to customers and allow them to manage their use accordingly. With this level of information a customer would have a greater understanding of the impact of lawn watering and other outdoor water use on their overall consumption.

³⁶ <http://www.projectwet.org/>

³⁷ <https://www.epa.gov/students/lesson-plans-teacher-guides-and-online-resources-educators#Water>

- **Leak Alerts:** Through advanced meters and data analytics, potential leakage on the customer side of the meter can be detected earlier and customers can be provided with alerts via text or email. This not only saves water by reducing the run-time of any leaks, but provides an enhanced level of service to the customer, and would protect CW&L from any customer leakage write-offs.
- **Consumption Alerts:** For utilities such as CW&L where the cost per unit of water increases at specific consumption levels (i.e., rate tiers), AMI systems can provide valuable alerts to customers to indicate when they are at pre-determined levels of consumption.

In addition to water conservation potential, AMI provides significant efficiencies and opportunities across many aspects of the utility's operations and it is generally these savings that drive AMI implementations. AMI results in decreased meter reads (by replacing either manual reads or drive-by AMR), fewer estimated reads, improved understanding of customer consumption (better diurnal profiling and more accurate data for hydraulic modeling), improved detection of theft, meter tampering and backflow, fewer physical trips (truck rolls), reduced liabilities and improved customer service.

AMI solutions apply to electric and water utilities and therefore CW&L may have an opportunity to develop an integrated AMI that provides a solution for both utility services and takes advantage of economies of scale that may not be readily available to most utilities. AMI implementation projects require significant levels of investment and utility-specific planning, but CW&L appears to be in a strong position to benefit from AMI technology. A pilot study could provide a cost-effective approach to scale into a full AMI. For example AMI implementation in the areas of the city with a high turnover of accounts (e.g., residences of college students) could provide the city with valuable insight and experience in AMI in an area that is likely to generate significant operational efficiencies for CW&L. Some utilities also use AMI to implement remotely connect or disconnect meters for customers in specific areas where it is useful to be able to start and stop service.

A specific use case example of AMI relates to a water conservation and water use issue that developed for CW&L during the summer of 2016. CW&L provided a recommended voluntary scheduling of irrigation for customers in southwestern Columbia³⁸ that encouraged the staggering of irrigation by customers in order to equalize water pressure in the subdivisions during the early morning hours. AMI has the ability to provide insight into whether customers are adhering to the voluntary scheduling, at the individual customer level.

Due to the multi-faceted nature of AMI implementations, the costs and benefits have not been quantified under this technical memo; such assessments are usually achieved through a full business case assessment.

6.5.2.4 Lawn Watering Conservation Strategies.

There are a number of strategies that have the potential to reduce landscape irrigation such as education, water rates changes, irrigation system audits and tune-ups, and irrigation ordinances. These different strategies have different levels of potential savings and would not be additive; for example, the most restrictive strategy would likely be the implementation of an irrigation ordinance.

³⁸ <http://www.como.gov/WaterandLight/Documents/IrrigationCyclesSWColumbia.pdf>

For the purposes of estimating potential water demand reductions associated with landscape irrigation customer consumption data was reviewed. Table 6-3 shows the ratio of the peak month to average month consumption³⁹ for the four customer classes. The table also shows the variability over recent years and indicates which month was the peak month in each year for each customer class. As is typical of most water systems, CW&L residential use has a higher peak month factor than residential master meter customers which are typically apartments and other multi-family units with limited opportunities for outdoor water use. In fact, the peak month for master metered customers was not always a summer month. Commercial and large commercial customers show the largest peak month factors, however the extent to which this peak factor is driven by irrigation, compared to a general increase in business activity in the summer months, is unclear. Such information could be obtained through customer surveys and onsite water audits.

Table 6-3 Peak-To-Average Month Factors by Customer Class

YEAR	RESIDENTIAL	RESIDENTIAL MASTER METER	COMMERCIAL	LARGE COMMERCIAL
2012	1.59 (Aug)	1.11 (Sep)	1.79 (Aug)	1.88 (Jul)
2013	1.46 (Sep)	1.16 (Sep)	1.56 (Sep)	1.69 (Jul)
2014	1.24 (Sep)	1.14 (Oct)	1.49 (Sep)	1.74 (Jun)
2015	1.39 (Jun)	1.13 (Mar)	1.50 (Sep)	1.70 (Jun)

As the residential customer class accounts for the majority of water consumption, and high use in the summer months is highly likely to be associated with irrigation and outdoor uses, this customer class was reviewed in greater detail in order to quantify potential savings from reducing irrigation and outdoor water use.

For each residential account, a ratio was developed that compared the consumption in the summer months (July, August, and September) against winter use (December, January, and February). The rationale for this assessment is that the higher the value of the Summer-to-Winter use, the more likely it is that the customer uses a significant amount of water for irrigation and other outdoor water uses. Figure 6-9 shows consumption values for customers at different levels of summer-to-winter use.

³⁹ Although a Maximum Daily Demand and Average Daily Demand can be estimated at the system level (due to daily data recording), customer usage is measured on a monthly basis so peaking factors are limited to a monthly basis and should not be compared to a daily peaking factor.

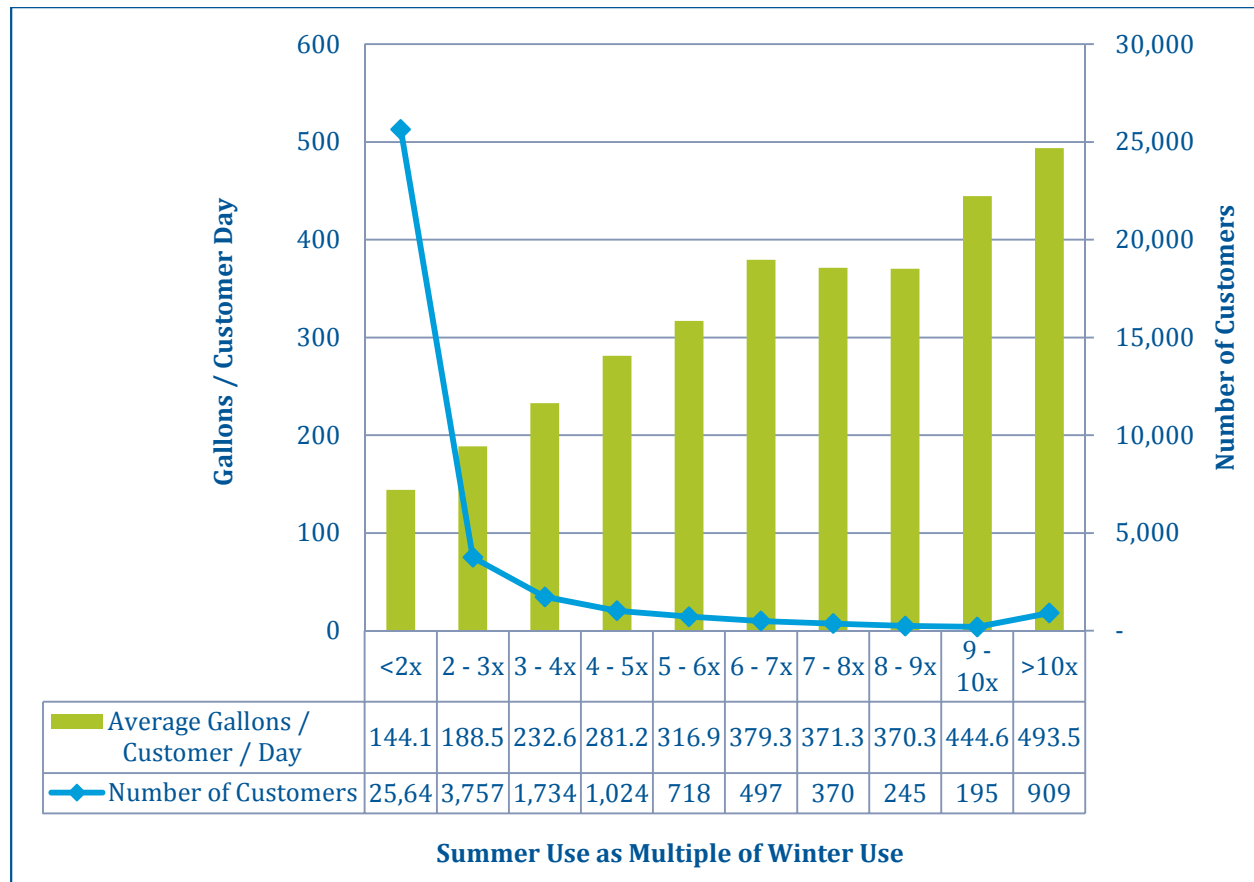


Figure 6-9 Average Water Consumption per Customer, by Summer-To-Winter use ratio

Figure 6-9 shows that the majority of customers’ summer consumption is less than three times their winter use. However usage does increase for those customers with high multiples of summer-to-winter use and this data was used to estimate potential savings due to decreased irrigation. Assuming that the approximately 3,000 customers with summer water use more than five times their winter use could reduce their consumption to the same level as the 4-5x category, the estimated savings would be approximately 450,000⁴⁰ gallons per day (on an annual basis, with the actual savings concentrated in the summer months). This estimate was used as the assumed savings from implementation of a landscape irrigation ordinance that would restrict lawn watering to no more than three days per week. For the purposes of forecasting the impact, it was assumed that an ordinance could be introduced in 2019 and would scale up to full implementation (covering all CW&L customers) by 2026. An additional assumed impact of the ordinance is that it reduces the MDD/ADD ratio from 1.8 (used to develop the baseline scenario), to 1.7 by the time of full implementation.

6.5.2.5 Tiered Irrigation Strategies.

An irrigation ordinance for all CW&L customers is the strategy that is likely to produce the greatest irrigation-related water savings. Other approaches are possible and could be considered if an irrigation ordinance was politically unacceptable. These approaches are summarized in Table 6-4.

⁴⁰ This is equivalent to a savings of approximately 10 gallons per residential account which was used as an assumption in the conservation forecast for all accounts.

Table 6-4 Possible Strategies for Reducing Irrigation Demand

IRRIGATION STRATEGY		SAVINGS*	APPROACH
Customer Education	Broad guidance on irrigation best practice, communicated through mass media, social media and billing inserts	5%	No direct customer interaction, broad or targeted outreach
Targeted Outreach	Billing data analysis and outreach communication to high use irrigation customers, including estimates of potential savings	15%	
Irrigation Contractor Education	Facilitated outreach to irrigation contractors regarding best practices and CW&L recommendations regarding set up of automatic sprinkler systems	25%	Requires customer / contractor interaction. Costs will depend on scale of program and if CW&L staff or third-party contractors are used
Customer Irrigation Consultancy	Site visits to customers to provide specific irrigation advice, tunes up and savings potential	30%	
Ordinance	Ordinance implementation	85%**	Regulatory
*Savings expressed as a percentage of the estimated savings from full compliance with an irrigation scheduling ordinance, as calculated in 4.2.1. **Assumes that full (100%) compliance and enforcement will not be achieved.			

An additional water conservation strategy that can be effective for irrigation is conservation oriented rate structures. Utilities that adopt this strategy usually have a three tier rate structure (for residential customers) with the third tier set at a consumption level that is designed to capture discretionary uses, such as high levels of irrigation.

Therefore, there are multiple strategies that CW&L can investigate focused on reducing water use for irrigation.

6.5.2.6 Water Conservation Rebate Programs

The City of Columbia already has energy rebate offerings for residential and commercial customers and could consider expanding these programs to include water using devices, especially as many fixtures and appliances use both water and energy (e.g., showerheads and clothes washers) and therefore provide an opportunity for dual savings. If CW&L chooses to implement a water efficiency rebate program it should be driven by products that qualify for the EPA WaterSense label as these are products have to meet both water saving standards (20% more efficient than Energy Policy Act standards) and have to meet minimal performance standards to ensure customer satisfaction. The greatest benefit from a water efficiency rebate program will be achieved by replacing only older fixtures and appliances, as newer homes will already have reasonably efficient water using devices, as prescribed by the Energy Policy Act that became effective in 1994. For example, although WaterSense labeled devices, such as toilets (1.28 gallons per flush), are even more efficient than the Energy Policy Act standards (1.6 gpf), the

incremental savings is generally not sufficient to warrant replacement under a rebate program (as the cost-benefit is not favorable), compared to replacement of pre-1994 toilets that typically use 3.5gpf, or greater. To estimate the potential scope of water savings for CW&L, U.S. Census data was used to provide information on the approximate age of housing in the City of Columbia and this data is presented in Figure 6-10.

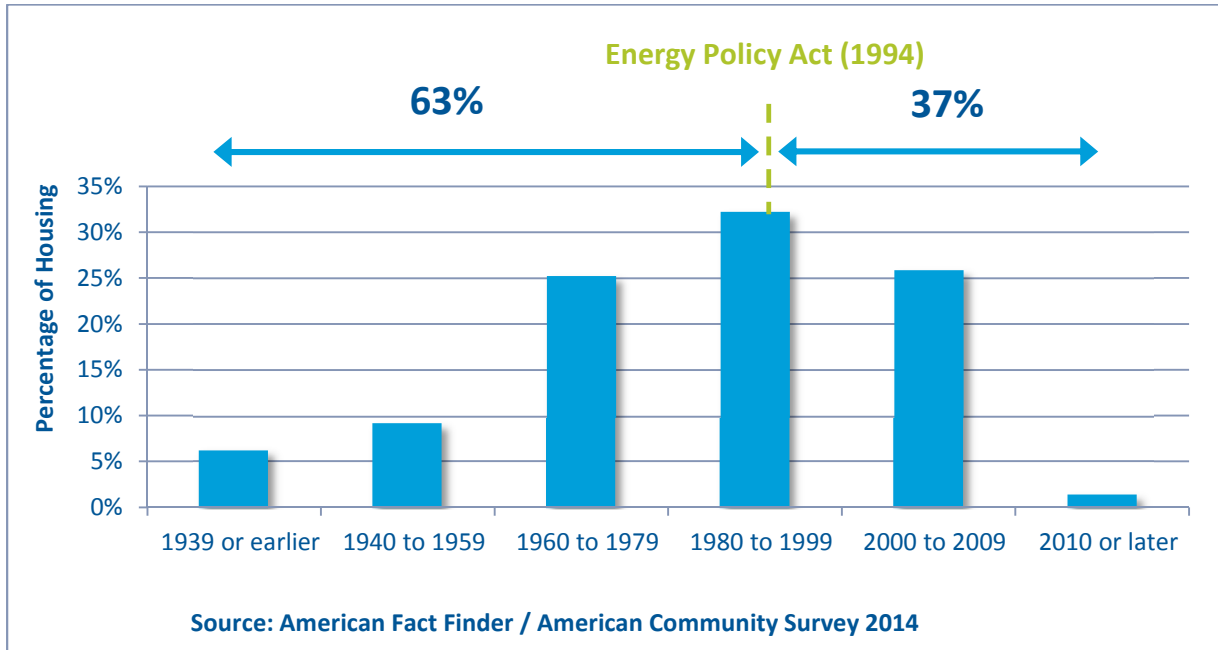


Figure 6-10 Estimated Construction Year for Homes in the City of Columbia

Although Figure 6-10 shows that the majority of housing was constructed prior to the Energy Policy Act, many of the original fixtures will have already been replaced with more efficient devices due to the natural rate of plumbing fixture replacement and remodeling. It should be noted that some portion of the existing older fixtures and appliances will be updated through the natural rate of replacement (i.e., property renovations and remodeling), even in the absence of a dedicated rebate program by CW&L. Prior to the implementation of a water conservation rebate program, it is recommended that CW&L perform a survey of its customers to further understand the existing saturation rate of water efficient fixtures and appliances. The survey should be designed to adequately reflect different demographics within the customer base, such as housing age and income levels which may influence fixture and appliance age and efficiency levels. In the absence of more specific data, and for the purposes of estimating the potential savings from replacing inefficient fixtures, it was estimated that 25% of the entire housing stock may still have pre-Energy Policy Act fixtures and that a rebate program could result in all but 5% of the housing stock upgrading to efficient fixtures over the next 10 years (this also includes natural replacement of fixtures). In other words, 20% of existing homes will benefit from efficiency upgrades over the next ten years. For reference, the Water Research Foundation REUWS study⁴¹ published in 2016 observed that 37% of homes had water efficient toilets, 46% had efficient clothes washers and 80% had efficient showerheads, therefore the potential for water conservation savings may

⁴¹ Water Research Foundation. 2016. Residential End Uses of Water, Version 2 (REUWS 2016)

be larger, but should be verified through a customer survey. The REUWS also notes that reductions in indoor water use are primarily due to improved efficiency of clothes washers and toilets, and are not the result of behavioral changes, or changes in occupancy rates. This suggests that structural water conservation savings, such as those achieved through fixtures and appliance replacements, have measurably improved indoor water efficiency and may be likely to yield more savings than efforts to influence behavior.

Water saving fixtures and appliances that are often included in water utility rebate programs, and should be considered for inclusion in a CW&L rebate program, are described below. The cost and impact of a potential rebate program was developed for the residential, residential master meter and commercial customer classes.

6.5.2.7 Water Efficient Toilets

A review of the current market for toilets as sold in large retail home improvement outlets and online, indicates that WaterSense labeled toilets currently dominate the market with more WaterSense labeled models available compared to non-WaterSense labeled models. WaterSense toilets were often the best-selling units, indicating that these are popular products among consumers. The effectiveness of lower flush volume toilets has increased since their introduction over two decades ago, in addition to meeting efficiency standards, WaterSense labeled products also have to meet minimal performance standards, so customer satisfaction with these devices is expected to be high. Both single flush and dual flush WaterSense toilets are available. Based on a review of water utility rebate programs, a toilet rebate program is typically limited to a maximum of two WaterSense toilets per customer account would apply to the single-family toilet rebate program, with a rebate value of \$75.

6.5.2.8 Water Efficient Showerheads

A review of the current market for showerheads as sold in large retail home improvement outlets and online, indicates that WaterSense branded shower-heads are available but are not market leaders with an estimated 10-20% of readily available showerheads carrying the WaterSense label. This marks a contrast with WaterSense toilets which currently dominate the market. There is therefore an opportunity for increased water efficiency through incentivizing consumers to adopt these products. Based on a review of water utility rebate programs, a showerhead rebate is typically limited to a maximum of two WaterSense showerheads per customer account, with a rebate value of \$15.

6.5.2.9 Water Efficient Clothes Washers

A review of the current market for clothes washers indicates that there are currently no WaterSense labeled models available. However the ENERGY STAR program features a water use component that is measured through a Water Factor (WF) that specifies the gallons of water use per cubic foot of laundry and so allows a comparison between washers of different sizes. The most water efficient models on the market are Consortium for Energy Efficiency (CEE) Tier 2 and Tier 3 washers which have WFs of 4.5 gallons and 4.0 gallons respectively (Table 6-5).

Table 6-5 Water Efficiency Specifications for Clothes Washers

SPECIFICATION	WATER FACTOR	GALLONS PER 4CU FT LAUNDRY LOAD
Federal Standard	9.5	38
ENERGY STAR®	6	24
CEE Tier I	6	24
CEE TIER II	4.5	18
CEE TIER III	4	16

Based on a review of water utility rebate programs, a limit of one clothes washer rebate per customer account typically applies to the single-family clothes washer rebate program, with a rebate value of \$100. Clothes washer rebates are also offered by several water utilities for multi-family and commercial customers, with specific models for these types of facilities (i.e., common area laundries and laundromats / hotels etc).

6.5.2.10 Water Efficient Urinals

WaterSense labeled urinals offer potential for water savings in commercial, institutional and industrial facilities as they use no more than 0.5 gallons per flush (gpf). While the current Energy Policy Act standard for urinals is 1.0 gpf, some older urinals may use up to 5.0 gpf⁴². A review of water efficiency rebate programs run by other utilities shows that rebates for WaterSense urinals are a part of many CII (Commercial, Institutional, and Industrial) focused programs with a typical rebate value of \$100.

6.5.2.11 Pre-Rinse Spray Valves

Pre-rinse spray valves are common in restaurants and other food-service establishments. They are used by kitchen staff to remove food particles prior to the cookware or dishes being washed by hand or in a dishwasher. Typically, both hot and cold water supply lines feed the spray head, and the user can adjust the mixed water temperature exiting the spray head. Low-flow, high efficiency pre-rinse spray heads are available, including WaterSense labeled models. These produce a fan-like spray pattern that removes the food particles just as effectively as standard heads. These high-efficiency heads generally have a much lower flow rate than standard models. Replacing old heads with this type saves water and energy by reducing the gas or electric energy required to heat the water.

The specific efficiency levels of typical water conservation program rebate items are listed in Table 6-6.

⁴² <http://www3.epa.gov/watersense/products/urinals.html>

Table 6-6 Examples of Water Saving Products for Rebate Programs

CUSTOMER	FIXTURE / APPLIANCE	PERFORMANCE REQUIREMENT	PERFORMANCE SPECIFICATION AND/OR REFERENCE
Residential / Commercial	High-efficiency Toilet	1.28 gallons per flush (average) Single or Dual Flush	https://www3.epa.gov/watersense/products/toilets.html https://www3.epa.gov/watersense/products/flushometer-valve-toilets.html
Commercial	Urinals	0.5 gallons per flush	https://www3.epa.gov/watersense/products/urinals.html
Residential	Sink Faucet Aerators	1.5 gallons per minute	https://www3.epa.gov/watersense/products/bathroom_sink_faucets.html
Residential	Low-flow Showerheads	2.0 gallons per minute	https://www3.epa.gov/watersense/products/showerheads.html
Commercial	Pre-Rinse Spray Valves	1.28 gallons per minute	https://www3.epa.gov/watersense/products/urinals.html
Residential / Commercial	High-efficiency Clothes Washers	4.0 gallons, or less, per cubic foot of laundry capacity	ENERGY STAR / Consortium for Energy Efficiency rating Tier 3. (High efficiency models available for commercial / common area laundromats.)

6.5.2.12 Rebate Administration

Rebate administration is an important element of a rebate program and overall plan implementation. It includes the process through which the customer applies for and redeems the rebate and the process in which the utility verifies and processes the rebate application. The rebate administration process is a point of engagement between the utility and the customer. The customer will be looking for a process that is straight-forward and transparent and the utility will want an efficient process that provides sufficient assurance that the rebate eligibility requirements have been met.

A review of water conservation rebate programs indicates that the majority of programs use a paper-based application process. Typically, a rebate application form is downloaded from the utility website, completed by the customer and sent back to the utility along with any documentation such as a receipt confirming the purchase of an eligible product.

As an alternative to the paper-based rebate process, some utilities are using online rebate redemption solutions typically backed by third party administrators which streamline the process of rebate redemption as the customer's account is verified online and the rebate applied at the point of transaction.

6.5.2.13 Commercial and Large Commercial Audits

It is widely recognized that benchmarking efficiency for commercial and large commercial facilities is extremely difficult because there are few metrics that can be used consistently to analyze and compare

water demand⁴³. This provides a challenge for implementing audits as without a benchmark of efficiency it is not clear how to prioritize effort. Although commercial water uses can be highly specialized, many facilities have common water using fixtures such as toilets, urinals, showerheads and pre-rinse spray valves. As part of an evaluation of water conservation potential for the City of Columbia, a rebate program focusing on the replacement of these common water using fixtures was evaluated. Water audits could be performed to develop additional insight into water using processes by commercial and large commercial customers. As the City already has a commercial energy efficiency program it is likely that this could be expanded at reasonable cost to include water efficiency. Water audits may directly result in water savings through the identification of leaks, or process or behavioral changes that can improve efficiency at minimal cost, as well as the identification of water efficient equipment upgrades.

Within the Commercial water audit process, the following aspects can be reviewed:

- **Water Use Analysis.** Major water uses within the facility can be identified in coordination with building owners and facility managers. Where possible, estimated end uses of water within the facility can be compared to metered consumption. This will check the overall understanding of water uses within the facility and can also be used to identify possible unidentified leaks. For standard plumbing fixtures, the analysis will be driven by the number of employees and visitors within a facility, but will need to be customized for more specialized facilities and processes.
- **Equipment and fixture inventory.** This will help to identify potential equipment and fixtures that are below current high efficiency standards (e.g., WaterSense specification) and can be used to assess potential for replacement.
- **Summary of Savings Potential.** An evaluation can be made on the efficiency of equipment and practices at the facility, and the potential for water-saving upgrades to fixtures or processes.
- **Development of Case Studies.** If the audit shows water saving potential and the customer wishes to move ahead with installation of water efficient equipment, there may be an opportunity to turn the project into a case study (subject to the customer's willingness to participate); case studies specific to the City of Columbia are likely to be useful to other commercial facilities and may encourage others to adopt water efficient approaches.

Water used for landscaping and other outdoor uses should be included as part of commercial water audits. Commercial and large commercial customers have the highest ratio of peak-to-average-month use, with peak use consistently occurring during summer months. Through an on-site water audit, and discussion with facility staff, it should be possible to identify to what extent peak water use is driven by irrigation, compared to a general increase in business activity during the summer months.

6.5.2.14 Water Loss Audit

Based on the development of a preliminary water audit for CW&L, utilizing the AWWA water audit methodology (for 2014 data), the key performance metrics are shown in Table 6-7, along with suggested benchmark levels. Table 6-7 indicates that the city shows good performance in this area, although it should be emphasized that further scrutiny of the water audit inputs is required in order to develop a

⁴³ Frost, D., Sversvold, D., Wilcut, E., & Keen, D.J. Journal AWWA 108:3:64 March 2016

reliable water audit. Once confidence in the underlying data has reached a satisfactory level it is appropriate for the utility to develop strategies to control water losses as these are likely to be built on reliable data and will empower decision making.

As the preliminary water audit shows good performance for CW&L, no specific water demand reductions have been assumed over the forecast period. However, it is recommended that effort is placed on this area and an annual audit in the AWWA format is performed. This will ensure that CW&L keeps close track of water loss issues in both volume and cost terms as these are central tenets of the AWWA water audit methodology. Furthermore, for CW&L to maintain this level of water loss performance it will be necessary to pro-actively monitor and address water losses, otherwise system efficiency will decrease and water losses are likely to increase.

Table 6-7 Benchmark Levels for Sound Water Loss Performance

INDICATOR	CW&L	SUGGESTED BENCHMARK	SUPPORTING INFORMATION
Real Losses (gallons per connection per day)	25 gallons/conn./day	<50 gallons/conn./day	56 gal/connection/day: median value from AWWA 2014 WADI dataset
Apparent Losses (gallons per connection per day) ¹	6 gallons/conn./day	<7 gallons/conn./day	7.2 gal/connection/day: median value from AWWA 2014 WADI dataset
Infrastructure Leakage Index (ILI)		<3.0	2.7: median ILI value from AWWA 2014 WADI dataset

¹ Losses impact revenue and not real, physical losses

6.5.3 Estimating Water Conservation Costs and Impacts

An estimate of potential costs and water savings has been conducted as part of this study. Program costs should be evaluated in the context of potential water savings including consideration of whether water conservation could delay the need for water supply projects. However a full cost benefit analysis is beyond the scope of this assessment, although it is recommended if CW&L wishes to pursue a water conservation program and develop a deeper understanding of how costs and benefits compare to supply-side investments. The unit savings, underlying assumptions, and cumulative program savings are shown in Table 6-8.

For the purposes of this assessment, water conservation and efficiency program savings have been estimated over the next 10 years such that the programs are fully implemented in the year 2026. These efficiency enhancements have then been held constant throughout the remainder of the forecast period (through 2040). The costs associated with achieving these water savings have also been estimated. Annualized costs have been estimated (in 2016 dollars) that are required to achieve the full implementation and benefit of the water conservation programs in 2026. The water conservation savings have been phased in over the 10 year period. All measures have been estimated to begin in 2017; the only exception to this is the irrigation ordinance which has been estimated to take effect in 2019, should the City choose to move ahead with such an approach. Alternative strategies to address irrigation have been described in section 6.3.4 and potential levels of effectiveness for these strategies

have been included in Table 6-8. However for the purposes of developing a demand forecast to reflect water conservation, the irrigation ordinance scenario has been modeled.

The potential impact of the conservation measures described in section 6.4 have been estimated for the planning period 2017 – 2040. The combined impact of these individual measures is shown in Figure 6-11 (and Table 6-8) under both average day demand (ADD) and maximum day demand (MDD) conditions. The baseline scenarios represent the forecast developed and described in TM3 and have been included here for comparison against the water conservation scenario. At the end of the forecast period (2040), the water conservation scenarios represent a reduction of approximately 5% and 10% relative to the ADD and MDD Baseline scenarios, respectively. The greater reduction under the MDD scenario reflects that an irrigation ordinance, if appropriately implemented, is likely to reduce peak day consumption.

Table 6-8 Water Conservation Savings and Program Assumptions

CUSTOMER CLASS	CONSERVATION MEASURE	EST. UNIT SAVINGS	IMPACTED CUSTOMERS (WITHIN SECTOR)	TOTAL 10 YR IMPACT (MGD)	UNIT COST	TOTAL 10 YR COST
Residential	WaterSense Toilet (Rebate Program)	2.2 gallons per flush	20%	0.151	\$75 rebate	\$ 1,707,560
Residential	WaterSense Showerhead (Rebate Program)	0.5 gallons per minute	20%	0.093	\$15 rebate	\$ 341,512
Residential	WaterSense Clothes Washer (Rebate Program)	10 gallons per load	20%	0.094	\$100 rebate	\$ 1,138,373
Multi-Family	WaterSense Toilet (Rebate Program)	2.2 gallons per flush	20%	0.025	\$75 rebate	\$ 81,067
Multi-Family	WaterSense Showerhead (Rebate Program)	0.5 gallons per minute	20%	0.008	\$15 rebate	\$ 16,213
Multi-Family	WaterSense Clothes Washer (Rebate Program)	10 gallons per load	20%	0.008	\$100 rebate	\$ 21,618
Commercial	Facility Audits / Technical Assistance	100 gallons / day	20%	0.095	\$1,500 audit	\$ 1,428,056
Commercial	WaterSense Toilet / Urinal (Rebate Program)	2.2 gallon per flush	20%	0.019	\$100 rebate	\$ 476,019
All	Irrigation - Education	10 gallons / account / day	5%	0.031	N/A	
All	Irrigation - Targeted Outreach	10 gallons / account / day	15%	0.094	N/A	
All	Irrigation - Contractor Education	10 gallons / account / day	25%	0.157	N/A	
All	Irrigation - Customer Consultancy	10 gallons / account / day	30%	0.188	N/A	
All	Irrigation - Ordinance	10 gallons / account / day	85%	0.534	N/A	\$ 800,000

Table 6-9 Estimated Annual Costs for CW&L Water Conservation Program

CONSERVATION ACTIVITY	ANNUAL COST 2017-2026 (2016 DOLLARS)	ESTIMATED WATER SAVINGS 2026 (MGD)
Conservation Coordinator & Program Admin	\$110,000	N/A
AWWA Water Audit	\$50,000	N/A
Public Information & Customer Surveys	\$140,000	N/A
School Education	\$37,500	N/A
Audit Programs for Commercial and Large Commercial Accounts	\$142,806	0.095
Residential Toilet Incentive Program	\$178,863	0.176
Commercial Toilet Incentive Program	\$47,602	0.019
Residential Clothes Washer Incentive Program	\$115,999	0.101
Residential Showerhead / Aerator Retrofit	\$35,773	0.101
Landscape Irrigation Scheduling Ordinance & Enforcement	\$80,000	0.534
TOTAL PROGRAM	\$938,542	1.027

It is recommended that if CW&L wish to explore any of the suggested water conservation measures further, more data should be collected and analyzed to develop greater confidence in the estimated water saving impact and associated costs.

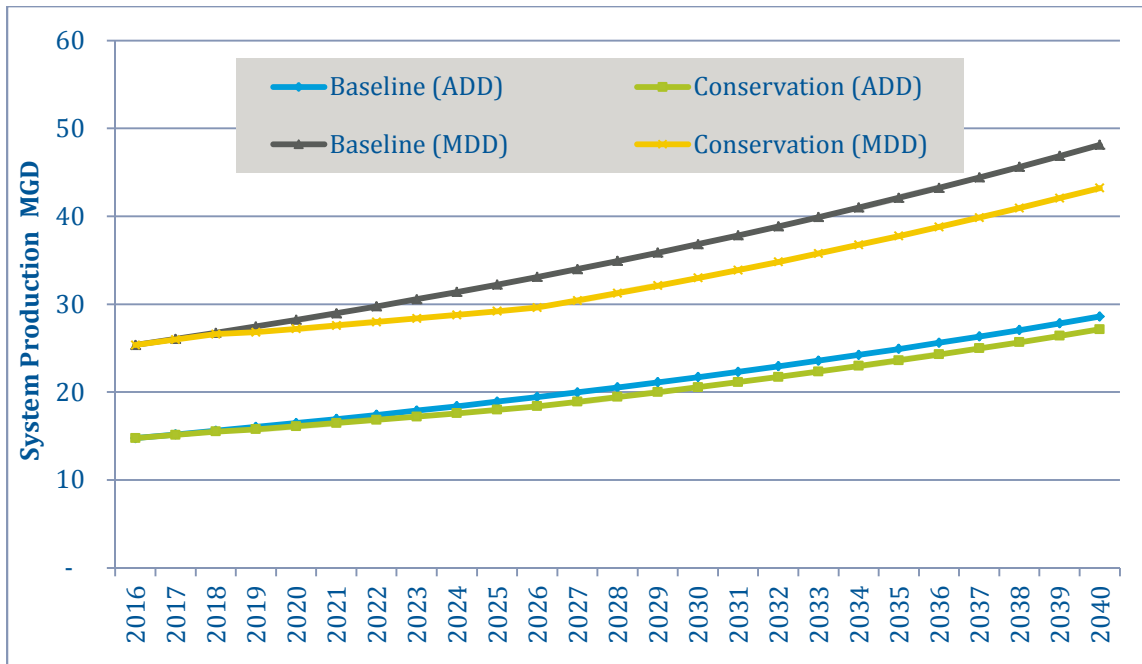


Figure 6-11 Demand Projections for CW&L for Baseline and Conservation Scenarios (ADD and MDD)

Table 6-10 Demand Projections for CW&L for Baseline and Conservation Scenarios (ADD and MDD)

			2020	2025	2030	2035	2040
Average Daily Demand		Baseline (MGD)	16.47	18.90	21.69	24.90	28.59
		Conservation (MGD)	16.11	17.98	20.54	23.61	27.14
Maximum Daily Demand		Baseline (MGD)	28.20	32.22	36.82	42.09	48.13
		Conservation (MGD)	27.19	29.19	32.98	37.75	43.21

6.5.4 Recommendations

Based on a review of the available data and information, the following recommendations are provided regarding the implementation of a CW&L water conservation program.

- **Data-Driven.** Prior to implementing any of the aforementioned water conservation strategies, it is recommended that additional data is gathered from customers (via more detailed surveys or customer liaison groups) in order to ensure the programs are tailored to the specific needs of CW&L customers.
- **Water-Energy Nexus.** As CW&L already has energy efficiency programs there may be an opportunity to leverage these existing programs to include water efficiency measures; such opportunities are not typically available to many utilities.
- **Irrigation Focus.** Five different strategies have been identified to address irrigation demands on the system. Based on the available data, there appears to be significant potential to address irrigation demand and these approaches could be among the most cost effective. CW&L could adopt a tiered approach to irrigation strategies that move from education, through specific outreach efforts, to enforced irrigation ordinances.
- **Pilot Programs.** The conservation programs outlined can all be adopted initially as pilot programs. This is a sensible strategy as each utility's customer base is unique and the response to customer incentive program can vary for a multitude of reasons. A pilot strategy can limit the cost of the programs while real data is gathered to evaluate program savings. Pilot programs can be limited in scope (a subset of customers) or duration.
- **Monitoring & Evaluation.** Monitoring and frequent evaluation of the conservation program's effectiveness will be essential to verify the impact of the program and to ensure it is responsive to customers' needs. Water savings can be estimated based on adoption rates of water efficient products and can be validated by examining water use records (i.e., billing data) to help verify savings. The overall water conservation program involves a number of individual components and program priorities may change in response to customer feedback and the results of program evaluations.

7.0 Public Engagement

Early and continuous public involvement brought diverse perspectives and values into the planning process. Desired outcomes of the public engagement effort included:

- Developing an informed group of stakeholders that understand the benefits and tradeoffs of implementing available water management strategies.
- Informing the stakeholders by providing balanced and objective information to assist them in understanding the problems, alternatives, opportunities, and solutions.
- Consulting the stakeholders by obtaining feedback on analysis and alternatives.
- Involving the stakeholders by working directly with them throughout the process to ensure that concerns and aspirations are consistently understood and considered, ensuring stakeholder groups are included and consulted.
- Building partnerships with other agencies and stakeholders, recognizing the effect this effort has on the community and other sustainable infrastructure initiatives.

Information on water supply alternatives, non-potable water uses, and conservation practices were presented to stakeholders so that they understood the benefits and trade-offs of implementing available water management strategies. Stakeholders were consulted on the developed options and recommendations so that the Integrated Water Resource Plan represents the best balance for the community. Elements of the public engagement included:

- **Integrated Water Resource Planning Committee:** A 10-person steering committee was created to guide the development of a reliable, cost-effective water supply for Columbia. The committee met 5 times over the course of a year. The committee consisted of five Water & Light Advisory Board members, the City Sustainability Manager, and four members appointed by the City Council that are qualified voters and customers of the water utility. The Committee evaluated supply and demand management resource opportunities and discussed preferred alternatives.
- **Media Relations:** Press releases were issued for all Water Resource Plan open house meetings and media briefings occurred on the day of open house meetings.
- **Social Media:** Social media posts were used to keep stakeholders informed and to notify the public of opportunities to provide input into the Water Resource Plan.
- **Factsheets:** A series of four informational factsheets were developed to provide stakeholders with an in-depth look at water supply alternatives, non-potable water uses, and conservation practices. The factsheets provided information such as the feasibility, the costs, and the phasing of the proposed alternatives. Factsheets were posted to the project website, distributed via an extensive email distribution list, and available at the public meetings.
- **Community Survey:** A four-part online survey was used to gather input from over 65 respondents. The survey asked for input on water supply alternatives, non-potable water uses, and water conservation practices. The survey was hosted on the website and participants who

attended the first public meeting were provided with a paper version. The online survey was sent out along with project factsheets to a distribution list of over 150 stakeholders.

- **Open House Public Meeting #1:** The first meeting was held in an open house format where feedback was solicited from 35 stakeholders in attendance. A questionnaire was posted online with fact sheets regarding options so that stakeholders could provide informed and refined input into the process. The following questions were posed and participants were asked to provide input on the following questions:

Should Columbia....

- Increase raw water supply?
- Reclaim and reuse water?
- Manage demand for water?
- Implement more water conservation/efficiency measures?
- Put in place a combination or all of these options?

Participants were also asked to provide input into the decision-making criteria to make these recommendations based upon what they value in their community.

- **Open House Public Meeting #2:** The second meeting was held in an open house format that included a presentation at a designated time. The proposed alternative was presented to the public and the project team walked participants through the alternative details. Participants were provided the opportunity to ask questions, share comments and concerns, and submit written comments on proposed alternative.

7.1.1 Public Surveys

In summer 2016, a survey of Columbia water users made available online through the City's website showed that customers are active participants in water conservation and are willing to do their part to conserve water. Responses to the following items were collected from mid-August 2016 through the beginning of November and range from community involvement to specifics on water supply alternatives and conservation measures.

Question: What are you willing to do to help conserve water?

The first question presented was intended to gauge the interest of residents to conserve water. Figure 7-1 summarizes the results of five questions pertaining to conservation.

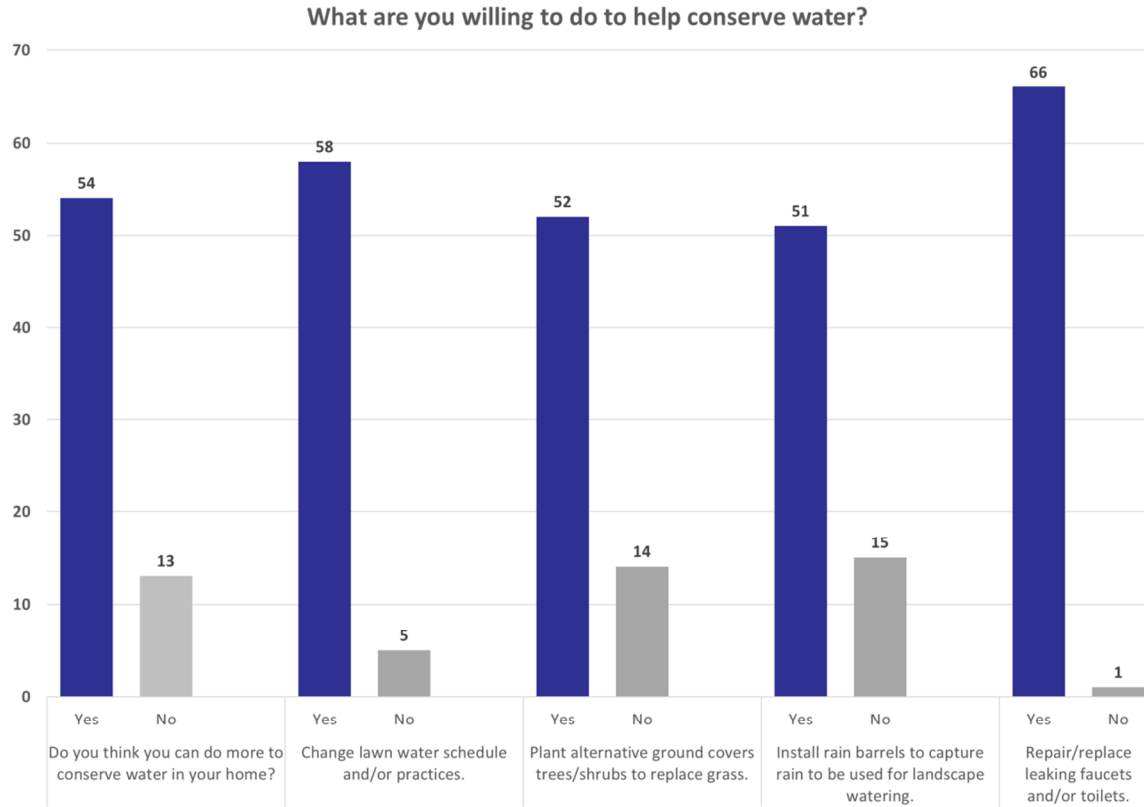


Figure 7-1 : Get Involved Public Outreach Survey Results

The results show overwhelming support of implementing measures to conserve water. What remains unclear from this survey is how willing each individual would be to still proceed with the conservation measure if there were additional costs to implement these conservation measures. However, the survey did reveal that the community is interested in finding ways to conserve water.

Question: Water Supply Alternatives

Citizens were polled on the water supply alternatives highlighted in previous sections of this report. The designations and descriptions provided included;

1. Horizontal Wells – Horizontal collector wells located along the Missouri River bank can produce 5 to 10 times the volume of one vertical groundwater well. This supply system is expensive to install but has lower long-term operating and maintenance costs than vertical wells. Water from these wells is regulated differently than existing vertical wells and would require additional treatment at the plant. Horizontal collector wells could be used in addition to the current vertical groundwater system.
2. Expansion into Overton Bottoms – This alternative includes the addition of vertical wells in an aquifer west of the Missouri River. Locating wells on the west side would be more expensive since it requires a pipeline crossing the river and would be more difficult to access and maintain from the plant side.

3. Expansion of McBaine Bottoms-Current System – Additional vertical wells would be installed in the same aquifer as the existing wells. Based on modeling the aquifer is capable of providing about 58 MGD with the addition of 15 more wells. The wells could be installed incrementally over time as demands increase to minimize one-time costs. Water quality would be the same as the existing supply to meet future demands.
4. Rehabilitation of Wells in the City Limits – Rehabilitation of the existing deeps wells within the City limits and additional deep wells in the Ozark Aquifer has supply limitations and treatment challenges that make this not a good long term alternative for drinking water to meet all future demands. The wells could be utilized for non-drinking water uses to reduce impacts at the treatment plant.

Figure 7-2 summarizes the results of supply questions.

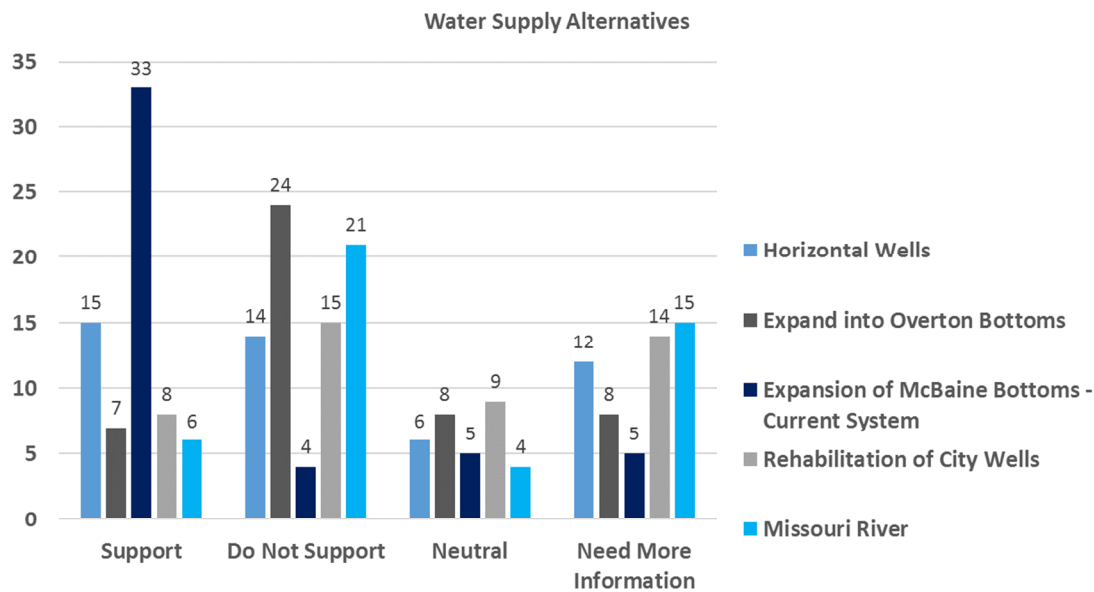


Figure 7-2 : Water Supply Alternatives Public Survey Results

Overall, citizens were supportive of the expansion of the existing vertical well field for water supply. Treatment would occur at an expanded McBaine Water Treatment Plant. Horizontal collector wells and expansion of the McBaine Bottoms were also shown to be favorable. Understandably, the options to expand into the Overton Bottoms on the other side of the Missouri River and rehabilitation of the existing City wells were not well received. The option to pull water from the Missouri River lacked public support, however many survey respondents were in need of additional information.

Question: Non-Potable Water Supply Alternatives

A broad range of non-potable supply alternatives were presented in the public survey. Information about the non-potable alternatives were presented on a fact sheet shown in Figure 7-3.



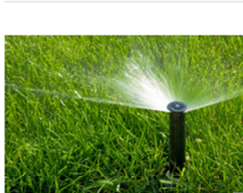
Rain Barrels have been used for centuries to conserve water. Downspouts direct rainwater from roofs into barrels so water can be used later to water lawns or gardens.

-  LOW Cost
-  HIGH Feasibility
-  LOW Impact on water demand



Groundwater from existing wells may be used to meet irrigation demands or a combination of industrial and irrigation demands. A combination of using retired wells and some new wells could be a reliable source for meeting non-potable demands, even in times of drought.

-  MODERATE Cost
-  HIGH Feasibility
-  HIGH Impact on water demand



Recycled water from the City's treated wastewater tends to be relatively expensive (due to much higher degree of treatment and a separate delivery system) compared to drinking water and to other sources of non-potable water, but can be a reliable option for an industrial user.

-  HIGH Cost
-  LOW Feasibility
-  MODERATE Impact on water demand

Recycled wastewater is currently used to support wildlife habitat at the Missouri Department of Conservation's Eagle Bluff Conservation Area. As the city grows and more wastewater is generated, additional treated flows could be recycled to meet non-potable demands. However, recycled water could cost relatively more than other non-potable options described here, and even more than treated drinking water.

-  HIGH Cost
-  LOW Feasibility
-  LOW Impact on water demand

Figure 7-3 Non Potable Supply Alternatives

Results from the survey on non-potable supply are summarized in Figure7-4.

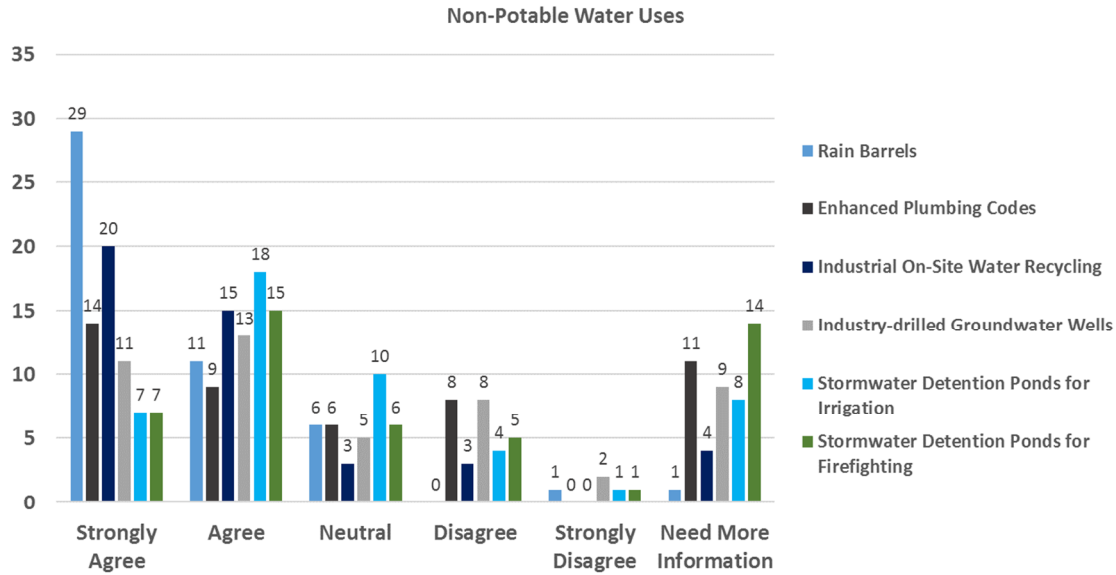


Figure 7-4 : Non-Potable Water Uses Public Survey Results

Results from the non-potable water supply alternatives show general support for the non-potable water supply alternatives, with the most support for implementation of rain barrels and industrial on-site water recycling. Similar to the previous conservation question, no costs were included with these alternatives, so the impact costs would have on the responses is unclear.

Question: Water Conservation

Potential water conservation measures were presented in the public survey. The survey questions included restrictions on watering, peak usage pricing, rebates for replacing leaking faucets and inefficient toilets, and investment in distribution system to reduce leaks. Background information was presented to the citizens on a fact sheet as shown on Figure 7-5.



Why Conserve Drinking Water?

Conserving and using water more efficiently can reduce the amount of water treated to drinking water standards. Reducing the amount of treated water used by the community can add resiliency to and ease demands on the drinking water system. Although expenditures are required to maintain our water infrastructure, conserving water may also help defer the need for major new water supply facilities.

Could customers limit lawn watering to certain times of day or days of the week to reduce the demand on the system?

Yes. A water restriction strategy may include limits on car washing, landscape watering, and other outdoor water use to balance water supply and demand. Scheduled lawn watering is key to a successful program.

LOW Cost
 MODERATE Feasibility
 HIGH Impact on water demand

Could customers conserve more water and use water more efficiently?

Yes. A water restriction strategy may include limits on car washing, landscape watering, and other outdoor water use to balance water supply and demand. Scheduled lawn watering is key to a successful program.

HIGH Cost
 MODERATE Feasibility
 MODERATE to HIGH Impact on water demand

Could the utility invest in the water system to reduce main breaks and water loss due to leaks in the system?

Yes. The conservation message will be better received by the utility's customers if they utility itself is engaging in and showing leadership by improving water supply efficiency. A water loss audit in accordance with the American Water Works Association (AWWA) methods provides a solid framework to focus water conservation efforts within the drinking water system.

HIGH Cost
 MODERATE Feasibility
 HIGH Impact on water demand

Figure 7-5 Water Conservation Background Factsheet

Results from the survey are summarized in Figure 7-6.

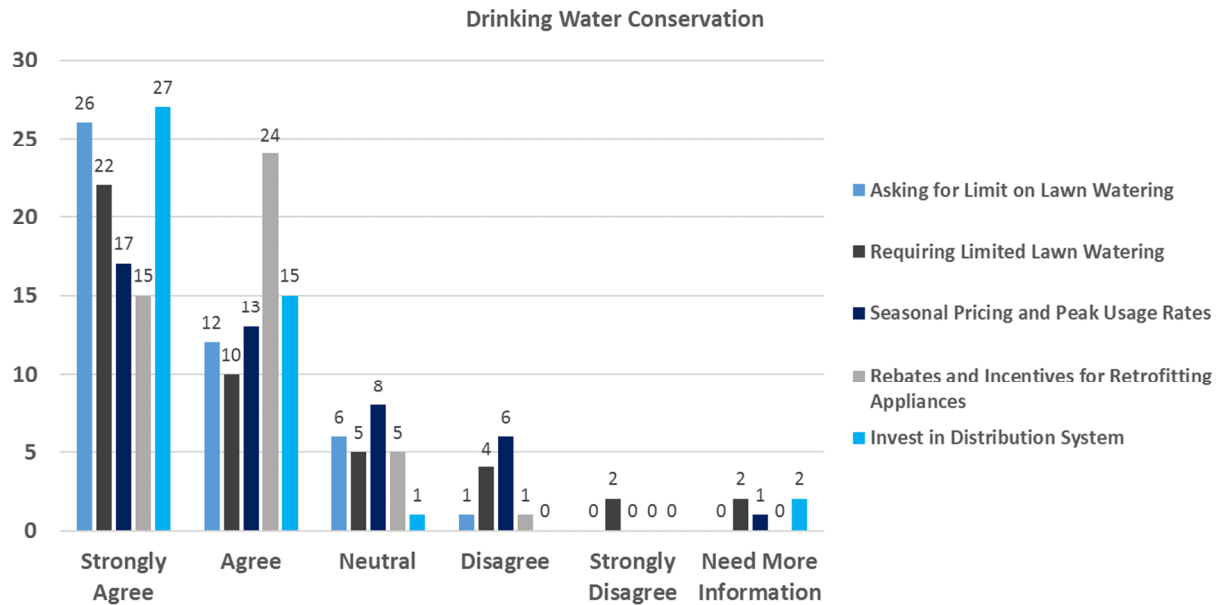


Figure 7-6: Drinking Water Conservation Public Survey Results

The results of the survey showed most responders either strongly agreed or agreed with implementation of conservation measures. The two most favorable responses were requesting volunteer watering restrictions and investment in distribution systems. Table 7-1 further summarizes the results of the conservation responses.

TO CONSERVE WATER, I'M WILLING TO:	RESIDENTIAL CUSTOMERS	COMMERCIAL CUSTOMERS
Replace leaking faucets and toilets	85%	86%
Change landscape from grass to trees & shrubs	57%	45%
Change my lawn watering schedule	68%	53%
Install a rain barrel	57%	38%

8.0 Cost Estimation Development

8.1 APPROACH AND METHODOLOGY

Cost estimates were developed for all of the alternatives based on existing cost models and recent bid or project data. Additional amounts for general requirements (permitting, contingencies) and engineering, legal, and administrative costs were combined to obtain a total estimated capital cost for the project. Quantities for structures, building, process components, pipeline lengths, and basin sizes were developed based on preliminary process sizing of the treatment components, preliminary site layout, and similar regional plant facilities.

The cost data pertaining to the McBaine water treatment plant has been assessed as a part of previous studies, including the cost to rehabilitate the plant at its current size. The plant expansions are based on detailed understanding of the existing equipment and facilities and what would be required to expand at various increments.

Ten percent of the construction cost was added to all components of the water treatment facility as an allowance for mobilization(s), bonds, insurance, supervision, temporary facilities, temporary utilities, equipment rental, and miscellaneous for the water treatment plant construction.

Contingencies are defined as unknown or unforeseen costs. The level of detail available at the planning/conceptual phase of the project does not provide sufficient definition to fully capture all the costs associated with the project. The Association for the Advancement of Cost Engineering (AACE International) defines five levels of “class estimates” that are typically used for planning purposes. These range in level of complexity from Class 5 (generally associated with conceptual level evaluations) to Class 1 (prepared to confirm the control baseline for a project). A Class 4 Estimate was utilized for this project. Following is a brief description of a Class 4 estimate:

Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, confirmation of economic and/or technical feasibility, and preliminary budget approval. Typically, engineering is from 1% to 15% complete. Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.

Based on this, twenty five percent of the construction cost was added to each component of the treatment facility as a contingency, which is customary for projects at this level of development. Costs for engineering, easements, permitting and project approvals, legal, and administration is included at 18 percent of the construction cost.

The construction costs were annualized over a 30 year period with an interest rate of 5 percent to develop a relative cost per gallon of expansion. These annualized costs do not factor in operation and maintenance costs.

The Unified Cost Model was developed as a part of the Texas Regional Water Planning process, and used for projects proposed across all 16 planning regions which develop 50 year water supply plans. The cost

model includes estimated costs for facilities and appurtenances for wells, pipeline, treatment, storage, and other supply components up to, but not including, local-level distribution. Where applicable, the model costs were updated to more site specific cost information. Land and construction cost inputs were updated in the Cost Model based on recent bids or completed projects where that information was available. This model was primarily used for the development of cost estimates for non-potable alternatives, and was populated with the potable alternatives for comparison to the costs developed using more detailed information for verification purposes. Table 8-1 summarizes the assumptions used in development of cost estimates.

Table 8-1 Assumptions in Capital Cost Estimates

COST PARAMETER	ASSUMPTION
Land cost (outside city limits, "good cropland" estimate) ⁴⁴	\$5,283/acre
Land cost (small parcel, inside city limits) ⁴⁵	\$52,830/acre
Land cost (large parcel, inside city limits) ⁴⁶	\$21,132/acre
Engineering	18% of construction costs
Contingencies	25% of construction costs
General Requirements	10% of construction costs
Interest	5.0 %
Loan duration	30 years
Producer Price Index Factor (November, 2015)	205.8
Construction Cost Index Factor (November, 2015)	10092

8.2 CAPITAL COSTS

8.2.1 Potable Supply Capital Costs

A preliminary opinion of probable construction cost was prepared for vertical well supply and collector well supply alternatives that would deliver additional flow to the McBaine Water Treatment Plant for treatment and distribution into the system. Table 8-2 summarizes the costs for vertical well field alternatives at various peak day capacities. Table 8-3 summarizes the costs for each collector well field expansion alternative.

⁴⁴ Plain, Ron and Joyce White. "Missouri Farm Land Values Opinion Survey, 2015." Agricultural Economics Newsletter, University of Missouri Extension. <http://agebb.missouri.edu/mgt/landsurv/landsurv15.pdf>

⁴⁵ Assume land cost for satellite treatment facilities are within the urban areas and limited in location alternatives, and therefore more costly. A multiplier of 10 was used on the rural land cost.

⁴⁶ Assume land cost for stormwater retention facilities are within the urban areas and preferentially low-lying areas, and therefore more costly than rural land and less costly than small parcels. A multiplier of 4 was used on the rural land cost.

Table 8-2 Potable Water Treatment Expansion Capital Costs with Vertical Wells

	Alternative 1: Vertical Well Field Expansion			
EXPANSION COSTS	5MGD	10MGD	16MGD	20MGD
Well Supply	\$2,525,000	\$5,049,000	\$7,574,000	\$10,098,000
Raw Piping to Site	\$3,060,000	\$3,060,000	\$3,060,000	\$3,528,000
Plant Expansion	\$17,739,000	\$23,840,000	\$29,505,000	\$36,581,000
TOTAL	\$23,324,000	\$31,949,000	\$40,139,000	\$50,207,000
Annual Costs	\$1,517,000	\$2,078,000	\$2,611,000	\$3,266,000
Cost per 1,000gal (average)	\$1.41	\$0.97	\$0.76	\$0.76
Cost per 1,000gal (peak)	\$0.83	\$0.57	\$0.45	\$0.45

Table 8-3 Potable Water Treatment Expansion Capital Costs with Collector Wells

	Alternative 2: Collector Well Field Expansion			
EXPANSION COSTS	5MGD	10MGD	16MGD	20MGD
Well Supply	\$11,316,000	\$11,316,000	\$22,632,000	\$22,632,000
Raw Piping to Site	\$4,162,000	\$4,162,000	\$4,162,000	\$4,813,000
Plant Expansion	\$18,189,000	\$24,113,000	\$29,814,000	\$37,424,000
TOTAL	\$33,667,000	\$39,591,000	\$56,608,000	\$64,869,000
Annual Costs	\$2,190,000	\$2,575,000	\$3,682,000	\$4,220,000
Cost per 1,000gal (average)	\$2.04	\$1.20	\$1.07	\$0.98
Cost per 1,000gal (peak)	\$1.20	\$0.71	\$0.63	\$0.58

The costs above do not include rehabilitation costs of the well field and water treatment plant required to continue to operate the facility and restore peak reliable capacity to 32 MGD. The preliminary estimated costs of the plant rehabilitation improvements are approximately \$18M and are required whether the plant is expanded or not. Therefore, the rehabilitation costs would be applied to any of the alternatives developed.

Distribution piping costs are not included in the costs for potable water supply alternatives as any new development would still require a distribution system sized for fire flow requirements, which is typically the controlling factor when designing a distribution system. Thus, lowering the expected potable water demand for a service area does not typically reduce the size of the distribution system.

8.2.2 Non-Potable Supply Capital Costs

Capital costs were developed for the non-potable water supply alternatives. The capital costs include source water supply development, treatment, pumping, and distribution system piping. Costs were developed for both single point end user applications and residential irrigation systems with large distribution networks.

For single point end user applications such as industrial or commercial use, an estimated one mile pipeline was assumed from the non-potable supply source to the user. For these applications the pipeline and pump station were sized to accommodate the annual average supply with no peaking factor.

A non-potable distribution system intended for residential irrigation must be designed for the peak demand for the area served by that system. The peak instantaneous demand for a system is significantly larger than the average annual irrigation usage, or even the average monthly demand since most people water in the morning. For dedicated non-potable system, the size of the piping is a function of the area served by the system and the number of lawns being watered at one time. Most non-potable irrigation systems require specific irrigation scheduling ordinances to minimize the instantaneous water demand from the system to avoid larger pumping and distribution piping systems. Even with these restrictions, the distribution piping system would still be substantial. For example, an annual average 1 MGD non-potable water source could supply sufficient capacity for 1,720 acre residential area, assuming an average lot size of 1 acre and irrigation applied to 30% of the land area. Assuming restrictions were in place to prevent no more than 1/8th the homes sprinkling at one time (thus allowing 4 – 1 hour water periods per day), the instantaneous peak demand for that non-potable system would be about 3,200 gallons per minute (4.6 MGD). To meet this instantaneous demand the non-potable pump station would need to match this capacity, or elevated non-potable storage would be required. In addition, the main trunk line of the irrigation system would need to be sized to convey this flow rate. A 4.6 MGD instantaneous demand would require a 16 inch pipeline.

Table 8-4 summarizes distribution system costs based on various supply capacities and areas served. Capital costs include both distribution piping and also required pumping.

Table 8-4 Distribution System Capital Costs

	Distribution Systems		
Annual Capacity	0.25 MGD	0.5 MGD	1 MGD
Peak Day Capacity	0.675 MGD	1.35 MGD	2.7 MGD
Distribution System Sizing			
Average Lot Size	1 acre	1 acre	1 acre
Percent Area Irrigated	30%	30%	30%
Service Area, acres	430	860	1720
% Lots Irrigating at One Time	13%	13%	13%
Peak Instantaneous Flow, MGD	1.16	2.32	4.65
TOTAL CAPITAL COST	\$3,326,000	\$6,892,000	\$15,114,000
Annual Costs	\$216,000	\$448,000	\$983,000
Cost per 1,000 gal (average)	\$2.37	\$2.45	\$2.69
Cost per 1,000 gal (peak)	\$0.88	\$0.91	\$1.00

Table 8-6 shows capital costs for each alternative using an annual average capacity of 1 MGD. As discussed previously, there are many variations for flows and configurations for non-potable use. For

instance, a larger watershed area will result in a lower capital cost as the size of the detention basin is decreased. How far away the supply source is to the user also has a significant impact on costs.

Modeled scenarios in Chapter 9 include variations of supplies, capacities, and distribution systems to establish a full range of costs, including operational and maintenance costs. Operation and maintenance costs will impact the overall costs to implement, and are discussed in detail in section 8.2.3. Therefore, this table should be used as a means to general compare the capital costs for each alternative.

Table 8-5 Non-Potable Capital Costs (Based on 1 MGD Annual Average)

	Wastewater Reuse		Ground water	Stormwater Catchment		
	Central	Satellite		Small Watershed	Medium Watershed	Large Watershed
Annual Capacity	1 MGD	1 MGD	0.33 MGD	1 MGD	1 MGD	1 MGD
Peak Day Capacity	2.7 MGD	2.7 MGD	1 MGD	2.7 MGD	2.7 MGD	2.7 MGD
Irrigation non-potable						
Supply and Treatment	\$6,015,000	\$18,268,000	\$725,000	\$5,749,000	\$3,474,000	\$2,602,000
Distribution and Pumping	\$15,114,000	\$15,114,000	\$3,326,000	\$15,114,000	\$15,114,000	\$15,114,000
TOTAL	\$21,129,000	\$33,383,000	\$4,052,000	\$20,863,000	\$18,588,000	\$17,716,000
Annual Costs ¹	\$3,448,000	\$5,236,000	\$768,000	\$3,409,000	\$3,068,000	\$2,937,000
Cost per 1,000gal (average)	\$9.45	\$14.35	\$6.38	\$9.34	\$8.41	\$8.05
Cost per 1,000gal (peak)	\$3.50	\$5.31	\$2.10	\$3.46	\$3.11	\$2.98
Single Point Non-Potable						
Supply and Treatment	\$6,015,000	\$18,268,000	\$725,000	\$5,749,000	\$3,474,000	\$2,602,000
Distribution and Pumping	\$638,000	\$638,000	\$319,000	\$638,000	\$638,000	\$638,000
TOTAL	\$6,653,000	\$18,906,000	\$1,044,000	\$6,387,000	\$4,112,000	\$3,240,000
Annual Costs ¹	\$1,204,000	\$3,116,000	\$226,000	\$1,161,000	\$779,000	\$627,000
Cost per 1,000gal (average)	\$3.30	\$8.54	\$1.88	\$3.18	\$2.13	\$1.72
Cost per 1,000gal (peak)	\$1.22	\$3.16	\$0.62	\$1.18	\$0.79	\$0.64

8.2.3 Operations and Maintenance

Operation and maintenance (O&M) costs for each alternative were divided into fixed and variable costs. Fixed costs pertain to the staffing requirements and maintenance of the equipment. Variable costs, such as power requirements, cost of pumping, and chemical the cost of pumping, vary with the amount of water delivered. All the variable costs are based on an average annual rate for each alternative.

8.2.3.1 Maintenance Costs

The maintenance costs were calculated as a percentage of the total estimated cost of the equipment installed based on Black & Veatch experience and reference to percentages used in the Texas Unified Cost Model. Table 8-6 summarizes the estimated maintenance costs for major system components.

Table 8-6 Assumptions in Maintenance Costs

COST PARAMETER	ASSUMPTION
Pipeline Maintenance Costs	1.00% Capital Cost
Water Treatment Plants/Pump Stations	3.0% Capital Cost
Dam/Reservoir O&M	1.50% Capital Cost
Producer Price Index Factor (November, 2015)	205.8
Construction Cost Index Factor (November, 2015)	10092

8.2.3.2 Staffing Requirements

While there are no regulations establishing the number of operators and support staff required for a water treatment plant or management of non-potable supplies, Missouri Department of Natural Resources (MDNR) does designate requirements for the class of operator needed at plants based on the size of the plant as well as the complexity of treatment processes needed to treat the raw water to exceed all minimum water quality regulatory limits. Additional staffing was estimated for the alternatives based on the complexity of the system, water quality requirements, additional maintenance, and operation of the system.

For the potable water alternatives, additional staffing was minimal as the processes would be similar to what are currently being utilized at the plant. Water quality, pond and pumping maintenance, distribution systems, and administration staffing were included for the stormwater and groundwater non-potable supply alternatives. Additional operating staffing was included for any satellite water reuse facilities.

8.2.3.3 Power Costs

Power costs for equipment and pumps are a function of the electricity requirements to operate the equipment at the average plant production. The total average power requirement was multiplied by the cost of electricity to establish the power costs. A unit cost of \$0.09/kWhr was used to establish power costs.

8.2.3.4 Chemical Costs

Annual chemical costs were estimated based on the raw and finished water parameters, water produced, and available chemical prices. For the potable supply alternatives current chemical costs were used to establish additional costs for the higher treated flows. For non-potable systems requiring disinfection estimated chemical feed rates and costs were developed.

8.2.3.5 Total Annual Operation and Maintenance Costs

Table 8-7 summarizes the annualized operation and maintenance costs for the supply alternatives. The non-potable supply alternatives have been shown at 1 MGD annual average supply capacity. Many variations of supply capacities are available for the non-potable alternatives. These variations and costs are incorporated into the model scenarios.

Table 8-7 Annual Operation and Maintenance Costs

	Single Point Distribution		Residential Irrigation	
Peak Day Capacity	Annual O&M	Cost/1000 gal	Annual O&M	Cost/1000 gal
Potable Supply - Vertical Wells				
5 MGD (2.9 MGD Average)	\$582,000	\$0.54	\$582,000	\$0.54
10 MGD (5.9MGD Average)	\$1,024,000	\$0.48	\$1,024,000	\$0.48
16 MGD (9.4MGD Average)	\$1,626,000	\$0.47	\$1,626,000	\$0.47
20 MGD (11.8MGD Average)	\$2,007,000	\$0.47	\$2,007,000	\$0.47
Potable Supply - Collector Wells				
5 MGD (2.9 MGD Average)	\$787,000	\$0.73	\$787,000	\$0.73
10 MGD (5.9MGD Average)	\$1,151,000	\$0.54	\$1,151,000	\$0.54
16 MGD (9.4MGD Average)	\$1,914,000	\$0.56	\$1,914,000	\$0.56
20 MGD (11.8MGD Average)	\$2,238,000	\$0.52	\$2,238,000	\$0.52
Wastewater Reuse				
Centralized - Single Point	\$789,000	\$2.16	\$806,000	\$2.21
Satellite - Single Point	\$1,752,000	\$4.80	\$1,773,000	\$4.86
Stormwater				
Small Watershed (1MGD)	\$376,000	\$1.03	\$607,000	\$1.66
Medium Watershed 1 MGD)	\$361,000	\$0.99	\$592,000	\$1.62
Large Watershed (1 MGD)	\$355,000	\$0.97	\$587,000	\$1.61
Groundwater (1 MGD)	\$132,000	\$0.36	\$288,000	\$0.79

8.2.4 Conservation Costs

Costs for implementing a conservation program were described in previous chapters. To provide a comparison between potable and non-potable supplies the conservation costs were annualized based on overall costs to implement the program. Table 8-8 summarizes the conservation costs.

Table 8-8 Conservation Annualized Costs

	Full Conservation	Irrigation Only	No Irrigation
Annual Capacity	1 MGD	0.5 MGD	0.4 MGD
Peak Day Capacity	4.7 MGD	2.5 MGD	2.3 MGD
Present Worth Capital Costs	\$4,267,000	\$568,000	\$3,699,000
Yearly O&M Costs	\$338,000	\$338,000	\$338,000
TOTAL	\$615,000	\$374,000	\$572,000
Cost per 1,000gal (average)	\$0.93	\$1.85	\$2.32
Cost per 1,000gal (peak)	\$0.36	\$0.41	\$0.68

8.2.5 Annualized Costs

The capital and operational costs for each alternative are annualized in Figure 8-1 over a 30 year period at interest rate of 5 percent.

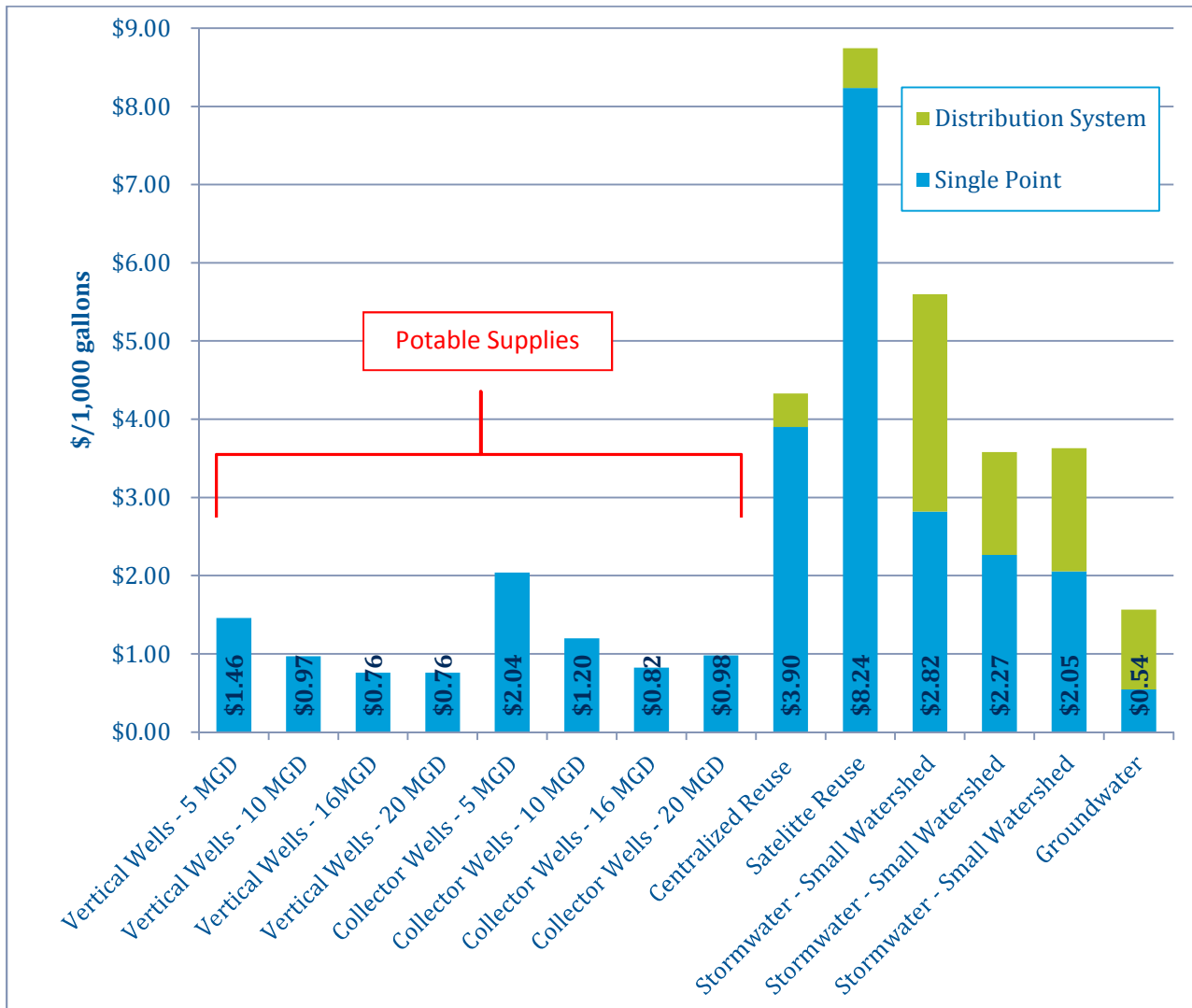


Figure 8-1 Annualized Costs (Based on Average Demand)

Analysis of the annualized costs show that generally the potable supply alternatives are less costly to implement than non-potable supplies, especially if distribution piping is required, with the exception of groundwater non-potable wells. Groundwater supply wells have similar annualized costs as potable supply alternatives.

9.0 Model Development

A model was developed to evaluate various scenarios of supply alternatives to meet the City's current and future demands. The model platform used, GoldSim, is a decision-making tool which can be used to help answer the following critical questions as they plan water supply system improvements:

- When should the water treatment plant be expanded to continue to provide reliable service?
- How should the plant be supplied with raw water?
- What should the plant capacity be to reliably meet demands over a 25-year planning period?
- How can conservation measures and alternative water supplies affect decisions regarding the plant expansion?
- How much will various portfolios of potable supplies, non-potable supplies, and demand management programs cost?

In order to answer these questions, work has been conducted to characterize available potable water supplies, forecast future demand, determine opportunities for demand reduction through conservation measures, and identify potential non-potable supply sources and uses, as discussed in previous sections.

This information has been combined into an integrated decision tool which allows the user to act as a system planner by selecting and scheduling potable supplies, non-potable supplies, and conservation programs.

9.1 GOLDSIM PLATFORM DESCRIPTION

The model is constructed on the GoldSim platform. GoldSim is a flexible system simulation software package. Models are distributed as Player files, which may be opened and run with a freely available version of the GoldSim software. The model user builds scenarios and views output charts, tables, and metrics through a series of dashboards. The model user may also browse underlying functions and model logic if desired, but may not change the calculations.

The GoldSim Model has been constructed to evaluate the costs and reliability of meeting demands through demand management and new or expanded supplies.

9.2 MODEL STRUCTURE

The model runs through a simulation period of 2016-2040. Each selected portfolio of supply and demand management options may be saved as an individual scenario. The model is populated with several illustrative scenarios. Users may also add or delete custom scenarios. The model then performs an annual mass balance to analyze the scenario over a 25-year planning period and generates outputs characterizing the ability of the system to meet forecasted peak demands and average annual demands. Total and annual costs for the selected options are also tabulated.

Appropriate relationships are maintained for interrelated variables. For example, if a selected conservation best management practice (BMP) reduces indoor water use, then there is a corresponding reduction in the amount of water available to capture for reuse. Figure 9-1 shows the general model overview.

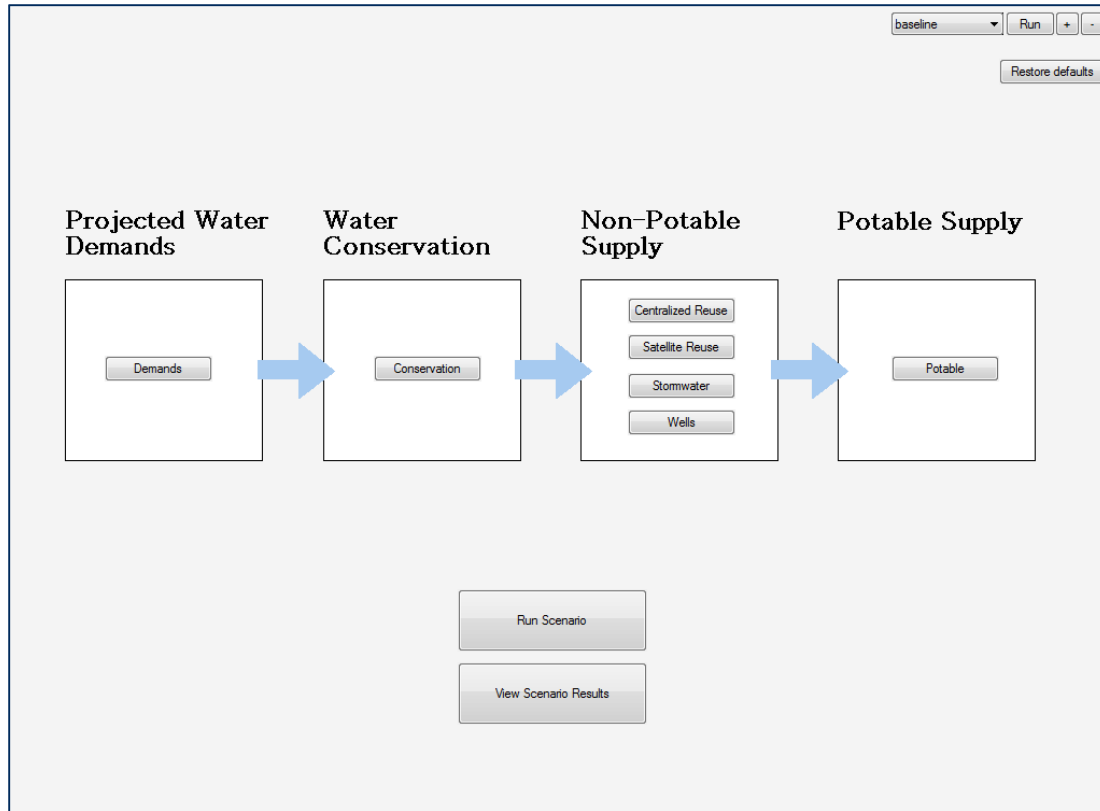


Figure 9-1 Model Overview Screen

9.3 MODEL ASSUMPTIONS

9.3.1 Potable Water Supplies

Current wellfield and WTP capacity constitutes the baseline for potable supplies. The WTP begins with a 24-mgd reliable capacity as estimated by the recent condition assessment. This capacity must be restored to the rated 32-mgd capacity by specifying the recommended retrofit project before further plant expansion is applied. Potable supply is taken to be the capacity of the water treatment plant or wellfield that supplies the plant, whichever is more limiting.

9.3.2 Demands

Future customer demands are estimated based on forecasts of number of accounts, usage per account, and a peaking factor. Each of these parameters is input as an independent annual time series. A separate annual forecast of non-revenue water is added to customer demands to give total system demands. Annual growth assumptions, which may be modified by the user, affect the increase in the number of accounts throughout the simulation period. Figure 9-2 shows the available growth assumptions that are capable of being modified.

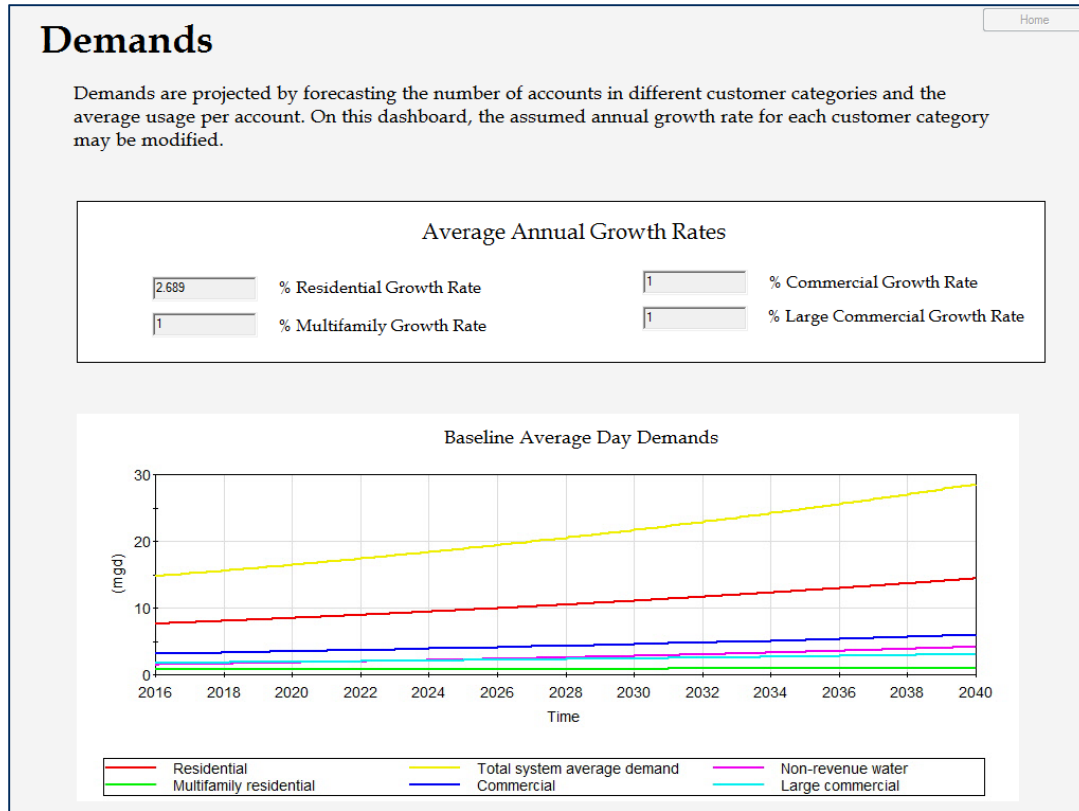


Figure 9-2 Demand Model User Screen

Selected conservation BMPs affect the usage per account. Different BMPs target different customer demand components, for example residential or commercial usage. The irrigation-focused conservation ordinance uniquely affects the peaking factor applied to transform average annual daily demands to maximum daily demands.

9.3.3 Non-Potable Supplies

Non-potable supplies were modeled from the three different sources discussed in previous sections (groundwater, stormwater, and wastewater). All non-potable systems are limited in quantity both by the available supply as well as reasonable demand. All non-potable alternatives were limited to a total of annual capacity of 3 MGD, which represents a conservative estimate of current or future potable demands which could be offset by non-potable supplies.

The type of uses considered were irrigation and industrial, which guided the design of the distribution system and assumptions about the pattern of use. Daily demands for irrigation water from the pond were modeled on the monthly distribution of demand in irrigation meter records from the City of Columbia’s voluntary irrigation metering program. The supply and distribution systems for irrigation demand are estimated based on a meeting peak irrigation flows described in previous sections, with monthly peaking factor of 2.7, and peak instantaneous flows as described in previous sections.

Industrial users of non-potable water were assumed to have a constant demand, so supplies were not designed with a peaking factor and distribution systems were estimated based on 2 miles of trunk line, without any additional distribution network.

9.3.3.1 Wells

Non-potable wells have both an associated average annual capacity and peak capacity used to meet average annual and maximum day demands.

9.3.3.2 Storm ponds

Storm ponds are modeled as a monthly output. This output was provided by modeling conducted to characterize this non-potable supply availability based on precipitation and evaporation inputs and a demand pattern derived from irrigation usage records. Six different watershed locations are available for locating the stormwater pond. Specific costs have been developed for each location based on the watershed area. Figure 9-3 shows the available user inputs for stormwater model inputs.

Figure 9-3 Stormwater Model User Screen

9.3.3.3 Reuse

Reuse is first calculated as a goal, set by the selected facility capacity. The model checks the availability of wastewater to meet this goal. Wastewater availability is calculated as potable water usage times an indoor usage percent, so reductions in usage due to conservation also affect reclaimed water availability. Additionally, water available for centralized reuse is also affected by water diverted for satellite reuse prior to delivery to the WWTP. Figure 9-4 shows the available user inputs for satellite reuse model inputs.

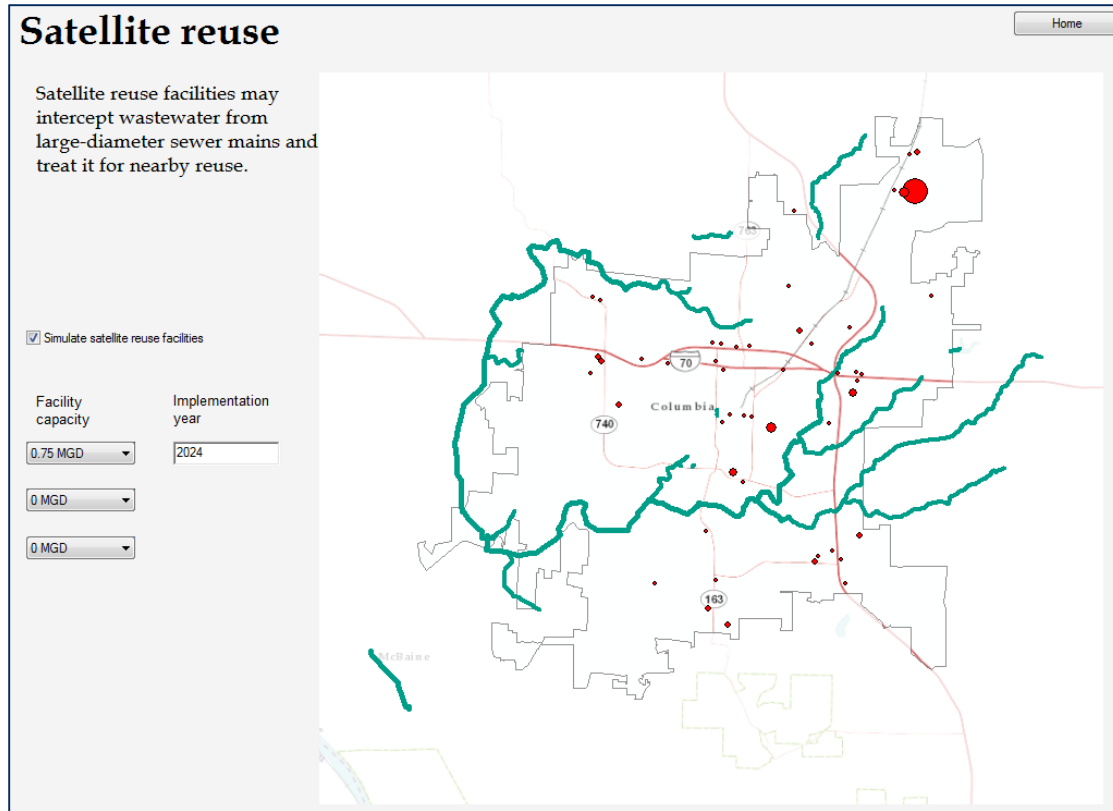


Figure 9-4 Satellite Model User Inputs

9.3.3.1 Conservation

Conservation inputs include selection of any of the available ordinances or programs described in previous sections. If any conservation measure is selected annual costs for operation of the system, including conservation coordination, water audits, public information, and school education are applied throughout the entire planning period. Figure 9-5 shows the available user inputs for conservation model inputs.

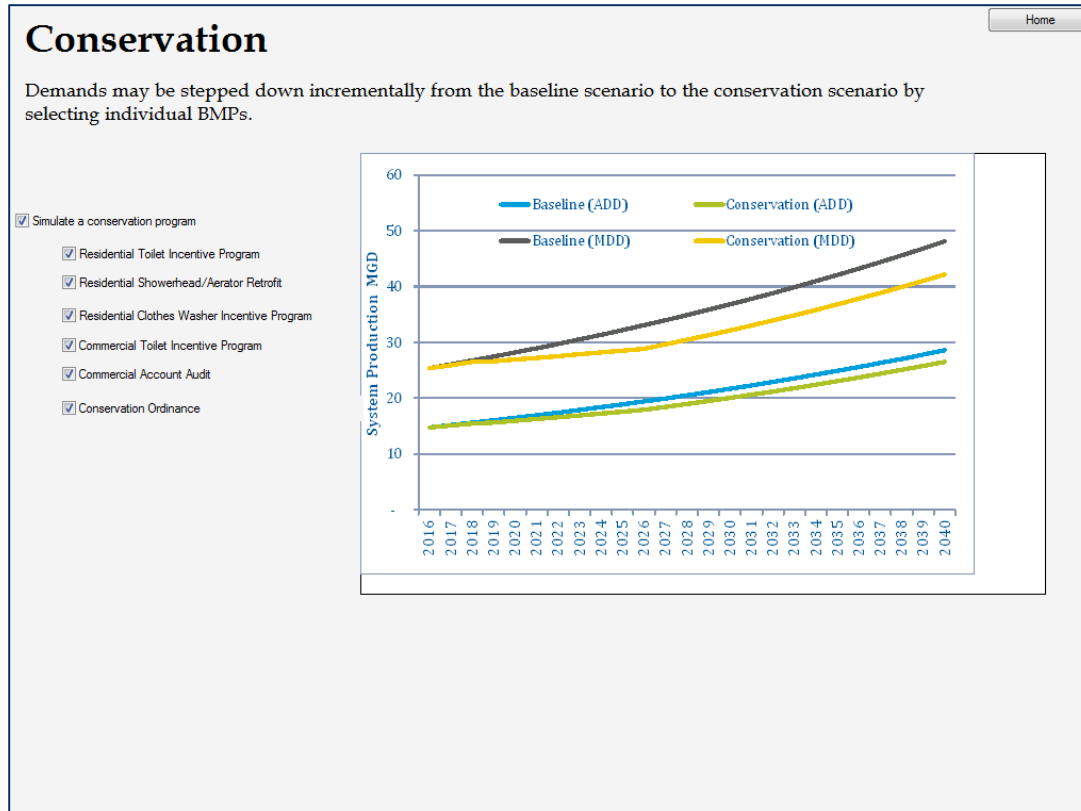


Figure 9-5 Conservation Model User Inputs

9.4 CAPABILITIES AND LIMITATIONS

For each scenario constructed by the user, the model produces an output time series, available as charts or tabular outputs:

- Average demands by customer category, annual system average and maximum demands as composed of customer demands and non-revenue water.
- Supplies provided by potable and non-potable sources.
- Total scheduled supplies and annual demands plotted together for a visual representation of the calculated supply reliability metrics.
- A single net present value roll-up cost for selected capital projects and conservation programs
- An annual expenditure schedule with estimates for debt service, energy costs, and other annual O&M costs for selected capital projects and conservation programs.
- Average annual and maximum day reliability:

These metrics are expressed as percentages. They represent the proportion of years in the simulation period during which scheduled supplies are sufficient to meet projected average and maximum day demands.

The main output dashboard allows the model user to choose among different scenarios and view both the scheduled supplies and demands which define each and the corresponding cost and reliability

summary. Buttons on this dashboard allow the user to open charts and access tabular data in order to drill down into more specific outputs by year and cost category.

Figure 9-6 illustrates the dashboard for the model.

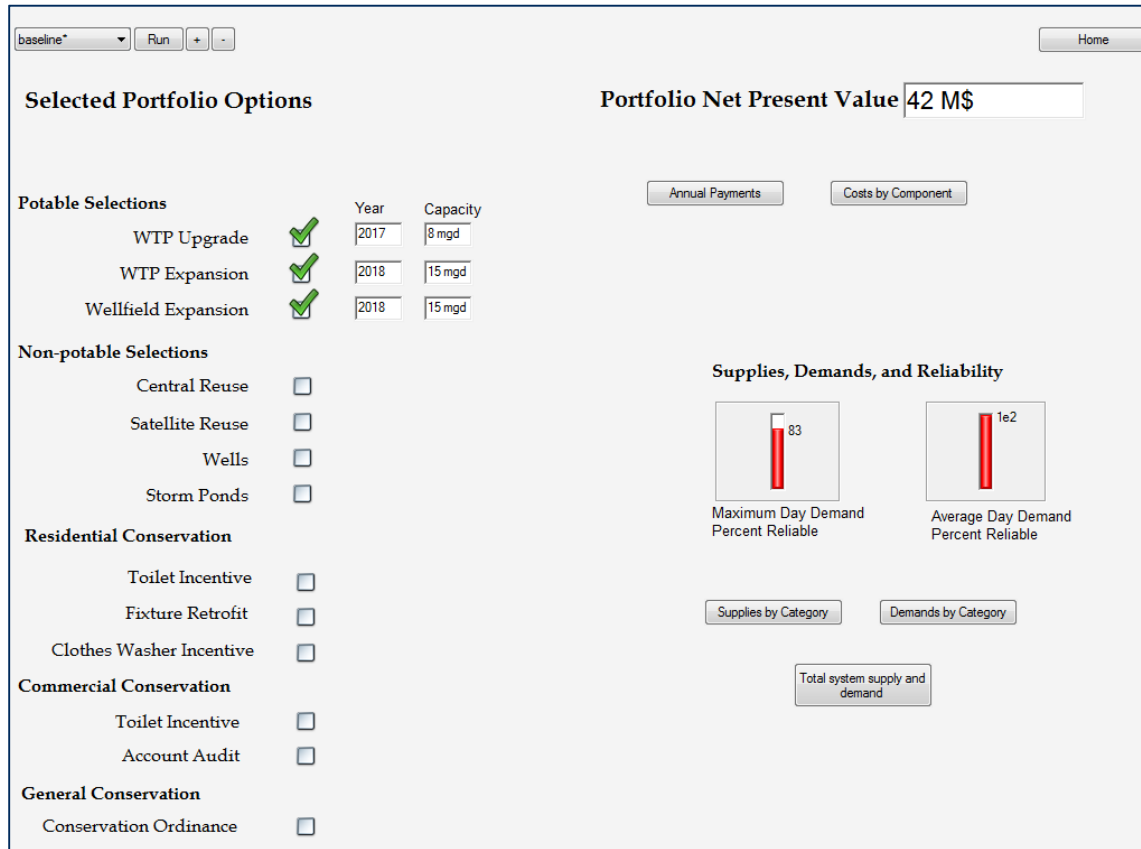


Figure 9-6 Model Dashboard with Results

The model is intended for high-level screening of different water supply options. While estimates of energy costs and distribution costs for non-potable options are provided, the model does not contain a detailed physical representation of the service area or distribution system. Maximum day demands for each year are appropriately matched to peak facility capacities, but generally inputs and results are at an annual time step.

10.0 Scenario Definitions

A range of nine scenarios were selected to represent possible supply configurations. These scenarios are shown in terms of peak supply at full implementation and annual cost. All of the selected scenarios are designed to meet the median demand projection, although demand can be varied in the model.

The annual costs are shown in Table 10-1 for each major component, including debt service and O&M, at the decade of full implementation. The rehabilitation of the WTP is not included as a line item cost in each scenario, but it is required for any expansion of WTP, and is the same annual cost for every scenario (\$1,814,300). A scenario that satisfies the study timeframe must have total supply capacity of 48 MGD. Some of the scenarios may fall slightly short of this requirement.

Table 10-1 Supply Scenarios

SCENARIO #	SOURCE DETAILS	PEAK (MGD)
1	Potable Water Expansion Only	
	16 MGD Expansion of McBaine Water Treatment Plant	48
2	Limited WTP Expansion & Conservation	
	10 MGD Expansion of McBaine Water Treatment Plant	42
	Conservation	4.8
3	WTP Expansion, Conservation	
	Partial 16 MGD Expansion of McBaine Water Treatment Plant, Phased Expansion	43 to 48
	Conservation	4.8
4	WTP Expansion, Conservation, & Non-Potable Groundwater	
	10 MGD Expansion of McBaine Water Treatment Plant	42
	Conservation	4.8
	2 Non-Potable Groundwater Wells (Irrigation)	2.0
5	WTP Expansion, Non-potable Wells	
	10 MGD Expansion of McBaine Water Treatment Plant	42
	3 Non-Potable Groundwater Wells (Point Source)	8.3
6	WTP Expansion & Stormwater Ponds	
	10 MGD Expansion of McBaine Water Treatment Plant	42
7	WTP Expansion, Stormwater Ponds & Conservation	
	10 MGD Expansion of McBaine Water Treatment Plant	42
	Stormwater Pond	1.4
	Conservation	4.8
8	WTP Expansion, Centralized Reuse & Conservation	
	10 MGD Expansion of McBaine Water Treatment Plant	42
	Centralized Wastewater Reuse	2
9	WTP Expansion, Satellite Reuse & Conservation	
	10 MGD Expansion of McBaine Water Treatment Plant	42
	Satellite Reuse	2
	Conservation	4.8

11.0 Model Results

11.1 SCENARIO 1: 16 MGD POTABLE

11.1.1 Overview of Implementation Timeline and Supplies

This scenario includes expanding the existing water treatment plant to meet all demands through 2040, with no implementation of conservation programs or non-potable supplies. The expansion of the plant would consist of the rehabilitation to restore existing capacity to 32 MGD, and expansion of the water treatment plant by constructing a new process train sized for 16 MGD to provide a plant capacity of 48 MGD. Additional raw water supply is required, and both vertical wells and collector wells were considered. The vertical well field assumes the water supply would remain classified as a groundwater supply. The variation utilizing collector wells includes converting the plant process to be capable of treating water classified as groundwater under the influence of surface water.

11.1.2 Cost Analysis

Estimated costs were developed for this alternative for both additional vertical wells supplying the McBaine Treatment Plant and for new collector wells supplying a modified plant capable of meeting water quality requirements for source water classified under the influence of surface water. Each alternative includes costs for rehabilitation of the existing plant. Table 11-1 summarizes the costs for both options.

Table 11-1 Scenario 1 Cost Analysis

SCENARIO #	SOURCE DETAILS	PEAK (MGD)	\$/YR
1A	16 MGD Potable (Vertical Wells)		
	16 MGD Expansion of McBaine Water Treatment Plant	48	\$6,051,000
		TOTAL	\$6,051,000
1B	16 MGD Potable (Collector Wells)		
	16 MGD Expansion of McBaine Water Treatment Plant	48	\$6,590,000
		TOTAL	\$6,590,000

11.1.3 Reliability and Implementation

Both alternatives satisfy the projected demand requirements until year 2040. Based on the current flow projections implementation of the rehabilitation of the plant should occur in the near future with the expansion to be completed prior to year 2022.

This scenario has a very high level of reliability associated with the abundant supplies from the McBaine Wellfield and standard treatment and delivery facilities. There are likely to be minimal issues with permitting this alternative, and construction activities are mostly limited to areas where facilities already exist (except the new well locations).

This scenario limits the environmental impact of construction. Continuing environmental impacts during operation include the energy use required for the WTP and for pumping treated water, and possible impacts on direction or character of transport in the aquifer.

The costs for this alternative are higher than the more limited WTP expansion scenarios which include conservation programs. However, there is some degree of uncertainty associated with reductions in demand associated with conservation, which makes those scenarios slightly less reliable.

11.2 SCENARIO 2: 10 MGD + CONSERVATION

11.2.1 Overview of Implementation Timeline and Supplies

Scenario 2 examines the impact of limiting the plant expansion to 10 MGD versus the 16 MGD included in Scenario 1 and offsetting the reduced capacity by implementation of the conservation program. It is anticipated the City would implement the conservation program that would include replacement of high water use toilets, washers, and showerhead, and initiate an irrigation scheduling ordinance. It is estimated by the end of the planning period a potential peak day reduction of about 4.8 MGD could be achieved assuming the conservation program was actively promoted and accepted within the community.

11.2.2 Cost Analysis

Table 11-2 summarizes estimated annualized costs for this Scenario.

Table 11-2 Scenario 2 Cost Analysis

SCENARIO #	SOURCE DETAILS	PEAK (MGD)	\$/YR
2	16 MGD + Conservation		
	10 MGD Expansion of McBaine Water Treatment Plant	42	\$4,917,000
	Conservation	4.8	\$615,000
		TOTAL	\$5,532,000

11.2.3 Reliability and Implementation

This alternative provides a total supply capacity of 46.8 MGD, which is 1.2 MGD short of the 2040 demand estimates. Based on the flow projections the demand would exceed supply in year 2038.

This scenario includes the smallest quantity of supplied water (potable or non-potable) coupled with a conservation program. The costs are lower as a result, but the reliability of the facilities to meet peak demands is lower than other alternatives.

The uncertainty associated with the demand reductions from conservation has potential to result in shortfalls. For all conservation programs, monitoring the efficacy can be difficult but critical to the success of the program. Conservation has the environmental benefit of reducing overall demands on a water system, and therefore reducing the need for both water and the chemicals and power required to treat and pump it. The challenge with this scenario is the known effectiveness of conservation will not be realized for some time.

11.3 SCENARIO 3: PARTIAL 16 MGD + CONSERVATION

11.3.1 Overview of Implementation Timeline and Supplies

Alternative No. 3 includes a partial 16 MGD expansion and conservation. The partial 16 MGD expansion would include initially constructing the process train (basins, filters, clearwell, pump station) able to treat a capacity of 16 MGD, but the remaining treatment components, such as well field, pipelines, aerators, chemical feed systems, to be expanded only when needed based on supply needs. Many of these facilities, such as the well and aerators, can be increased in capacity incrementally over time with minimal impact to operations.

Conservation would play a critical component to this plan as it will allow the expansion of the remaining facilities to potentially be delayed, and the overall peak day of the capacity of the plant to be reduced. The effectiveness of conservation measures could be re-evaluated in 5-7 years, at which point demand projections could be adjusted and its impact on overall implementation of the remaining improvements.

11.3.2 Cost Analysis

Table 11-3 summarizes the annualized costs for this Scenario.

Table 11-3 Scenario 3 Cost Analysis

SCENARIO #	SOURCE DETAILS	PEAK (MGD)	\$/YR
3	WTP Expansion, Conservation		
	16 MGD Expansion of McBaine Water Treatment Plant, Limited Wellfield Expansion	44	\$5,109,000
	Conservation	4.8	\$615,000
		TOTAL	5,724,000

11.3.3 Reliability and Implementation

Expanding the process components to full plant to the full capacity and allowing the conservation program to be implemented provides a reliable approach to meeting demands on the water system. If the conservation program is not as effective as projected, the project could be adjusted by moving up the schedule of additional well installations. Similarly, the wellfield construction can be adjusted if the City's growth varies from the projections. Therefore, this scenario is slightly more costly than Scenario 2, but provides a much more reliable supply and is easily adjusted to meet changes in demands.

11.4 SCENARIO 4: 10 MGD POTABLE + CONSERVATION + WELLS (IRRIGATION)

11.4.1 Overview of Implementation Timeline and Supplies

This scenario includes expansion of the treatment plant by 10 MGD, implementation of conservation, and installation of three 1 MGD non potable groundwater wells. In this scenario, the well water is used for irrigation purposes, so the average annual capacity is 0.4 MGD with a peak production of 1 MGD and a distribution system sized to handle concentrated demands in the peak watering season.

11.4.2 Cost Analysis

Table 11-4 summarizes the annualized costs for this Scenario.

Table 11-4 Scenario 4 Cost Analysis

SCENARIO #	SOURCE DETAILS	PEAK (MGD)	\$/YR
4	10 MGD Potable + Conservation + Wells		
	10 MGD Expansion of McBaine Water Treatment Plant	42	\$4,917,000
	Conservation	4.8	\$615,000
	3 Non-Potable Groundwater Wells (Irrigation)	3.0	\$1,810,000
		TOTAL	\$7,342,000

11.4.3 Reliability and Implementation

Expansion of the WTP provides reliability for the CW&L system, and has a limited environmental impact. Conservation allows for a reduction in the size of WTP required, as does the development of a non-potable supply. While non-potable groundwater used for irrigation still requires energy for pumping and distribution, the need to treat it is limited to disinfection.

A non-potable distribution system is required to deliver irrigation water to users. The extent (and cost) of the distribution system depends on the concentration of users and the quantity of demand. Residential irrigation with non-potable water is only likely to be feasible in a new residential development, and will require a significant education and public relations component so that this water does not pose a health risk for users. Additionally, the timing and quantity of use must be closely monitored and controlled to stay within the supply limits of the system.

11.5 SCENARIO 5: 10 MGD POTABLE + CONSERVATION + WELLS (SINGLE POINT)

11.5.1 Overview of Implementation Timeline and Supplies

Scenario 5 includes the limited expansion of the treatment plant, conservation, and three 1-MGD wells used to provide non-potable supplies to a hypothetical industrial user(s) with year-round demand. The costs assume that the three wells each deliver water up to 2 miles to a point of use, sized to deliver a consistent 1 MGD from each.

11.5.2 Cost Analysis

Table 11-5 summarizes the annualized costs for this Scenario, including debt service and O&M for each component.

Table 11-5 Scenario 5 Cost Analysis

SCENARIO #	SOURCE DETAILS	PEAK (MGD)	\$/YR
5	10 MGD Potable + Conservation + Wells		
	10 MGD Expansion of McBaine Water Treatment Plant	42	\$4,917,000
	Conservation	4.8	\$615,000
	3 Non-Potable Groundwater Wells (Single Point)	3.0	\$788,000
		TOTAL	\$6,320,000

11.5.3 Reliability and Implementation

This scenario includes conservation and a larger investment in deep groundwater wells for industrial use. Because a single point user does not require a distribution system the costs for using non potable wells is less costly than alternative 4.

11.6 SCENARIO 6: 10 MGD POTABLE + STORMWATER (IRRIGATION)

11.6.1 Overview of Implementation Timeline and Supplies

Scenario 6 utilizes the largest of the stormwater catchment ponds to meet demands that remain after the rehabilitation and 10 MGD expansion of the WTP. The supplies from the storm pond are assumed to be used for irrigation purposes, so they impact summer months and peak demand more than average annual demand. The distribution system costs are estimated based on an assumed service area of approximately 4,000 acres of 1-acre residential lots.

11.6.2 Cost Analysis

Table 11-6 summarizes the annualized costs for this Scenario, including both capital costs and O&M.

Table 11-6 Scenario 6 Cost Estimate

SCENARIO #	SOURCE DETAILS	PEAK (MGD)	\$/YR
6	10 MGD Potable + Stormwater		
	10 MGD Expansion of McBaine Water Treatment Plant	42	\$4,917,000
	Stormwater Pond (500 Acre Ft)	6.5	\$3,100,000
		TOTAL	\$8,017,000

The pond costs only incorporate what is required for non-potable supply. Additional costs would be required if used for stormwater detention or if a minimum pool level is desired.

11.6.3 Reliability and Implementation

Stormwater ponds have the potential to retain runoff for use in irrigation, but are not drought resistant and have a limited reliability. The supply limitations of this alternative are discussed in detail in Section 5.2. Additionally, the construction of a dam or embankment and inundation of the pond area will have a significant local environmental impact which will need to be assessed and mitigated. Permitting will be more complex if the pond sites are on the channel of a creek or in an otherwise environmentally sensitive area.

A non-potable distribution system is required to deliver irrigation water to users, which can vary significantly based on density and type of use. Residential irrigation with non-potable water is only likely to be feasible in a new residential development. Any non-potable project used for irrigation will require an education and public relations component so that this water is used properly and does not pose a health risk for users. Additionally, the timing and quantity of use must be closely monitored and controlled to stay within the supply limits of the system.

If the stormwater ponds were not used for irrigation or peak demands then multiple ponds would be required to achieve a 6.5 MGD peak reduction in overall system demand. For instance, three equivalent 500 acre foot ponds would be required to supply 6.5 MGD of flow. The annualized cost for this scenario would be more costly than a single pond used for irrigation, and most likely not feasible.

11.7 SCENARIO 7: 10 MGD POTABLE + CONSERVATION + STORMWATER

11.7.1 Overview of Implementation Timeline and Supplies

Scenario 7 includes a limited expansion of the WTP, inclusion of a smaller sized stormwater catchment pond, and a conservation program. Inclusion of a smaller non-potable supply from stormwater allows more flexibility in terms of the location of the pond and where the water is used. The distribution system is estimated based on delivery to 860 acres of 1-acre residential lots.

11.7.2 Cost Analysis

Table 11-6 summarizes the annualized costs for this Scenario, including capital and O&M costs.

Table 11-7 Scenario 7 Cost Analysis

SCENARIO #	SOURCE DETAILS	PEAK (MGD)	\$/YR
7	10 MGD Potable + Conservation + Stormwater		
	10 MGD Expansion of McBaine Water Treatment Plant	42	\$4,917,000
	Stormwater Pond (171 acre ft)	1.4	\$1,040,000
	Conservation	4.8	\$615,000
		TOTAL	\$6,572,000

11.7.3 Reliability and Implementation

This alternative requires both conservation and stormwater water supply to meet the supply needs. As discussed, the effectiveness of conservation is highly variable and unknown at this time. Although stormwater ponds can provide the necessary additional supply to meet needs till 2040 on average, it too is susceptible to drought, and therefore less reliable than other alternatives.

11.8 SCENARIO 8: 10 MGD POTABLE + CONSERVATION + CENTRALIZED REUSE

11.8.1 Overview of Implementation Timeline and Supplies

Scenario 8 includes a limited water treatment plant expansion, conservation, and wastewater reuse program utilizing wastewater treatment plant effluent, treated and piped to the point of use. The wastewater reuse program assumes that the user is industrial with year-round demand and a single point of delivery.

11.8.2 Cost Analysis

Table 11-8 summarizes the annualized costs for this Scenario, including capital and O&M costs.

Table 11-8 Scenario 8 Cost Analysis

SCENARIO #	SOURCE DETAILS	PEAK (MGD)	\$/YR
8	10 MGD Potable + Conservation + Centralized Reuse		
	10 MGD Expansion of McBaine Water Treatment Plant	42	\$4,917,000
	Centralized Wastewater Reuse (Single Point)	2	\$2,722,000
	Conservation	4.8	\$615,000
		TOTAL	\$8,254,000

11.8.3 Reliability and Implementation

Using the wastewater treatment plant effluent requires significantly less treatment than the Satellite Wastewater Reuse alternative, and is therefore more cost effective and lower-impact. However, reuse water would need to be pumped to the point or area of use, which requires a significant environmental disturbance during construction and pumping energy use and associated costs. This option is significantly more costly than other supply alternatives.

11.9 SCENARIO 9: 10 MGD POTABLE + CONSERVATION + SATELLITE REUSE

11.9.1 Overview of Implementation Timeline and Supplies

Scenario 9 includes a limited water treatment plant expansion, conservation, and satellite wastewater treatment plants that divert wastewater from sanitary sewer collector lines within the city and uses advanced treatment to produce non-potable water. The wastewater reuse program assumes that the user is industrial with year-round demand and a single point of delivery.

11.9.2 Cost Analysis

Table 11-9 summarizes the annualized costs for this Scenario, including capital and O&M costs.

Table 11-9 Scenario 9 Cost Analysis

SCENARIO #	SOURCE DETAILS	PEAK (MGD)	\$/YR
9	WTP Expansion, Satellite Reuse & Conservation		
	10 MGD Expansion of McBaine Water Treatment Plant	42	\$4,917,000
	Satellite Reuse	2	\$6,013,000
	Conservation	4.8	\$615,000
		TOTAL	\$11,544,000

11.9.3 Reliability and Implementation

The benefit of Satellite wastewater treatment is that it can be located within the city, nearer to the point of use. However, advanced treatment is required which is costly and energy intensive. This alternative is the most expensive, and does not constitute a significant reduction of environmental impacts, given the treatment and construction of a new facility.

12.0 Evaluation of Scenarios

Section 10 summarizes the annualized costs for the various scenarios selected to meet water supply needs. Section 10 also includes general discussion on non-economic criteria such as reliability of the system to meet needs, social impact, and environmental aspects. The evaluation process should include both these economic and non-economic factors to determine the best combination of strategies for ensuring a sustainable and cost-effective water supply for today and the future.

The evaluation and selection process was performed as follows:

- Annualized costs for each scenario were calculated based on outputs from the model
- A comparison of non-economic factors utilizing a weighted average approach.
- A cost to benefit ranking system factoring in economic and non-economic criteria.

12.1 COST EVALUATION

Nine scenarios were discussed in Section 11 that included alternatives utilizing a wide range of potable supply, non-potable supply, and conservation measures. These nine were selected from the model as representative of the potential alternatives available. However, other combinations exist that would present different results, but would generally fall within the ranges included in this evaluation.

Figure 12-1 summarizes the annualized cost for each of the alternatives described in Section 11. The annualized costs will continue for a 30-yr period from point of implementation.

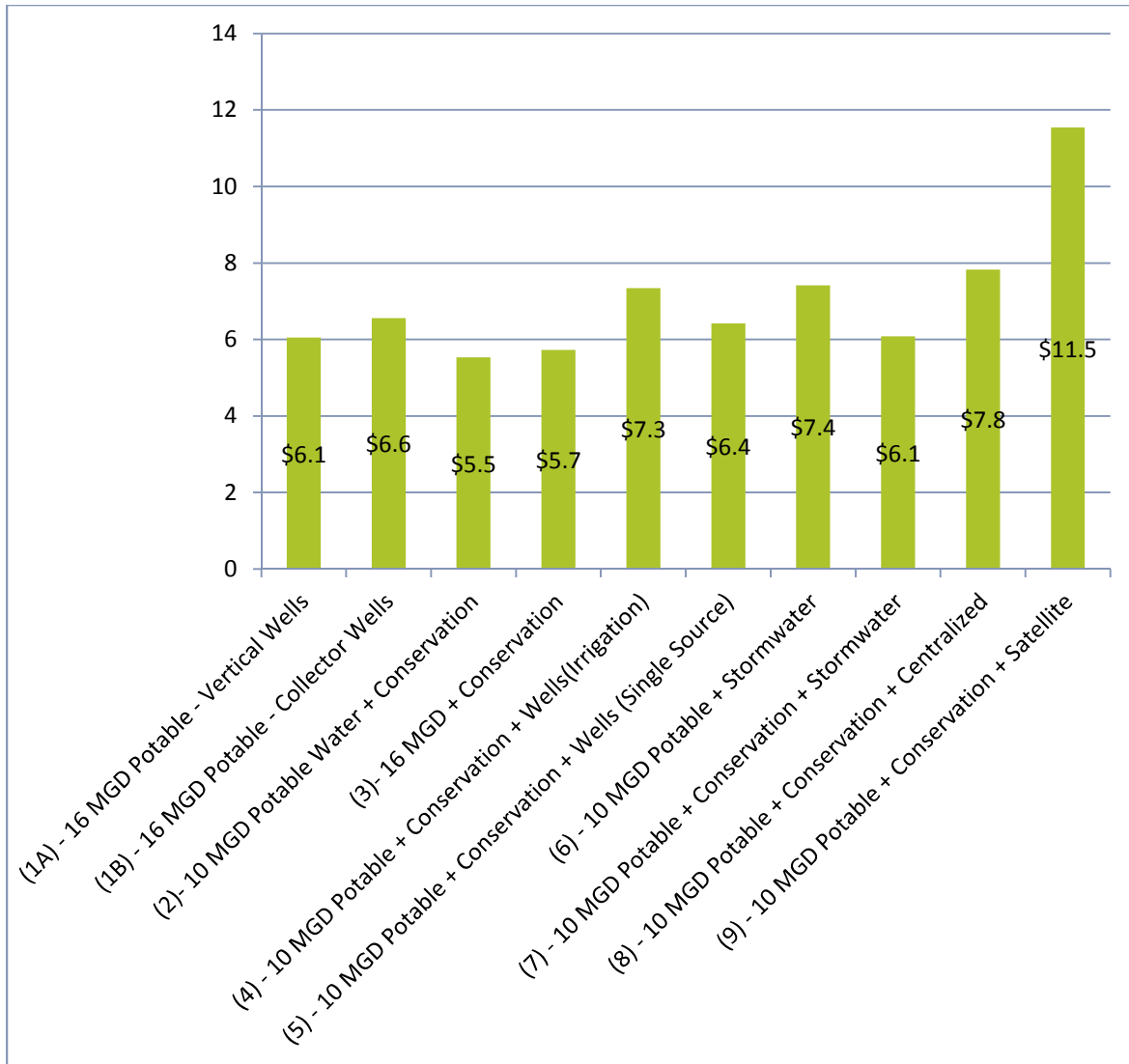


Figure 12-1 Annualized Cost for Each Scenario (in Millions of Dollars)

12.2 ECONOMIC AND NON-ECONOMIC EVALUATION

The lowest cost scenario does not necessarily result in the best long term solution to satisfy the City’s needs for water supply. Critical non-economic factors such as reliability of the selected plan, the social impact on how the perceived plan would be accepted by residents, and environmental and safety aspects all should be included in the selection process.

To incorporate both economic and non-economic factors into the evaluation a weighted average evaluation was conducted. A percentage was assigned to each non-economic criteria as well as percentage for costs. The percentages are used to develop a weighted average evaluation. The criteria and weighting factor for the economic and non-economic comparisons are shown in Table 12-1.

Table 12-1 Economic and Non-Economic Evaluation Criteria

NON-ECONOMIC EVALUATION CRITERIA	
Criteria	Weighting Factor
Annualized Costs	30%
Reliability	25%
Social	15%
Environmental	30%
Summary	100%

After establishing the weighting factor, each alternative was considered with regard to the criteria, and a score was assigned to each alternative on scale of 1 to 10, with 10 indicating the best performing alternative in the respective criteria category. The lowest capital cost received a 10, and then the other alternatives were ratio' d from that number. Based on the importance factors of the criteria and the individual criteria scores for each alternative, a total score was calculated. The higher the total score, the better that the alternative met the criteria. Table 12-2 summarizes the results.

Table 12-2 Economic and Non-Economic Evaluation

	ALTERNATIVE	ANNUALIZED COSTS	RELIABILITY	SOCIAL	ENVIRONMENTAL	EVALUATION SCORE
	ASSIGNED WEIGHT	30%	25%	15%	30%	
3	16 MGD + Conservation	9.8	8	10	10	9.4
1A	16 MGD Potable - Vertical Wells	9.5	10	9	9	9.4
1B	16 MGD Potable - Collector Wells	9.0	10	8	8	8.8
5	10 MGD Potable + Conservation + Wells	9.1	8	8	9	8.6
4	10 MGD Potable + Conservation + Wells	8.2	8	8	9	8.4
2	10 MGD Potable Water + Conservation	10	5	7	10	8.3
7	10 MGD Potable + Conservation + Stormwater	9.5	6	8	6	7.3
6	10 MGD Potable + Stormwater	8.1	7	7	6	7.0
8	10 MGD Potable + Conservation + Centralized	7.7	7	4	4	5.9
9	10 MGD Potable + Conservation + Satellite	0.0	6	3	3	2.9

Figure 12-2 shows the results in column form. The higher the column, the better the alternative met the project goals.

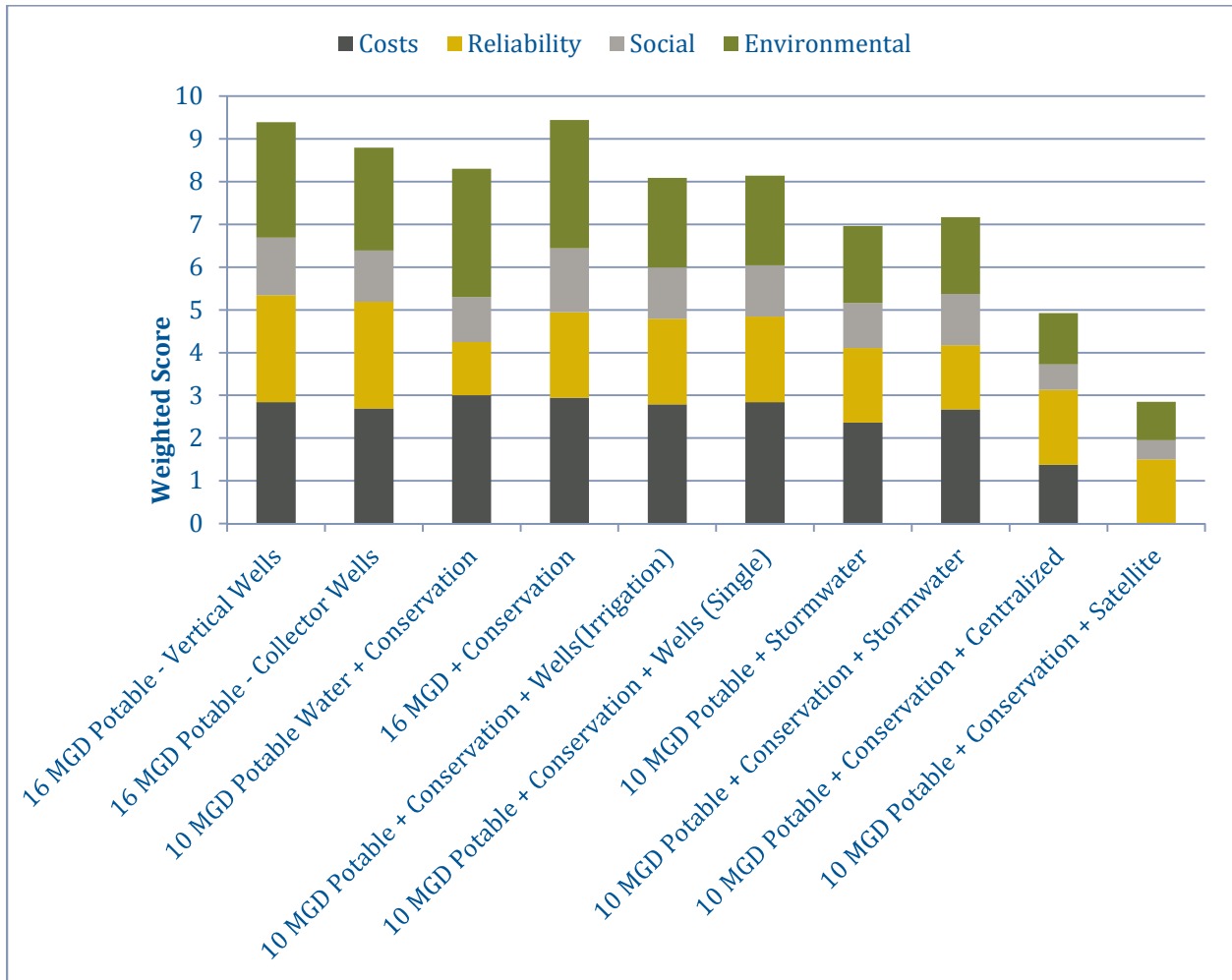


Figure 12-2 Summary of Scenario Scores

13.0 Recommendations

Based on the evaluation completed including economic and non-economic factors the following recommendations have been developed:

Scenarios that incorporate non-potable supplies were generally slightly more costly than the potable supply alternatives, and also scored lower on the non-economic factors. A significant cost component of non-potable systems is the distribution system required for irrigation purposes. Non-potable supplies can be a viable source of water supply if used for single point users where large distribution networks aren't required and flow demands are relatively constant. However, the location of the user relative to the source of supply will impact costs and be the primary driver relative to feasibility.

For the four non-potable sources evaluated, the centralized wastewater and satellite wastewater reuse supplies were extremely costly to construct, and did not score high in non-economic criteria, especially public perception. Therefore, these supply sources should not be considered in the overall supply plan for the City, especially given the availability of other water sources in the region.

Deep groundwater wells were the lowest cost non-potable supply alternative. When deep wells are installed to supply a single user they provided the lowest supply cost of any of the potable or non-potable alternatives. Therefore, the continued use of deep groundwater wells to serve industries, golf courses, and parks should continue, which can help delay installation of new supply wells required for expansion at the water treatment plant.

Implementing deep groundwater wells are not as effective for residential irrigation due to the patterns of extremely high peaks. Wells are generally sized for a specific capacity and do not have the ability to meet peak day or hour conditions unless extremely oversized for the area it serves, multiple wells are installed, and/or ample storage is provided. The distribution piping also needs to be sized for sufficient flow to handle the peak hour demands when a large percentage of the area is watering at one time. Furthermore, installation of a non-potable distribution system for irrigation doesn't significantly reduce the size of the piping for the potable system as most areas fire flow dictates the potable system pipe sizing.

Stormwater ponds used for non-potable supply would generally be more expensive to implement than potable supply expansion. In addition to being more costly, environmental aspects and finding optimal locations for the ponds further diminish the viability of this source of supply. Similar to deep groundwater wells, there may be some small scale instances where a pond could be utilized for a single point user or small residential area. However, these would be site specific and difficult to implement at a large scale by the City. For residential irrigation, stormwater ponds have the same distribution costs as groundwater wells, but are more flexible for peak demands. Ponds are impacted more by drought conditions so they are also not as reliable as other sources of supply. The City is currently conducting an Integrated Stormwater Management Plan (IMP) that may consider large stormwater retention basins. Additional

volume could be incorporated into these basins to serve as non-potable supply. However, any volume built into the basin for non-potable use would be in addition to volume required for stormwater detention, making the basin larger. Therefore, utilizing a combination of stormwater detention and non-potable water storage in basin is not real feasible as they serve different purposes.

For all the non-potable supply alternatives the City could require developers to provide the source water and distribution network as part of their development. This would burden these costs onto the developer and ultimately the home owners. By implementing this approach the potable supply capacity could be reduced, thus delaying installation of additional wells and expansion costs at the plant. However, this approach would not have a major impact on overall costs to the City as the infrastructure to supply the area with potable supply would still be required. This approach may also detrimentally impact development and growth within the City, which should also be considered.

Generally, other City's move forward with non-potable supplies when there is a shortage of available potable supply to serve the future growth. This is not the case for Columbia as there is abundance of supply, either with the existing vertical well field, collector wells located along Missouri River, or even the Missouri River itself.

Therefore, the most reliable, cost effective approach for the City to address future water supply needs is to expand the potable supply, which consideration of implementing conservation to reduce overall supply needs. Three potable supply expansion concepts were considered and listed below:

Alternative 1 – 16 MGD Water Treatment Expansion

Alternative 2 – 10 MGD Water Treatment Plant Expansion and Conservation

Alternative 3 – Partial 16 MGD Treatment Plant Expansion and Conservation

Alternative 1, 16 MGD Treatment Plant Expansion, would meet the projected future maximum day demands through year 2040 without impacting current water usage. Expanding a treatment facility to meet anticipated water needs is a traditional approach taken by many communities, especially for those with ample water supply such as Columbia. This also is a similar approach to what Columbia has done in the past, both in the 1990's and 2000's, when the plant was expanded by 8 MGD on two separate occasions to meet projected demands. The major difference is that in lieu of two smaller expansions, this alternative recommends one larger expansion to cover a longer timeframe to lower the overall cost to meet water supply for the planning period. The estimated annualized cost for comparison of this alternative is \$6.1 million dollars.

If capital and operational costs were the only factors to consider, then the recommended approach would be to upgrade the water treatment plant with a 10 MGD expansion and implement the conservation program. However, this alternative (Alternative No. 2) would require significant changes to the standard irrigation practices currently in place, including

ordinances, replacement of high flow toilets, inefficient washers and showerheads, new rate structures, and aggressive education on conservation. Even with implementing these measures, it is estimated based on similar programs around the country that have already implemented conservation that the peak day demand reduction from conservation would not be sufficient to offset your demand needs by the end of the evaluation period, year 2040. Therefore, to meet the system demands for the full planning period, either additional conservation restrictions beyond what has been identified in this study, lower expected population growth, or another plant expansion, would have to occur before 2040. The estimated annualized cost for this alternative is \$5.5 million dollars, which is approximately \$0.6 million dollars per year less than Alternative No. 1. However, if conservation was not successful in offsetting future water requirements and another plant expansion would be required, the overall cost of this alternative would be more than Alternative 1. Therefore, this alternative scored lower on reliability to meet supply needs throughout the planning period.

Alternative No. 3 includes a partial 16 MGD expansion and conservation. The partial 16 MGD expansion would include initially constructing the process train (basins, filters, clearwell, pump station) able to treat a capacity of 16 MGD, but the remaining treatment components, such as well field, pipelines, aerators, chemical feed systems, to generally be expanded only when needed based on supply needs. Many of these facilities, such as the well and aerators, can be increased in capacity incrementally over time with minimal impact in operations.

Conservation would still play a critical component to this plan as it will allow the expansion of the remaining facilities to be delayed, and the overall peak day of the capacity of the plant to be reduced. The effectiveness of conservation measures could be re-evaluated in 5-7 years, at which point demand projections could be adjusted and its impact on overall implementation of the remaining improvements. The essential elements and approach for implementing a conservation plan are outlined in Section 6 of this report.

Based on this evaluation, the recommendation is to proceed with Alternative No. 3, partial 16 MGD expansion. Expanding a portion of the facilities to 16 MGD versus the 10 MGD included in Alternative No. 2 will reduce the potential risk of a future plant expansion within the planning period. Furthermore, the 16 MGD process train provides additional flexibility at the plant to incorporate the necessary improvements to the existing plant and a more reliable treated water supply. If the conservation program is as effective as estimated, or even more effective, the additional wells and remaining plant expansion costs could be pushed out further in the implementation schedule. It is possible that the full 16 MGD plant expansion could not be required until beyond the 2040 planning period with an effective conservation plan. Based on a partial plant expansion the estimated annualized cost for this alternative is \$5.7 million, which is approximately \$0.2 million more per year than Alternative No. 2.

Unless the City desires to enforce strict irrigation ordinances, it will take time for the conservation program to impact the overall water usage. Therefore, implementation of conservation program should not delay the expansion of the treatment facility. Some conservation measures could help to limit localized supply issues, specifically education regarding irrigation practices. However, it should be noted that there is sufficient supply in the

existing well field to meet all demands through at least year 2040 whether or not conservation is implemented. Therefore, conservation should be decision the community makes related to environmental impact and social behaviors.

As indicated, there is approximately \$18M in plant improvements required whether or not the plant is expanded. By building the infrastructure in place at the plant for the partial 16 MGD expansion in conjunction with the rehabilitation, some of these costs associated with the existing plant could be deferred, along with delaying the well field expansion until the supply is needed. This approach provides the most cost efficient and reliable method to meeting the city's water supply needs.

Implementation

Based on current demand projections, the peak day of 32 MGD will be exceeded in year 2023. It is recommended that at least 3 years be included from start of the preliminary design to project completion for the expansion project. Therefore, the partial plant expansion should start by mid-2019 at the latest to assure completion before end of 2022. However, it is recommended that the project start in year 2018 to assure completion and satisfactory operation before peak capacity is exceeded. It is recommended the initial capacity of the plant be increased by at least 5 MGD. However, additional evaluation should be completed to determine the most cost effective approach for incremental expansion.

The historical peak day capacity of 23.8 MGD essentially matches the current 24 MGD reliable capacity of the water treatment plant. City staff have already implemented some of the rehabilitation improvements and continue to proceed on specific components as funding is available. The City should proceed with critical rehabilitation components in the near term, but consideration should be given to combining the plant rehabilitation into the expansion project to incorporate as many aspects as possible into one project for efficiency in construction. The sooner these improvements are started the more reliable the overall system will become.