# Determining Future Water Supply in Washington County

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CEE 6440, Fall 2017

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**Introduction**
Washington County, Utah is located in extreme southwestern Utah and is currently undergoing rapid population growth. The population is anticipated to grow from 138,748 in 2010 to 581, 731 in 2060 (Governor's Office of Planning and Budget 2012). Due to the aridity of the county, the anticipated population growth will cause a water deficit by 2060 if no additional water resources are developed. Climate change could also compound this problem. Washington County has begun to implement water conservation methods, but their current water conservation estimates will not come close to combating the anticipated water deficit. This project will investigate the changes in the water budget due to anticipated climate change and if the county has enough water resources to support the population.

**Objective**
The overall objective of this project is to determine if Washington County will have a water deficit, and if so, when the deficit could occur. There are four major steps to determine when Washington County could have a water deficit. First, the population growth will need to be accounted for. Second, the water usage and conservation efforts of Washington County will need to be identified. Third, the current water balance will need to be analyzed. Last, the potential climate change will need to be quantified.

**Methods**
**Population.** This project began with determining the anticipated population growth in Washington County through the year 2060. The historic population and population growth estimates shown in Table 1 were used throughout this project (Governor's Office of Planning and Budget 2012). It is important to note that the population in Washington County has been growing at a lesser rate than anticipated, so this projection likely overestimates what the actual population will be in 2060.

*Table 1. Historic and Future Population Estimates*

| Year | 1990 | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|---|---|---|
| Population | 48,978 | 91,090 | 138,748 | 196,762 | 280,762 | 371,743 | 472,567 | 581,731 |

**Water Use and Conservation.** The next step was to quantify the current water use and the projected water use in Washington County. Washington County gets about 20 percent of its water from groundwater sources, and the remaining 80 percent from surface water sources (Washington County Water Conservancy District (WCWCD) 2015).

In 2010, Washington County was estimated to use a total of 325 gallons per capita per day (GPCD) with residents using 155 GPCD (MWH 2016). By 2060, Washington County hopes to decrease the total usage to 285 GPCD, which would lead to a yearly demand of about 186,000 acre-feet (WCWCD 2015). Table 2 from MWH 2016 shows the conservation measures Washington County plans to implement.

*Table 2. Conservation Measures*

| Measure Name | Category |
|---|---|
| Real Water Loss Reduction | General Measures |
| Conservation Pricing | General Measures |
| Public Information Program | General Measures |
| Water Budgeting/Monitoring | General Measures |
| Billing Report Educational Tool | General Measures |
| Efficient Outdoor Use Education and Training Program | General Measures |
| Distribute Retrofit Kits | Residential Measures (Indoor) |
| Single Family (SF) Water Surveys | Residential Measures (Indoor) |
| Toilet Leak Detection | Residential Measures (Indoor) |
| Multifamily Washer Rebate | Residential Measures (Indoor) |
| High Efficiency Toilet (HET) Rebates | Residential Measures (Indoor), Commercial Measures (Indoor) |
| CII Surveys | Commercial Measures (Indoor) |
| CII Rebates to Replace Inefficient Equipment | Commercial Measures (Indoor) |
| Replace Spray Nozzles | Commercial Measures (Indoor) |
| High Efficiency Urinal Rebate (<.5 gallon) | Commercial Measures (Indoor) |
| School Building Retrofit | Commercial Measures (Indoor) |
| Install High Efficiency Fixtures in Government Buildings | Commercial Measures (Indoor) |
| Irrigation Water Surveys (Water Checks) | Irrigation Measures (Outdoor) |
| Xeriscape Demonstration Gardens | Irrigation Measures (Outdoor) |
| Train Landscape Maintenance Workers | Irrigation Measures (Outdoor) |
| Financial Incentives for Irrigation Upgrades | Irrigation Measures (Outdoor) |
| Smart Irrigation Controller Rebates | Irrigation Measures (Outdoor) |

The per capita water use in Washington County is high compared to other arid climates. This is due, in part, to unique circumstances in the county. The county has a variable population, about thirty percent of the population are ‘snowbirds’ (MWH 2016). Snowbirds only live in the county in winter months and do not count in the population total, but do use water year-round. Washington County also hosts over five million visitors each year (MWH 2016). Additionally, in some areas, the turbidity of surface water prevents the use of more efficient irrigation systems.

According to WCWCD 2015 Conservation Plan, “most of the readily available water in the county has been developed and virtually no new water rights are available.” Washington County currently has approximately 59,200 acre-ft per year of reliable yield for culinary systems and 8,500 acre-ft per year of reliable yield for secondary systems (MWH 2016).

The lack of availability of additional water rights has led to the Lake Powell Pipeline Project. This project will bring over 82,000 acre-ft per year to Washington County through 140 miles of underground pipeline (Lake Powell Pipeline 2017). The Lake Powell Pipeline Project is anticipated to be less expensive than other alternatives such as reusing water, mandating conservation, drying up farms, and developing reverse osmosis treatments (Lake Powell Pipeline 2017). The Lake Powell Pipeline Project Water Needs Assessment outlines a few additional water supply projects that, including the Lake Powell Pipeline Project, could develop an additional 142,000 acre-ft per year of culinary and secondary water (MWH 2016).

**Water Balance.** The next step in this project was to analyze the current water balance of Washington County. The best estimate of mean natural flow was identified for each flowline developed using NHDPlusV2 (Horizon Systems Corporation 2012) and ArcGIS Pro (ESRI 2017) (See Figure 1). This estimated flow was then used to sum flow into and out of the county for all streams with a flow greater than two cubic feet per second (cfs). The net flow out Washington County was found to be 115 cfs.

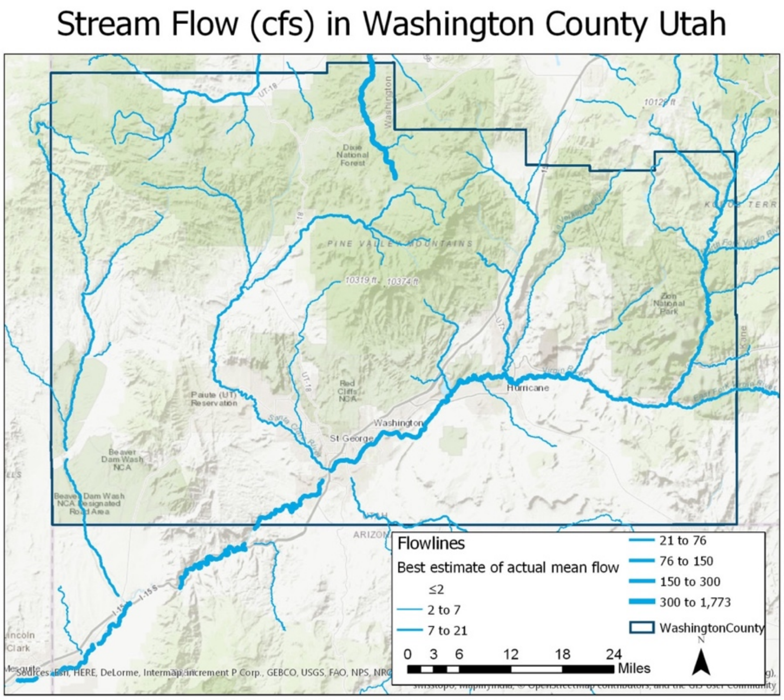


*Figure 1. Stream Flow in Washington County*

Using gages at ten stations (NOAA 2017), the average precipitation was found to be 1.11 feet and the average temperature was 57.7 °F (NOAA 2017). The average temperature and precipitation (P) was found using the thiessen polygon method (see Equation 1 for the precipitation calculation). The county was found to have an average precipitation of 1.56 million acre-ft per year.

$$P_{avg} = \Sigma(P_i * A_i)/\Sigma A_i$$

*Equation 1.*

The thiessen polygons were delineated using ArcGIS Pro (ESRI 2017) (see Figure 2). A hypsometric precipitation analysis was considered, but when precipitation versus elevation was plotted there was not enough of a correlation for that method to be used (see Figure 3).

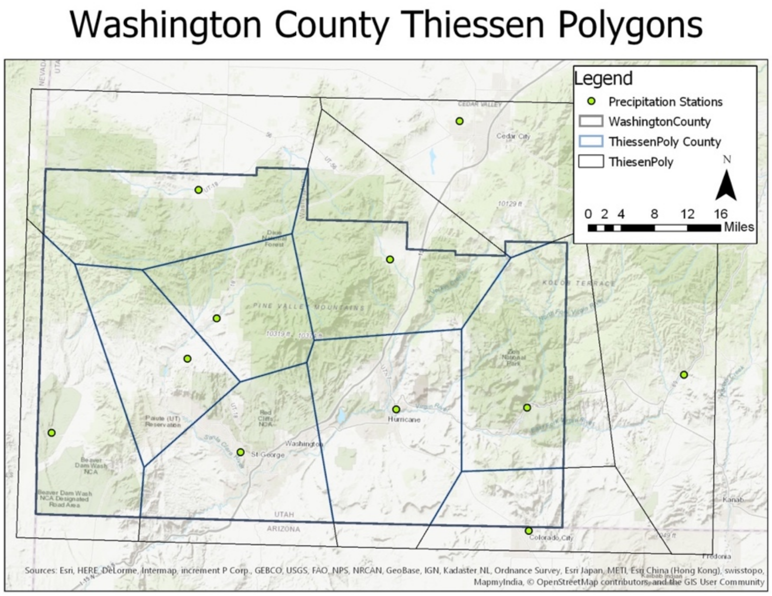


*Figure 2. Thiessen Polygons*

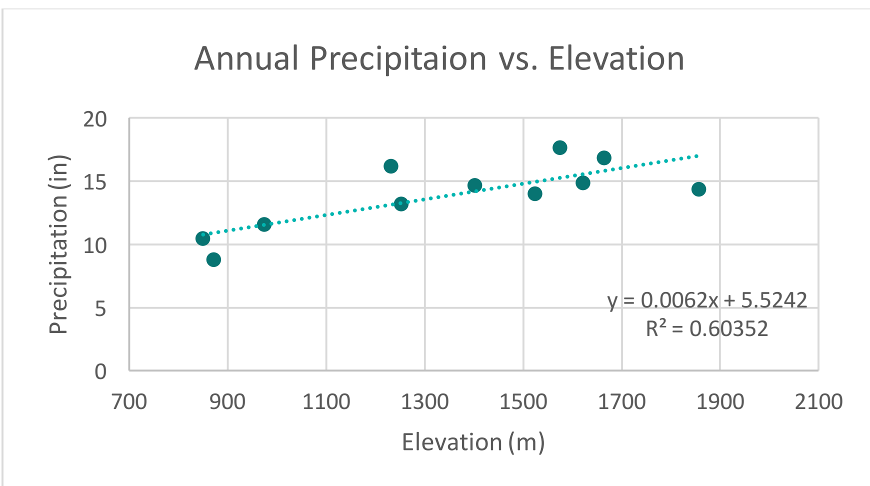


*Figure 3. Plot of Annual Precipitation vs. Elevation*

The flow out of the system (Q), of 115 cfs, was converted into 0.054 feet per year over the county. Using the simplified water balance equation, ET=P-Q, the evapotranspiration (ET) was found to be 1.05 feet per year. The simplified water balance equation does not account for changes in water storage and inputs or outputs from groundwater. There are multiple reservoirs in the county that could have changes in storage that were not accounted for. Groundwater flow in and out of the county was not accounted for due to limited time. The runoff ration r=Q/P was calculated and found to be 0.051.

**Potential Climate Change.** The final step was to analyze the potential for climate change. This analysis began with a linear interpolation of the temperature from four stations to find how climate has changed over the last 13-124 years (see Figure 4). The slope of the linear interpolation was multiplied by 42 years (the number of years from 2018-2060) to find an anticipated change in temperature. Only four stations were used due to the format of available data.

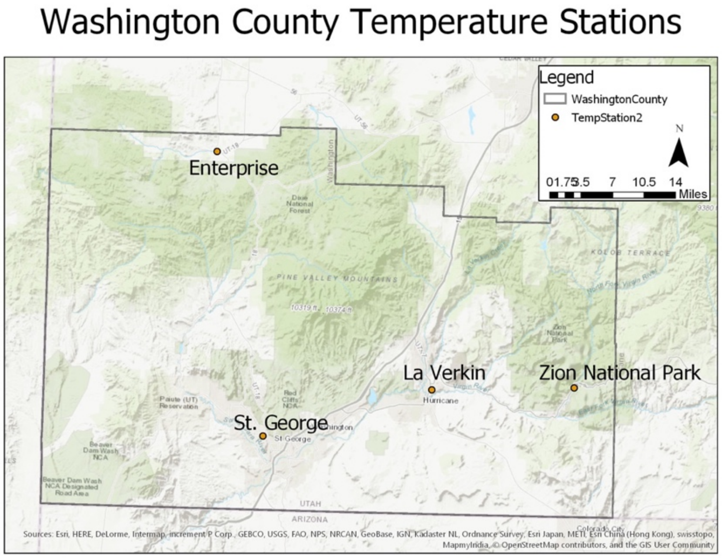


*Figure 4. Temperature Stations*

The results of this climate change temperature analysis are in Table 3. The changes in temperature were averaged based on the length of the period of record to find and average change of 3.30 °F, or 1.83 °C. The thiessen polygon method was not used since the stations were not spread out enough to create polygons that covered the entire county in ArcGIS.

*Table 3. Temperature Stations*

| Station | Change in Temperature (°F) | Period of Record (years) |
|---|---|---|
| St. George | 3.07 | 124 |
| La Verkin | 4.60 | 67 |
| Zion National Park | 0.92 | 13 |
| Enterprise | 1.53 | 16 |

In addition, climate change projections from the US Bureau of Reclamation (USBR) (2014) were used to estimate potential climate change. Climate projections from Beijing Climate Center based off of a representative concentration pathway (RCP) of 2.6, 4.5, 6.0, and 8.5 were used. This climate projection was chosen based on the availability of data. The RCP is a measure of projected emission pathways. RCP 2.6 is the lowest emission pathway and RCP 8.5 is the highest.

The climate projections were used to find an estimated change in temperature and precipitation. The given projections were plotted and the slope of a linear interpolation was multiplied by 42 years to find the estimated changes in climate (see Table 4).

The next step was to perform an elasticity analysis to determine the change in runoff due to potential climate change. The next four equations are found in Dingman 2015. First, the potential evapotranspiration (PET) was calculated from Equation 2 (where T is the average temperature in Kelvin):

$$PET = 1.2 * 10^{10} * e^{-4620*T}$$

*Equation 2.*

The PET was found to be 4.12 feet. PET is defined as the amount of evapotranspiration that would occur if there was an unlimited supply of water. Next, the watershed factor, ω, was found to be 1.81 by equating the calculated runoff from ArcGIS Pro (0.054 ft) to the runoff calculated in Equation 3:

$$Q = P * \left[1 - \frac{PET}{(P^{\omega} + PET^{\omega})^{1/\omega}}\right]$$

*Equation 3.*

The next step was to estimate the change in runoff due to a change in temperature. Equation 4 was used (where dT equals the anticipated change in temperature in Kelvin):

$$\frac{\delta Q}{Q} = -\frac{5.54 * 10^{13} * e^{-\frac{4620}{T}}}{T^2 * P * \left[1 + \left(\frac{PET}{P}\right)^{\omega}\right]^{1+\frac{1}{\omega}} * \left[1 - \frac{PET}{(P^{\omega} + PET^{\omega})^{1/\omega}}\right]} * dT$$

*Equation 4.*

The climate elasticity, which is the ratio of change in runoff due to changes in precipitation, was calculated to be 2.68. This means that a 1% change in precipitation will change runoff by 2.68%. The climate elasticity was calculated using Equation 5:

$$\varepsilon(Q,P) = \frac{dQ/Q}{dP/P} = \frac{1 - \frac{1}{\left[1 + \left(\frac{PET}{P}\right)^{\omega}\right]^{1+\frac{1}{\omega}}}}{1 - \frac{PET}{(P^{\omega} + PET^{\omega})^{1/\omega}}}$$

*Equation 5.*

Table 4 summarizes the estimated change in temperature, percent change in runoff due to a change in temperature, and percent change in precipitation from the various methods used to estimate climate change. The estimated change in precipitation varies by ±20.5%. Since there is such a spread of potential changes in precipitation, the effect that changes in precipitation could have on the climate was not considered.

*Table 4. Estimations of Climate Change*

| Method | Change in Temperature (°F) | Percent Change in Runoff | Percent Change in Precipitation |
|---|---|---|---|
| Linear Regression | 3.30 | -17.2 | N/A |
| RCP 2.6 | 1.33 | -6.96 | -20.5 |
| RCP 4.5 | 2.63 | -13.8 | 1.49 |
| RCP 6.0 | 2.05 | -10.7 | 20.5 |
| RCP 8.5 | 3.61 | -18.9 | 14.1 |

**Results**

Washington County is undergoing rapid population growth and the population could quadruple by 2060. Washington County residents currently use 325 GPCD. By 2060, residents are anticipated to use only 285 GPCD, which creates a yearly demand of 186,000 acre-feet of water. Washington County currently has reliable use of 68,000 acre-feet. By 2060, an additional 142,000 acre-feet are expected to be available.

On average, 1.11 feet of water falls on the county every year and only 0.05 feet of water runs off. This means that ninety-five percent of water is lost to storage, ground water, or evapotranspiration. Water loss is expected to increase as the climate warms by 1.33 °F to 3.61°F over the next 42 years, which could lead to a 6.96% to 18.9% decline in runoff. This decrease in runoff could lead to the loss of 4,000 to 10,000 acre-ft per year of water.

The climate is also very sensitive to changes in runoff, with an elasticity of runoff due to precipitation value of 2.68. The climate models from USBR 2014 predict a potential change in precipitation of ±20.5%. Since there is a large variance in potential change in precipitation, the change in precipitation was considered to be zero for the rest of the analysis.

Washington County is quickly running out of water. According to the gathered data, Washington County could have a water deficit by 2020 if no additional water sources are developed (see Figure 5). Figure 5 does not include additional water resources that will be developed, since the time frame of these projects is unknown. Figures 5-7 use a change in temperature of 3.30°F to estimate a total loss of 9,000 acre-ft per year of surface water by 2060.

Even with the additional resources, the county could run out of water by 2070. Figure 6 shows the additional water resources being added by 2060, through a linear interpolation of the total additional water resources, and the water demand being projected to 2070 through a linear interpolation. The linear interpolation of additional water resources was used since the timeline of the development of these resources is unknown.

The conservation measures that will be implemented by Washington County are essential to sustaining the communities of Washington County. If the conservation efforts are not implemented, the demand will be greater than the available resources. Figure 7 shows the water demand without conservation measures and with additional resources through linear interpolation.

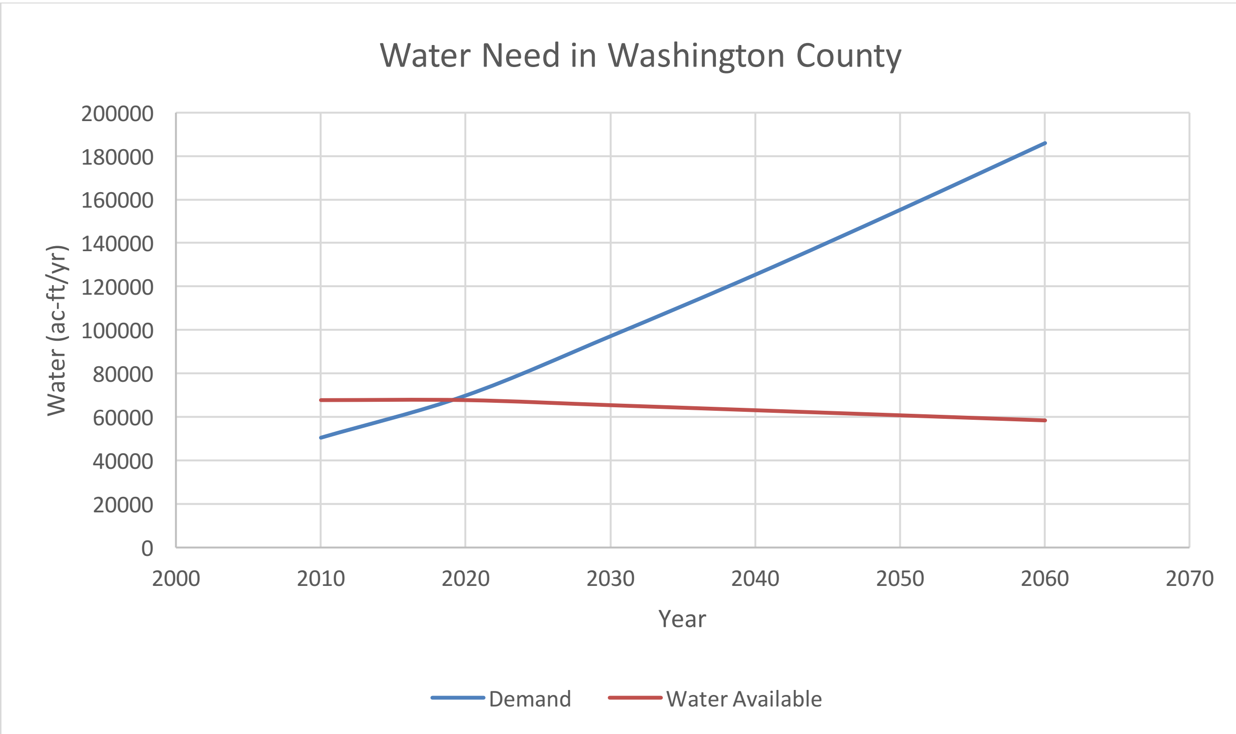


*Figure 5. Water Need in Washington County*

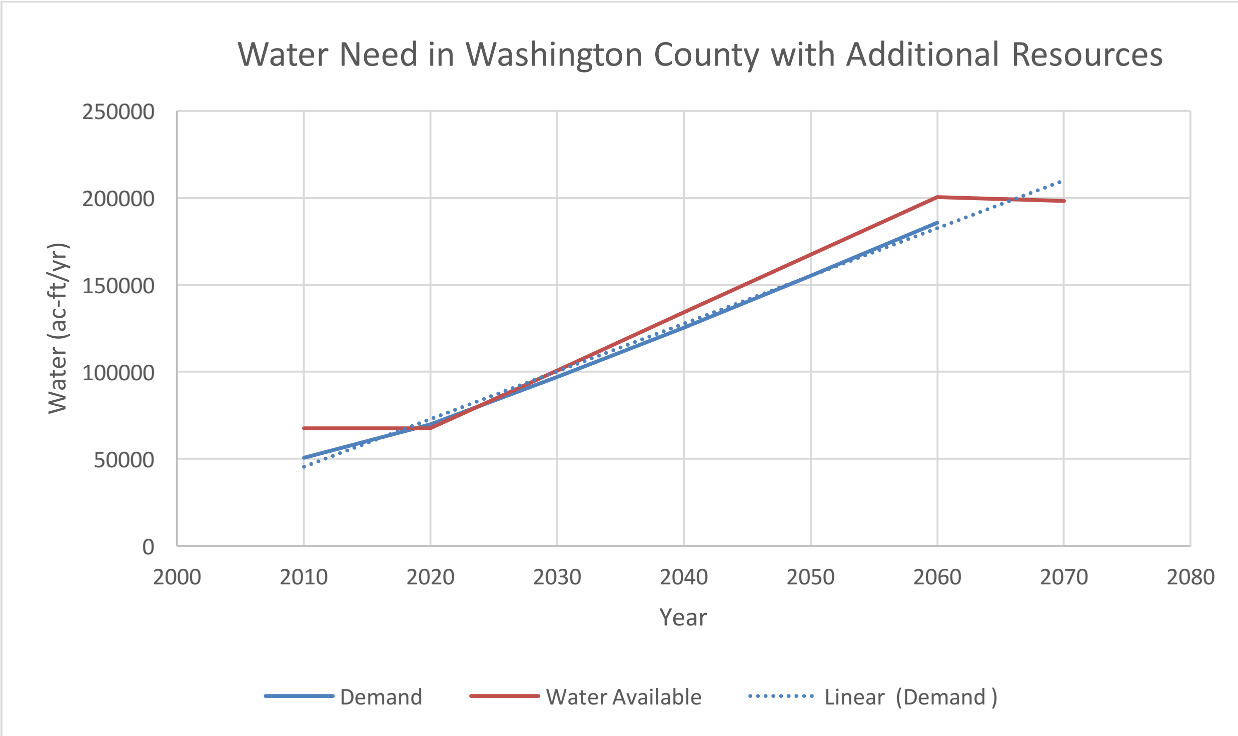


*Figure 6. Water Need in Washington County with Additional Resources*

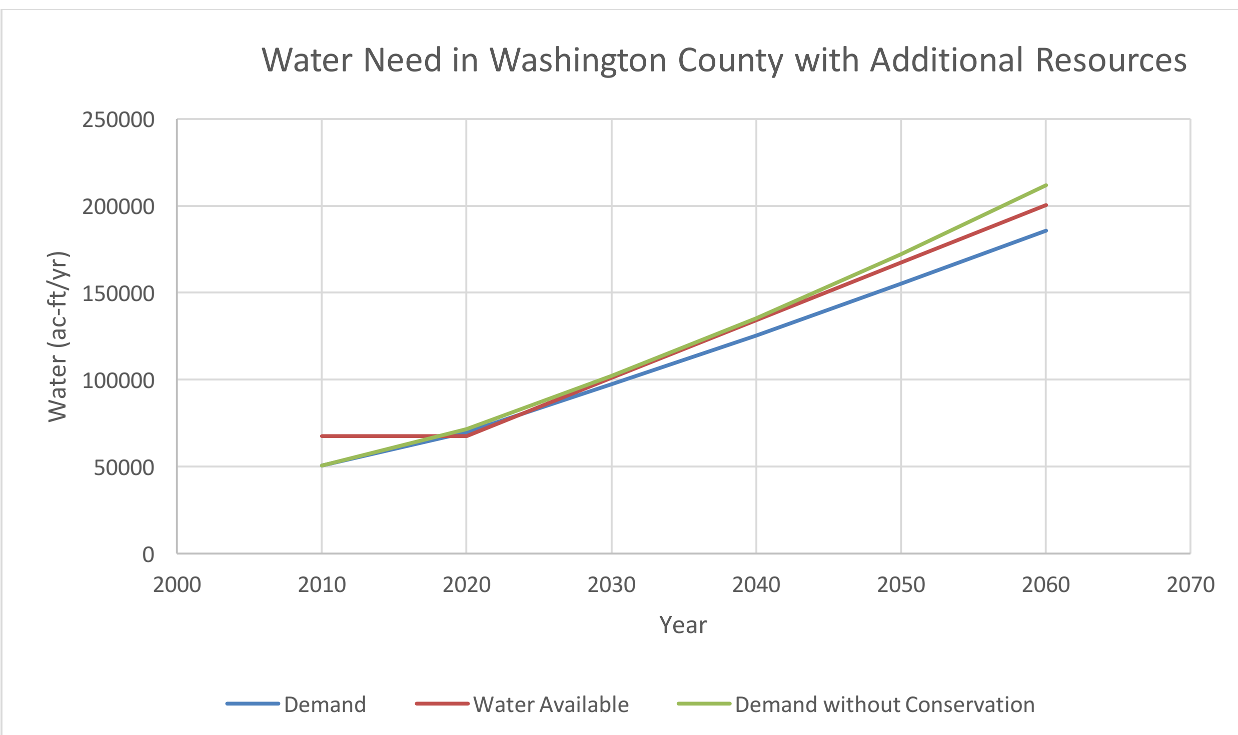


*Figure 7. Water Need in Washington County without Conservation*

**Conclusions**

The water conservation efforts by Washington County will not be enough to prevent a water deficit. However, the conservation measures will help prevent a water deficit by 2060 as long as additional water resources are developed. If additional water resources are not developed, there will be a water deficit by 2020. Climate change is projected to have a significant impact on the local environment. An increase in 3.30 °F over the next 42 years could lead to a 17.2% decline in runoff.

The current measures planned by Washington County to increase water supply, and decrease water demand, are adequate through 2060. However, these measures are unlikely to sustain the county much past 2060.

Washington County should look into cost effective methods of reusing water and cleaning water so it is acceptable for use. Washington County should also look into ways to capture rainfall. Over 1.5 million acre-ft per year of rain falls on the county and yet the county is unable to find 200,000 acre-ft of local water for their citizens.

Given more time and appropriate data, the next steps for this project would be to look into water conservation and development of additional local water resources. This would be in an effort to find a way for Washington County to be more self-sustaining in the future.

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