Geospatial Analysis of The Big Spring, TX Area

Why Direct Potable Reuse Makes Sense

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Big Spring Raw Water Production Facility

Executive Summary

Wastewater reuse has become an important part of overall water management strategies for municipalities in areas where water sources are scarce. Wastewater effluent has already been established as a supplemental water source for municipal and private irrigation needs. Treated wastewater (also called "reclaimed" or "black" water) has been used to irrigate landscaping and for cooling in industrial systems. Wastewater reuse has even gone so far as to be used for indirect potable reuse in places like Orange County, CA and El Paso, TX. In these cases, treated wastewater is injected into the aquifer and then re-pumped to a drinking water plant for further treatment. Droughts that have occurred in Texas in recent years have prompted one city to go one step further and apply treated wastewater as a direct potable source. When faced with the enormous cost of transporting water and the uncertainty of water availability from surface water sources, direct potable reuse becomes an important option for water conservation.

This report looks at the geospatial and environmental influences surrounding the Big Spring, TX Raw Water Production Facility (RWPF) project. It looks at the water transport system in the area that is owned and operated by Colorado River Municipal Water District (CRMWD) which also operates the Big Spring RWPF. The factors analyzed include the piping distances and elevations in the area, the annual rainfall, annual evaporation, the projected annual water demand, and the energy savings and added benefits that the Big Spring RWPF provides.

The conclusions found from this analysis are as follows:

- The elevations and distance from the reservoirs make withdraws costly and energy intensive. The maximum distance and elevation for transportation of water is from the O.H. Ivie reservoir to the city of Odessa which spans a pipe distance of about 192 miles and an elevation of approximately 422 meters (1385 feet).
- The average annual rainfall and evaporation for Region F is approximately 17.8 and 98.0 inches respectively. This creates a water deficit that makes it difficult to maintain water in the surface reservoirs.
- The current capacities of the reservoirs are approximately 1.8%, 5.0%, and 15.0% for the J.B. Thomas, E.V. Spence, and O.H. Ivie reservoirs respectively.
- There is not much demand for municipal irrigation in the region due to the climate so non-potable reuse is not very feasible.
- The piping distances and elevations make indirect potable reuse also very energy intensive and costly.
- The application of direct potable reuse is optimal in this case because it contributes directly to the water supply without losses to evaporation, extensive pumping costs, or depletion of valuable surface water resources.
- The Big Spring RWPF produces between 0.5 to 1.5 million gallons per day which is added directly to the raw water supply for the region.
- The energy used for the Big Spring RWPF is about 5.34 kWh/1000 gallons produced water. This is comparable to the energy used to transport water from Lake E.V. Spence and manage the treated wastewater stream which totals about 5.04 kWh/1000 gallons. The added benefit for the RWPF is the water resource which is drawn from the treated wastewater instead of the heavily depleted Spence reservoir.

The Big Spring RWPF is only a small part of the solution in this area. The bulk of the water resources for this region still comes from groundwater which will continue to provide the majority of the drinking water supply in the future. However, the RWPF is an important step for the future of the direct potable reuse not only in Texas but around the country. The initiatives taken at Big Spring, TX show a promising water conservation method in the face of sustained droughts and increasing water demand.

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Introduction

My goal for this project is to justify the cost and construction of a new raw water production facility that has recently come online in Big Spring, TX. This plant is owned and operated by the Colorado River Municipal Water District (CRMWD) which is the main utility that supplies municipal drinking water in the Texas Water Development Board (TWDB) Region F. An important factor involved in this analysis is the geospatial and environmental aspects in the region that have prompted CRMWD to look to an unconventional method of water conservation.

Wastewater reuse is considered an essential water conservation strategy in regions where water is scarce. The most common type of water reuse is non-potable water reuse. This is the reuse (or reclamation) of treated wastewater that is typically used in applications like lawn irrigation and industrial cooling. Another type of reuse that is closer to human consumption is indirect potable reuse. This generally involves transporting treated wastewater to an environmental buffer. In places like Orange County, CA and El Paso, TX, reclaimed wastewater is pumped directly into the aquifer which holds the water until drinking water plants in the area withdraw it for drinking water treatment. A final type of reuse that is closest to human consumption is direct potable reuse which has been applied at the Big Spring Raw Water Production Facility (RWPF). This type of reuse removes the environmental buffer and transports treated wastewater directly into a pipeline to distribute to area cities for drinking water treatment.

Direct Potable Reuse Background

Direct potable water reuse has been a technically feasible source of drinking water for many years but has ultimately been viewed as a last resort. This view is mostly due to public opinion and the stigma associated with "toilet to tap" nature of the source water. This was also the case in Big Spring, TX and the surrounding municipalities that obtain their water from CRMWD. The decision to go forward with the direct potable reuse project in Big Spring was met with public outcry along with a long and arduous regulatory process for approval. However, there were a few geospatial and environmental factors that made direct potable reuse an optimal choice over non-potable and indirect potable reuse. The driving push towards direct potable reuse in Big Spring was the sustained drought and rapidly decreasing surface water resources available. After a long review process and multiple public input meetings, the Big Spring Raw Water Processing Facility (RWPF) was granted approval for construction and started producing water in April of 2013.

The Big Spring RWPF uses effluent water from the Big Spring Wastewater Treatment Plant (WWTP) located on a site directly adjacent to the RWPF. The reclaimed water from Big Spring WWTP effluent is treated in three different stages in the RWPF. The final product water from the RWPF is blended with other raw surface water and piped directly to the drinking water treatment facilities in the surrounding area.

Project Background

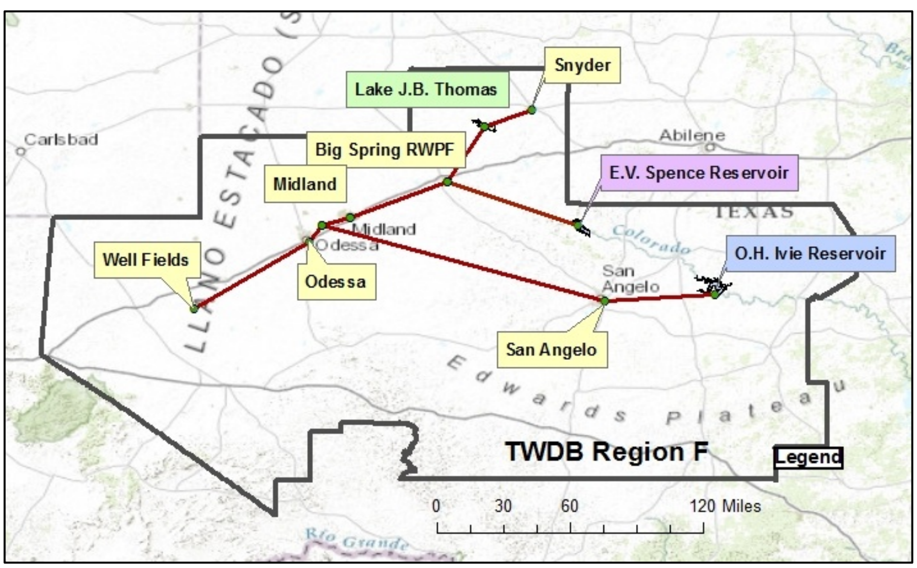
CRMWD supplies the majority of the municipal drinking water to Region F. This region includes a large portion of west Texas. The major cities in this region include Big Spring, Odessa, Midland, San Angelo, and Snyder. CRMWD proposed to build the Big Spring RWPF in 2010. The approval process went through years of public opinion and stakeholder meetings, planning reviews, and discussions with regulators. In 2011, the Texas Commission on Environmental Quality (TCEQ) approved the piloting of the membranes used in the RWPF. After completion of the pilot study, construction on the plant started in 2012. The plant took about a year to build, and after review and approval of the operating and monitoring plan by TCEQ, the plant started producing water in April of 2013.

Figure 1 shown below displays TWDB Region F where CRMWD operates. The red star on the map shows the location of the Big Spring RWPF. The shapefiles for the TWDB Regions were obtained from TWDB website and overlayed onto a topographic basemap with Region F highlighted in green.

Figure 1 – CRMWD Water Service Area

The following figure shows Region F in more detail. The red lines represent the pipelines that carry raw water from the three reservoirs in the region. The three main reservoirs that CRMWD has water rights to are shown on the map. The reservoirs are: Lake J.B. Thomas (green), E.V. Spence (purple), and O.H. Ivie Reservoir (blue). The Thomas and Spence reservoirs are the most heavily used because of their proximity to the major cities in the area. The Ivie reservoir is used mainly to feed San Angelo but does distribute some water into the raw water network.

Figure 2 – CRMWD System Map



Method of Analysis

Data Sources

Most of the data used in ArcGIS for the analysis was obtained through either the TWDB or USGS websites. The sources and the data obtained from them are as follows:

- TWDB Website:
    - Shapefiles for all the regions in Texas – premade shape file
    - Shapefiles for existing reservoirs in Texas including the Thomas, Spence, and Ivie reservoirs – premade shape file
    - Projected demand for the years 2020 to 2070 for Region F – manually input into database file
- USGS Website:
    - Reservoir capacities for the Thomas, Spence, and Ivie reservoirs for the years 2005 to 2012 – manually input into a database file
- NOAA Website:
    - Precipitation station data for 26 stations in the area in and around Region F – manually input into database file
    - Evaporation station data for 12 stations throughout Texas – imported from Exercise 3 data
- NED Server:
    - NED 30 meter dataset – premade raster file imported from the NED server in ArcGIS
- CRMWD Website:
    - Geospatial coordinates of the cities and reservoirs – manually input into database file

Data Anlysis

The data imported into GIS was analyzed in a few different ways. The analysis incorporated many of the techniques learned in the *GIS in Water Resources* class. The techniques and how they were used are as follows:

- *Interpolation Using Kriging* – This method was used in order to interpolate the data from precipitation and evaporation gages.
    - The data for each of these gages was manually input into a database file that included the location (longitude and latitude) and values for each station. In these cases only data for the year 2011 was used.
    - *Display XY coordinates* was used to put a point set on the map. The *Kriging* interpolation tool was then used to create a raster that interpolated regions with different precipitation or evaporation values.
- *Time Series* – A time series was created for reservoir capacities and the projected demand
    - First a database was created for each reservoir (for capacity) and city (for demand). This file contained a value for each time step as well as the location of the point.
    - *Display XY coordinates* was used to put a point set on the map with time values associated with each one. Then the time series was enabled for each point and the symbol was adjusted to each size range for the values.
- *3D Analyst* – A 3D profile was created for the pipelines within the CRMWD network that showed the pipeline distance versus elevation.
    - First a tiff file of the NED30m raster set was exported into the database. Then the *Interpolate Line* tool was used to trace over the system pipes from the source reservoir to each city where the water is distributed.
    - Next a profile graph was created from the line segments that displayed the elevation versus the distance along the line. This data was exported to Excel for graphing.

Elevations and Pumping Distances in Region F

One of the factors that influenced the decision to build the Big Spring RWPF was the energy costs associated with the transportation of water within the CRMWD system. A large amount of energy is needed to transport water due to the large distances and elevations from the surface reservoirs to the cities where the water is then treated for drinking. Figure 3 below shows the pipeline system for CRMWD and the connections between each city. Based on the elevations analysis, the lowest point in the system is the O.H. Ivie reservoir. The highest location is the city of Odessa which also happens to have the largest population and water demand in the region.

Figure 3 – CRMWD System Map

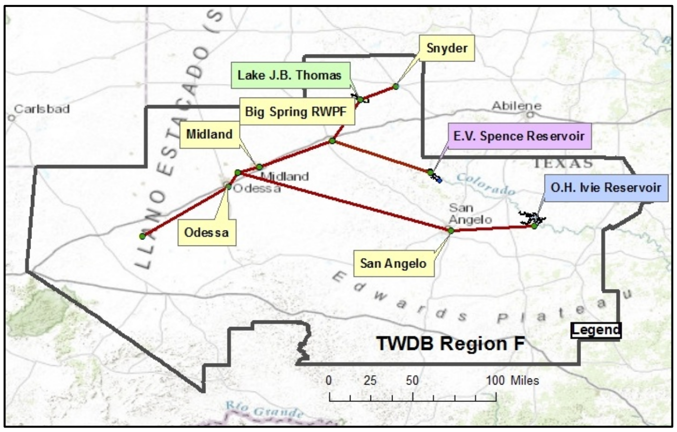
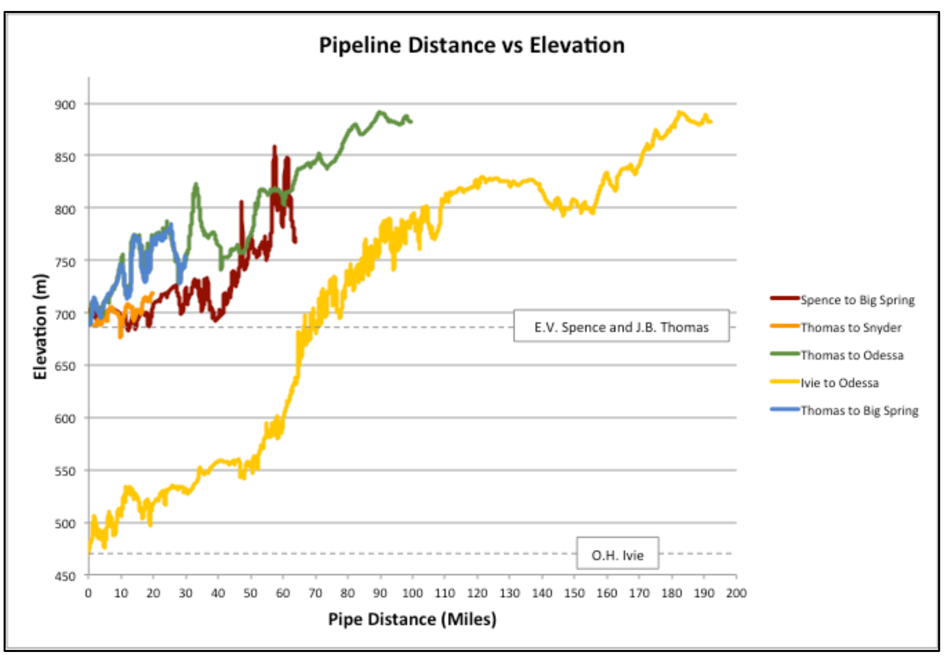


Figure 4 shows the pipe distance in miles on the x-axis versus the elevation in meters on the y-axis. The farthest distance that water has to travel is about 192 miles from the O.H. Ivie reservoir up to Odessa. This pipeline also has to lift water from an elevation of about 475 to 880 meters. The distances and elevations are less for the Thomas and Spence reservoirs because they are closer to the cities in the area. However, the main point to notice is that all of the water that is pumped from the surface water reservoirs has to be lifted up in elevation and travel between 20 to 190 miles.

Figure 4 – Graph of CRMWD: Pipeline Distance vs. Elevation



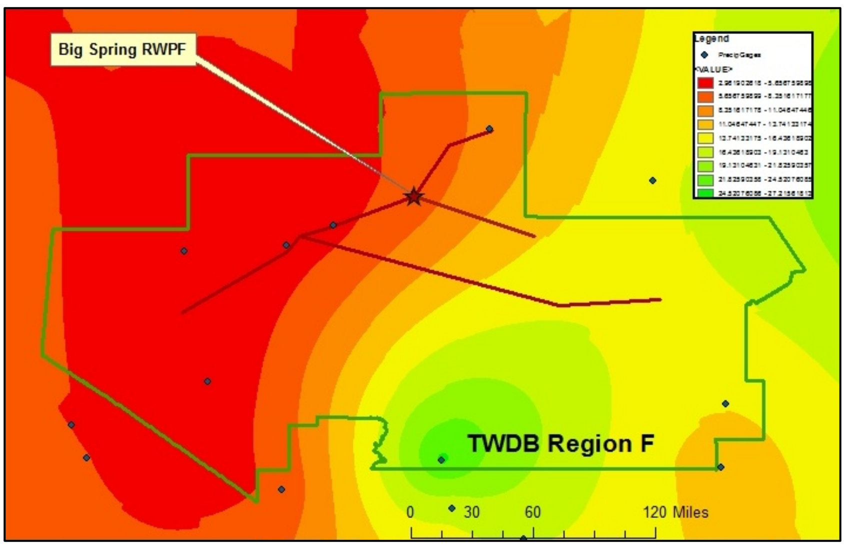
Climate in Region F

Another important factor that influenced the decision to build the Big Spring RWPF was the climate in Region F. The rainfall and evaporation rates are very important for maintaining the water levels in the surface water reservoirs that CRMWD uses. The region in general has a low amount of rainfall and high evaporation rates when compared to the rest of Texas and was hit especially hard during the drought of 2011.

Precipitation in Region F

The precipitation in Region F is fairly low when compared to the eastern part of Texas. Figure 5 below was created using precipitation data from gages operated by the National Climatic Data Center (NCDC). The gages are represented by the green dots on the map. The method used to create the various regions was the Kriging interpolation method. The results of this method show that the precipitation for Region F ranges from about 3 inches/year (the bright red portion in the West) up to about 30 inches/year (the bright green portion in the South-central). The average total annual precipitation for Region F is about 17.8 inches/year which was calculated from this map using the zonal statistics tool.

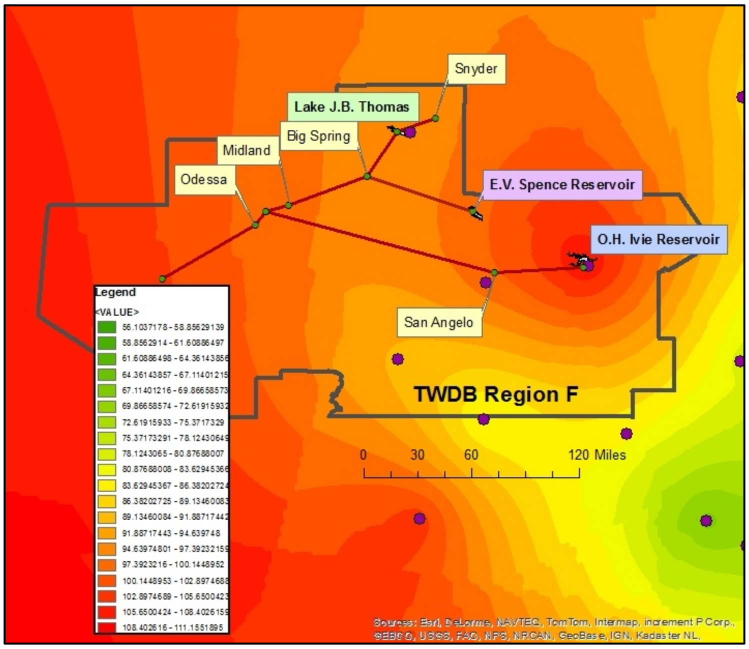
Figure 5 – Diagram of Average Annual Precipitation for Region F



Evaporation in Region F

The evaporation in Region F is high when compared to the eastern part of Texas. Figure 6 below was created using the evaporation gages operated by the NCDC and used in Class Exercise 3. The gages are represented by the purple dots on the map, and the Kriging method was also used to create the regions on the map. The results of this method show that the evaporation for Region F ranges from about 80 inches/year (the bright yellow portion in the Southeast) up to about 108 inches/year (the bright red portion). The average total annual evaporation for Region F is about 98 inches/year which was calculated from this map using the zonal statistics tool.

Figure 6 – Diagram of Average Annual Evaporation for Region F

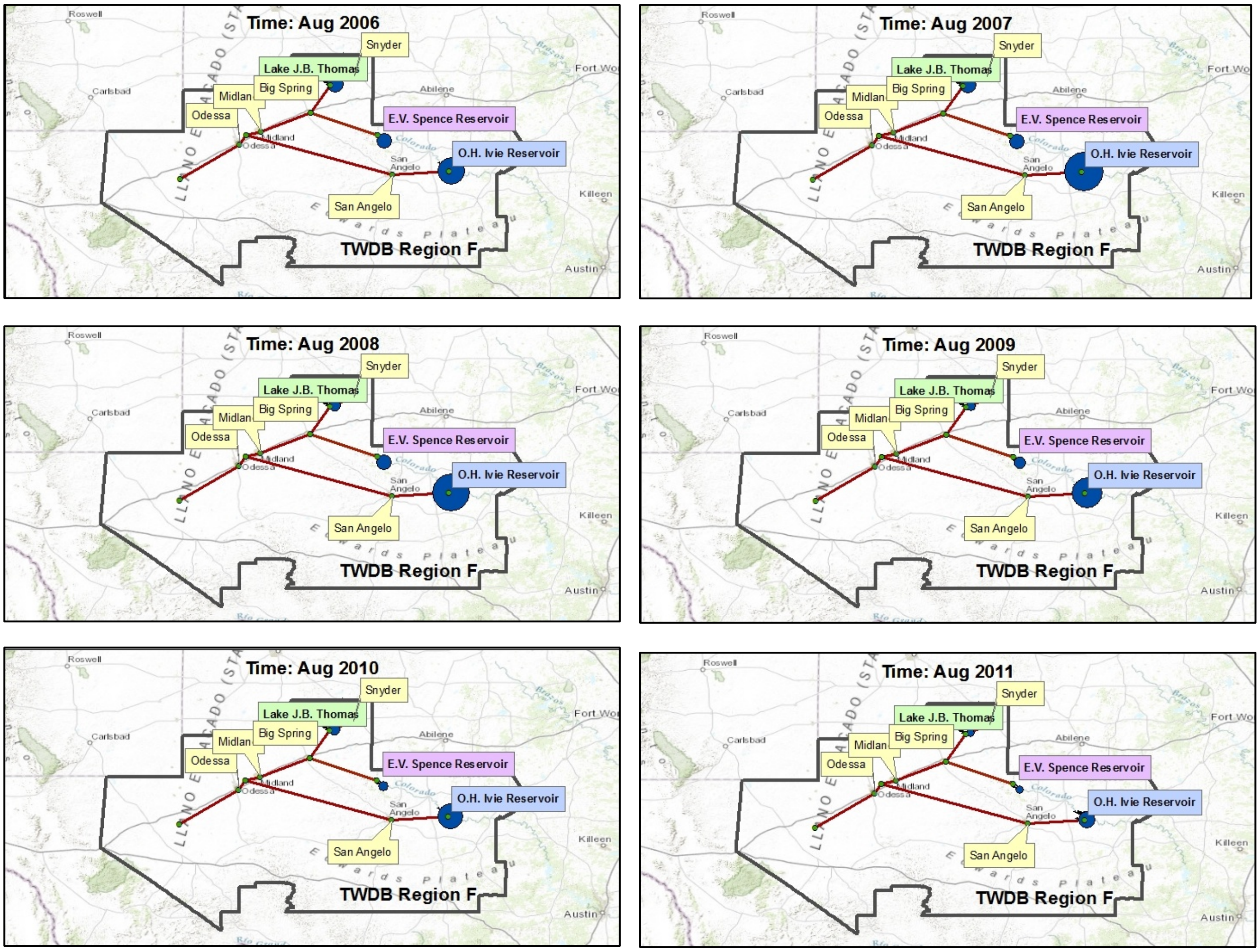


It is important to note that due to the low amount of precipitation in this region and high evaporation losses, landscaping is difficult to maintain. A large amount of water is needed to keep lawns looking green therefore municipal irrigation demand is very low which makes non-potable reuse fairly impractical. In many indirect potable reuse applications in Texas, treated wastewater is passed through constructed wetlands for further treatment before entering the drinking water treatment process. This is also unfavorable in this region due to the high evaporation losses.

Surface Water Resources in Region F

Most of the municipal drinking water in Region F comes from groundwater sources however the surface water resources are a very important part of the water supply. The three reservoirs in the region been have steadily depleted due to use and the sustained drought that has occurred over the last few years. The relatively low precipitation and high evaporation losses analyzed in the previous section show that it is difficult to maintain water levels in surface reservoirs for this region. Figure 7 below shows a time series that was constructed using USGS water level gages at the three reservoirs. The selected snapshots are for the month of August which is typically when the levels are lowest and range from the year 2006 to 2011 (the height of the recent drought). The blue symbols represent the percent capacity in each reservoir and range between 68% (Ivie reservoir in 2006) down to 1.5% (Thomas Reservoir in 2011).

Figure 7 – Time Series of Surface Water Reservoirs in Region F



The following graph shows the reservoir capacities for the Thomas, Spence, and Ivie reservoirs which were used to construct the time series above. The Spence and Thomas reservoirs dropped to less than 5% of capacity by the year 2012 and the Ivie reservoir dropped to about 13% capacity.

Figure 8 – Graph of Reservoir Capacities (2006-2012, % Full)

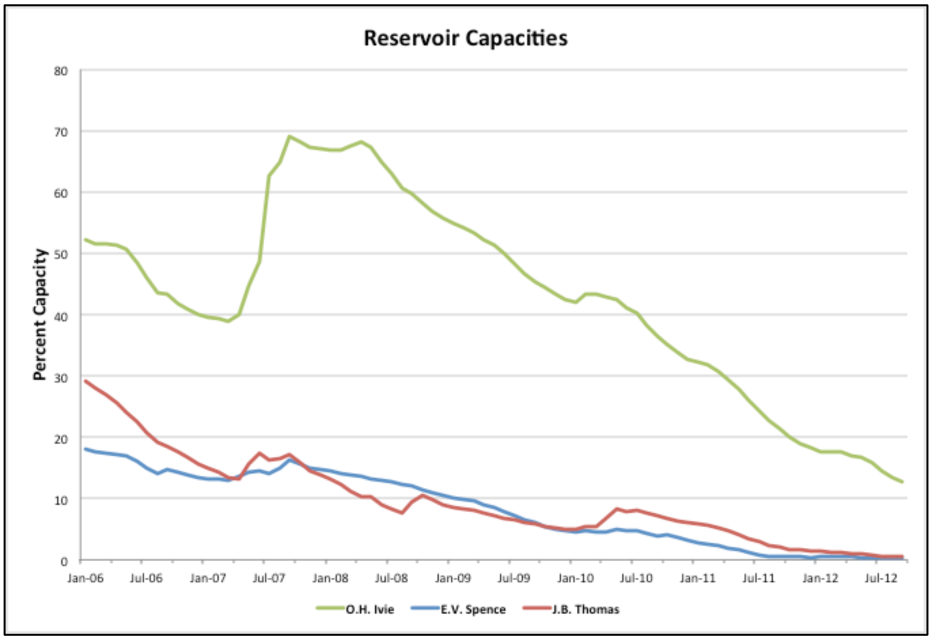
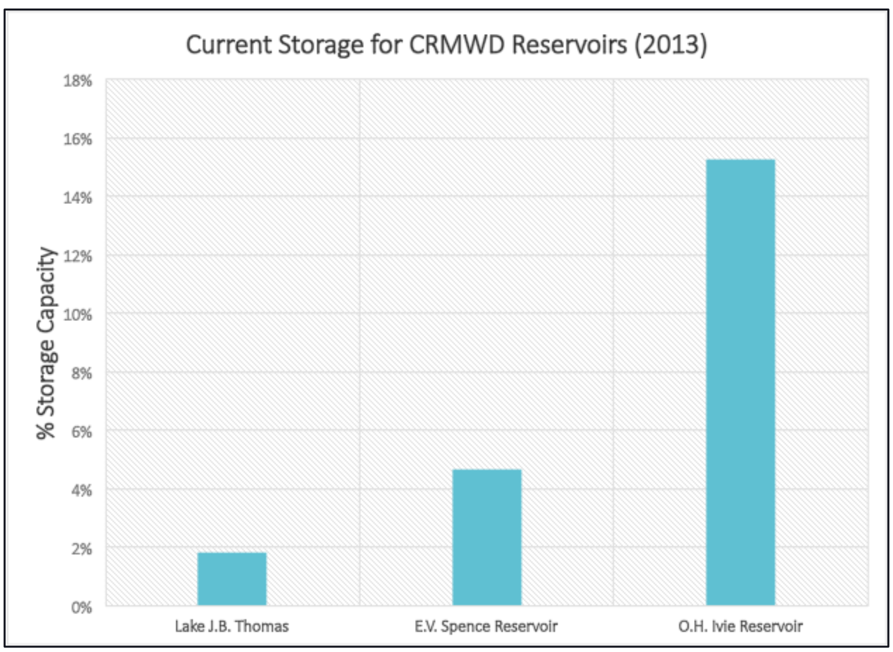


Figure 9 below shows the reservoir capacities for the three reservoirs for October 2013.

Figure 9 –Reservoir Capacities in Region F (October 2013)



Water Demand for Region F

The water demands for Region F based on the TWDB 2012 Water Plan forecast that the demands for the main cities in this region will steadily increase through 2070. The two cities that have the largest current and projected demands are Midland and Odessa which have demands projected to be about 47,500 and 35,300 acre-feet/year for the year 2070. Figure 10 below shows snapshots of a time series of the demands in the region from the year 2020 to 2070 increasing by 10-year increments. The cities represented by the red circles are Odessa, Midland, Big Spring, Snyder, and San Angelo.

Figure 10 – Time Series of Projected Demand in Region F (2020-2070, acre-ft/yr)

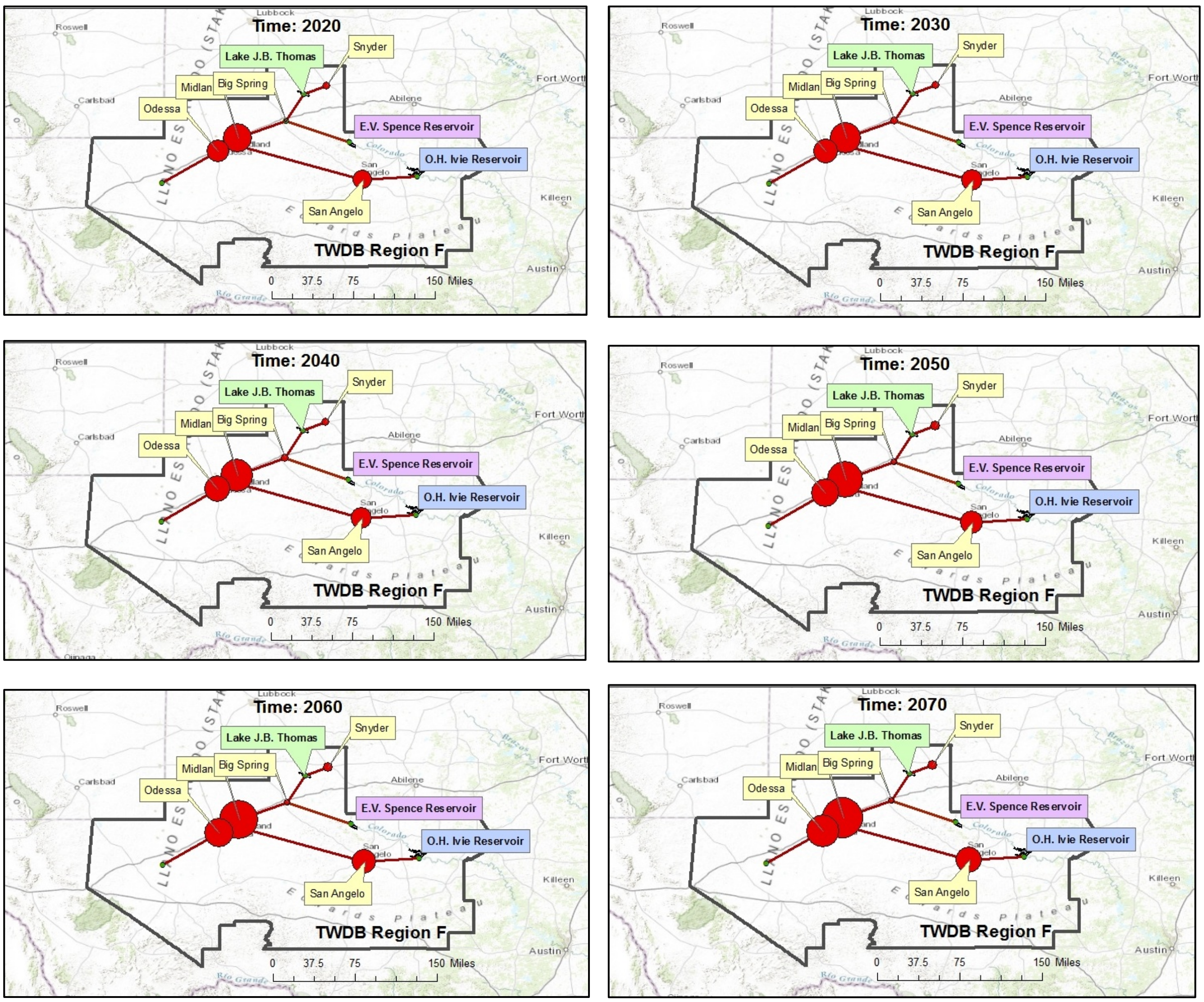
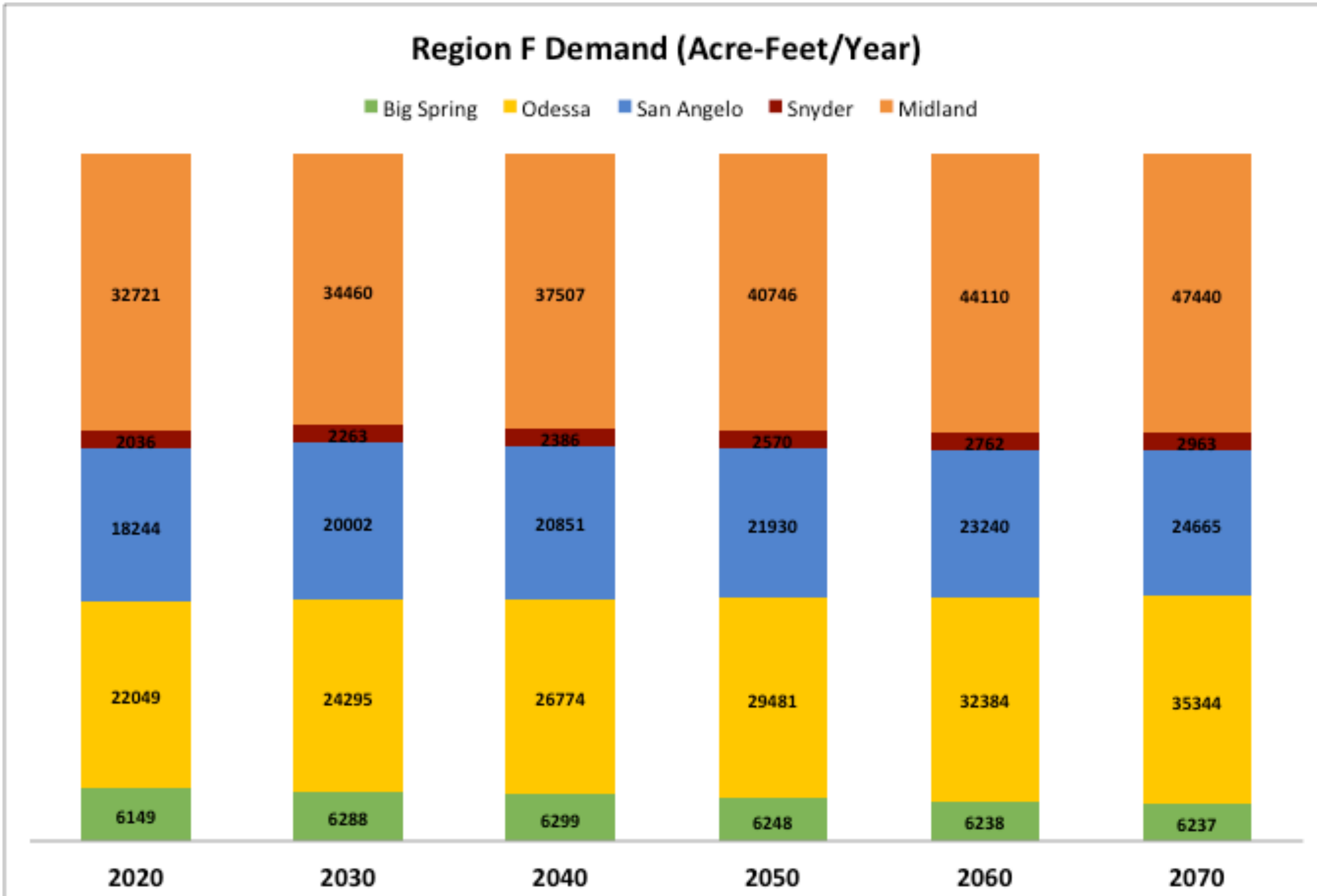


Figure 11 shows a graph of the projected demands from the year 2020 to 2070 for the major cities in Region F. This is the same data used to create the time series but displayed in a bar graph.

Figure 11 – Projected Demand for Region F for the years 2020-2070 (Acre-feet/year)



Water Savings for the Big Spring RWPF

The Big Spring RWPF requires a large amount of energy input in order to produce high quality water from wastewater effluent. This energy cost can be compared to the cost of pumping water from the E.V. Spence reservoir. The following energy comparison was performed by Freese & Nichols in their planning study for the Big Spring RWPF in 2005. The major energy components for the Big Spring RWPF are the reverse osmosis treatment, UV oxidation, and water pumping to the E.V. Spence pipeline. The major energy components for pumping water from the E.V. Spence reservoir to the city of Big Spring are the lifting pumps and the wastewater diversion for the Big Spring wastewater treatment plant (the Big Spring RWPF eliminates this diversion).

Table 1 – Energy Comparison: Big Spring RWPF vs. Water From E.V. Spence (Freese & Nichols)

Big Spring RWPF		**PumpingWater from E.V. Spence**	
Energy Component	Energy Use (kWh/1000 gal)	Energy Component	Energy Use (kWh/1000 gal)
Reverse Osmosis Treatement	3.55	Water Pumping	4.20
UV Oxidation	0.39	Wastewater Diversion	0.84
Water Pumping	1.40	-	-
Total	**5.34**	**Total**	**5.04**

The total energy use for each scenario is comparable. However, the major benefit for the Big Spring RWPF is the conservation of between 0.5-1.5 million gallons of water per day that would have normally been pulled from the Spence. Because of the steadily depleting water level of the Spence reservoir, the direct potable reuse application at Big Spring preferred in order to help sustain the reservoir and conserve water.

Conclusions

The conclusions found from this analysis are as follows:

- The elevations and distance from the reservoirs make withdraws costly and energy intensive. The maximum distance and elevation for transportation of water is from the O.H. Ivie reservoir to the city of Odessa which spans a pipe distance of about 192 miles and an elevation of approximately 422 meters (1385 feet).
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