Texas Reservoir Storage Trends

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GIS in Water Resources

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Introduction

The main objective of this report is to convey reservoir storage trends across the state of Texas over the past fifteen years. Reservoir storage is defined as the total available water volume (acre-feet) available at any one time. Metrics that are used to evaluate reservoir storage trends include how full the reservoirs are and the magnitude of deviation from historic storage levels. At least one reservoir from each climatic region in Texas was chosen for the analysis. Most lakes detailed in this report are man-made and were dammed in the mid-twentieth century.

The information given in this report is applicable for public policy makers and city planners to determine if new water sources are needed to supplement historically used reservoirs. In addition to visually representing storage trends over time a brief summary of one city's response to dwindling water resources is detailed.

Methods

At least one reservoir was chosen from each climatic region in the state of Texas. The climatic regions of Texas are: East Texas, Edwards Plateau, High Plains, Low Rolling Plains, North Central, South, South Central, Trans Pecos, and Upper Coast[10].

Pan evaporation data across the state of Texas was taken from exercise 1 of the fall term CE 394K course. Precipitation data was gathered from NOAA's National Centers for Environmental Information website[9]. In choosing precipitation gauge stations, close proximity to the reservoirs was prioritized. Reservoir storage data was gathered from USGS gauges presented on the Water Data for Texas website[10]. The USGS National Elevation Dataset with 30 meter cells was used for the height above reservoir digital elevation models.

Average annual evaporation data was imported as a .shp file into ArcGIS. Average annual precipitation was found by taking the mean of all precipitation measurements for a single gauge over the 2000-2015 period.

Reservoir gauge station data is available from the date of reservoir completion to present on the Water Data for Texas website. An average of all data points till the year 2000 was taken to determine historical reservoir storage. Yearly reservoir storage averages from 2001 to 2015 were calculated in Microsoft Excel. Total reservoir capacity, or the volume of a completely full reservoir, was calculated by taking reservoir storage and dividing by (0.01*)percent full. The three key calculations for the analysis were percent capacity, historical deviation, and projected time until zero. These three calculations are shown in table 1.

Table 1: Calculations performed for reservoir analysis

Value	Calculation
Percent Capacity	$\frac{Average\ Storage\ for\ Year}{Total\ Reservoir\ Capacity}$

Percent Historical Deviation	$100 * (1 - \frac{Average\ Storage\ for\ Year}{Historical\ Storage})$
Projection Till Zero % Capacity (Linear Regression)	$\frac{b}{m}\ from\ y = mx + b$ $where\ y = 0, m = annual\ decreas\ in\ res.storage$ $and\ b = res.storage\ at\ year\ 2000$

The height above reservoir digital elevation model was calculated using the extract by mask tool to only look at counties of interest. Next the geoprocessing tool rastercalc was used to modify the original NED30 m by subtracting by the reservoir of interest's elevation. That way the reservoir would be at zero elevation while any city above the reservoir would have a value corresponding to the elevation difference.

Most figures were best visualized using graduates symbols with varying color gradations. The time slider tool was used for data sets with time series. A built in animation editor and video exporter was used for final animation rendering.

Results

Annual precipitation and evaporation were both found to be correlated with longitude across the state of Texas. As Figure 1 illustrates, precipitation on average is more intense on the eastern side of the state, while evaporation is more intense on the western side. Interestingly, population density placed alongside precipitation data shows that many of the largest cities in Texas were established in areas of high water resource availability relative to other parts of the state. Figure 2 shows this connection.

Precipitation and Evaporation Across Texas

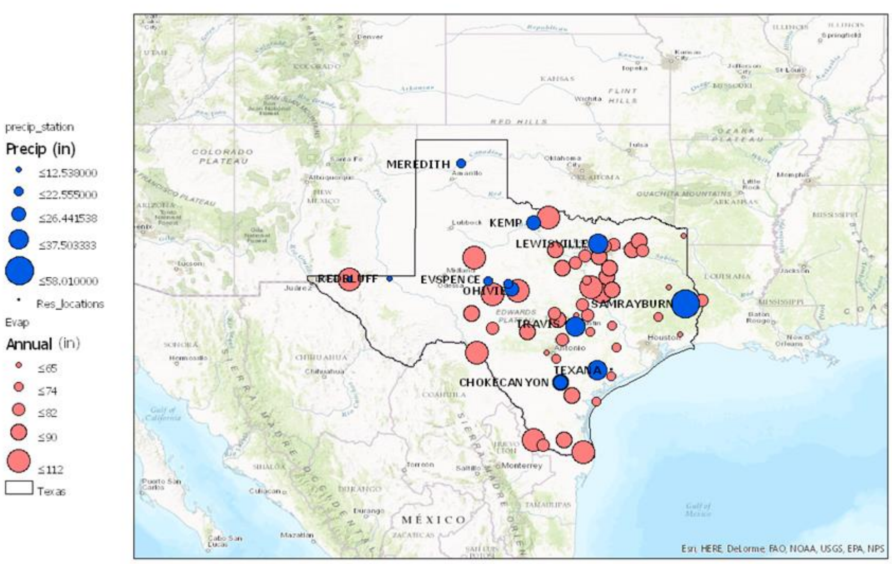


Figure 1: Annual Precipitation and Evaporation Data for Texas

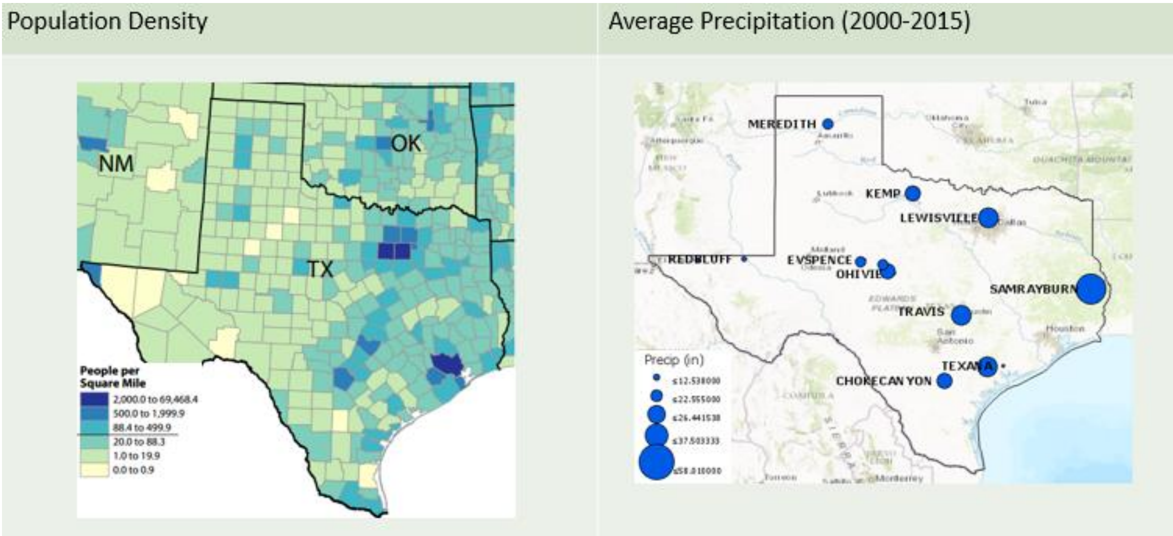


Figure 2: US 2010 Census population density and precipitation data for the state of Texas

Figure 3 illustrates percent capacity snapshots for four different years during the period of 2000 to 2015. Reservoirs Lewisville, Sam Rayburn, and Texana on the eastern side of the state consistently maintained above 70% capacity, barring the major drought year of 2011 and a few other anomalies. In contrast, western reservoirs like Meredith, E.V. Spence, O.H. Ivie, and Red Bluff consistently were at storage levels below 50%. Lakes O.H. Ivie, E.V. Spence, and Meredith from 2011 onwards, were consistently below 35%. Lake E.V. Spence was below 20% capacity for the whole period of study, while Lake Meredith averaged 21% capacity from 2000 to 2015.

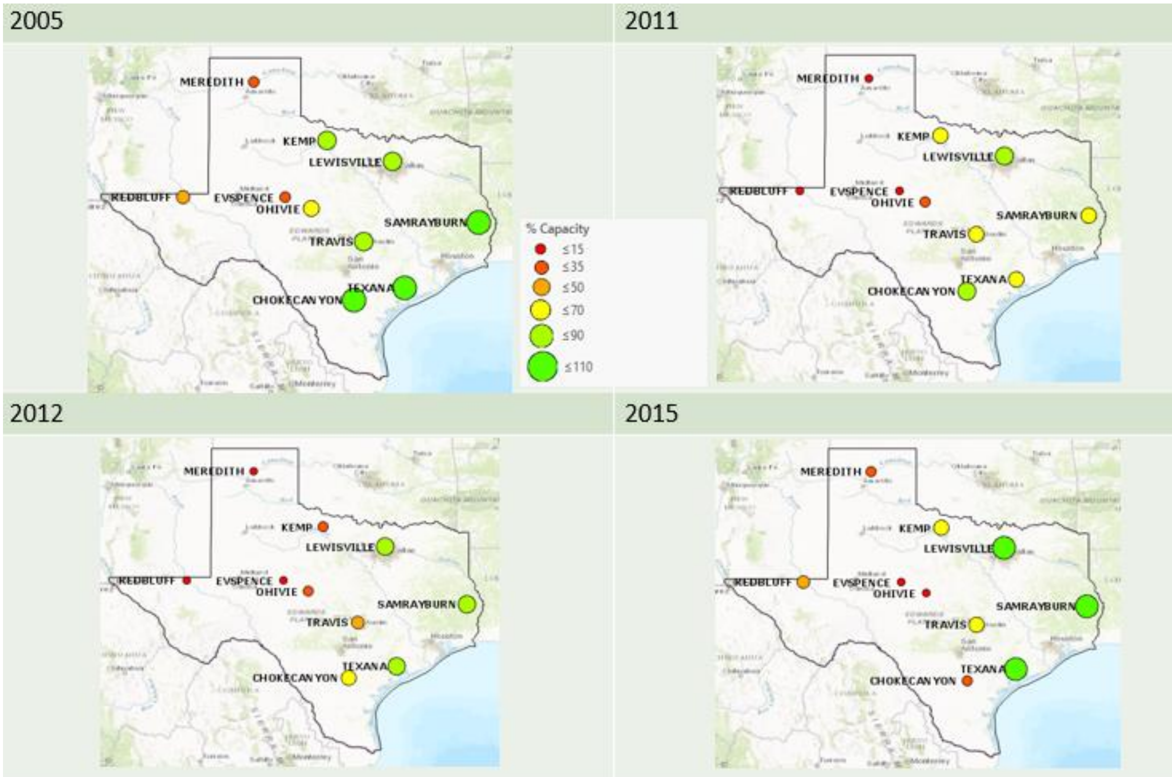
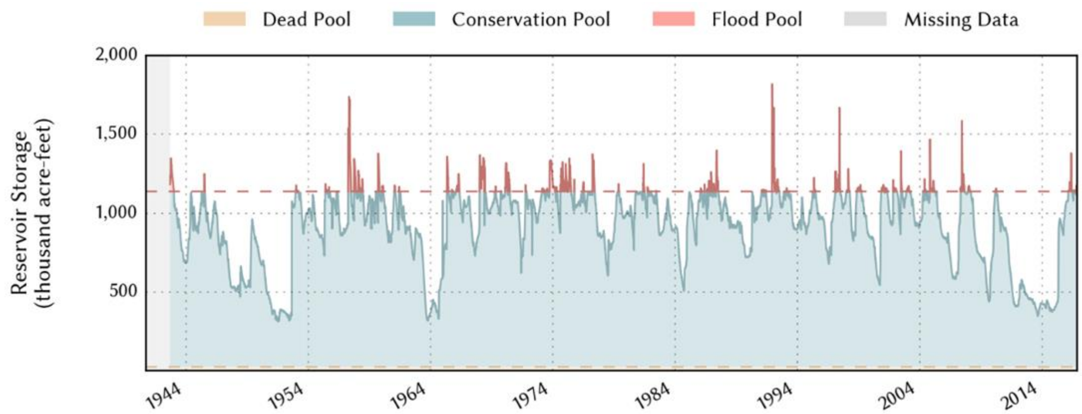
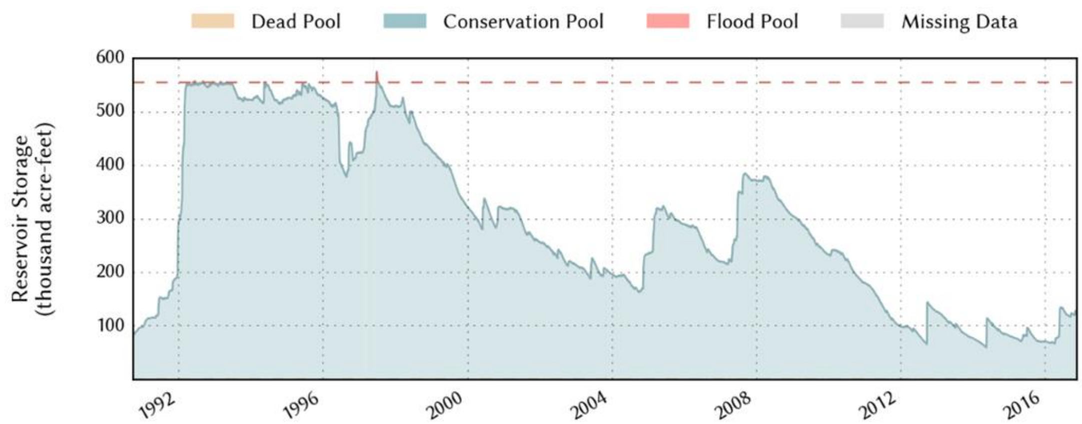
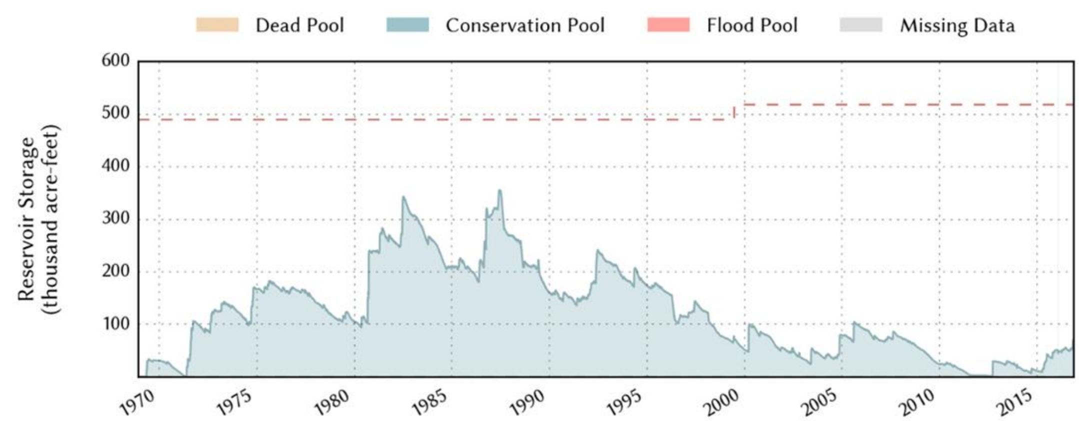


Figure 3: Yearly snapshots of percent capacity for reservoirs of interest across Texas

With a cutoff R^2 value of 0.45 only four reservoirs showed a significant trend for decreasing water levels. Lakes O.H. Ivie, E.V. Spence, Meredith, and Travis predicted roughly 20 years until zero percent capacity in each reservoir. Historical trends of water storage levels for the reservoirs of interest are illustrated in figure 4.

Table 2: Projected Time Till Zero Percent Capacity

Reservoir	R^2	Years Till Zero
O.H. Ivie	0.52	23
E.V. Spence	0.48	20
Meredith	0.71	21
Travis	0.67	23

Travis	
O.H. Ivie	
E.V. Spence	

Meredith

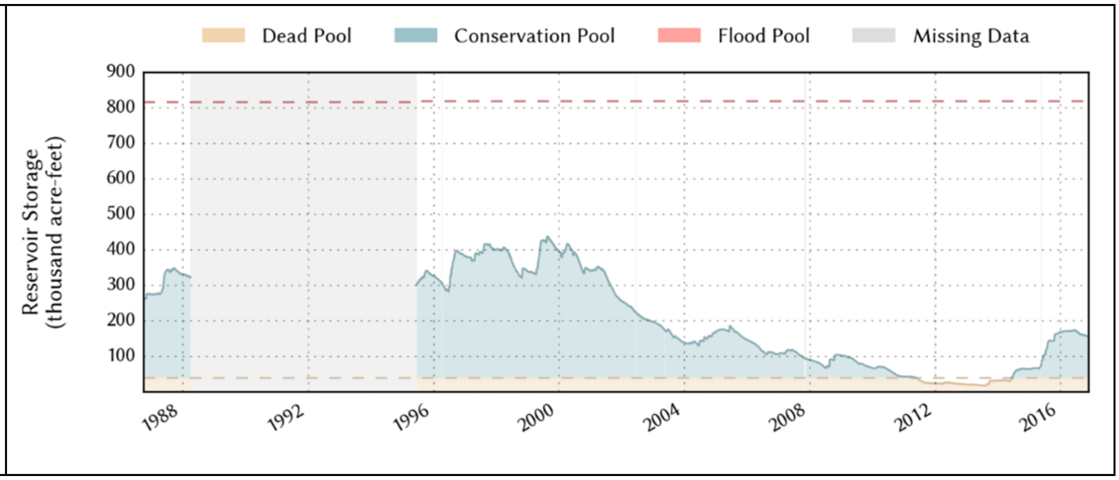


Figure 4: Historical reservoir storage trends for lakes with predicted zero percent capacity in the near future

The snapshots of percent historical deviation in figure 5 help to show when reservoir storage levels are atypical. The averaged historical deviation in the bottom right corner of figure 5 shows that lakes O.H. Ivie, E.V. Spence, and Meredith all deviate from historical storage levels by more than 40%. Reservoirs lining the eastern border of the state were either above or equal to historical levels.

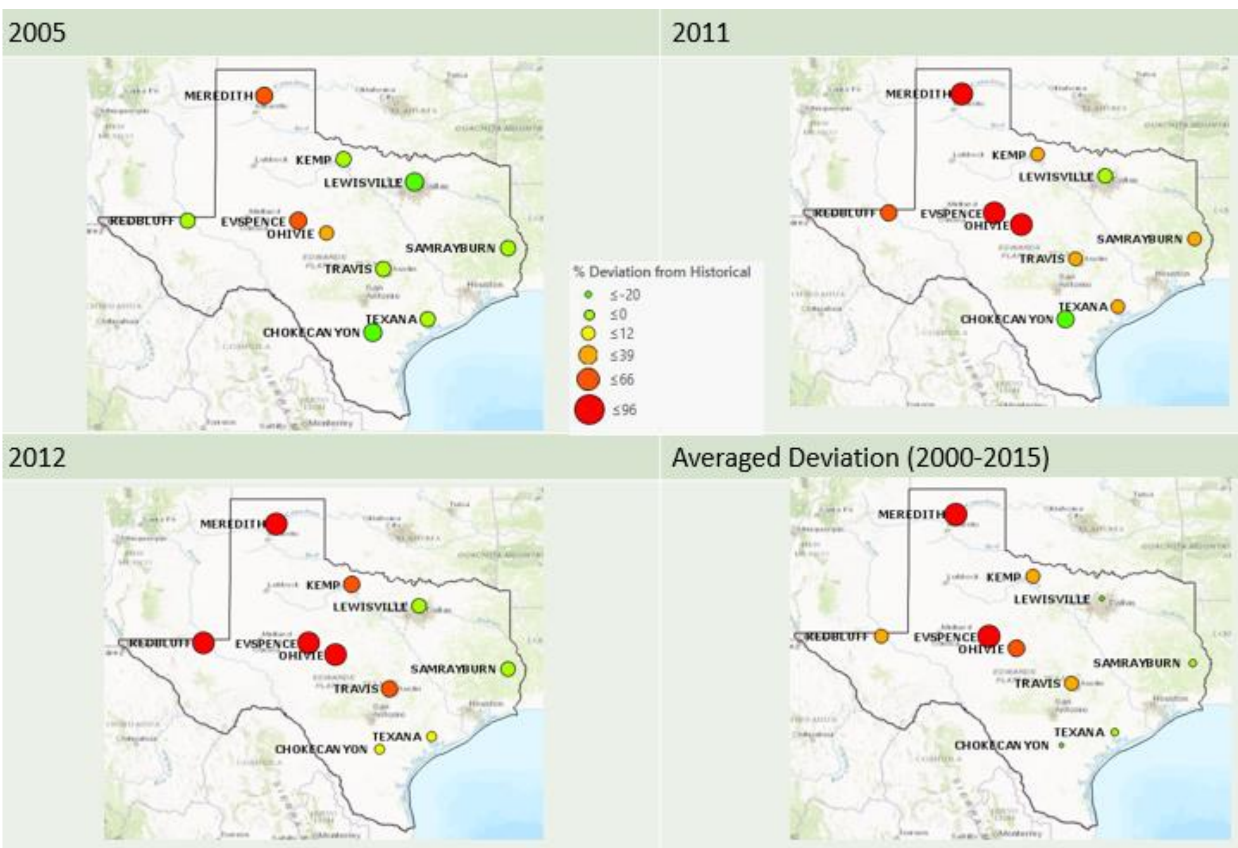


Figure 5: Yearly snapshots of deviation from historic reservoir levels

An illustration of water source elevation differences is given in figure 6. For the cities of Odessa and Midland, water needs to be pumped roughly 500 vertical meters. Dr. Maidment provided figure 7 that illustrates the extensive network of pipelines and pump stations needed to distribute water across this section of western Texas [11]. Western Texas communities are dealing with lower water storage levels along with the energy needs of transporting water.

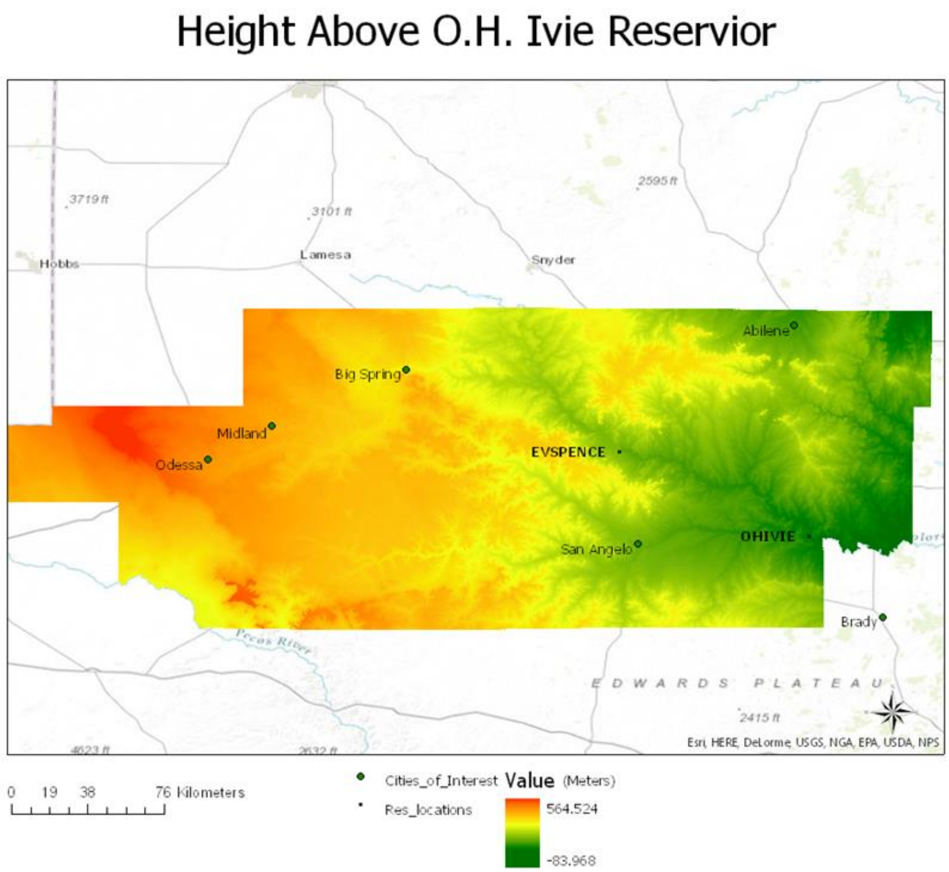


Figure 6: Height Above O.H. Ivie illustrates the challenges of transporting water resources to western Texas communities

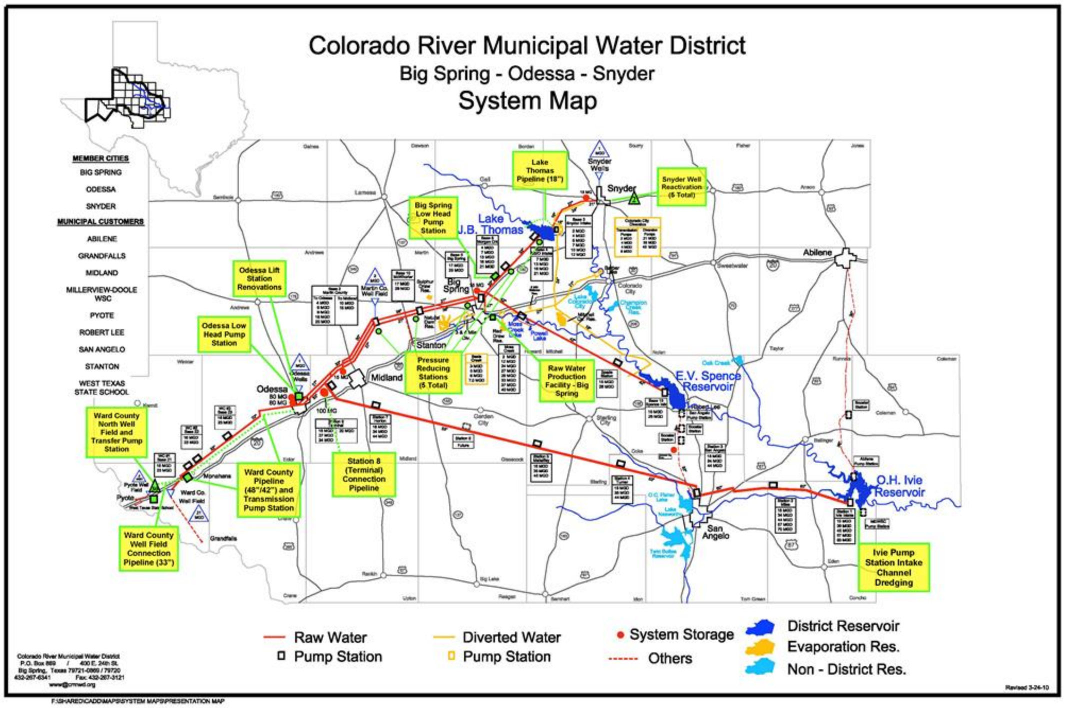


Figure 7: Network of pipelines, pump stations, and well fields servicing the Colorado River Municipal Water District [11]

San Angelo Case Study

The city of San Angelo and its 100,000 residents have historically received water from Lake O.H. Ivie, Lake E.V. Spence, and a number of smaller reservoirs [2]. As shown in the previous section reservoir storage in both of their main water sources has been steadily decreasing since the early 2000's. This section will provide history on how the city came about a solution to their long term water needs while exemplifying just how desperate many western cities are.

In 2009 Alvin New beat out 7 other competitors for the mayoral office on a platform of water security and planning. Alvin New previously worked as CEO for Town and Country Food Stores before deciding to research local water resources and run for the mayoral office [7]. Mayor New kept his promises and helped implement a project to extract and pump groundwater from an aquifer 60 miles to the southeast near the town of Brady Texas. The city attained water rights to this aquifer in the early 1970's, but did not invest in needed infrastructure until 2009. In the wake of the economic recession, Alvin New argued that interest rates and construction costs would never be lower [12]. The Hickory Aquifer project commenced with 120 million dollars financed through a floating bond. In addition to the 60 miles of pipeline, considerations were needed to avoid health hazards in the aquifer's naturally occurring radium. The city of Brady Texas discovered that rust/calcium buildup in their pipe network attracted radium. The pipes had such high radiation that a local scrap yard refused to take them. Therefore non corrosive pipes and treatment options for the water were high priorities for the city of San Angelo [6]. In 2016 an additional 43 million dollars was spent to purchase land on top of the Hickory Aquifer to avoid a potentially costly legal battle over water rights [12]. The water needs of San Angelo citizens was so severe that a total of 163 million was spent to pump water with trace amounts of radioactivity from 60 miles away.

Conclusion

Eastern Texas reservoirs are characterized by being largely at or near capacity throughout the 2000-2015 period, while having a low percentage deviation from historical levels. In contrast, reservoirs in western and northern Texas have been characterized by low annual percent capacity in addition to a high percentage deviation from historic storage levels. Figures 3 and 5 illustrate the major differences in reservoir storage trends in recent history.

Water resources in Lakes O.H. Ivie, E.V. Spence, and Meredith have been uncharacteristically low in the past decade. Although periodic rain events raise water levels over the short term, the trend in all three reservoirs is one of decreasing water resources. To prepare for potentially empty reservoirs in the coming decades, cities that are dependent upon these sources must evaluate alternative water resource options and increase conservation measures. As resources dwindle cities like Odessa and San Angelo race to increase the groundwater supply capacity with new wells and pipelines. If economically feasible, western and northern Texas cities could invest in cradle to cradle treatment options to re-utilize wastewater as drinking water or agricultural water.

Reservoir storage trends over the past 15 years in west Texas is concerning. Evaluation of alternative water resource options and implementation of contingency plans should be accelerated to prepare for a potentially water barren future.

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