A Visualization of Water Resources in Montgomery County, Texas

By James Bronikowski

Introduction:

Groundwater has been a cheap reliable source of water since people first began settling the upper gulf coastal region of the State of Texas, and this was especially true for the people of Montgomery County as it contains no natural surface water reservoirs. However, over the past few decades he population has grown tremendously, and community leaders have become aware of changes in aquifer levels that many associated with the increased withdrawal of groundwater. Since a single shared aquifer underlies the entirety of Montgomery County, the need for a regional solution led county voters to approve the creation of a groundwater conservation district to study and manage the county's groundwater resources. A further growth in population and the district's activities have resulted in plans to address the issue, but opinions have shifted in recent years and the current regional water planning solutions are under revaluation by some communities.

The goal of this study is to use ArcGIS Pro to compile information from numerous sources to develop a visualization of the water resources of Montgomery County, and to increase the level of understanding among community members so that all stakeholders involved have additional perspectives for informed decision making.

Background:

Location

Montgomery County is located directly north and adjacent to Harris County, which contains most of the City of Houston. It encompasses an area of approximately 500 square miles.

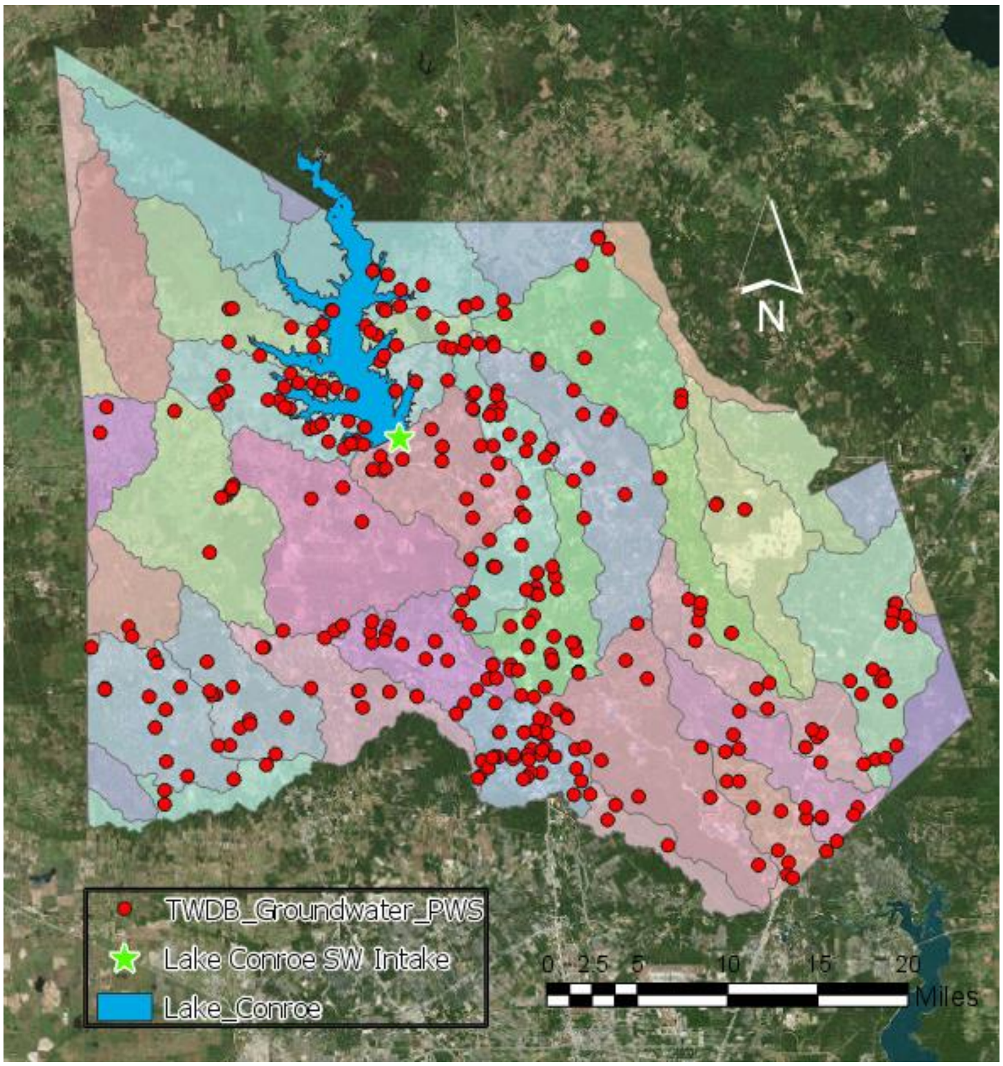
Groundwater

Historically, Montgomery County has relied primarily on groundwater resources to meet the water supply demands of its residents and businesses. This has resulted in the over 200 plus public water supply (PWS) entities that serve the county to drill and operate over 400 wells to meet the water demands of the public. There are thousands of small volume groundwater wells across the county that supply private homesteads, irrigation farmers, and other uses, but this study focuses on PWS systems since their wells account for about 85% of the total pumped annually.

To start the analysis of PWS groundwater wells, I searched online GIS data sources and located a shapefile on the Texas Water Development Board (TWDB) website that contained all the PWS wells in their database. This file also contained information in tabular format that included many fields for each well such as the geographical coordinates, depth, owner, purpose of use, etc. The PWS well shapefile was added to a new basemap in ArcGIS Pro along with a shapefile for Texas counties so that the data could be refined to only reflect those wells that were in Montgomery County. It should be noted that the all layers used and created were applied using the GCS WGS 1984 as the spatial reference.

Using the Select tool, a new feature class was created from the Texas Counties shapefile that contained only Montgomery County. This new feature layer is key, and would be needed in the creation of several other layers. Next a shapefile containing HUC 12 catchments was added to the geodatabase and the Select tool was again used to show only the catchments and catchment portions contained within the county. It should be noted that all the catchments shown in Montgomery County are a part of the San Jacinto River Basin.

The results so far are seen in the figure below, and one could make a few observations at this point. The majority of PWS wells appear to be densely packed in some areas and sparse in other parts of the county. It can also be noted that some smaller catchments contain many wells and several larger catchments contain relatively few wells.



At this point only the geographic data for the wells has been analyzed, but more analysis can be done since the data model for the PWS wells contains information on well depth also. The data for well depths are important as this adds another physical dimension for analysis.

Most of the water withdrawn from PWS wells in Montgomery County comes from the Chicot and Evangeline Aquifers which make up the upper portion of the Gulf Coast Aquifer System in Texas. As seen in the figure below, these two aquifers lie above the Burkeville confining unit and most of Montgomery County is covered by their recharge zones.

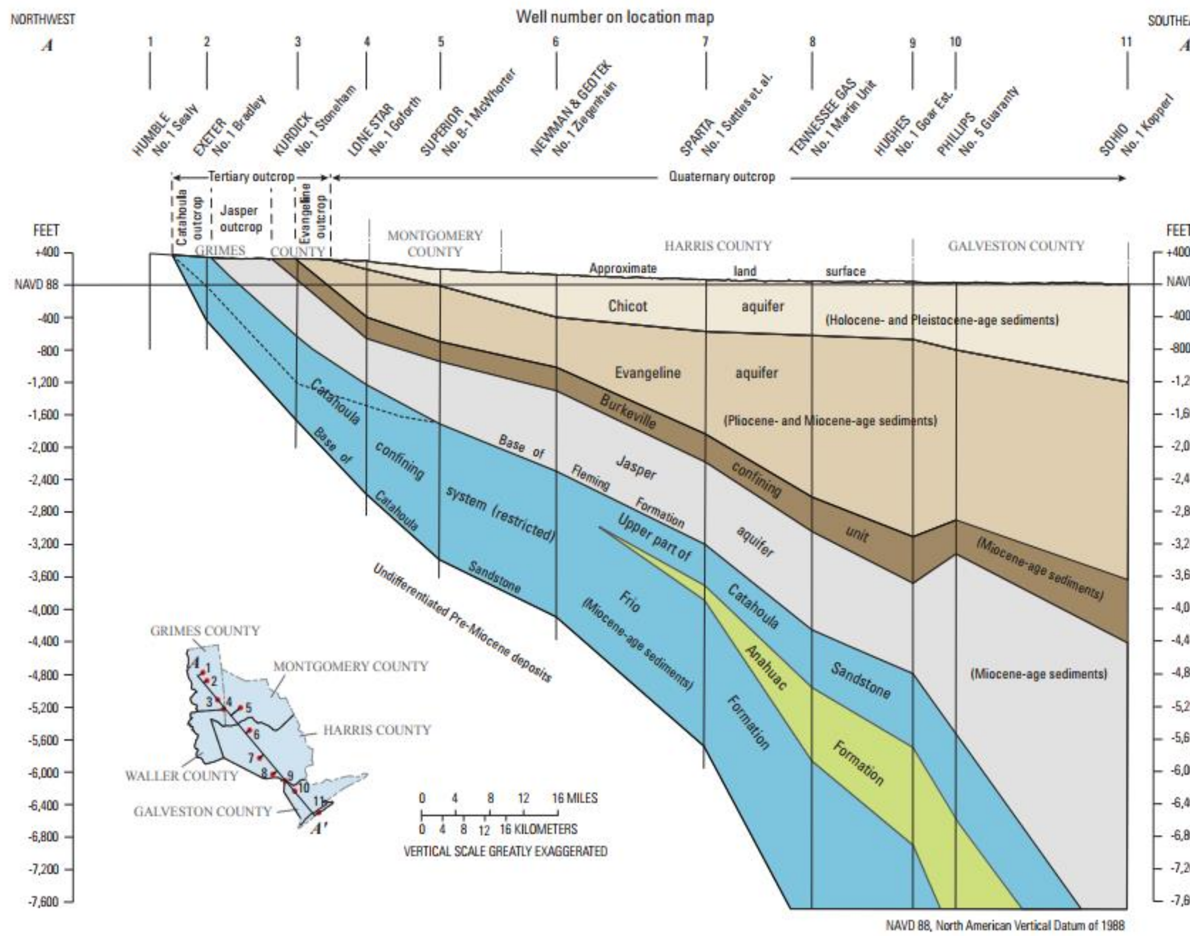
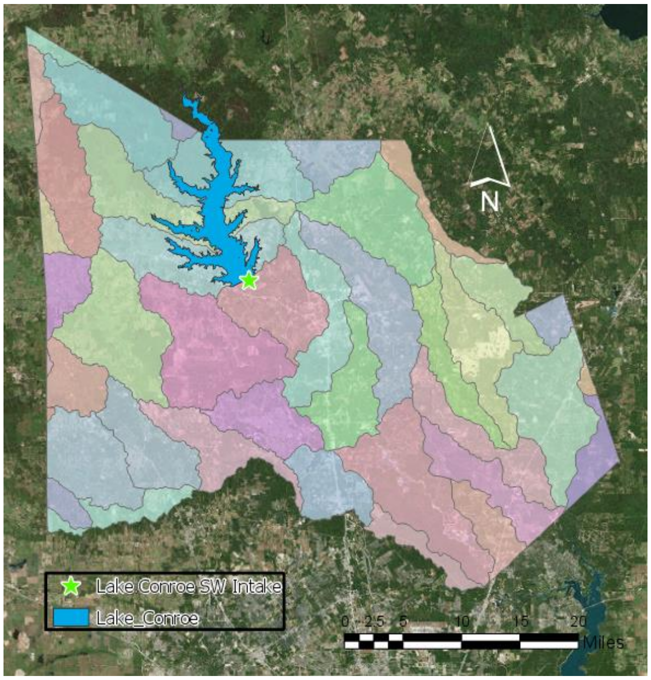


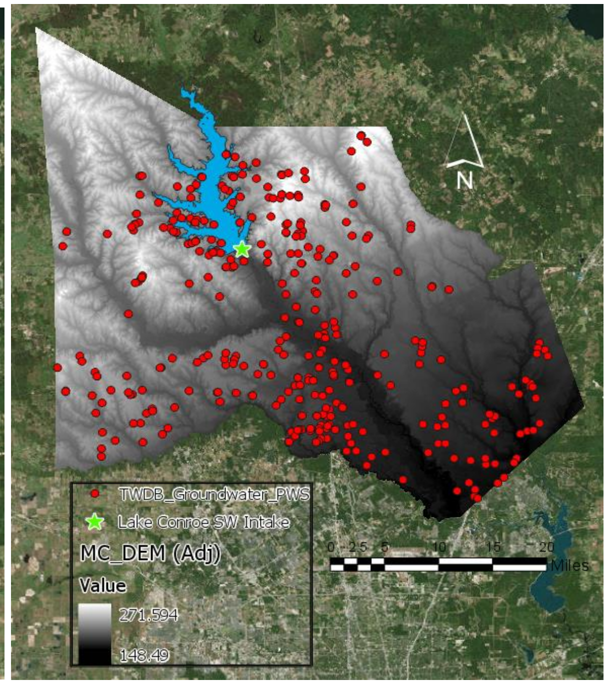
Figure 4. Hydrogeologic section of the Gulf Coast aquifer system in part of Montgomery County and adjacent counties, Texas (modified from Baker, 1979, fig. 4).

Surface Water

While groundwater from the Chicot and Evangeline formations have historically been the primary source of water for the county, surface water supplies have been and will be increasingly relied on to as water demands increase. There is only one surface water reservoir currently available to supply water users in Montgomery County, and that is Lake Conroe. The lake has a normal pool elevation of 201 feet above mean sea level (MSL), which was used as a baseline when performing analysis.

In 2015, the San Jacinto River Authority completed construction on a surface water treatment plant on Lake Conroe that has an initial capacity of 30 million gallons per day (MGD) with potential for a future total buildout of 120 MGD.





Lake Conroe is situated in the northwestern portion of Montgomery County on the West Fork of the San Jacinto River. A shapefile for the major reservoirs of Texas was located on the TWDB website, and the Select tool was used to create a new layer containing only the polygon representing Lake Conroe.

As shown in the left side figure above, only a small portion of the San Jacinto River Basin drains into Lake Conroe, however significant average annual rainfall across the basin has resulted in up 100,000 acre-feet per year being available through permitted use. This more than 120% of the current amount supplied by groundwater. It can also be noted from the right side figure above that many PWS wells are located in close proximity to Lake Conroe, and that a majority of PWS wells are downstream and downhill from the water treatment plant's surface water intake.

GCD Regulatory Plan

In 2001, the Texas Legislature passed and the voters subsequently approved the creation of the Lone Star Groundwater Conservation District to address issues and concerns regarding the groundwater supply in Montgomery County. The District commissioned several studies of the available scientific evidence and determined that the average annual recharge of county-wide groundwater resources was approximately 64,000 acre-feet (~21 billion gallons). At the time, annual groundwater withdrawals exceeded this recharge amount by about 4 billion gallons. With this amount in mind, the District developed a regulatory plan for all large volume water users to reduce their annual pumpage by 30% in an effort to stabilize groundwater levels. It was this plan that led to the construction of SJRA's surface water treatment plant, and most communities were initially very receptive of the plan. Rising surface water prices and above average rainfall has since led some to doubt the data presented by the District and others to call for their outright dissolution.

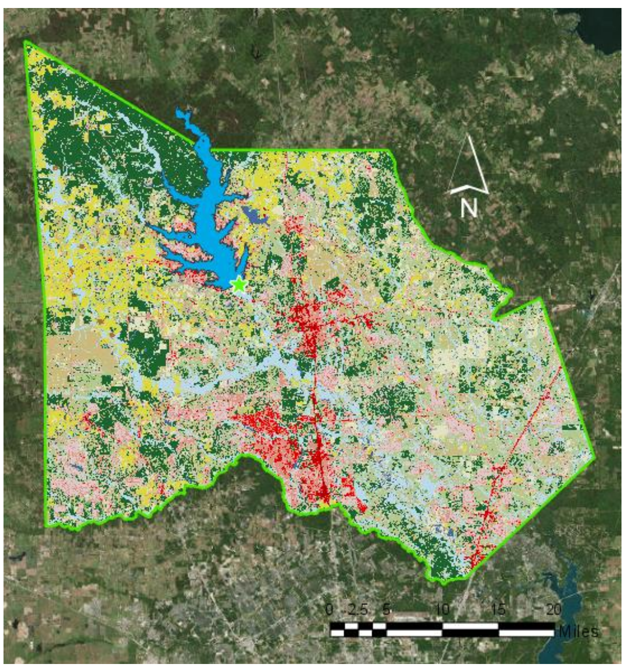
Surface Trends

Population

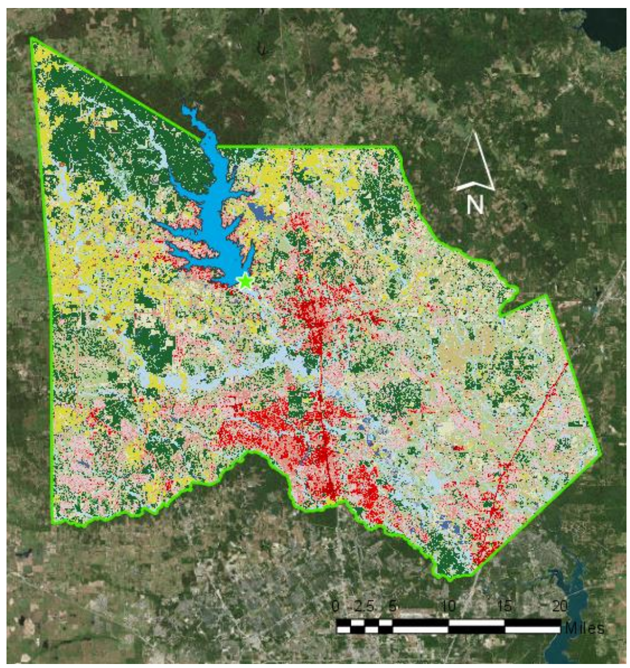
Montgomery County has consistently been one of the fastest growing counties in the state over the past decade, with the largest city Conroe recently leading the nation in population growth rate. The city has seen a population increase of 7.8% over the last year according to the US Census Bureau. This rapid influx of people into the county has and will only further drain the water resources of the area.

Land Cover

The increasing population of the county is evident when viewing and comparing the changes in land cover imagery over time. To analyze this, raster data files containing land cover information for the years 2001 and 2011 were downloaded from the Texas Natural Resources Information System (TNRIS) website and added to the geodatabase in ArcGIS Pro. These two layers were then analyzed with the Select to only contain the data for Montgomery County. A comparison of the two shows that the substantial population growth and accompanying land development has significantly increased the amount of impervious cover within Montgomery County.



2001

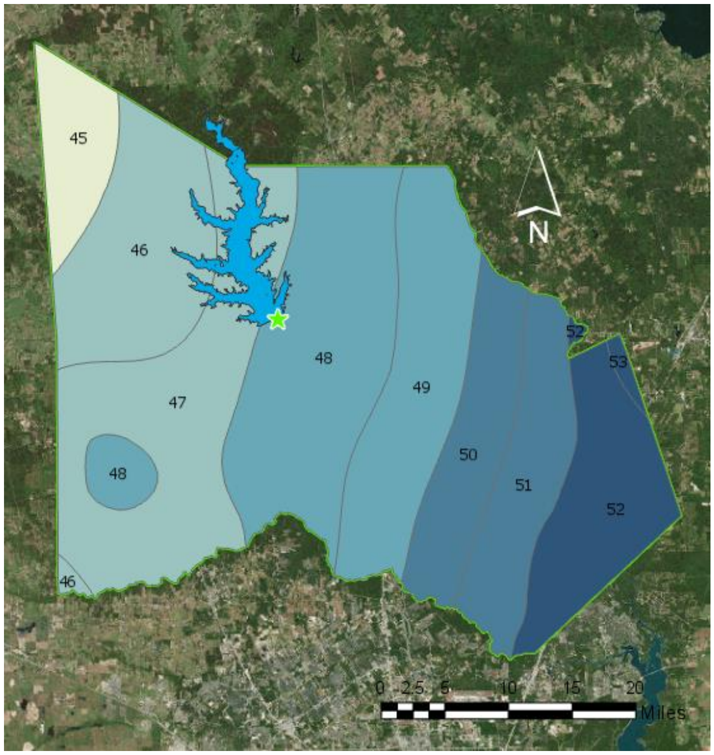


2011

For a more precise calculation of the increase in impervious cover, an analysis was done comparing the number of cells in each raster that are coded as developed land. This calculation shows a 21.3% increase in impervious cover from 2001 to 2011. For grid cells that are 30 m by 30 m, this translates to an additional 46.2 square miles of developed land between 2001 and 2011.

Precipitation

Due to its location along the gulf coast in the southeastern part of Texas, Montgomery County receives a relatively large amount of rainfall compared to the remainder of the state. The far eastern portion of the county averages about 52 inches of rainfall per year, while the annual average decreases to about 45 inches in the western portion of the county as the varied blue bands show in the figure below.



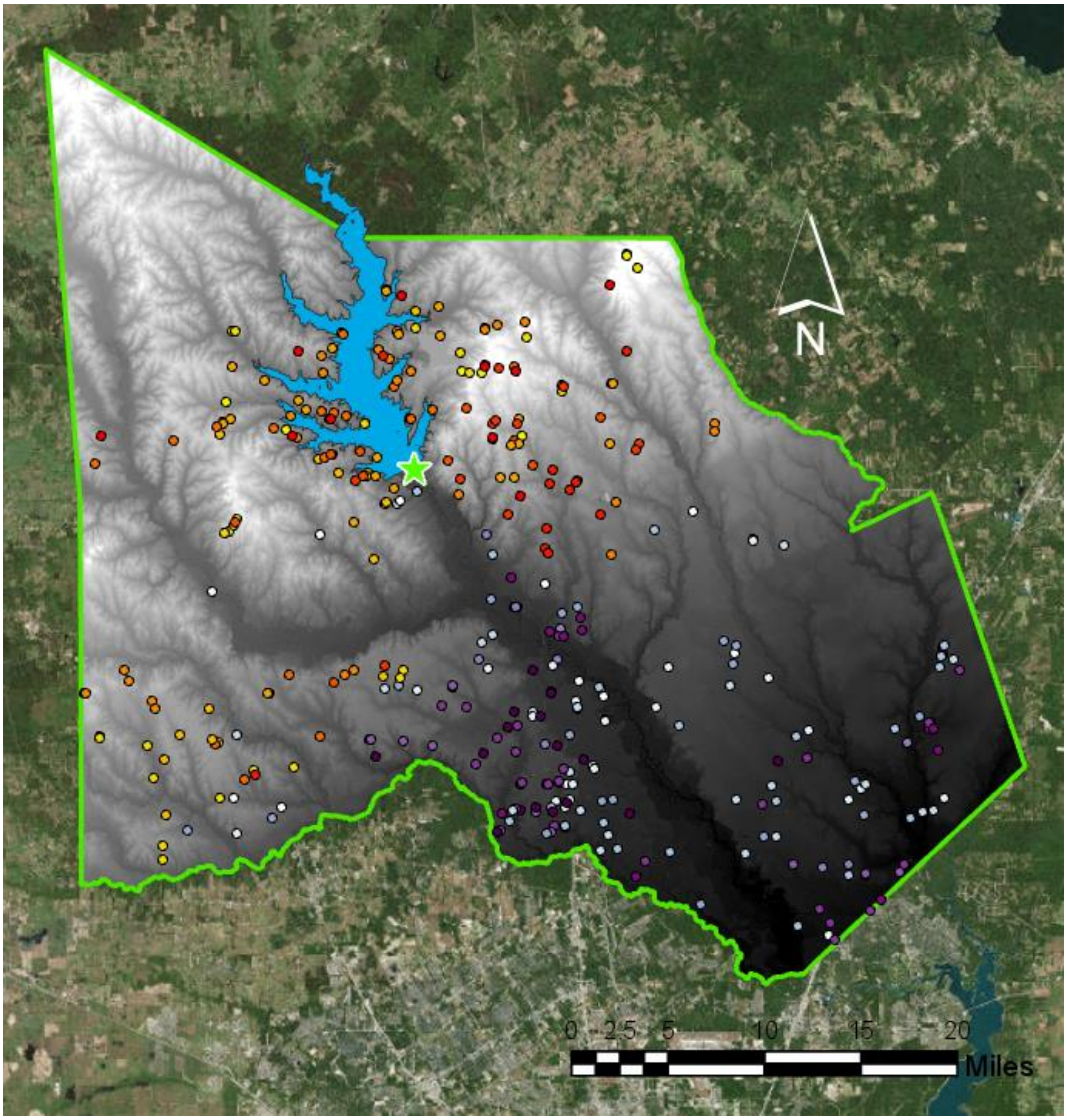
DEM/Height to SW Intake

The powerful analysis toolbox provided in ArcGIS Pro, along with some assumptions, allowed for the information in the data model to be analyzed and compiled into new layers that show interesting new interpretations and understandings. With the PWS well data, sites were split into two groups with one containing all that have a surface elevation above the Lake Conroe normal pool and the other containing all that have a surface elevation below the lake's normal pool. Once split into two layers by use of the Select tool, a new Field was added to the attribute tables of these two new layers to calculate the elevation of the actual well pumps. This new Field is referred to as the Pump Height Above Surface Water Intake (PHASWI), and was calculated with the two formulas shown below.

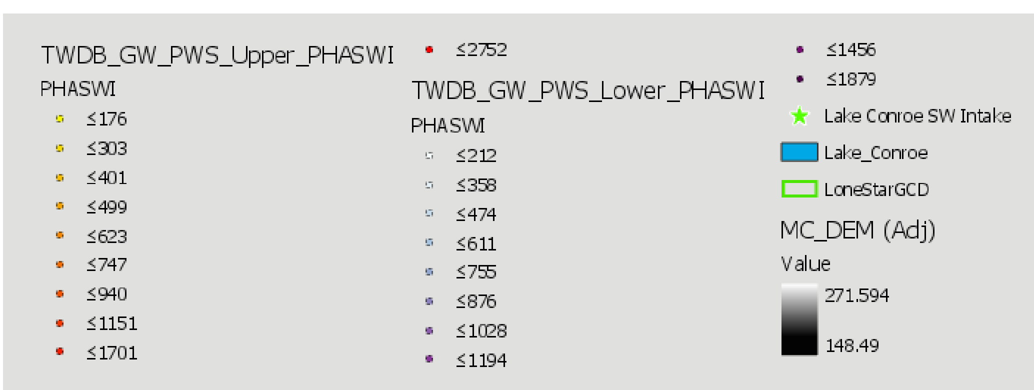
Well Depth – (Well Elevation – 201) = PHASWI (Upper PWS Wells)

Well Depth + (201 – Well Elevation) = PHASWI (Lower PWS Wells)

This new Field allowed for the Symbology of these two new PWS well feature layers to display the current actual PWS well pump heights so that they could be compared to the elevation of Lake Conroe's surface water intake. The Graduated Colors option was used to show the well pumps' relative height above the surface water intake with darker colors (red and purple) signifying those wells that are relatively deeper than the intakes elevation.


N
0 2.5 5 10 15 20
Miles

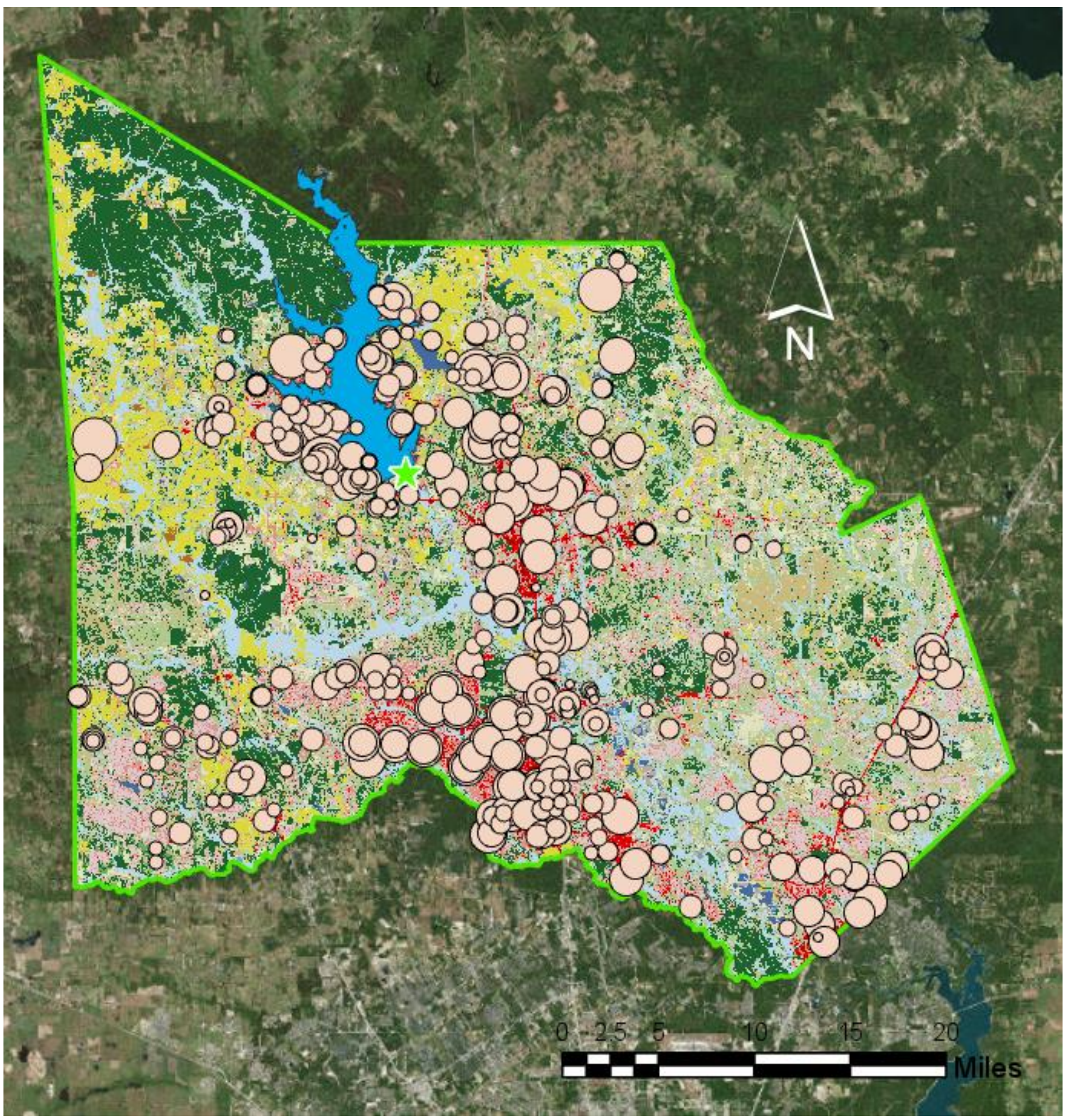
Legend


TWDB_GW_PWS_Upper_PHASWI
PHASWI
≤176
≤303
≤401
≤499
≤623
≤747
≤940
≤1151
≤1701
≤2752
TWDB_GW_PWS_Lower_PHASWI
PHASWI
≤212
≤358
≤474
≤611
≤755
≤876
≤1028
≤1194
≤1456
≤1879
Lake Conroe SW Intake
Lake_Conroe
LoneStarGCD
MC_DEM (Adj)
Value
271.594
148.49

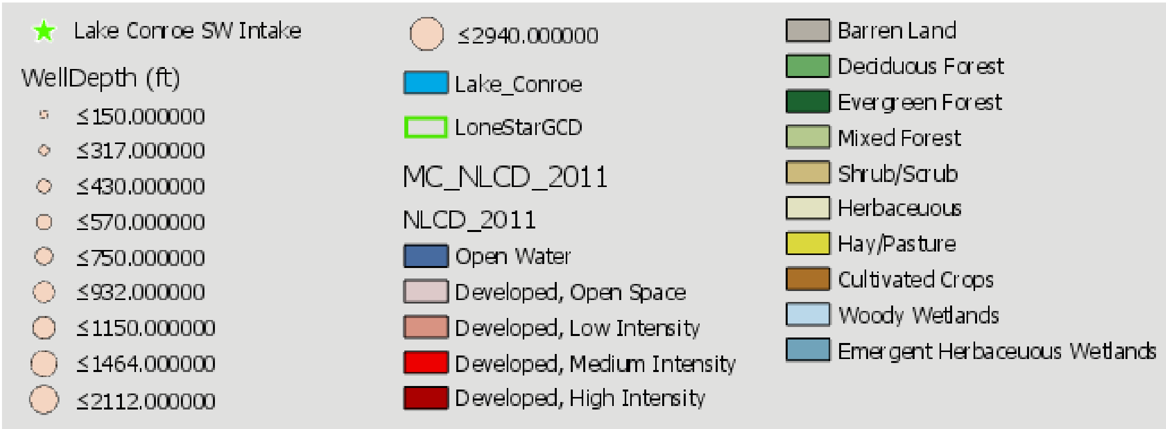
This visualization is important due to the restrictions on permitted groundwater withdrawals, and due to the increasing depths that wells must be drilled to reach groundwater levels. The darker colored wells are those that could potentially benefit from lower electrical operations costs since the depths of their well pumps are much lower (hundreds of feet or more) than the elevation of the surface water intake. This assumption does not account for changes in elevation that a potential pipeline would have to traverse if these sites were converted from groundwater supply points to surface water supply points. However, this informative visual does give a preliminary estimate of each PWS well sites potential for changing to surface water as an economically feasible option for reducing electrical operations costs.

Well Depth/Population Centers

The data model was also used to develop a visualization that compares well depth to population centers. For this, the 2011 Land Cover layer and the PWS well layer were utilized with the graduated symbols option being used for the latter. The results of this comparison are shown below.



Legend



This visualization shows that PWS wells located near densely populated areas are deeper than those at similar elevations and/or latitudes. A more in depth look at the tabular data offers additional insight by showing that newer wells appear to be drilled deeper than older wells that were in close proximity. This result supports the view that groundwater levels are dropping in many areas and that those changes in water level can be tremendous in some highly populated areas. This coincides with the concerns of many that additional unrestricted withdrawals could result in costly new deeper wells in the near future.

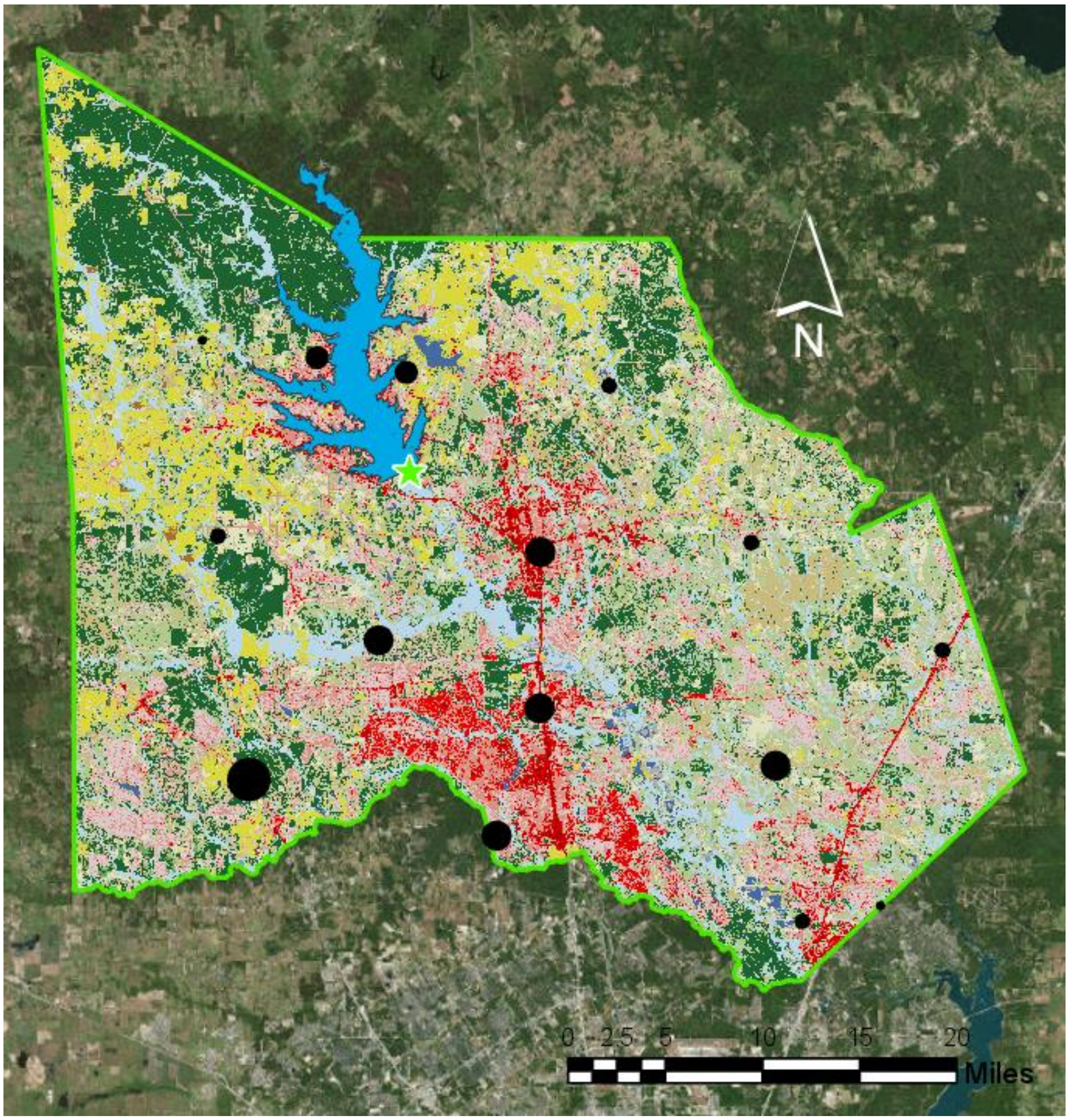
Recharge

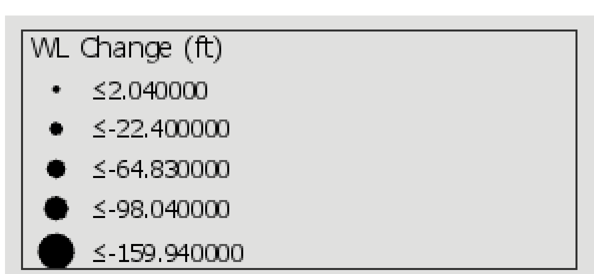
As shown in a previous figure detailing the cross-sectional makeup of the Gulf Coast Aquifer system and its sub-formations, the Burkeville confining unit covers most of the county and divides the upper two formations with the lower ones. The presence of this confining layer means that most of the precipitation that falls on Montgomery County fails to reach the lower aquifer sub-formations. The Lone Star Groundwater Conservation District has estimated that the annual recharge rate for the portions of the Gulf Coast Aquifer system underlying Montgomery County is approximately 64,000 acre-feet. This amount however is under further review with many stakeholders interested in the outcome due to the District's use of this number when setting permitted groundwater pumping limits.

Groundwater levels

Data regarding measured groundwater levels at several monitoring wells across the Montgomery County was collected from the TWDB in spreadsheet format for the years 2001 and 2011. This spreadsheet contained information regarding the wells' geographic location, depth, aquifer formation drawn from, water level, water elevation, and measurement date. Initially the spreadsheet was extremely large and contained much information that was outside the target years, so care was taken to refine the spreadsheet by selecting 15 representative well sites that were spread across the county and that had complete information for the date range. These selected sites were saved as a separate CSV file, and added to the data model in ArcGIS. The Make XY Event Layer tool was then used to create a point feature layer containing the spreadsheet data for each of the well sites. To symbolize the changes in groundwater levels, the graduated symbols option was chosen to properly proportionalize these changes.

The resulting graphic, though limited in data points, shows that water levels at all but one of the monitoring well sites has lowered in elevation over the 10-year period. That well is located the far northwest part of the county, and not near a large population center. All the remaining monitoring well sites showed drops in the water level elevation, with those in or near heavily populated areas showing the largest decreases in water levels. It should be noted that three of the monitoring wells are measuring aquifer formations below the Burkeville confining layer, and this would appear to show that water levels are dropping across several of the overlapping aquifer formations.





Conclusions

Groundwater has long been the primary water supply source for Montgomery County throughout its history. As the population has grown however, that reliance has called into question the sustainability of the aquifers and conversely brought forth discussions of groundwater rights as the attempts have been made to change the status quo. Most would agree that a more diverse water resource supply portfolio is needed with a greater use of surface water, conservation, and other alternative water sources. The questions being debated are: to what lengths these changes are to occur; the timeline of implementation; cost sharing breakdowns; and, by whose authority are these changes to be made.

The visualizations that have been compiled seek to show the water resource situation in Montgomery County from new perspectives though the analysis of available geographical and tabular data with the assistance of the ArcGIS Pro software package. The goal was to provide this information to the general public, stakeholders, and decision makers affected by these issues. In general, the data shows the degree to which the county has grown and the effects that the associated increases in groundwater withdrawals has had on the local water resources. The effects can be seen through the declining groundwater levels in monitoring wells, and the noticeably larger declines in or near the more heavily populated parts of the county. They can also be seen in the increasingly deeper wells that are shown to be drilled in and near the heavily populated areas.

Work for the Future

Reports like this should be viewed as snapshots in time, and as such are always subject to change and improvements when data is updated. There is also future work that could be done to expand the study by performing additional analysis.

The data model could be expanded by adding well production and/or permitted capacity data for all PWS sites, which could be available through the Lone Star Groundwater Conservation District. The layout of the current SJRA surface water transmission system could also be included to show communities that are currently able to receive treated surface water.

Additional analysis could include ways to compensate for changes in elevation along the potential surface water transmission line routes. This would give a more realistic comparison on sources as groundwater levels change. A way to include cost factors into the database would also be beneficial since financial concerns are a major driver for many stakeholders.