Task 3 Technical Memorandum
Regarding
Future Groundwater Availability

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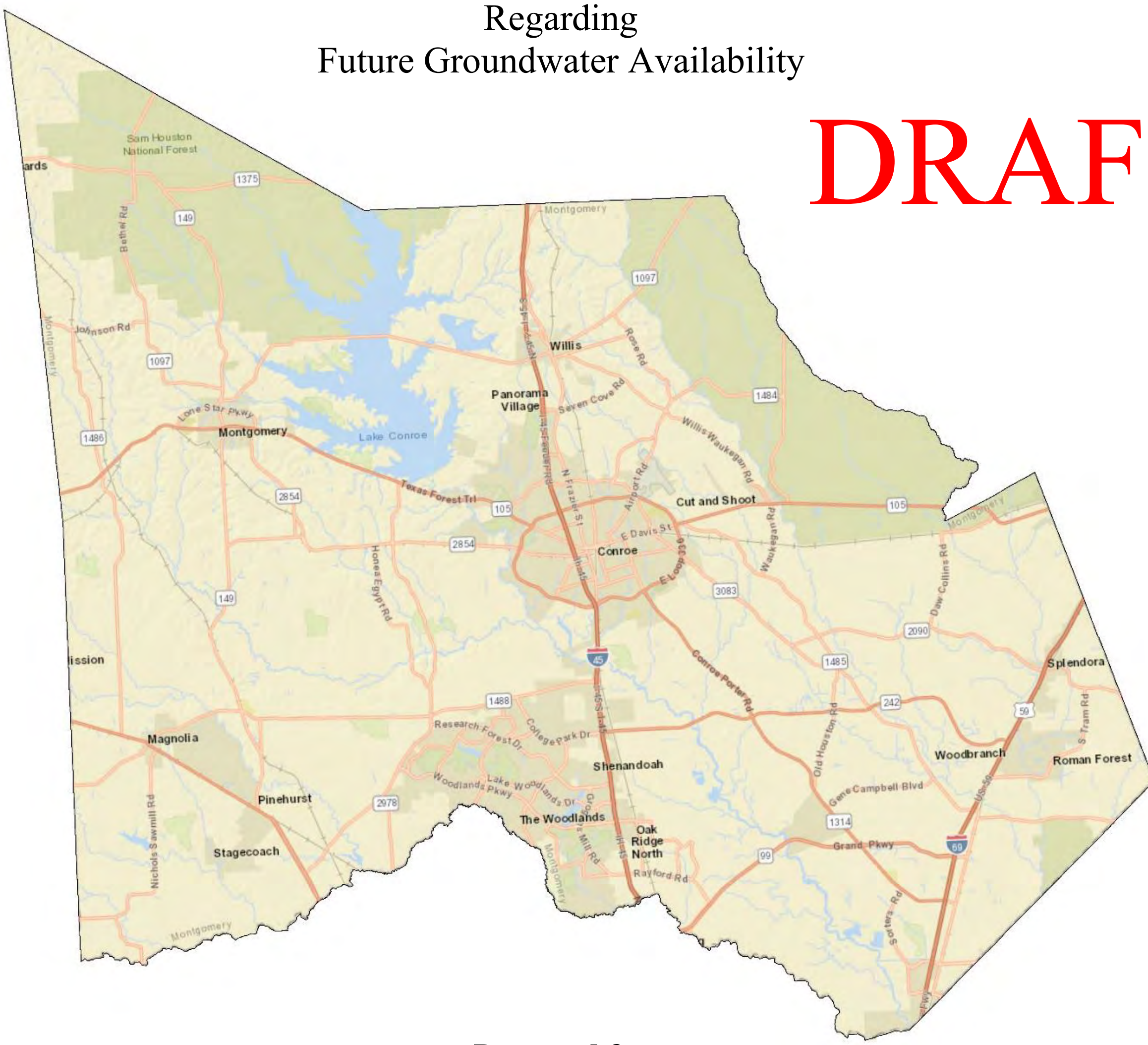

Prepared for

Lone Star Groundwater Conservation District

by

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December 6, 2017

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December 6, 2017

Ms. Kathy Turner Jones
General Manager
Lone Star Groundwater Conservation District
655 Conroe Park North Drive
Conroe, Texas 77303

Dear Ms. Jones:

Enclosed is a draft of our Task 3 Technical Memorandum regarding future groundwater availability for the District. An executive summary is included at the beginning of the Technical Memorandum.

The Technical Memorandum is being submitted as a deliverable included in Task 3 of the Lone Star Groundwater Conservation District's Strategic Water Resources Planning Study.

If you or others have any questions regarding the memorandum, please contact us.

Sincerely,

LBG-GUYTON ASSOCIATES

W. John Seifert, Jr., P.E.
Senior Project Manager

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EXECUTIVE SUMMARY

- A study was performed to evaluate the potential for additional development of groundwater within the Lone Star Groundwater Conservation District (District). Estimates regarding the amount of subsidence or potential water quality changes that could occur with the development of additional groundwater also was a consideration as part of this study. Hydrogeological data also were assembled regarding the Catahoula Formation and the groundwater production that has occurred from the aquifer in approximately the last five years along with water-level and water-quality data.

- The potential for the development of additional groundwater within the District from the Chicot, Evangeline and Jasper aquifers was explored to assess the effects that would occur as the result of additional pumping. The Groundwater Management Area (GMA) 14 Run 2 simulation of future pumping in the District was used as a starting point in the evaluation of future groundwater pumping options. The effort was conducted in collaboration with the Findings and Review Committee as various pumping options were explored. This was part of the iterative process in evaluating the potential for additional development of groundwater in the District, as was prescribed by the District Board of Directors when this study was launched in October of 2014. The results of the effort included the evaluation of four pumping scenarios with the last scenario, Run D, concluded to be a feasible approach for additional development of groundwater. This conclusion occurred while taking into consideration a survey of large volume groundwater users (LVGUs) in the District regarding the amounts of additional static water-level decline they could tolerate in their wells and still maintain production from the wells.

- The results of the Run D simulation showed that varying amounts of artesian head decline or water-level decline in wells were estimated to occur, with the areas of greater decline occurring in the areas where higher amounts of groundwater production were simulated. These areas were principally in the central part of the District along the I-45 corridor and extending a few to several miles east and west of the corridor. It is estimated that about 100,000 acre-feet per year (ac-ft/yr) could be developed from the

Chicot, Evangeline and Jasper aquifers with about 88 percent of that total being withdrawn from the Evangeline and Jasper aquifers. As a result of the pumping, it is estimated that pumps in some wells will require lowering and/or replacement to maintain some level of production. Some wells could require the installation of higher horsepower pumps to maintain pumping rates. Over the past few decades as groundwater pumping in the District has increased, similar pumping equipment upgrades have occurred as static and pumping water levels declined in wells.

- Jasper Aquifer pumping in Run D results in an increase in average drawdown in the surrounding counties of from 60 to 200 feet compared to GMA 14 Run 2 values. This is occurring because there is a substantial increase in pumping from the Jasper Aquifer projected or included for the District in Run D compared to GMA 14 Run 2.

- Based on the Houston Area Groundwater Model (HAGM, also referred to as the Northern Gulf Coast Aquifer Groundwater Availability Model), the amount of additional subsidence estimated to occur as a result of the quantities of pumping in Run D is up to about 1/2-foot greater than was calculated with HAGM for GMA 14 Run 2, the current simulation utilized during the development of desired future conditions for the District within GMA 14. The average District-wide subsidence as a result of the amounts of pumping in Run D is estimated at 0.55 feet compared to 0.50 feet for GMA 14 Run 2.

- As groundwater pumping in the District continues in the future, pumping water levels in wells and groundwater quality should be monitored, so that on a real-time basis, the response of the aquifer to pumping can be evaluated and that evaluation utilized for future groundwater supply planning and management.

- The reduction in pumping from the Chicot, Evangeline and Jasper aquifers in 2016 has resulted in static water-level recovery over a substantial part of the areas where the pumping is occurring in the District. A vast majority of the static water-level recovery is occurring in the Evangeline and Jasper aquifers as about 97 percent of the overall permitted pumping reduction in 2016 of 15, 244 ac-ft has been recorded in those two aquifers.

- The pumping of groundwater from the Catahoula Formation that began in 2011 has gradually increased to approximately 4,400 acre-feet in 2016. The pumping has resulted in modest static water-level declines in wells that have averaged about 20 feet for the pumping that was spread over an area of about 100 square miles. Based on the response of the Catahoula Formation to date, it is estimated that additional groundwater could be developed on a long-term basis. As is occurring now, the monitoring of pumping and water levels in wells should continue to advance the assessment of the response of the aquifer to additional pumping and the data could be used in the future for development or enhancement of a groundwater flow model.

- The development of groundwater from the Catahoula Formation has been focused on areas with better water quality that is being used for public supply. The water quality data developed over the last three to five years is showing that the total dissolved solids (TDS) content or general mineralization of the water produced by wells completed in the Catahoula Formation is stable. Well water quality data should continue to be collected in the future to lengthen the record and improve further assessment of water quality in the Catahoula Formation.

- Increasing pumping from the Catahoula Formation by thousands of ac-ft/yr, if it occurs, most likely will necessitate the lowering of pumps and increasing motor horsepower in some Catahoula Formation screened wells.

INTRODUCTION

The Lone Star Groundwater Conservation District (LSGCD or District) is conducting a strategic water resources planning study to evaluate potential opportunities for additional development of groundwater resources while ensuring long-term viability of the aquifers in the District. As part of this strategic evaluation, Task 3 study objectives included assessments of the potential for developing additional groundwater from the Chicot, Evangeline, Jasper aquifers and the Catahoula Formation. This process included the development of potential pumping scenarios in the District and calculating the effects of those groundwater pumping scenarios on the Chicot, Evangeline and Jasper aquifers using the Houston Area Groundwater Model (HAGM, also referred to as the Northern Gulf Coast Aquifer Groundwater Availability Model). As part of the process, the distribution of pumping between the aquifers, both spatially and temporally, was varied while assessing the potential for additional development of groundwater resources in different parts of the District. While working closely with the Findings and Review Committee of the Board of Directors, recommendations were developed for potential future pumping opportunities in the District and data were developed regarding the potential effects of the pumping relative to artesian head changes and subsidence. Additionally, an estimate is provided of the potential effects of developing additional groundwater from the Catahoula Formation.

Sections of this Technical Memorandum include a review of the Task 2 Technical Report, a model simulation adapted by Groundwater Management Area (GMA) 14 during the last cycle of planning and model simulations of groundwater pumping scenarios considered as part of this Task 3 study.

A summary of the initial evaluation of the reduction in groundwater pumping in 2016 and its effects on artesian heads in the Chicot, Evangeline and Jasper aquifers is provided in Appendix A.

TASK 2 REVIEW

A review of the total estimated recoverable storage (TERS), estimates released by the Texas Water Development Board (TWDB) and their possible implications to groundwater management in the District were studied as part of the Task 2 effort. The TERS estimates included in the data released by the TWDB in 2014 show that there are large quantities of groundwater in storage within the District. The Task 2 Technical Memorandum documented that this understanding of large quantities of groundwater in Montgomery County has been known by water resources planners for decades. The Task 2 Technical Memorandum also notes that estimates of TERS produced by the TWDB do not give weight to, among other considerations, the longevity of a supply, the economics of pumping the water, subsidence resulting from lowering artesian water levels, impacts on water quality, and did not consider the practicality or the effects of pumping on both short-term and long-term basis. The 25 to 75 percent bounds set by the TWDB as estimates of the amount of groundwater that might be withdrawn by pumping do not appear applicable when assessing the availability of a groundwater supply from the artesian aquifers in the District. The estimates of TERS do show that there is a very large amount of groundwater in storage and that information is valuable in understanding the areal extent and thickness of the Chicot, Evangeline and Jasper aquifers and that they are a regional, major water supply extending under at least 21 counties in the southeast part of the state, including all of the counties surrounding the District.

CATAHOULA FORMATION ASSESSMENT

As part of Task 3, an assessment was performed of the aquifer response of the Catahoula Formation to the recent pumping from the aquifer in the District. Since 2011, about 14 wells have been constructed in the northern part of the District and screened to withdraw water from the Catahoula Formation. Catahoula Formation well and pumping data were obtained from the LSGCD, the U.S. Geological Survey (USGS) and Municipal Utility Districts (MUDs) within the District. The Catahoula Formation is located just below the base of the Gulf Coast Aquifer System and it has the capability of providing water to large capacity wells. In the north part of the District, available electric log and water quality data indicate the Catahoula Formation contains water with less than 1,000 milligrams per liter (mg/l) total dissolved solids (TDS) over about 360 square miles and contains water with greater than 1,000 mg/l TDS over a larger part of the District, as shown on Figure 1. The Catahoula Formation is currently being utilized as a supply of fresh groundwater in the north part of the District and could be considered as a potential supply of brackish groundwater in other areas of the District.

The 14 constructed wells along with their screened intervals, TDS, and fluoride levels, are listed in Table 1.

Table 1. Catahoula Formation Screened Wells

Well Owner & Number	Ground Level Elevation (ft)	Screened Interval (ft)	TDS (mg/l)	Fluoride (mg/l)
Dobbin-Plantersville WSC -Well 8	260	2,022-2,582	972	2.33
Montgomery Co. MUD 18 – Well 3	272	1,833-2,453	455	NA
City of Montgomery – Well 4	245	2,450-2,560	511	2.1
Stanley Lake MUD – Well 3	249	2,238-2,666	916	1.93
Corinthian Point MUD 2 – Well 4	260	1,865-2,092	691	1.36
Point Aquarius MUD – Well 4	248	1,668-1,728	764	0.52
City of Willis – Well 6	343	1,898-2,665	643	1.55
City of Willis – Well 7	389	2,094-2,920	941	1.94
Montgomery Co. MUD 8	219	2,174-2,660	574	NA
Far Hills UD – Well 6	216	2,372-2,602	416	1.55
Cal Sierra International, LLC	395	1,768-2,255	718	NA
City of Panorama Village – Well 4	299	2,142-2,814	783	2.07
Montgomery Co. UD 3 – Well 3	294	2,290-2,587	568	1.96
City of Conroe – Well 24	260	2,258-2,623	991	2.13

The wells are located in the north part of Montgomery County and are shown on Figure 1.

Pumping from the Catahoula Formation in Montgomery County started in 2011 with the Montgomery Co. UD 3 well and the other 13 wells have followed in subsequent years. Table 2 shows the pumping amounts for the past six years. Pumping data from the recently constructed Far Hills UD Well 6 was not available at the time of this report. Annual pumping totals from the Catahoula Formation currently average about 3.9 million gallons a day (mgd) or 4,400 acre-feet per year (ac-ft/yr) as of 2016.

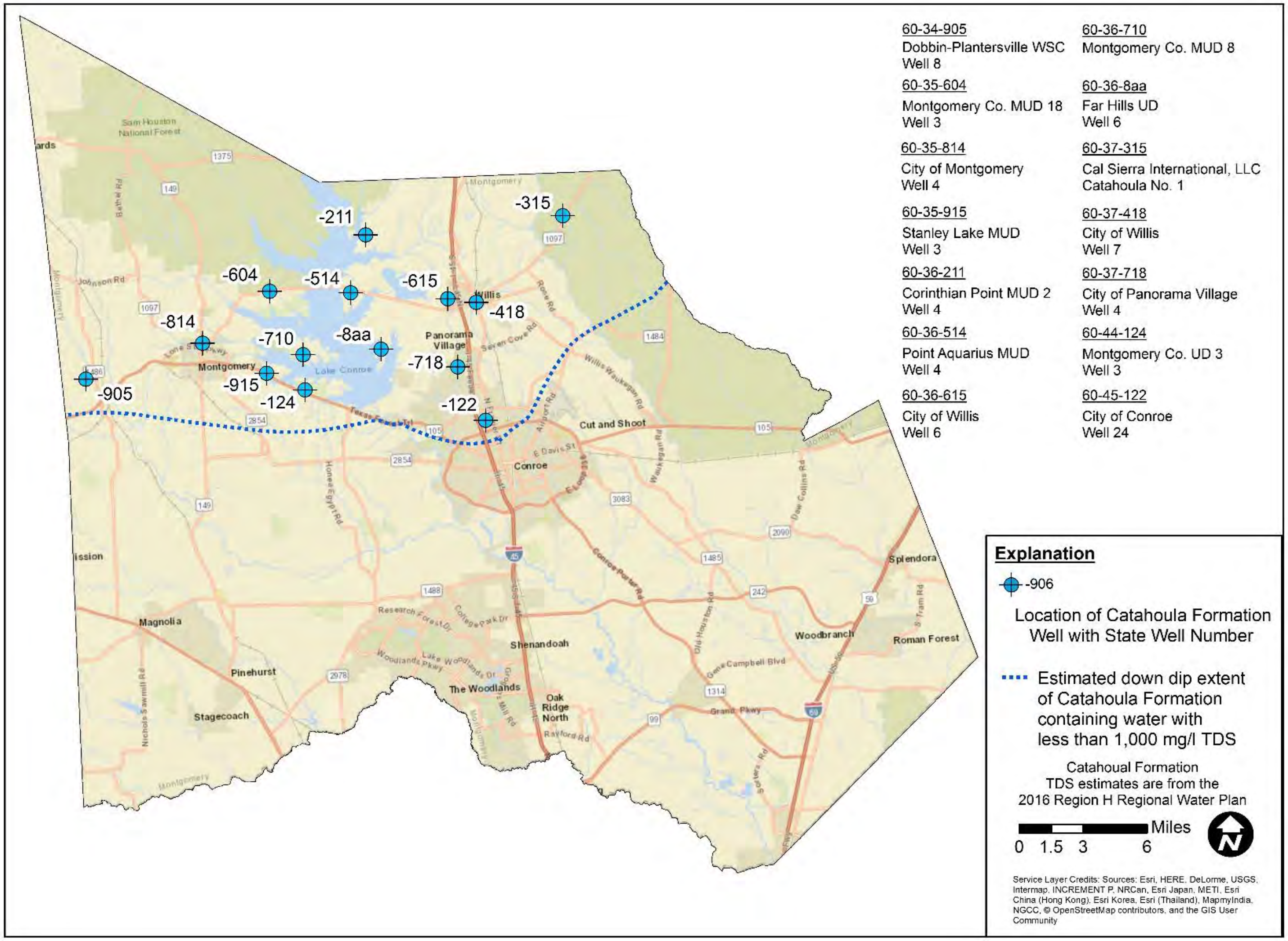

Figure 1. Catahoula Wells Screening the Catahoula Formation

Table 2. Catahoula Pumping

Well Owner & Number	2011 (gallons)	2012 (gallons)	2013 (gallons)	2014 (gallons)	2015 (gallons)	2016 (gallons)
Dobbin-Plantersville WSC – Well 8	0	0	0	0	0	31,202,000
Montgomery Co. MUD 18 – Well 3	0	163,434,000	323,140,000	316,266,600	265,481,000	338,089,000
City of Montgomery – Well 4	0	0	0	10,396,000	53,165,000	71,817,000
Stanley Lake MUD – Well 3	0	0	80,212,000	60,118,000	63,294,000	118,399,000
Corinthian Point MUD 2 – Well 4	0	0	0	1,998,000	35,658,000	37,085,000
Point Aquarius MUD – Well 4	0	0	0	0	87,770,000	120,855,000
City of Willis – Well 6	0	0	5,817,000	49,298,000	66,509,000	76,913,000
City of Willis – Well 7	0	0	3,084,000	90,809,000	66,509,000	47,717,000
Montgomery Co. MUD 8	0	0	0	113,621,000	264,856,000	283,998,000
Far Hills UD – Well 6	0	0	0	0	0	0
Cal Sierra International, LLC	0	0	0	0	0	7,996,000
City of Panorama Village – Well 4	0	0	7,130,000	115,589,000	111,006,000	99,937,000
Montgomery Co. UD 3 – Well 3	81,787,600	215,067,800	263,459,000	233,955,000	217,862,000	96,465,000
City of Conroe – Well 24	0	0	0	0	24,795,000	94,437,000
Total Gallons	**81,787,600**	**378,501,800**	**682,842,000**	**992,050,600**	**1,177,848,000**	**1,424,910,000**
Total MGD	**0.22**	**1.04**	**1.87**	**2.72**	**3.23**	**3.90**
Total Acre-ft	**245**	**1,200**	**2,100**	**3,000**	**3,600**	**4,400**

Pumping from the Catahoula Formation increased from .022 mgd (245 ac-ft/yr) in 2011 to 3.9 mgd (4,400 ac-ft/yr) in 2016 and the wells that are withdrawing water are spread over about 100 square miles in the District. Water levels have shown modest declines during that period in response to pumping, as shown on Figure 2. The well with the longest record of static water levels is Montgomery County UD 3 Well 3 and it shows about 20 feet of decline from 2011 – 2017. The static water levels in the City of Willis Wells 6 and 7 essentially show no decline since 2013, probably due to the low pumping rate from the wells as given in Table 2 and the locations of the wells away from the area of greater pumping to the southwest. The collection in the future of pumping and static water-level data will further the understanding of the artesian head response in the Catahoula Formation to changes in pumping.

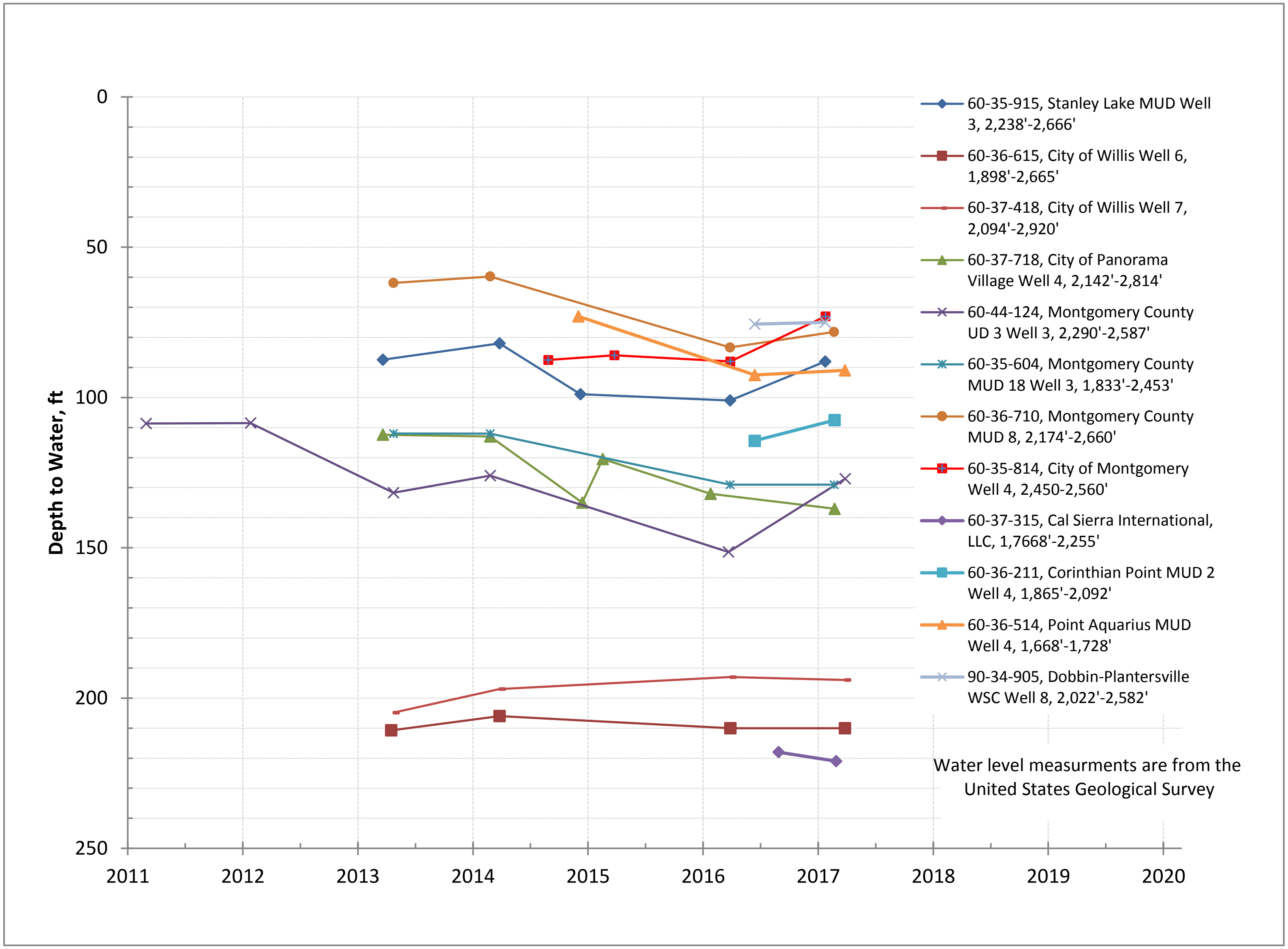

Figure 2. Catahoula Formation Water-Level Hydrographs

Pumping and static water-level data collected to date have been essential in evaluating the Catahoula Formation response to pumping. Short term pumping tests are also available for 8 wells constructed in the north part of Montgomery County. From these tests transmissivity values range from 19,000 god/ft to 37,000 gpd/ft with an average of 28,000 gpd/ft. Similar data, plus water quality data should be collected in the future and used to empirically forecast the aquifer response to pumping and/or be used in conjunction with the development of a groundwater flow model or improvement of the existing model to estimate the effects of future pumping and groundwater availability.

For the current study, we considered the findings from a 2012 modeling evaluation study of the Catahoula Formation conducted by LBG-Guyton Associates and Intera. Modeling results calculated a 20-foot head decline in the Catahoula Formation over a 50-year period for 3,000 ac-ft/year pumping, a 50-foot head decline in the Catahoula Formation over a 50-year period for 6,550 ac-ft/year of pumping and a 210-foot head decline in the Catahoula Formation over a 50-year period for 36,000 ac-ft/year pumping. These numbers could be underestimating to some degree the actual artesian head declines that might occur as the approximately 20 feet or so of head decline that has already occurred is for far less than 50 years of pumping.

Generally, the water quality in the Catahoula Formation is better in the north part of Montgomery County. Water quality data for TDS and fluoride are included in Table 1. The TDS values show a maximum of 908 mg/l TDS and a minimum of 416 mg/l TDS with an average of 736 mg/l TDS, which is acceptable for potable water supply.

Water samples were collected and analyzed by the USGS and show that the TDS content of the water has remained stable except for one well. That well, 60-35-914 is located in proximity to the area where it is estimated that the aquifer can contain water with an increasing TDS content. The water quality data are provided in Appendix B. Water samples from the wells screening the Catahoula Formation should continue to be analyzed to extend the current record that spans about three to five years. With additional water quality and pumping data estimates can be developed regarding water quality trends for wells screening the Catahoula Formation.

It is not uncommon to find elevated fluoride levels at the depths where the Catahoula Formation wells are screened. The data in Table 1 show a maximum value of 2.4 mg/l which exceeds the Secondary Standard of 2.0 mg/l but does not exceed the Primary Standard of 4.0 mg/l. The temperature of water produced from the Catahoula Formation can be in the range of 95 to 110° F. At those temperatures, if needed, a cooling tower can be installed to lower the water temperature prior to piping the water to public water supply distribution systems. Where the water quality is better it is estimated the TDS, fluoride, and other measurements to remain relatively stable in the short term. For wells located closer to the transition areas of poorer water quality, as shown on Figure 1, it is estimated the water could increase in TDS over time and likely will not improve.

RESULTS FROM GMA 14 RUN 2 SIMULATION

As part of the joint-planning effort of GMA 14, a simulation was developed that was utilized in developing the desired future conditions (DFCs) for GMA 14. In that simulation there were assumptions regarding groundwater pumping within the District for a period from 2010 through 2070, based on current water demands, groundwater pumping, and projections of future water demands. An objective of the effort was to estimate the artesian head changes that would occur in the Chicot, Evangeline and Jasper aquifers during the period from 2010 to 2070. A figure showing the pumping by aquifer for the District in the GMA 14 Run 2 simulation for the District is include as Figure 3. In the simulation, the overall pumping for the three aquifers in Montgomery County is held constant at 64,000 ac-ft/yr from 2016 through 2070.

Based on the pumping assumptions regarding the District and the other counties in GMA 14, model simulation estimates were developed utilizing the HAGM of the amount of artesian head change that would occur during the period. The results, in terms of artesian head changes for GMA 14 Run 2, are shown for the Chicot, Evangeline and Jasper aquifers on Figures 4, 5 and 6, respectively. Positive numbers on the contours represent artesian head decline and negative numbers represent artesian head recovery. The results of the simulation show that for the Chicot Aquifer, there could be up to about 40 feet of artesian head decline in parts of the District, principally in the southwest part of the District.

For the Evangeline Aquifer, the model simulation shows that there could be an artesian head rise in the south part of the District and an artesian head decline in the north part of the District, principally because, as shown on Figure 3 the amount of pumping from the Evangeline

Aquifer decreases from about 37,000 ac-ft/yr in 2015 to about 28,000 ac-ft/yr after 2016. Also included in the GMA 14 Run 2 pumping assumptions for the Evangeline Aquifer is a reduction in pumping from the aquifer in Harris County, ranging from 240,000 ac-ft/yr in 2015 to 135,000 ac-ft/yr by 2070. The artesian head increase or recovery attributable to the reduction in pumping from the Evangeline Aquifer is reflected in the amount of artesian head rise estimated to occur in the south part of the District as the effects of reducing pumping in Harris County extend into the District.

For the Jasper Aquifer, the model results also show an increase in artesian head in the south-central part of the District and water-level declines or artesian head declines in the north part of the District in response to the reduction in pumping from the Jasper Aquifer from about 41,000 ac-ft/yr in 2015 to about 24,000 ac-ft/yr in 2016 and the pumping remaining in the range of 22,000 to 24,000 ac-ft/yr through 2070. The main area of the reduction in pumping is in the south-central part of the District and that is where the highest amount of artesian head rise is estimated to occur.

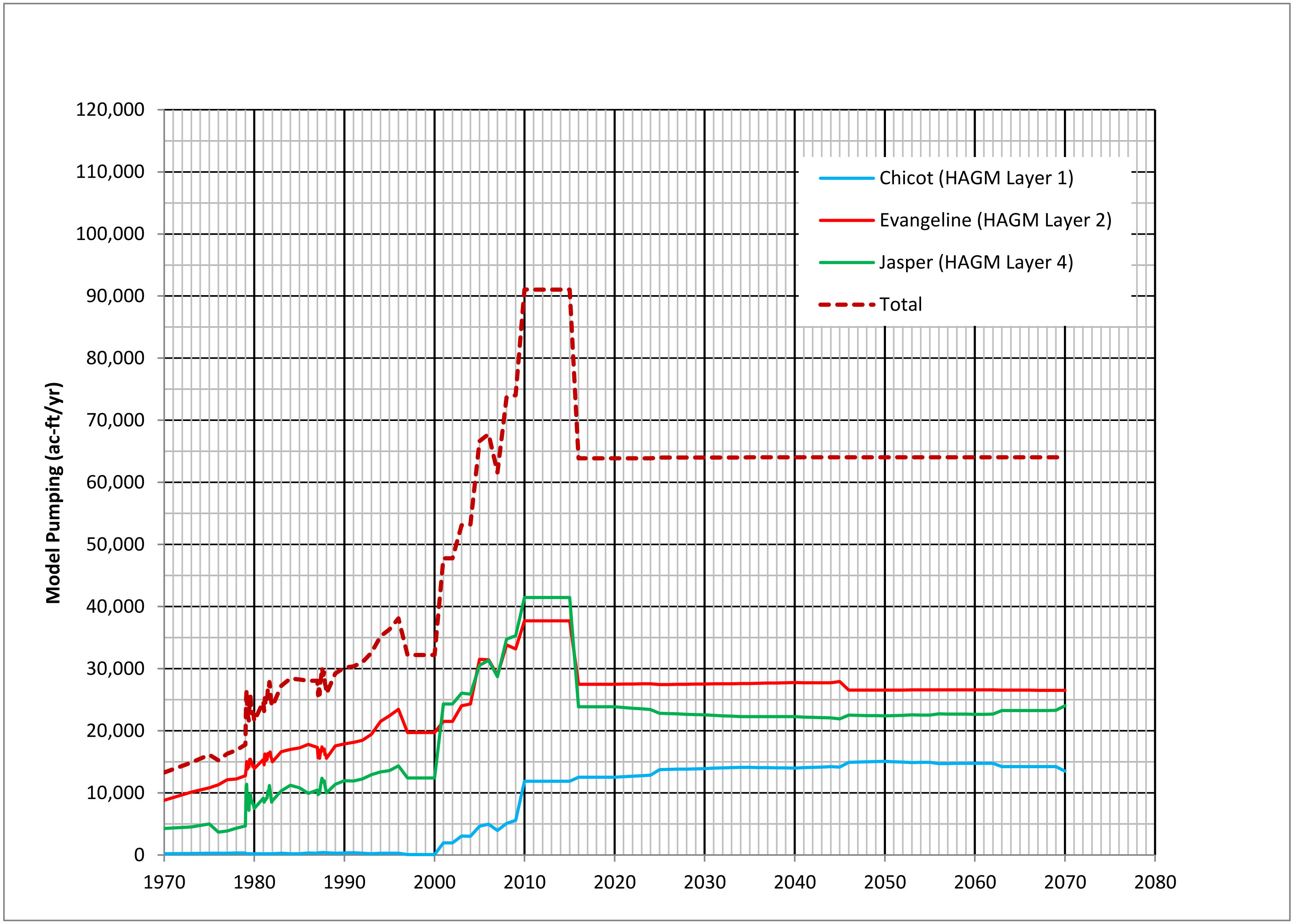

Figure 3. LSGCD Pumping Included in GMA 14 Run 2 Model Simulation

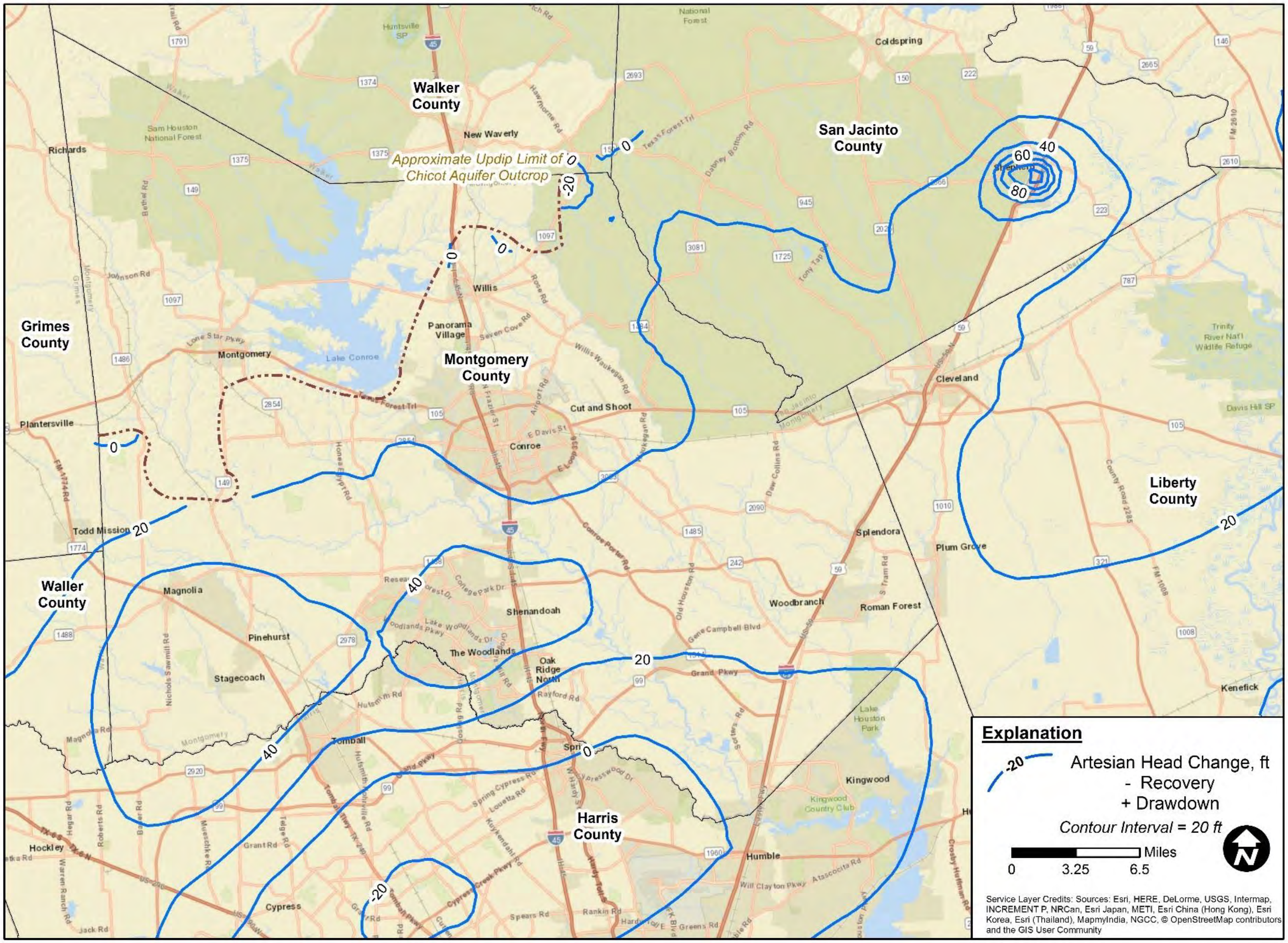

Figure 4. GMA 14 Run 2 Chicot Aquifer Artesian Head Change from 2010 to 2070

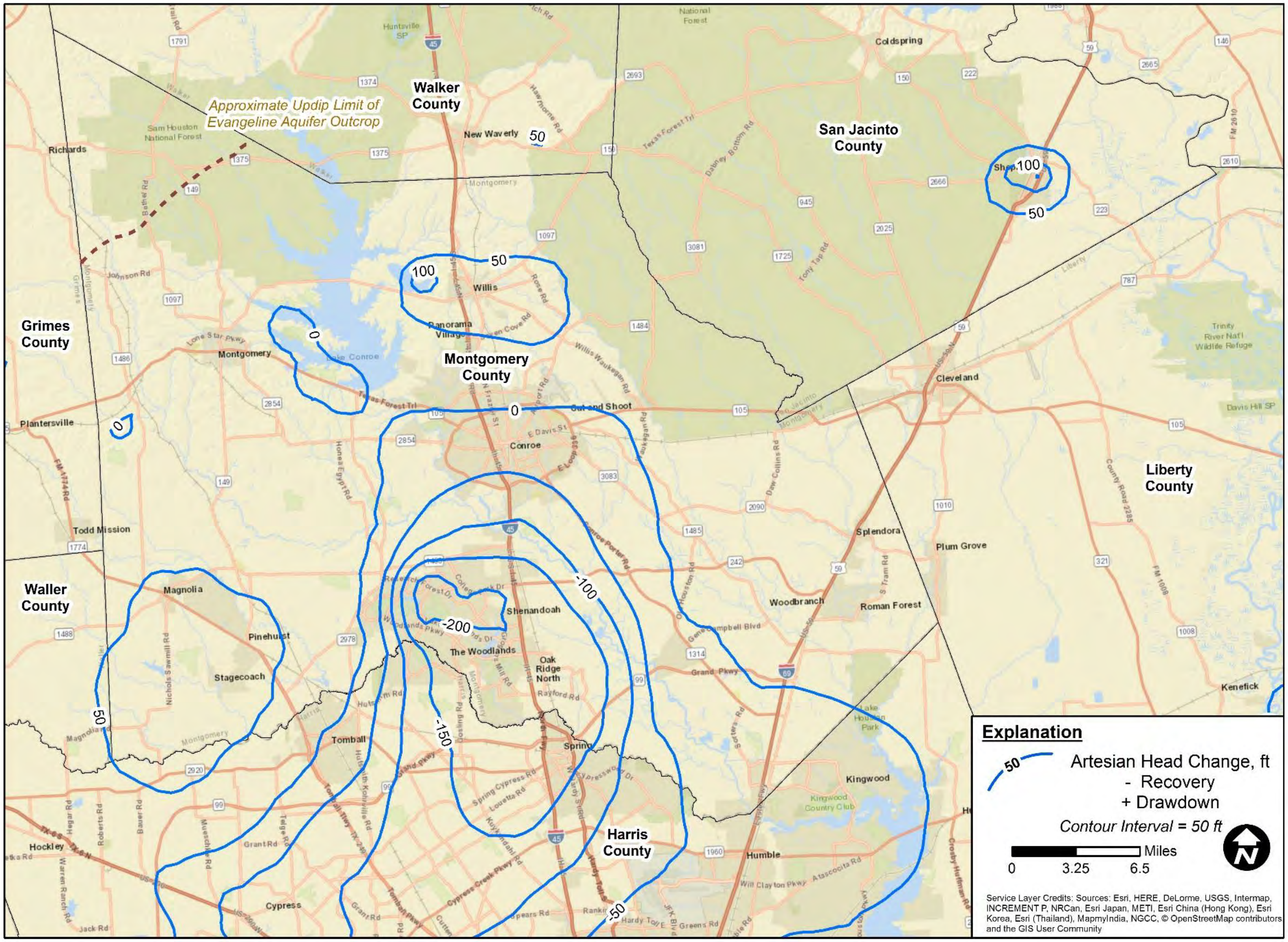

Figure 5. GMA 14 Run 2 Evangeline Aquifer Artesian Head Change at 2070

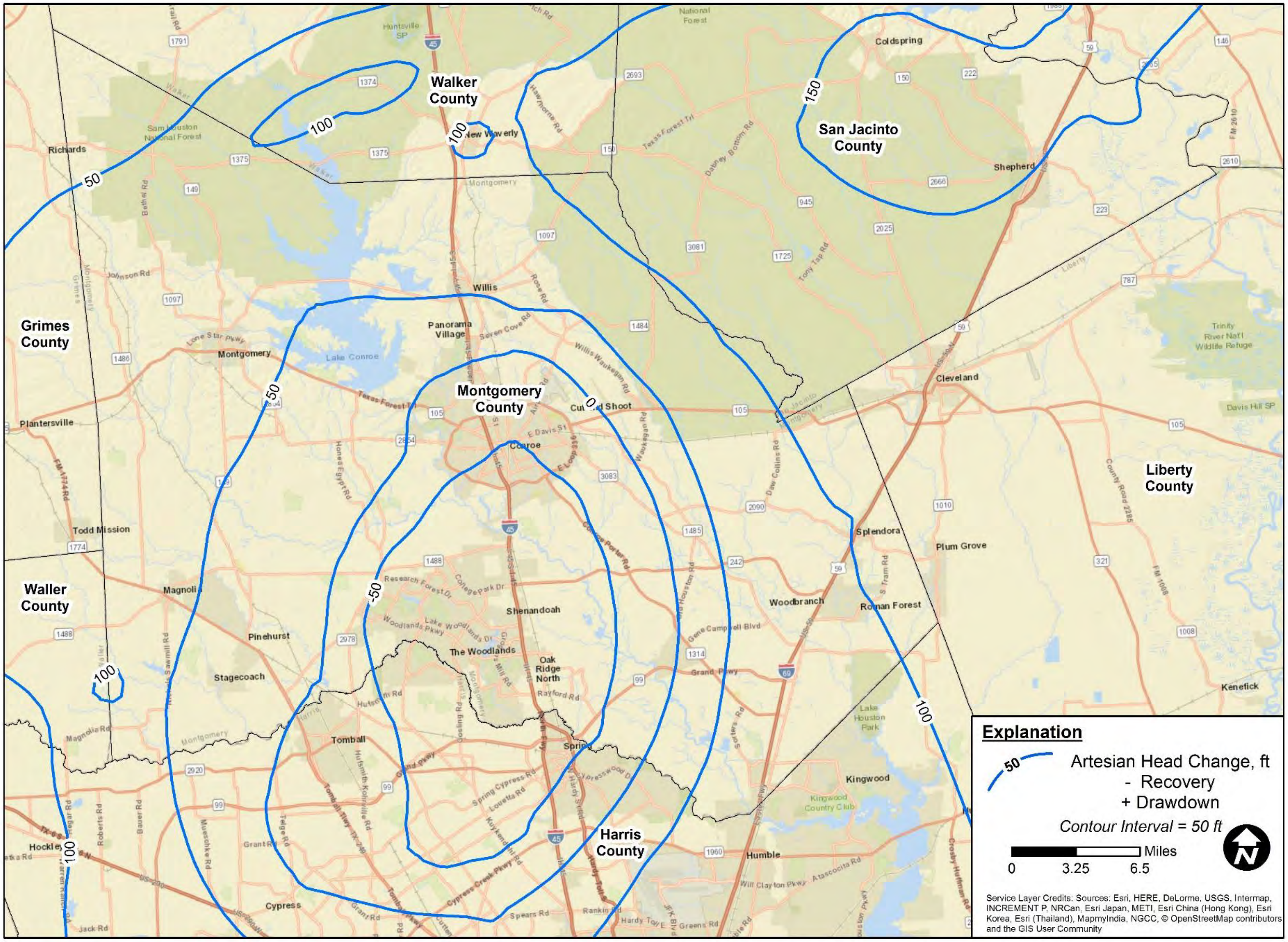

Figure 6. GMA 14 Run 2 Jasper Aquifer Artesian Head Change at 2070

DEVELOPMENT OF PUMPING SCENARIOS

With the results of GMA 14 Run 2 available and reviewed, a next step was to develop estimates of future pumping that could occur within the District while taking into consideration that the 2017 Texas Water Plan estimated that the population in the District could increase to slightly over 1 million people by 2040 and be close to 2 million people by 2070. Along with the increase in population, the 2017 Texas Water Plan estimates that by 2040 the demand for water in the District is projected to be 163,626 ac-ft/yr and by 2070 it is projected to be 291,791 ac-ft/yr. By comparison, in 2015 permitted groundwater pumping in the District was 74,472 ac-ft/yr based on data from the LSGCD with an additional 6,707 acre-feet of surface water consumed almost exclusively for power generation, based on data from the TWDB.

Prior to developing the potential pumping scenarios, a substantial amount of work was performed to update groundwater pumping data with respect to the aquifer pumped, the spatial distribution of pumping, and temporally, in the HAGM for 2010 through 2016 so that the groundwater pumping in the model was a better representation of pumping for that period. This effort built upon updates to the LSGCD's geodatabase that was accomplished as part of Task 2 for this strategic water resources planning study.

Updating HAGM Representation of Groundwater Pumping

As the result of meetings and discussions with the Findings and Review Committee and staff, the historical pumping in the HAGM pumping file for 2010 through 2016 was updated based on pumping data available from the LSGCD. As this occurred, a substantial effort was expended to distribute the pumping as accurately as possible between the Chicot, Evangeline and Jasper aquifers and areally through the District. This effort included working cooperatively with the LSGCD staff to develop a geodatabase of pumping information throughout the District. Data were collected for large volume groundwater users (LVGU) and small volume groundwater users (SVGU) and other entities considered to represent exempt pumping. After the HAGM pumping files were updated and the files reviewed and checked, the next step was the development of pumping scenarios for different quantities of future groundwater pumping distributed in the District.

Development of Pumping Scenarios

General Description

Meetings were conducted with the Findings & Review Committee to develop future groundwater pumping scenarios. An iterative process was used to develop the scenarios that represented varying amounts and spatial or areal distribution of pumping. With any scenario, the pumping was distributed in areas that, based on regional water planning, projected growth in population resulting in an increase in water demand. Scenarios A MOD and B MOD were developed followed by Run C and after the results of Run C were reviewed, a Run D was developed. The preceding are the names of the scenarios used when developing them with the Findings & Review Committee. Pumping in the simulations by aquifer for 2016, 2030 and 2070 is provided in Table 3. A brief description of the scenarios follows.

Table 3. Montgomery County Pumping (ac-ft/yr)

2016

Aquifer	*GMA14 Run 2*	*Run A MOD*	*Run B MOD*	*Run C*	*Run D*
Chicot	**12,500**	**5,900**	**5,900**	**5,900**	**5,900**
Evangeline	**27,500**	**31,800**	**31,800**	**31,800**	**31,800**
Jasper	**23,900**	**21,500**	**21,500**	**21,500**	**21,500**
Total	**63,900**	**59,100**	**59,100**	**59,100**	**59,100**

2030

Aquifer	*GMA14 Run 2*	*Run A MOD*	*Run B MOD*	*Run C*	*Run D*
Chicot	**13,900**	**8,000**	**8,900**	**8,000**	**8,900**
Evangeline	**27,500**	**37,800**	**47,800**	**46,600**	**39,000**
Jasper	**22,600**	**25,100**	**36,200**	**38,400**	**42,200**
Total	**64,000**	**70,900**	**92,900**	**92,900**	**90,100**

2070

Aquifer	*GMA14 Run 2*	*Run A MOD*	*Run B MOD*	*Run C*	*Run D*
Chicot	**13,500**	**10,200**	**11,200**	**10,200**	**11,200**
Evangeline	**26,500**	**43,600**	**54,500**	**53,300**	**44,500**
Jasper	**24,000**	**25,900**	**38,000**	**40,300**	**44,300**
Total	**64,000**	**79,700**	**103,800**	**103,800**	**100,000**

There were generally four objectives with the scenarios. The objective of Run A MOD was to have the LVGU pumping held constant at 70 percent of the Total Qualifying Demand (TQD) or at 56,140 ac-ft/yr for the planning period of 2017 - 2070. Another part of the objective was to let the SVGU pumping increase at a rate of 2.1 percent per year as included in the 2017 Texas State Water Plan and the exempt pumping at 2.4 percent per year that is equal to the rate of growth in exempt well permits issued by the District over the past few years, which resulted in an overall pumping that reached 79,780 ac-ft/yr by 2070.

The objective of Run B MOD was to take the difference between the TQD in 2009 and 70 percent of the TQD, or 24,060 ac-ft/yr and return that to the LVGUs that had experienced the 30-percent reduction in allowable pumping. The gradual return of the 24,060 ac-ft/yr began in 2020.

The objective of Run C was to allow the same amount of pumping as in Run B MOD, but to have the 30 percent of the TQD distributed in areas outside the I-45 growth corridor to more rural areas that are projected to experience significant growth in population and thus, an increase in water demand in the upcoming decades. Illustrations providing estimates of areas of population increases and allocation of pumping to the projected areas of urban expansion are shown on Figures 7 and 8, respectively. The projected areas of urban development or population growth were developed as part of the 2013 regional Groundwater Update Plan by the Harris-Galveston Subsidence District (HGSD) and subsequently used in the 2017 Texas State Water Plan.

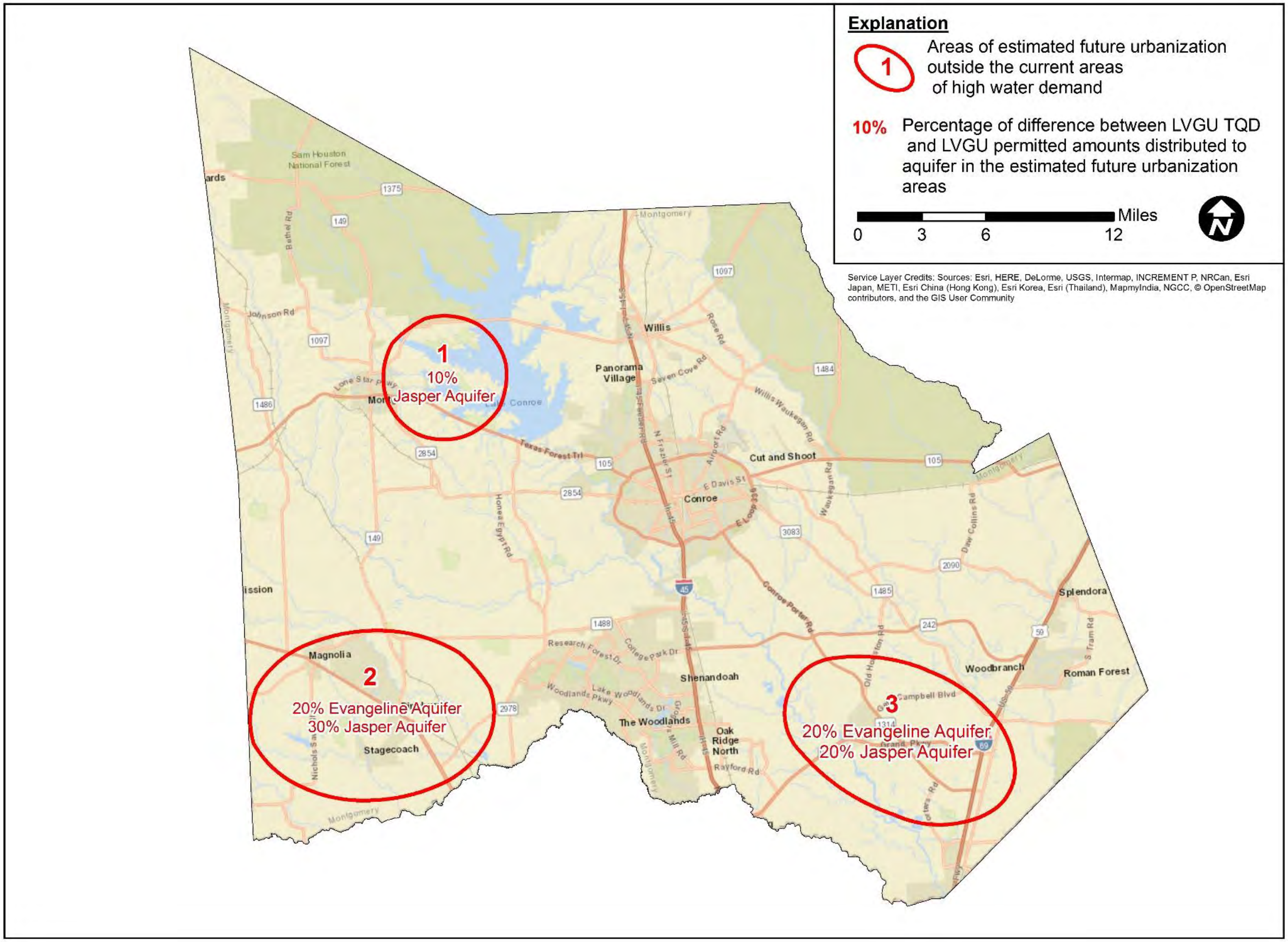

Figure 7. Projected Areas of Additional Groundwater Demand Utilized in Distribution of Pumping in Run C

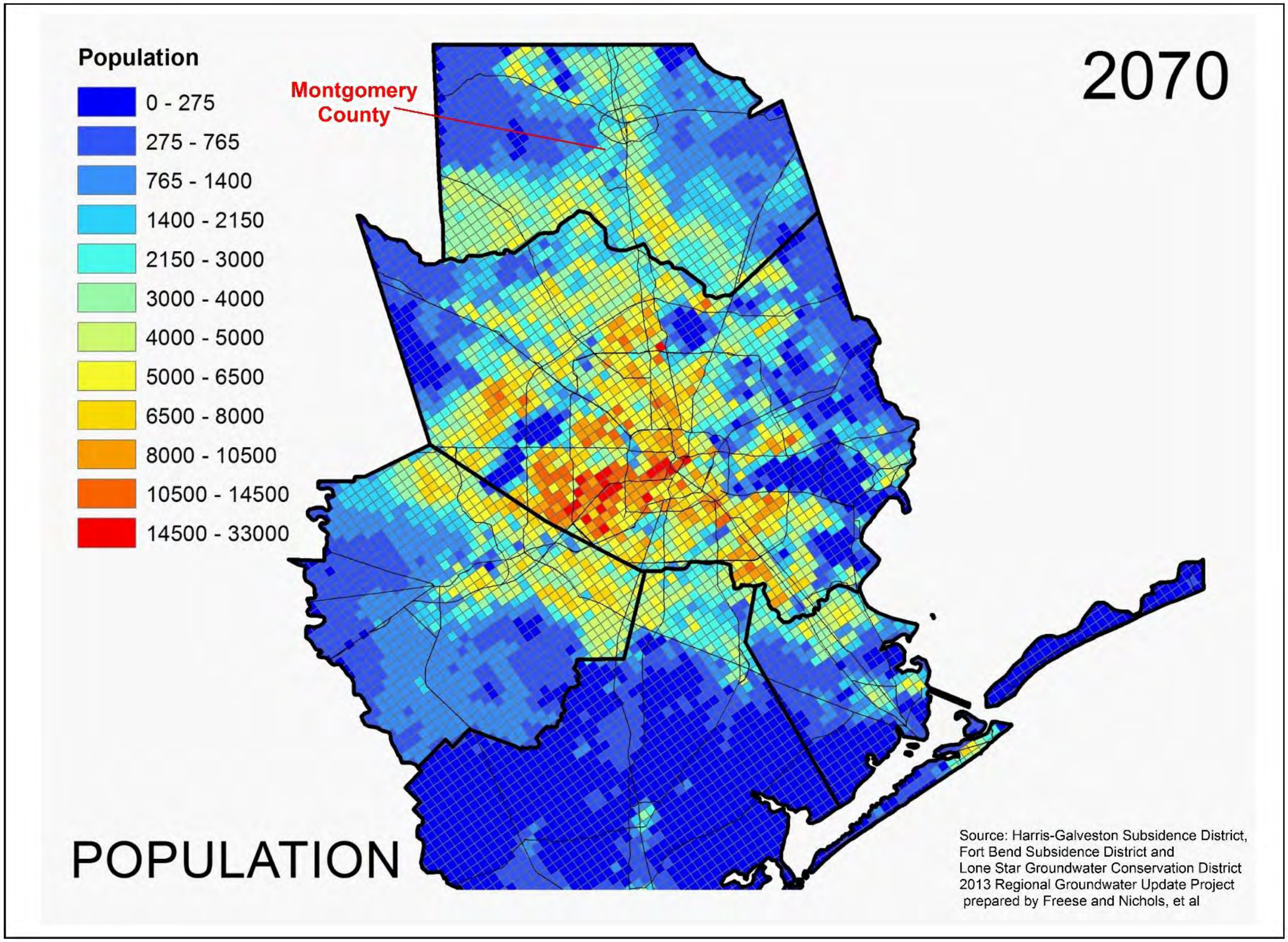

Figure 8. Projected Areas of Future Population Increases

The objective of Run D was to represent pumping in the same locations as Run B MOD, but redistribute the pumping between the Evangeline and Jasper aquifers so that there was a reduction in pumping in the Evangeline Aquifer and in increase in pumping in the Jasper Aquifer compared to Run C. This change in pumping allocation between the two aquifers was made to better reflect the proportional distribution in pumping for the historical period of 2010 through 2016.

As part of the District Groundwater Reduction Plan, there was a schedule for initiating the use of surface water for public supply beginning in 2016 and that is referred to as the 2016 surface water conversion. As the use of surface water occurred in 2016 there was a reduction in the amount of groundwater usage.

Refined Description of Scenarios

The following provides some details of the methodology used for developing the groundwater pumping distribution, temporally, areally and vertically between the aquifers for the four scenarios. A summary of Runs A MOD, B MOD, C and D includes the following.

Run A MOD

1. Perform a simulation using the calibrated HAGM with the updated 2010 through 2016 pumping for the District.
2. After 2016 for LVGUs, assume pumping is equivalent to their permitted pumping, which is equivalent to a total of 56,140 ac-ft/yr. The difference between 56,140 ac-ft/yr and the LVGU 2016 pumping is 6,155 ac-ft/yr and it was distributed among the LVGUs that previously relinquished pumping to reach a permitted amount of 56,140 ac-ft/yr. The distribution of pumping between the Chicot, Evangeline and Jasper aquifers would be equivalent to the pumping percentage for each aquifer that existed in 2015 prior to the 2016 surface water conversion.
3. Exempt pumping, which started at 6,000 ac-ft/yr beginning in 2010, would be increased at a rate of 2.4 percent per year until reaching 8,000 ac-ft/yr in 2028 and then held constant through 2070. It is estimated that in future decades more of the population will be served by LVGUs and SVGUs and thus the amount of exempt pumping was capped at 8,000 ac-ft/yr. The 2.4 percent is the rate of increase in the number of exempt well

permits issued in a year by the District during the past few years. The maximum exempt pumping is reached in 2028 and is held at this value through 2070.

4. SVGU pumping in 2017 would be a product of the average of SVGU yearly pumping for 2010 through 2016 (3,223 ac-ft/yr) plus the permitted SVGU pumping of 7,258 ac-ft/yr. The total 10,481 ac-ft is divided by two and 5,240 ac-ft/yr is the starting SVGU pumping amount in 2017. The SVGU pumping would increase at a rate of 2.1 percent from 2017 through 2070. The estimate of 2.1 percent per year is based on the growth in water demand projected in the 2017 Texas Water Plan for Montgomery County.

Total withdrawal of groundwater in the District would reach 79,700 ac-ft/yr by 2070.

Run B MOD

1. Utilize the same historical pumping in the model up to 2017 as in Run A with the following additions.
2. The difference between the TQD (80,200 ac-ft/yr) for LVGUs and the permitted amount of pumping (56,140 ac-ft/yr) for the LVGUs in Run A is about 24,060 ac-ft/yr. The 24,060 ac-ft/yr of pumping was redistributed to the LVGUs that reduced pumping to meet conversion requirements from TQD to the lower permitted amounts. The pumping redistribution to LVGUs started in 2020 with the addition of the pumping ramped up linearly to 24,060 ac-ft/yr by 2032, which is at a rate of pumping increase less than the projected increase in water demand in Montgomery County during that period based on the 2017 Texas State Water Plan. When the additional pumping amount reaches 24,060 ac-ft/yr it will be held constant in the simulation through 2070.
3. The SVGU and exempt pumping was the same as in Run A.

With this pumping methodology, total withdrawal of groundwater in Montgomery County would reach about 103,800 ac-ft/yr by 2070.

Run C

1. The simulation was the same as Run B MOD with one addition.
2. The 24,060 ac-ft/yr of pumping that was distributed to existing LVGUs for Run B MOD was redistributed to areas of projected future urbanization in the county outside the current areas of high water use. The areas of new urbanization are estimated to occur,

based on state and regional water planning projections, in the southeast, southwest and northern parts of the District. The pumping redistribution was started in 2020 with the addition of the pumping ramped up linearly to 24,060 ac-ft/yr by 2032.

3. The 24,060 ac-ft/yr was distributed between the Chicot, Evangeline and Jasper aquifers in percentages equivalent to those that existed prior to the introduction of surface water or believed appropriate for the areas of pumping.

Total estimated pumping in this simulation will reach about 103,800 ac-ft/yr by 2070.

Run D

1. Same pumping as Run B Mod until 2020.
2. Pumping in Chicot Aquifer is the same as Run B Mod through 2070.
3. Using the pumping scenario of Run B Mod, the pumping of all wells in the Evangeline Aquifer was reduced by 19 percent starting in 2020 compared to their amount of pumping in 2019. The 19 percent reduction was applied to the yearly pumping in Run B MOD for 2020 through 2070.
4. Using the pumping scenario of Run B Mod, the pumping of all wells in the Jasper Aquifer was increased by 16 percent starting in 2020 compared to their amounts of pumping in 2019. The addition was applied to the yearly pumping in Run B MOD through 2070.

Total estimated pumping in this simulation will reach about 100,000 ac-ft/yr by 2070.

Graphs of pumping from 1970 to 2070 for the Chicot, Evangeline and Jasper aquifers for Run A MOD, Run B MOD, Run C and Run D are provided on Figures 9, 10, 11 and 12. The yearly variations in pumping are evident on the graphs up through 2016. Following 2016, the estimates of future pumping vary depending on the assumptions included in the four scenarios.

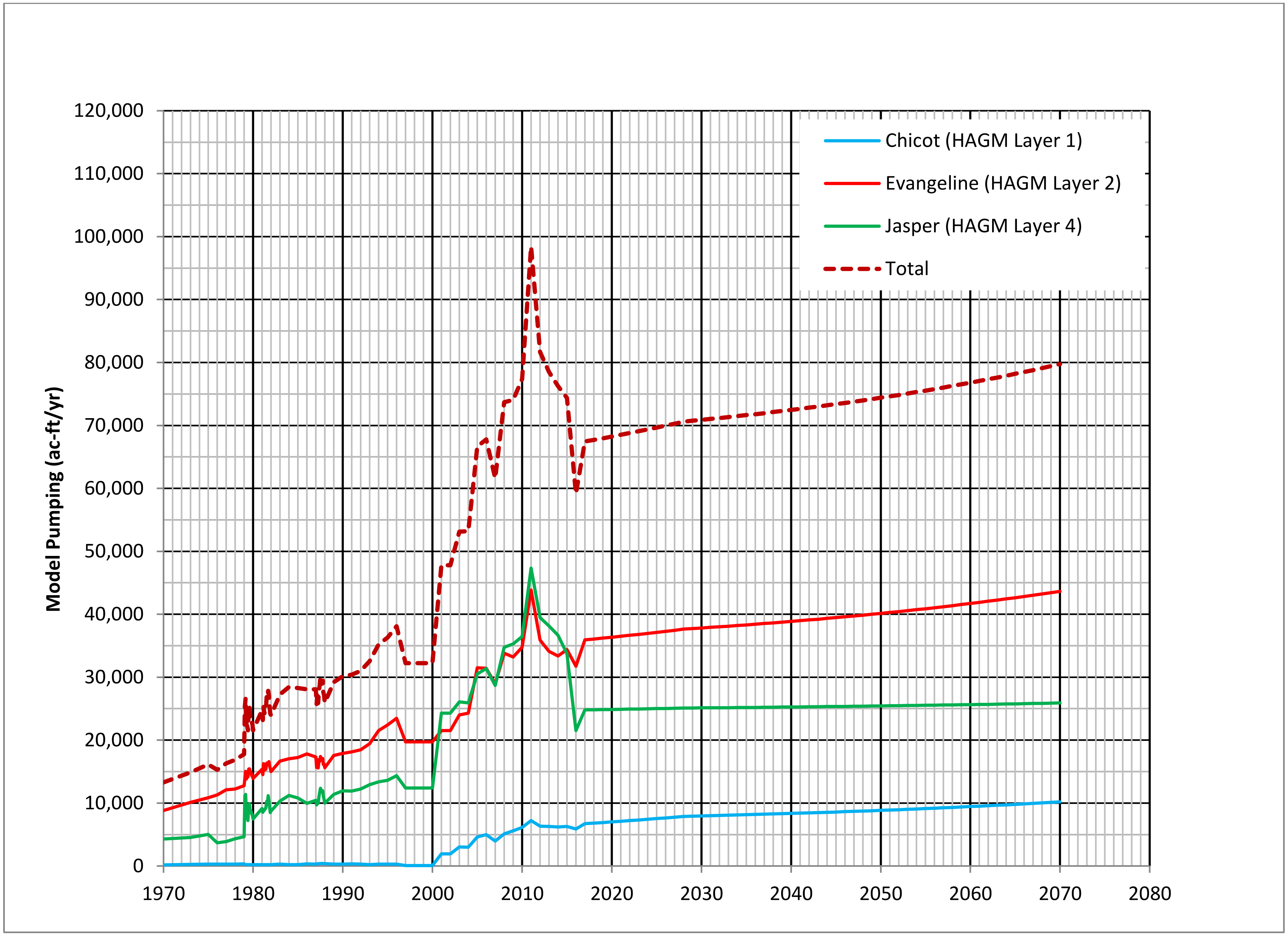

Figure 9. LSGCD Pumping Included in Run A MOD

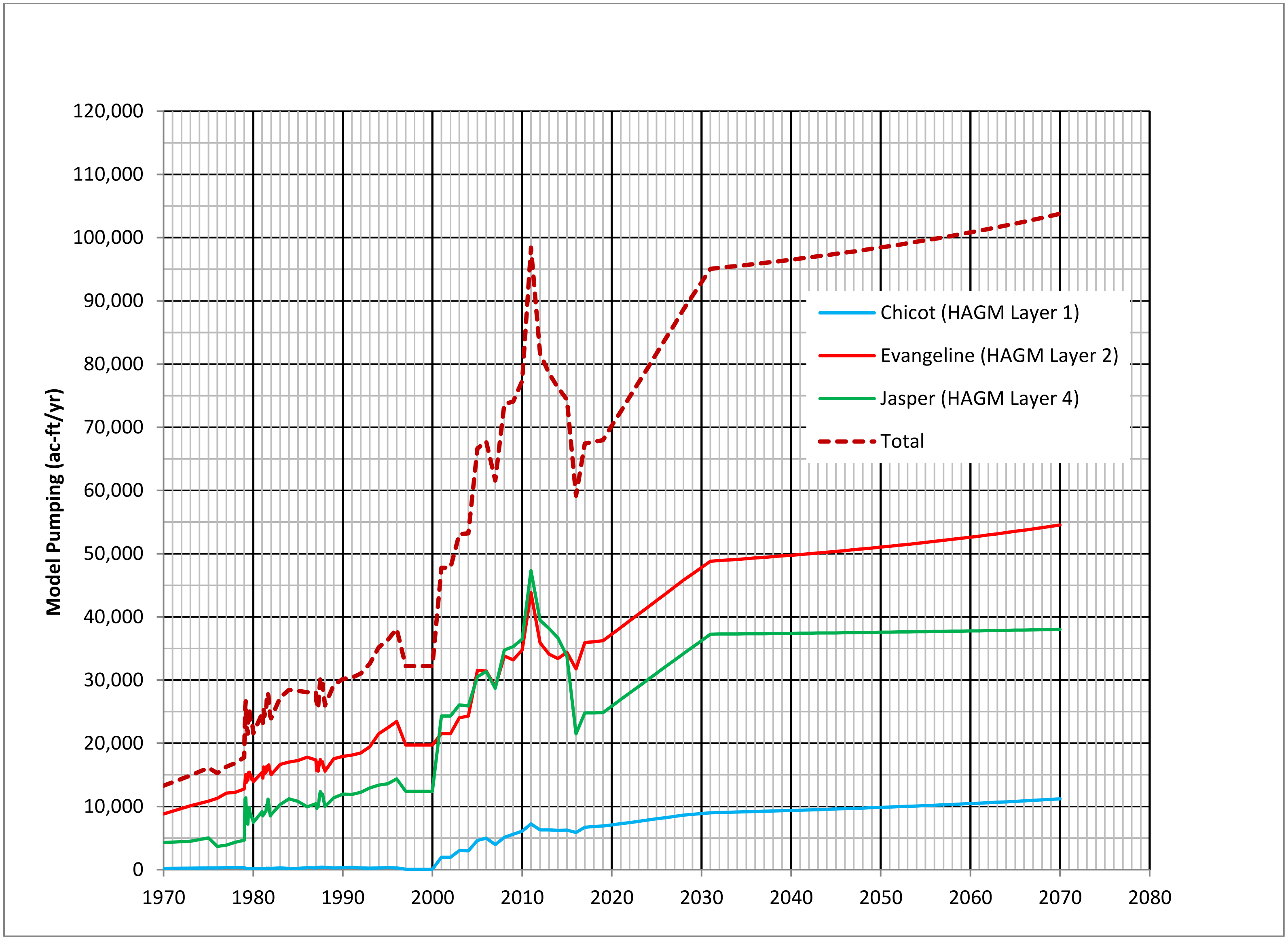

Figure 10. LSGCD Pumping Included in Run B MOD

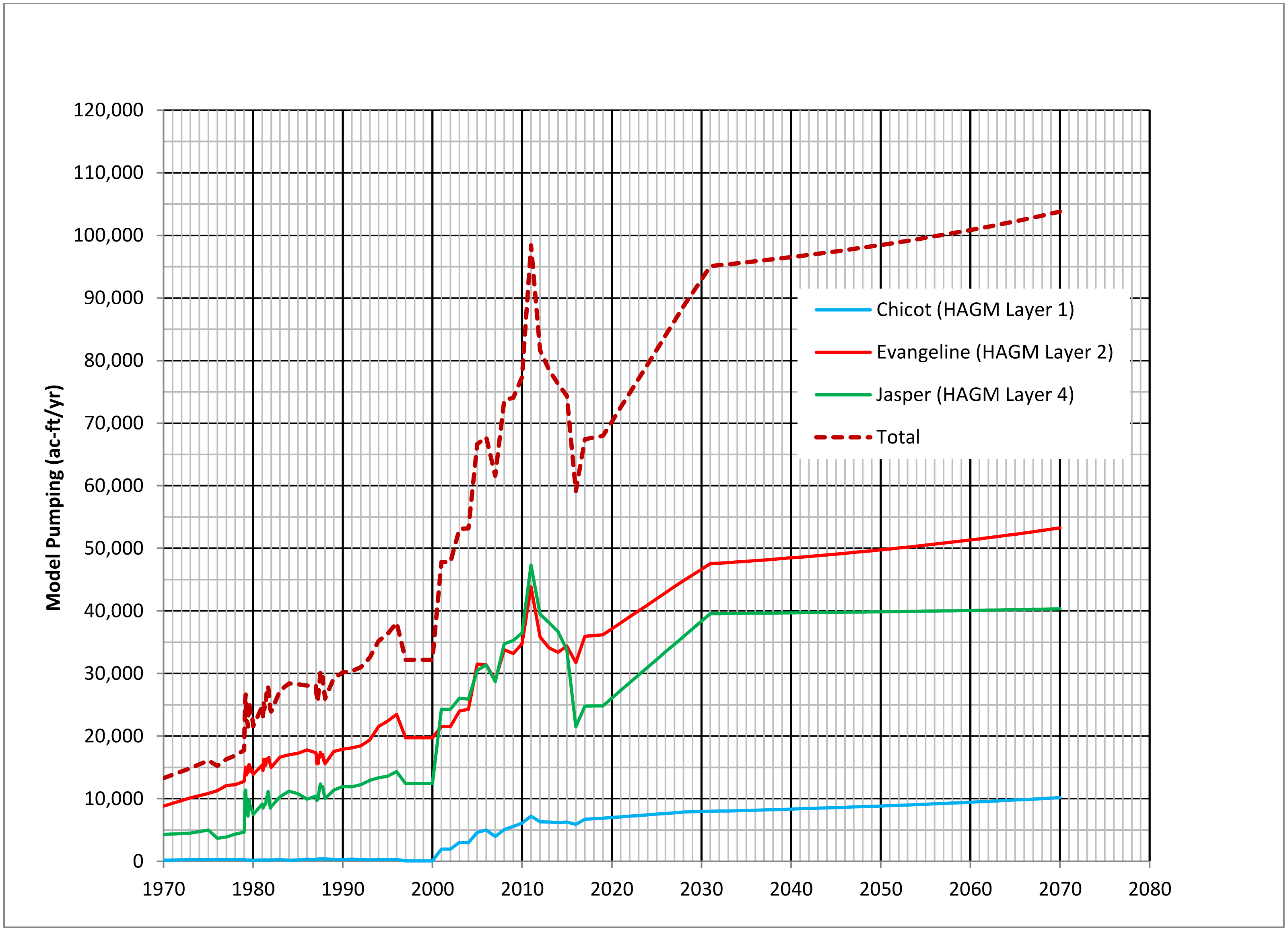

Figure 11. LSGCD Pumping Included in Run C

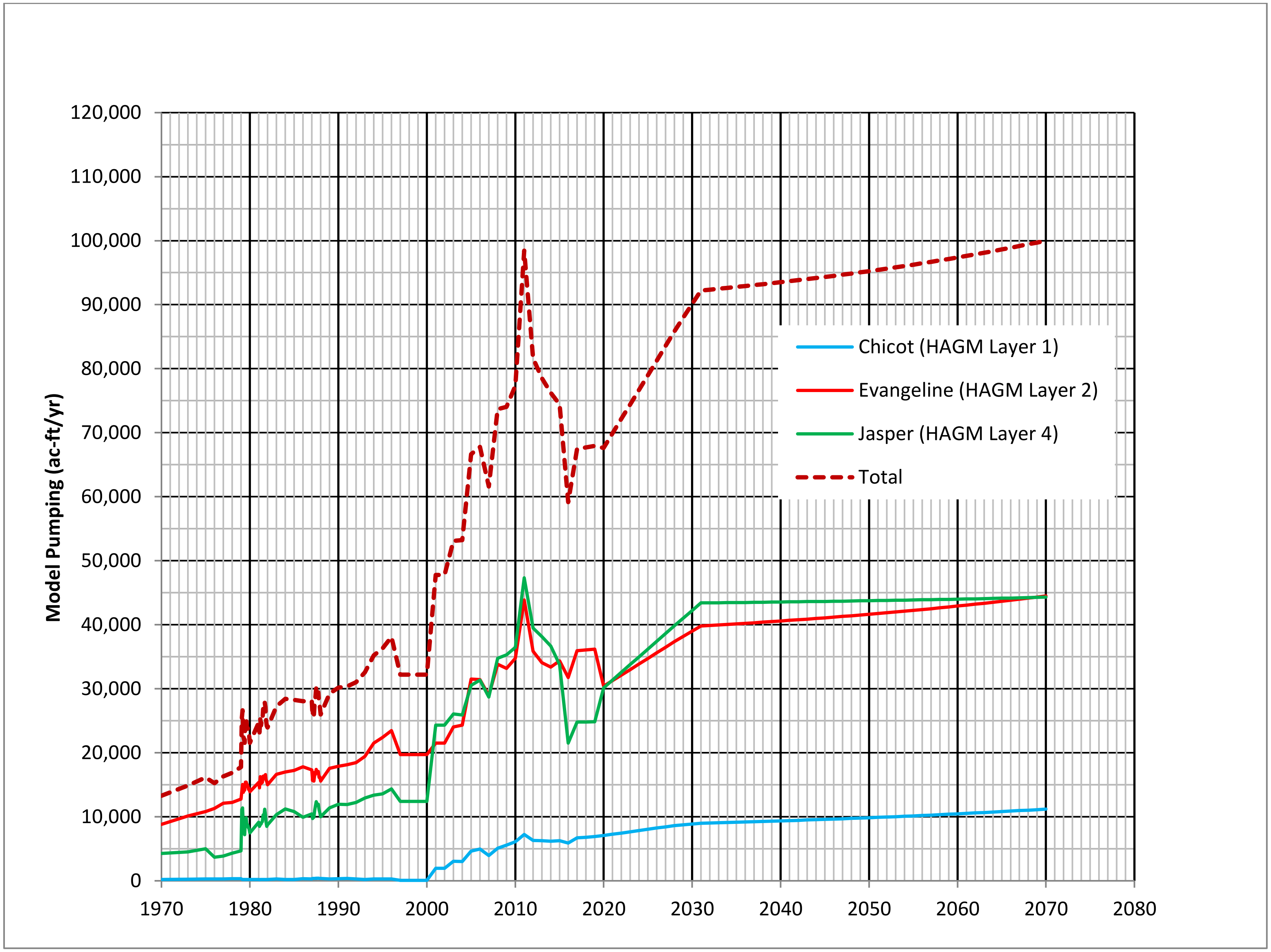

Figure 12. LSGCD Pumping Included in Run D

RESULTS OF PUMPING SCENARIOS

As stated previously, modeling scenarios Run A MOD, Run B MOD, Run C and Run D were performed and results provided to the Findings and Review Committee for their review. Amounts of pumping for the four scenarios plus GMA 14 Run 2 are provided in Table 3 for milestone years 2016, 2030 and 2070. The following are the results from the four modeling scenarios, along with information from the District's survey of LVGU permit holders, which is discussed in more detail later in this report.

Results of Runs A MOD and B MOD and Run C

Chicot Aquifer Results

The artesian head declines resulting from Runs A MOB, B MOD, and Run C are shown for the Chicot Aquifer on Figures 13 and 14. The artesian head decline results show for the period from 2010 to 2070 that the magnitude of the head decline for Run A MOD is about 60 feet in the very south part of the District in an essentially urbanized area and decreases to less than 20 feet in the north part of the District. For Run B MOD the pumping from the Chicot Aquifer increase some compared to Run A MOD and that causes an increase in the size of the area of the artesian head decline of 40 feet. For Run C, pumping from the Chicot Aquifer is essentially the same as in Run A MOD, but the area of 40 feet of artesian head decline is greater than the area for Run A MOD because of the expanded distribution of pumping from the Chicot Aquifer and increase in pumping from the Evangeline Aquifer. With the Evangeline Aquifer occurring just below the Chicot Aquifer, increases in pumping from the Evangeline Aquifer can affect the artesian head declines that occur in the Chicot Aquifer.

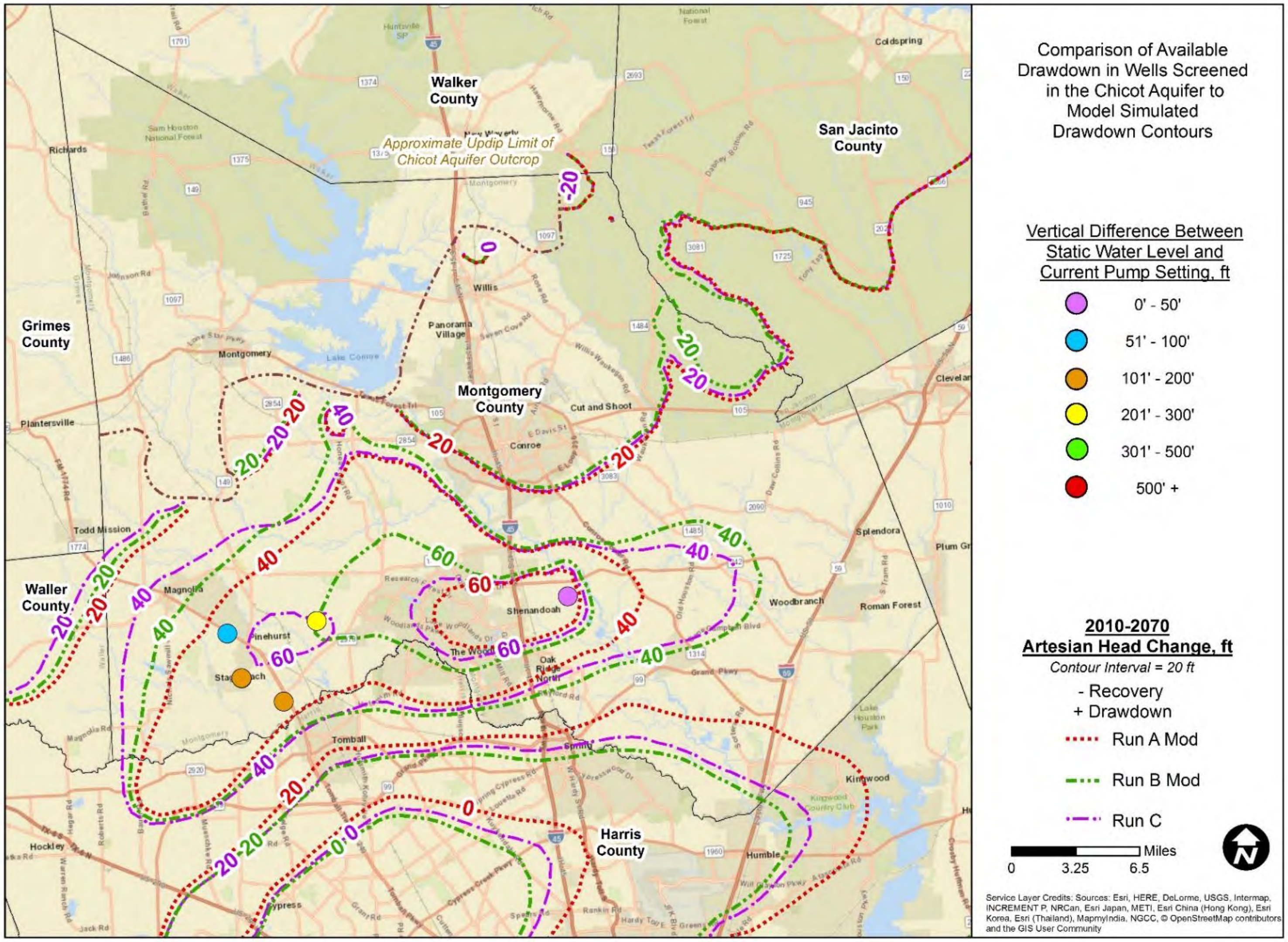

Figure 13. Artesian Head Changes in Chicot Aquifer for 2010-2070

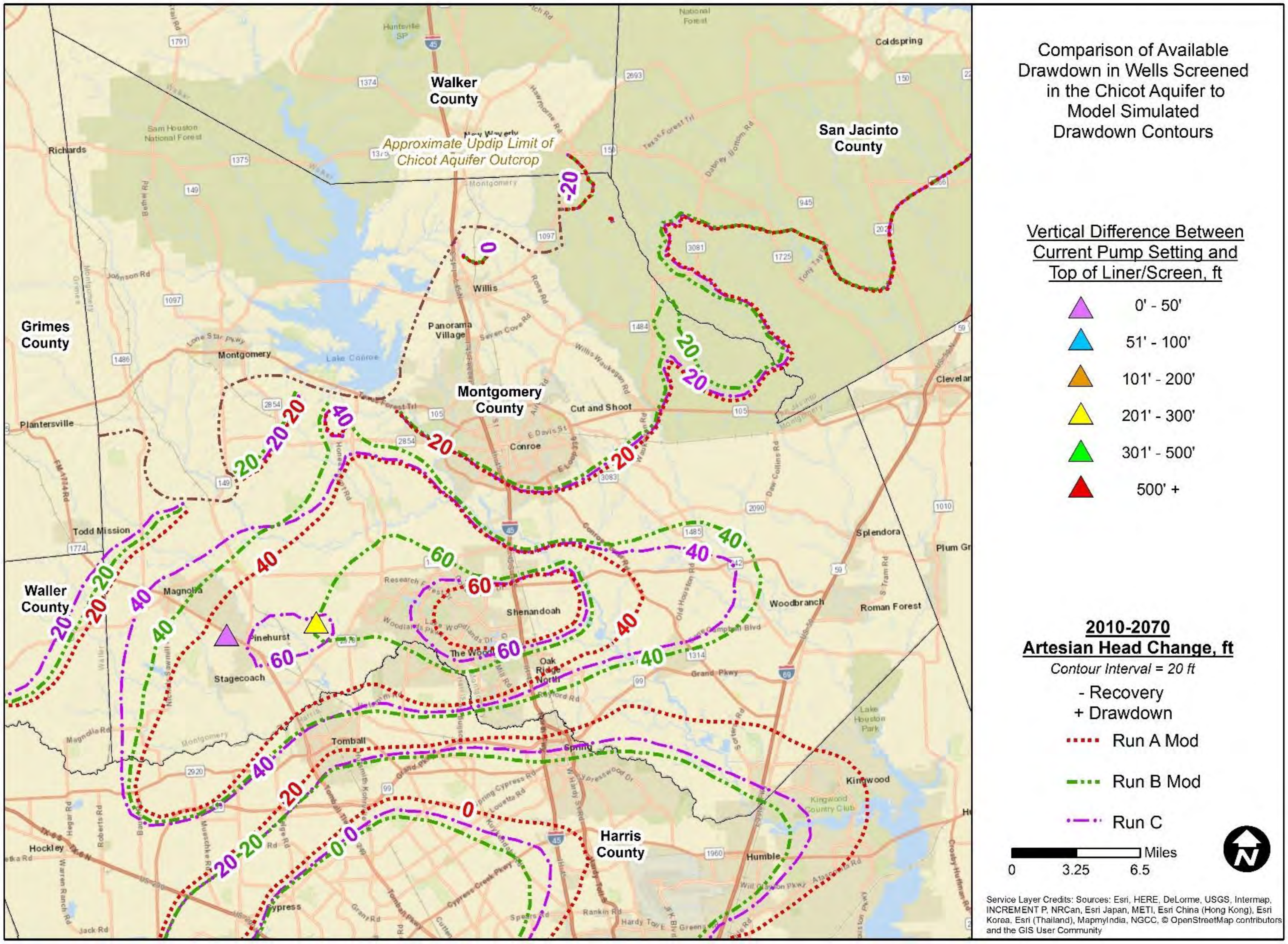

Figure 14. Available Drawdown in Wells Screened in the Chicot Aquifer

Evangeline Aquifer Results

Estimates of artesian head changes calculated for the Evangeline Aquifer are shown on Figures 15 and 16 for Runs A MOD, B MOD and C. The results show that in the very south part of Montgomery County for all of the simulations there is an increase in the artesian head indicated by the negative contour numbers. This results from a reduction in pumping from the Evangeline Aquifer that is estimated to occur in the north part of Harris County due to scheduled conversions to surface water required by the HGSD, in turn causing a rise in the artesian head in the south part of Montgomery County. This is apparent by the artesian head rises of 100 feet that are shown in the very north part of Harris County. The model simulation does show some artesian head decline of 50 feet, but less than 100 feet in the north part of Montgomery County in proximity to and north of the City of Conroe for Runs A MOD, B MOD and C.

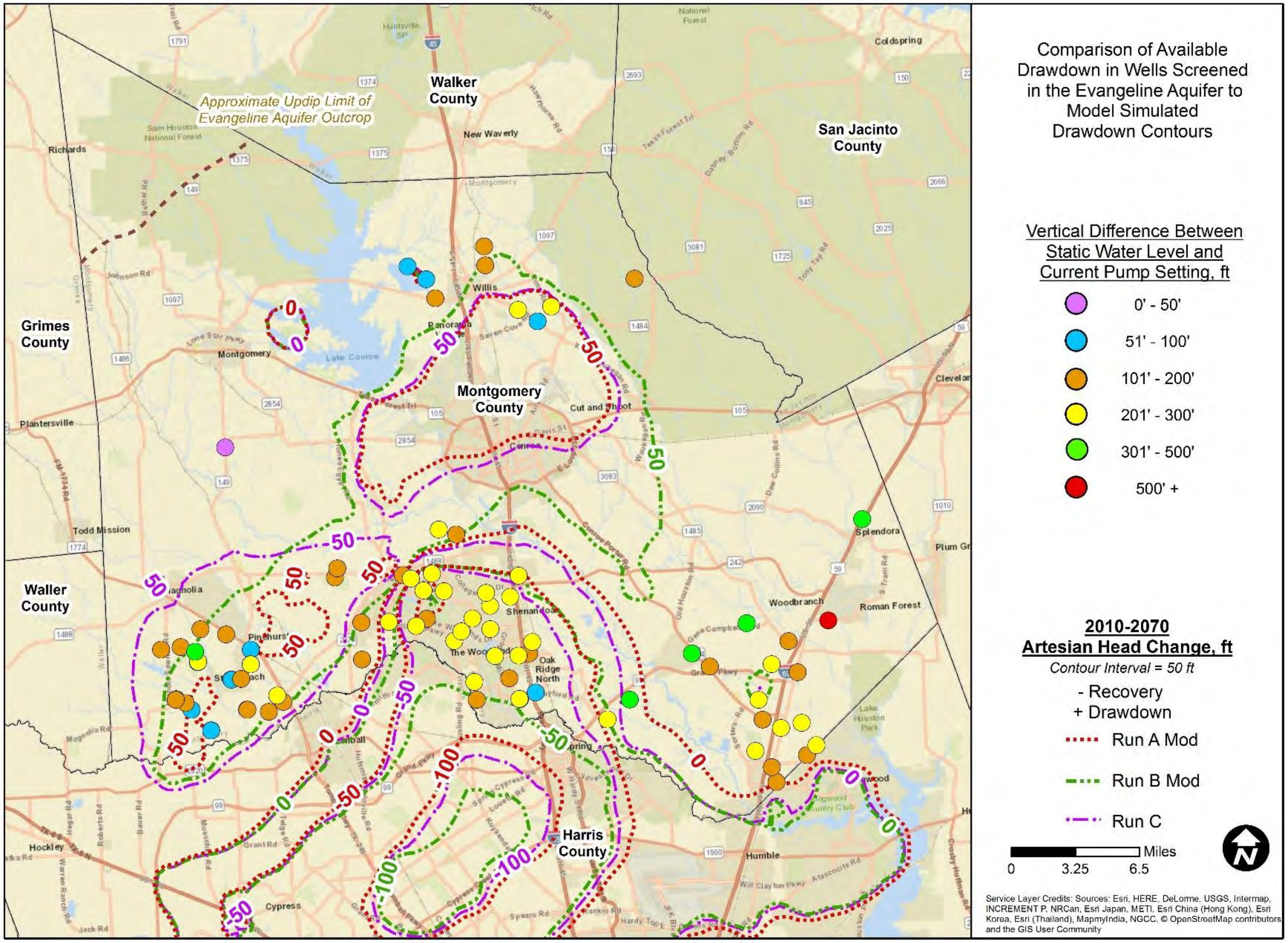

Figure 15. Artesian Head Change in Evangeline Aquifer for 2010-2017

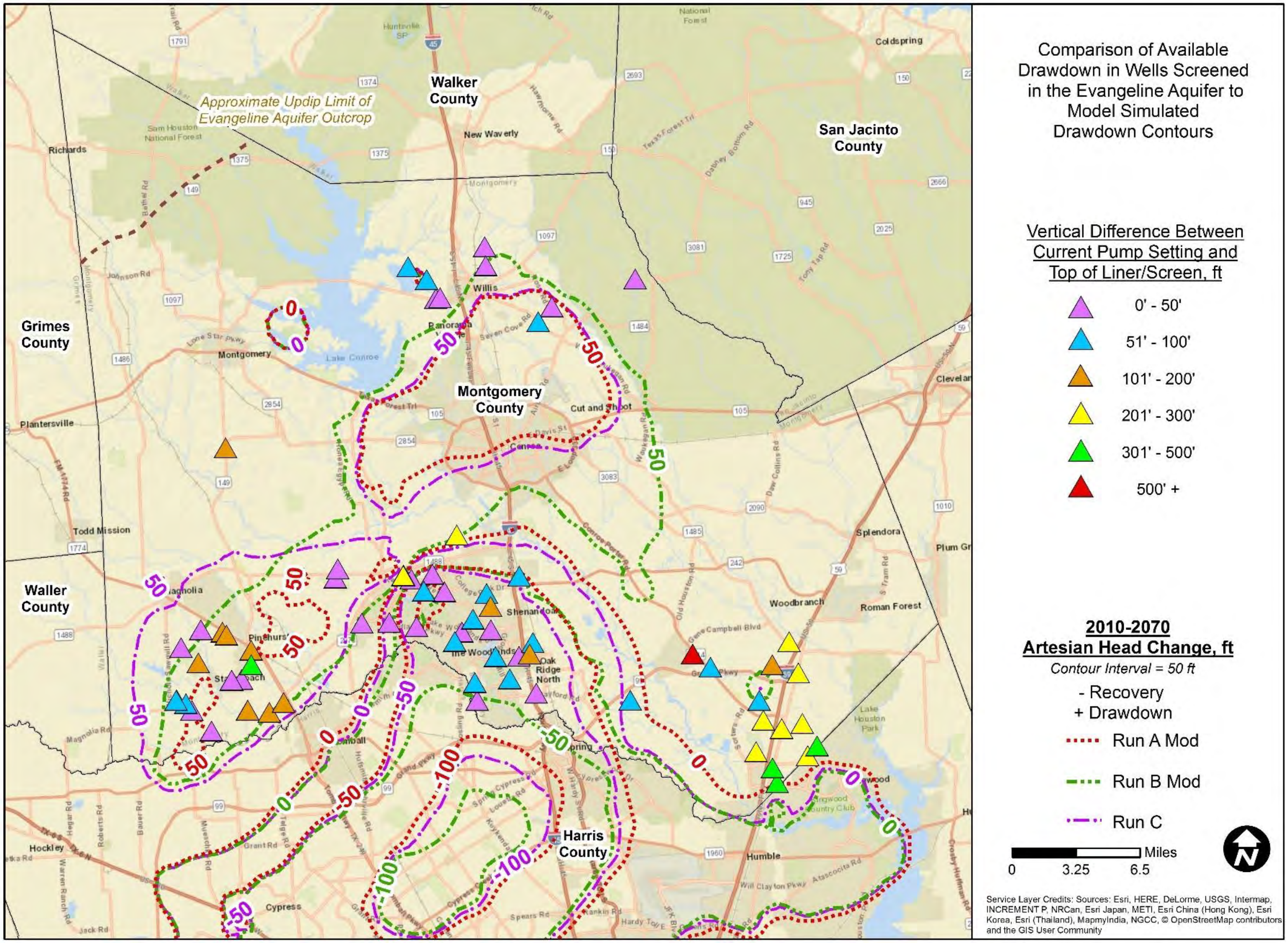

Figure 16. Available Drawdown in Wells Screening the Evangeline Aquifer

Jasper Aquifer

Calculations of artesian head changes for the Jasper Aquifer are presented on Figures 17 and 18. The simulated results show artesian head declines between 2010 and 2070 of less than 50 feet in the south-central part of the District. Those head declines increase in the east and west parts of the county as a result of pumping in the county and pumping from the Jasper Aquifer from other counties surrounding Montgomery County to the east and west. For Run B MOD, there is a substantial increase in pumping (46.7 percent) in the Jasper Aquifer by 2070 from 25,900 ac-ft/yr for Run A MOD to 38,000 ac-ft/yr for Run B MOD. With that increase in pumping, as shown by the dashed green contour lines, there are estimates of artesian head decline of 150 to 200 feet over a substantial part of the District. For Run C when the increase in pumping is distributed to areas outside the I-45 growth corridor, the amount of the artesian head decline estimates increase to up to 300 feet between 2010 and 2070 in the very southeast part of Montgomery County. Calculations of future artesian head declines in the District are, to varying degrees, affected by projected future pumping from the Jasper Aquifer in San Jacinto County.

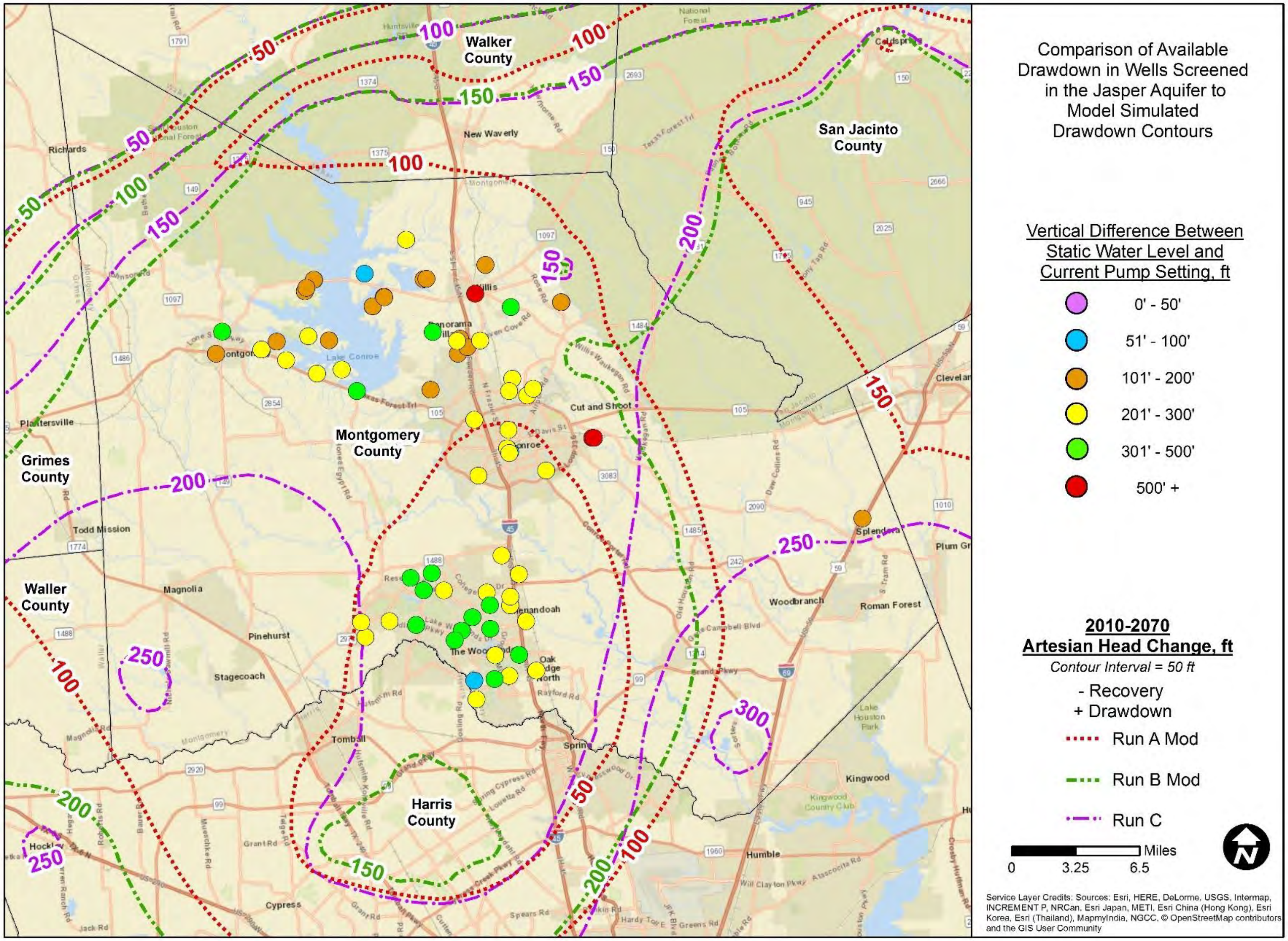

Figure 17. Artesian Head Changes in Jasper Aquifer for 2010-2070

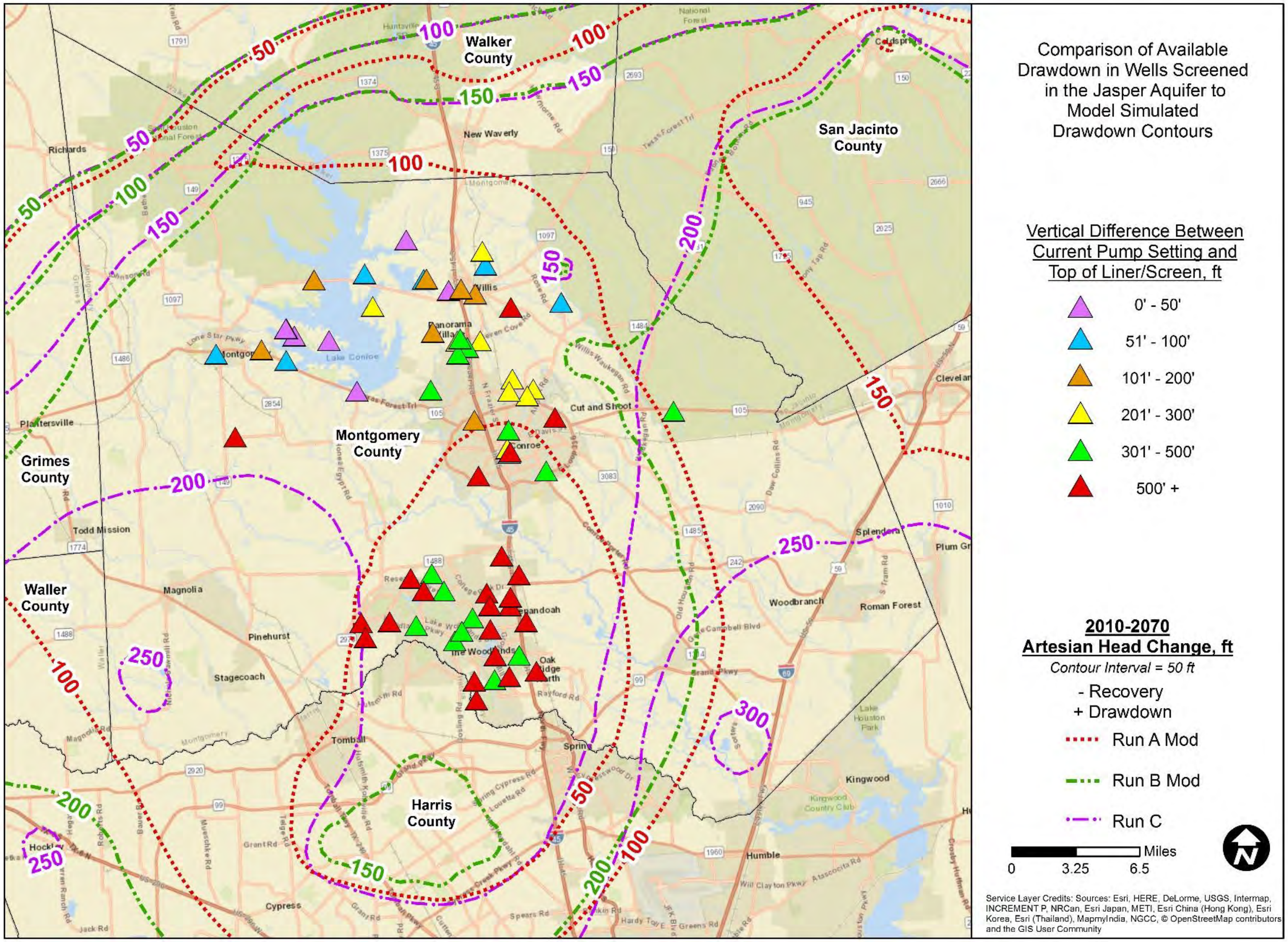

Figure 18. Available Drawdown in Wells Screened in the Jasper Aquifer

COMPARISON OF AVAILABLE DRAWDOWN

In order to better understand the practical applications of results from the various pumping scenarios modeled, with a focus on the amount of currently available drawdown in existing wells, the District developed and distributed a survey tool to all permitted Large Volume Groundwater Users (LVGUs) in order to collect information determined to be important to this study. For a complete listing of questions included in the survey, see questionnaire in Attachment C. The survey was distributed to all 198 LVGU permit owners and ultimately 85 LVGUs provided responses (either partial or completed) for 252 individual permitted wells. Thus, the survey presents information from 42.4 percent of the LVGUs in the District.

Upon receipt of the survey responses, the raw data were compiled into a comprehensive dataset and then processed to correct certain fields in the survey responses, with the primary changes made to non-standardized latitude/longitude identifiers for individual wells. On June 27, 2017, the Findings and Review Committee met to receive and review initial survey results and to provide guidance on any additional analyses needed including level of quality assurance necessary prior to completion of the Survey Report. This guidance included the identification of additional quality assurance needed with respect to responses submitted for targeted data fields including aquifers in which the well is completed and depth remaining that individual pumps can be lowered in wells. The Findings and Review Committee requested that additional analysis be performed to better understand the potential impacts of lowering water levels in wells on existing wells including current pumping levels.

In total, responses (both partial and complete) were received for 6 wells completed in the Catahoula Formation, 14 wells completed in the Chicot Aquifer, 138 wells completed in the Evangeline Aquifer, 89 wells completed in the Jasper Aquifer, and 5 wells dually completed in the Chicot and Evangeline aquifers, for a total of 252 wells. A copy of the survey results, with evaluation of the survey data by Mullican and Associates, is provided in Appendix C.

The primary focus of the survey analysis was to quantify the difference between the existing static water level and the current pump setting and between the current pump setting and the top of the blank liner above the screen. An objective of the survey, in part, was to provide data regarding whether the estimates of artesian head decline would impair the ability of the pumps in the wells from providing water near the current well pumping rates. Figures for each of the three aquifers, Chicot, Evangeline, and Jasper, show the results of this survey: 1) vertical difference between the static water level and the current pump setting for each well and 2) vertical difference between the current pump setting and the top of the well liner/screen for each well. Results for the Catahoula Formation were presented to the Findings and Review Committee, but are not included here due to the scope of the modeling effort with the HAGM that was developed for the Chicot, Evangeline and Jasper aquifers.

Chicot Aquifer

The data on Figures 13 and 14 show that except for one well located just east of Shenandoah that the survey respondents reported that the amounts of artesian head decline estimated to occur with the three scenarios would not impair their wells from providing water, assuming that in some instances the pumps would be lowered below their current settings and potentially a pump would be replaced.

Evangeline Aquifer

The survey also included data collected for wells screening the Evangeline Aquifer. For the survey, data were provided for 78 wells and the locations of the wells are shown on Figures 15 and 16. The results of the survey show that for the respondents that estimated amounts of artesian head decline that would occur with the three scenarios should not result in impairment to the wells providing water, except in one area. That area is in the southwest part of the District south of Magnolia where possibly the 50 feet of artesian head decline could cause a reduction in the pumping rates of a few wells. The lowering of pumps at some time in the future in some wells could be required to maintain pumping rates and this has already occurred in the past decades as groundwater pumping increased in the District.

Jasper Aquifer

Results of the survey, in terms of depth between the static water level and the current pump setting and the distance between the current pump setting and the top of the liner for the

Jasper Aquifer are shown on Figures 17 and 18, respectively. Survey data were reported for 68 wells. The data show that in general, the wells either have distance between the static water level and the pump setting or if combined with the distance between the current pump setting and top of the liner that the wells have adequate available drawdown so that they should be capable of continuing to provide water at or near their current pumping rates with, if needed, pumping equipment upgrades. The upgrades could include pump lowering and replacement and increasing motor horsepower could be required to maintain pumping rates. One area where pumping rates of wells may not be maintained is in proximity to Lake Conroe where the depth of the aquifer is not as deep as in the area to the south and thus, the available drawdown is less. Runs B MOD and C projects about 150 to 200 feet of static water-level decline in the Lake Conroe area and that could lead to some reduction in the pumping rate of wells.

Results of Run D Simulation

Artesian head decline results calculated for the pumping scenario included in Run D are shown on Figures 19 through 25. As stated previously, Run D is very similar to Run B MOD, but the pumping from the Evangeline Aquifer is 19 percent less than in Run B MOD and for the Jasper Aquifer was 16 percent greater than in Run B MOD and those percentage adjustments in pumping are incrementally included from 2020 through 2070.

Chicot Aquifer Head Changes

The results of the simulation show that for the Chicot Aquifer the artesian head decline could be about 60 feet in the very southern part of the District and that in other parts of the District the artesian head decline can be in the range of about 40 feet to zero head decline. Pumping from the Chicot Aquifer, as discussed earlier, principally occurs in the central to southern parts of the District where the aquifer is deep enough to support domestic, stock and a few wells that provide water for industry and public supply. The upper edge of the outcrop of the Chicot Aquifer is shown on Figures 17 and 18.

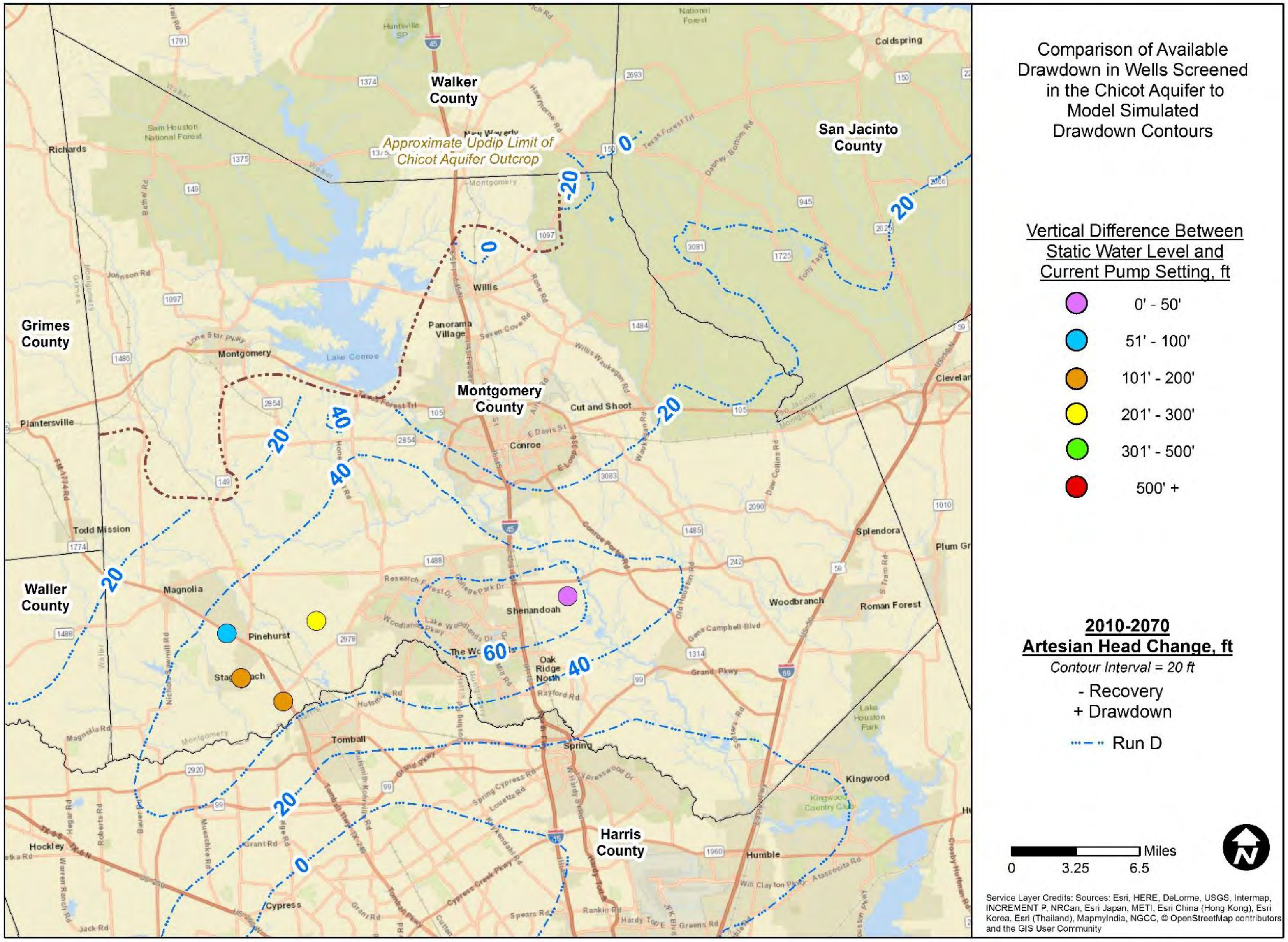

Figure 19. Run D Artesian Head Changes in Chicot Aquifer for 2010-2070

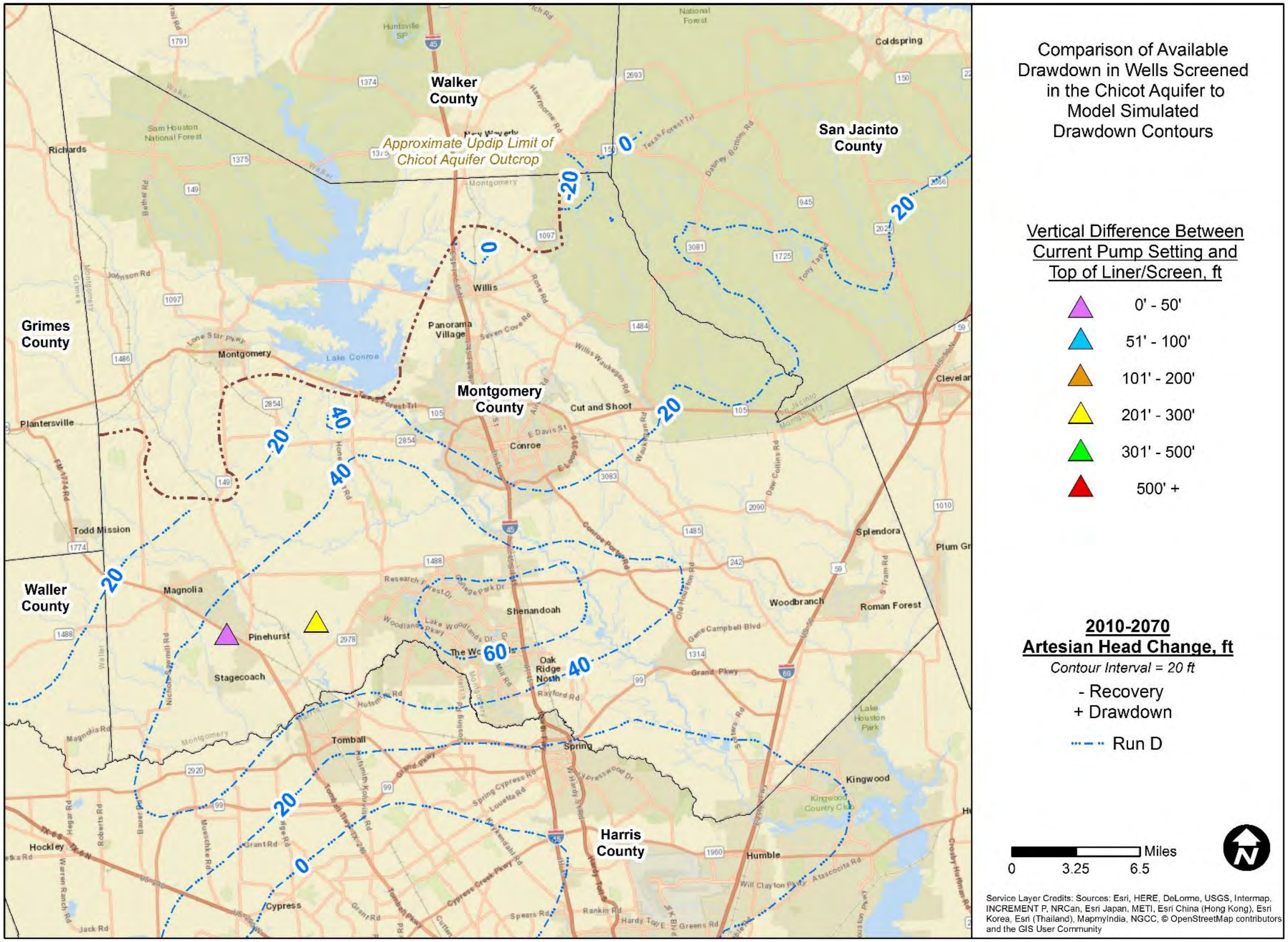

Figure 20. Run D Available Drawdown in Wells Screened in the Chicot Aquifer

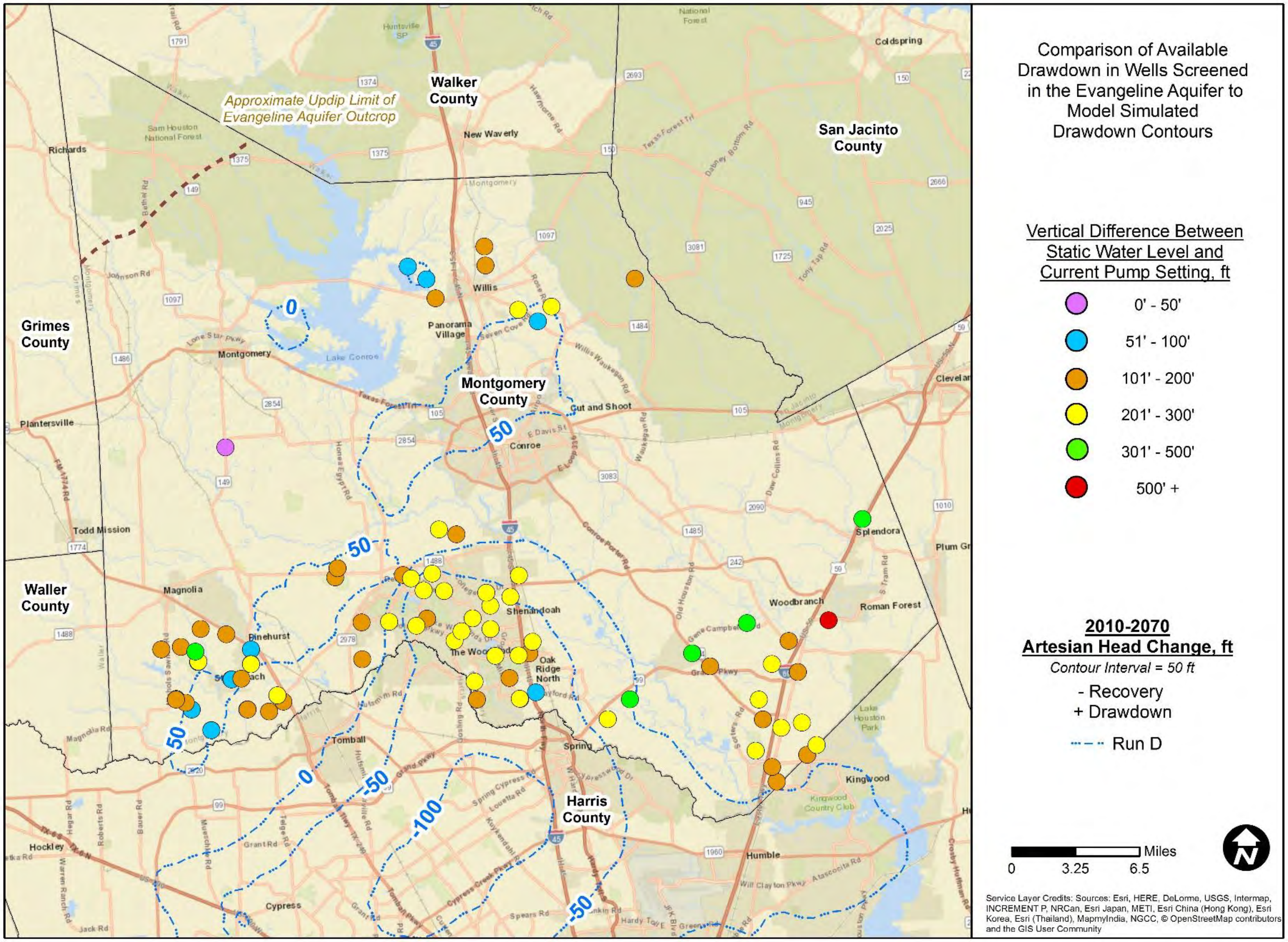

Figure 21. Run D Artesian Head Change in Evangeline Aquifer for 2010-2070

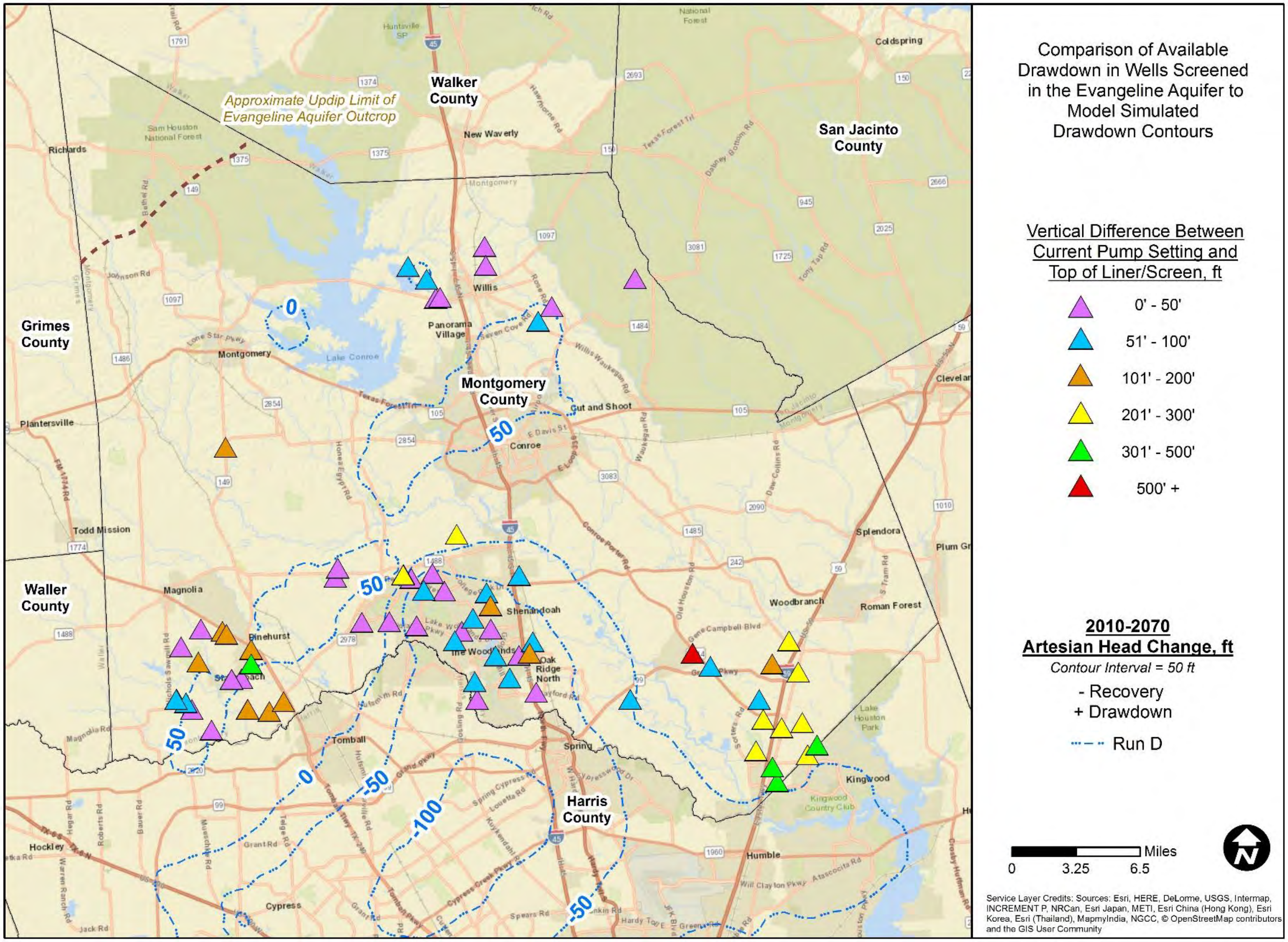

Figure 22. Run D Available Drawdown in Wells Screened in the Evangeline Aquifer

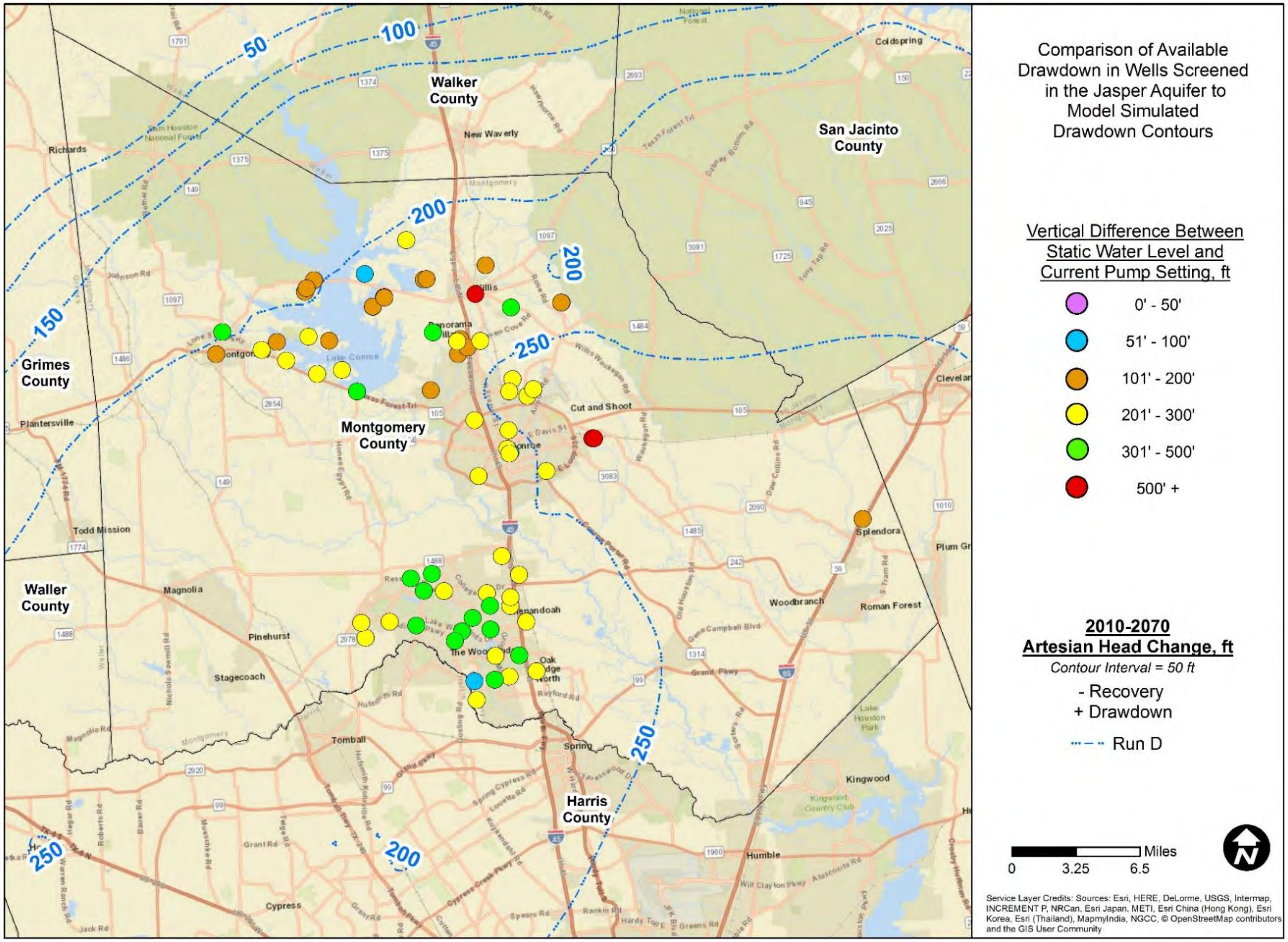

Figure 23. Run D Artesian Head Changes in Jasper Aquifer for 2010-2070

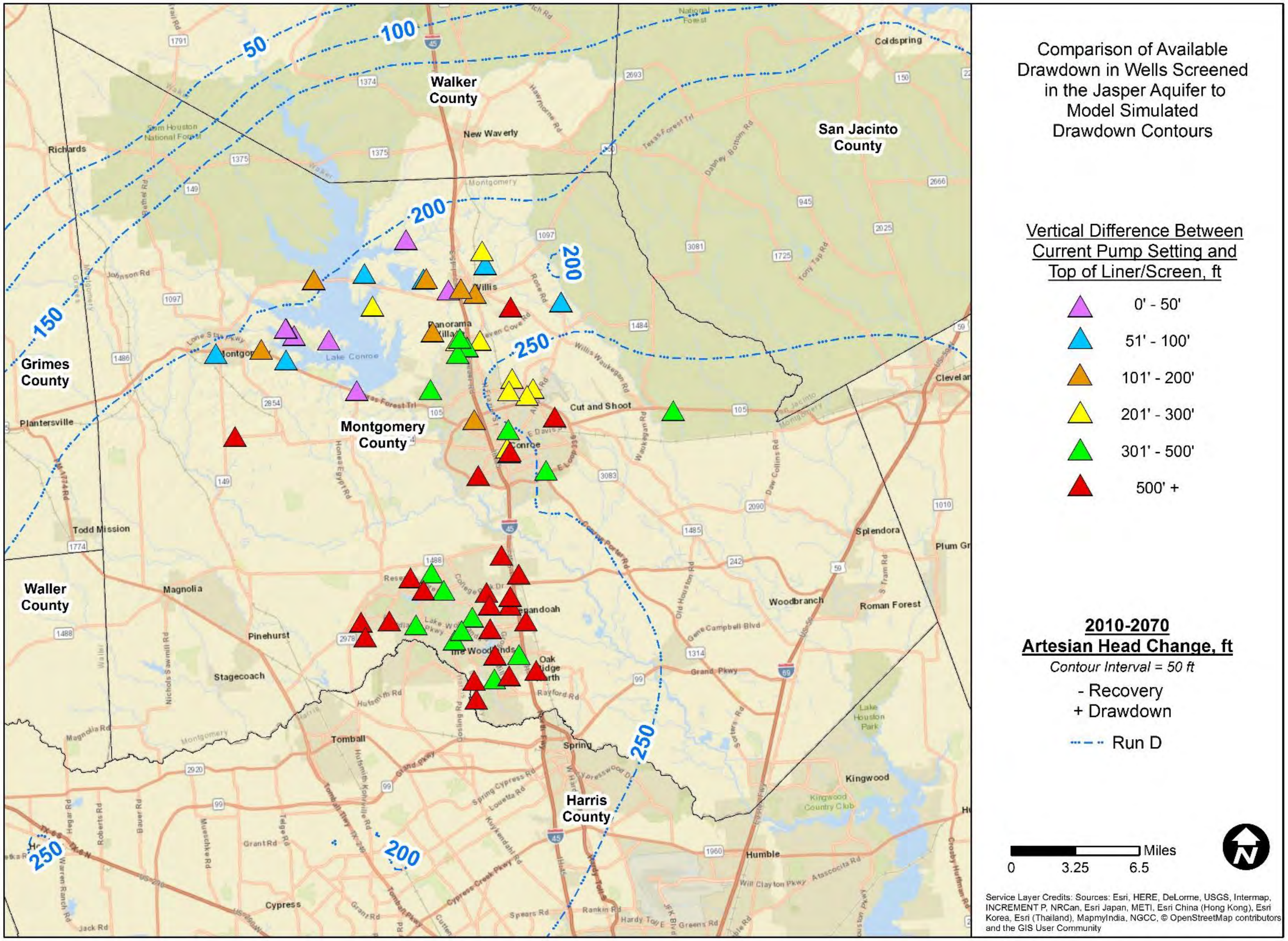

Figure 24. Run D Available Drawdown in Wells Screened in the Jasper Aquifer

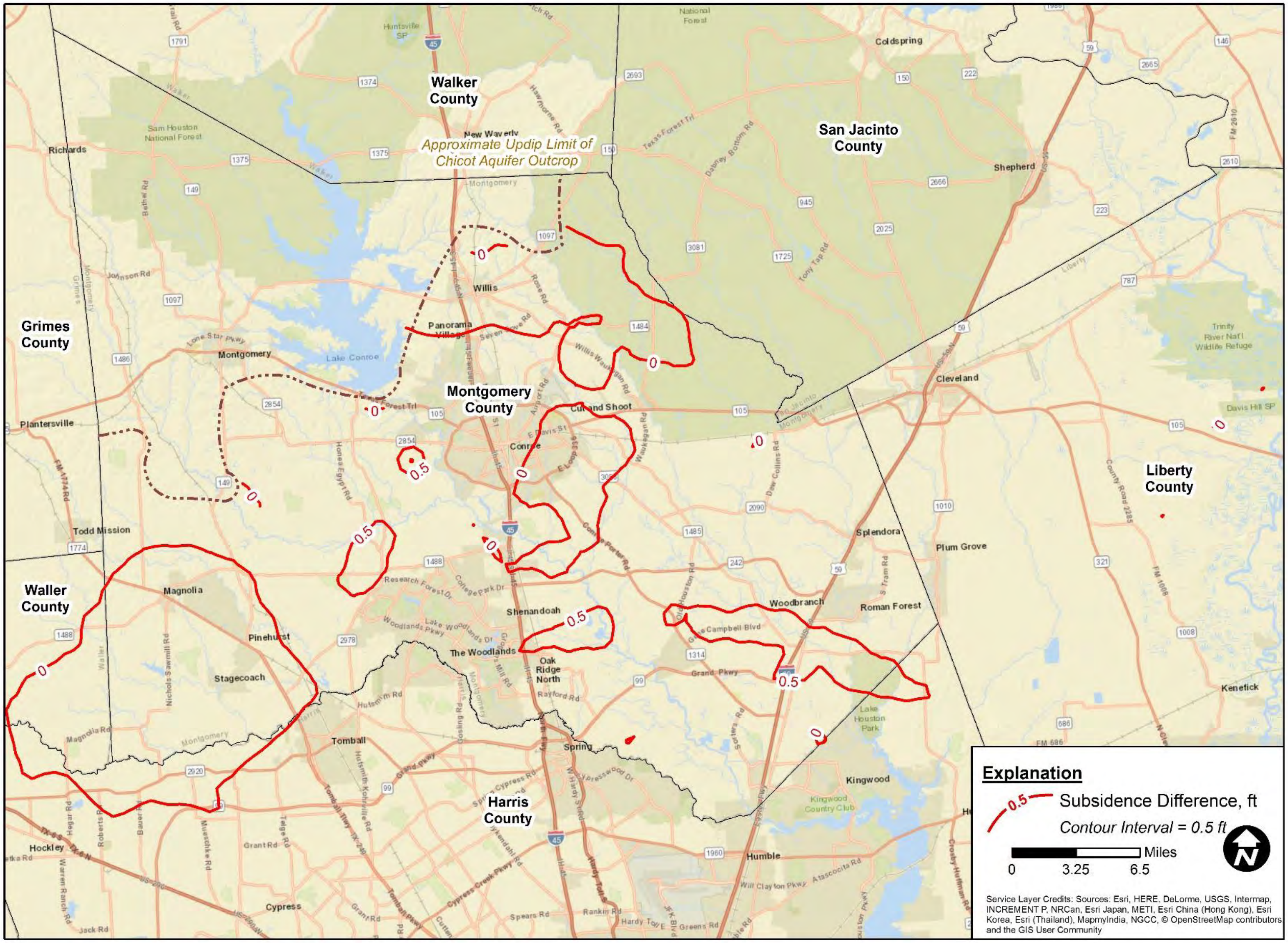

Figure 25. Average Subsidence Difference Between Run D and GMA 14 Run 2 for 2010 to 2070

Evangeline Aquifer Head Changes

For the Evangeline Aquifer the results of Run D show an increase in artesian head in the very southern part of the county, primarily the result of a conversion to surface water in northern Harris County required by the Harris-Galveston Subsidence District, as explained for Runs A MOD, B MOD and C. The simulation shows modest amounts of additional artesian head decline in the range of 50 feet in some areas to the north in the county and in proximity to the City of Pinehurst.

Jasper Aquifer Head Changes

The results for the Jasper Aquifer show artesian head declines that are as much as 250 feet in the east and southeast parts of the District and between 200 and 250 feet in the south-central to north-central part of the District for the period 2010 through 2070.

Effects on Well Pumping Rates

Chicot Aquifer Screened Wells

The results from the survey of LVGUs are also shown on Figures 19 through 24. The results for the Chicot Aquifer provided on Figures 19 and 20 show that, at least for well owners that responded to the survey, there should be adequate available drawdown between the static water level and the top of the screen liner so that wells can continue to produce water at or near current production rates. Pump lowering and replacement may be required for some wells to maintain pumping rates depending on the level of additional pumping in an area. In one area just east of I-45 the estimated distance between the static water level and current pump setting is 0 to 50 feet, based on the survey response received from one well owner. The respondent did not report the distance between the current pump setting and the top of the screen liner, so available drawdown may or may not be an issue at that well.

Evangeline Aquifer Screened Wells

The results of the survey of wells screening the Evangeline Aquifer show that for the estimated changes in artesian head between 2010 and 2070 that there should be adequate available drawdown in the wells so that they can continue to provide water at or near current rates. Pump lowering and replacement may be required in some wells.

Jasper Aquifer Screened Wells

The well survey responses and the estimates of artesian head decline for the Jasper Aquifer are shown on Figures 23 and 24. The data show that pumping from the Jasper Aquifer at the rates included in Run D should not impair wells from providing water at their current rates, except potentially in the area in proximity to Lake Conroe. In that area if the estimated artesian head declines occur, some wells may require that their pumping rates be reduced to maintain adequate pump submergence. In the area where the survey respondents indicated that this could occur is an area where water wells also have been constructed that screen sands from the Catahoula Formation, and thus provide water users an alternative supply to the Jasper Aquifer. In other areas of the District pump lowering or replacement may be required if the pumping of the aquifer reaches to amounts assumed in Run D.

Summary

The results from Run D indicate that a pumping amount of 100,000 ac-ft/yr distributed according to the pumping quantities prescribed for each of the three aquifers, both spatially and temporally, could be feasible in the District. The areal distribution of pumping may vary from the locations assumed in Run D, but as long as there is adequate available drawdown in those areas and overall pumping does not exceed 100,000 ac-ft/yr, an alternative areal distribution of pumping could be acceptable. As pumping is increased above the current level, the monitoring of water levels in wells throughout the District should continue as that data will be valuable in evaluating the response of the aquifers to potential increases in pumping in the coming decades. The collection of groundwater pumping data on a monthly or yearly basis also should continue so that an accurate accounting can be assembled of the quantity of water that is being pumped from the Chicot, Evangeline, Jasper aquifers and the Catahoula Formation. In addition, the District should continue to look for opportunities to establish dedicated monitor wells in areas of concentrated pumping so as to collect more robust data regarding artesian water levels in the aquifers.

ESTIMATED DESIRED FUTURE CONDITIONS

As part of the GMA 14 planning effort, DFCs were adopted for aquifers both on a GMA 14-wide basis, and for each of the 20 counties in GMA 14. As such, DFCs were developed for Montgomery County and the counties surrounding Montgomery County that are within GMA 14. As pumping increases in Montgomery County, then the amount of calculated artesian head decline increases and thus the DFCs, in terms of average artesian head decline in a county, also increase. The following is a discussion of DFCs for model simulations GMA 14 Run 2, Run A MOD, Run B MOD, Run C and Run D.

Montgomery County

Calculated DFCs for the District are the estimated average artesian head decline or drawdown that could occur by the year 2070 for the area of the District that is within the area where the aquifer exists. The Chicot Aquifer occurs under about 74 percent of the District. The Evangeline Aquifer occurs under about 95 percent of the District and the Jasper Aquifer under all of the District.

The average drawdowns calculated for the Chicot, Evangeline and Jasper aquifers for the District for GMA 14 Run 2, Run A MOD, Run B MOD, Run C and Run D are shown on Figure 26. The results on the figure show that for GMA 14 Run 2 the average drawdown for 2070 was 25, -5 and 36 feet for the Chicot, Evangeline and Jasper aquifers, respectively and Run D 30, 20 and 224 feet for the Chicot, Evangeline and Jasper aquifers, respectively. The average drawdown increases are in response to the increases in pumping included in the simulations.

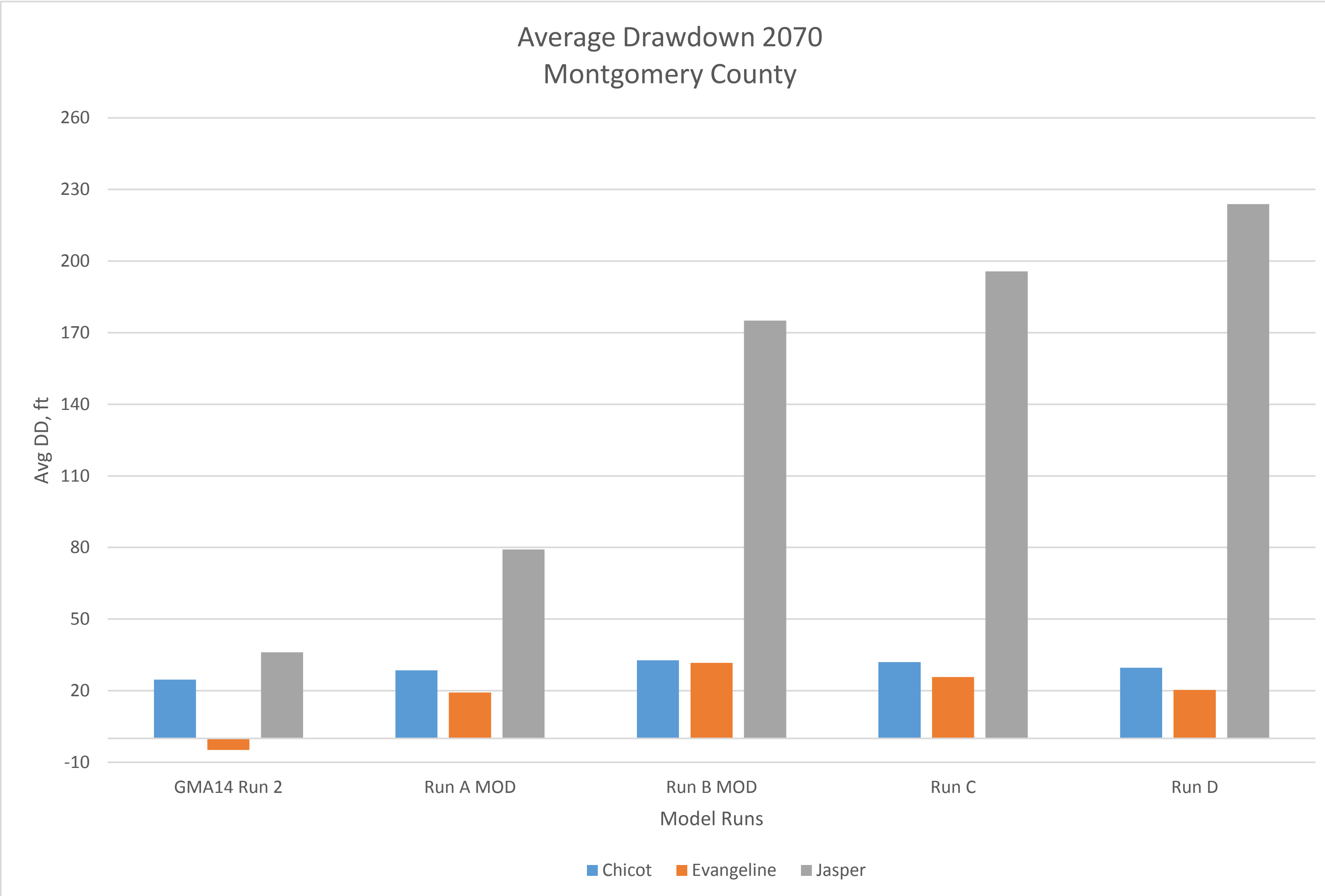

Figure 26. Average 2010-2070 Drawdown in Montgomery County

Surrounding Counties

A comparison between average drawdowns for GMA 14 Run 2 and Run D in Montgomery and surrounding counties is provided on Table 4. The Chicot Aquifer pumping in Run D is less than the pumping in GMA 14 Run 2, therefore the Run D average drawdowns for the surrounding counties are essentially the same as for GMA 14 Run 2. The increase in pumping in the District from the Evangeline Aquifer has a minimal effect on the average drawdowns in the surrounding counties for one main reason. A majority of the pumping occurs in the middle part of the county and the effect of that pumping dissipate at distance to the east and west county boundaries. This is evident by the artesian head changes shown on Figures 13 and 14. The results show that as the overall amount of pumping from the Jasper Aquifer in the District increases as listed in Table 3, the pumping increases the average drawdown in the surrounding counties for the Jasper Aquifer. The magnitude of the average drawdown effect of Run D pumping compared to GMA 14 Run 2 is highest in Liberty and Waller counties and less in the other surrounding counties and ranges from 60 to 200 feet.

Table 4. Average Drawdown 2010 to 2070, ft.

	GMA14 Run 2			Run D		
County	Chicot	Evangeline	Jasper	Chicot	Evangeline	Jasper
Montgomery	25	-5	36	30	20	224
Grimes	6	5	53	6	5	88
Walker	1	9	42	1	9	61
San Jacinto	24	19	109	23	19	165
Liberty	28	29	121	28	30	228
Waller	34	40	102	33	39	202

AQUIFER WATER QUALITY

The quality of water contained in the Chicot, Evangeline and Jasper aquifers, and the Catahoula Formation has been studied for a number of decades as groundwater has been developed in the District. The study performed by the TWDB (Popkin, 1971) concluded that groundwater in the Chicot, Evangeline, and upper part of the Jasper aquifers, essentially contained less than 1,000 mg/l TDS in almost all of the District. An area that was an exception was in proximity to the Conroe Oil Field that is located to the southeast of Conroe and encompasses an area of less than 16 square miles out of a total county are of 1,077 square miles.

In the oil field area where principally oil has been extracted for decades, groundwater can contain TDS of greater than 1,000 mg/l. The Catahoula Formation contains fresh water bearing sands in the north central parts of the District. Further south in the District the Catahoula Formation contains water that can range from brackish to saline.

As part of the Task 2 Technical Memorandum for this study regarding total estimated recoverable storage and implications for groundwater management, conclusions similar to those contained in Popkin 1971 were provided regarding groundwater quality in Montgomery County for the Chicot, Evangeline and Jasper aquifers that provide a vast majority of the groundwater pumped in the county. The Chicot, Evangeline and Jasper aquifers essentially contain water with less than 1,000 mg/l TDS, except in close proximity to the Conroe Oil Field, as mentioned in a previous section of this report.

Large-scale pumping of groundwater has occurred in the District for at least 30 years and during that time substantial changes have not been reported in the general quality of groundwater. If water well owners are careful to only screen sands in the Chicot, Evangeline and Jasper aquifers that contain water of good quality and locate wells away from any areas like the Conroe Oil Field, these steps should increase the likelihood of wells producing water of acceptable quality in the future.

SUBSIDENCE

As part of the evaluation of the pumping options of the Chicot, Evangeline and Jasper aquifers the resulting subsidence also was computed and evaluated. For the Run D pumping scenario, the average subsidence for the District from 2010 to 2070 was 0.55 feet compared to 0.5 feet for GMA 14 Run 2. Comparing Run D pumping scenario to the GMA14 Run 2 simulation, the additional subsidence occurs in the southern portion of the District with a few small areas showing an additional 0.5 feet of subsidence over the 2010 to 2070 period and is shown in Figure 25.

MANAGEMENT ZONE CONSIDERATIONS

The LSGCD considered management zones for the District in the period from about 2003 to 2005. During that review and evaluation, it was concluded that management zones were not warranted for the District to effectively manage the groundwater resources. The District also determined that management zones would not be effective in achieving the District. Management zones normally are developed with the anticipation that the management of groundwater resources within the various zones will be performed with rules and regulations that can vary between the zones. The Findings & Review Committee, as part of this study, considered the potential for management zones and decided that they are not needed at this time. They may be considered in the future if the conservation and management of the groundwater resources warrants them.

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APPENDIX A

AQUIFERS RESPONSE TO 2016 REDUCTION IN PUMPING

As part of the Groundwater Reduction Plan by the District, there was a requirement that the pumping of groundwater be reduced in 2016 and forward and that pumping be replaced with alternative water supplies. One of the alternative water supplies was the introduction of surface water in principally the central and south part of the District. The magnitude of that reduction in pumping was smallest for the Chicot Aquifer and largest for the Jasper Aquifer. A discussion of the response of the aquifers to the reduction in groundwater pumping is provided in the following sections.

Reductions in Pumping from The Chicot Aquifer

Permitted pumping from the Chicot Aquifer was 3,584 acre feet in 2015 and 3,203 acre feet in 2016, representing a reduction of 381 acre feet. With the reduction in pumping water-level data collected by the U.S. Geological Survey in 2015 prior to the reduction and at the end of 2016 or the beginning of 2017 indicate that in six monitor wells located in the south part of the District, water levels rose less than 10 feet and were in the range of 1 to 3 feet with water-level change data on Illustration 1. There was one well in the very south part of the county which showed a decline in the water level of 11 feet. With the small change in pumping, the change in water levels in wells should be small. In the future, if the overall pumping from the Chicot Aquifer is reduced further, there should be some additional rise in water levels in well screening the aquifer.

Reductions in Pumping from The Evangeline Aquifer

Based on data collected by the District, permitted pumping from the Evangeline Aquifer was 31,763 acre feet in 2015 and 29,131 acre feet in 2016, representing a reduction of 2,632 acre feet. The primary area where large-capacity wells are constructed screening the Evangeline Aquifer is in the south part of the District. The water-level data collected by the U.S. Geological Survey is presented on Illustration 2. The data show that the water-level changes in the wells range from a decline of 21 to 50 feet reported for one well to a recovery or rise of 21 to 50 feet reported for numerous other wells. As can be seen by the data on Illustration

1, predominately water-level rises were occurring in the wells. There were 21 wells that reported water-level rises, 12 wells had no change and 8 wells showed water-level declines with five of those wells heaving declines of less than 5 feet. The less than 5 feet declines are based on a query of the water-level data collected for the wells.

Reductions in Pumping from The Jasper Aquifer

The recorded permitted pumping from the Jasper Aquifer was 33,107 acre feet in 2015 and 20,876 acre feet in 2016. This is a reduction in pumping of 12,231 acre feet. Water-level changes measured by the U.S. Geological Survey in wells are shown on Illustration 3. The recoveries in water levels in 65 wells are spread over a geographic area that includes the I-45 corridor and the area in proximity to Lake Conroe. There are a very limited number of wells which showed water-level declines that range to a maximum of 21 to 50 feet. Thirty feet was the maximum water-level decline and it was recorded in one well in the very south part of the District. The data for 65 wells showing water-level recoveries indicates that the reduction in pumping did lead to significant water-level rises in wells or artesian head recovery spread over the area that includes where almost all of the wells are located.

SUMMARY

The well pumping and water-level data should continue to be collected as they will provide a basis for assessing the overall response of the aquifer to changes in pumping in upcoming years. A similar assessment of the well water-level changes and thus, aquifer response to changes in pumping should occur in future years to increase the length of the record of aquifer pumping and static water levels in wells. The data indicate that the area of major pumping from the Evangeline Aquifer is in the south part of the District and thus the water-level changes would be anticipated to be greater in that area. For the Jasper Aquifer, the change in pumping occurs over a wider area and the water-level response in wells to changes in pumping also should occurred over a larger area. It is estimated in water planning studies like the 2017 Texas State Water Plan that there will be urbanization in other areas of the District. As that occurs with increased water use, pumping and static water-level data should be collected which will expand the area in which analysis can be performed of aquifer response to pumping.

LBG-GUYTON ASSOCIATES

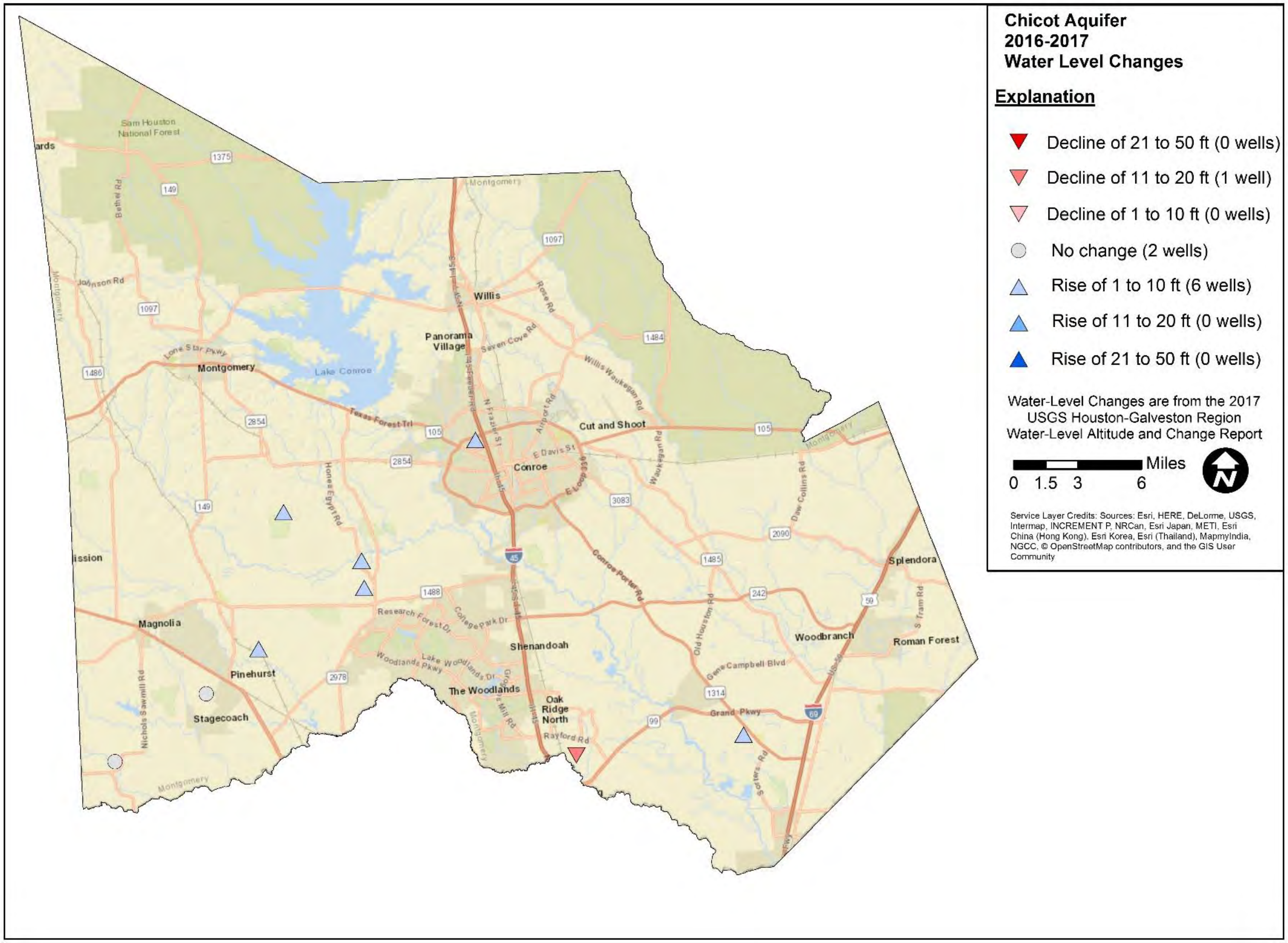

Illustration 1. Static Water-Level Changes for Chicot Aquifer Screened Wells from Beginning of 2016 to Beginning of 2017

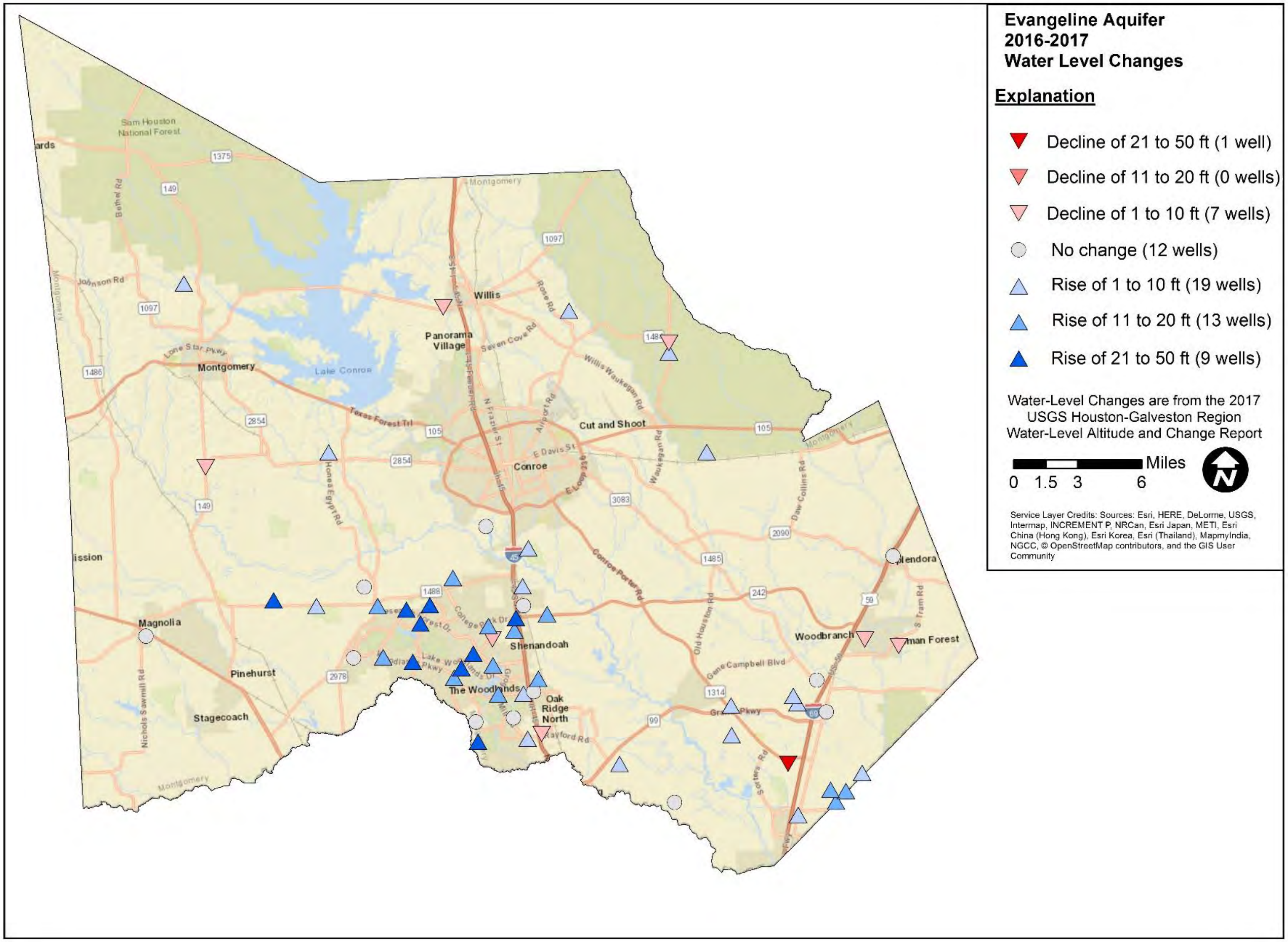

Illustration 2. Static Water-Level Changes for Evangeline Aquifer Screened Wells from Beginning of 2016 to Beginning of 2017

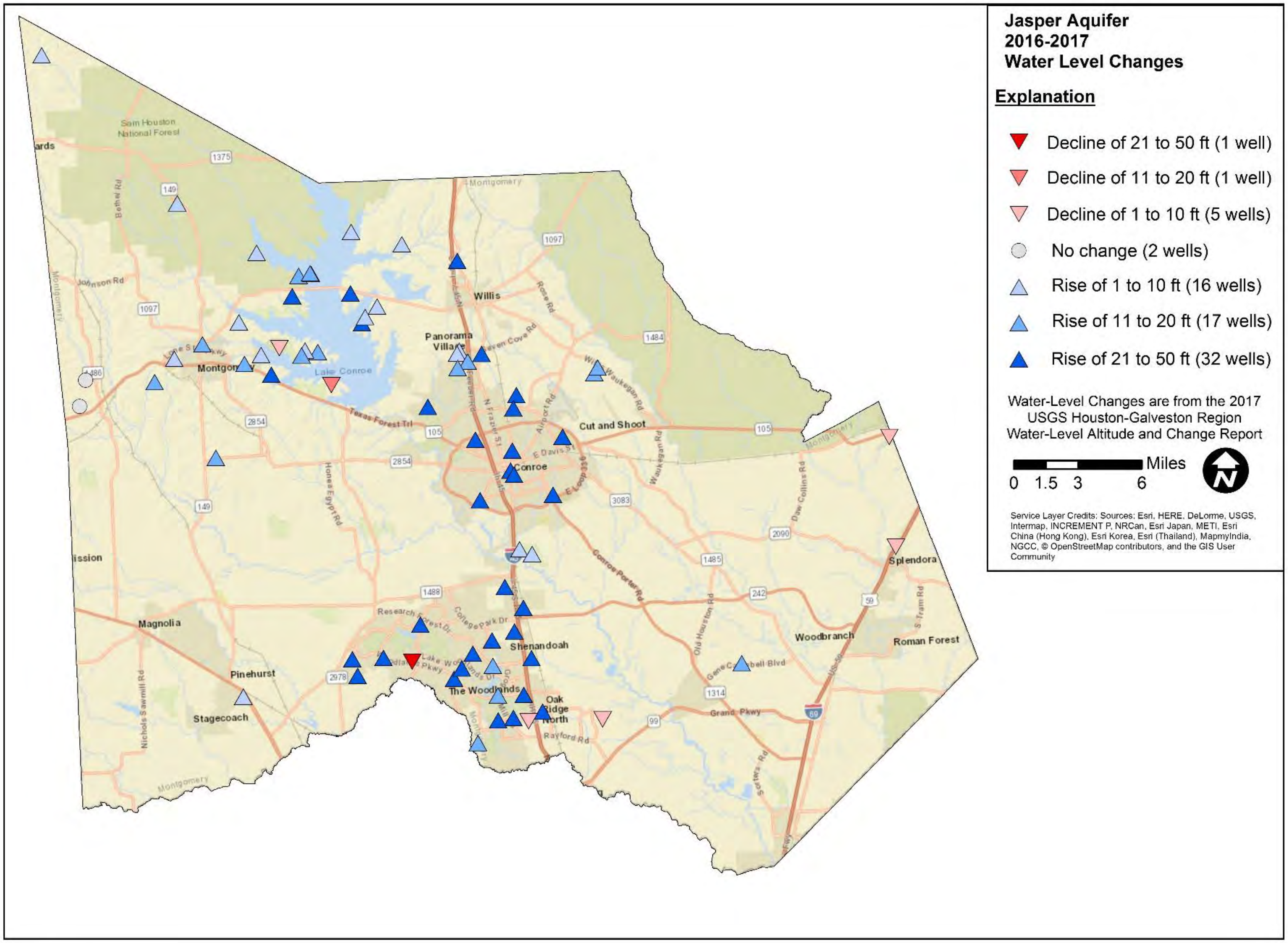

Illustration 3. Static Water-Level Changes for Jasper Aquifer Screened Wells from Beginning of 2016 to Beginning of 2017

APPENDIX B

Appendix B. Water Quality Data for Wells Screening the Catahoula Formation

State Well Number	Well Owner & Number	Sample Date	TDS (mg/l)	Fluoride (mg/l)
60-34-905	Dobbin-Plantersville WSC	09-29-2016	972	2.50
	Well 8			
60-35-604	Montgomery County MUD 18	11-29-2012	484	1.01
	Well 3	11-29-2012	500	1.06
		11-13-2013	449	0.91
		11-20-2014	471	0.94
		10-18-2016	494	0.80
		07-25-2017	455	0.83
60-35-814	City of Montgomery	11-24-2014	502	1.88
	Well 4	11-24-2014	501	1.89
		12-15-2015	517	1.76
		10-24-2016	511	1.73
		07-27-2017	501	1.71
60-35-915	Stanley Lake MUD	11-14-2013	583	2.25
	Well 3	11-14-2013	581	2.35
		11-25-2014	601	2.31
		12-15-2015	635	2.28
		10-24-2016	617	2.25
		07-24-2017	916	1.93
60-36-211	Corinthian Point MUD 2	09-06-2016	687	1.44
	Well 4	07-18-2017	691	1.38
60-36-514	Point Aquarius MUD	08-15-2016	748	0.98
	Well 4	07-18-2017	764	0.99
60-36-615	City of Willis	12-19-2013	804	1.70
	Well 6	11-04-2014	674	1.49
		12-14-2015	646	1.43
		10-27-2016	671	1.42
		08-07-2017	643	1.50
60-36-710	Montgomery County MUD 8	11-20-2014	606	1.50
		12-17-2015	596	1.43
		10-18-2016	591	1.37
		07-25-2017	574	1.38
60-37-315	Cal Sierra International, LLC	09-14-2016	857	1.23
	Catahoula No. 1	09-14-2016	853	1.21
		07-24-2017	718	1.08
60-37-418	City of Willis	11-04-2014	978	2.29
	Well 7	11-12-2015	966	1.89
		10-27-2016	948	2.12
		08-07-2017	941	2.15

Appendix B. Water Quality Data for Wells Screening the Catahoula Formation

State Well Number	Well Owner & Number	Sample Date	TDS (mg/l)	Fluoride (mg/l)
60-37-718	City of Panorama Village	12-11-2013	737	2.62
	Well 4	11-25-2014	729	2.06
		12-14-2015	660	2.57
		08-11-2016	754	2.24
		07-17-2017	768	2.09
		07-17-2017	783	2.07
60-44-124	Montgomery County UD 3	09-06-2012	818	2.20
	Well 3	11-13-2013	819	2.42
		11-20-2014	826	2.38
		10-18-2016	772	2.24
		07-25-2017	563	1.97
		07-25-2017	568	1.96
60-45-122	City of Conroe	01-11-2016	896	1.79
	Well 24	01-11-2016	919	1.56
		10-26-2016	927	2.23
		07-20-2017	991	2.13

** Water Quality data from the United States Geological Survey*

APPENDIX C

Lone Star Groundwater Conservation District

Strategic Water Resources Planning Study

Large Volume Groundwater Users Survey Responses - UPDATED

Survey Overview

As part of the ongoing Lone Star Groundwater Conservation District (Lone Star GCD) Strategic Water Resources Planning Study (the Study), a survey tool (the Survey) was developed and distributed to all permitted Large Volume Groundwater Users (LVGUs) in order to collect information determined to be important to the Study. For a complete listing of questions included in the Survey, see Attachment A. The Survey was distributed to all 198 LVGU permit owners and ultimately 85 LVGUs provided responses (either partial or completed) for 252 individual permitted wells. Thus, the Survey presents information from 42.4 percent of the LVGUs in the Lone Star GCD.

Upon receipt of the survey responses, the raw data was compiled into a comprehensive dataset and then processed to correct certain fields in the Survey responses, with the primary changes made to non-standardized latitude/longitude identifiers for individual wells. On June 27, 2017, the Findings and Review Committee met to receive and review initial survey results and to provide guidance on any additional analyses needed including level of quality assurance necessary prior to completion of the Survey Report. This guidance included the identification of additional quality assurance needed with respect to responses submitted for targeted data fields including aquifers in which the well is completed and depth remaining that individual pumps can be lowered in wells. The Findings and Review Committee requested that additional analysis be performed to better understand the potential impacts of lowering water levels in wells on existing wells including current pumping levels. This additional analysis is included in this Updated Survey Report.

In total, responses (both partial and complete) were received for 6 wells completed in the Catahoula Formation (see Figure 1), 14 wells completed in the Chicot Aquifer (see Figure 2), 138 wells completed in the Evangeline Aquifer (see Figure 3), 89 wells completed in the Jasper Aquifer (see Figure 4), and 5 wells dually completed in the Chicot and Evangeline aquifers (see Figuere 5) for a total of 252 wells.

Digital files, by aquifer, with complete survey responses (with corrected latitude/longitude), are transmitted separately and identified as Lone Star GCD SWRP Survey Update files.

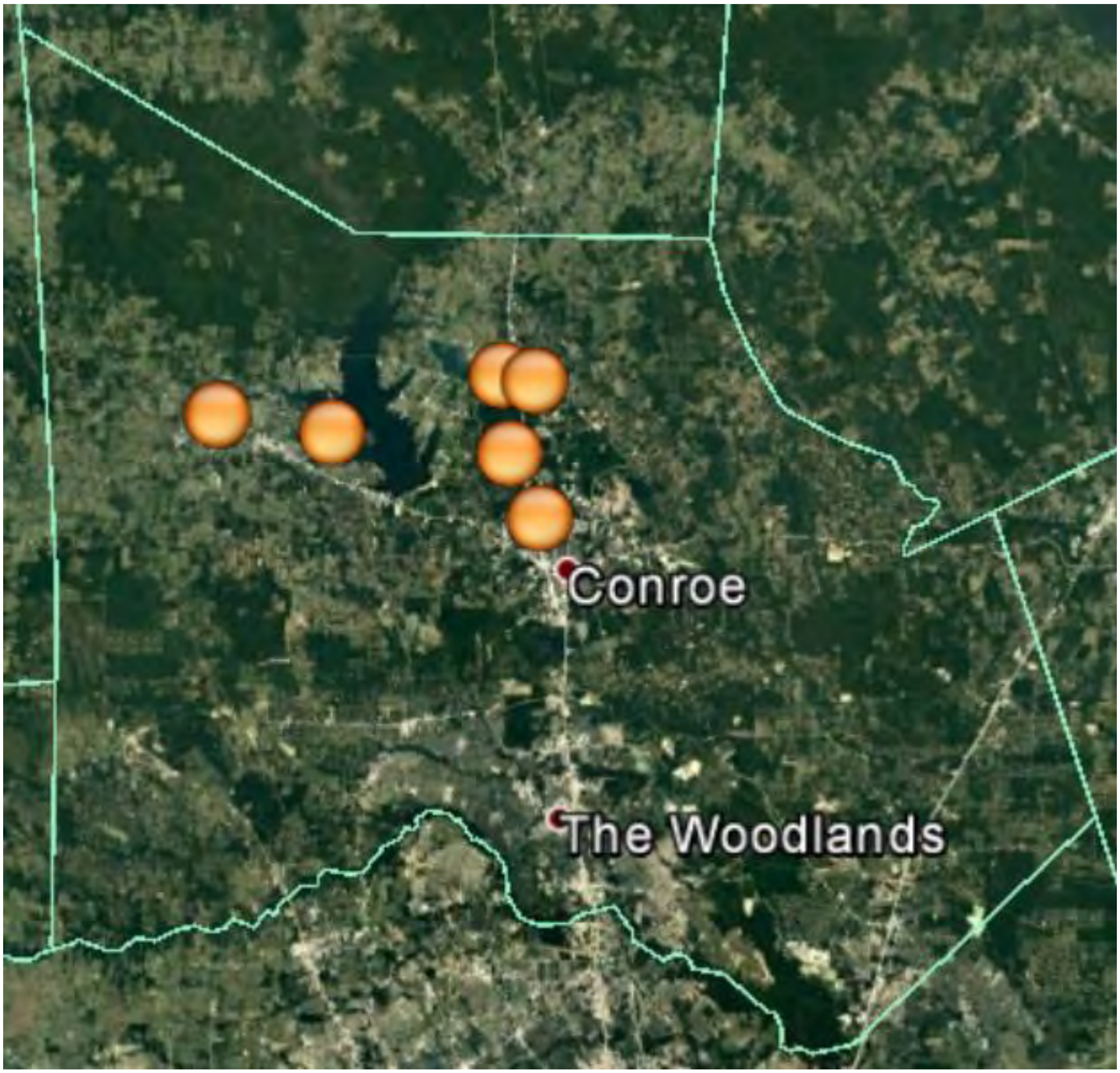

Figure 1 – Locations of wells reported as completed in the Catahoula Formation by respondents to the Lone Star GCD SWRP Survey.

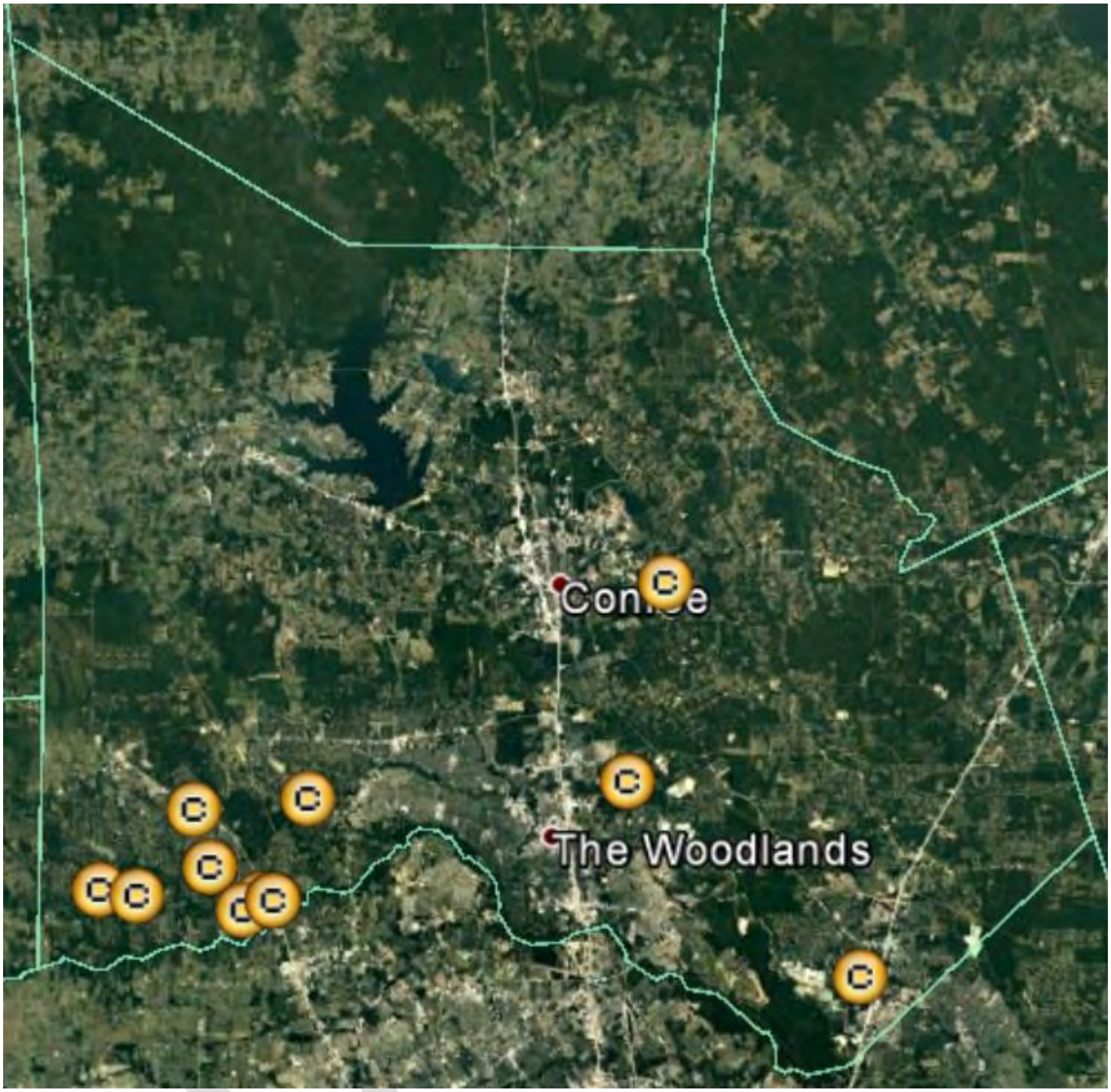

Figure 2 – Locations of wells reported as completed in the Chicot Aquifer by respondents to the Lone Star GCD SWRP Survey.

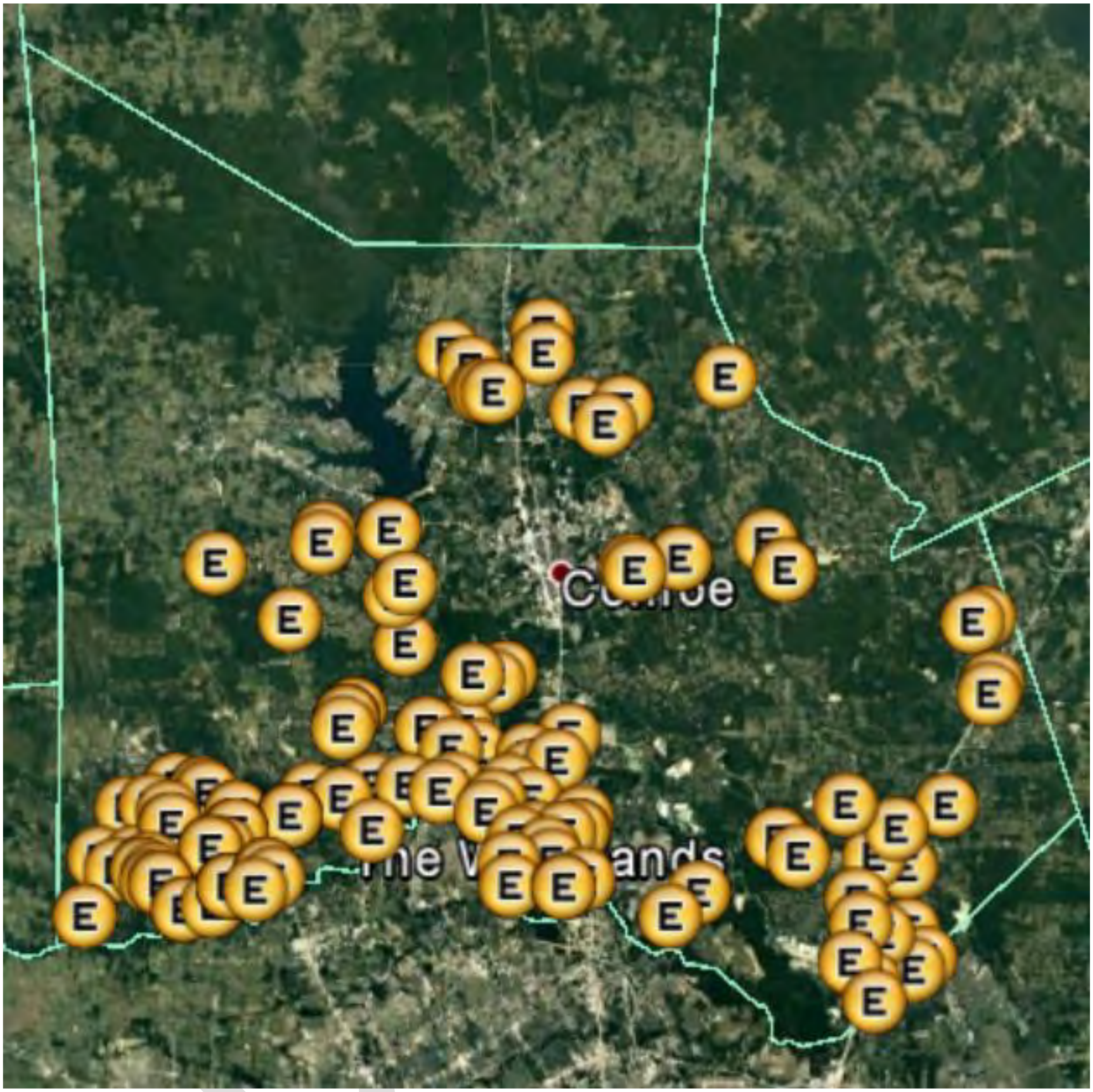

Figure 3 – Locations of wells reported as completed in the Evangeline Aquifer by respondents to the Lone Star GCD SWRP Survey.

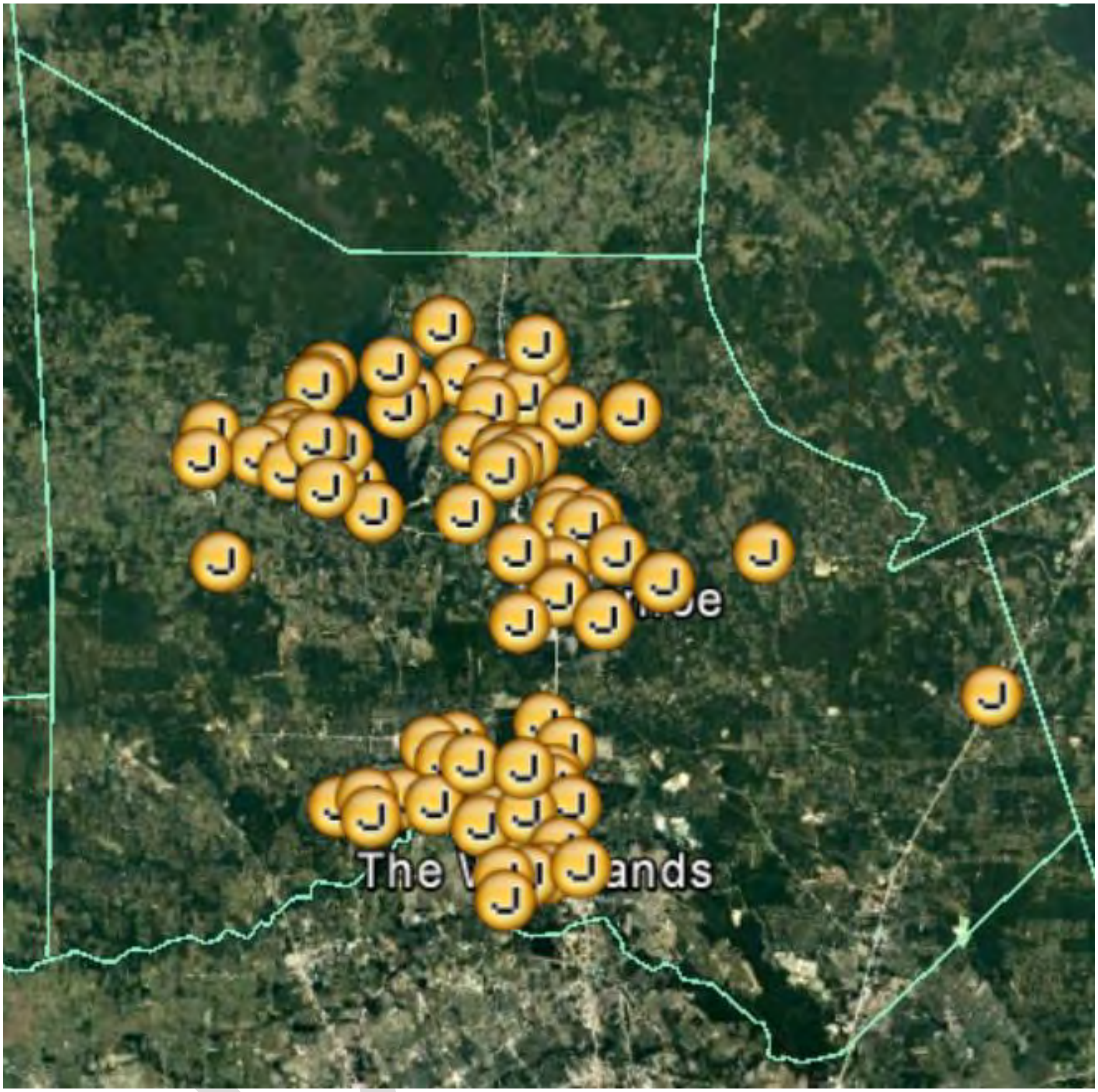

Figure 4 – Locations of wells reported as completed in the Jasper Aquifer by respondents to the Lone Star GCD SWRP Survey.

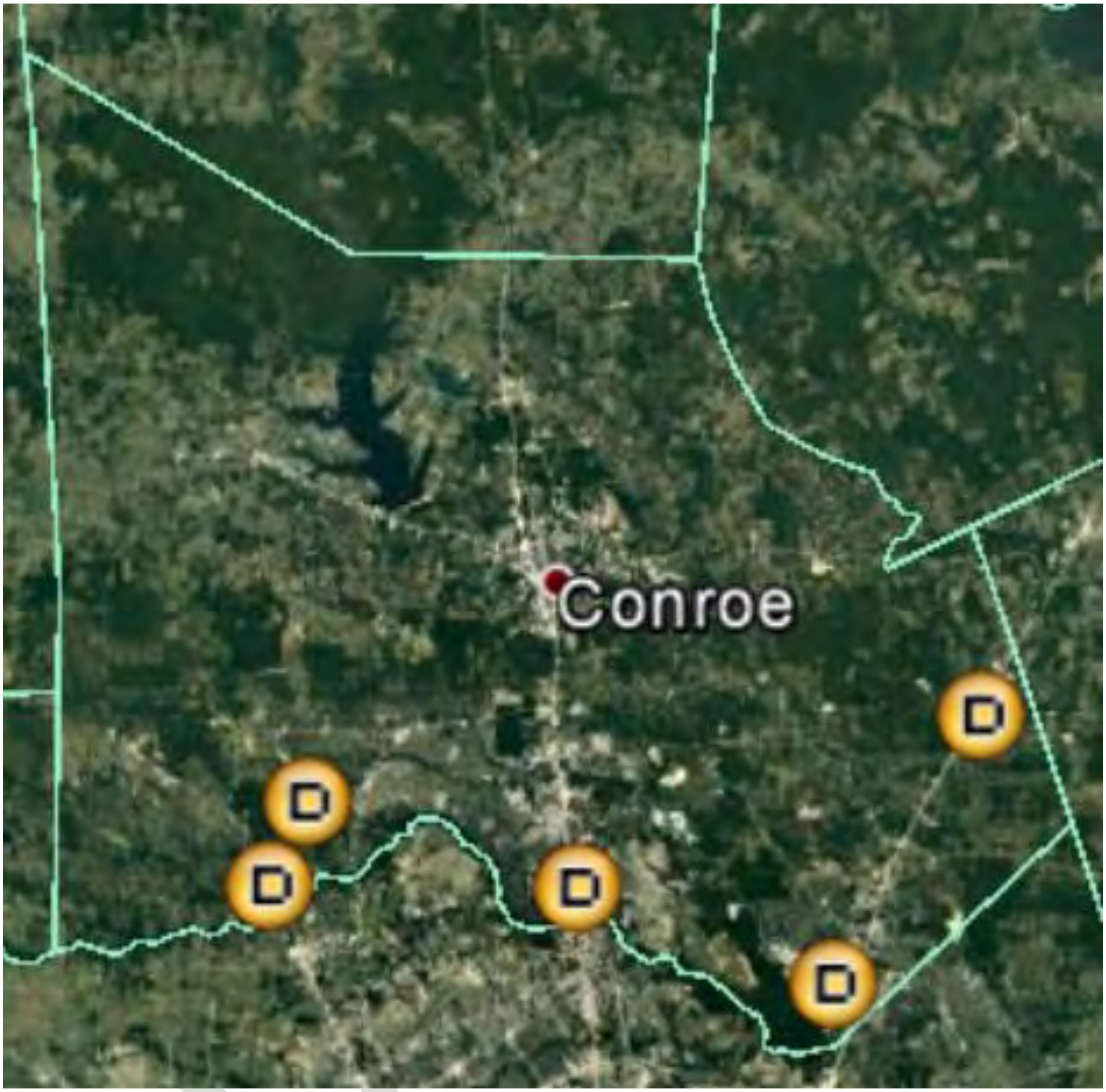

Figure 5 – Location of wells reported as dual completions in both the Chicot and Evangeline aquifers by respondents to the Lone Star GCD SWRP Survey.

Individual Survey Responses

In the design of the Survey, the Lone Star GCD Findings and Review Committee asked that specific information be requested so as to maximize the value of the Study. In particular, as the Lone Star GCD looks to evaluate potential pumping levels for the future, the impacts of various pumping scenarios on existing LVGU well owners was one area of focus. The following presents results from some of the primary Survey questions.

Is well a main supply well? ☐ *Yes* ☐ *No*

Summary statistics for this question, by aquifer, are provided below in Table 1. For all aquifers, 94.1 percent of the LVGU individual permitted wells are reported to serve as the main water supply. For a complete listing of responses to this and other questions discussed below, please refer to the digital files submitted separately.

Table 1 - Summary statistics regarding number of LVGUs responding to question asking if the well is a main water supply.

Aquifer	Number of LVGUs responding to "Is well a main supply well" question and response	Yes	No
Catahoula	6	6	0
Chicot	8	7	1
Evangeline	114	104	10
Jasper	88	86	2
Chicot/Evangeline	4	4	0
Total	220	207	13

Primary use of well: (Check one): ☐ *Public Water Supply,* ☐ *Irrigation* ☐ *Industrial* ☐ *Other*

Summary statistics to this question, by aquifer, are provided below in Table 2. For all aquifers, responses were received for 245 individual permitted LVGU wells. The primary use for individual permitted LVGU wells was public water supply (224 wells, or 91.4 percent). Five wells completed in the Evangeline Aquifer reported "other" uses, such as for emergency supply only, to maintain level of Ridge Lake, to maintain level of Trophy Lake, and well is inactive/capped/to be plugged.

Table 2 - Summary statistics regarding primary use of water for individual permitted LVGU wells.

Aquifer	Responses to "Primary water use" question	Public Water Supply	Industrial	Irrigation	Other
Catahoula	6	6	0	0	0
Chicot	11	9	1	1	0
Evangeline	135	121	2	7	5
Jasper	89	84	4	1	0
Chicot/Evangeline	4	4	0	0	0
Total	245	224	7	9	5

How many connections does well provide water for?

Responses to this question were received for 168 of the 252 individual permittted wells. Detailed information is provided in digital datasets provided separately. Summary statistics, by aquifer, are presented in Table 3 below. The majority, 79.6 percent of individual connections reported (348,711 out of total 437,818 connections) were for wells completed in the Jasper Aquifer. The average number of connections per LVGU individual permitted well is 2,606 connections.

Table 3 – Summary statistics regarding number of connections associated to individual permitted LVGU wells.

Aquifer	Number of LVGUs responding to number of connections per individual well question	Number of connections	Average number of connections per LVGU
Catahoula	5	28,226	5,645
Chicot	10	4,780	478
Evangeline	87	50,147	576
Jasper	62	348,711	5,624
Chicot/Evangeline	4	5,954	1,488
Total	168	437,818	2,606

Age of well?

Responses to this question were received for 207 of the 252 individual permittted wells. Detailed information is provided in digital datasets provided separately.

Summary statistics, by aquifer, are presented in Table 4 below. As one might expect based on general depth to water for the different aquifers, the average and median age of wells completed in the Chicot Aquifer are older and wells completed in the Catahoula Formation are significantly younger than those completed in the Evangeline and Jasper aquifers. Maps, by aquifer, illustrating the spatial distribution and age range of wells are presented below in Figures 6 – 10.

Table 4 – Summary statistics regarding age of individual permitted LVGU wells.

Aquifer	Number of responses	Average well age (years)	Median well age (years)
Catahoula	6	10.2	4
Chicot	13	28.0	29
Evangeline	113	23.7	20.0
Jasper	72	24.8	20.5
Chicot/Evangeline	3	22.2	19.0

Figure 6 – Age of wells completed in the Catahoula Formation. 0 = 0 – 9 years; and 4 = 40 – 49 years.

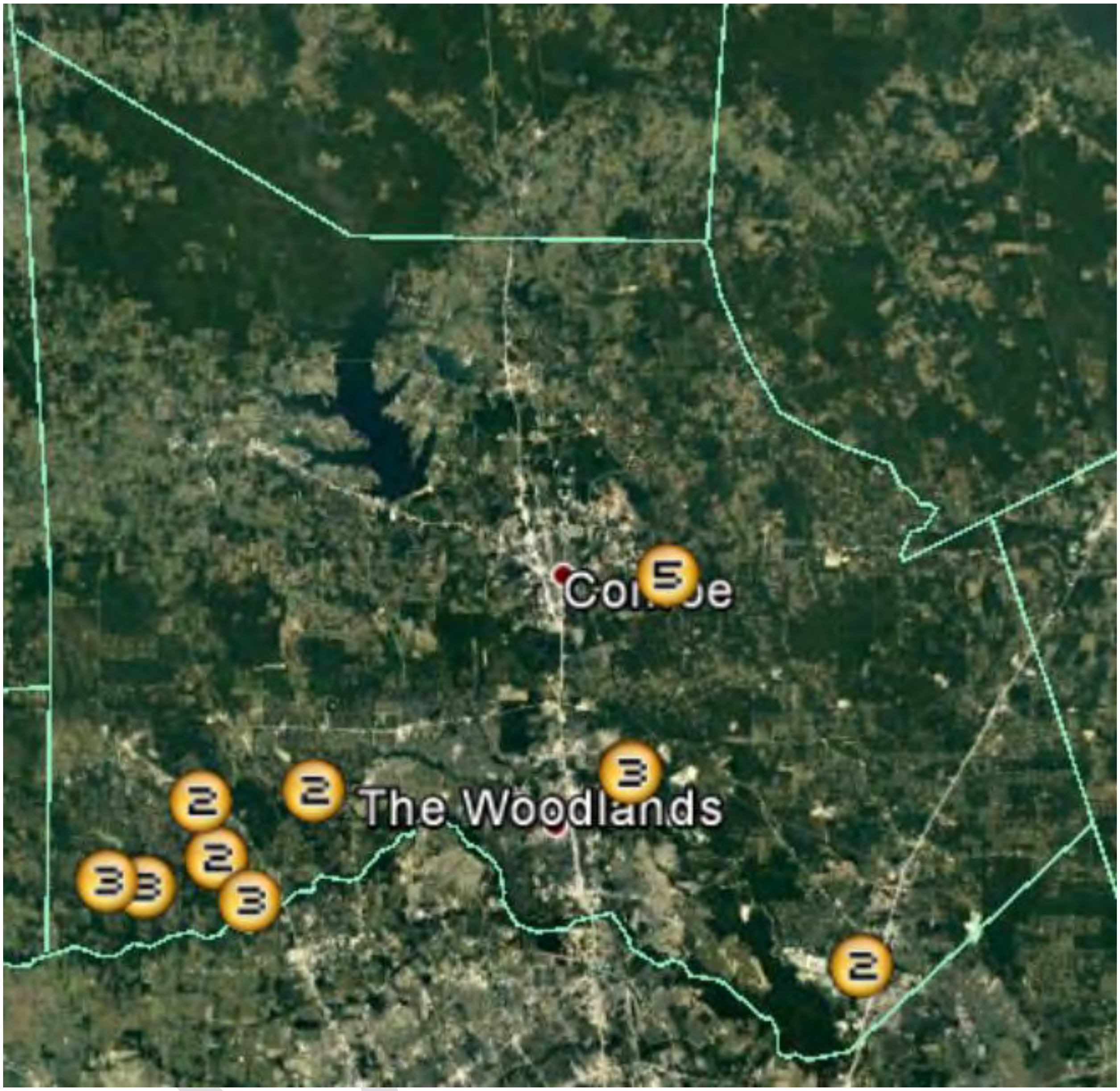

Figure 7 – Age of wells completed in the Chicot Aquifer. 2 = 20 – 29 years; 3 = 30 – 39 years; and 5 = 50+ years.

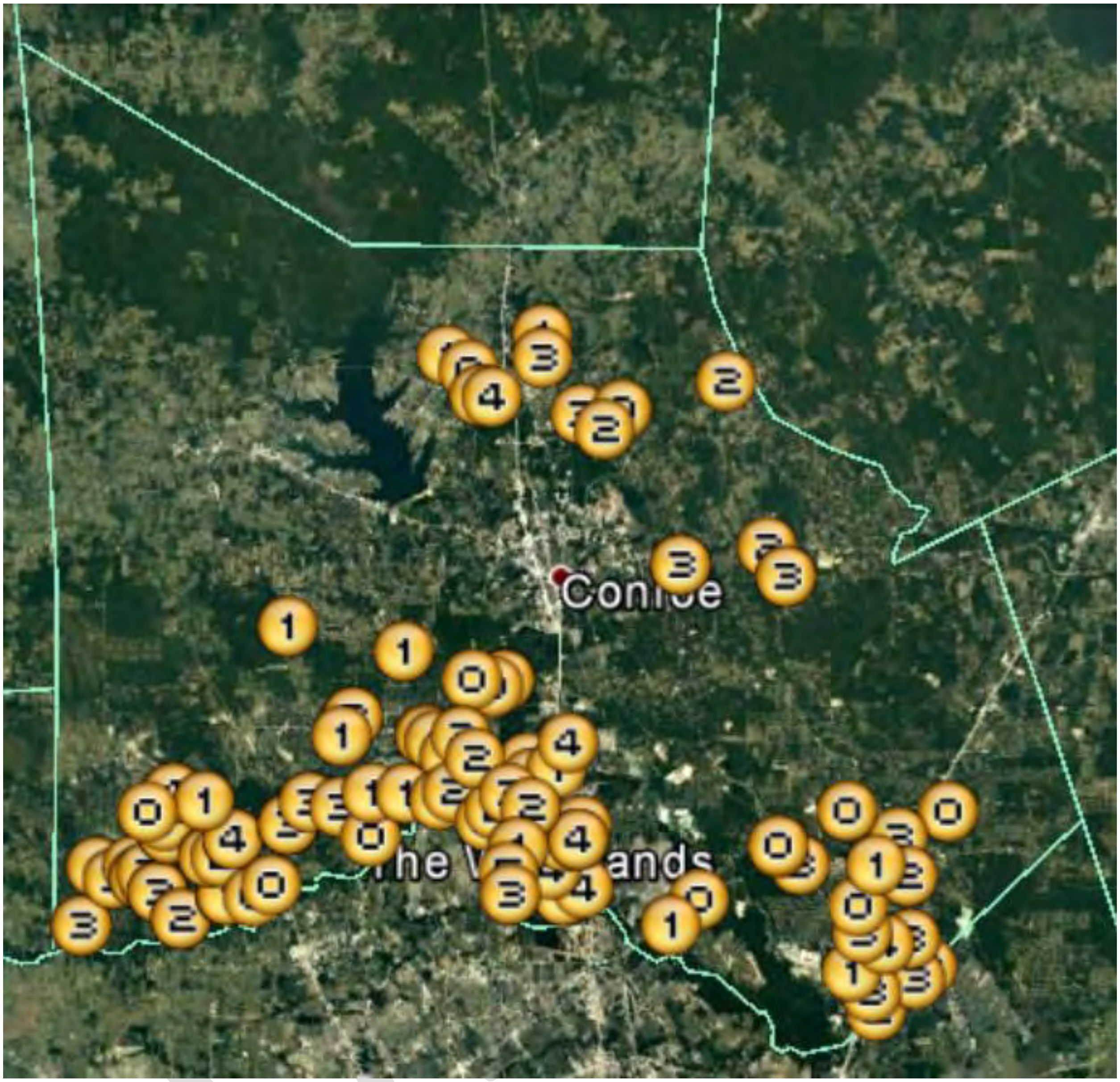

Figure 8 – Age of wells completed in the Evangeline Aquifer. 0 = 0 – 9 years; 1 = 10 – 19 years; 2 = 20 – 29 years; 3 = 30 – 39 years; 4 = 40 – 49 years; and 5 = 50+ years.

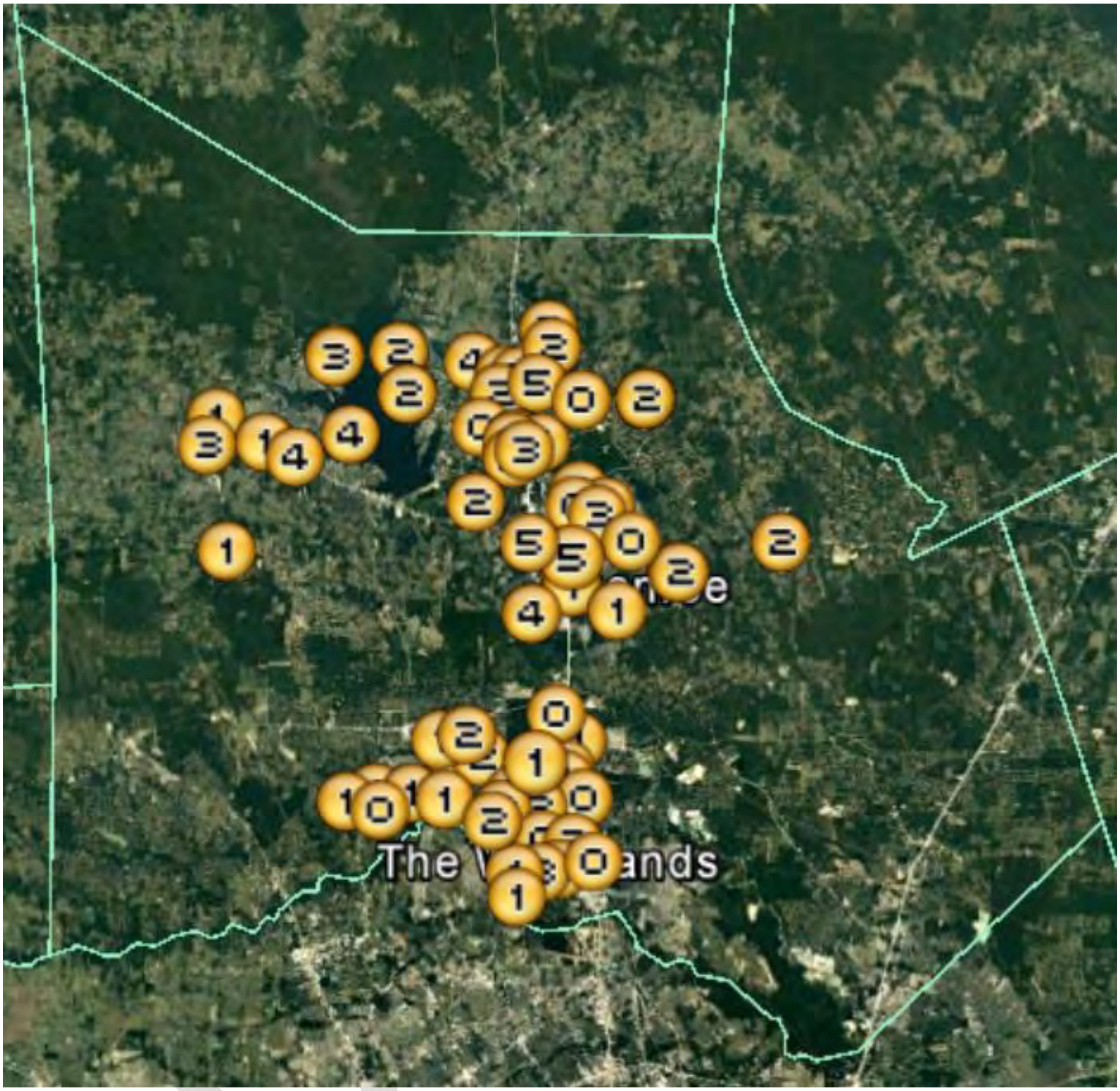

Figure 9 – Age of wells completed in the Jasper Aquifer. 0 = 0 – 9 years; 1 = 10 -19 years; 2 = 20 – 29 years; 3 = 30 – 39 years; 4 = 40 – 49 years; 5 = 50+ years.

Figure 10 – Age of wells completed in both the Chicot and Evangeline aquifers. 0 = 0 – 9 years; 1 = 10 -19 years; 4 = 40 – 49 years.

The following multi-part questions were discussed at length during the June 27, 2017 Findings and Review Committee meeting.,

Is it physically possible to lower the well pump, if necessary? ☐ *Yes* ☐ *No*

If yes, how much deeper in the well can the pump be lowered (feet)? __________

These are SWL, not pumping levels, so will need to add 50-75 feet.

<u>And</u>

How many additional feet of decline in water level in your well can you experience before the operations of your well will be negatively impacted? An additional ____________ feet.

An evaluation by the Findings and Review Committee of a sampling of responses demonstrated that in certain cases, information provided was deemed to be inconsistent with the goal of this line of questions. The goal of these questions was to, in part, gain a better understanding of the ability of existing well owners to continue to utilize wells at current well pump depths and ability to lower pumps in existing wells, under various water level decline scenarios. Due to the inconsistency in how these questions were interpreted by the respondents, the following alternative approach was developed.

As part of the Survey, LVGU well owners were asked to provide the current water level, current depth to the well pump, and depth to the top of the liner/screen. Based on this information, two relationships may be quantified. First, the vertical difference between the current water level and the pump level. This vertical difference gives an indication of how much additional water level can occur before a pump must be lowered. It is recognized that the current water level is presented as a static water level, and therefore the vertical difference presented would need to be reduced by some amount, depending on the hydraulics of the well and the aquifer in which the well is completed. The Survey did request information on the well's pumping level, but the number of responses and basis for this information was significantly less than the current water level responses. Summary statistics on the relationship between current water level and depth of pump are included in Table 5. Maps illustrating the spatial relationships of these vertical differences by aquifer are included in Figures 11 – 14.

The second relationship developed is the vertical difference between the current pump level and the top of the liner/screen in the well. This relationship is also important because it provides a quantitative analysis of the ability of LVGU well owners to lower their pumps if water levels drop below current pump levels. In a very small number of responses, it appears that the pump is installed inside the liner/screen. These wells appear to be, for the most part, shallow wells located in outcrop areas. These wells are not included in the summary statistics or maps that follow.

Table 5 – Summary statistics regarding the vertical difference between reported static water level and depth of well pump.

Aquifer	Vertical difference between reported static water level and depth of well pump		
	Number of Wells	Average (ft)	Median (ft)
Catahoula	6	497	560
Chicot	6	119	105
Evangeline	90	196	185
Jasper	77	263	241

Figure 11 – Vertical difference between reported static water level and well pump, in feet, for wells completed in the Catahoula Formation.

Legend (ft)

Color	Range (feet)
Light Green	201 – 400
Purple	400+

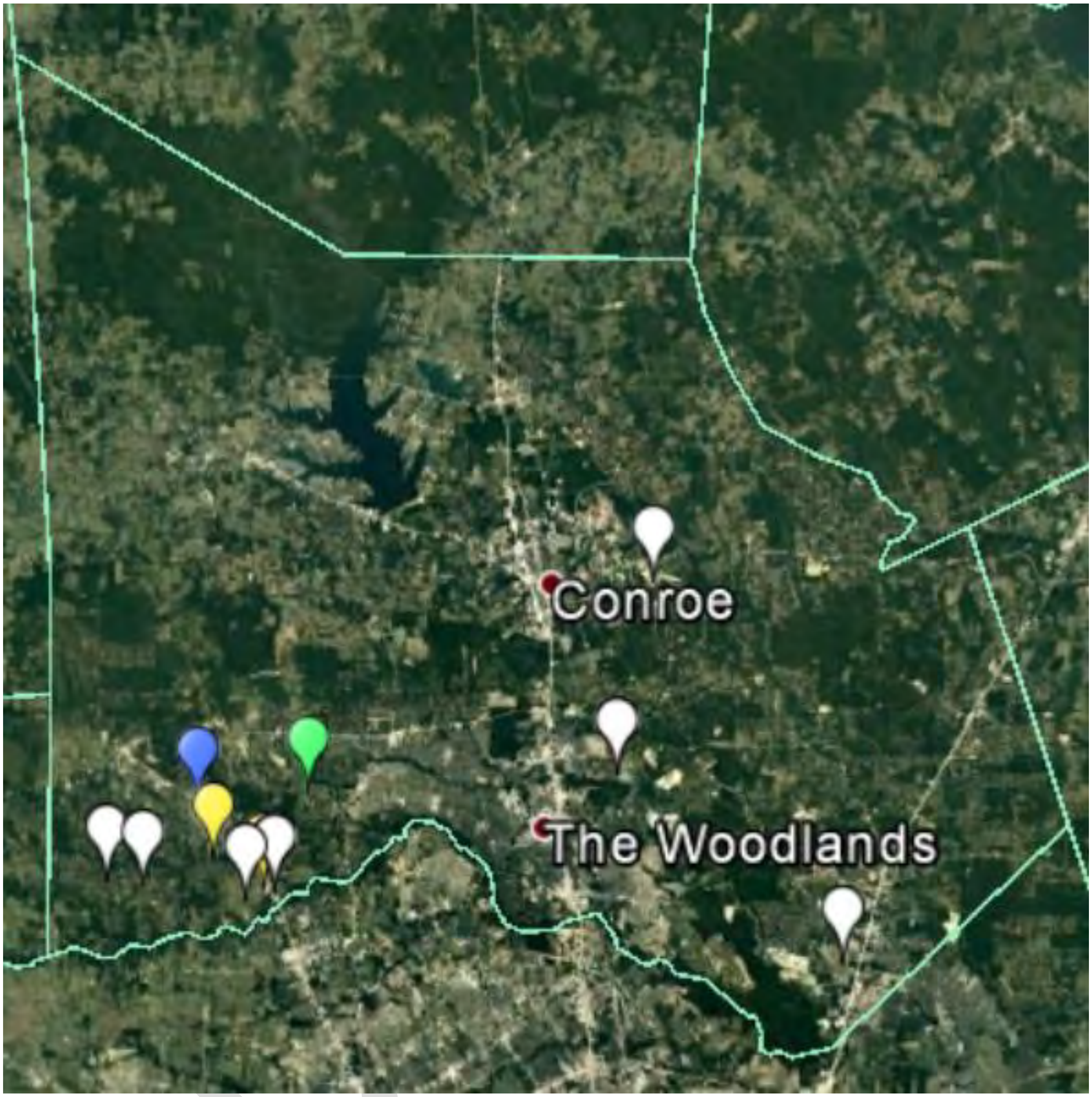

Figure 12 – Vertical difference between reported static water level and well pump, in feet, for wells completed in the Chicot Aquifer.

Legend (ft)

Color	Range (feet)	Color	Range (feet)
White	No data	Yellow	101 – 200
Pink	0 – 50	Light Green	201 – 400
Blue	51 – 100	Purple	400+

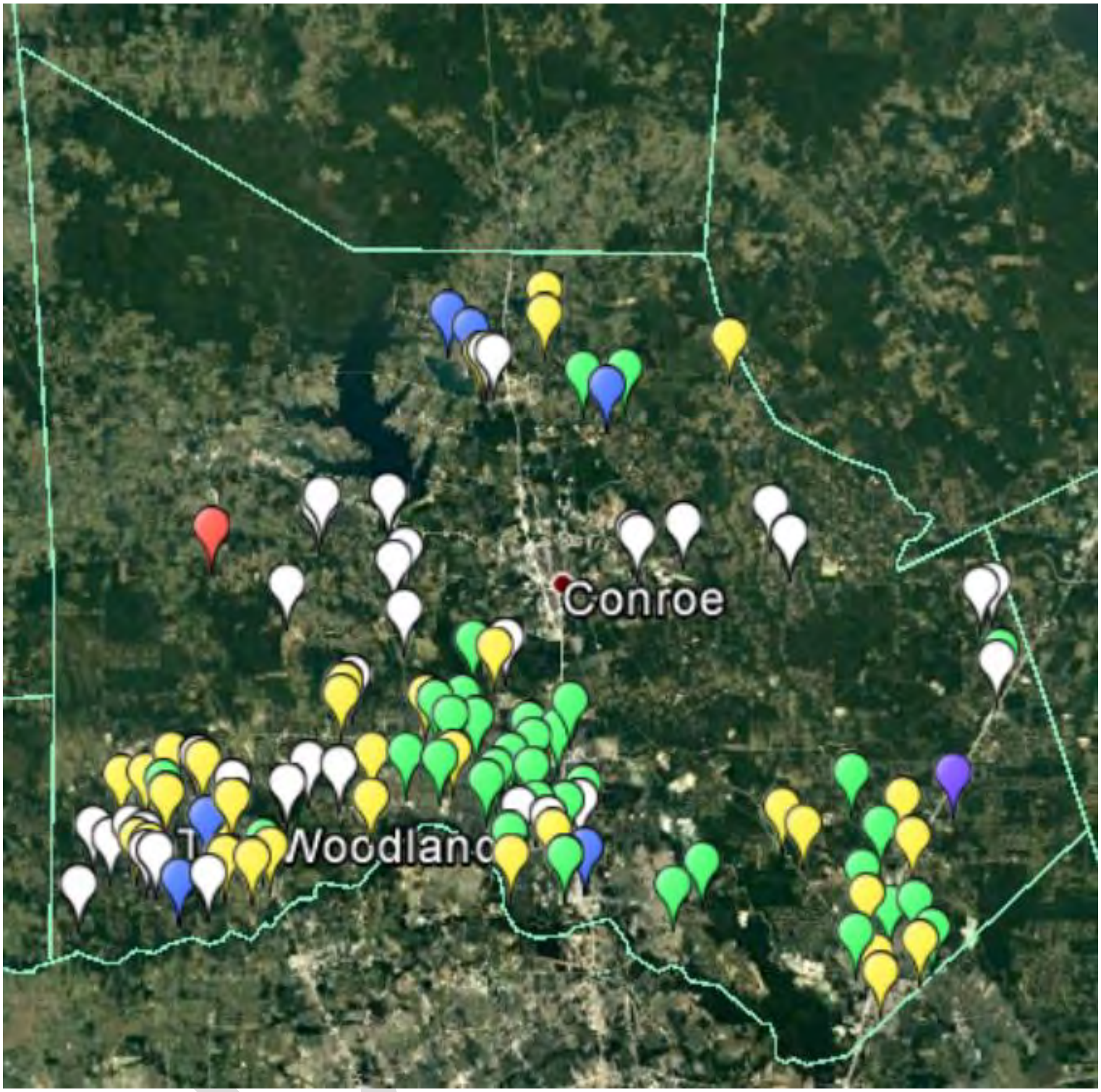

Figure 13 – Vertical difference between reported static water level and well pump, in feet, for wells completed in the Evangeline Aquifer.

Legend (ft)

Color	Range (feet)	Color	Range (feet)
White	No data	Yellow	101 – 200
Pink	0 – 50	Light Green	201 – 400
Blue	51 – 100	Purple	400+

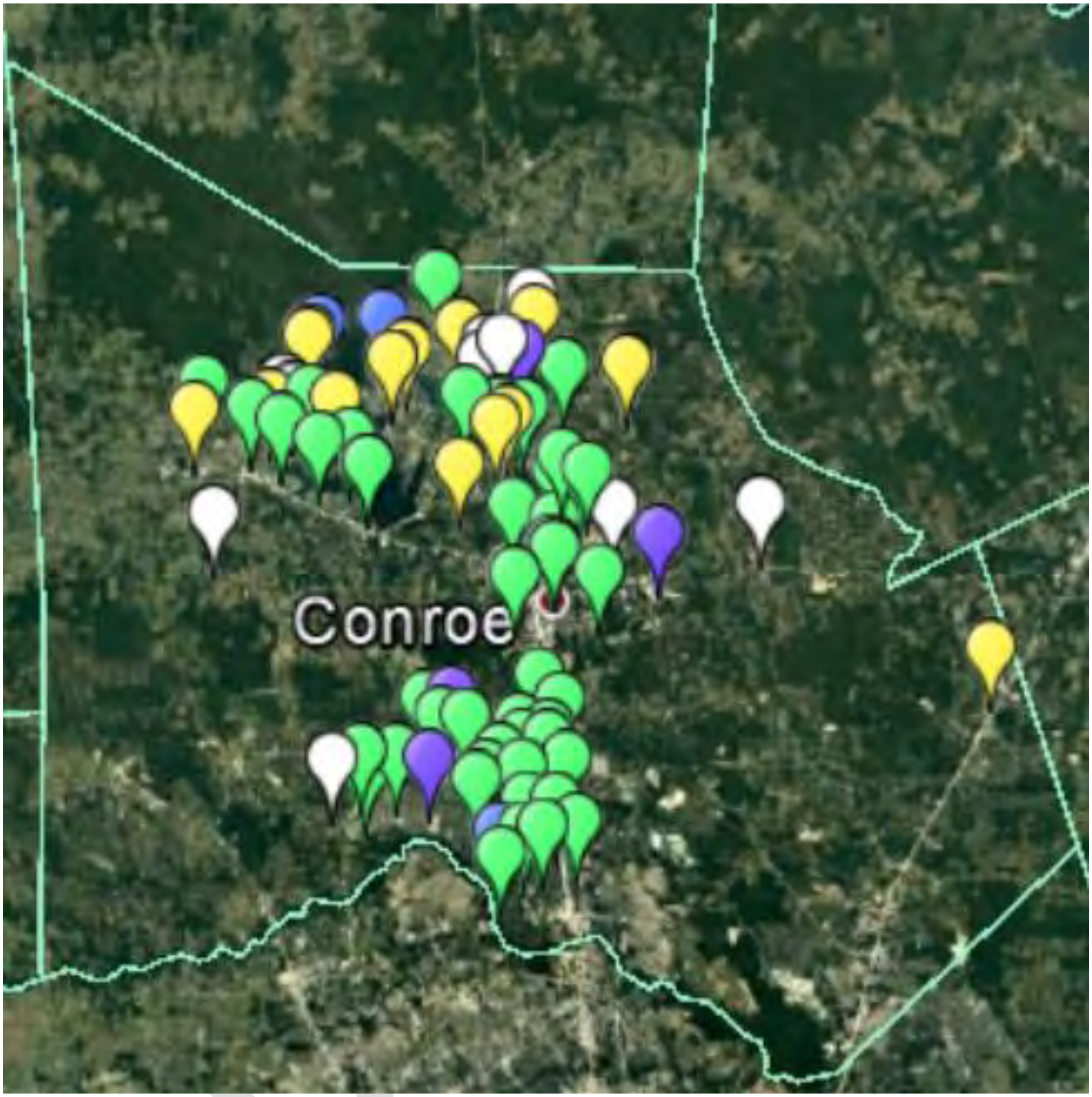

Figure 14 – Vertical difference between reported static water level and well pump, in feet, for wells completed in the Jasper Aquifer.

Legend (ft)

Color	Range (feet)	Color	Range (feet)
White	No data	Yellow	101 – 200
Pink	0 – 50	Light Green	201 – 400
Blue	51 – 100	Purple	400+

Summary statistics on the relationship between the depths of pumps and depths to the top of liner/screen are included in Table 6. Maps illustrating the spatial relationships of these vertical differences by aquifer are included in Figures 15 – 18.

Information developed with these two relationships was also provided to LBG Guyton so that the spatial and vertical data produced may be overlaid onto maps of predicted water level declines resulting from predictive simulations in Run A, Run B, and Run C. This information will be included as part of Task 2 in the Lone Star GCD SWRP Study.

Table 6 – Summary statistics regarding the vertical difference between reported depth of well pump and depth of liner/screen.

Aquifer	Vertical difference between reported depth of well pump and depth of liner/screen		
	Number of Wells	Average (ft)	Median (ft)
Catahoula	6	1274	1486
Chicot	2	159	160
Evangeline	77	119	79
Jasper	73	350	320

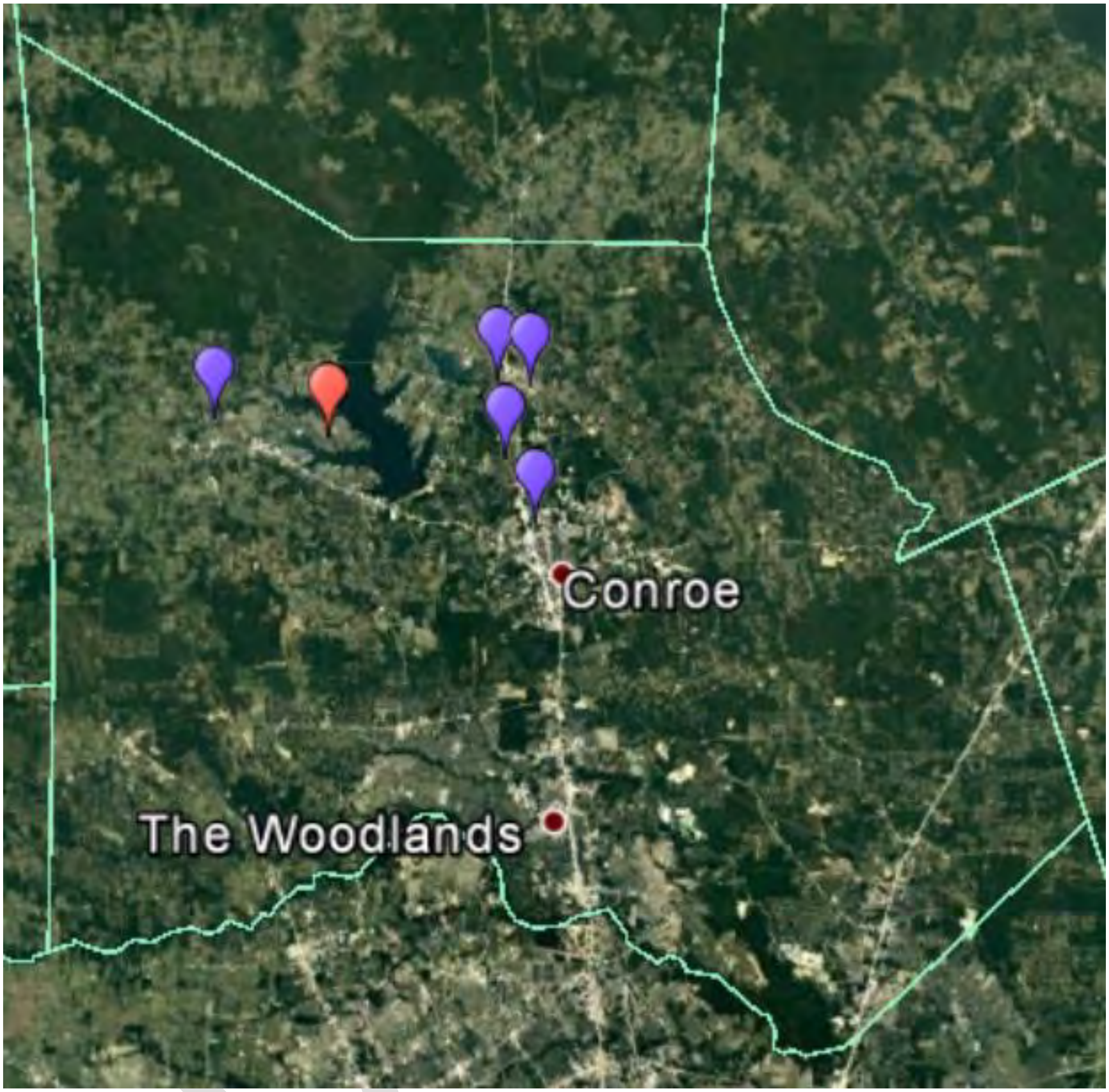

Figure 15 – Vertical difference between reported well depth and top of liner/screen, in feet, for wells completed in the Catahoula Formation.

Legend (ft)

Color	Range (feet)
Pink	0 – 50
Purple	1,000+

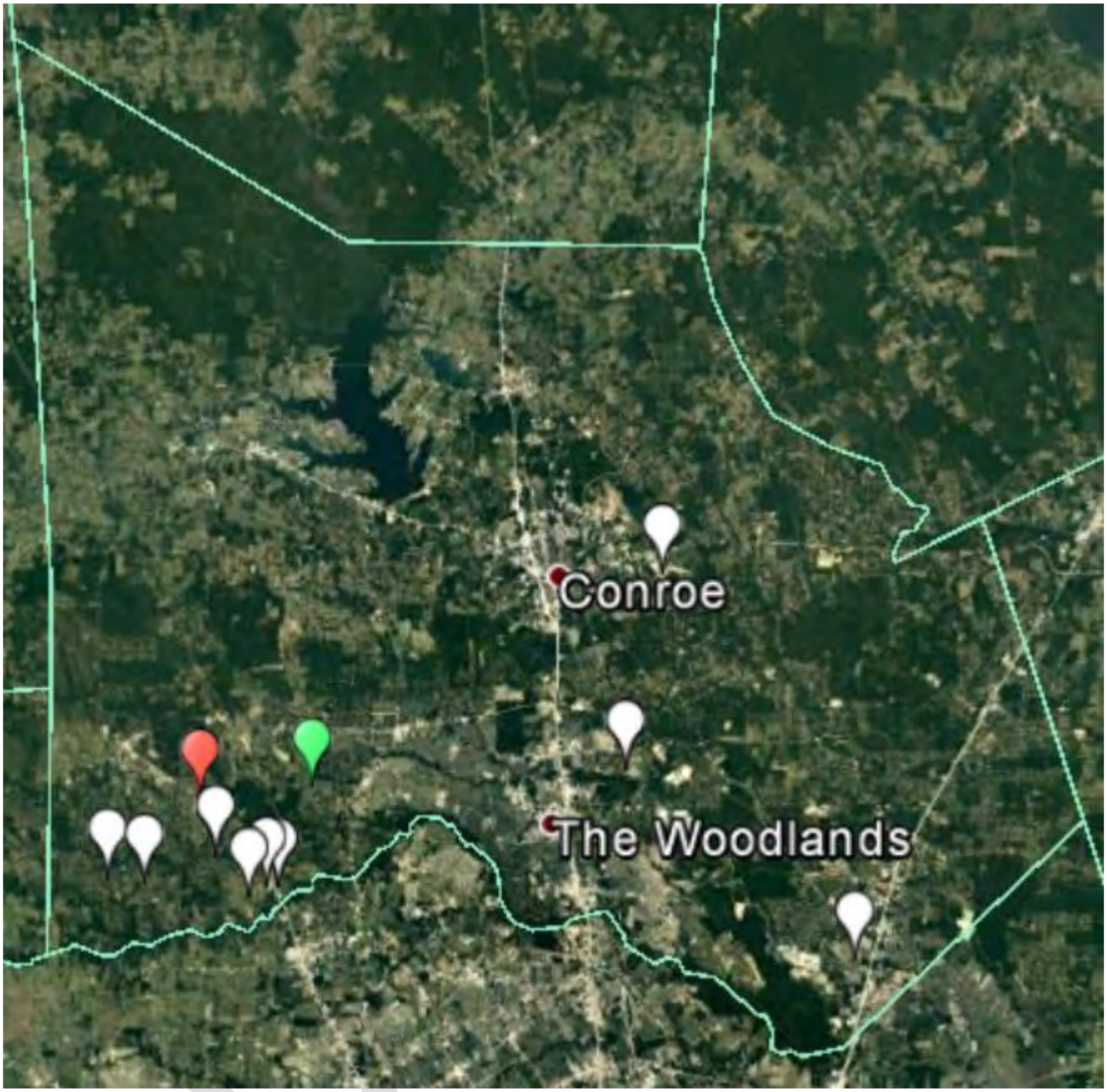

Figure 16 – Vertical difference between reported well depth and top of liner/screen, in feet, for wells completed in the Chicot Aquifer.

Legend (ft)

Color	Range (feet)	Color	Range (feet)
White	No data	Yellow	101 – 200
Pink	0 – 50	Light Green	201 – 400
Blue	51 – 100	Purple	400+

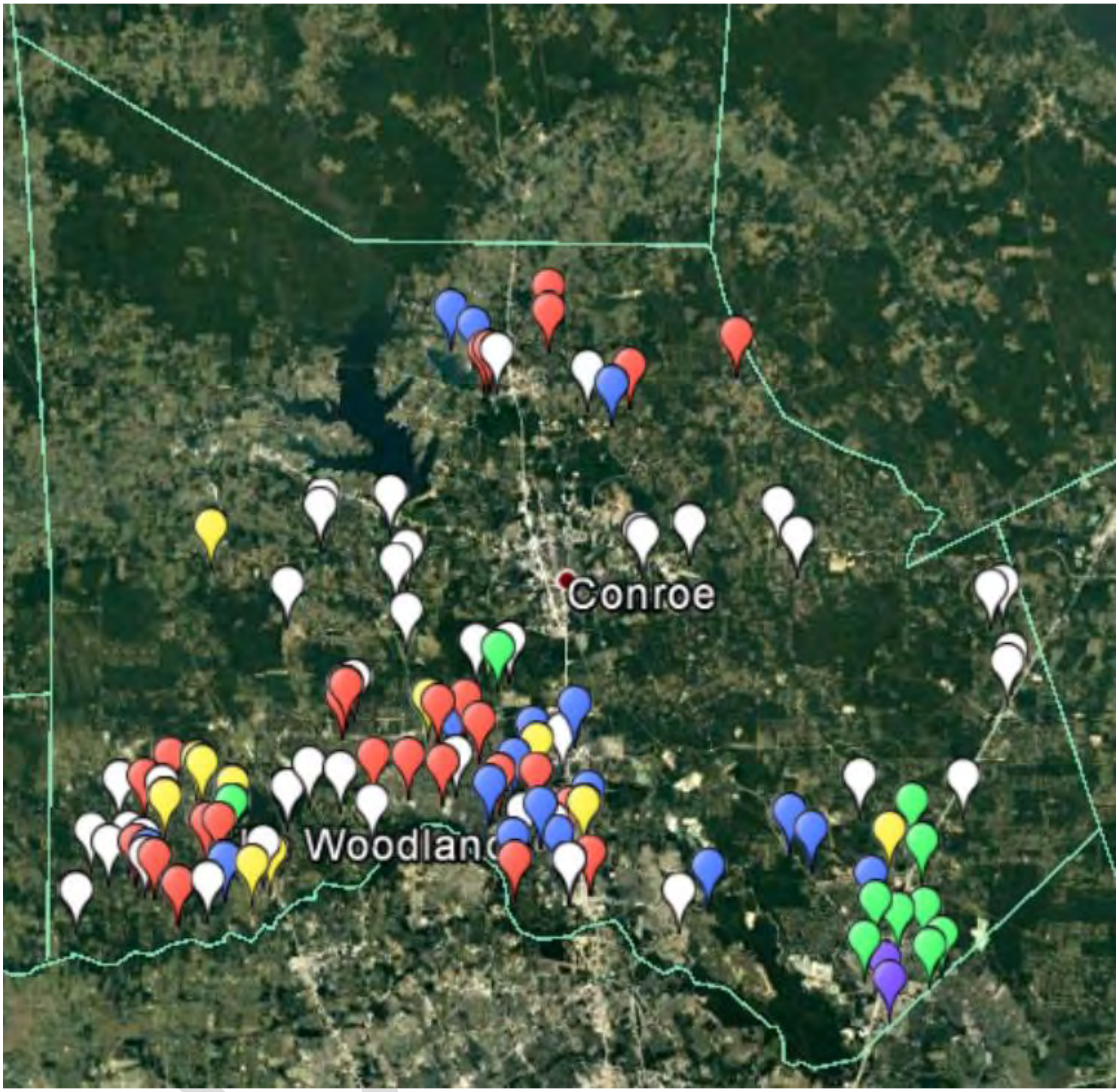

Figure 17 – Vertical difference between reported well depth and top of liner/screen, in feet, for wells completed in the Evangeline Aquifer.

Legend (ft)

Color	Range (feet)	Color	Range (feet)
White	No data	Yellow	101 – 200
Pink	0 – 50	Light Green	201 – 400
Blue	51 – 100	Purple	400+

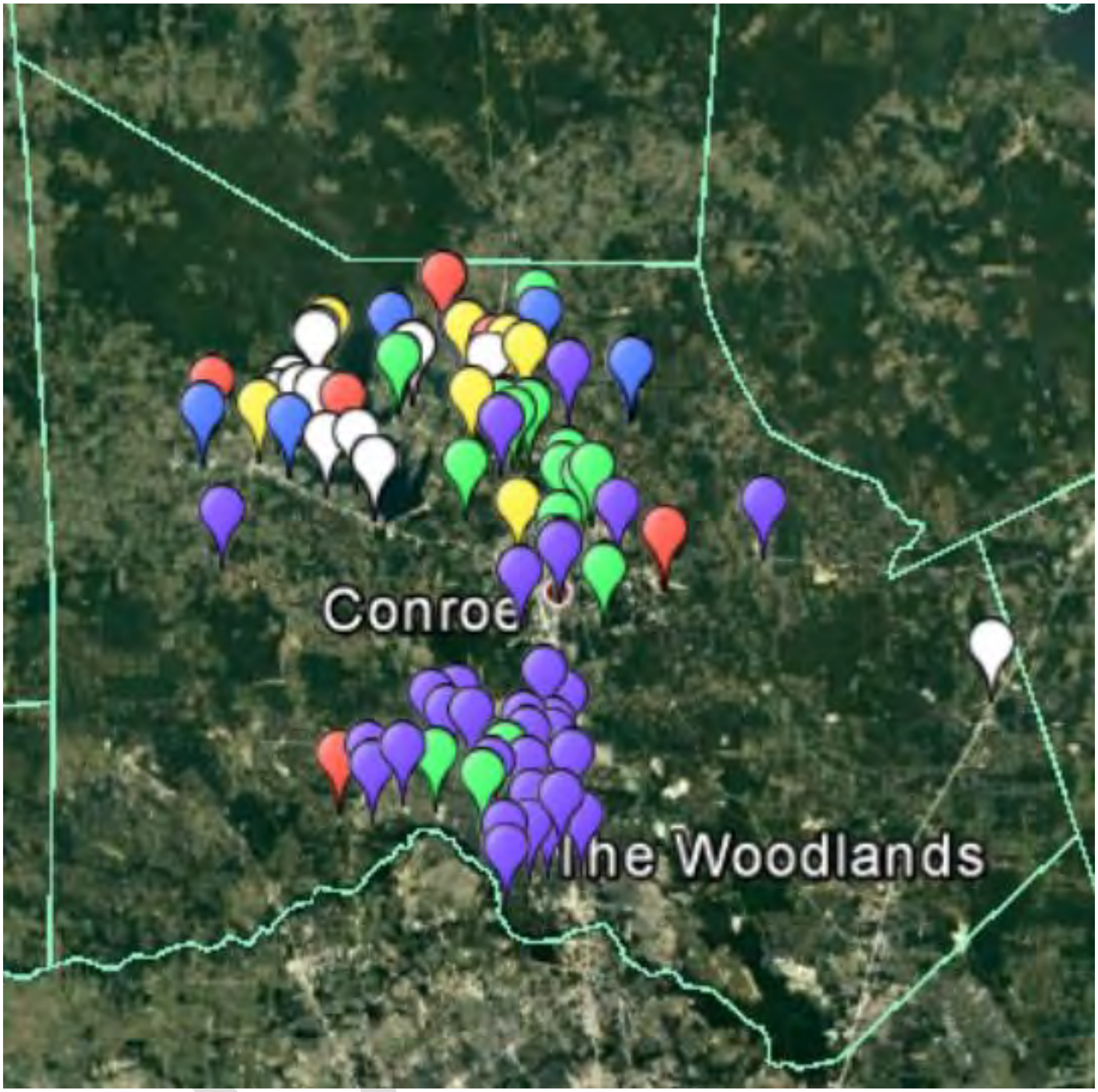

Figure 18 – Vertical difference between reported well depth and top of liner/screen, in feet, for wells completed in the Jasper Aquifer.

Have you experienced water level declines and to what extent for this well, and if so, over what years? Have you had to lower the well pump due to declining water levels? Are you concerned about experiencing future water declines with respect to this well, and if so please explain?

While this series of questions does not easily afford statistical analysis, some general observations are possible. For detailed responses, please refer to digital files provided separately.

LVGUs in the Chicot Aquifer stated that either their wells had not experienced water level declines, experienced very little to minimal water level declines, or the level of declines was unknown. No LVGU reported that wells had been lowered due to declining water levels. For LVGU individually permitted wells completed in the Chicot Aquifer, concerns expressed related to declining water levels included the following:

- No
- Yes, there is a general concern but unknown specifically to this well.
- Not at this time
- Variable declines and recovery +/- 20 ft in last 20 years. No, pump submergence has remained steady (note, this response is for a well dually completed in the Chicot and Evangeline aquifers).

LVGUs with permitted wells completed in the Evangeline Aquifer responded more broadly to the question of has the well experienced water level declines, ranging from well has rebounded, well has declined, no, yes, and unknown. For responses stating that water levels had declined, the range of decline was from approximately 3 feet to 213 feet over specified periods of time. Survey respondents reported that it had been necessary to lower 12 wells on one or more occasions up to 670 feet. LVGU well owners expressed the following concerns related to declining water levels in wells completed in the Evangeline Aquifer:

- Yes. If the water level declines below the 2011 drought, we will probably need to take WW#2 out due to submergence concerns and the City will only have 1 water well to meet demand along with surface water capacity from SJRA.
- Yes – 1991 – 1998 it dropped from 264 feet to 380 feet.
- Yes, pump submergence at 42 feet. Reduced pumping capacity from 1,000 GPM to 550 GPM to keep submergence on pump.

- Yes, variation in static levels are significant during season changes, up to 40' some years.
- Yes, 50 feet between 2005 and 2014.
- If the water level declines below the 2011 drought, we will only have 50 feet of submergence to play with until our pump is at its critical submergence level. With seasonal aquifer changes, this concerns us.
- Yes, there is a general concern but unknown specifically to this well.
- Not enough information to know.
- There are big seasonal variations in the water level. If greater sustained pumping continues all year long there could begin to be declines.
- Many times due to declining water levels.
- Yes, pump is set as low as it can go without reducing pump size & going into liner pipe & screens.
- No. It's an emergency well that may be taken out of service.
- During drought 2010-2011 well showed signs of depletion. Long drought condition could be a fact.
- Not yet. Insufficient history with this well. 1st post startup test scheduled for early April.
- If an alternate water source such as surface water is not used or a groundwater demand reduction does not occur, this well may not be able to be used once the static water level declines into the pump liner.
- Yes, because public water supplies will need the water for future demands.
- Yes; the demand for water is growing due to population growth.
- Yes, public water supply will be needed in future.
- Yes
- No/none/not at this time.

LVGUs with permitted wells completed in the Jasper Aquifer, similar to responses for the Evangeline Aquifer, provided broadly diverse feedback with respect to this series of questions. Forty-three permitted wells reported water level declines ranging to as much as 283 feet. Other responses to this question regarding water level declines in wells included “has maintained both increases and decreases”, “no”, “no but rebounded in last 3 years”, “no since 2011”, “non-significant”, “not in last 3 years”, “unknown”, and “very little”. Survey responses indicate that 32 LVGU permitted well pumps had to be lowered, 50 LVGU permitted wells were not lowered, and 2 LVGU permitted well responses were “unknown”. For LVGU individually permitted wells completed in the Jasper Aquifer, concerns expressed related to declining water levels included the following:

- No, Huntsman has not experienced any water decline issues.
- Yes, because pump cannot be lowered.
- Yes, possibility but due to design & water strata it is our most trusted long term source. Production cost!
- Yes, this is our main well.
- If an alternate water source such as surface water is not used or a groundwater demand reduction does not occur, this well may not be able to be used once the static water level declines into the pump liner.
- Clearly the drought in 2011 declined the level in this pump, but it has since recovered to pre-drought levels.
- Yes; there is a general concern but unknown with this specific well.
- If GRP works, we should be fine.
- Yes, continued decline will increase horsepower demand, pump stages, total dynamic head & cost of operation.
- No, the well is 66 years old and when it is not producing anymore, the well will be plugged.
- Yes, the District cannot lower the pump further.
- Yes
- No/none/not presently.

Would you be willing and able to lower the well pump in the future, if necessary?
☐ *Yes* ☐ *No*

If no, please explain why:

Summary statistics for responses to this question regarding willingness and ability to lower the well pump in the future if necessary are provided in Table 7 below. Overall, 57 percent stated “yes” they were willing to lower pumps in individual well whereas 33 responded “no”. LVGUs with Chicot and Evangeline wells were somewhat evenly split on this question (Yes versus No), whereas a clear majority of LVGUs with wells completed in the Jasper Aquifer replied “yes” to their willingness to lower wells (81 percent). Reasons given for not being willing to lower the well pump included:

- Lowering the pump increases the chance of producing sand.
- Would have to look at various options on case by case basis.
- Pump cannot be lowered any further since we do not know what diameter the submersible motor is and if it will fit inside the 6" liner.
- Pump cannot be lowered any further since it is already in the first screen section.
- This pump cannot be lowered.
- Due to age and integrity of Deep Well No. 1 a replacement well would be more suitable.
- The pump does not fit inside the liner without reducing the capacity of the pump which the District cannot afford.
- Cost & probably can't.
- Age of well.
- Depends on various factors.
- The pump cannot be lowered any further due to the interior liner.
- Well used to occasionally add fresh water to Ridge Lake. Cost of lowering not worth benefit.

- Well used to occasionally add fresh water to Trophy Lake. Cost of lowering not worth benefit.
- Pump is set as low as it can go without reducing pump size & going into liner pipe & screens.
- Pump cannot be lowered due to size of 10' blank liner.
- Pump cannot be lowered; just above well screens.
- Near top of screen.
- Pump setting at level where lowering would not be achievable.
- Casing narrows below current setting.
- It is a shallower well.
- Well will be plugged this year.
- Cannot lower due to 10.75" column reduction starts at 610' and current bowl set at 600'.
- Any lower would be below screens.
- No more room to lower.

Table 7 – Summary statistics regarding willingness of LVGU to lower pump in individual permitted well.

Aquifer	Willing to lower pump in the future?			
	Yes	No	Unknown - possibly - NA	No response
Chicot	4	9	0	7
Evangeline	57	59	3	9
Jasper	71	11	2	3
Total	132	79	5	19
% of Total	56%	34%	2%	8%

In the event you had to lower the well pump as a result of continued water level declines, in your opinion, at what depth would lowering the pump result in the well no longer serving as an economically viable means of producing water for you? ____________ feet.

The wording of this question resulted in responses to what would appear to be two different questions. An examination of the responses indicates that either the response provided was in reference to “how much lower can you lower your pump from its current depth result in the well no longer serving...” whereas others were responding to “at what depth below land surface would lowering your well no longer serve...?” Due to the inherent overlap in the answers to these two questions, and the inability to resolve this conflict, no responses are provided herein. For well specific information, please refer to digital datasets provided separately.

In the event you chose to or were no longer able to produce groundwater from this well due to unfavorable aquifer conditions or deeper static water levels, how would you be able to meet the water needs that production from this well provided? _______________

Responses to this question were quite diverse and, in some cases, detailed. The following is a compilation of those responses.

- Drill a new well at a different location.
- Transport production water in from another source or well. Water recycling efforts.
- Interconnects if able, look to GRP Sponsor/surface water increase, drill a new well, or transfer water via water truck.
- Would have to drill deeper or establish interconnects.
- Drill new, deeper well.

- Drill a new well or increase surface water capacity agreement with SJRA.
- Possibly use wastewater.
- Our understanding well is required by our lake permit for maintaining the level.
- The system has interconnect B that it could use to supply water.
- There will be a 2nd water plant & well that can be used.
- The District has interconnects with other water systems that can provide water.
- The system would have to use a temporary submersible pump or drill a new well.
- SJRA surface water.
- Drill a new well or build a surface water transmission main across the San Jacinto River.
- We have 3 different plants.
- 3 options: 1) deeper well, 2) purchase from surface water producer, 3) effluent reuse.
- The District could drill a new well & go on interconnect with City of Houston.
- Drill a new well deeper or make this one bigger.
- I would not be able to meet my water needs.
- No other economical option for water at this time.
- The MUD would need another source of water.
- Alternate water source such as surface water and increased pumpage from alternate wells in the overall system.
- Replacement Well.

Are there any other factors or conditions that you have experienced that have impacted your ability to produce from this well that you would like for the District to consider? ________________

As with other "open-ended" questions, responses to this question were variable. However, the clear majority of respondents stated that they had no "other factors or conditions" other than those discussed in previous questions. For the Chicot Aquifer, LVGU responses included:

- No, Huntsman has not experienced any issues with well production.
- Typically see failures due to age of well, well screen problems & other non-water level related issues.
- "No" or "Not at this time"
- Minimal data at this time.

For the Evangeline Aquifer, LVGU responses included:

- Typically see failures due to age of well, well screen problems & other non-water level related issues.
- "No" or "Not at this time" or "Not yet"
- Hydrogen sulfide and iron increasing in production & tax base loss due to subsidence & flooding
- Light brass trace-extra vibration. Currently the City is using this well as backup

For the Evangeline Aquifer, LVGU responses included:

- Natural gas production, hydrogen sulfide, iron, & flooding over well head by Spring Creek once
- LSGCD's mandated reductions have been the only known limiting factor.
- Water quality.
- Water quality declines with higher production. Subsidence would cause further property loss & reduce tax base
- No; well is rarely used to supply system
- I think that all counties that pull from the same aquifer should all be accountable and required to follow the same rules and regulations for that aquifer.

- Age of well.
- No, Huntsman has not experienced any issues with well production.
- “No opinion”, “No”, “Not at this time”, or “Not yet”

In balancing property owners’ rights to produce the groundwater beneath their property with the desire to maintain favorable aquifer conditions and water levels to ensure an economically viable resource, based on your experience in operating this well, would you prefer that the District authorize increased production in the area that this well is located, including additional production by LVGUs? ___________Please explain why or why not: ________________________

LVGU responses to this question were more varied and covering the full spectrum of possible responses. While not statistically analyzed due to the open-ended nature of this question, generally speaking it appears that responses to this question are relatively evenly divided between “yes” and “no” responses. Chicot Aquifer LVGU responses to this question included:

- Huntsman would consider its response to increased production on a case by case basis.
- Yes, dependent on individual well specifics
- Yes, if needed
- Yes; pumping levels have held very well.
- Yes, well has room to lower static levels (note – this response is for a dually completed in the Chicot and Evangeline aquifers).

Evangeline Aquifer LVGU responses to this question included:

- Yes, dependent on individual well specifics.
- No, this well also produces sand when pumped hard.
- The District can authorize more production but worries about future declines should be noted; however in the future more production could affect the well's productivity.

- No; well will be rendered useless due to water decline.
- The District can increase production; at this time, increased production will not affect the wells ability to produce water
- No. Overall static water levels have shown a steep decline over the history of the well operations; continued groundwater pumpage will result in lower static levels and deeper wells. This will cause some current wells to be plugged and new, deeper wells to be drilled.
- The District can authorize increased production in the area; at this time there is no significant drawdown in the aquifer so, more pumping wouldn't affect the well's production
- Yes. Increased production in the area would be beneficial as long as it is authorized in a manner that doesn't negatively impact production of current wells in the area.
- At this time the District could pump more; currently more production in the area would not affect the production of the well.
- No, City of Houston has additional wells within Harris County.
- During the 2011 drought, the District saw the Static Water Level drop to '-215 but then it rebounded back
- At least remain the same. An increase would be good. During drought times, water usage is critical.
- Only for potable public water wells…to maintain the viable resource that is currently available.
- Yes, we believe we could sustain moderate levels of water level drop in aquifer without seeing adverse water quality changes.
- Only to public water supplies to ensure viable resource for future public needs.
- Only if necessary.
- Yes, well has room to lower static levels.
- No opinion.

- Yes; pumping levels have held very well.
- Yes.
- Not at this time.
- No. Any changes to the Evangeline Aquifer that lowers pumping levels could cost the District over $2.0 million to replace.
- No.

Jasper Aquifer LVGU responses to this question included:

- The District can increase production in the area; at the present time increased production would not affect the well's production.
- No; cost of lowering, pumps, increased production costs, & subsidence.
- Yes; pumping levels have held very well.
- No; thought that was the purpose behind SJRA and Surface Water.
- Yes. LSGCD's mandated reductions have made it more difficult for MUD's to supply the water needed by their customers.
- No; we are permitted 16,120,000 gallons. We only need more if we increase the number of connections.
- Yes; more growth, the static level from the 1970 to present only dropped 105 ft. except in South County where they never pumped their wells. If SJRA stays on surface water & leave wells off, they should see static level rise in their wells in time.
- No; it is important we protect these supplies for long term sustainability.
- Production by Willis, yes; the City will need water for growth. By allowing more pumpage, the City can support the growth.
- No. Overall static water levels have shown a steep decline over the history of the well operations; continued groundwater pumpage will result in lower static levels and deeper wells. This will cause some current wells to be plugged and new, deeper wells to be drilled.

- Yes. Increased production in the area would be beneficial as long as it is authorized in a manner that doesn't negatively impact production of current wells in the area.
- Yes; allows the City to defer significant capital expenses in lowering AWS well or constructing additional AWS well.
- Yes, the Jasper aquifer is a confined aquifer therefore does not adversely affect levels within other aquifers.
- Huntsman would consider its response to increased production on a case by case basis.
- Yes, well has room to lower static levels.
- Yes.
- No.

In the event you are permitted to produce more groundwater in the future, do you think you would produce more groundwater from this specific well? ____________________? Please explain why or why not: ________________

Consistent with other open-ended questions posed by the Survey, LVGU responses are quite variable and include the entire spectrum of possible answers. Chicot Aquifer LVGU responses to this question included:

- No, unless there were changes to well. Producing at max capacity currently.
- Yes, static levels & capacity has remained the same for 20 years (note – this response is for a dually completed in the Chicot and Evangeline aquifers).
- Huntsman would consider increasing production on this well on a case by case basis.
- Yes, systems have growth in connections.
- No, unless changes were made to well.
- Offline.
- If possible.

Evangeline Aquifer LVGU responses to this question included:

- No, unless a future development requested water service. The City does not currently need additional capacity, however there is developable land projected to develop by 2025. It is possible additional production could be necessary.
- Yes, static levels has increased since 2009, capacity has increased also.
- No, well has no room for adjustment and cannot increase pumping capacity.
- No, unless there were changes to well. Producing at max capacity currently.
- Yes, have seen consistent recovery (30 + feet) since 2014.
- Yes; the system is growing and more permitted water would enable it to sustain its growth
- The weather determines our demand.
- Yes; if there is growth in the district being able to pump more water would be beneficial.
- No. most years we have used less than 50% of our permitted amount
- No; the District is not growing and therefore future water demands should not change.
- No, sand production.
- No, it will render well inoperable; no water to produce
- Yes, if necessary. City of Houston would cycle this well more regularly with the Harris County Wells
- No; unless a future development requested water service. The District has one 12-AC undeveloped tract that is likely to be commercial. We do not anticipate this tract to increase the well capacity demand.
- Yes; this well services areas that are growing in population
- No; the well is old and we would not try to pump any more than it is now, location as well.
- Possibly; it is in a good location for distribution.

- No; it is a good design with excellent efficiency now.
- Yes.
- No, emergency well.
- Under drought conditions; it is our only water supply.
- Yes; only in drought conditions. The above average rainfall the last two years we had not had to worry about allotments. We are dependent on what Mother Nature provides for the year.
- Yes. As the development grows, so will the water demand. It is highly likely that the demand will exceed the permitted allocation of 146 MG.
- No-currently meeting demand; Yes-future demand increases or loss of alternate supply…wells or surface water.
- Yes, this well serves a new, developing MUD. Water use will increase as it continues to build out.
- Possibly; would depend on multiple factors
- Not at this time
- If possible; depends on many factors cost, potential of existing well, etc.
- Possibly; depends on the potential for lowering, etc.
- No

Jasper Aquifer LVGU responses to this question included:

- Yes; the District expects to have growth in the coming years & an increase in the permitted allotment would be needed when that growth occurs.
- Yes, well has capability to increase pumping.
- No, only if extreme drought or growth
- Yes, systems have growth in connections
- Yes, to meet system demands and lower production costs.
- No; Irrigation well to replenish the lake.

- Yes, it could become one of only 2 viable sources of water presently available to furnish demand.
- No, the well column limits the City's ability to increase pump capacity
- No, Catahoula wells.
- Yes; if the GRP works we will be fine with current wells
- Yes
- No. Not large enough to meet demands without another well producing larger volumes.
- Yes, if demand on the system required us to use more water for this well and our permit allocation was sufficient, we would.
- No, unless the necessary improvements to the well to increase capacity were feasible at that time.
- No.
- It is possible continued growth in this area will require it. We have to meet system demand to remain viable. This is one of two wells the District has viable life in at this time.
- Huntsman would consider increasing production on this well on a case by case basis
- Only as needed; currently adequate for present usage
- No. Currently barely adequate for usage. New well will be under construction soon in aggregate to this well.
- As needed; would need to drill new well if demand increases
- No. AWS wells produce more than enough water
- No, pump is designed at capacity; no room for increase

Appendix A – Lone Star GCD Survey

Lone Star Groundwater Conservation District [illegible] [illegible] Phone [illegible] Metro [illegible] Fax [illegible] Email: [illegible] Web Site: [illegible] **LARGE VOLUME GROUNDWATER USER WATER WELL INFORMATION SURVEY**	**For District Use Only** *Date of Receipt:* ____________ *GRP Sponsor:* ____________

INSTRUCTIONS: **Please complete, sign, and fax or email the survey to sreiter@lonestargcd.org.** The survey is due back to the District no later than **March 31, 2017**. This form should only be used by a Large Volume Groundwater User ("LVGU") as defined in the District Regulatory Plan Phase II(B) ("DRP Phase II(B)"). **Please complete one form for each well registered under the LVGU permit(s).**

SECTION 1 – PERMIT/WELL INFORMATION

LVGU Permit Name: ____________________________

LSGCD Permit Number: ______________ LSGCD Well Registration Number: ______________

Well Physical Address: ____________________________
(Street) (City) (State) (Zip)

Latitude: ______________ Longitude: ______________

SECTION 2 – WELL DETAILS

Permittee Well Number/Name: ______________

What aquifer is well screened in? (Check all that apply): ☐ Chicot ☐ Evangeline ☐ Jasper

Pump Setting (Depth in feet below land surface): ____________ Pump Bowl Diameter (Inches): ____________

Present Pumping Rate (GPM): ____________ Pump Submergence (Feet): ____________

Depth to Top of Screen Liner (Feet): ____________ Diameter of Screen Liner (Inches): ____________

Depth of Well Screened Interval (Feet): ____________ Diameter of Surface Casing (Inches): ____________

Current Static Water Level (Feet): ____________ Pumping Water Level (Feet): ____________

SECTION 3 – ADDITIONAL INFORMATION (if applicable)

Is well a main supply well? ☐ Yes ☐ No

Primary use of well: (Check one): ☐ Public Water Supply ☐ Irrigation ☐ Industrial ☐ Other

If "other", please explain: ____________________________

How many connections does well provide water for: ____________

Age of well: ____________

Is it physically possible to lower the well pump, if necessary? ☐ Yes ☐ No

If yes, how much deeper in the well can the pump be lowered (feet)? ____________

SECTION 4 – WATER LEVELS AND PREFERENCES Note: If you have already completed this section in a separate survey form for a well screened in the same aquifer as the well in this survey form and your answers to the questions below are the same for both wells, please do not feel obligated to complete this section of the survey again.

Have you experienced water level declines and to what extent for this well, and if so, over what years? ________________________

Have you had to lower the well pump due to declining water levels? ☐ Yes ☐ No If yes, when? _______________

Are you concerned about experiencing future water declines with respect to this well, and if so please explain

why?____

____

Would you be willing and able to lower the well pump in the future, if necessary? ☐ Yes ☐ No

If no, please explain why: ____

How many additional feet of decline in water level in your well can you experience before the operations of your well will be negatively impacted? An additional ____________ ft.

In the event you had to lower the well pump as a result of continued water level declines, in your opinion, at what depth would lowering the pump result in the well no longer serving as an economically viable means of producing water for you? ____________ ft.

In the event you chose to or were no longer able to produce groundwater from this well due to unfavorable aquifer conditions or deeper static water levels, how would you be able to meet the water needs that production from this well provided? _______________

____

How many feet of water above the well pump would you prefer to be maintained to allow for the continued operation of this well? ____________ ft.

Are there any other factors or conditions that you have experienced that have impacted your ability to produce from this well that you would like for the District to consider? ____

____

In balancing property owners' rights to produce the groundwater beneath their property with the desire to maintain favorable aquifer conditions and water levels to ensure an economically viable resource, based on your experience in operating this well, would you prefer that the District authorize increased production in the area that this well is located, including additional production by LVGUs?

____

Please explain why or why not: ____

____

In the event you are permitted to produce more groundwater in the future, do you think you would produce more groundwater from this specific well? ____

Please explain why or why not: ____

____

SECTION 5 – AKNOWLEDGEMENT

______________________	______________________	______________
Printed Name of Authorized Representative	Signature of Authorized Representative	Date
______________________	______________________	
Phone Number	Email Address	

District to Complete

Permit Number. ____________________

Additional Permit(s) associated with Permit Name: ____

Permit TQD: ________________________ Permit ICO: ________________________

GRP Type: ☐ Single ☐ Joint

GRP Sponsor: ____

Reviewed by: ____ Date: ________________

Staple all well surveys together by permit name