# GAM Task 10-002: Review of model simulation by AECOM for Groundwater Management Area 14

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## EXECUTIVE SUMMARY:

This report outlines the review of the predictive simulations developed by AECOM at the request of Groundwater Management Area 14 using the groundwater availability model for the northern portion of the Gulf Coast Aquifer. We compared the simulation results with the AECOM memorandum dated January 19, 2010. Our findings are summarized as follows:

- The pumpage values listed in AECOM's memorandum match the well component of the model water budget output within 5 percent.
- Dry cells were minimal in the model run.
- The drawdown values reported by AECOM, matched our calculated drawdown values within one foot.
- A quick analysis was performed to check the assumption that heads in 2008 (which were used to calculate drawdown) are equal to heads at the end of the model calibration period (2000). . In some cases, simulated trends between 2000 and 2008 are opposite to actual measured heads. TWDB recommends that AECOM review and adjust the pumpage in the model from 2000 to 2008 to reflect observed water level trends and recalculate the drawdowns.

## REQUESTOR:

Mr. Lloyd Behm of Bluebonnet Groundwater Conservation District (on behalf of Groundwater Management Area 14).

## DESCRIPTION OF THE REQUEST:

Numerical groundwater flow simulations were performed by AECOM in support of the joint planning process for Groundwater Management Area 14 to help determine the desired future condition of the hydrostratigraphic units that encompass the Gulf Coast Aquifer system. Groundwater Management Area 14 requested TWDB verify the AECOM predictive run and results. Specific pumping volumes were used by AECOM for the Lone Star Groundwater Conservation District, Bluebonnet Groundwater Conservation District, Lower Trinity Groundwater Conservation District, Harris-Galveston Subsidence District, Fort Bend Subsidence District, and Southeast Texas Groundwater Conservation District. The pumping volumes in the remaining districts and counties were based on estimates of groundwater availability from the 2006 regional water planning data. The memorandum dated January 19, 2010 from Bill Thaman (AECOM) to Lloyd Behm (Bluebonnet Groundwater Conservation District) provided the methodology and draft statements of desired future conditions broken by county and aquifer (Appendix A).

## METHODS:

TWDB ran the groundwater availability model for the northern portion of the Gulf Coast Aquifer and compared the results with AECOM's reported results (outlined in Appendix A). TWDB compared and verified reporting pumping amounts per county and reported average water level drawdown and/or water level recovery amounts per county. TWDB also reviewed the assumption of using modeled water levels in 2008 as a basis for drawdown calculations by comparing modeled water level drawdowns in 2008 with observed water level drawdowns in 2008. The comparisons were based on calculated drawdowns from 2000 (last year of model calibration) to 2008.

TWDB divided the verification process into four different phases. The methods used for the verification process are described as follows:

1. Verify the proposed pumpage

Various programming techniques were used to extract the pumpage values from the MODFLOW WEL package. The MODFLOW WEL package provides the input to the model for pumping values. The results from this exercise were compared with the AECOM reported pumpage (Table 1).

Since the managed available groundwater estimates will be based on model output for pumping, pumpage was also verified using a water budget analysis. TWDB ran the model in Groundwater Vistas and the model water budget output was used to summarize the pumpage using various programming techniques. The summary results include the pumpage volumes per year and per county. See Table 1 for details of the pumpage verification and comparison.

2. Review model trends using the water budget

In addition to analyzing the pumping from the model water budget, other components of the water budget were also extracted and reviewed. A set of graphs showing the net recharge, pumpage from wells, net change in storage, net lateral flow into and out of Groundwater Management Area 14, and net vertical flow within the aquifers (model layers) within Groundwater Management Area 14 were plotted (Figures 1 to Figures 7).

3. Verify the drawdown

Various programming techniques were used to extract the head values from the model heads output file and summarize the average drawdown per county. The calculated drawdowns were compared with the AECOM reported values. The head extraction programs were verified using Groundwater Vistas and geographical information system techniques to extract and calculate average drawdown values per county. See Table 2 to Table 4 for detail drawdown verification and comparison.

4. Verify starting conditions for calculating the drawdown

Modeled water levels were compared to observed water levels for several wells. The wells were selected based on (1) location within Groundwater Management Area 14, (2) well depth, and (3) availability of data up to the year 2008. The observed data of these wells were collected from TWDB's Groundwater Database.

## PARAMETERS AND ASSUMPTIONS:

The parameters and assumptions for the run using the groundwater availability model for the northern portion of the Gulf Coast Aquifer are described below:

- Version 2.01 of the groundwater availability model was used for the northern portion of the Gulf Coast Aquifer. See Kasmarek and Robinson (2004) and Kasmarek and others (2005) for assumptions and limitations of the model.
- Groundwater Vistas version 5.39 Build 15 (Environmental Simulations, Inc., 2007) was used as the interface to process model output.
- The model includes four layers representing the Chicot Aquifer (Layer 1), the Evangeline Aquifer (Layer 2), the Burkeville Confining Unit (Layer 3), and the Jasper Aquifer, which also includes the more transmissive portions of the Catahoula Formation where it outcrops (Layer 4).
- The model contains 129 individual stress periods representing the calibration and predictive time periods. Stress periods 69 and 77 correspond to years 2000 and 2008, respectively.
- The pumpage specified in the district for each year of the 2008 to 2060 predictive simulation was distributed spatially and among the model layers as described by Zoun (2010) and the model input file for pumping developed by AECOM was used for this analysis.
- Recharge, evapotranspiration, and surface water inflows and outflows were modeled using the MODFLOW general-head boundary package as described in Kasmarek and Robinson (2004).
- ESRI® ArcMap 9.3.1 was used for various spatial analyses of the model run results.
- Lahey/Fujitsu FORTRAN 95 was used as a programming language to process the model run results.
- Microsoft SQL Server 2008 was used to query the observed data from the Groundwater Database provided by TWDB.

## RESULTS:

**Pumpage verification: Modflow WEL package file verification**

Table 1 summarizes the results of the model pumping file analysis. The pumpage are summarized by layer of the model and by county. There is no significant difference between AECOM reported pumpage values and the results of TWDB's analyses. For this comparison compare column 5 to 8 and column 6 to 9 in Table 1.

**Pumpage verification: Pumpage analysis from the water budget**

The model was run using the MODFLOW WEL package provided by AECOM. The model run results were used to summarize the pumpage from the water budget as shown in column 10 of Table 1. The summary shows the pumpage per county and per layer of the model. A percent of difference of the pumpage were calculated between the WEL package pumpage and pumpage from the water budget (column 11 of Table 1). In most of the cases, there are no differences in pumpage between the model input (WEL package) and model output (water budget). Model input for pumpage does not always match model output due to the occurance of dry cells. Dry cells occur when the water level in a model cell falls below the bottom of the cell. If high pumping is the primary factor for a cell going dry, pumping may be too great for the aquifer in this area. In Brazos County the difference is 869 percent because one model cell goes dry during the simulation.

**Review model trends with water budget**

Water budget values were extracted and plotted for each year of the model simulation The results for Groundwater Management Area 14 are shown in Figures 1 through 7. The figures do not include stress period 1. The components of the water budgets are described below.

- Figure 1- Net Recharge: The net recharge refers to recharge to the aquifer sourced from precipitation and surface water inflow minus evapotranspiration and surface water outflow within Groundwater Management Area 14. In the groundwater availability model for the northern portion of the Gulf Coast Aquifer, recharge is modeled using the MODFLOW General Head Boundary package.

- Figure 2 - Pumpage: Water produced from wells within Groundwater Management Area 14. Wells are simulated in the model using the MODFLOW Well package. It is important to note that a constant value of pumpage was used by AECOM between the years of 2000 to 2008. Year 2000 is start of predictive model run and year 2008 is the start of district requested pumping.

- Figure 3 - Net Change in Storage: The changes in the water stored in the aquifer within Groundwater Management Area 14. Note that water added to storage reflects an increase in water levels while water removed from storage indicates a water level decline.

- Figure 4 - Lateral flow: This figure shows lateral flow within an aquifer between Groundwater Management Area 14 and adjacent areas.

- Figure 5 - Vertical flow between Chicot and Evangeline: This figure shows the vertical flow, or leakage, between Chicot and Evangeline aquifers. It shows that the groundwater is flowing from the Chicot Aquifer downward to the Evangeline Aquifer through the year 2060.

- Figure 6 - Vertical flow between Evangeline and Burkeville: This figure shows the vertical flow, or leakage, between the Evangeline Aquifer and the Burkeville confining unit. It shows that the flow direction changes between 2007 and 2008 and groundwater begins to flow from the Evangeline Aquifer to the Burkeville confining unit.

- Figure 7 - Vertical flow between Burkeville and Jasper: This figure shows the vertical flow, or leakage, between the Burkeville confining unit and the Jasper Aquifer. It shows that the flow is towards Jasper Aquifer throughout predictive run period.

## Drawdown Verification

Table 2 shows the average drawdown in the Chicot Aquifer between 2008 and 2060 for each county and groundwater conservation district within Groundwater Management Area 14. Note that a negative drawdown value indicates an increase in water levels. The drawdowns (2008 water-level minus 2016 water-level and 2008 water-level minus 2020 water-level) were calculated using two different methods (GIS tool and Program Tool) There were no differences in drawdown values between these two methods. For example, compare column 2 with column 3 and column 6 with column 7 of Table 2. The AECOM reported drawdowns matched with TWDB calculated values except one slight difference in Brazoria County (2008 minus 2016).

Table 3 shows the average drawdown in the Evangeline Aquifer between 2008 and 2060 for each county and groundwater conservation district within Groundwater Management Area 14. The drawdowns (2008 water -level minus 2020 water-level) were calculated using two different methods (GIS tool and Program Tool) as indicated before. There are no differences in drawdown values between these two methods. For example, compare column 5 with column 6 in Table 3. The AECOM reported drawdown values matched with TWDB calculated values.

Table 4 shows the average drawdown in the Jasper Aquifer between 2008 and 2060 for each county and groundwater conservation district within Groundwater Management Area 14. The drawdowns (2008 water –level minus 2020 water-level) were calculated using two different methods (GIS tool and Program Tool) as indicated before. There are no differences in drawdown values between these two methods. For example, compare column 5 with column 6 in Table 4. The AECOM reported drawdown values matched with TWDB calculated values.

## Hydrograph Analysis

A quick analysis was performed to check the assumption that heads in 2008 (which were used to calculate drawdown) are equal to heads at the end of the model calibration period (2000).. In some cases, simulated trends between 2000 and 2008 are opposite to actual measured heads. TWDB recommends that AECOM review and adjust the pumpage in the model from 2000 to 2008 to reflect observed water level trends and recalculate the drawdowns.

## REFERENCES:

Reem Zoun, P.E., Memorandum, 2010,AECOM, 7p

Kasmarek, M.C., and Robinson, J.L., 2004, Hydrogeology and simulation of groundwater flow and land-surface subsidence in the northern part of the Gulf Coast aquifer system, Texas: U.S. Geological Survey Scientific Investigations Report 2004-5102, 111 p.

Kasmarek, M.C., Reece, B.D., and Houston, N.A., 2005, Evaluation of groundwater flow and land-surface subsidence caused by hypothetical withdrawals in the northern part of the northern part of the Gulf Coast aquifer system, Texas: U.S. Geological Survey Scientific Investigations Report 2005-5024, 70 p.

Texas Water Development Board, 2002, Water for Texas – 2002—Volumes I-III; Texas Water Development Board Document No. GP-7-1, 155 p.

Environmental Simulations, Inc., 2007, Guide to Using Groundwater Vistas Version 5, 381 p.

**Table 1: Pumpage values verification for groundwater availability model for the northern portion of the Gulf Coast Aquifer within Groundwater Management Area 14.**

| County<br><br>(1) | Year<br><br>(2) | Stress Period<br><br>(3) | Layer<br><br>(4) | Pumpage from MODFLOW Wel package<br><br>AFY /Layer<br>(5) | Pumpage from MODFLOW Wel package<br><br>AFY/County<br>(6) | Layer<br><br>(7) | Target Pumpage from AECOM Report<br><br>AFY/Layer<br>(8) | Target Pumpage from AECOM Report<br><br>AFY/County<br>(9) | Pumpage from Water Budget Calculation<br><br>AFY/Layer<br>(10) | % of Difference (11)={(A)-(B)}/(B)<br><br>A is (5) or (6)<br>B is (9) or (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| **AUSTIN** | 2008 | 77 | 1 | 1,300 | | 1 | 1,300 | | 1,301 | 0% |
| | | | 2 | 20,000 | | 2 | 20,000 | | 20,013 | 0% |
| | | | 3 | 0 | | 3 | 0 | | 0 | 0% |
| | | | 4 | 1,000 | | 4 | 1,000 | | 1,001 | 0% |
| **BRAZORIA** | 2008 | 77 | 1 | 48,131 | | | | | 48,130 | 0% |
| | | | 2 | 2,269 | 50,400 | | | 50,400 | 2,271 | 0% |
| **BRAZOS** | 2008 | 77 | 4 | 4,186 | 4,186 | | | 4,150 | 432 | 869%[a] |
| **CHAMBERS** | 2008 | 77 | 1 | 22,622 | | | | | 22,264 | 2% |
| | | | 2 | 379 | 23,001 | | | 23,001 | 379 | 0% |
| **FORT BEND** | 2008 | 77 | 1 | 83,077 | | | | | 83,131 | 0% |
| | | | 2 | 30,778 | 113,855 | | | 113,855 | 30,798 | 0% |
| | 2009 | 78 | 1 | 83,014 | | | | | 83,069 | 0% |
| | | | 2 | 30,841 | 113,855 | | | 113,855 | 30,861 | 0% |
| | 2010 | 79 | 1 | 82,953 | | | | | 83,007 | 0% |
| | | | 2 | 30,902 | 113,855 | | | 113,855 | 30,923 | 0% |
| | 2020 | 89 | 1 | 75,866 | | | | | 75,916 | 0% |
| | | | 2 | 32,767 | 108,633 | | | 108,633 | 32,789 | 0% |
| | 2030 | 99 | 1 | 61,617 | | | | | 61,657 | 0% |
| | | | 2 | 30,399 | 92,016 | | | 92,016 | 30,419 | 0% |

| County<br><br>(1) | Year<br><br>(2) | Stress Period<br><br>(3) | Layer<br><br>(4) | Pumpage from MODFLOW Wel package<br><br>AFY /Layer<br>(5) | Pumpage from MODFLOW Wel package<br><br>AFY/County<br>(6) | Layer<br><br>(7) | Target Pumpage from AECOM Report<br><br>AFY/Layer<br>(8) | Target Pumpage from AECOM Report<br><br>AFY/County<br>(9) | Pumpage from Water Budget Calculation<br><br>AFY/Layer<br>(10) | % of Difference (11)={(A)-(B)}/(B)<br><br>A is (5) or (6)<br>B is (9) or (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2040 | 109 | 1 | 60,964 | | | | | 61,004 | 0% |
| | | | 2 | 31,146 | 92,110 | | | 92,110 | 31,167 | 0% |
| | 2050 | 119 | 1 | 60,022 | | | | | 60,061 | 0% |
| | | | 2 | 32,230 | 92,252 | | | 92,252 | 32,251 | 0% |
| **FORT BEND** | 2060 | 129 | 1 | 60,137 | | | | | 60,177 | 0% |
| | | | 2 | 32,292 | 92,429 | | | 92,429 | 32,313 | 0% |
| **GALVESTON** | 2008 | 77 | 1 | 4,328 | | | | | 4,310 | 0% |
| | | | 2 | 486 | 4,814 | | | 4,814 | 465 | 4% |
| | 2009 | 78 | 1 | 4,325 | | | | | 4,306 | 0% |
| | | | 2 | 489 | 4,814 | | | 4,814 | 468 | 4% |
| | 2010 | 79 | 1 | 4,322 | | | | | 4,303 | 0% |
| | | | 2 | 492 | 4,814 | | | 4,814 | 471 | 4% |
| | 2020 | 89 | 1 | 4,713 | | | | | 4,697 | 0% |
| | | | 2 | 586 | 5,299 | | | 5,299 | 560 | 5% |
| | 2030 | 99 | 1 | 5,246 | | | | | 5,233 | 0% |
| | | | 2 | 663 | 5,909 | | | 5,909 | 634 | 5% |
| | 2040 | 109 | 1 | 5,202 | | | | | 5,194 | 0% |
| | | | 2 | 679 | 5,881 | | | 5,881 | 647 | 5% |
| | 2050 | 119 | 1 | 5,160 | | | | | 5,152 | 0% |
| | | | 2 | 695 | 5,855 | | | 5,855 | 662 | 5% |
| | 2060 | 129 | 1 | 5,161 | | | | | 5,153 | 0% |
| | | | 2 | 695 | 5,856 | | | 5,856 | 662 | 5% |
| **GRIMES** | 2008 | 77 | 2 | 3,000 | | 2 | 3,000 | | 3,002 | 0% |
| | | | 4 | 11,000 | | 4 | 11,000 | | 10,848 | 1% |

| County (1) | Year (2) | Stress Period (3) | Layer (4) | Pumpage from MODFLOW Wel package AFY /Layer (5) | Pumpage from MODFLOW Wel package AFY/County (6) | Layer (7) | Target Pumpage from AECOM Report AFY/Layer (8) | Target Pumpage from AECOM Report AFY/County (9) | Pumpage from Water Budget Calculation AFY/Layer (10) | % of Difference (11)={(A)-(B)}/(B) A is (5) or (6) B is (9) or (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| **HARDIN** | 2008 | 77 | 1 | 1,816 | | | | | 1,818 | 0% |
| | | | 2 | 17,681 | 19,498 | | | 19,498 | 17,693 | 0% |
| **HARRIS** | 2008 | 77 | 1 | 70,879 | | | | | 70,925 | 0% |
| | | | 2 | 234,126 | | | | | 234,280 | 0% |
| | | | 3 | 325 | | | | | 325 | 0% |
| | | | 4 | 19 | 305,349 | | | 305,349 | 19 | 0% |
| | 2009 | 78 | 1 | 70,531 | | | | | 70,577 | 0% |
| | | | 2 | 234,470 | | | | | 234,624 | 0% |
| | | | 3 | 329 | | | | | 330 | 0% |
| | | | 4 | 19 | 305,349 | | | 305,349 | 19 | 0% |
| | 2010 | 79 | 1 | 70,173 | | | | | 70,219 | 0% |
| | | | 2 | 234,822 | | | | | 234,977 | 0% |
| | | | 3 | 334 | | | | | 335 | 0% |
| | | | 4 | 19 | 305,349 | | | 305,349 | 19 | 0% |
| | 2020 | 89 | 1 | 68,793 | | | | | 68,839 | 0% |
| | | | 2 | 193,632 | | | | | 193,760 | 0% |
| | | | 3 | 329 | | | | | 329 | 0% |
| | | | 4 | 19 | 262,774 | | | 262,774 | 19 | 0% |
| | 2030 | 99 | 1 | 56,813 | | | | | 56,851 | 0% |
| | | | 2 | 152,155 | | | | | 152,256 | 0% |
| | | | 3 | 255 | | | | | 256 | 0% |
| | | | 4 | 15 | 209,239 | | | 209,239 | 15 | 0% |

| County<br><br>(1) | Year<br><br>(2) | Stress Period<br><br>(3) | Layer<br><br>(4) | Pumpage from MODFLOW Wel package<br>AFY /Layer<br>(5) | Pumpage from MODFLOW Wel package<br>AFY/County<br>(6) | Layer<br><br>(7) | Target Pumpage from AECOM Report<br>AFY/Layer<br>(8) | Target Pumpage from AECOM Report<br>AFY/County<br>(9) | Pumpage from Water Budget Calculation<br>AFY/Layer<br>(10) | % of Difference (11)={(A)-(B)}/(B)<br>A is (5) or (6)<br>B is (9) or (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| **HARRIS** | 2040 | 109 | 1 | 58,602 | | | | | 58,641 | 0% |
| **(Continue)** | | | 2 | 151,026 | | | | | 151,125 | 0% |
| | | | 3 | 249 | | | | | 249 | 0% |
| | | | 4 | 14 | 209,891 | | | 209,891 | 14 | 0% |
| | 2050 | 119 | 1 | 61,145 | | | | | 61,185 | 0% |
| | | | 2 | 149,127 | | | | | 149,225 | 0% |
| | | | 3 | 254 | | | | | 254 | 0% |
| | | | 4 | 15 | 210,540 | | | 210,540 | 15 | 0% |
| | 2060 | 129 | 1 | 61,232 | | | | | 61,272 | 0% |
| | | | 2 | 149,338 | | | | | 149,436 | 0% |
| | | | 3 | 254 | | | | | 254 | 0% |
| | | | 4 | 15 | 210,838 | | | 210,838 | 15 | 0% |
| **JASPER** | 2008 | 77 | 1 | 10,399 | | | | | 10,406 | 0% |
| | | | 2 | 29,893 | | | | | 29,913 | 0% |
| | | | 3 | 22 | | | | | 22 | 0% |
| | | | 4 | 9,652 | 49,966 | | | 49,966 | 9,658 | 0% |
| **JEFFERSON** | 2008 | 77 | 1 | 2,400 | | | | | 2,345 | 2% |
| | | | 2 | 100 | 2,500 | | | 2,500 | 100 | 0% |
| **LIBERTY** | 2008 | 77 | 1 | 14,567 | | | | | 14,577 | 0% |
| | | | 2 | 27,652 | | | | | 27,670 | 0% |
| | | | 3 | 215 | | | | | 0 | 0% |
| | | | 4 | 787 | 43,221 | | | 43,221 | 788 | 0% |

| County (1) | Year (2) | Stress Period (3) | Layer (4) | Pumpage from MODFLOW Wel package AFY /Layer (5) | Pumpage from MODFLOW Wel package AFY/County (6) | Layer (7) | Target Pumpage from AECOM Report AFY/Layer (8) | Target Pumpage from AECOM Report AFY/County (9) | Pumpage from Water Budget Calculation AFY/Layer (10) | % of Difference (11)={(A)-(B)}/(B) A is (5) or (6) B is (9) or (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| **MONTGOMERY** | 2000 | 69 | 1 | 1,362 | | | | | 1,363 | 0% |
| | | | 2 | 32,695 | | | | | 32,717 | 0% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 21,643 | 55,701 | | | 55,701 | 21,658 | 0% |
| | 2001 | 70 | 1 | 1,384 | | | | | 1,385 | 0% |
| | | | 2 | 33,720 | | | | | 33,742 | 0% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 22,558 | 57,662 | | | 57,662 | 22,572 | 0% |
| | 2002 | 71 | 1 | 1,406 | | | | | 1,407 | 0% |
| | | | 2 | 34,744 | | | | | 34,767 | 0% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 23,473 | 59,623 | | | 59,623 | 23,489 | 0% |
| | 2003 | 72 | 1 | 1,428 | | | | | 1,428 | 0% |
| | | | 2 | 35,766 | | | | | 35,790 | 0% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 24,390 | 61,584 | | | 61,584 | 24,406 | 0% |
| | 2004 | 73 | 1 | 1,449 | | | | | 1,450 | 0% |
| | | | 2 | 36,788 | | | | | 36,813 | 0% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 25,308 | 63,545 | | | 63,545 | 25,324 | 0% |

| County<br>(1) | Year<br>(2) | Stress Period<br>(3) | Layer<br>(4) | Pumpage from MODFLOW Wel package<br>AFY /Layer<br>(5) | Pumpage from MODFLOW Wel package<br>AFY/County<br>(6) | Layer<br>(7) | Target Pumpage from AECOM Report<br>AFY/Layer<br>(8) | Target Pumpage from AECOM Report<br>AFY/County<br>(9) | Pumpage from Water Budget Calculation<br>AFY/Layer<br>(10) | % of Difference (11)={(A)-(B)}/(B)<br>A is (5) or (6)<br>B is (9) or (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| **MONTGOMERY** | 2005 | 74 | 1 | 1,470 | | | | | 1,471 | 0% |
| **(Continue)** | | | 2 | 37,809 | | | | | 37,834 | 0% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 26,226 | 65,506 | | | 65,506 | 26,243 | 0% |
| | 2006 | 75 | 1 | 1,491 | | | | | 1,492 | 0% |
| | | | 2 | 38,830 | | | | | 38,855 | 0% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 27,146 | 67,467 | | | 67,467 | 27,164 | 0% |
| | 2007 | 76 | 1 | 1,512 | | | | | 1,513 | 0% |
| | | | 2 | 39,850 | | | | | 38,329 | 4% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 28,066 | 69,428 | | | 69,428 | 28,085 | 0% |
| | 2008 | 77 | 1 | 1,521 | | | | | 1,522 | 0% |
| | | | 2 | 41,119 | | | | | 39,387 | 4% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 28,750 | 71,389 | | | 71,389 | 28,769 | 0% |
| | 2009 | 78 | 1 | 1,541 | | | | | 1,542 | 0% |
| | | | 2 | 42,144 | | | | | 40,188 | 5% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 29,665 | 73,350 | | | 73,350 | 29,684 | 0% |

| County (1) | Year (2) | Stress Period (3) | Layer (4) | Pumpage from MODFLOW Wel package AFY /Layer (5) | Pumpage from MODFLOW Wel package AFY/County (6) | Layer (7) | Target Pumpage from AECOM Report AFY/Layer (8) | Target Pumpage from AECOM Report AFY/County (9) | Pumpage from Water Budget Calculation AFY/Layer (10) | % of Difference (11)={(A)-(B)}/(B) A is (5) or (6) B is (9) or (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| **MONTGOMERY** | 2010 | 79 | 1 | 1,481 | | | | | 1,482 | 0% |
| **(Continue)** | | | 2 | 41,450 | | | | | 39,381 | 5% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 32,379 | 75,311 | | | 75,311 | 32,401 | 0% |
| | 2011 | 80 | 1 | 1,518 | | | | | 1,519 | 0% |
| | | | 2 | 42,678 | | | | | 40,555 | 5% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 33,590 | 77,786 | | | 77,786 | 33,612 | 0% |
| | 2012 | 81 | 1 | 1,554 | | | | | 1,555 | 0% |
| | | | 2 | 43,906 | | | | | 41,727 | 5% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 34,802 | 80,262 | | | 80,262 | 34,825 | 0% |
| | 2013 | 82 | 1 | 1,590 | | | | | 1,591 | 0% |
| | | | 2 | 45,133 | | | | | 42,900 | 5% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 36,014 | 82,737 | | | 82,737 | 36,037 | 0% |
| | 2014 | 83 | 1 | 1,626 | | | | | 1,627 | 0% |
| | | | 2 | 46,360 | | | | | 44,072 | 5% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 37,226 | 85,212 | | | 85,212 | 37,250 | 0% |

| County (1) | Year (2) | Stress Period (3) | Layer (4) | Pumpage from MODFLOW Wel package AFY /Layer (5) | Pumpage from MODFLOW Wel package AFY/County (6) | Layer (7) | Target Pumpage from AECOM Report AFY/Layer (8) | Target Pumpage from AECOM Report AFY/County (9) | Pumpage from Water Budget Calculation AFY/Layer (10) | % of Difference (11)={(A)-(B)}/(B) A is (5) or (6) B is (9) or (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| **MONTGOMERY** | 2015 | 84 | 1 | 2,357 | | | | | 2,359 | 0% |
| **(Continue)** | | | 2 | 55,735 | | | | | 52,467 | 6% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 29,595 | 87,688 | | | 87,688 | 29,614 | 0% |
| | 2016 | 85 | 1 | 1,721 | | | | | 1,722 | 0% |
| | | | 2 | 40,679 | | | | | 38,293 | 6% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 21,600 | 64,000 | | | 64,000 | 21,614 | 0% |
| **NEWTON** | 2008 | 77 | 1 | 187 | | | | | 187 | 0% |
| | | | 2 | 9,104 | | | | | 9,110 | 0% |
| | | | 3 | 0 | | | | | 0 | 0% |
| | | | 4 | 6,624 | 15,915 | | | 15,914 | 6,628 | 0% |
| **ORANGE** | 2008 | 77 | 1 | 18,798 | | | | | 18,810 | 0% |
| | | | 2 | 1,202 | 20,000 | | | 20,000 | 1,203 | 0% |
| **POLK** | 2008 | 77 | 2 | 8,306 | | | | | 8,311 | 0% |
| | | | 3 | 744 | | | | | 744 | 0% |
| | | | 4 | 27,668 | 36,717 | | | 36,717 | 27,686 | 0% |
| **SAN JACINTO** | 2008 | 77 | 2 | 8,172 | | | | | 8,178 | 0% |
| | | | 3 | 2,697 | | | | | 2,699 | 0% |
| | | | 4 | 10,096 | 20,965 | | | 20,965 | 10,102 | 0% |
| **TYLER** | 2008 | 77 | 2 | 7,986 | | | | | 7,991 | 0% |
| | | | 3 | 95 | | | | | 95 | 0% |
| | | | 4 | 8,164 | 16,245 | | | 16,245 | 8,150 | 0% |

| County (1) | Year (2) | Stress Period (3) | Layer (4) | Pumpage from MODFLOW Wel package AFY /Layer (5) | Pumpage from MODFLOW Wel package AFY/County (6) | Layer (7) | Target Pumpage from AECOM Report AFY/Layer (8) | Target Pumpage from AECOM Report AFY/County (9) | Pumpage from Water Budget Calculation AFY/Layer (10) | % of Difference (11)={(A)-(B)}/(B) A is (5) or (6) B is (9) or (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| **WALKER** | 2008 | 77 | 2 | 2,000 | | 2 | 2,000 | | 2,001 | 0% |
| | | | 4 | 16,000 | | 4 | 16,000 | | 16,011 | 0% |
| **WALLER** | 2008 | 77 | 1 | 300 | | 1 | 300 | | 300 | 0% |
| | | | 2 | 41,000 | | 2 | 41,000 | | 41,027 | 0% |
| | | | 4 | 300 | | 4 | 300 | | 300 | 0% |
| **WASHINGTON** | 2008 | 77 | 2 | 3,237 | | | | | 3,239 | 0% |
| | | | 3 | 367 | | | | | 368 | 0% |
| | | | 4 | 9,431 | 13,036 | | | 13,036 | 9,437 | 0% |

Note: a) The calculated pumpage from the water budget is much smaller than the well file pumpage in this case. It is because of dry cell problem.

**Table 2: Average water level changes in the Chicot Aquifer in Groundwater Management Area 14.**

| County | 2008-2016 | | | | 2008-2020 | | | | 2008-2030 | | | 2008-2040 | | | 2008-2050 | | | 2008-2060 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AECOM Report- Draw Down (1) ft | Calculated Draw Down from - GIS Tool (2) ft | Calculated Draw Down from Program Tool (3) ft | Drawdown Difference (1)~(3) (4) ft | AECOM Report- Draw Down (5) ft | Calculated Draw Down from GIS Tool (6) ft | Calculated Draw Down from Program Tool (7) ft | Drawdown Difference (5)~(7) (8) ft | AECOM Report- Draw Down (9) ft | Calculated Draw Down from Program Tool (10) ft | Drawdown Difference (9)~(10) (11) ft | AECOM Report- Draw Down (12) ft | Calculated Draw Down from Program Tool (13) ft | Drawdown Difference (12)~(13) (14) ft | AECOM Report- Draw Down (15) ft | Calculated Draw Down from Program Tool (16) ft | Drawdown Difference (15)~(16) (17) ft | AECOM Report- Draw Down (18) ft | Calculated Draw Down from Water budget- Program Tool (19) ft | Drawdown Difference (18)~(19) (20) ft |
| AUSTIN | 4 | 4 | 4 | 0 | 6 | 6 | 6 | 0 | 10 | 10 | 0 | 12 | 12 | 0 | 15 | 15 | 0 | 17 | 17 | 0 |
| BRAZORIA | 5 | 6 | 6 | 1 | 7 | 7 | 7 | 0 | 11 | 11 | 0 | 13 | 13 | 0 | 15 | 15 | 0 | 17 | 17 | 0 |
| BRAZOS | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| CHAMBERS | 6 | 6 | 6 | 0 | 8 | 8 | 8 | 0 | 13 | 13 | 0 | 17 | 17 | 0 | 20 | 20 | 0 | 23 | 23 | 0 |
| FORT BEND | 8 | 8 | 8 | 0 | 11 | 11 | 11 | 0 | 12 | 12 | 0 | 12 | 12 | 0 | 14 | 14 | 0 | 15 | 15 | 0 |
| GALVESTON | 3 | 3 | 3 | 0 | 4 | 4 | 4 | 0 | 7 | 7 | 0 | 8 | 8 | 0 | 10 | 10 | 0 | 12 | 12 | 0 |
| GRIMES | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| HARDIN | 3 | 3 | 3 | 0 | 5 | 5 | 5 | 0 | 8 | 8 | 0 | 11 | 11 | 0 | 14 | 14 | 0 | 17 | 17 | 0 |
| HARRIS | 2 | 2 | 2 | 0 | 2 | 2 | 2 | 0 | -5 | -5 | 0 | -9 | -9 | 0 | -8 | -8 | 0 | -7 | -7 | 0 |
| JASPER | 2 | 2 | 2 | 0 | 3 | 3 | 3 | 0 | 5 | 5 | 0 | 7 | 7 | 0 | 9 | 9 | 0 | 10 | 10 | 0 |
| JEFFERSON | 4 | 4 | 4 | 0 | 5 | 5 | 5 | 0 | 8 | 8 | 0 | 10 | 10 | 0 | 13 | 13 | 0 | 15 | 15 | 0 |
| LIBERTY | 6 | 6 | 6 | 0 | 8 | 8 | 8 | 0 | 12 | 12 | 0 | 15 | 15 | 0 | 17 | 17 | 0 | 19 | 19 | 0 |
| MONTGOMERY | 4 | 4 | 4 | 0 | 5 | 5 | 5 | 0 | 7 | 7 | 0 | 8 | 8 | 0 | 8 | 8 | 0 | 9 | 9 | 0 |
| NEWTON | 2 | 2 | 2 | 0 | 3 | 3 | 3 | 0 | 4 | 4 | 0 | 6 | 6 | 0 | 7 | 7 | 0 | 9 | 9 | 0 |
| ORANGE | 3 | 3 | 3 | 0 | 4 | 4 | 4 | 0 | 6 | 6 | 0 | 8 | 8 | 0 | 10 | 10 | 0 | 11 | 11 | 0 |
| POLK | 2 | 2 | 2 | 0 | 2 | 3 | 2 | 0 | 3 | 3 | 0 | 3 | 3 | 0 | 4 | 4 | 0 | 4 | 4 | 0 |

| County | 2008-2016 | | | | 2008-2020 | | | | 2008-2030 | | | 2008-2040 | | | 2008-2050 | | | 2008-2060 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AECOM Report- Draw Down | Calculated Draw Down from - GIS Tool | Calculated Draw Down from Program Tool | Drawdown Difference (1)~(3) | AECOM Report- Draw Down | Calculated Draw Down from GIS Tool | Calculated Draw Down from Program Tool | Drawdown Difference (5)~(7) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (9)~(10) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (12)~(13) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (15)~(16) | AECOM Report- Draw Down | Calculated Draw Down from Water budget- Program Tool | Drawdown Difference (18)~(19) |
| | (1) ft | (2) ft | (3) ft | (4) ft | (5) ft | (6) ft | (7) ft | (8) ft | (9) ft | (10) ft | (11) ft | (12) ft | (13) ft | (14) ft | (15) ft | (16) ft | (17) ft | (18) ft | (19) ft | (20) ft |
| SAN JACINTO | 2 | 2 | 2 | 0 | 3 | 3 | 3 | 0 | 4 | 4 | 0 | 4 | 4 | 0 | 4 | 4 | 0 | 4 | 4 | 0 |
| TYLER | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 2 | 2 | 0 | 2 | 2 | 0 | 3 | 3 | 0 |
| WALKER | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WALLER | 3 | 3 | 3 | 0 | 4 | 4 | 4 | 0 | 6 | 6 | 0 | 6 | 6 | 0 | 7 | 7 | 0 | 7 | 7 | 0 |
| WASHINGTON | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - |

**Table 3: Average water level changes in the Evangeline Aquifer in Groundwater Management Area 14.**

| County | 2008-2016 | | | 2008-2020 | | | | 2008-2030 | | | 2008-2040 | | | 2008-2050 | | | 2008-2060 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (1)~(2) | AECOM Report- Draw Down | Calculated Draw Down from GIS Tool | Calculated Draw Down from Program Tool | Drawdown Difference (4)~(6) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (8)~(9) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (11)~(12) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (14)~(15) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (17)~(18) |
| | (1) ft | (2) ft | (3) ft | (4) ft | (5) ft | (6) ft | (7) ft | (8) ft | (9) ft | (10) ft | (11) ft | (12) ft | (13) ft | (14) ft | (15) ft | (16) ft | (17) ft | (18) ft | (19) ft |
| AUSTIN | 2 | 2 | 0 | 3 | 3 | 3 | 0 | 5 | 5 | 0 | 6 | 6 | 0 | 7 | 7 | 0 | 8 | 8 | 0 |
| BRAZORIA | 5 | 5 | 0 | 7 | 7 | 7 | 0 | 11 | 11 | 0 | 14 | 14 | 0 | 16 | 16 | 0 | 18 | 18 | 0 |
| BRAZOS | - | - | | - | | - | | - | - | | - | - | - | - | - | - | - | - | - |
| CHAMBERS | 4 | 4 | 0 | 6 | 7 | 6 | 0 | 11 | 11 | 0 | 14 | 14 | 0 | 17 | 17 | 0 | 20 | 20 | 0 |
| FORT BEND | 8 | 8 | 0 | 10 | 10 | 10 | 0 | 11 | 11 | 0 | 12 | 12 | 0 | 14 | 14 | 0 | 15 | 15 | 0 |
| GALVESTON | 2 | 2 | 0 | 3 | 3 | 3 | 0 | 6 | 6 | 0 | 8 | 8 | 0 | 11 | 11 | 0 | 13 | 13 | 0 |
| GRIMES | 1 | 1 | 0 | 2 | 2 | 2 | 0 | 3 | 3 | 0 | 3 | 3 | 0 | 4 | 4 | 0 | 4 | 4 | 0 |
| HARDIN | 5 | 5 | 0 | 7 | 7 | 7 | 0 | 13 | 13 | 0 | 18 | 18 | 0 | 23 | 23 | 0 | 27 | 27 | 0 |
| HARRIS | -3 | -3 | 0 | -6 | 6 | -6 | 0 | -20 | -20 | 0 | -24 | -24 | 0 | -24 | -24 | 0 | -23 | -23 | 0 |
| JASPER | 4 | 4 | 0 | 6 | 6 | 6 | 0 | 10 | 10 | 0 | 14 | 14 | 0 | 18 | 18 | 0 | 23 | 23 | 0 |
| JEFFERSON | 4 | 4 | 0 | 6 | 6 | 6 | 0 | 9 | 9 | 0 | 12 | 12 | 0 | 15 | 15 | 0 | 17 | 17 | 0 |
| LIBERTY | 6 | 6 | 0 | 8 | 8 | 8 | 0 | 12 | 12 | 0 | 15 | 15 | 0 | 18 | 18 | 0 | 20 | 20 | 0 |
| MONTGOMERY | 12 | 12 | 0 | 15 | 15 | 15 | 0 | 21 | 21 | 0 | 27 | 27 | 0 | 32 | 32 | 0 | 37 | 37 | 0 |
| NEWTON | 3 | 3 | 0 | 5 | 5 | 5 | 0 | 9 | 9 | 0 | 13 | 13 | 0 | 16 | 16 | 0 | 20 | 20 | 0 |
| ORANGE | 4 | 4 | 0 | 5 | 5 | 5 | 0 | 8 | 8 | 0 | 11 | 11 | 0 | 14 | 14 | 0 | 16 | 16 | 0 |
| POLK | 1 | 1 | 0 | 2 | 2 | 2 | 0 | 2 | 2 | 0 | 2 | 2 | 0 | 2 | 2 | 0 | 2 | 2 | 0 |

| | 2008-2016 | | | 2008-2020 | | | | 2008-2030 | | | 2008-2040 | | | 2008-2050 | | | 2008-2060 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **County** | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (1)~(2) | AECOM Report- Draw Down | Calculated Draw Down from GIS Tool | Calculated Draw Down from Program Tool | Drawdown Difference (4)~(6) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (8)~(9) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (11)~(12) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (14)~(15) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (17)~(18) |
| | (1) ft | (2) ft | (3) ft | (4) ft | (5) ft | (6) ft | (7) ft | (8) ft | (9) ft | (10) ft | (11) ft | (12) ft | (13) ft | (14) ft | (15) ft | (16) ft | (17) ft | (18) ft | (19) ft |
| SAN JACINTO | 2 | 2 | 0 | 3 | 3 | 3 | 0 | 4 | 4 | 0 | 4 | 4 | 0 | 4 | 4 | 0 | 5 | 5 | 0 |
| TYLER | 2 | 2 | 0 | 3 | 3 | 3 | 0 | 6 | 6 | 0 | 9 | 9 | 0 | 12 | 12 | 0 | 16 | 16 | 0 |
| WALKER | 4 | 4 | 0 | 5 | 6 | 5 | 0 | 7 | 7 | 0 | 7 | 7 | 0 | 8 | 8 | 0 | 8 | 8 | 0 |
| WALLER | 3 | 3 | 0 | 3 | 3 | 3 | 0 | 4 | 4 | 0 | 4 | 4 | 0 | 4 | 4 | 0 | 4 | 4 | 0 |
| WASHINGTON | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |

**Table 4: Average water level changes in the Jasper Aquifer in Groundwater Management Area 14.**

| | 2008-2016 | | | 2008-2020 | | | | 2008-2030 | | | 2008-2040 | | | 2008-2050 | | | 2008-2060 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **County** | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (1)~(2) | AECOM Report- Draw Down | Calculated Draw Down from GIS Tool | Calculated Draw Down from Program Tool | Drawdown Difference (4)~(6) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (8)~(9) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (11)~(12) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (14)~(15) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (17)~(18) |
| | (1) ft | (2) ft | (3) ft | (4) ft | (5) ft | (6) ft | (7) ft | (8) ft | (9) ft | (10) ft | (11) ft | (12) ft | (13) ft | (14) ft | (15) ft | (16) ft | (17) ft | (18) ft | (19) ft |
| AUSTIN | 10 | 10 | 0 | 12 | 12 | 12 | 0 | 12 | 12 | 0 | 12 | 12 | 0 | 13 | 13 | 0 | 14 | 14 | 0 |
| BRAZORIA | - | - | | - | - | - | | - | - | | - | - | | - | - | | - | - | |
| BRAZOS | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 2 | 2 | 0 | 2 | 2 | 0 | 3 | 3 | 0 | 3 | 3 | 0 |
| CHAMBERS | - | - | | - | - | - | | - | - | | - | - | | - | - | | - | - | |
| FORT BEND | 36 | 36 | 0 | 47 | 47 | 47 | 0 | 41 | 41 | 0 | 36 | 36 | 0 | 36 | 36 | 0 | 37 | 37 | 0 |
| GALVESTON | - | - | | - | - | - | | - | - | | - | - | | - | - | | - | - | |
| GRIMES | 15 | 15 | 0 | 13 | 12 | 13 | 0 | 14 | 14 | 0 | 17 | 17 | 0 | 21 | 21 | 0 | 24 | 24 | 0 |
| HARDIN | 13 | 13 | 0 | 17 | 16 | 17 | 0 | 21 | 21 | 0 | 26 | 26 | 0 | 31 | 31 | 0 | 36 | 36 | 0 |
| HARRIS | 63 | 63 | 0 | 57 | 55 | 57 | 0 | 36 | 36 | 0 | 30 | 30 | 0 | 30 | 30 | 0 | 32 | 32 | 0 |
| JASPER | 3 | 3 | 0 | 5 | 4 | 5 | 0 | 9 | 9 | 0 | 12 | 12 | 0 | 17 | 17 | 0 | 21 | 21 | 0 |
| JEFFERSON | - | - | | - | - | - | | - | - | | - | - | | - | - | | - | - | |
| LIBERTY | 52 | 52 | 0 | 52 | 51 | 52 | 0 | 44 | 44 | 0 | 45 | 45 | 0 | 49 | 49 | 0 | 53 | 53 | 0 |
| MONTGOMERY | 56 | 56 | 0 | 14 | 14 | 14 | 0 | 1 | 1 | 0 | 3 | 3 | 0 | 8 | 8 | 0 | 14 | 14 | 0 |
| NEWTON | 3 | 3 | 0 | 4 | 4 | 4 | 0 | 7 | 7 | 0 | 11 | 11 | 0 | 14 | 14 | 0 | 18 | 18 | 0 |
| ORANGE | - | - | | - | - | - | | - | - | | - | - | | - | - | | - | - | |
| POLK | 11 | 11 | 0 | 13 | 11 | 13 | 0 | 17 | 17 | 0 | 22 | 22 | 0 | 26 | 26 | 0 | 31 | 31 | 0 |

| | 2008-2016 | | | 2008-2020 | | | | 2008-2030 | | | 2008-2040 | | | 2008-2050 | | | 2008-2060 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **County** | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (1)~(2) | AECOM Report- Draw Down | Calculated Draw Down from GIS Tool | Calculated Draw Down from Program Tool | Drawdown Difference (4)~(6) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (8)~(9) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (11)~(12) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (14)~(15) | AECOM Report- Draw Down | Calculated Draw Down from Program Tool | Drawdown Difference (17)~(18) |
| | (1) ft | (2) ft | (3) ft | (4) ft | (5) ft | (6) ft | (7) ft | (8) ft | (9) ft | (10) ft | (11) ft | (12) ft | (13) ft | (14) ft | (15) ft | (16) ft | (17) ft | (18) ft | (19) ft |
| SAN JACINTO | 35 | 35 | 0 | 30 | 28 | 30 | 0 | 32 | 32 | 0 | 37 | 37 | 0 | 43 | 43 | 0 | 49 | 49 | 0 |
| TYLER | 6 | 6 | 0 | 9 | 8 | 9 | 0 | 14 | 14 | 0 | 20 | 20 | 0 | 26 | 26 | 0 | 33 | 33 | 0 |
| WALKER | 10 | 10 | 0 | 11 | 9 | 11 | 0 | 16 | 16 | 0 | 21 | 21 | 0 | 26 | 26 | 0 | 30 | 30 | 0 |
| WALLER | 31 | 31 | 0 | 29 | 29 | 29 | 0 | 22 | 22 | 0 | 21 | 21 | 0 | 21 | 21 | 0 | 23 | 23 | 0 |
| WASHINGTON | 3 | 3 | 0 | 5 | 5 | 5 | 0 | 7 | 7 | 0 | 10 | 10 | 0 | 12 | 12 | 0 | 14 | 14 | 0 |

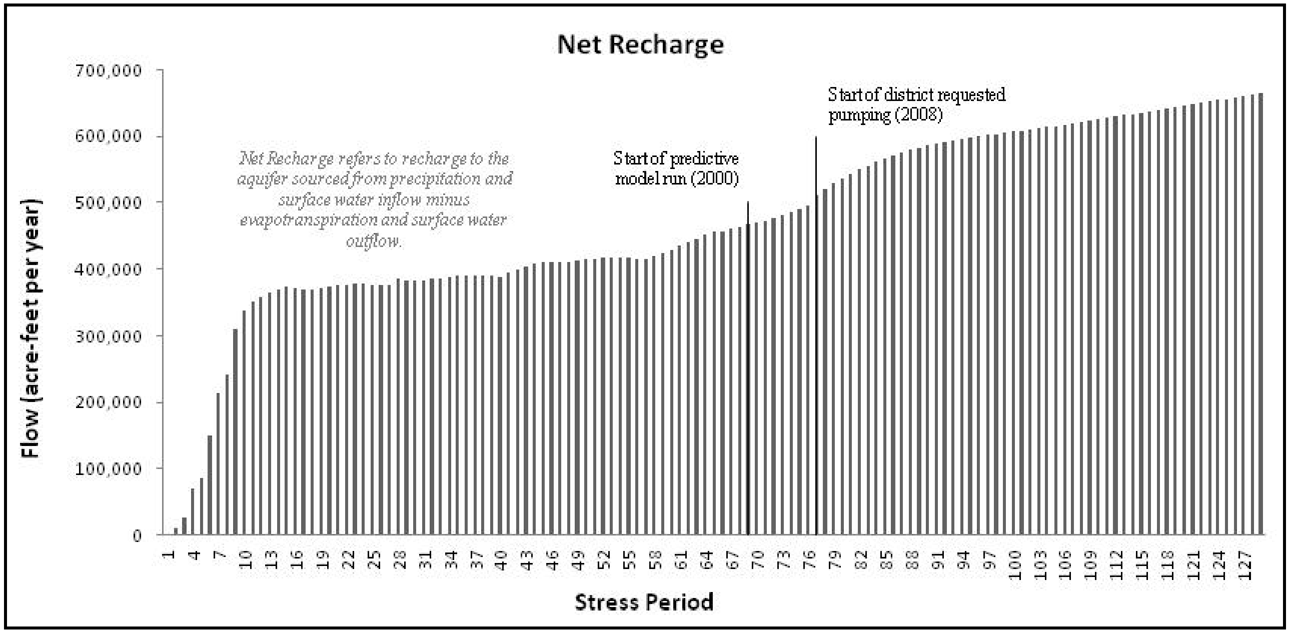



**Figure 1: Net Recharge to Groundwater Management Area 14 for each stress period in the groundwater availability model for the northern portion of the Gulf Coast Aqufier.**

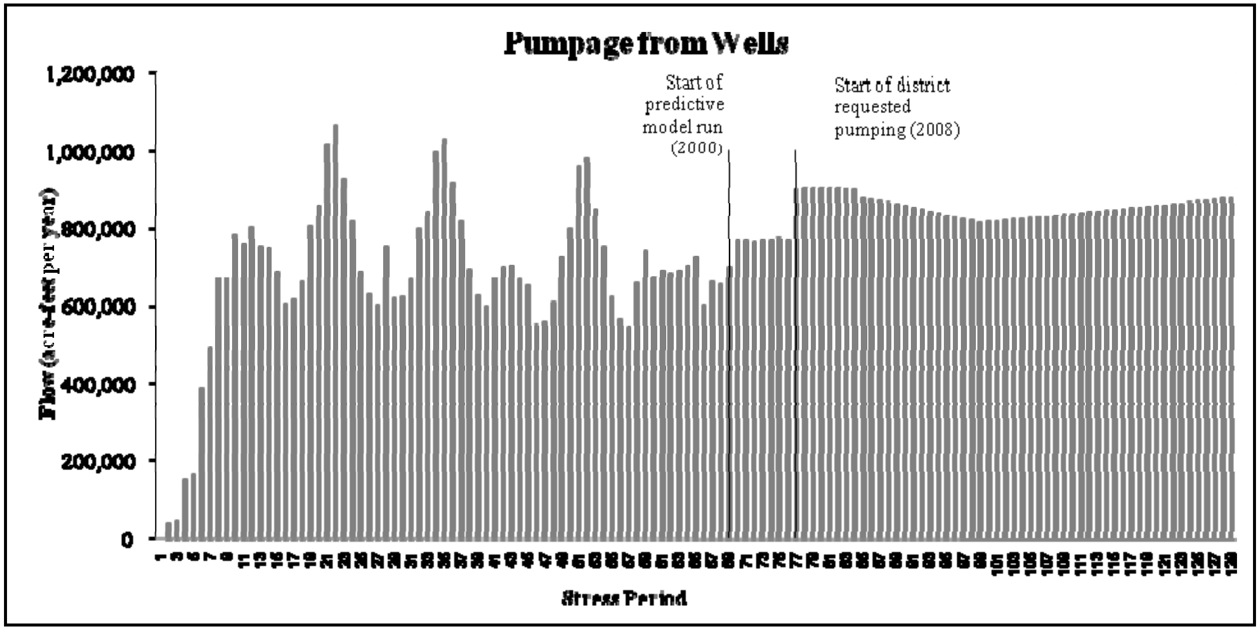



**Figure 2: Pumpage output from the groundwater availability model for the northern portion of the Gulf Coast Aquifer for each stress period in Groundwater Management Area 14.**

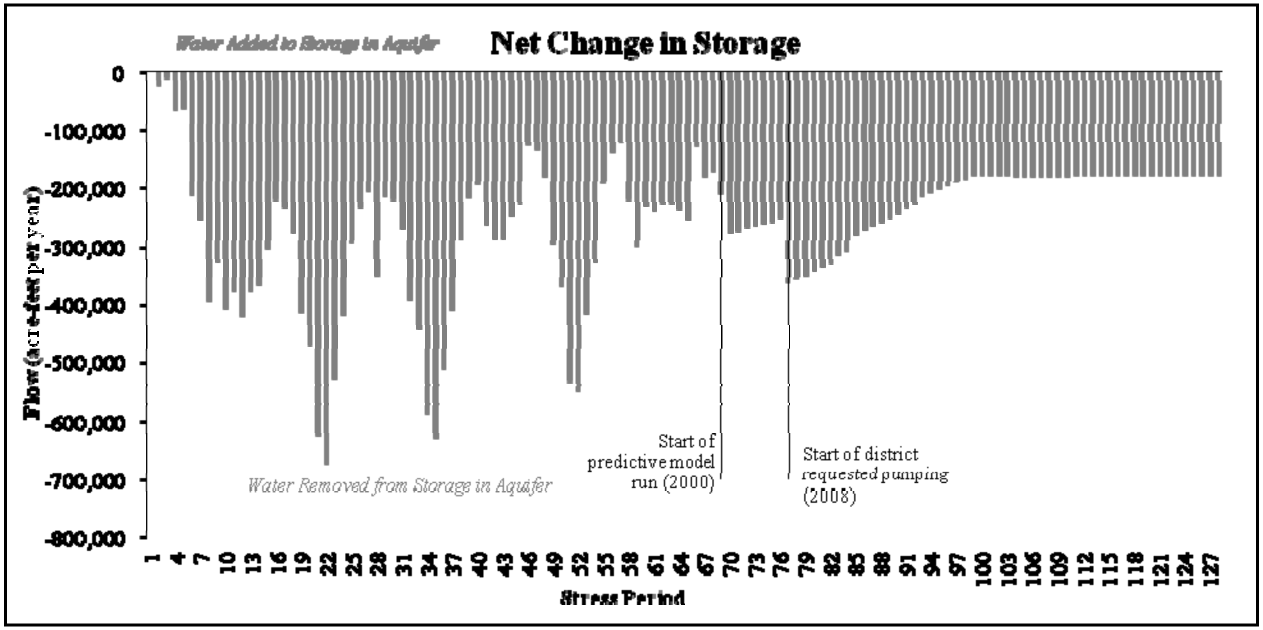



**Figure 3: Net change in the storage in the groundwater availability model for the northern portion of the Gulf Coast Aquifer for each stress period in Groundwater Management Area 14.**

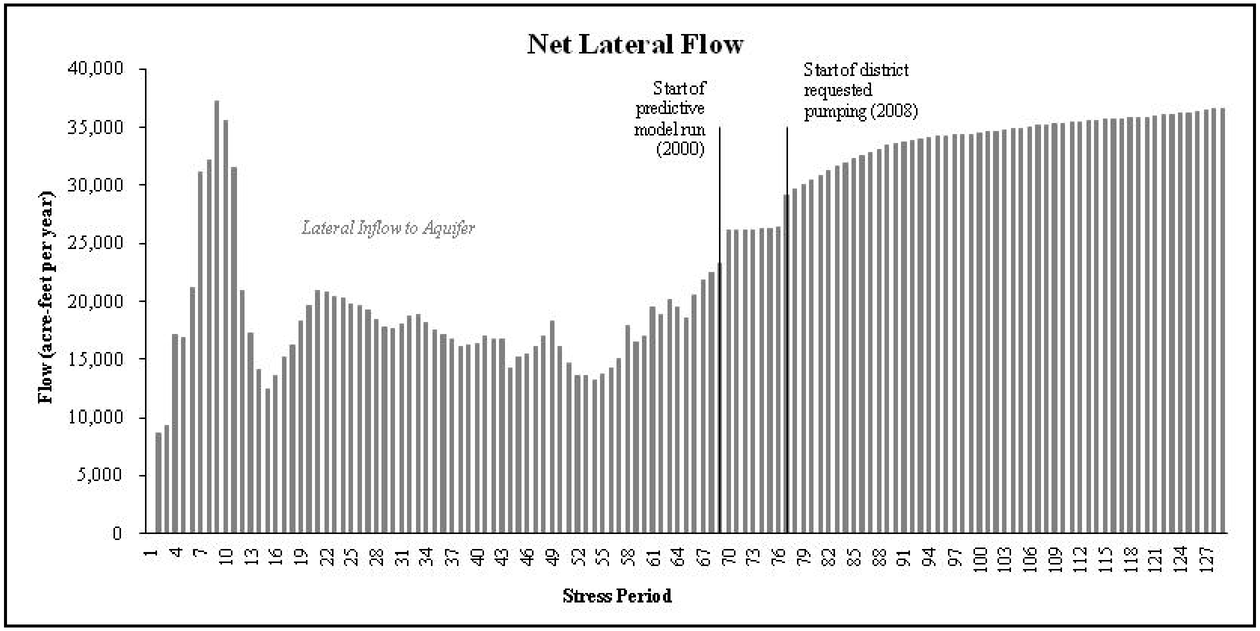



**Figure 4: Net lateral flow into or out of Groundwater Management Area 14 for each stress period in the groundwater availability model for the northern portion of the Gulf Coast Aquifer.**

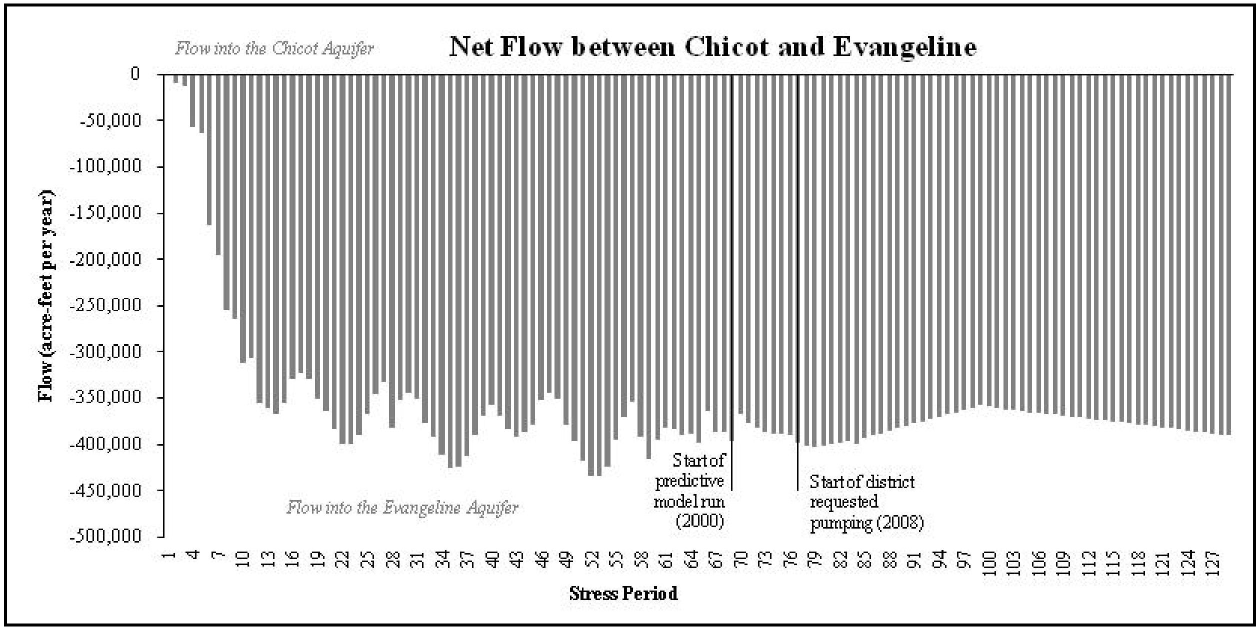



**Figure 5: Net vertical flow between Chicot and Evangeline aquifers in Groundwater Management Area 14 for each stress period in the groundwater availability model for the northern portion of the Gulf Coast Aquifer.**

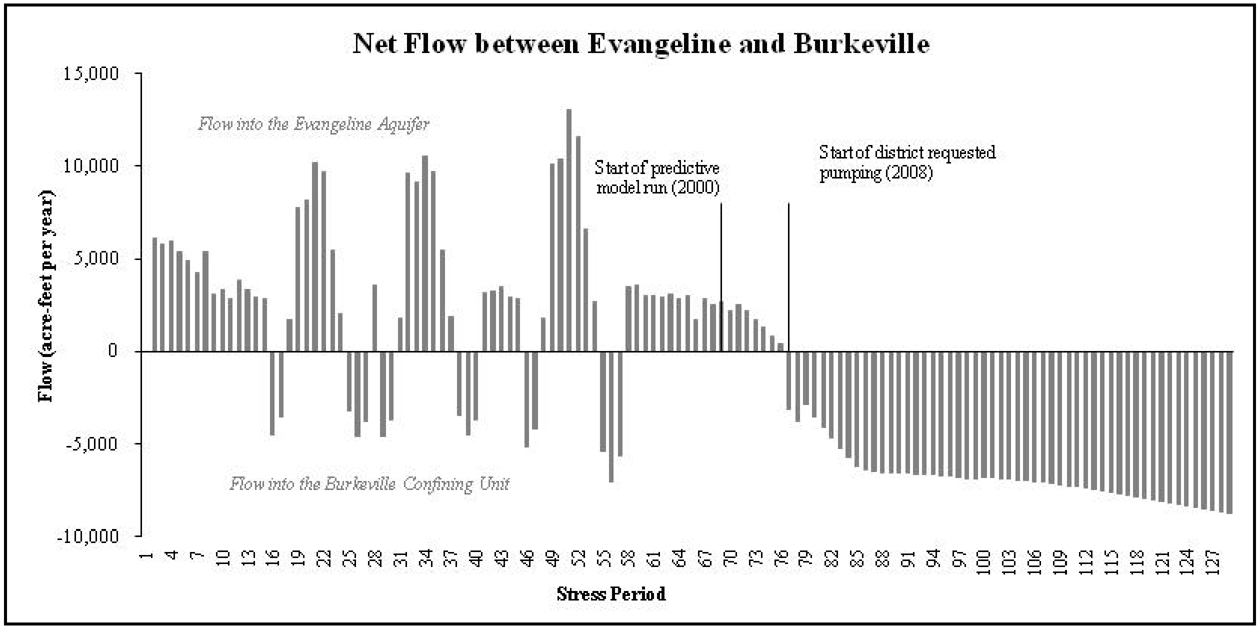



**Figure 6: Net vertical flow between Evangeline Aquifer and Burkeville Confining Unit in Groundwater Management Area 14 for each stress period in the groundwater availability model for the northern portion of the Gulf Coast Aquifer.**

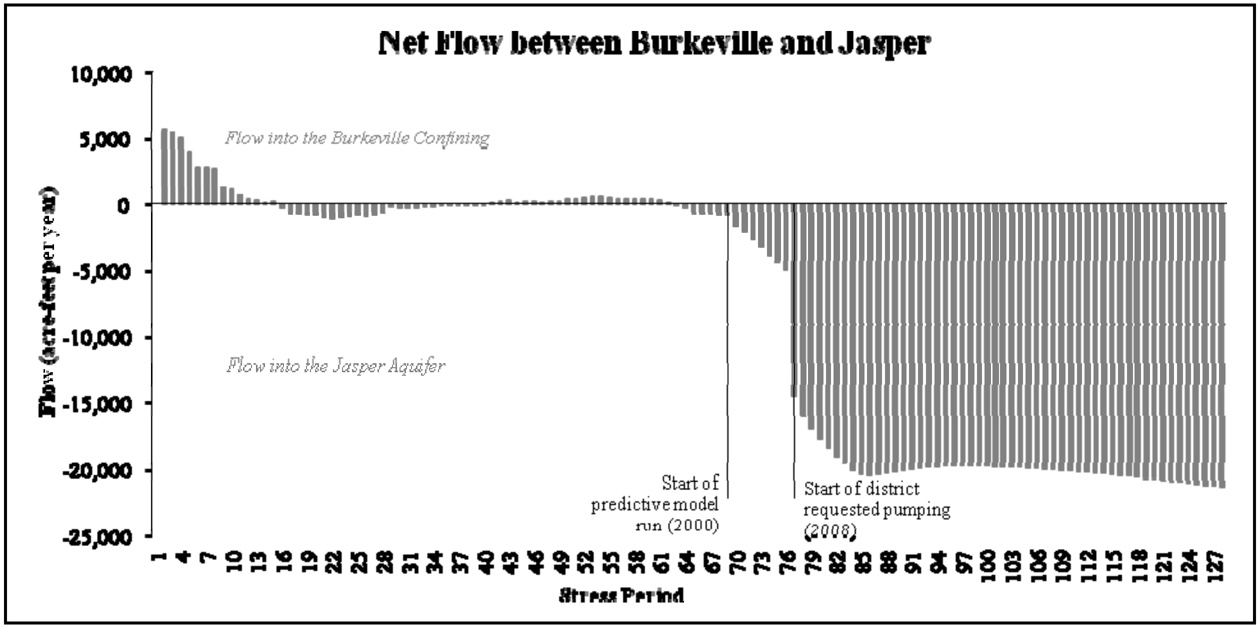



**Figure 7: Net vertical flow between Burkeville Confining Unit and Jasper Aquifer Aquifer in Groundwater Management Area 14 for each stress period in the groundwater availability model for the northern portion of the Gulf Coast Aquifer.**

# Appendix A

# Memorandum from AECOM to Groundwater Mangement Area 14

AECOM

**AECOM**
400 West 15th Street, Suite 500, Austin, Texas 78701
T 512.472.4519 F 512.472.7519 www.aecom.com

# Memorandum

| | |
|---|---|
| Date | January 19, 2010 |
| To | Lloyd Behm, General Manager<br>Bluebonnet Groundwater Conservation District<br>Managing Agent for Groundwater Management Area 14 |
| From | Bill Thaman, P.E. |
| Subject | Draft Desired Future Conditions of Northern Gulf Coast Aquifer |
| Distribution | Kathy Turner Jones |

## Introduction

Groundwater Management Area 14 (GMA-14) is a groundwater management area of the State of Texas as defined by Statute with responsibility for developing a desired future condition (DFC) for aquifers within an approximately 21-County area. Membership of the GMA is composed of the groundwater conservation districts (GCDs) that occur all or in part within the GMA boundary. (Fig. 1) At the request of GMA-14, AECOM developed statements describing DFCs for the portions of the northern segment of the Gulf Coast aquifer that occurs within the bounds of GMA-14. (Fig. 2)

## Methodology

The process used to develop DFCs was to establish preferred levels of pumping within the entire GMA-14 area, modify the Texas Water Development Board (TWDB) predictive Northern Gulf Coast Groundwater Availability Model (NGCGAM) accordingly, and consider whether the resulting water level changes were appropriate as DFCs. GMA-14 requested AECOM to perform all GAM runs.

As a starting point GMA-14 collected Regional Water Planning (RWP) data for each county in the GMA and presented the information to the six member GCDs and two non-voting subsidence districts. The data included availability, supply, and strategy amounts by decade, as well as population and total water demand. The GMA also collected and presented historical water use data by county. This provided the districts that did not have regulatory availabilities established to consider how their counties were represented in the State Water Plan, and how that compared to their expected level of pumping in the future.

Bluebonnet GCD (BGCD), Lone Star GCD (LSGCD), Harris-Galveston Coastal Subsidence District, and Fort Bend Subsidence District (the Subsidence Districts) previously assessed groundwater availability in the northern Gulf Coast aquifer using the TWDB groundwater availability model for the Northern Gulf Coast Aquifer (NGCGAM). There was some consideration given to the regulatory planning of other districts in these assessments, but in general these were independent studies. From these assessments BGCD, LSGCD, and the subsidence districts were comfortable recommending preferred levels of pumping to GMA-14.

Brazoria County GCD and Lower Trinity GCD had not established regulatory availabilities and decided to move forward with the 2006 RWP availabilities as their preferred levels of withdrawals in the GMA-14 process. Southeast Texas GCD (STGCD) submitted a GAM run request to TWDB with their preferred levels of withdrawal. Brazos Valley GCD (BVGCD), who has a small percentage of their jurisdiction within GMA, elected to not change the level of pumping in the predictive NGCGAM.

Figure 1. Boundary and GCDs of GMA-14

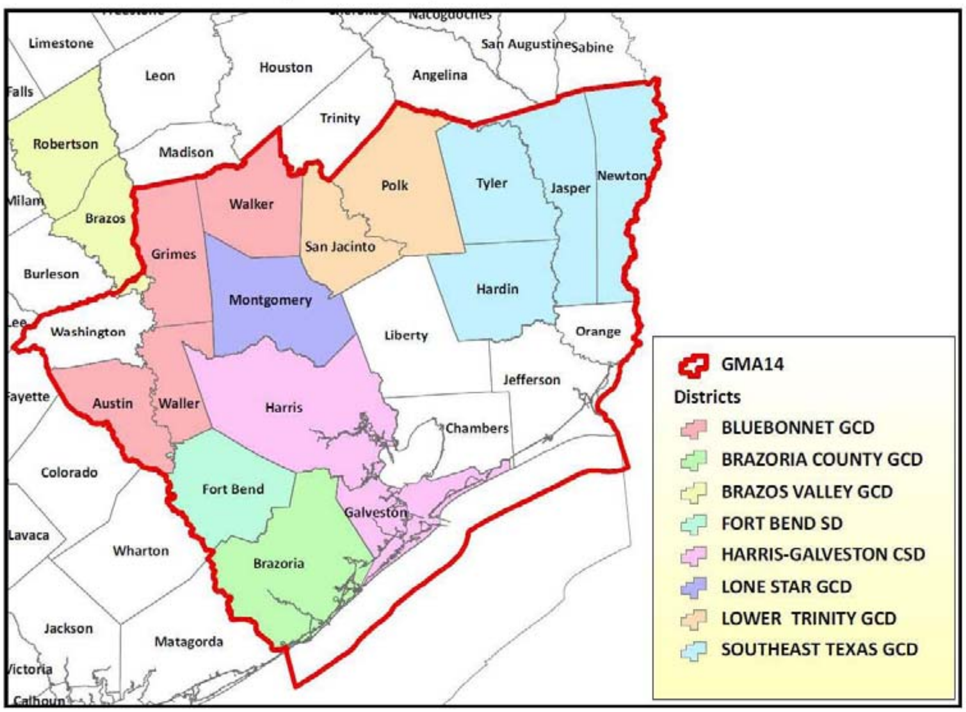
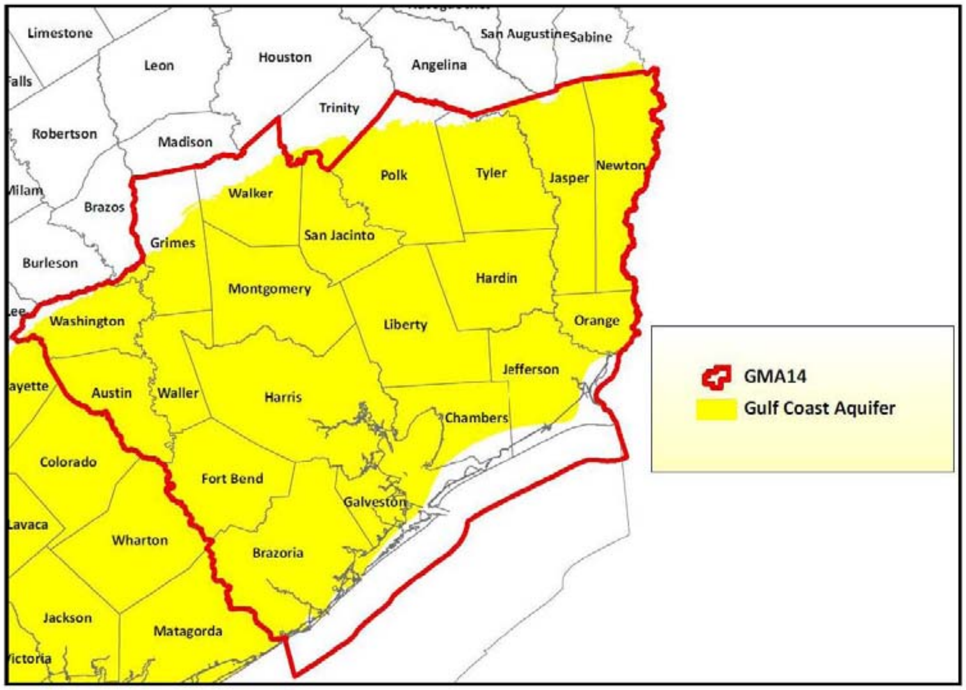


Figure 2. Gulf Coast Aquifer




## Discussion

The Gulf Coast aquifer consists of five hydrologic subdivisions. Each subdivision may consist of one or more geologic units. The GAM consists of four layers representing the Gulf Coast aquifer. Each layer represents an aquifer or a confining unit (Table 1). GAM pumpage is input by layer on an annual basis. The pumping simulated in the GAM may be changed within each layer individually, if desired, for a specific GAM run.

AECOM obtained the predictive NGCGAM dataset (Groundwater Vistas format) from TWDB that simulates pumpage through the year 2060. This DFC statement is based on a GAM run in which AECOM modified the pumpage for the years 2008 through 2060 according to GMA-14 direction.

Table 1. Relationships of Stratigraphic Units to Hydrogeologic Units and GAM Layers (Kasmarek and Robinson, 2004)

| Geologic (stratigraphic) units | | | Hydrogeologic units | Model layer |
|---|---|---|---|---|
| **System** | **Series** | **Formation** | **Aquifers and confining units** | |
| Quaternary | Holocene | Alluvium | Chicot aquifer | 1 |
| | Pleistocene | Beaumont Clay | | |
| | | Montgomery Formation | | |
| | | Bentley Formation | | |
| | | Willis Sand | | |
| Tertiary | Pliocene | Goliad Sand | Evangeline aquifer | 2 |
| | Miocene | Fleming Formation | Burkeville confining unit | 3 |
| | | Oakville Sandstone | Jasper aquifer | 4 |
| | | Catahoula Sandstone | | |
| | | Anahuac Formation[1] | Catahoula confining unit | |
| | | Frio Formation[1] | | |

## DFC Development Approach

The GMA-14 districts are in various stages of development; some have well-established regulatory plans while others have yet to adopt their first district management plan. HGCSD has developed a regulatory plan to halt subsidence and reverse historic water level declines. LSGCD has developed a regulatory plan that limits groundwater production to a sustainable level. BGCD has assessed various levels of pumping on water levels and is updating its management plan with that information. Each of these districts used the NGCGAM to assess impacts to water levels, and their experience was brought to the GMA-14 process.

Since there was not a single GAM run that reflects the various goals of the groundwater districts within the GMA-14 boundary, the GMA asked AECOM to develop a GAM for establishing DFCs based on district input. GMA-14 requested that each of the districts review the existing planning data and provide input as to the preferred level of pumping for the period 2008 through 2060. A summary of the preferred levels of pumping and pumping distribution is provided below:

- Lone Star GCD: The LSGCD regulatory plan requires that groundwater pumping be curtailed to 64,000 ac-ft/yr by 2016. For the years 2008-2015 the pumping is based on water demand and increases annually. From 2016-2060 total pumping is held constant at 64,000 ac-ft annually. The vertical distribution is held constant throughout this period.

- Bluebonnet GCD: BGCD provided constant levels of annual pumping for each layer of the Gulf Coast aquifer. The horizontal and vertical distribution of pumping from the TWDB predictive NGCGAM was maintained. While Washington County is not represented by a district, BGCD coordinated with county officials and recommended that the availability in the 2006 RWP be used.

- Lower Trinity GCD: LTGCD provided constant levels of total pumping for the entire 52 year period.

- Harris-Galveston Coastal and Fort Bend Subsidence Districts: The subsidence districts preferred to use a level of pumping equal to the sum of the 2006 Region H RWP supply plus water management strategies.

- Southeast Texas GCD: STGCD pumping is same as TWDB '*GAM Run 08-80 Revised*' requested by STGCD.

- Remaining districts and unprotected counties: 2006 RWP availability was agreed upon. The horizontal and vertical distributions from the TWDB predictive NGCGMA were maintained.

This information was incorporated into the GAM and results were presented to the GMA for review. The information was presented at the county level, and included average drawdown, maximum drawdown, and maximum water level increase. The GMA accepted the results and decided to use the average water level changes in each county, and for each model layer, as the DFCs. The average water level change as calculated from the GAM results are rounded the nearest foot, and the DFCs for each GMA-14 county are stated below in whole units of feet of drawdown over a specific period of time. A positive drawdown indicates a water level decline over the stated period; a negative drawdown indicates a water level increase. Since the stated drawdowns are rounded to the nearest foot, the drawdowns calculated from GAM results can differ by ±0.5 ft.

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## GMA-14 Desired Future Conditions for the Northern Gulf Coast Aquifer

**Austin County (BGCD)**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 17 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 8 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 8 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 14 feet after 52 years.

**Brazoria County (BCGCD)**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 17 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 18 feet after 52 years.

**Brazos County (BVGCD)**

- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 3 feet after 52 years.

**Chambers County**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 23 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 20 feet after 52 years.

**Fort Bend County (FBSD)**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 11 feet after 12 years.
- From estimated year 2020 conditions, the average draw down of the Chicot aquifer should not exceed approximately 1 feet after 10 years.
- From estimated year 2030 conditions, the average draw down of the Chicot aquifer should not exceed approximately 3 feet after 30 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 10 feet after 12 years.
- From estimated year 2020 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 1 foot after 10 years.
- From estimated year 2030 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 4 feet after 30 years.
- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 10 feet after 52 years.

- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 37 feet after 52 years.

**Galveston County (HGCSD)**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 7 feet after 22 years.
- From estimated year 2030 conditions, the average draw down of the Chicot aquifer should not exceed approximately 5 feet after 30 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 6 feet after 22 years.
- From estimated year 2030 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 7 feet after 52 years.

**Grimes County (BGCD)**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 0 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 4 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 10 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 24 feet after 52 years.

**Hardin County (STGCD)**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 17 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 27 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 26 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 36 feet after 52 years.

**Harris County (HGCSD)**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 2 feet after 12 years.
- From estimated year 2020 conditions, the average draw down of the Chicot aquifer should not exceed approximately -6 feet after 10 years.
- From estimated year 2030 conditions, the average draw down of the Chicot aquifer should not exceed approximately -5 feet after 10 years.
- From estimated year 2040 conditions, the average draw down of the Chicot aquifer should not exceed approximately 1 foot after 10 years.

- From estimated year 2050 conditions, the average draw down of the Chicot aquifer should not exceed approximately 1 foot after 10 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately -20 feet after 22 years.
- From estimated year 2030 conditions, the average draw down of the Evangeline aquifer should not exceed approximately -3 feet after 30 years.
- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately -8 feet after 12 years.
- From estimated year 2020 conditions, the average draw down of the Burkeville confining unit should not exceed approximately -17 feet after 10 years.
- From estimated year 2030 conditions, the average draw down of the Burkeville confining unit should not exceed approximately -4 feet after 30 years.
- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 57 feet after 12 years.
- From estimated year 2020 conditions, the average draw down of the Jasper aquifer should not exceed approximately -21 feet after 10 years.
- From estimated year 2030 conditions, the average draw down of the Jasper aquifer should not exceed approximately -6 feet after 20 years.
- From estimated year 2050 conditions, the average draw down of the Jasper aquifer should not exceed approximately 2 feet after 10 years.

**Jasper County (STGCD)**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 10 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 23 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 24 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 21 feet after 52 years.

**Jefferson County**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 14 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 17 feet after 52 years.

**Liberty County**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 19 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 20 feet after 52 years.

- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 15 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 53 feet after 52 years.

**Montgomery County (LSGCD)**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 4 feet after 8 years.
- From estimated year 2016 conditions, the average draw down of the Chicot aquifer should not exceed approximately 5 feet after 44 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 12 feet after 8 years.
- From estimated year 2016 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 25 feet after 44 years.
- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 10 feet after 8 years.
- From estimated year 2016 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 22 feet after 44 years.
- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 56 feet after 8 years.
- From estimated year 2016 conditions, the average draw down of the Jasper aquifer should not exceed approximately –42 feet after 44 years.

**Newton County (STGCD)**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 9 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 20 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 22 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 18 feet after 52 years.

**Orange County**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 11 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 16 feet after 52 years.

**Polk County (LTGCD)**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 4 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 2 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 19 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 31 feet after 52 years.

**San Jacinto County (LTGCD)**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 4 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 5 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 15 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 49 feet after 52 years.

**Tyler County (STGCD)**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 3 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 16 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 19 feet after 52 years.

- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 33 feet after 52 years.

**Walker County (BGCD)**

- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 8 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 5 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 30 feet after 52 years.

**Waller County (BGCD)**

- From estimated year 2008 conditions, the average draw down of the Chicot aquifer should not exceed approximately 7 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 4 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 5 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 23 feet after 52 years.

**Washington County**

- From estimated year 2008 conditions, the average draw down of the Evangeline aquifer should not exceed approximately 1 foot after 52 years.
- From estimated year 2008 conditions, the average draw down of the Burkeville confining unit should not exceed approximately 17 feet after 52 years.
- From estimated year 2008 conditions, the average draw down of the Jasper aquifer should not exceed approximately 14 feet after 52 years.

# Appendix B

# Memorandum from Reem Zoun (AECOM) to TWDB

**AECOM**
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## Memorandum

| | |
|---|---|
| Date | January 19, 2010 |
| To | Wade Oliver, Texas Water Development Board |
| From | Reem Zoun, PE |
| Subject | Northern Gulf Coast GAM Run for GMA 14 |

| | |
|---|---|
| Distribution | Lloyd Behm, Bluebonnet Groundwater Conservation District |
| | Kathy Jones, Lone Star Groundwater Conservation District |

The following memo outlines the assumptions, modifications and results of the simulation of Northern Gulf Coast Groundwater Availability Model (NGCGAM) performed at request of Groundwater Management Area 14 (GMA14). The simulation was performed by AECOM in support of GMA14 planning process.

### Parameters and Assumptions:

- Model and Pumpage files from Northern Gulf Coast GAM Run 08-80 Revised, requested by Southeast Texas GCD and performed by Texas Water Development Board (TWDB), was utilized for this simulation.
- Updates were made to Pumpage (wel) file of the model. All other parameters of the model remained unchanged.
- Groundwater Vistas version 5.33 Build 21 (Environmental Simulations, Inc., 2007) was utilized as the interface to process model output.
- The model includes four layers representing the Chicot Aquifer (Layer 1), the Evangeline Aquifer (Layer 2), the Burkeville Confining Unit (Layer 3), and the Jasper Aquifer (Layer 4).
- The model contains 129 individual stress periods (sp) representing the calibration and predictive time periods. Predictive time period extends from 2000 to 2060 (sp 69 to sp 129).

### Pumpage:

The Pumpage file was received from Wade Oliver at TWDB through ftp site transfer on November 5, 2009. Starting with this pumpage file, pumpage values were updated for the GMA14 counties using Model Grid Cell assignments generated by TWDB.

Pumpage values were updated starting in 2008 through 2060 for all GMA14 counties except Montgomery and the Southeast Texas GCD counties. Update for Montgomery County extends from 2000 through 2060 (details follows). Pumpage for Southeast Texas GCD Counties were not changed as requested by the GCD.

Spatial and vertical distributions of pumpage from the TWDB predictive NGCGMA were left unchanged except for Montgomery County. For Montgomery County, spatial distribution of pumpage was updated based on Lone Star GCD (LSGCD) Facility Planning Study starting 2000 through 2060.

GMA-14 requested that each of the groundwater districts in its jurisdiction review the existing planning data and provide input as to the preferred level of pumping for the period 2008 through 2060. District inputs were utilized for the NGCGAM simulation where available; elsewhere Regional Water Planning (RWP) data was used as approved by GMA14. A summary of the pumping and pumping distribution in the NGCGAM simulation is provided below:

- Pumpage in the Austin, Grimes, Waller and Walker Counties are based on values requested by Bluebonnet GCD (BBGCD). BBGCD requested constant levels of total pumping for the entire 52 year period of 2008 through 2060. The requested Pumpage values are listed in *Table 1*.
- Pumpage in Brazos County ranges from 4,116 ac-ft/yr to 4,229 ac-ft/yr in the years 2008 to 2060. These numbers are higher than the availability value in 2006 Region G Water Plan (RWP) which is 1,177 ac-ft/yr. Initially pumpage for Brazos County in GMA 14 was updated to 1,177 ac-ft/yr, availability value from RWP. Since this number was significantly lower than existing Pumpage in the TWDB model, it was later decided to have a Pumpage value closer to existing TWDB model Pumpage. Brazos pumpage in the model is updated to 4,150 ac-ft/yr from 2008 through 2060.
- Pumpage in Fort Bend, Galveston and Harris counties are based on the sum of supply and strategy values in the 2006 Region H Water Plan. Sum of supply and strategy values for 2010 was assigned to 2008, 2009 and 2010. Pumpage for 2020, 2030, 2040, 2050 and 2060 were updated with supply plus strategy values of the respective years and interpolated for the years in between.
- Pumpage in Hardin, Jasper, Newton and Tyler Counties are same as GAM Run 08-80 Revised, requested by Southeast Texas GCD and performed by TWDB.
- Pumpage in Jefferson, Liberty, Orange and Washington Counties are updated based on RWP availability numbers for the years 2008 through 2060.
- Pumpage in Montgomery County is updated based on Lone Star GCD Facility Planning study performed by AECOM. For this County, pumpage values and spatial distribution of pumpage are updated starting 2000 through 2060. Pumpage amounts from 2000 to 2015 are based on 'Montgomery County Surface Water Conversion aquifer Study', February 2008. In this study, Pumpage values for Montgomery County are based on Region H water demands that are supplied by groundwater for 2000 through 2010 and are adjusted for desired Woodlands demand for subsequent years. The LSGCD regulatory plan requires that groundwater pumping be curtailed to 64,000 ac-ft/yr by 2016. From 2016-2060 total

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pumping is held constant at 64,000 ac-ft annually. The vertical distribution is held constant throughout this period.

- Pumpage in the Polk and San Jacinto Counties are based on values requested by Lower Trinity GCD (LTGCD). The requested Pumpage values are listed in *Table 1*. LTGCD requested constant levels of total pumping for the entire 52 year period of 2008 through 2060.

The Pumpage values for the GMA14 counties are listed in *Table 1*.

**Table 1 Pumpage Values in Northern Gulf Coast GAM Run for GMA14**

| County Name | County Number | Layer | Stress Period [1] | Target Pumpage (ac-ft/yr) | Source |
|---|---|---|---|---|---|
| AUSTIN | 8 | 1 | 77 | 1,300 | Bluebonnet GCD |
| AUSTIN | 8 | 2 | 77 | 20,000 | Bluebonnet GCD |
| AUSTIN | 8 | 3 | 77 | 0 | Bluebonnet GCD |
| AUSTIN | 8 | 4 | 77 | 1,000 | Bluebonnet GCD |
| BRAZORIA | 20 | | 77 | 50400 | Availability |
| BRAZOS | 21 | | 77 | 4,150 | |
| CHAMBERS | 36 | | 77 | 23,001 | Availability |
| FORT BEND | 79 | | 77 | 113,855 | 2010 Supply plus strategy |
| FORT BEND | 79 | | 78 | 113,855 | 2010 Supply plus strategy |
| FORT BEND | 79 | | 79 | 113,855 | 2010 Supply plus Strategy |
| FORT BEND | 79 | | 89 | 108,633 | 2020 Supply plus Strategy |
| FORT BEND | 79 | | 99 | 92,016 | 2030 Supply plus Strategy |
| FORT BEND | 79 | | 109 | 92,110 | 2040 Supply plus Strategy |
| FORT BEND | 79 | | 119 | 92,252 | 2050 Supply plus Strategy |
| FORT BEND | 79 | | 129 | 92,429 | 2060 Supply plus Strategy |
| GALVESTON | 84 | | 77 | 4,814 | 2010 Supply plus strategy |
| GALVESTON | 84 | | 78 | 4,814 | 2010 Supply plus strategy |
| GALVESTON | 84 | | 79 | 4,814 | 2010 Supply plus Strategy |
| GALVESTON | 84 | | 89 | 5,299 | 2020 Supply plus Strategy |
| GALVESTON | 84 | | 99 | 5,909 | 2030 Supply plus Strategy |
| GALVESTON | 84 | | 109 | 5,881 | 2040 Supply plus Strategy |
| GALVESTON | 84 | | 119 | 5,855 | 2050 Supply plus Strategy |
| GALVESTON | 84 | | 129 | 5,856 | 2060 Supply plus Strategy |
| GRIMES | 93 | 2 | 77 | 3,000 | Bluebonnet GCD |
| GRIMES | 93 | 4 | 77 | 11,000 | Bluebonnet GCD |
| HARDIN | 100 | | 77 | 19,498 | Southeast TX GCD [2] |
| HARRIS | 101 | | 77 | 305,349 | 2010 Supply plus strategy |
| HARRIS | 101 | | 78 | 305,349 | 2010 Supply plus strategy |
| HARRIS | 101 | | 79 | 305,349 | 2010 Supply plus Strategy |
| HARRIS | 101 | | 89 | 262,774 | 2020 Supply plus Strategy |
| HARRIS | 101 | | 99 | 209,239 | 2030 Supply plus Strategy |
| HARRIS | 101 | | 109 | 209,891 | 2040 Supply plus Strategy |
| HARRIS | 101 | | 119 | 210,540 | 2050 Supply plus Strategy |

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| County Name | County Number | Layer | Stress Period [1] | Target Pumpage (ac-ft/yr) | Source |
|---|---|---|---|---|---|
| HARRIS | 101 | | 129 | 210,838 | 2060 Supply plus Strategy |
| JASPER | 121 | | 77 | 49,966 | Southeast TX GCD [2] |
| JEFFERSON | 123 | | 77 | 2,500 | Availability |
| LIBERTY | 146 | | 77 | 43,221 | Availability |
| MONTGOMERY | 170 | | 69 | 55,701 | LSGCD Baseline Run [3] |
| MONTGOMERY | 170 | | 70 | 57,662 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 71 | 59,623 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 72 | 61,584 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 73 | 63,545 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 74 | 65,506 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 75 | 67,467 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 76 | 69,428 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 77 | 71,389 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 78 | 73,350 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 79 | 75,311 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 80 | 77,786 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 81 | 80,262 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 82 | 82,737 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 83 | 85,212 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 84 | 87,688 | LSGCD Baseline Run |
| MONTGOMERY | 170 | | 85 | 64,000 | Pumpage from LSGCD Facility Plan |
| NEWTON | 176 | | 77 | 15,914 | Southeast TX GCD [2] |
| ORANGE | 181 | | 77 | 20,000 | Availability |
| POLK | 187 | | 77 | 36,717 | Lower Trinity GCD |
| SAN JACINTO | 204 | | 77 | 20,965 | Lower Trinity GCD |
| TYLER | 229 | | 77 | 16,245 | Southeast TX GCD [2] |
| WALKER | 236 | 2 | 77 | 2,000 | Bluebonnet GCD |
| WALKER | 236 | 4 | 77 | 16,000 | Bluebonnet GCD |
| WALLER | 237 | 1 | 77 | 300 | Bluebonnet GCD |
| WALLER | 237 | 2 | 77 | 41,000 | Bluebonnet GCD |
| WALLER | 237 | 4 | 77 | 300 | Bluebonnet GCD |
| WASHINGTON | 239 | | 77 | 13,036 | Availability |

[1] Stress Periods 69, 77, 79, 89, 99, 109, 119 & 129 represent years 2000, 2008, 2010, 2020, 2030, 2040, 2050 and 2060 respectively.
[2] Pumpage values remain unchanged from TWDB GAM Run 08 -80 Revised.
[3] '*Montgomery County Surface Water Conversion aquifer Study*', February 2008

## Results:

Results from this simulation were utilized to develop DFC statements for GMA 14. Average drawdown (decline in water levels from 2008) for each county in Groundwater Management Area 14 for Chicot, Evangeline and Jasper Aquifers are listed in *Table 2, Table 3* and *Table 4* respectively.

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A positive drawdown indicates a water level decline over the stated period; a negative drawdown indicates an increase in water levels. Since the stated drawdowns are rounded to the nearest foot, the drawdowns calculated from GAM results can differ by ±0.5 ft.

**Table 2 Average Water Level Change in Chicot Aquifer for each County in GMA 14**

| County | Chicot: Average Water Level Change (ft) | | | | | |
|---|---|---|---|---|---|---|
| | **2008 - 2016** | **2008-2020** | **2008-2030** | **2008-2040** | **2008-2050** | **2008-2060** |
| AUSTIN | 4 | 6 | 9 | 12 | 15 | 17 |
| BRAZORIA | 5 | 7 | 11 | 13 | 15 | 17 |
| BRAZOS | -- | -- | -- | -- | -- | -- |
| CHAMBERS | 6 | 8 | 13 | 17 | 20 | 23 |
| FORT BEND | 8 | 11 | 12 | 12 | 14 | 15 |
| GALVESTON | 3 | 4 | 7 | 8 | 10 | 12 |
| GRIMES | 0 | 0 | 0 | 0 | 0 | 0 |
| HARDIN | 3 | 5 | 8 | 11 | 14 | 17 |
| HARRIS | 2 | 2 | -4 | -9 | -8 | -7 |
| JASPER | 2 | 3 | 5 | 7 | 9 | 10 |
| JEFFERSON | 4 | 5 | 8 | 10 | 12 | 14 |
| LIBERTY | 6 | 8 | 12 | 15 | 17 | 19 |
| MONTGOMERY | 4 | 5 | 7 | 8 | 8 | 9 |
| NEWTON | 2 | 3 | 4 | 6 | 7 | 9 |
| ORANGE | 3 | 4 | 6 | 8 | 10 | 11 |
| POLK | 2 | 2 | 3 | 3 | 4 | 4 |
| SAN JACINTO | 2 | 3 | 3 | 4 | 4 | 4 |
| TYLER | 0 | 1 | 1 | 2 | 2 | 3 |
| WALKER | 0 | 0 | 0 | 0 | 0 | 0 |
| WALLER | 3 | 4 | 5 | 6 | 7 | 7 |
| WASHINGTON | -- | -- | -- | -- | -- | -- |

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**Table 3 Average Water Level Change in Evangeline Aquifer for each County in GMA 14**

| County | Evangeline: Average Water Level Change (ft) | | | | | |
|---|---|---|---|---|---|---|
| | **2008 - 2016** | **2008-2020** | **2008-2030** | **2008-2040** | **2008-2050** | **2008-2060** |
| AUSTIN | 2 | 3 | 5 | 6 | 7 | 8 |
| BRAZORIA | 5 | 7 | 11 | 14 | 16 | 18 |
| BRAZOS | -- | – | -- | – | -- | – |
| CHAMBERS | 4 | 6 | 11 | 14 | 17 | 20 |
| FORT BEND | 8 | 10 | 11 | 12 | 14 | 15 |
| GALVESTON | 2 | 3 | 6 | 8 | 11 | 13 |
| GRIMES | 1 | 2 | 3 | 3 | 4 | 4 |
| HARDIN | 5 | 7 | 13 | 18 | 23 | 27 |
| HARRIS | -3 | -6 | -20 | -24 | -24 | -23 |
| JASPER | 4 | 6 | 10 | 14 | 18 | 23 |
| JEFFERSON | 4 | 6 | 9 | 12 | 15 | 17 |
| LIBERTY | 6 | 8 | 12 | 15 | 18 | 20 |
| MONTGOMERY | 12 | 15 | 21 | 27 | 32 | 37 |
| NEWTON | 3 | 5 | 9 | 13 | 16 | 20 |
| ORANGE | 4 | 5 | 8 | 11 | 14 | 16 |
| POLK | 1 | 2 | 2 | 2 | 2 | 2 |
| SAN JACINTO | 2 | 3 | 4 | 4 | 4 | 5 |
| TYLER | 2 | 3 | 6 | 9 | 12 | 16 |
| WALKER | 4 | 5 | 7 | 7 | 8 | 8 |
| WALLER | 3 | 3 | 4 | 4 | 4 | 4 |
| WASHINGTON | 1 | 1 | 1 | 1 | 1 | 1 |

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**Table 4 Average Water Level Change in Jasper Aquifer for each County in GMA 14**

| County | Jasper: Average Water Level Change (ft) | | | | | |
|---|---|---|---|---|---|---|
| | **2008 - 2016** | **2008-2020** | **2008-2030** | **2008-2040** | **2008-2050** | **2008-2060** |
| AUSTIN | 10 | 12 | 12 | 12 | 13 | 14 |
| BRAZORIA | -- | – | -- | – | -- | – |
| BRAZOS | 1 | 1 | 2 | 2 | 3 | 3 |
| CHAMBERS | -- | – | -- | – | -- | – |
| FORT BEND | 36 | 47 | 41 | 36 | 36 | 37 |
| GALVESTON | -- | – | -- | – | -- | – |
| GRIMES | 15 | 13 | 14 | 17 | 21 | 24 |
| HARDIN | 13 | 17 | 21 | 26 | 31 | 36 |
| HARRIS | 63 | 57 | 36 | 30 | 30 | 32 |
| JASPER | 3 | 5 | 9 | 12 | 17 | 21 |
| JEFFERSON | -- | – | -- | – | -- | – |
| LIBERTY | 52 | 52 | 44 | 45 | 49 | 53 |
| MONTGOMERY | 56 | 14 | 1 | 3 | 8 | 14 |
| NEWTON | 3 | 4 | 7 | 11 | 14 | 18 |
| ORANGE | -- | – | -- | – | -- | – |
| POLK | 11 | 13 | 17 | 22 | 26 | 31 |
| SAN JACINTO | 35 | 30 | 32 | 37 | 43 | 49 |
| TYLER | 6 | 9 | 14 | 20 | 26 | 33 |
| WALKER | 10 | 11 | 16 | 21 | 26 | 30 |
| WALLER | 31 | 29 | 22 | 21 | 21 | 23 |
| WASHINGTON | 3 | 5 | 7 | 10 | 12 | 14 |

AECOM

cal review meeting that we were wanting the review the trends more than “target” analysis.