ANALYSIS PAPER: REVIEW OF HOUSTON AREA GROUNDWATER MODEL

by Shirley Wade, Ph.D., P.G.,
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EXECUTIVE SUMMARY:

We have reviewed the Houston Area Groundwater Model (Kasmarek, 2012) for consideration as either an updated groundwater availability model (GAM) for the northern part of the Gulf Coast Aquifer System or as an alternative model to use for Groundwater Management Area 14 joint planning.

The Houston Area Groundwater Model represents a modification and update of the Groundwater Availability Model for the northern part of the Gulf Coast Aquifer System (Kasmarek and Robinson, 2004), which is the groundwater availability model adopted by the Texas Water Development Board. That model was completed in 2004 by the United States Geological Survey (USGS) in cooperation with the Texas Water Development Board (TWDB), the Harris-Galveston Coastal Subsidence District, the City of Houston, the San Jacinto River Authority, and the Fort Bend Subsidence District. The final report and model are available on the TWDB website.

We reviewed the Houston Area Groundwater Model by compiling a set of TWDB water level data for the year 2000 from throughout the model area to compare with model results. We compared modeled water levels from the Houston Area Groundwater Model and from the original groundwater availability model for the northern part of the Gulf Coast Aquifer System against the TWDB water level data set by calculating average residuals and root mean squared errors and by charting modeled versus measured water levels. Results show the modeled water levels from the Houston Area Groundwater Model better match the set of 470 TWDB water levels than do modeled water levels from the groundwater availability model for the northern part of the Gulf Coast Aquifer System. We also compared modeled and observed water levels at hydrographs of select wells throughout the model area and both models compare well with the observations.

We observed that the Houston Area Groundwater Model did not match the year 2000 water levels in the Jasper Aquifer as well as the groundwater availability model for the northern portion of the Gulf Coast Aquifer. However, subsequent evaluations in

July 2013 by the U.S. Geological Survey show that the calibration of wells completed in the Jasper Aquifer in the Houston Area Groundwater Model reflect more reasonable groundwater levels in 2005 and 2009 compared to predictive simulations using the groundwater availability model for the northern portion of the Gulf Coast Aquifer (Attachment 1).

We plotted charts of modeled water budgets for pre-development through 2009 for the groundwater availability model for the northern part of the Gulf Coast Aquifer System using a predictive scenario simulation for 2001 to 2009 (GAM Run 10-023; Oliver, 2010) and the Houston Area Groundwater Model and both models produce similar transient water budgets.

We conclude that the Houston Area Groundwater Model is better than the Groundwater Availability Model for the northern part of the Gulf Coast Aquifer System to use for joint planning in Groundwater Management Area 14 because of the extension of the modeling period, implementation of land surface subsidence in all four layers and because of the better comparison with a set of TWDB water level data from throughout the model area for the Chicot Aquifer, Evangeline Aquifer, and Burkeville confining unit.

INTRODUCTION:

In 2012 the groundwater availability model for the northern part of the Gulf Coast Aquifer System was revised and updated by the United States Geological Survey (USGS) in cooperation with the Harris-Galveston Subsidence District, the Fort Bend Subsidence District and the Lone Star Groundwater Conservation District. Our review of the Houston Area Groundwater Model was formally requested by the Harris Galveston Subsidence District on April 15, 2013 (letter from Mr. Ron Neighbors to Mr. Larry French, Director of the Groundwater Resources Division of TWDB). This request was made on behalf of the cooperating agencies sponsoring the work including Harris Galveston Subsidence District, Fort Bend Subsidence District, Lone Star Groundwater Conservation District, and the USGS. The City of Houston, Brazoria County Groundwater Conservation District, and the North Harris Regional Water Authority also provided support to the effort. Background information, supporting documents, and electronic files were transmitted with the letter and in previous meetings (particularly the February 25, 2013 meeting between USGS personnel, Groundwater Management Area No. 14 representatives and consultants, and TWDB staff) with these organizations.

The new MODFLOW-2000 (Harbaugh and others, 2000) groundwater model, known as the Houston Area Groundwater Model (HAGM) was developed to simulate groundwater availability and land surface subsidence in the Houston area through 2009 (Kasmarek, 2012). The model calibration period was extended to 2009 to better reflect recent conditions and land surface subsidence was implemented in all four model layers rather than just in the layers representing the Chicot and Evangeline Aquifers of the Gulf Coast Aquifer System. The model was recalibrated against recent (2009) water level measurements. For water level targets located in the Houston area the root-mean-squared error of simulated heads compared with measured heads is less than 10 percent for the Chicot, Evangeline, and Jasper aquifers (Table 3; Kasmarek, 2012).

At the start of the model update project, TWDB staff indicated to the project team that several items should be considered for the update. In the original 2004 model (Kasmarek and Robinson, 2004), both precipitation recharge and groundwater/surface water interaction were modeled using the MODFLOW general head boundary package. The general head boundary represents a constant water table with no long term trends in elevation. For the historical modeling period hydrographs indicate that is a reasonable assumption (Kasmarek and Robinson, 2004). However, with the general head boundary package it is difficult to investigate the effects of long term drought and the fraction of inflow attributed to stream loss can only be roughly estimated. Consequently, TWDB staff recommended that the MODFLOW recharge package and streamflow routing or river package be used in place of the general head boundary

package for recharge and groundwater/surface water interaction. In addition, TWDB staff recommended that the model update process include public stakeholder meetings with stakeholder review of the model report. However, because of time and budget constraints these recommendations were not implemented,

This report discusses the methods and results of our review of the HAGM for consideration as either an alternative model for Groundwater Management Area 14 to use for their joint planning or as an updated TWDB groundwater availability model for the northern part of the Gulf Coast Aquifer System

METHODS:

The development and calibration of the HAGM is discussed in the USGS project report (Kasmarek, 2012). The root-mean-squared error for water level targets in the Houston from the year 2009 was 8 percent for the Chicot Aquifer and 6 percent for the Evangeline and Jasper aquifers (Table 3; Kasmarek, 2012). Simulated water level trends also match well at hydrographs located in Brazoria, Fort Bend, Galveston, Harris, and Montgomery counties (Kasmarek, 2012). However, to assess whether the model is a useful tool for Groundwater Management Area 14 we compared model simulated water levels with observed water levels for the entire northern part of the Gulf Coast Aquifer System.

For our comparison we put together a set of water level data covering the entire model area (Figure 1) from the TWDB groundwater database (TWDB, 2013). We selected the stress period representing the year 2000 so that we could also compare the water level data with the modeling results from the groundwater availability model for the northern part of the Gulf Coast Aquifer System.

We assembled all TWDB water level data collected in the year 2000 for the Gulf Coast Aquifer System in the model area. For wells with more than one measurement in the year 2000 we averaged the water levels. We eliminated data that was listed in the database as non-publishable or had remarks indicating other reasons why the measurement may not accurately reflect aquifer water levels.

We then assigned wells to model layers based on the elevations of the upper most screened interval and the lower most screened interval. If a well's screened intervals were completely within a model layer we assigned the well to that layer. We excluded wells with screened intervals extending over more than one layer. We also excluded wells where screen intervals or well bottom elevations were below the base

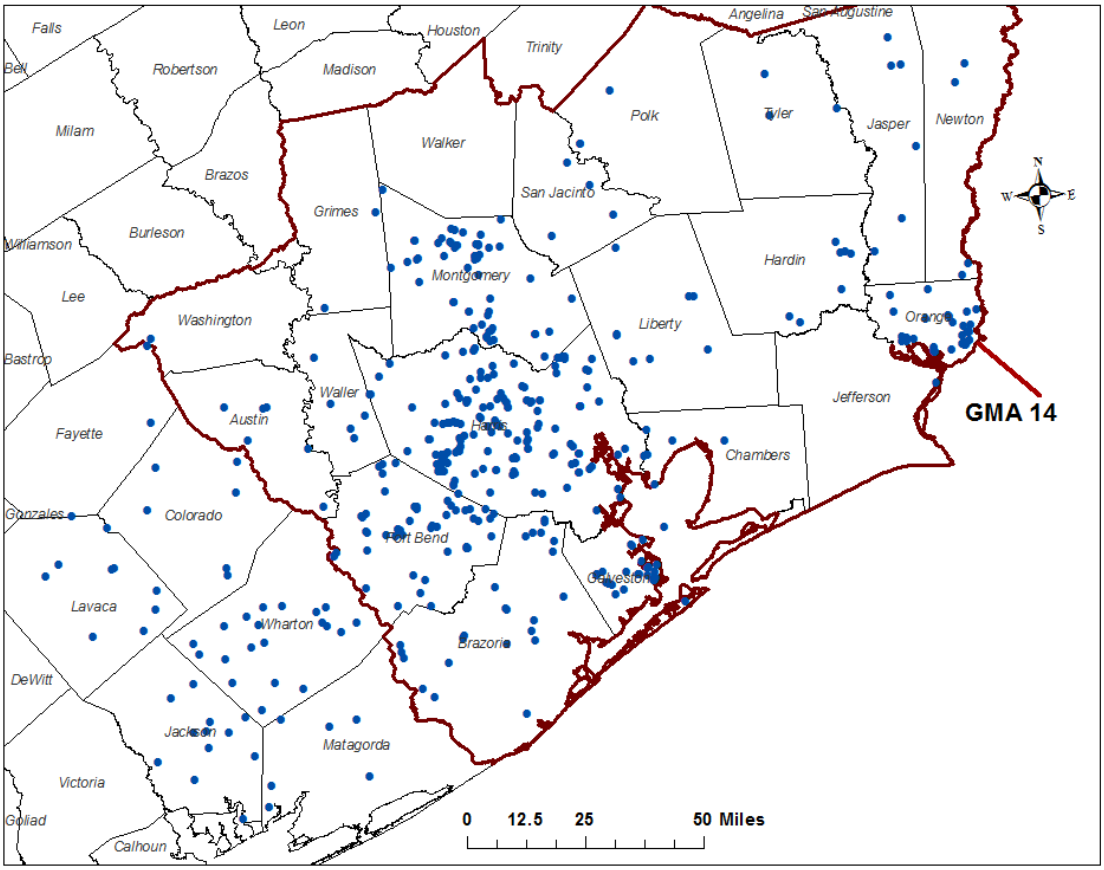


FIGURE 1 LOCATION OF WATER LEVEL OBSERVATIONS USED FOR COMPARING AGAINST MODELED WATER LEVELS.

of model layer 4 and where screen intervals were below the reported well bottom. Our final count of water level data points was 470: 254 in layer 1 (Chicot Aquifer); 145 in layer 2 (Evangeline Aquifer); 16 in layer 3 (Burkeville Confining Unit); and 45 in layer 4 (Jasper Aquifer including parts of the Catahoula Formation).

We compared the TWDB water level data set to modeled water levels from the groundwater availability model for the northern part of the Gulf Coast Aquifer System and modeled water levels from the HAGM. We calculated average residuals and root-mean-squared error which is the square root of the average squared residual. The model residual is calculated as the measured water level minus the model calculated water level. We also plotted the measured water levels versus the model calculated water levels and we plotted hydrographs located in each of the counties in the model area. As part of our review we also plotted water budgets for the model calibration period to help understand where water for pumping is coming from through time in the model. We extracted water budgets using ZONEBUDGET Version 3.01 (Harbaugh,

2009) for both the Groundwater Availability Model (GAM) for the northern part of the Gulf Coast Aquifer System and for the HAGM from the beginning of the calibration period to model year 2009. For the original GAM the water budget for the period from 2000 to 2009 is from a predictive run developed for the Groundwater Management Area 14 desired future condition analysis, GAM Run10-023 (Oliver, 2010).

RESULTS:

Water Levels and Statistics

In general, the HAGM does a better job of matching the observed water levels (Table 1). For the Chicot Aquifer, Evangeline Aquifer, and Burkeville Confining Unit (Layers 1 through 3) the root mean squared error is lower and the average residual is much closer to zero. An average residual close to zero indicates minimal bias in water level predictions. Further evaluation by the US Geological Survey provided to the TWDB (e-mail dated July 19, 2013 from Michael Turco to Larry French) shows that the HAGM results in an improved match with observed water levels in the Jasper Aquifer for the years 2005 and 2009 (Attachment 1). A plot of modeled water levels versus measured water levels shows the comparison graphically (Figures 2 and 3). Most of the modeled water levels from the groundwater availability model for the northern part of the Gulf Coast Aquifer System are greater than the observed water levels (Figure 2); whereas, for the HAGM, the modeled water levels are more evenly scattered about line with slope equal to one (Figure 3).

We also plotted maps of water levels residuals to determine whether there is a spatial bias in the residuals. Both models show the greatest residuals in Harris and Montgomery counties with some residuals exceeding +/-100 feet (Appendix A) For the remaining areas in both models the residuals are mostly between -100 and 100 feet (Appendix A).

Hydrographs for 1990 through 2009 from select wells in most counties in the modeled area are presented in Appendix B.

TABLE 1 STATISTICS FROM COMPARING MEASURED WATER LEVELS WITH MODEL CALCULATED WATER LEVELS. RMSE IS THE SQUARE ROOT OF THE AVERAGE SQUARED RESIDUAL.

Model	Aquifer or Confining Unit	Number of Measurements	Average Residual	RMSE	Range of Values	RMSE/Range
GLFC_N[1]	Chicot	254	-47.0	74.7	584	0.13
GLFC_N	Evangeline	145	-42.7	66.7	719	0.09
GLFC_N	Burkeville	16	-33.8	85.9	674	0.13
GLFC_N	Jasper	45	-24.9	41.5	433	0.10
GLFC_N	All	460	-43.0	70.1	851	0.08
HAGM[2]	Chicot	254	1.22	55.9	584	0.10
HAGM	Evangeline	145	2.10	47.1	719	0.07
HAGM	Burkeville	16	-0.30	87.6	674	0.13
HAGM	Jasper	45	-65.7	82.16	433	0.19
HAGM	All	460	-5.1	58.5	851	0.07

Water Budgets

A groundwater budget summarizes the amount of water entering and leaving the aquifer according to the groundwater model. A chart of groundwater budget components through time gives an indication of how an aquifer's recharge or discharge will change as pumping changes through time and whether water for pumping will come from storage or from increased recharge or decreased natural discharge.

For our analysis we extracted water budgets for both the groundwater availability model for the northern part of the Gulf Coast Aquifer System (Figure 4) and the HAGM (Figure 5). The calibration period for the groundwater availability model for the

[1] Groundwater Availability Model for the northern part of the Gulf Coast Aquifer
[2] Houston Area Groundwater Model

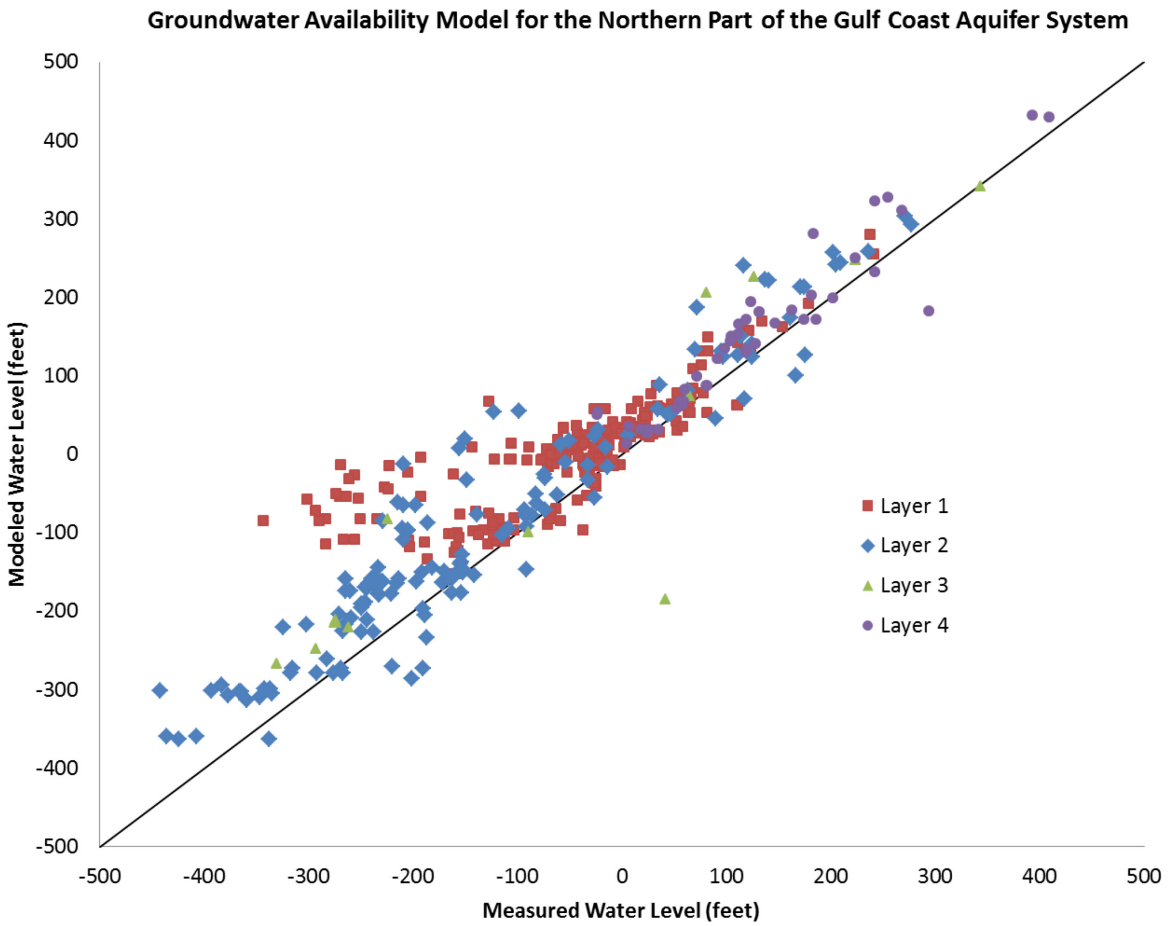


FIGURE 2 COMPARISON OF MODELED AND MEASURED WATER LEVELS IN YEAR 2000 FOR THE ORIGINAL GROUNDWATER AVAILABILITY MODEL FOR THE NORTHERN PART OF THE GULF COAST AQUIFER SYSTEM.

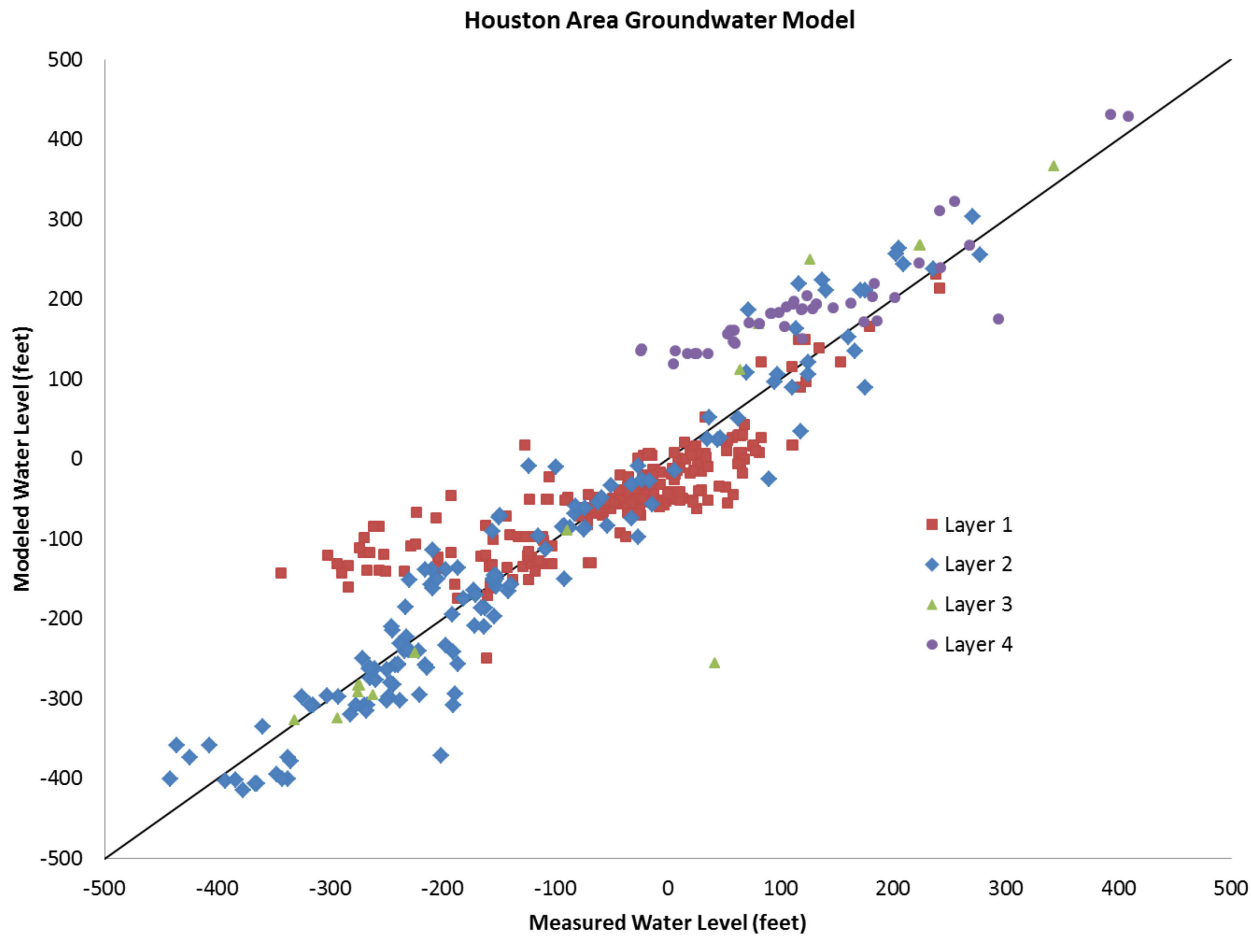


FIGURE 3 COMPARISON OF MODELED AND MEASURED WATER LEVELS IN YEAR 2000 FOR THE HOUSTON AREA GROUNDWATER MODEL.

northern part of the Gulf Coast Aquifer System ends in 2000. In order to compare the two water budgets after 2000 we used GAM Run 10-023 (Oliver, 2010). In GAM Run 10-023 TWDB staff adjusted pumping during the interim modeling period of 2000 (end of model calibration period) to 2009 (beginning of predictive period for Groundwater Management Area 14 modeling) to better match measured water levels during that period. The adjustments were made so that the model would have reasonable starting conditions prior to the predictive period.

Both models have very similar budgets through 1997 (Figures 4 and 5). When pumping was increasing through the 1960s, 1970s and 1980s a fair amount of water was extracted through inelastic storage or compaction (in). However, through time an increasing amount of water comes from recharge and surface water leakage represented by the general head boundary package (ghb). The decline in water levels represented by water coming out of storage is shown by the black line. As the line slopes down water comes out of storage (elastic). An upward slope of the line

represents water going back into storage (elastic). Note, in order to show the decline or rise in water levels using the water budget we reversed the sign of the model water budget component for storage.

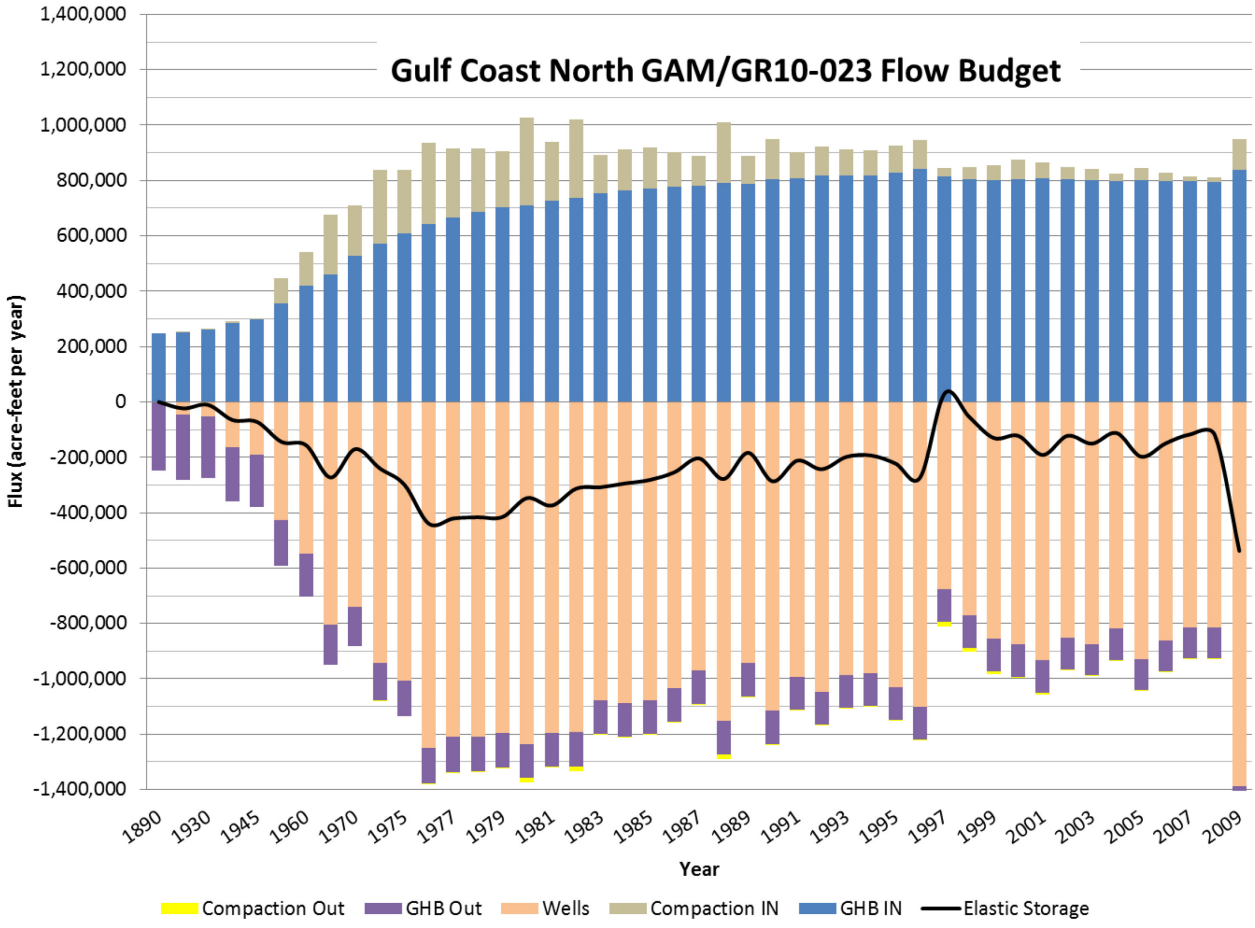


FIGURE 4 WATER BUDGET COMPONENTS EXTRACTED FROM GAM RUN (GR) 10-023 WHICH USES THE GROUNDWATER AVAILABILITY MODEL (GAM) FOR THE NORTHERN PART OF THE GULF COAST AQUIFER SYSTEM. NOTE, IN ORDER TO SHOW THE DECLINE OR RISE IN WATER LEVELS USING THE WATER BUDGET WE REVERSED THE SIGN OF THE MODEL WATER BUDGET COMPONENT FOR STORAGE.

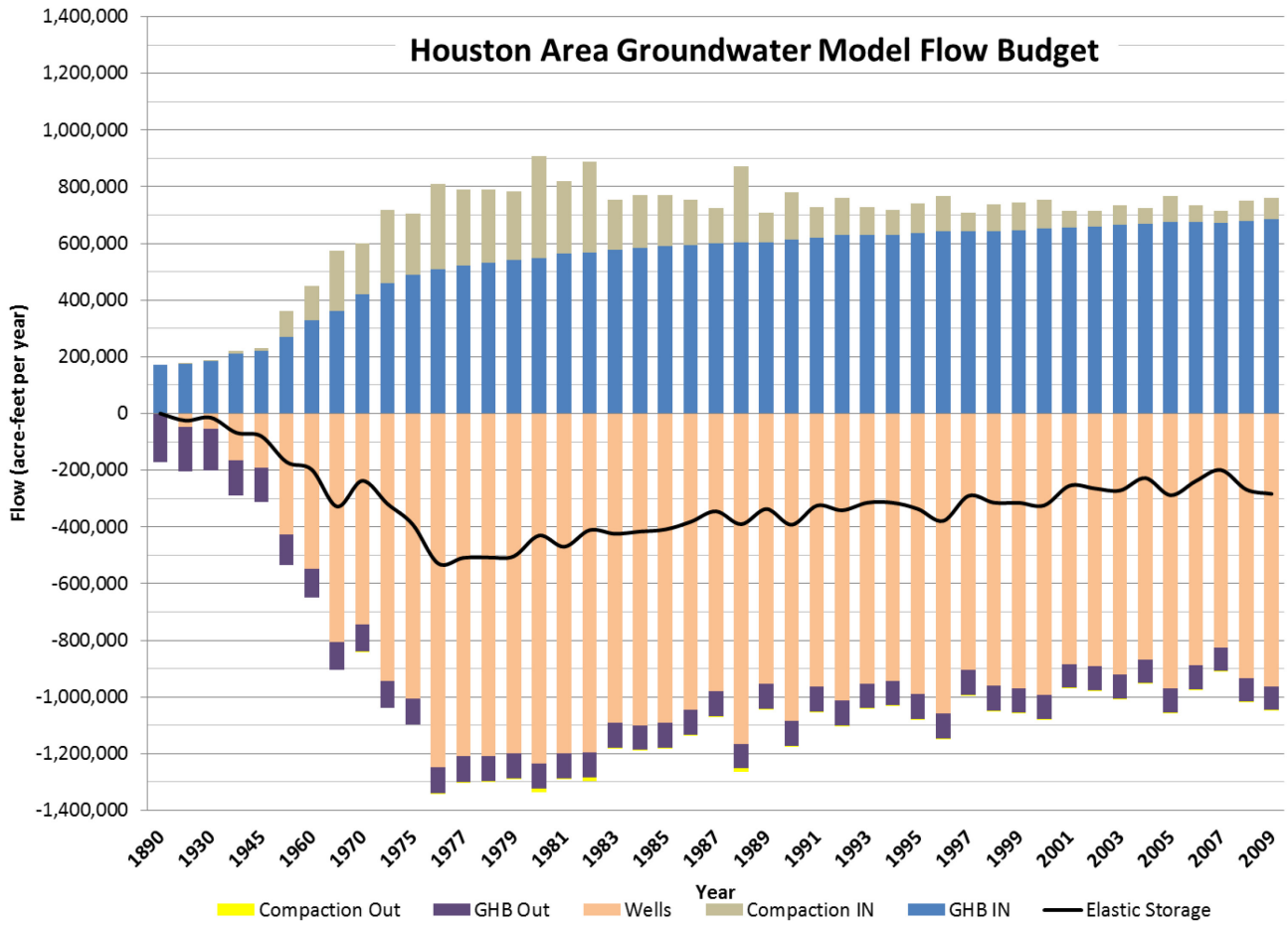


FIGURE 5 WATER BUDGET COMPONENTS EXTRACTED FROM THE HOUSTON AREA GROUNDWATER MODEL. NOTE, IN ORDER TO SHOW THE DECLINE OR RISE IN WATER LEVELS USING THE WATER BUDGET WE REVERSED THE SIGN OF THE MODEL WATER BUDGET COMPONENT FOR STORAGE.

CONCLUSIONS:

For the Houston Area Groundwater Model (HAGM) the calibration period was extended to 2009 to better reflect recent conditions and land surface subsidence was implemented in all four model layers rather than just in the layers representing the Chicot and Evangeline Aquifers of the Gulf Coast Aquifer System.

The modeled water levels from the Houston Area Groundwater Model better match a set of 470 TWDB water levels from throughout the model area than do modeled water levels from the original groundwater availability model for the northern portion of the Gulf Coast Aquifer. The average residual and root mean squared error for the Chicot and Evangeline Aquifers and the Burkeville Confining Unit are all lower for the Houston Area Groundwater Model (Table 1, Figures 2 and 3).

We observed that the Houston Area Groundwater Model did not match the year 2000 water levels in the Jasper Aquifer as well as the groundwater availability model for the northern portion of the Gulf Coast Aquifer. However, subsequent evaluations by the U.S. Geological Survey show that the calibration of wells completed in the Jasper Aquifer in the Houston Area Groundwater Model reflect more reasonable groundwater levels in 2005 and 2009 compared to predictive simulations using the groundwater availability model for the northern portion of the Gulf Coast Aquifer (Attachment 1).

The water budgets for both models are similar (Figures 4 and 5) and generally both models match hydrographs from select wells in each county equally well overall (Appendix B).

In light of the extension of the modeling period, implementation of land surface subsidence in all four layers and better comparison with a set of TWDB water level data we conclude that the Houston Area Groundwater Model is a better tool for Groundwater Management Area 14 to use for joint planning.

REFERENCES:

Harbaugh, A. W., 2009, Zonebudget Version 3.01, A computer program for computing subregional water budgets for MODFLOW ground-water flow models, U.S. Geological Survey Groundwater Software.

Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G., 2000, MODFLOW-2000, The U.S. Geological Survey modular ground-water model-User guide to modularization concepts and the ground-water flow process: U.S. Geological Survey, Open-File Report 00-92.

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: United States Geological Survey Scientific investigations Report 2004-5102, 111 p., http://www.twdb.texas.gov/groundwater/models/gam/glfc_n/GLFC_N_Full_Report.pdf.

Kasmarek, M.C., 2012, Hydrogeology and Simulation of Groundwater Flow and Land-Surface Subsidence in the Northern Part of the Gulf Coast Aquifer System, Texas, 1891-2009: United States Geological Survey Scientific investigations Report 2012-5154, 55 p.

Oliver, W., 2010, GAM Run 10-023, Texas Water Development Board, GAM Run Report, 32 p., http://www.twdb.texas.gov/groundwater/docs/GAMruns/GR10-23.pdf

TWDB (Texas Water Development Board), 2013, Groundwater Database Reports http://www.twdb.texas.gov/groundwater/data/gwdbrpt.asp, accessed May 6, 2013.

APPENDIX A: WATER LEVEL RESIDUAL MAPS

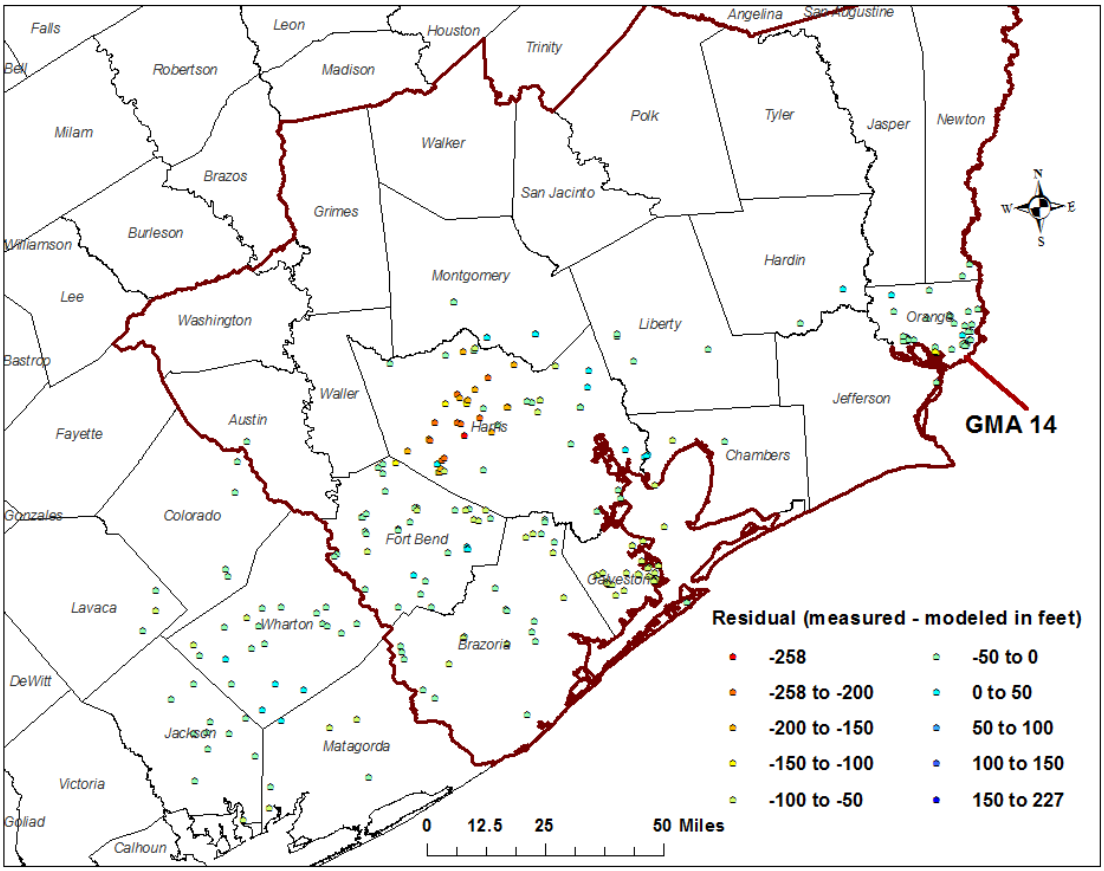


FIGURE 6 CHICOT AQUIFER (LAYER 1) WATER LEVEL RESIDUALS FOR THE YEAR 2000 FROM THE ORIGINAL GROUNDWATER AVAILABILITY MODEL FOR THE NORTHERN PART OF THE GULF COAST AQUIFER SYSTEM. NEGATIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE ABOVE THOSE MEASURED IN THE FIELD AND POSITIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE BELOW THOSE MEASURED IN THE FIELD.

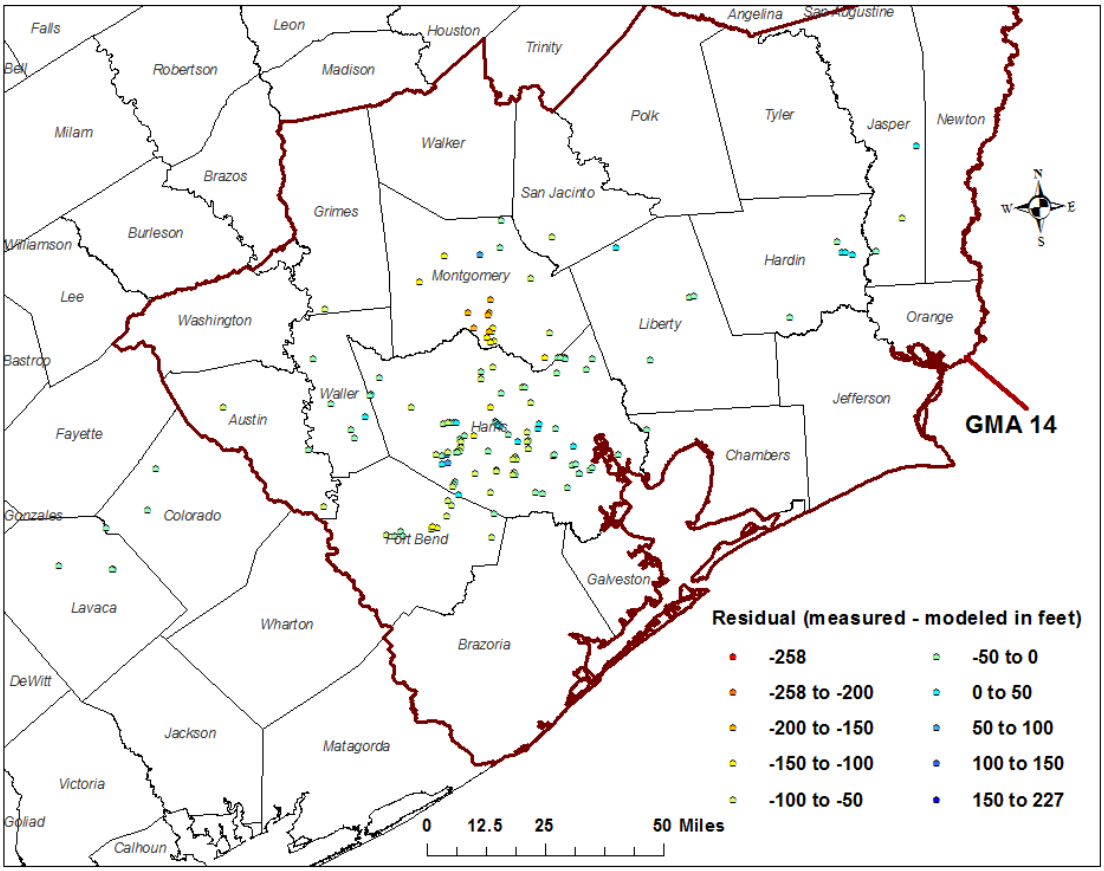


FIGURE 7 EVANGELINE AQUIFER (LAYER 2) WATER LEVEL RESIDUALS FOR THE YEAR 2000 FROM THE ORIGINAL GROUNDWATER AVAILABILITY MODEL FOR THE NORTHERN PART OF THE GULF COAST AQUIFER SYSTEM. NEGATIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE ABOVE THOSE MEASURED IN THE FIELD AND POSITIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE BELOW THOSE MEASURED IN THE FIELD.

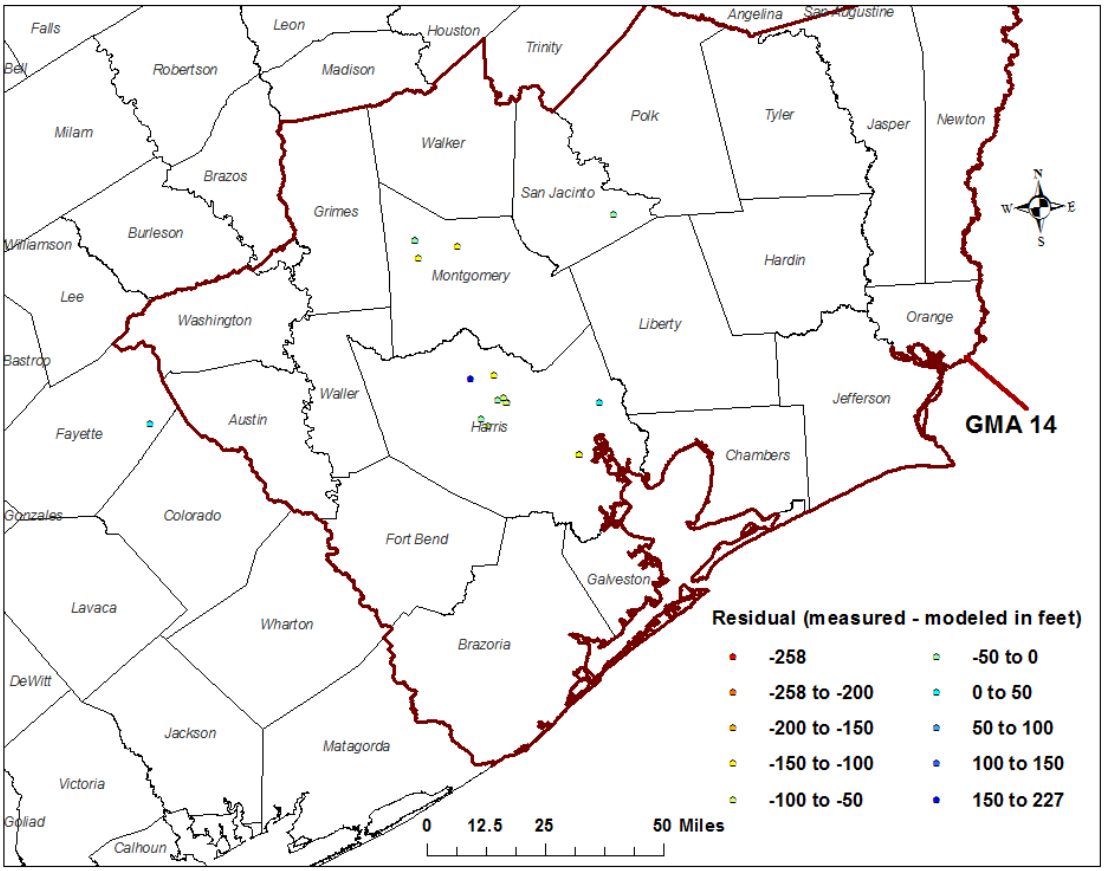


FIGURE 8 BURKEVILLE CONFINING UNIT (LAYER 3) WATER LEVEL RESIDUALS FOR THE YEAR 2000 FROM THE ORIGINAL GROUNDWATER AVAILABILITY MODEL FOR THE NORTHERN PART OF THE GULF COAST AQUIFER SYSTEM. NEGATIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE ABOVE THOSE MEASURED IN THE FIELD AND POSITIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE BELOW THOSE MEASURED IN THE FIELD.

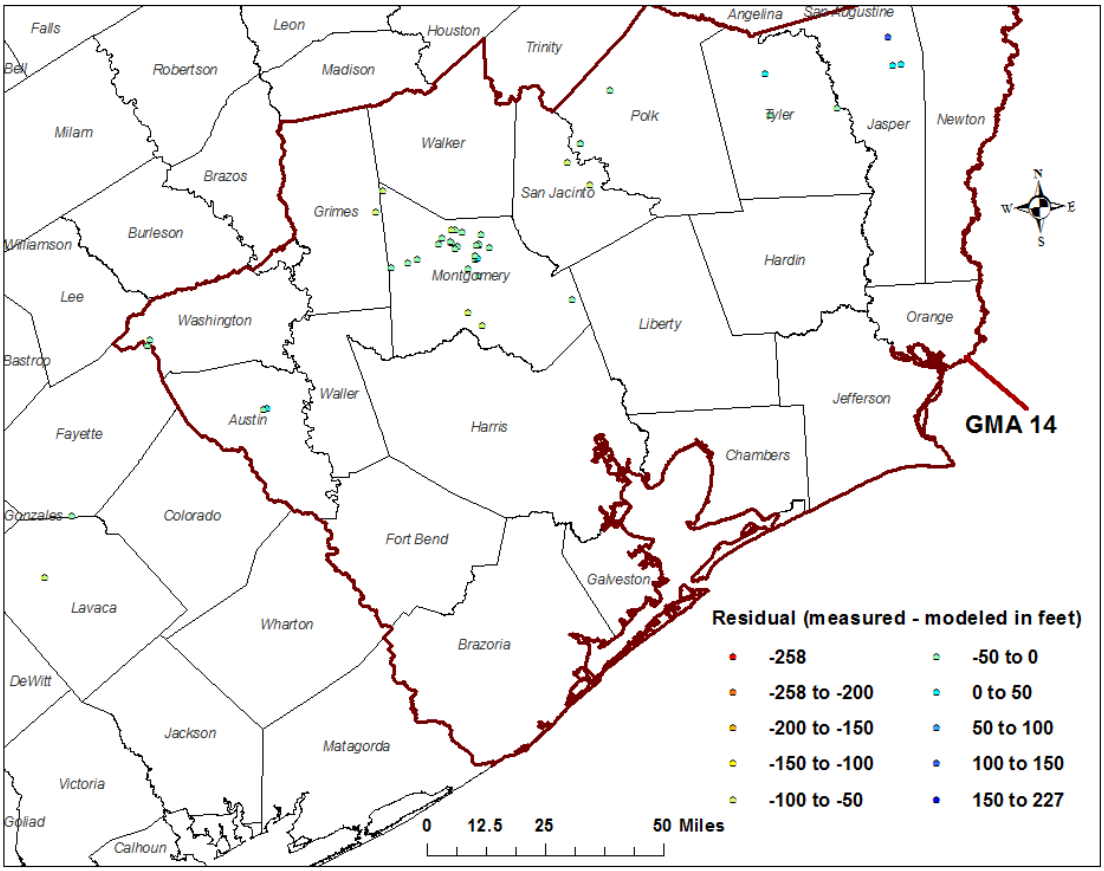


FIGURE 9 JASPER AQUIFER (LAYER 4) WATER LEVEL RESIDUALS FOR THE YEAR 2000 FROM THE ORIGINAL GROUNDWATER AVAILABILITY MODEL FOR THE NORTHERN PART OF THE GULF COAST AQUIFER SYSTEM. NEGATIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE ABOVE THOSE MEASURED IN THE FIELD AND POSITIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE BELOW THOSE MEASURED IN THE FIELD.

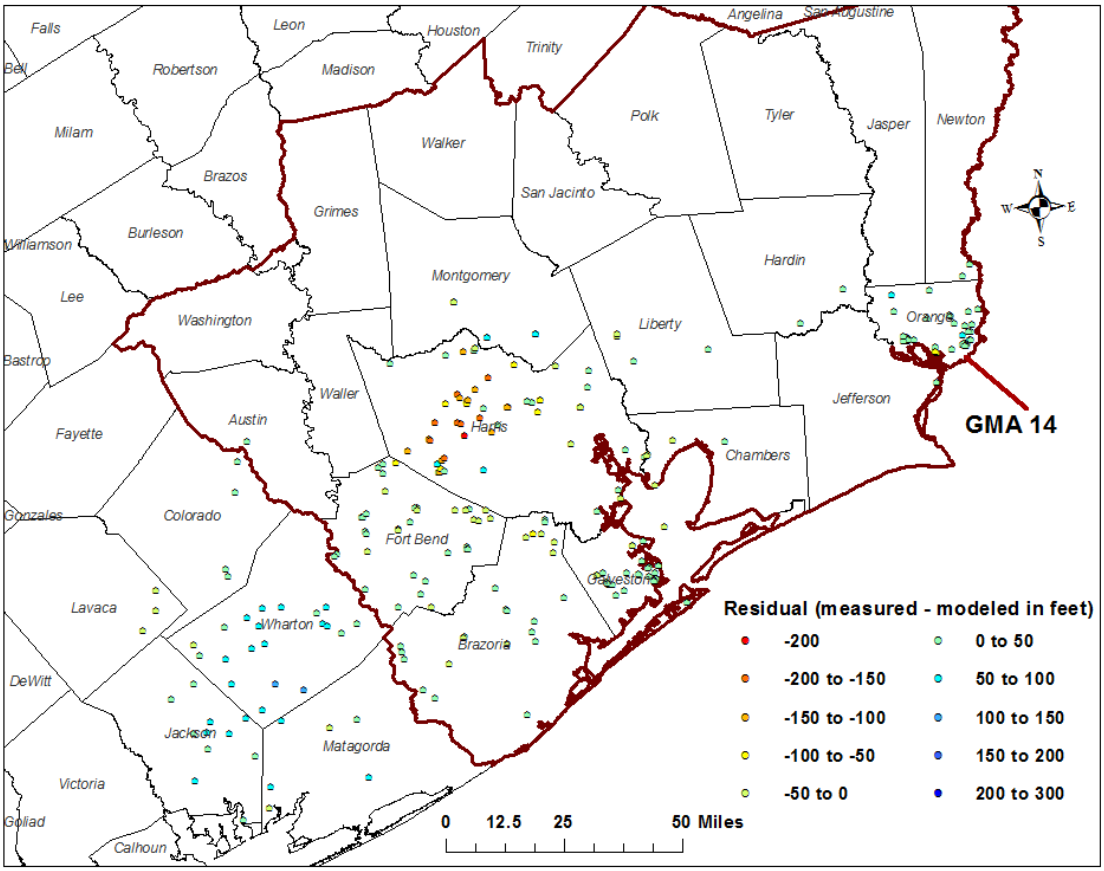


FIGURE 10 CHICOT AQUIFER (LAYER 1) WATER LEVEL RESIDUALS FOR THE YEAR 2000 FROM THE HOUSTON AREA GROUNDWATER MODEL. NEGATIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE ABOVE THOSE MEASURED IN THE FIELD AND POSITIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE BELOW THOSE MEASURED IN THE FIELD.

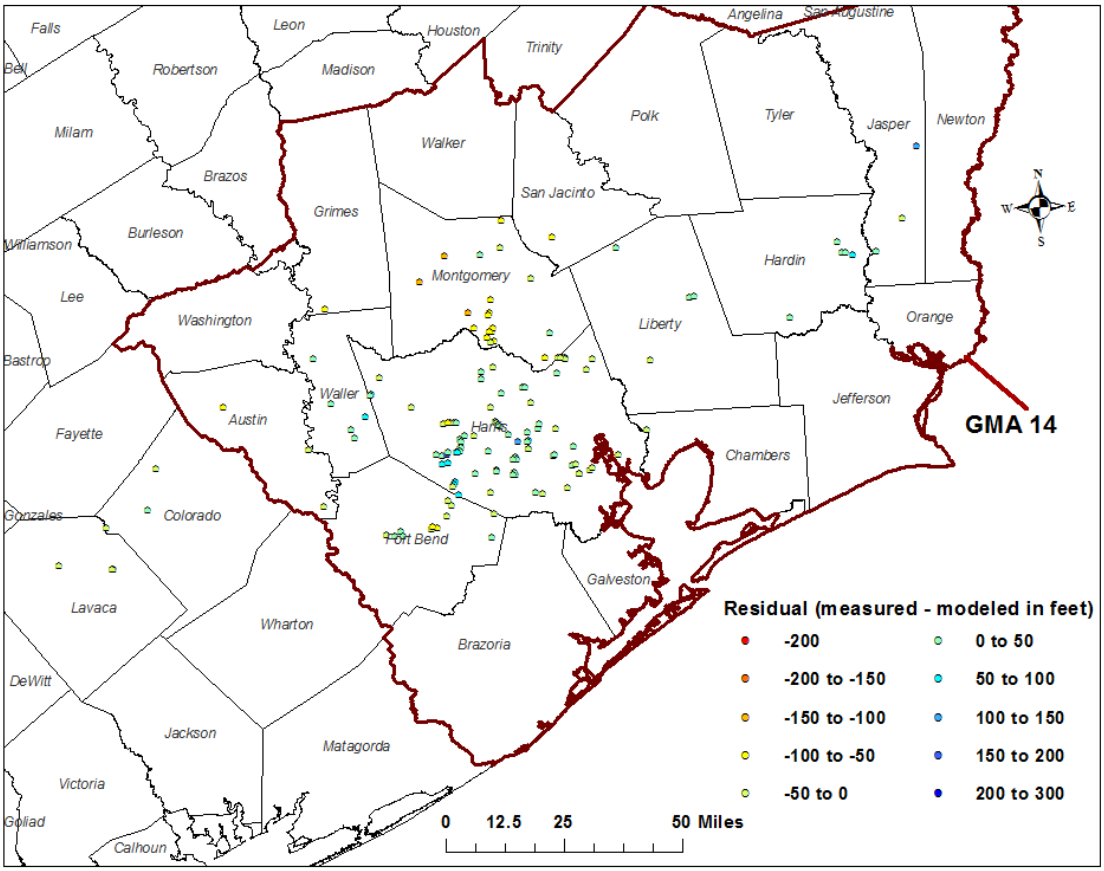


FIGURE 11 EVANGELINE AQUIFER (LAYER 2) WATER LEVEL RESIDUALS FOR THE YEAR 2000 FROM THE HOUSTON AREA GROUNDWATER MODEL. NEGATIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE ABOVE THOSE MEASURED IN THE FIELD AND POSITIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE BELOW THOSE MEASURED IN THE FIELD.

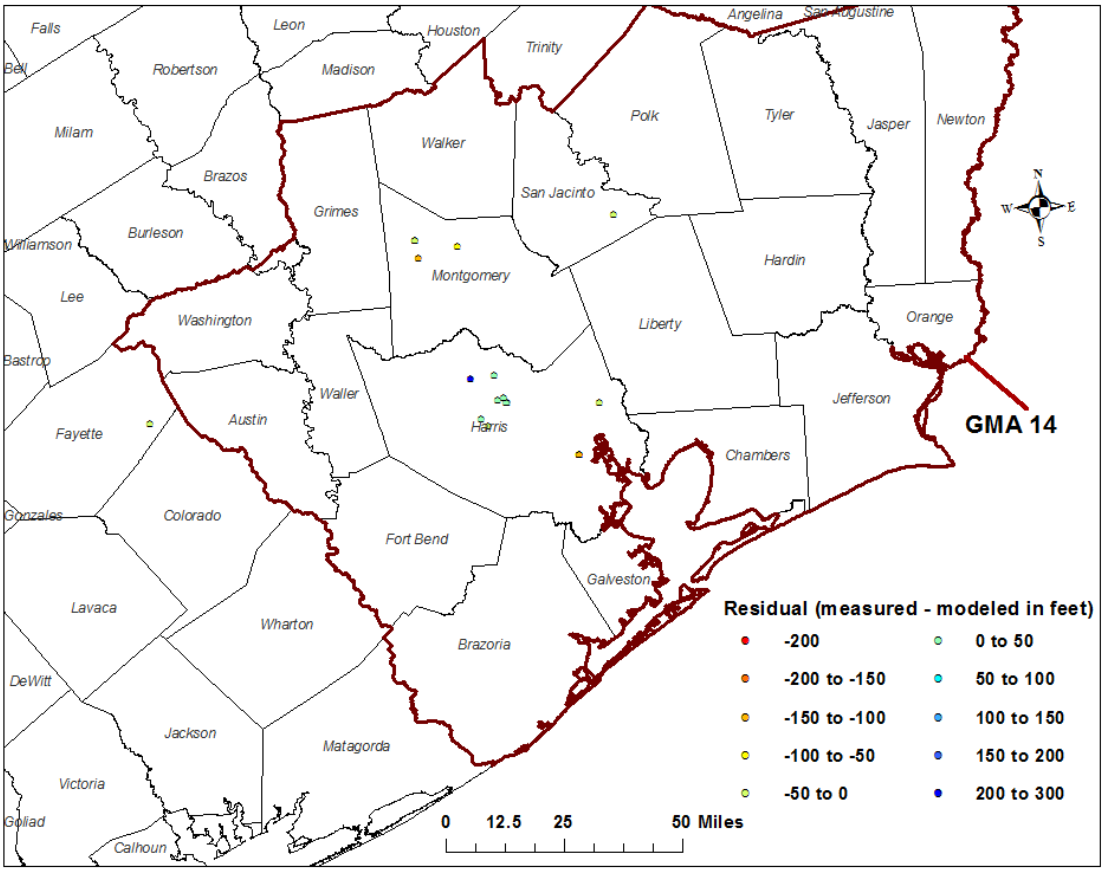


FIGURE 12 BURKEVILLE UNIT (LAYER 3) WATER LEVEL RESIDUALS FOR THE YEAR 2000 FROM THE HOUSTON AREA GROUNDWATER MODEL. NEGATIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE ABOVE THOSE MEASURED IN THE FIELD AND POSITIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE BELOW THOSE MEASURED IN THE FIELD.

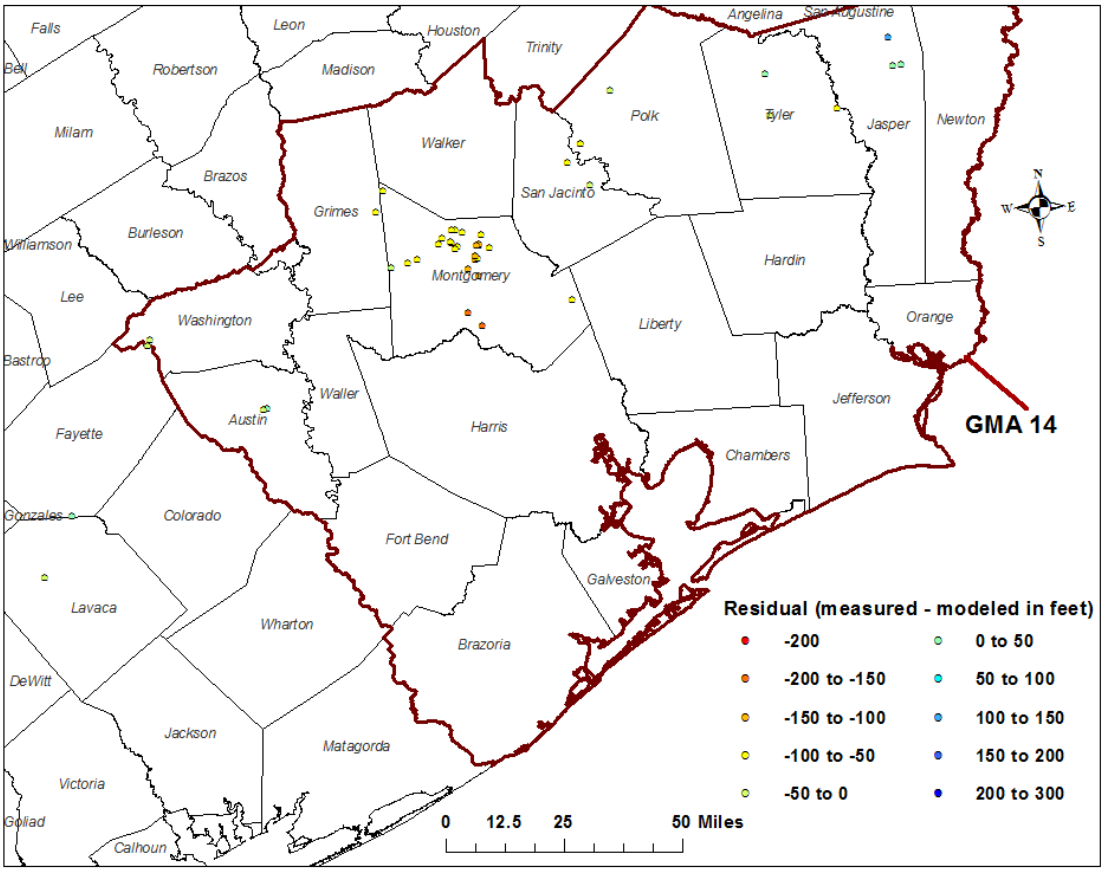


FIGURE 13 JASPER AQUIFER (LAYER 4) WATER LEVEL RESIDUALS FOR THE YEAR 2000 FROM THE HOUSTON AREA GROUNDWATER MODEL. NEGATIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE ABOVE THOSE MEASURED IN THE FIELD AND POSITIVE VALUES INDICATE WATER LEVELS IN THE MODEL WERE BELOW THOSE MEASURED IN THE FIELD.

APPENDIX B: HYDROGRAPHS FOR SELECT WELLS

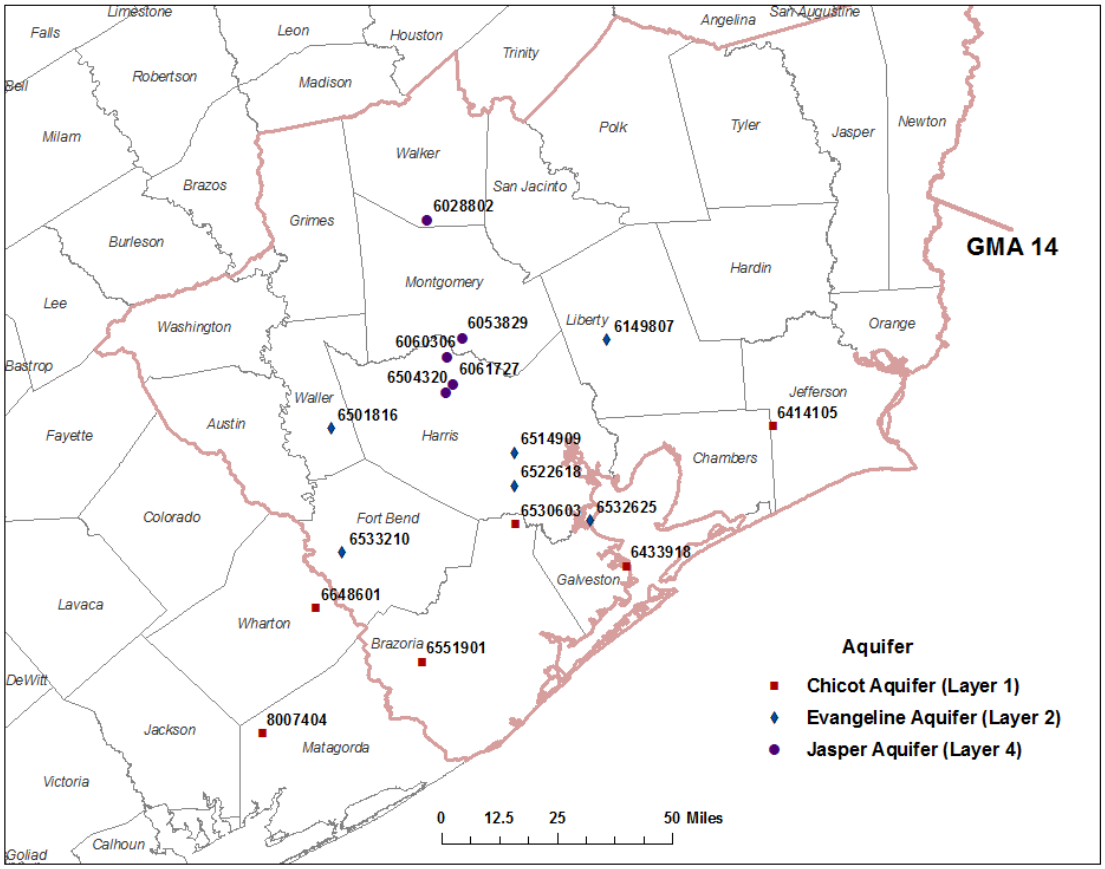
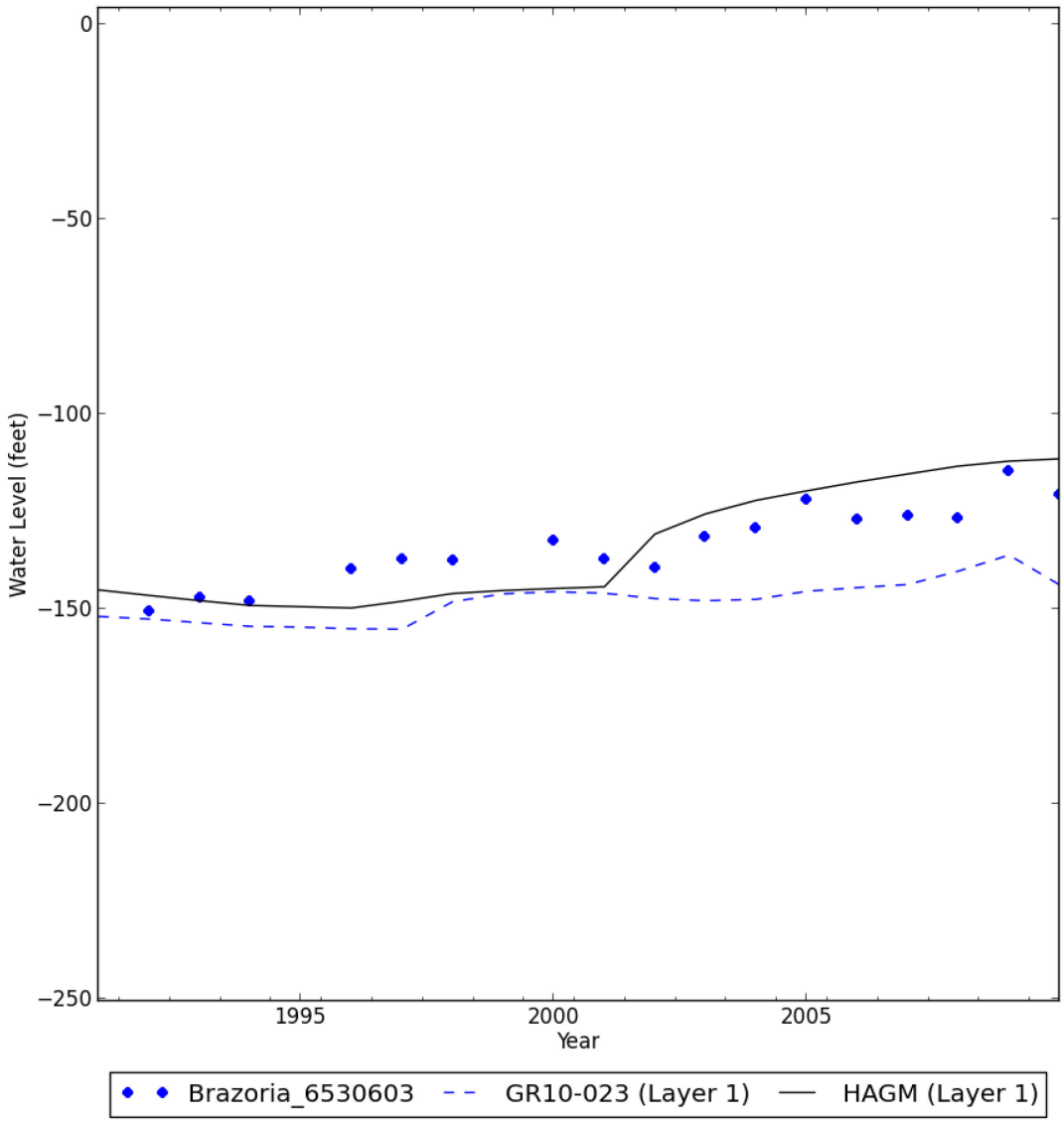
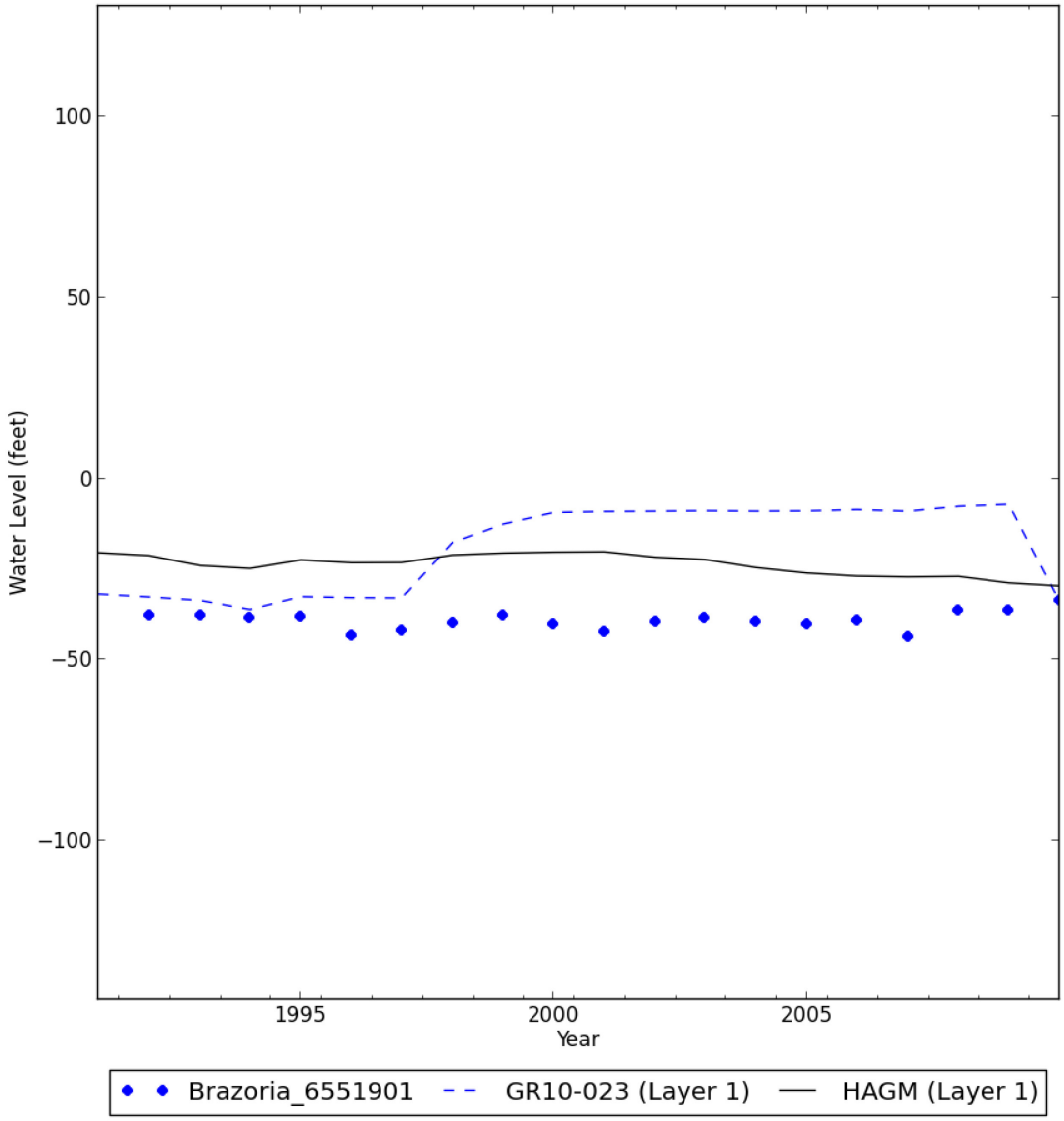
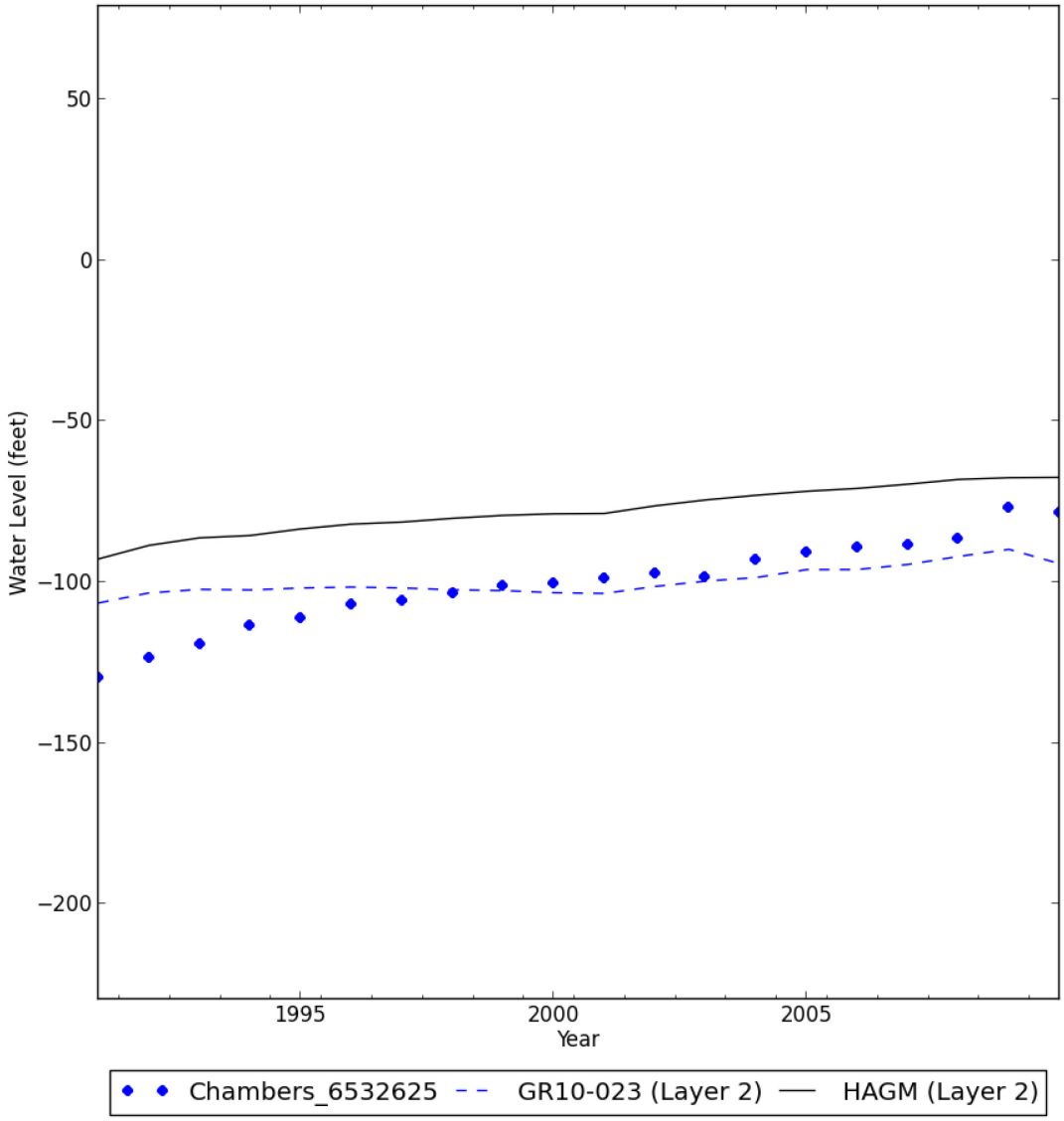


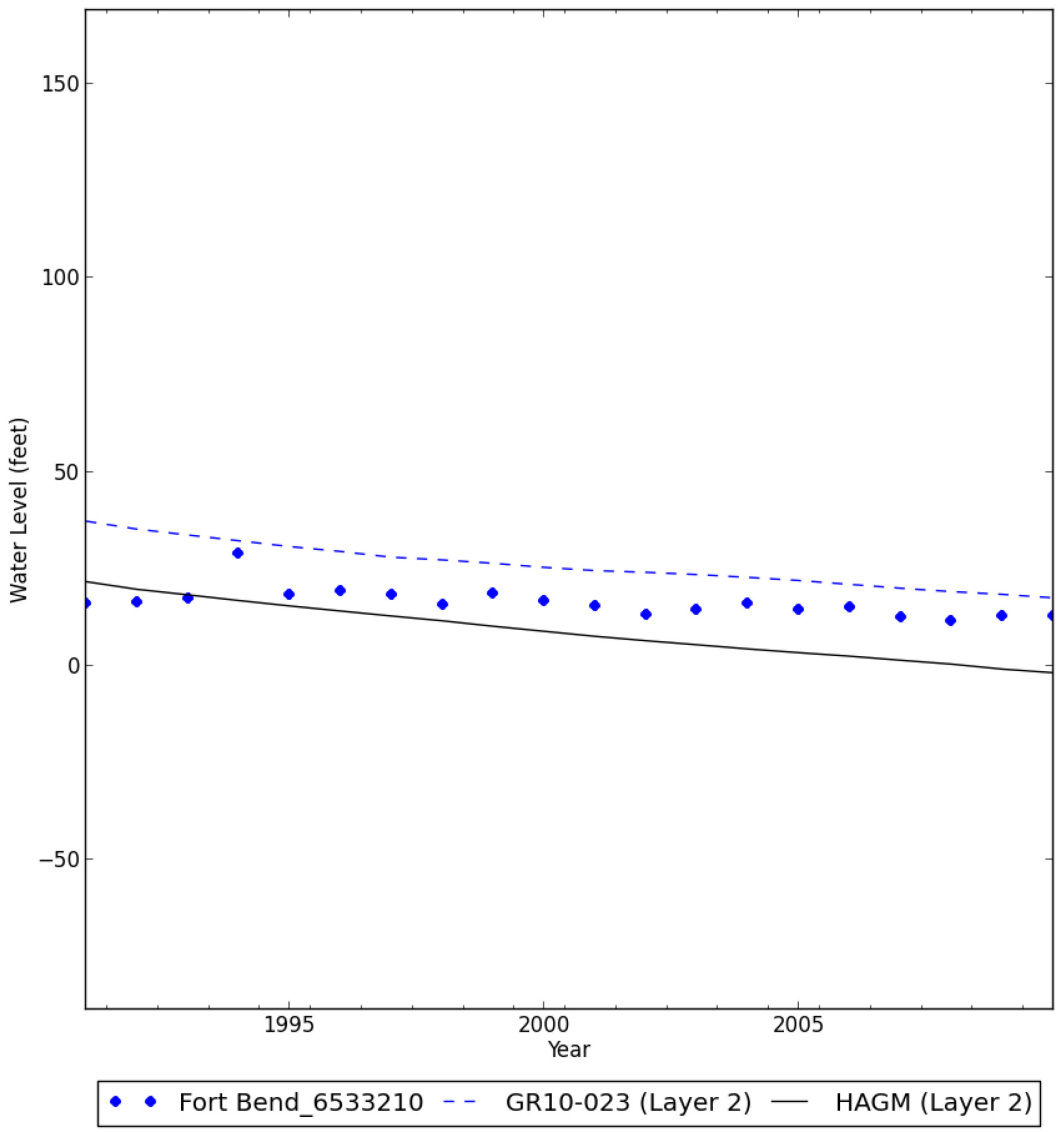
FIGURE 14. LOCATION OF OBSERVATION WELLS USED TO COMPARE WITH MODEL RESULTS IN THE APPENDIX B HYDROGRAPHS.

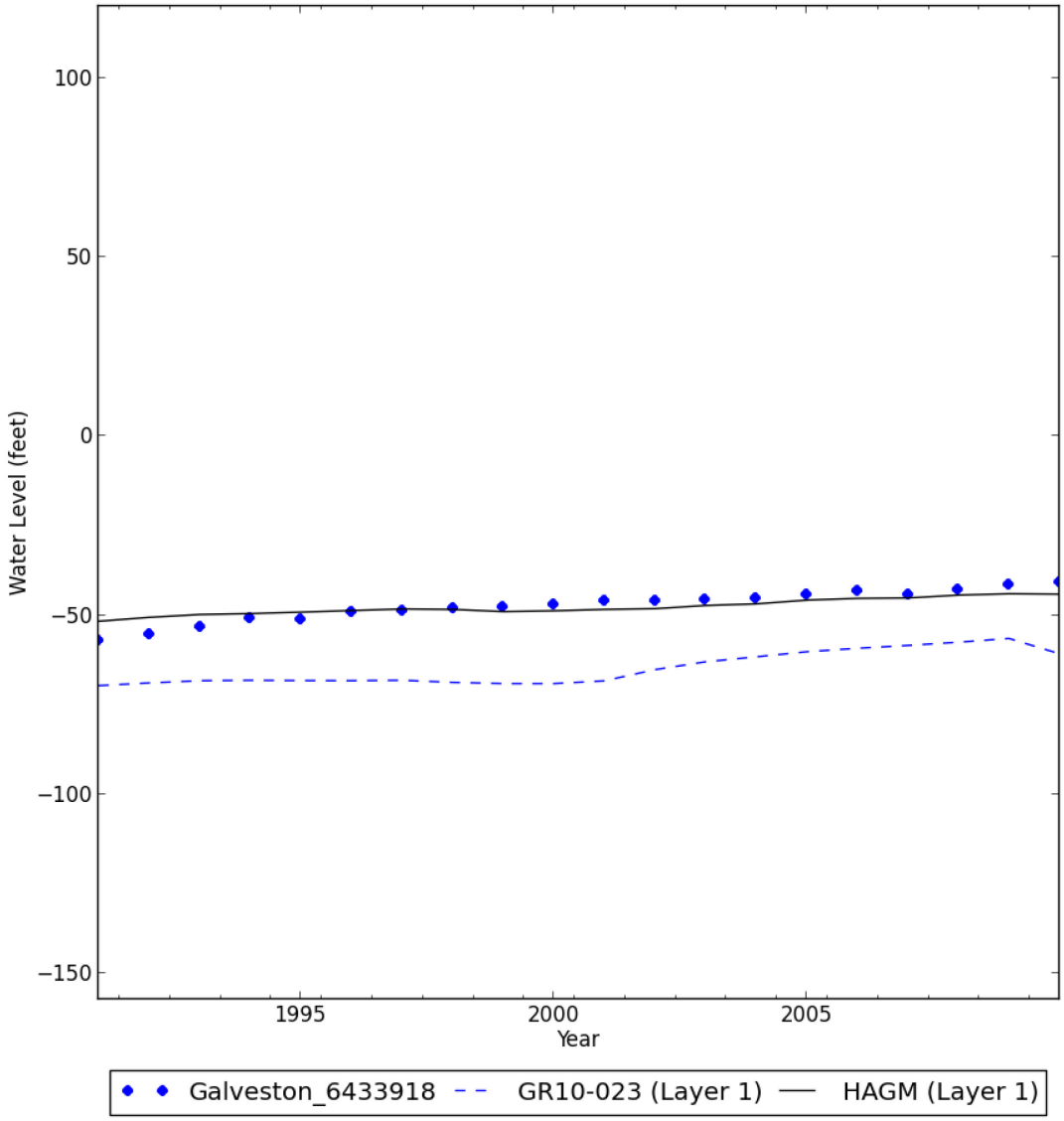
The following hydrographs compare water levels from the Houston Area Groundwater Model (HAGM) and the original groundwater availability model for the northern part of the Gulf Coast Aquifer System with observed water levels from select locations. We compared water for the time years 1990 to 2008. For the original groundwater availability model we extracted the modeled water levels for the period from 2000 to 2008 from a predictive run developed for the Groundwater Management Area 14 desired future condition analysis, GAM Run(GR) 10-023 (Oliver, 2010). The observation wells are identified in the charts by the county in which they are located and their state well numbers. The model layer from which the information was extracted is also identified on each hydrograph.

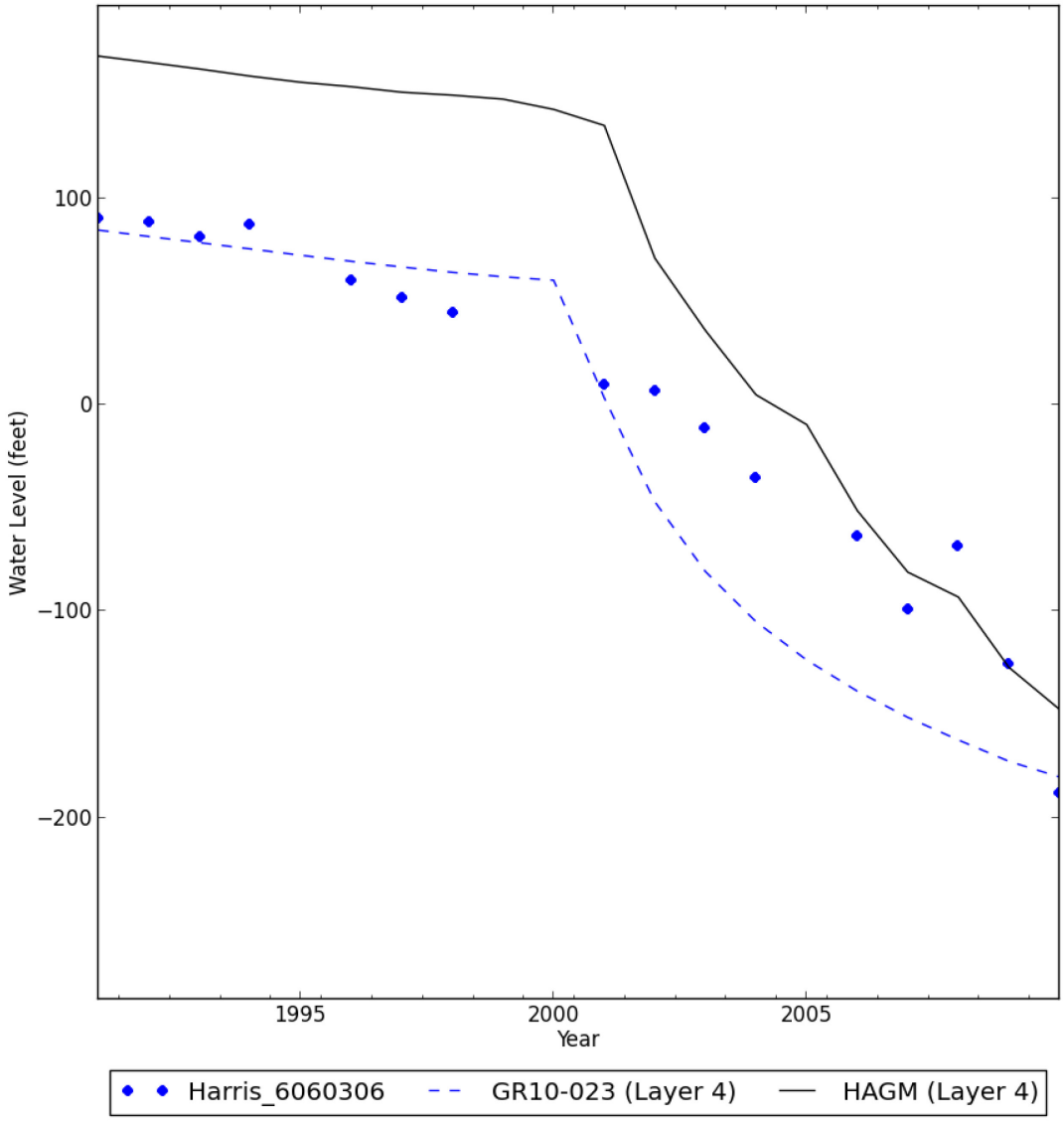

0
−50
−100
−150
−200
−250
Water Level (feet)
1995
2000
2005
Year
Brazoria_6530603
GR10-023 (Layer 1)
HAGM (Layer 1)

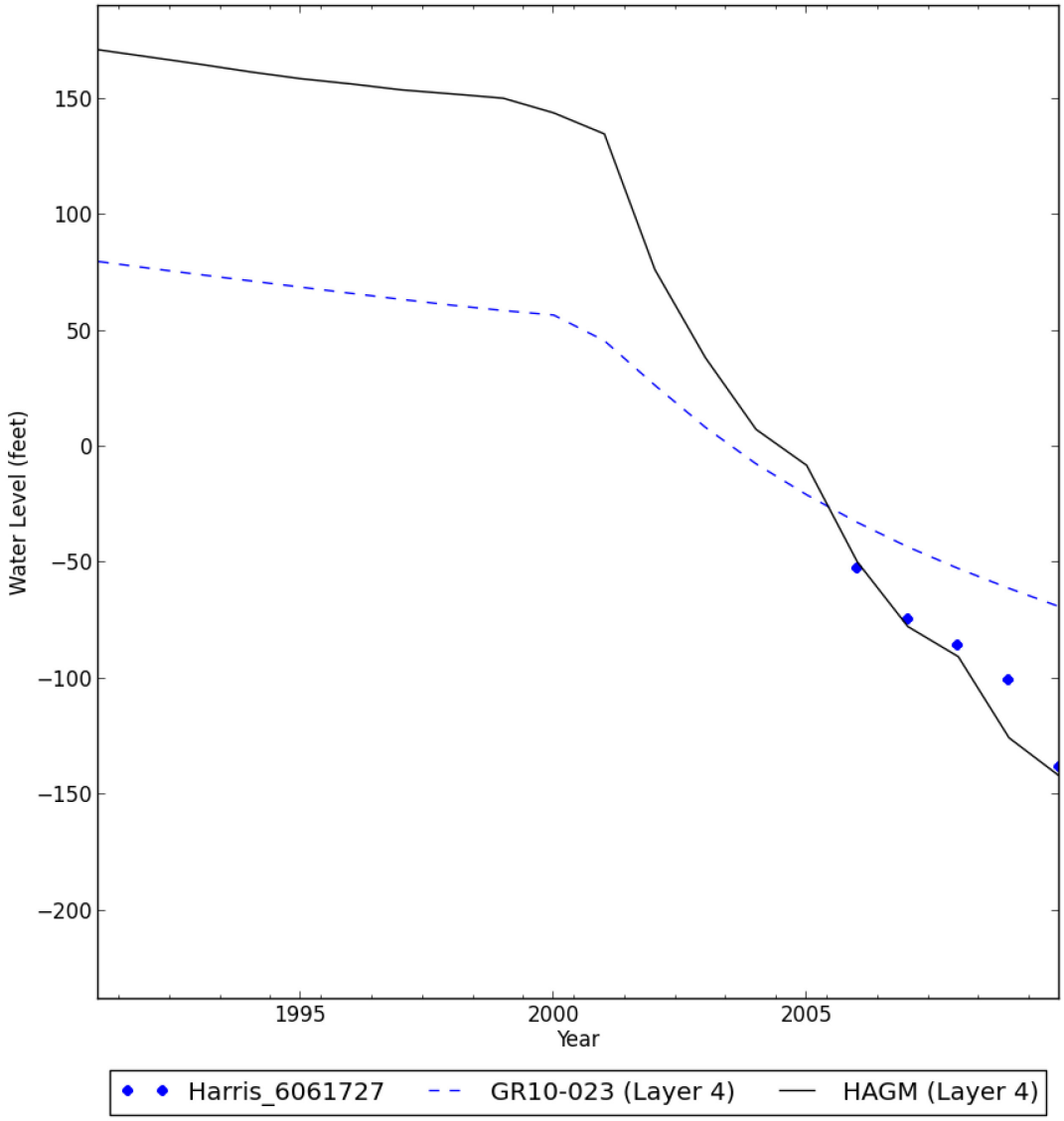

100
50
0
−50
−100
Water Level (feet)
1995
2000
2005
Year
Brazoria_6551901
GR10-023 (Layer 1)
HAGM (Layer 1)

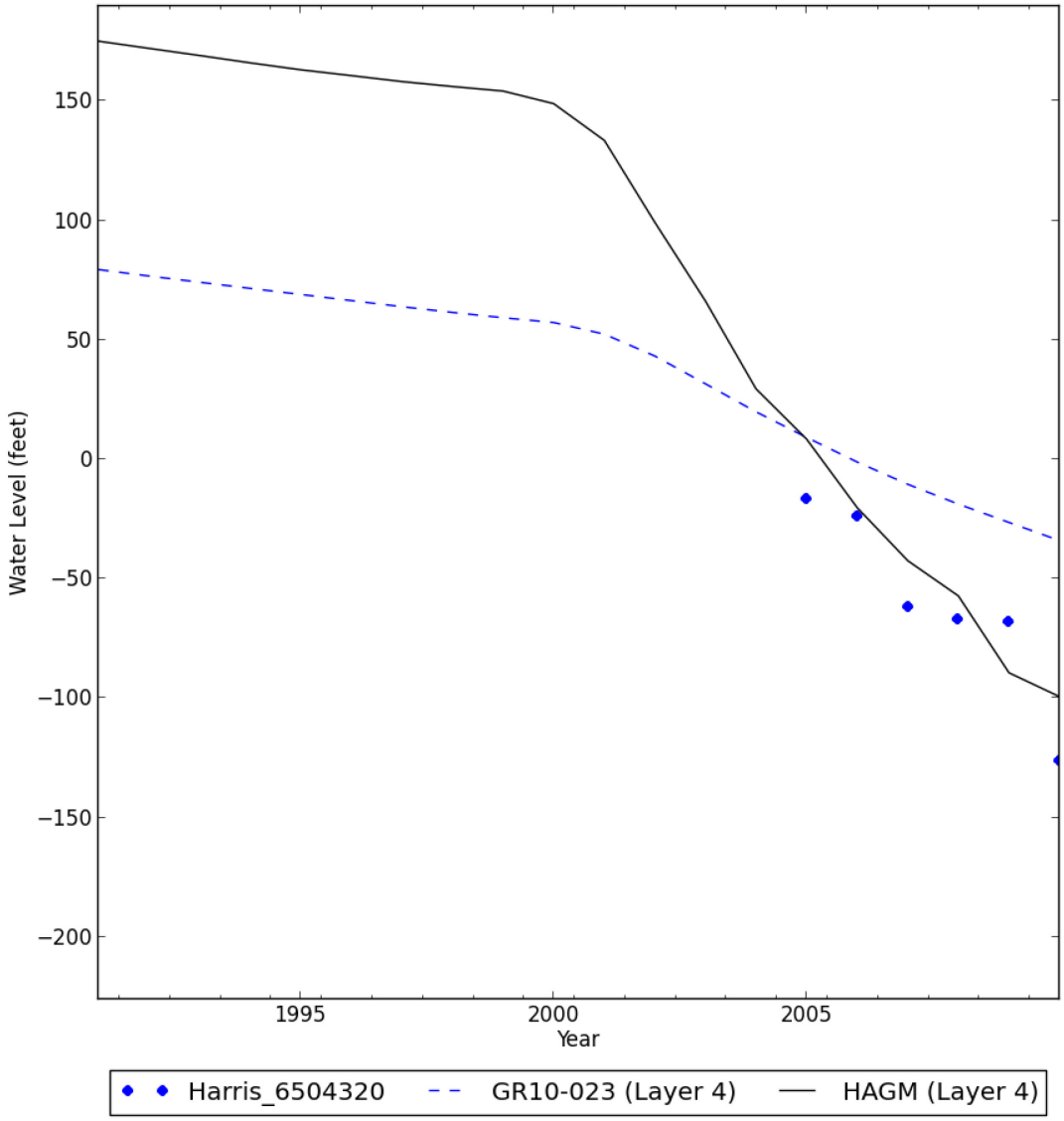

50
0
−50
−100
−150
−200
Water Level (feet)
1995
2000
2005
Year
Chambers_6532625
GR10-023 (Layer 2)
HAGM (Layer 2)

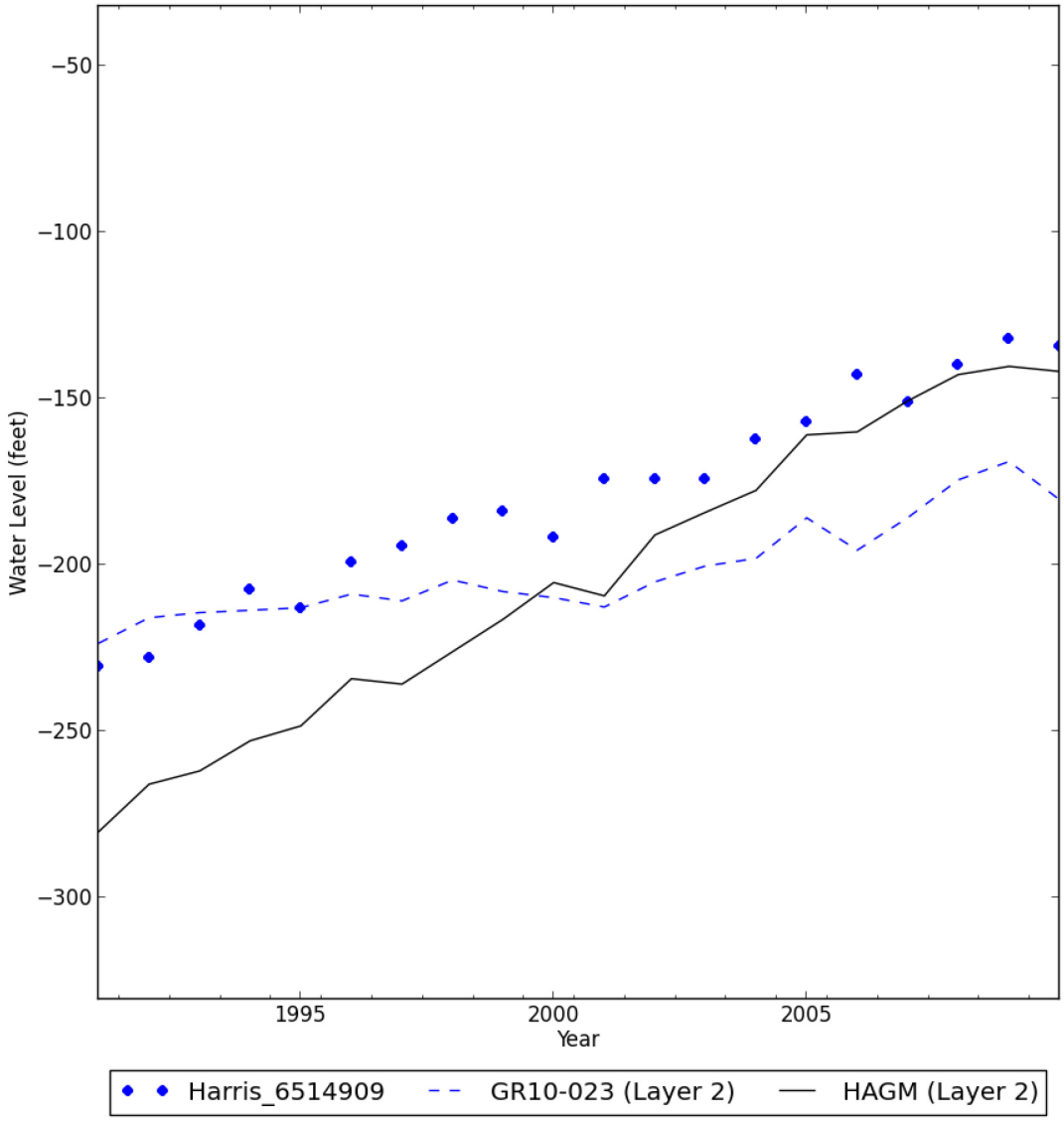

150
100
50
0
−50
Water Level (feet)
1995
2000
2005
Year
Fort Bend_6533210
GR10-023 (Layer 2)
HAGM (Layer 2)

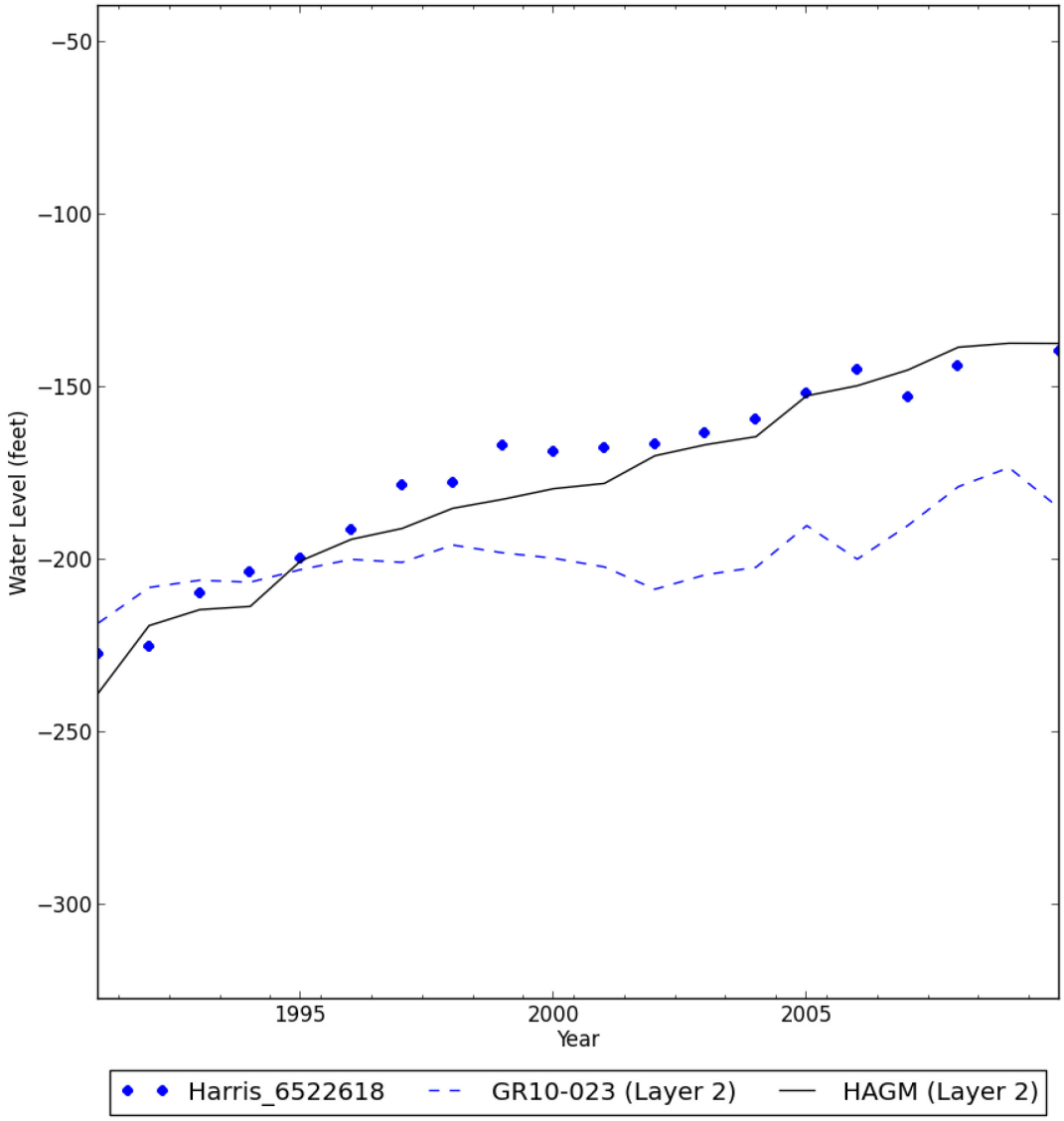

100
50
0
−50
−100
−150
Water Level (feet)
1995
2000
2005
Year
Galveston_6433918
GR10-023 (Layer 1)
HAGM (Layer 1)

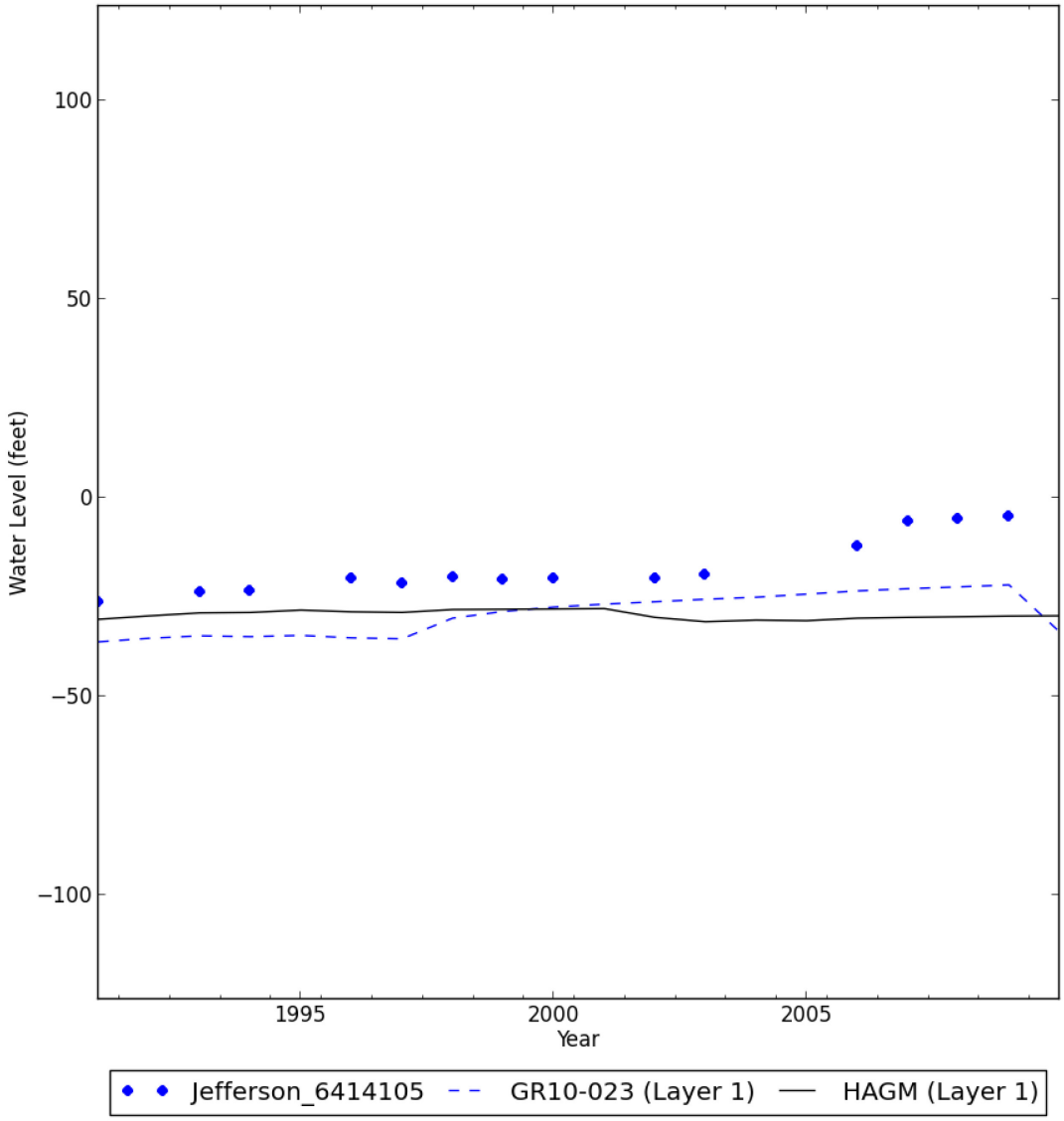

100
0
−100
−200
Water Level (feet)
1995
2000
2005
Year
Harris_6060306
GR10-023 (Layer 4)
HAGM (Layer 4)

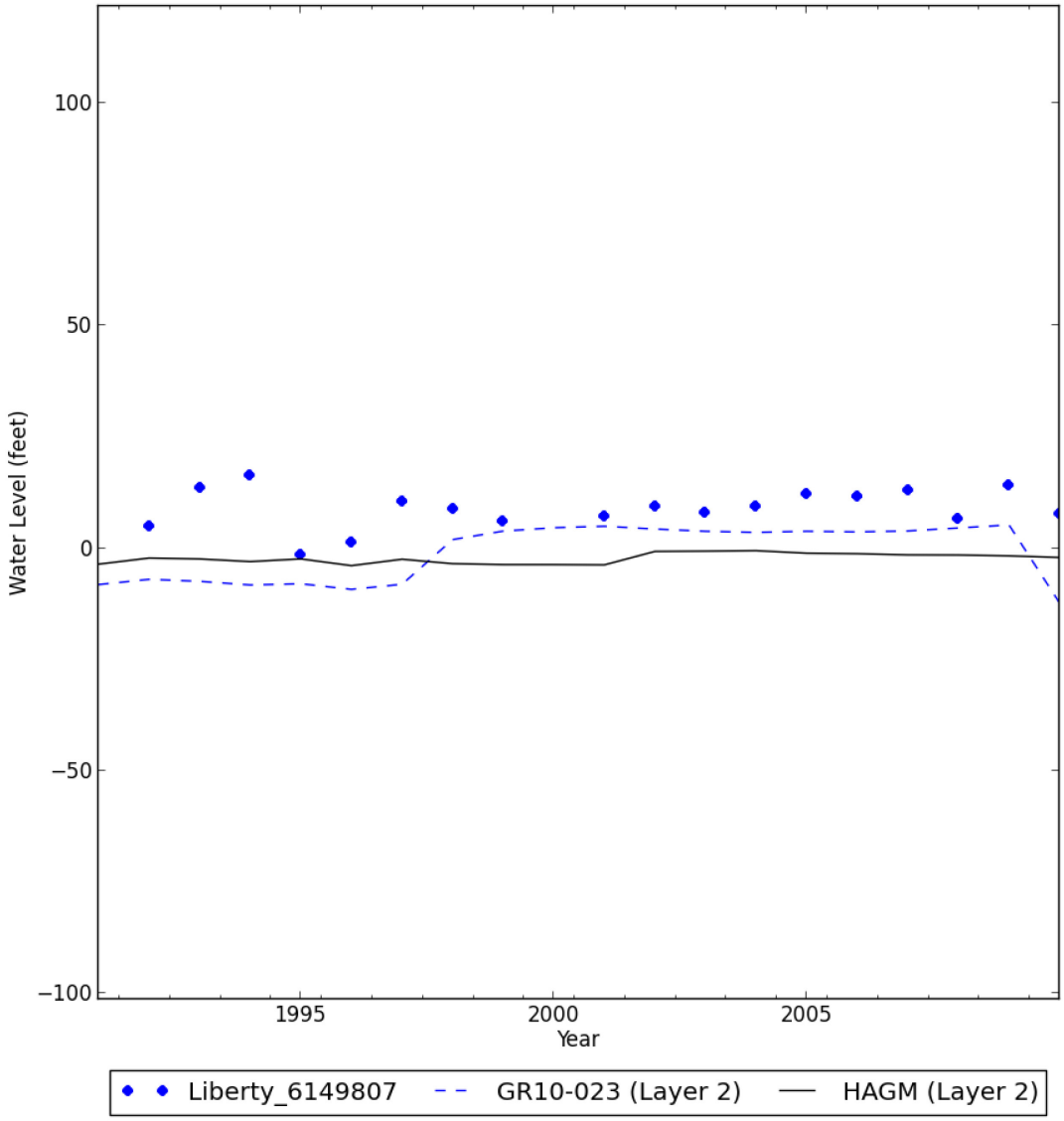

150
100
50
0
−50
−100
−150
−200
Water Level (feet)
1995
2000
2005
Year
Harris_6061727
GR10-023 (Layer 4)
HAGM (Layer 4)

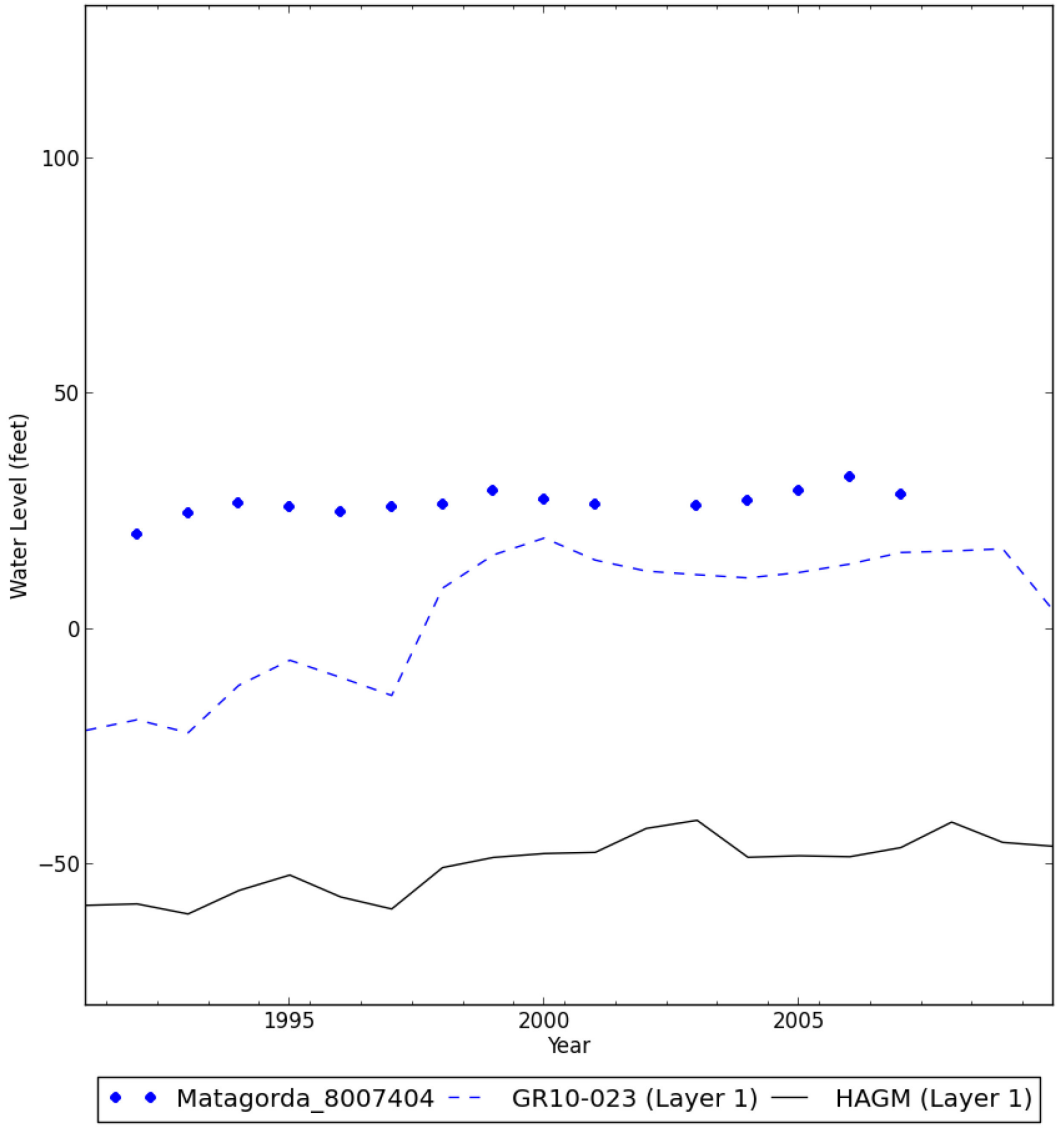

150
100
50
0
−50
−100
−150
−200
Water Level (feet)
1995
2000
2005
Year
Harris_6504320
GR10-023 (Layer 4)
HAGM (Layer 4)

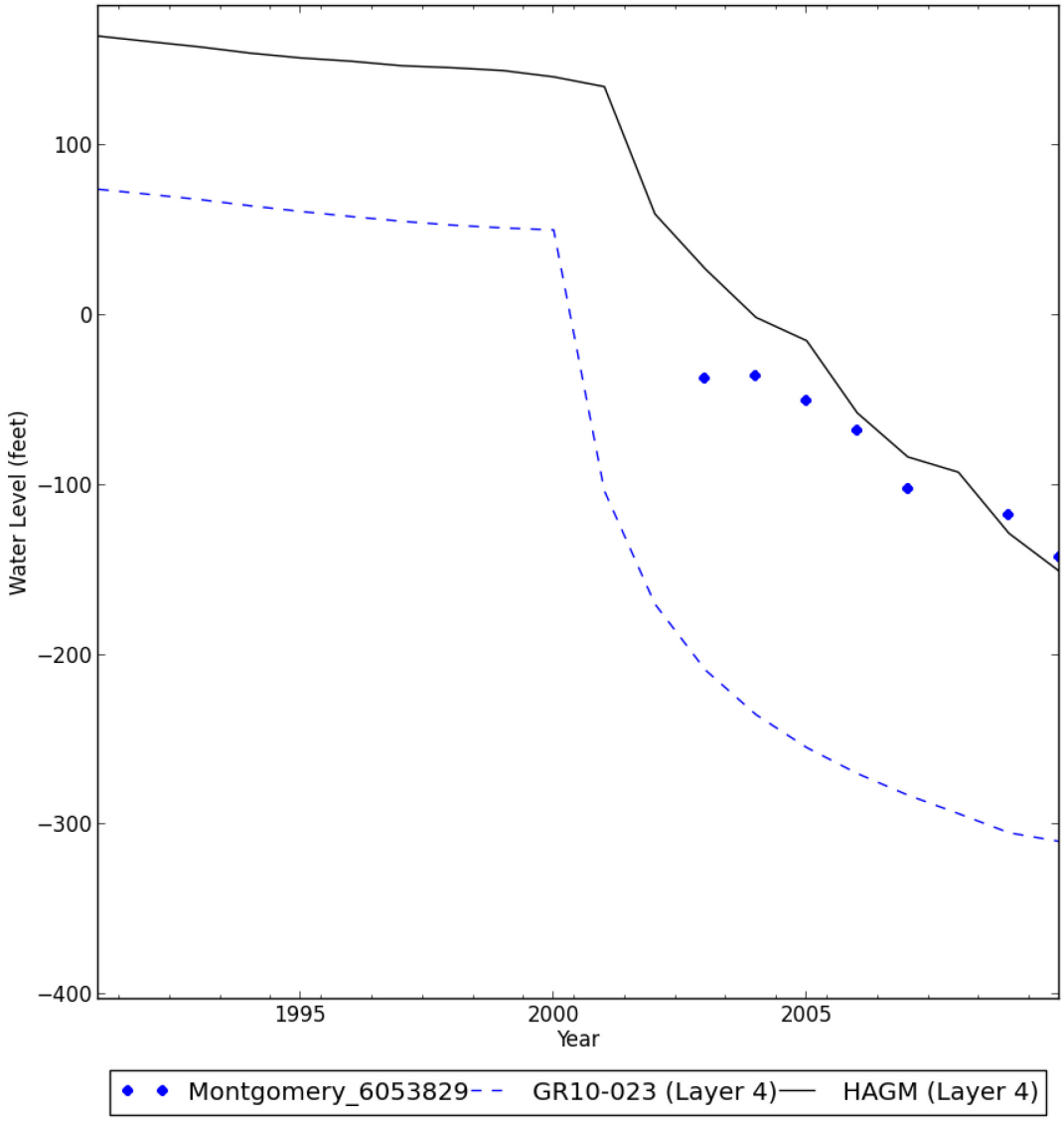

−50
−100
−150
−200
−250
−300
Water Level (feet)
1995
2000
2005
Year
Harris_6514909
GR10-023 (Layer 2)
HAGM (Layer 2)

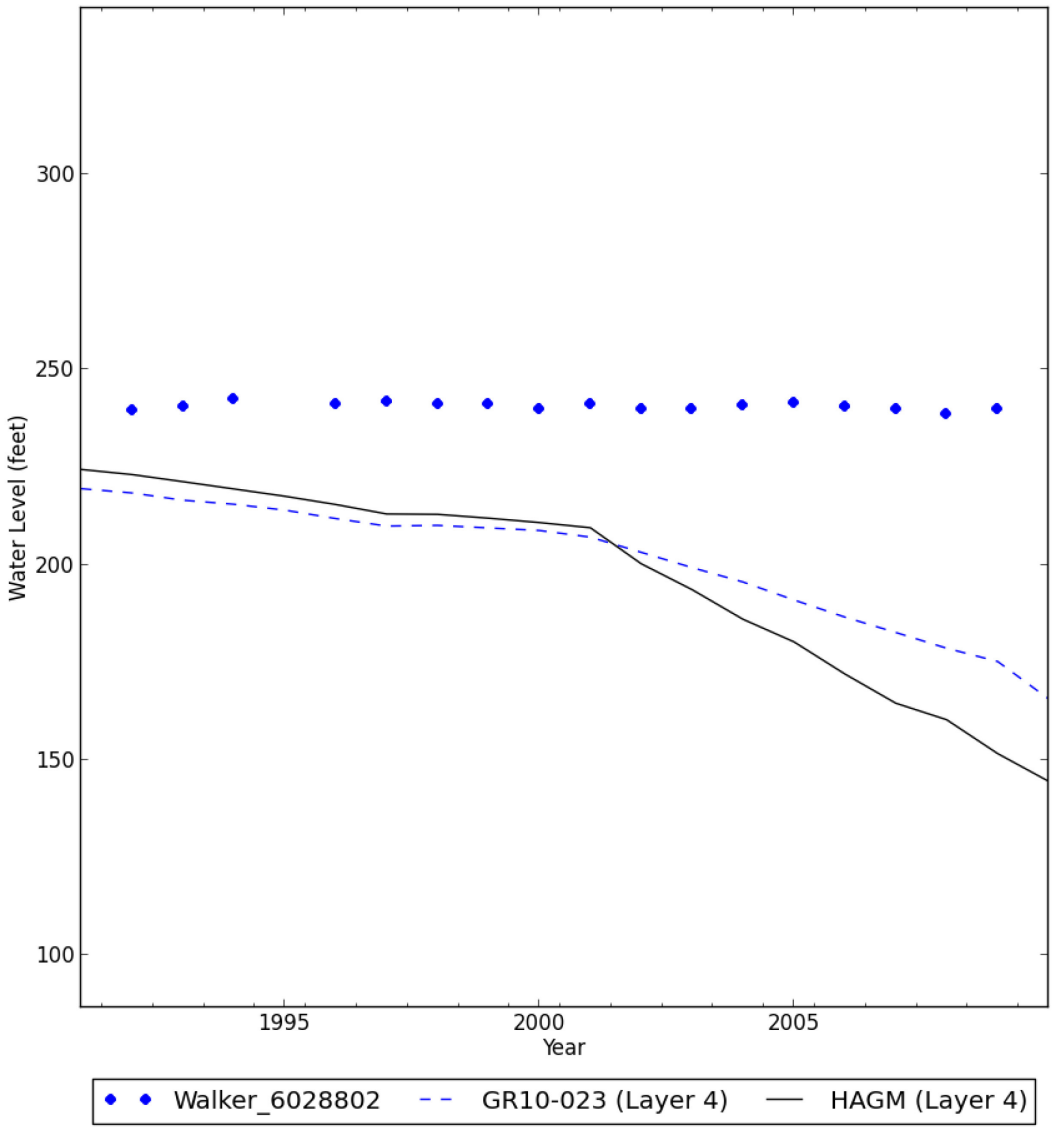

−50
−100
−150
−200
−250
−300
Water Level (feet)
1995
2000
2005
Year
Harris_6522618
GR10-023 (Layer 2)
HAGM (Layer 2)

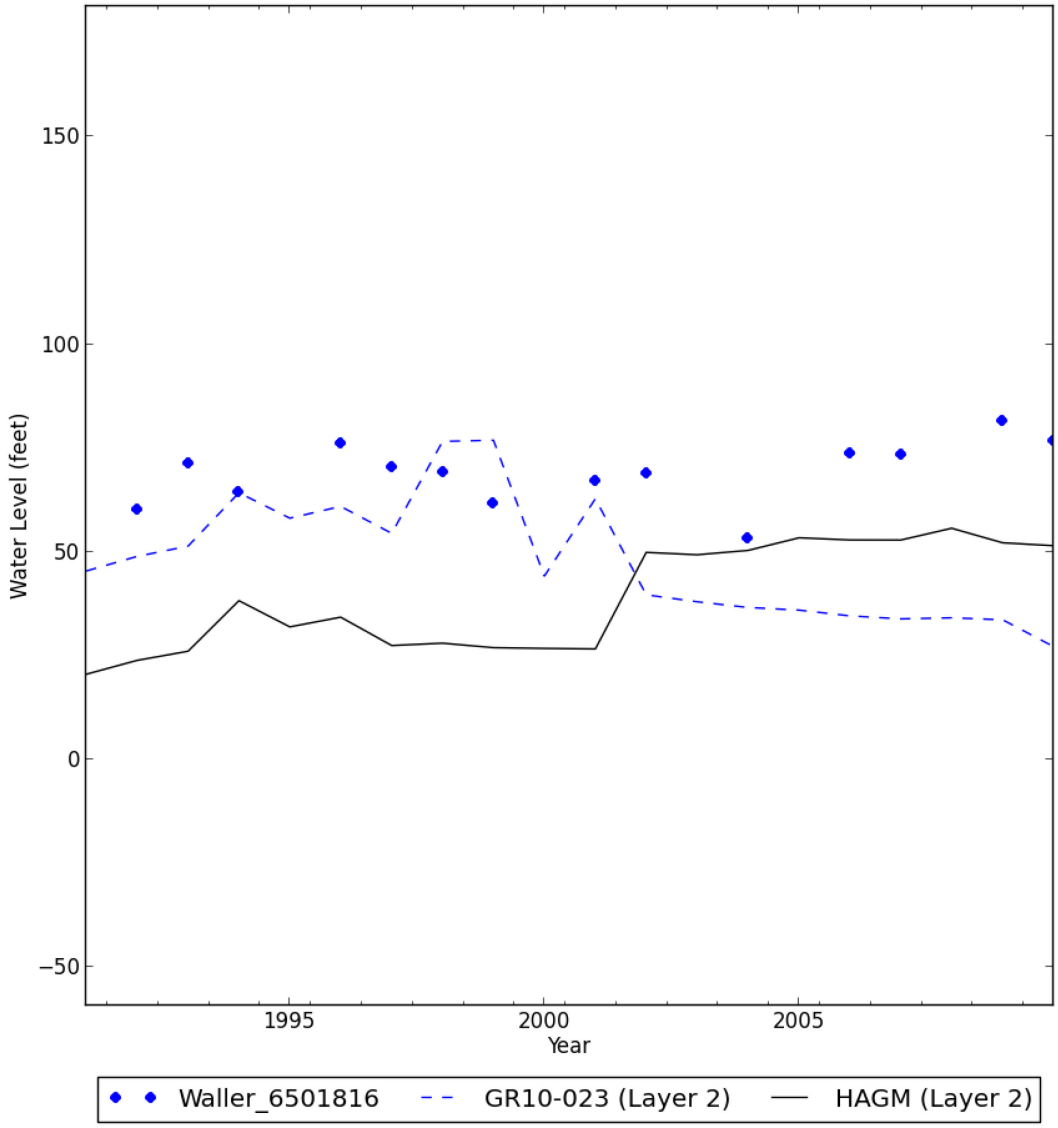

100
50
0
−50
−100
Water Level (feet)
1995
2000
2005
Year
Jefferson_6414105
GR10-023 (Layer 1)
HAGM (Layer 1)

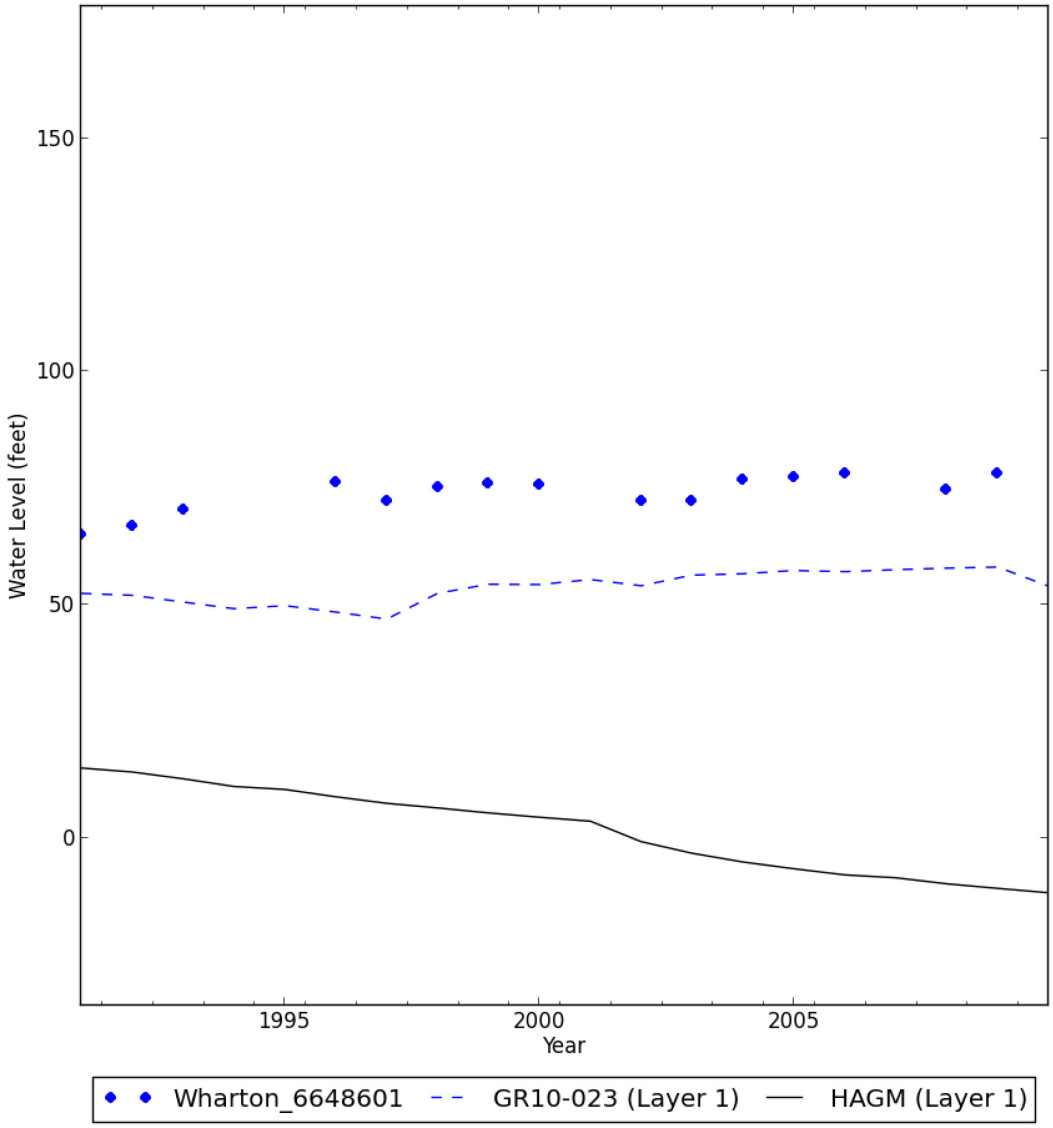

100
50
0
−50
−100
Water Level (feet)
1995
2000
2005
Year
Liberty_6149807
GR10-023 (Layer 2)
HAGM (Layer 2)


100
50
0
−50
Water Level (feet)
1995
2000
2005
Year
Matagorda_8007404
GR10-023 (Layer 1)
HAGM (Layer 1)


100
0
−100
−200
−300
−400
Water Level (feet)
1995
2000
2005
Year
Montgomery_6053829
GR10-023 (Layer 4)
HAGM (Layer 4)

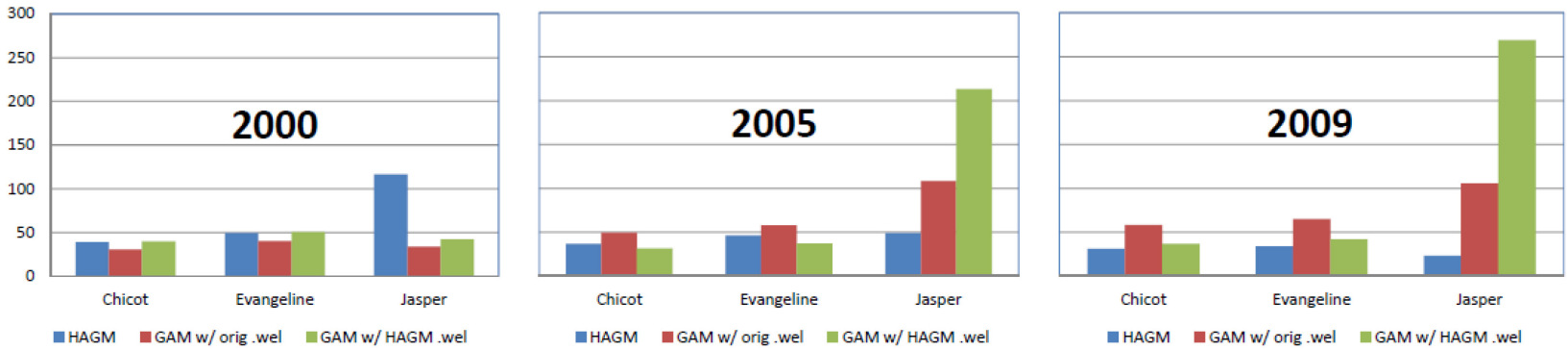

300
250
200
150
100
Water Level (feet)
1995
2000
2005
Year
Walker_6028802
GR10-023 (Layer 4)
HAGM (Layer 4)


150
100
50
0
−50
Water Level (feet)
1995
2000
2005
Year
Waller_6501816
GR10-023 (Layer 2)
HAGM (Layer 2)


150
100
50
0
Water Level (feet)
1995
2000
2005
Year
Wharton_6648601
GR10-023 (Layer 1)
HAGM (Layer 1)

ATTACHMENT 1: US GEOLOGICAL SURVEY EVALUATION OF HAGM AND NORTHERN GULF COAST GROUNDWATER AVAILABILITY MODEL USING UPDATED PUMPAGE

ROOT MEAN SQUARE ERROR OF SIMULATION FOR 2000, 2005, 2009 USING THE HAGM, NGC-GAM, AND NGC-GAM WITH UPDATED PUMPAGE



HAGM MODEL RESULTS FOR 2000, 2005, 2009 (scenario A)

Scenario A used the published HAGM model without any modification to the archive. The RMSE values calculated from simulated results at the end of 2000, 2005, and 2009 for the Chicot aquifer were 38.8, 36.6, and 31.1, respectively; for the Evangeline aquifer, 49.5, 46.2, and 33.7, respectively; and for the Jasper aquifer, 116.7, 49.2, and 23.3, respectively. The higher value of RMSE for the Jasper aquifer in 2000 is likely a result of the calibration criteria and approach. However the RMSE in the Jasper aquifer for 2005 significantly improved and in 2009, the RMSE of 23.3 is lower than any of the other scenarios.

NGC-GAM MODEL RESULTS USING ORIGINAL PREDICITIVE WELL FILE FOR 2000, 2005, 2009 (scenario B)

Scenario B used the published NGC-GAM using the original predictive dataset. The RMSE values at the end of 2000, 2005, and 2009 for the Chicot aquifer were 30.7, 49.3, and 58.3, for 2000, 2005, and 2009, respectively; for the Evangeline aquifer were 40.1, 57.8, and 64.9, respectively; and for the Jasper aquifer were 33.8, 108.6, and 105.6, respectively. For all three aquifers, RMSE increases in 2005 and 2009 from the calibrated published values in 2000, and for the Jasper aquifer, RMSE is about three times greater in 2005 and 2009 compared to the published RMSE value in 2000.

NGC-GAM MODEL RESULTS USING UPDATED HAGM WELL FILE FOR 2000, 2005, 2009 (scenario C)

Scenario C used the published NGC-GAM with the updated HAGM well file. The RMSE values at the end of 2000, 2005, and 2009 for the Chicot aquifer were 39.7, 31.4, and 36.8, respectively; for the Evangeline aquifer were 50.6, 37.0, and 41.9, respectively; and for the Jasper aquifer were 42.2, 213.0, and 268.9, respectively. For the Jasper aquifer, RMSE is about four times greater in 2005 and 2009 compared to the RMSE value in 2000.

CONCLUSION:

Comparing scenarios A, B, and C, the range of RMSE values for scenario A indicate that using the HAGM datasets with the most updated 2009 water-use data produces the lowest RMSE values for all 3 aquifers. For scenarios B and C, even though both scenarios produced adequate RMSE values for the Chicot and Evangeline aquifers, RMSE values for the Jasper aquifer are an order of magnitude larger.