



Regional Groundwater Update Project

Final Report

June 2013

Prepared for:

Harris-Galveston Subsidence District

Fort Bend Subsidence District

Lone Star Groundwater Conservation District

Prepared by:





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Appendix A: Interim Studies and Reports



1.0 INTRODUCTION

The purpose of this report is to summarize the results of the Regional Groundwater Update Project (RGUP). The RGUP originally started in 2010 as the Harris-Galveston Subsidence District (HGSD) 1999 Regulatory Plan Update, but due to its benefits to two other regional entities that also regulate the production of groundwater, the Fort Bend Subsidence District (FBSD) and the Lone Star Groundwater Conservation District (LSGCD), the three districts partnered to create the RGUP.

The primary benefit of collaboration between these three entities is that each of them could use the RGUP to vet their existing regulatory plans using updated population/water demand data and groundwater modeling capability, and in the case of HGSD and FBSD, investigate the physical effects of changing their existing regulatory plans to accommodate the practical realities facing their stakeholders. An additional benefit to LSGCD is that they can use the data and modeling tools as they monitor aquifer conditions and consider their future regulations.

The project was conducted over a nearly three year period, from April, 2010 to January, 2013, and included input and review from the three partners as well as the major stakeholders. Each project partner was at a different point in their groundwater regulations process, and each had different considerations in terms of their stakeholders' ability to secure and fund alternative water supplies to meet their regulations, leading to different outcomes in terms of future groundwater regulations.

The HGSD used the RGUP to verify that their existing regulatory plan was working, and weighed the effects of modifying their plan against the feasibility of stakeholders obtaining alternative water supplies necessary to meet the proposed groundwater reductions. The FBSD and LSGCD also confirmed that their existing regulatory plans were effective, and both opted not to seek any further changes to their plans at this time.

This report is intended as more of a summary of the project, rather than a comprehensive single document. All of the interim technical memos and reports completed over the course of the study are included as an attachment, and provide a very detailed reporting of the



assumptions and methodologies used during the course of the RGUP, as well as all the results. Section 2 describes the purpose of the project, and its benefit to the project partners and the region as a whole. Section 3 provides the final results of the RGUP, i.e. the projected water level and land-surface subsidence changes expected to occur as a result of the groundwater regulatory plans recommended by the RGUP project partners as a result of this study.



2.0 PROJECT INITIATION AND PURPOSE

2.1 HGSD REGULATORY PLAN UPDATE

In February 2010 the HGSD initiated a project for the purpose of updating its District Regulatory Plan (DRP). At that time, the latest major HGSD DRP update was completed in 1999. The HGSD began the update project to:

1. Update population and water demand projections, incorporating the 2010 U.S. Census;
2. Update and recalibrate the parameters in the groundwater models and subsidence models, and;
3. Evaluate the regulations in the 1999 DRP and make any necessary changes to the regulations for the upcoming decades.

Because of the impact of population and water demand from counties neighboring Harris and Galveston counties, the project study area also included Fort Bend, Montgomery, and Brazoria counties. These five counties represent 23 percent of the State's 2010 population.

2.2 REGIONAL BENEFIT AND COOPERATION

2.2.1 Creation of the RGUP

The project as conceived by the HGSD was always recognized to have benefits to the entire Houston region. The primary benefits are detailed population and water demand projections, and estimates of groundwater level changes and land surface subsidence for a five county area that is vital to the regional economy. To help defray the cost of developing this regional data, and to promote joint planning and data sharing, the FBSD and LSGCD accepted the invitation to become partners in the project, thereby creating the RGUP. By creating this partnership, all three Districts have the opportunity to provide input, review results, evaluate the effects of their future regulations in terms of groundwater resource protection, and to use the data in future studies.

Figure 1 shows the project team. The project roles are shown in Table 1.

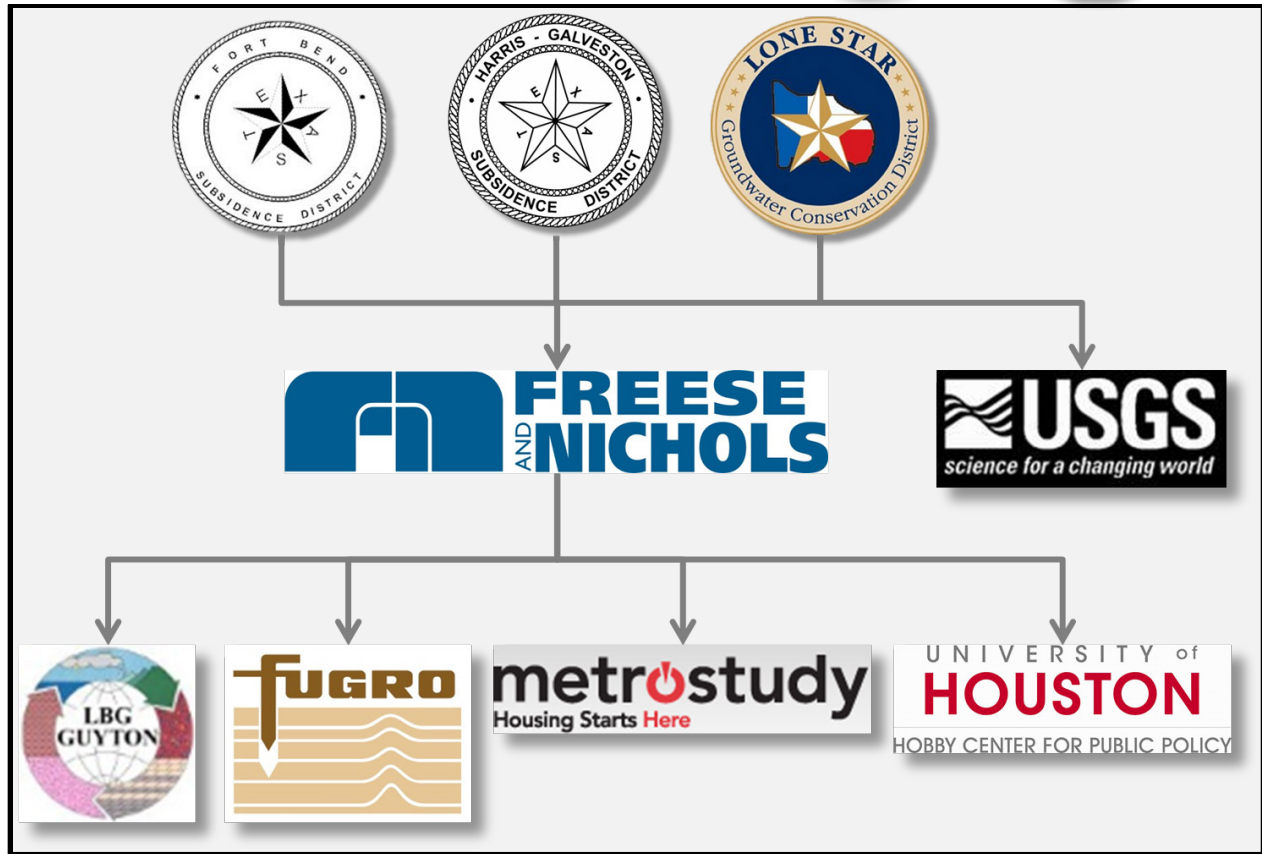


Figure 1. RGUP Team

Table 1. RGUP Team Members Roles

Team Member	Role
HGSD/FBSD/LSGCD	Project Partners
Freese and Nichols, Inc.	Project Management, population distribution, water demand projections, regulatory scenario development, Geographic Information Systems
USGS	Groundwater model and subsidence model update and calibration
LBG Guyton Associates	Groundwater model update, regulatory scenario groundwater analysis
Fugro, Inc.	Subsidence prediction using PRESS
Metrostudy, Inc.	Short-term population projections (2010-2020)
UH Center for Public Policy	Long-term population projections (2020-2070)



2.2.2 TWDB Coordination

One of the goals of the RGUP from the beginning was to have the county and Water User Group (WUG) level population projections for the study area be adopted by the Texas Water Development Board (TWDB) for use in the Region H water plan. To help ensure this outcome, the project team coordinated with the TWDB, as well as the State Demographer, throughout the duration of the project, keeping them updated on projection methodology and results. At the date of this report, the Region H Regional Water Planning Group, with concurrence by the TWDB, has adopted the population projections for use in the State Water Planning for this region.

2.2.3 Benefit to Project Partners and the Region

The benefits to the project partners are as follows:

1. Confirmation that adopted regulations provide an adequate level of positive impact in terms of future water level drawdown and land-surface subsidence.
2. Population and demand projections utilizing the 2010 U.S. Census and at a high level of spatial detail.
 - a. Detailed spatial projections provide accuracy and flexibility in developing pumping datasets for use in regulatory scenario analysis.
 - b. Project partners can use projections going forward to analyze permitting requests and GRPs.
3. Updated groundwater model. A new groundwater model, the Houston Area Groundwater Model (HAGM) was created and calibrated up to 2009 measured groundwater levels. The HAGM modeling effort addressed long-standing deficiencies in water level predictions for the Jasper Aquifer in Montgomery County and northern Harris County. The Jasper is an important water source in Montgomery County and is becoming more widely used in Harris County; more accurate predictions provide a solid foundation for future study of that aquifer system.



4. Creation of a comprehensive regional subsidence prediction tool. This tool will provide subsidence predictions throughout the study area instead of just at each of the 26 PRESS sites located in Harris, Galveston, and Fort Bend counties. In creation of the HAGM, the USGS used the Subsidence and Aquifer-System Compaction (SUB) package designed for the MODFLOW-2000 model to simulate clay compaction and storage, and thus land-surface subsidence, in the Chicot, Evangeline, and Jasper aquifers and the Burkeville confining unit (USGS Scientific Investigations Report 2012-5154, 2012). Since it is part of the HAGM model, the SUB package generates subsidence predictions at each model grid cell, meaning that subsidence predictions would be available everywhere in the RGUP study area, rather than just at each of the 26 PRESS sites. The SUB package calibration statistics were acceptable on a regional basis; however the SUB package was not used in RGUP due to problems with localized subsidence predictions in the area around NASA in northern Galveston and southern Harris counties, and the inability to address those problems within the project schedule and budget. While the SUB package results were not used in the RGUP, the package was developed to the extent that it can be used in the near future for comprehensive regional subsidence prediction.

Having the RGUP projections adopted in Region H facilitates use of a consistent set of projections for the region. This is particularly important in Region H because the HGSD, FBSD, and LSGCD regulatory plans play a crucial role in shaping water management strategies for the vast majority of the region. Additionally, the RGUP projections are the most detailed projections used in regional planning to date; their use will be required in TWDB-funded projects unless more accurate projections are available, which only strengthens the planning process.

3.0 STUDY RESULTS

The RGUP culminated in water level and land-surface subsidence predictions, through 2070, for groundwater withdrawals that take into account population and water demand projections and the HGSD, FBSD, and LSGCD regulatory plans that were in effect January, 2013. To get to that point, there were numerous interim studies conducted during the RGUP to build the required



data and models. This section lists the interim studies and reports that were developed: the actual documents are provided as attachments. Following this, the final results are described and documented.



3.1 INTERIM STUDIES AND REPORTS

Interim studies and reports are available as an attachment to this report. Table 2 provides a list of titles and their page numbers in the attachment.

Table 2. Interim Studies and Reports [Linked To PDF Documents](#)

1. Technical Memorandum: Groundwater Model Update and Improvements. LBG-Guyton, May 2011. (pp. 1-15)
2. Technical Memorandum: Evaluation of Exempt Groundwater Use from Registered Wells Within the Harris-Galveston Subsidence District, Fort Bend Subsidence District and Lone Star Groundwater Conservation District. LBG-Guyton, May 2011. (pp. 16-32)
3. Geotechnical Services: Work Order 2 – Data Preparation, Harris-Galveston Subsidence District, Harris, Galveston and Fort Bend Counties, Texas. Fugro Consultants, Inc., May 2011. (pp. 33-202)
4. HGSD Regional Groundwater Update Project Work Order 2 Population Projection Methodology Summary. Freese and Nichols, Inc., March 22, 2011. (pp. 203-205)
5. Geotechnical Services: Work Order 3 – PRESS Model Analyses, Harris-Galveston Subsidence District, Harris, Galveston and Fort Bend Counties, Texas. Fugro Consultants, Inc., November 2011. (pp. 206-354)
6. Methodology for Developing Baseline Per Capita Daily Water Demand. Freese and Nichols, Inc., December 22, 2011. (pp. 355-381)
7. Methodology for Developing 2010 Population and Water Demand. Freese and Nichols, Inc., December 22, 2011. (pp. 382-421)
8. Letter Report from Metrostudy to Freese & Nichols, Re: Annual Population Projections by Census Tract for the Harris-Galveston Subsidence District (HGSD) 1999 Regulatory Plan Update: Work Order 4. Metrostudy, January 6, 2012. (pp. 422-446)
9. SAM-HOUSTON: Description of Small Area Model Population Forecasts; Eight County Metropolitan Area of Houston. Steven G. Craig, Department of Economics, University of Houston, December 2011. (pp. 447-466)
10. Per Capita Demand Projections. Freese and Nichols, Inc., March 5, 2012. (pp. 467-475)
11. Calculation and Spatial Distribution of Non-PWS Per Capita Water Demand (GPCD). Freese and Nichols, Inc., August 29, 2012. (pp. 476-487)
12. Distribution of Population from Census Tracts to Blocks. Freese and Nichols, Inc., August 29, 2012. (pp. 488-535)
13. RGUP Census Tract Level Population Projections. Freese and Nichols, Inc. August 29, 2012. (pp. 536-589)
14. Hydrogeology and Simulation of Groundwater Flow and Land-Surface Subsidence in the Northern Part of the Gulf Coast Aquifer System, Texas, 1891-2009 (Scientific Investigations Report 2012-5154). U.S. Geological Survey, Revised November 2012. (pp. 590-658)
15. Regulatory Scenario Development, Analysis, and Results. Freese & Nichols, Inc., October 1, 2012. (pp. 659-854)
16. Geotechnical Services: PRESS Model Scenario Runs – Work Order 7. Fugro Consultants, Inc., June, 2013. (pp. 855-932)



3.2 FINAL RESULTS

One of the primary outputs of the RGUP are predictions of future groundwater levels and land-surface subsidence. Item 15 in Table 2, *Regulatory Scenario Development, Analysis, and Results*, provides the assumptions and results for the various regulatory scenarios that were evaluated in the RGUP. These scenarios were developed for the RGUP partners' consideration in evaluating their current regulatory plans.

This section compares Scenario 1, which assumes no future groundwater reduction beyond what was already in place in 2010, and the Final Scenario, which represents the HGSD regulatory plan adopted in January, 2013, the current FBSD regulatory plan, and the current LSGCD regulatory plan.

3.2.1 Scenario 1 (No Future Regulations)

A description of Scenario 1 is as follows:

- Harris and Galveston Counties (HGSD)
 - No increase in surface water supply beyond 2010 conversions.
 - No assumed reductions in surface water supply and all future increases in water demand are met with groundwater (Areas 1, 2, and 3).
 - Does not include Area 3 2020 70% groundwater reductions or 2030 80% groundwater reductions.
 - Future growth beyond 2010 supplied by groundwater in Areas 1 and 2.
- Fort Bend County (FBSD)
 - Assumes no conversions in 2014, 2016, or 2025. All future growth supplied with groundwater.
- Montgomery County (LSGCD)
 - No groundwater reductions in Montgomery County.
- Brazoria County (BCGCD)
 - No groundwater reductions in Brazoria County.

Full results can be found in the Item 15 report listed in Table 2. Partial results are repeated here to help demonstrate the effects of current regulations adopted by the RGUP partners in contrast to what would be predicted to happen without those regulations.

Figure 2 through Figure 4 show the incremental 2010-2050 drawdown for the Chicot, Evangeline, and Jasper aquifers respectively. Figure 5 shows the incremental 2010-2050



subsidence: the subsidence contours are interpreted from PRESS and MODLOW SUB package results.

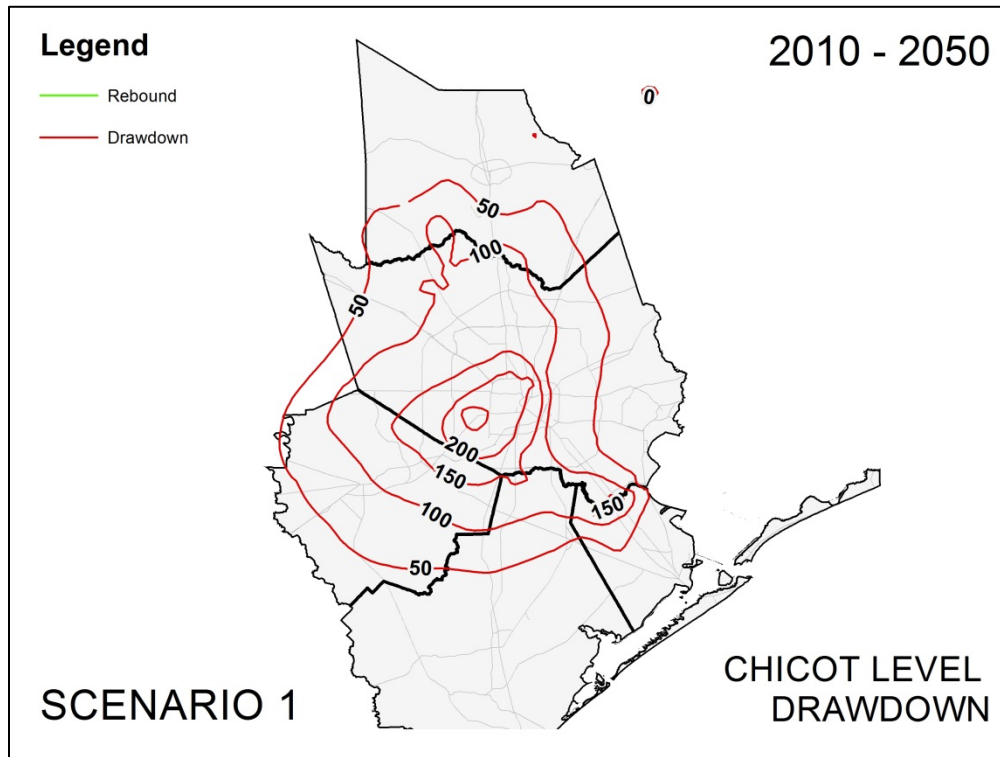


Figure 2. Scenario 1 Chicot Drawdown: 2010-2050

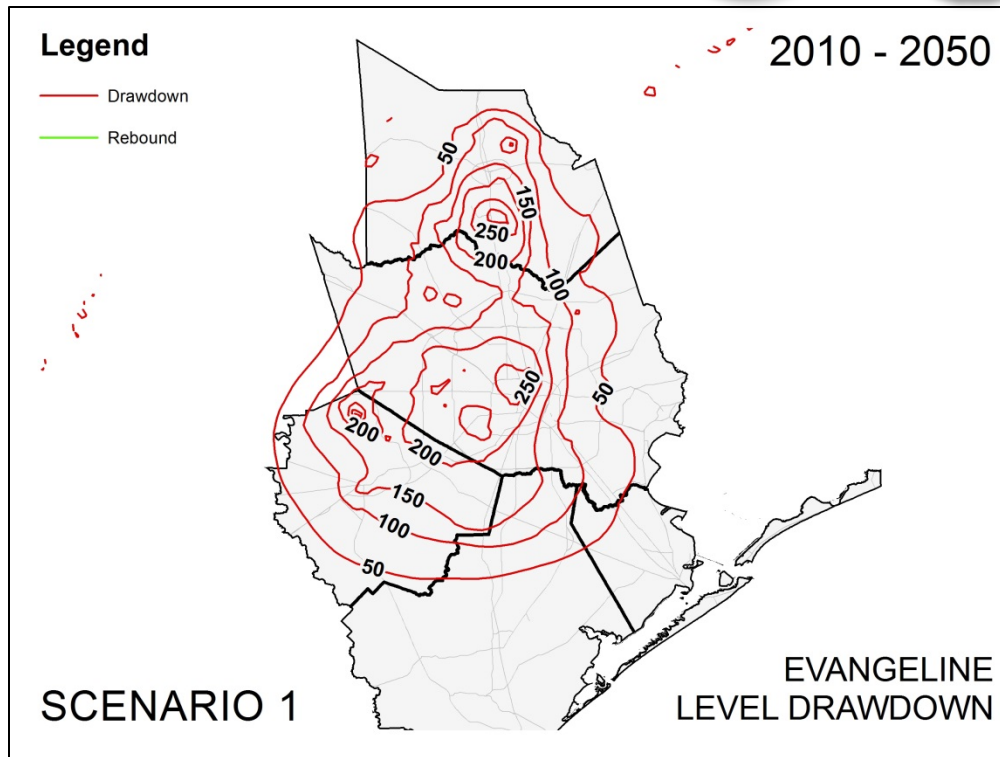


Figure 3. Scenario 1 Evangeline Drawdown: 2010-2050

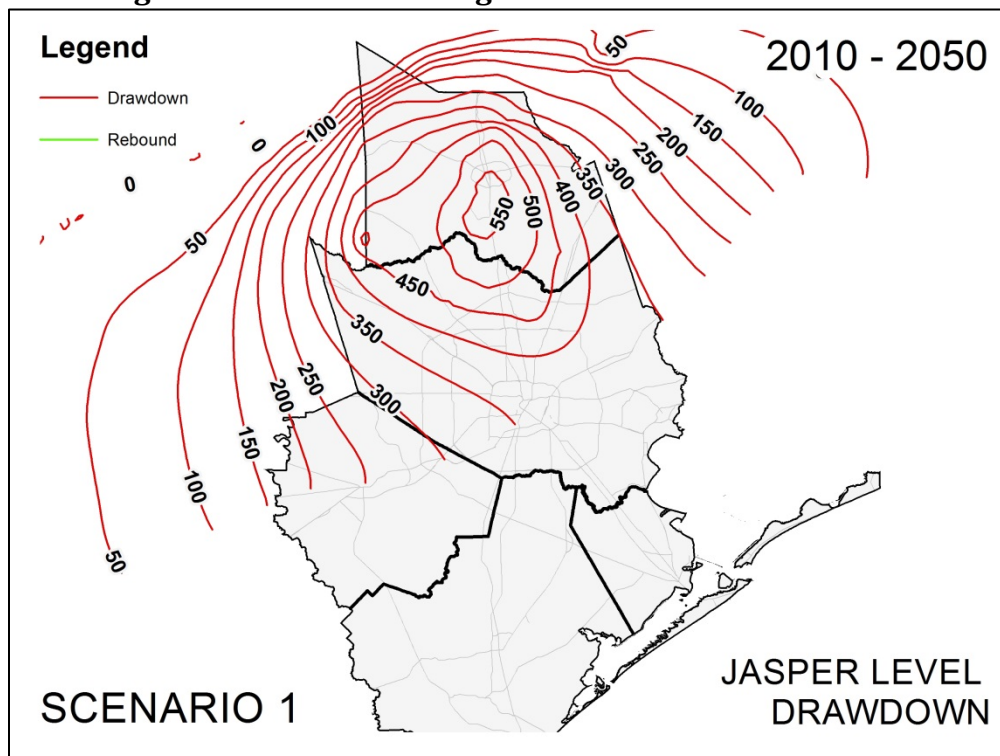


Figure 4. Scenario 1 Jasper Drawdown: 2010-2050

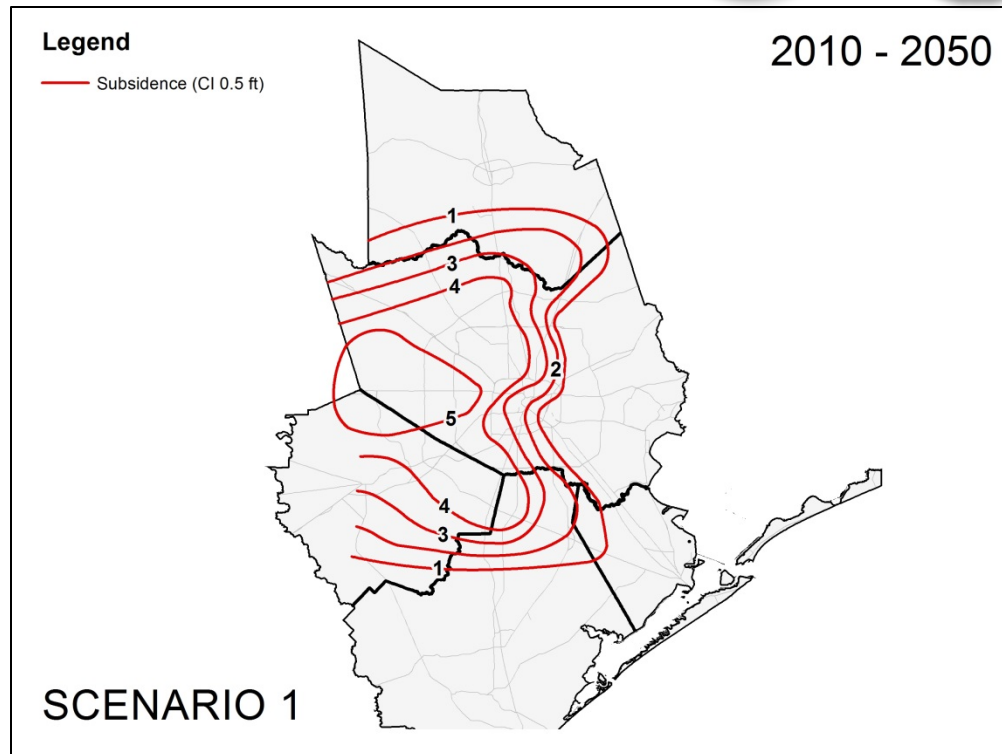


Figure 5. Scenario 1 Subsidence: 2010-2050

3.2.2 Final Scenario (Current Regulations)

The Final Scenario represents the RGUP partners' adopted regulatory plans as of January, 2013. HGSD was the only partner who modified their regulatory plan as a result of the RGUP. The regulations modeled in the Final Scenario are as follows:

- Harris and Galveston Counties (HGSD 2013 Regulatory Plan)
 - Area 1 = 90% conversion (same as 1999 DRP)
 - Area 2 = 80% conversion (same as 1999 DRP)
 - **Area 3 = 30% conversion current to 2024**
 - **Area 3 = 60% conversion 2025 to 2034**
 - **Area 3 = 80% conversion 2035 and beyond**
- Fort Bend County (FBSD 2003 Regulatory Plan)
 - Area A = 30% conversion 2014 to 2024
 - R/R Sub-Area = 30% conversion 2016 to 2024
 - Area A and R/R Sub-Area = 60% conversion 2025 and beyond
 - Area B remains on 100% groundwater.
- Montgomery County (LSGCD 2009 Regulatory Plan)



- 30% conversion in 2016 based on 2009 demands for Large Volume Groundwater Users (users with 2009 Groundwater production greater than or equal to 10 million gallons per year). Groundwater capped at 64,000 acre-feet per year for 2016 and beyond.
- Brazoria County (BCGCD)
 - **Assume City of Pearland (including ETJ) converts to 50% surface water by 2016 and beyond.**

Figure 6 through Figure 8 show the incremental 2010-2050 drawdown for the Chicot, Evangeline, and Jasper aquifers respectively. Figure 9 shows the 2010-2050 subsidence predicted by the individual PRESS models. Figure 10 shows the incremental 2010-2050 subsidence contours: the subsidence contours are interpreted from the PRESS models and MODLOW SUB package results.

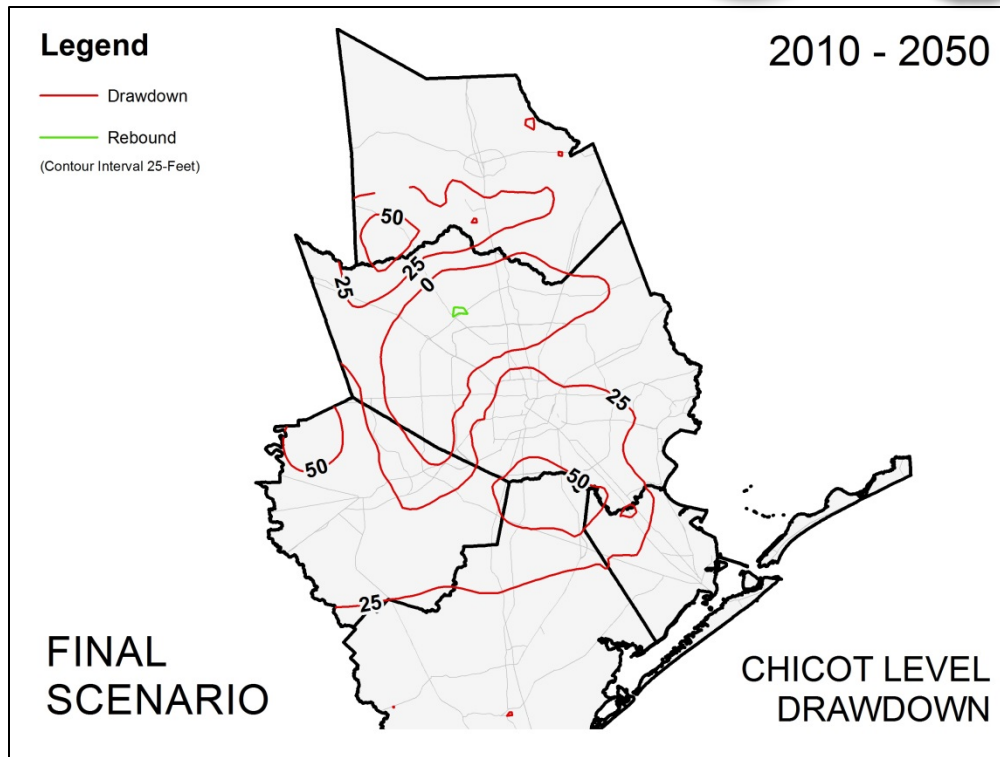


Figure 6. Final Scenario Chicot Drawdown: 2010-2050

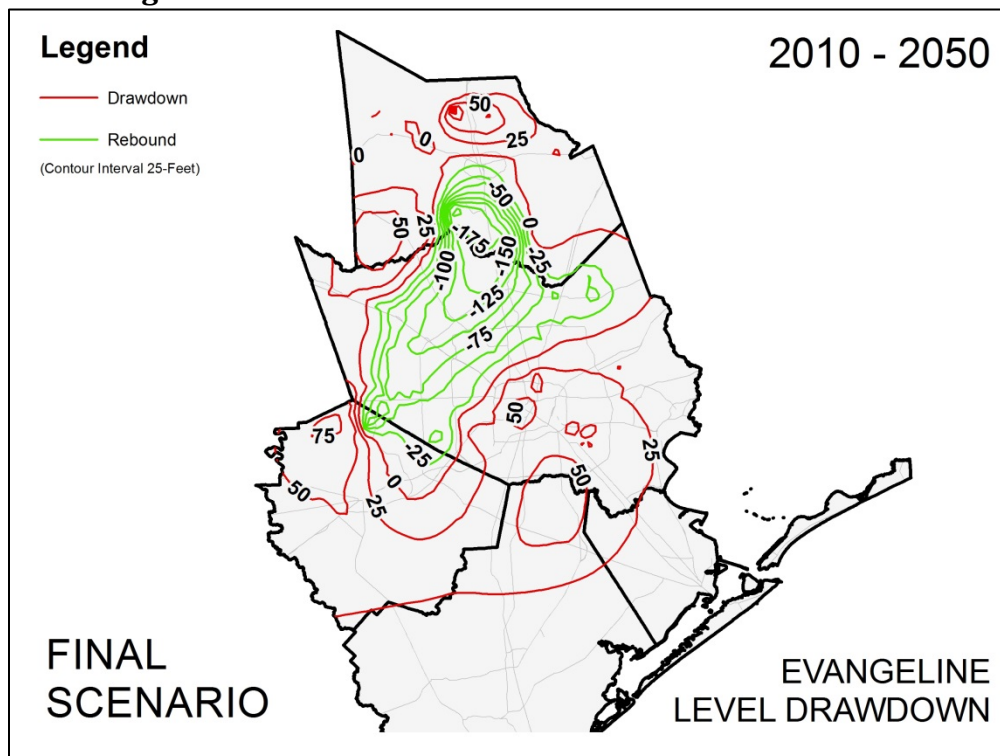


Figure 7. Final Scenario Evangeline Drawdown: 2010-2050

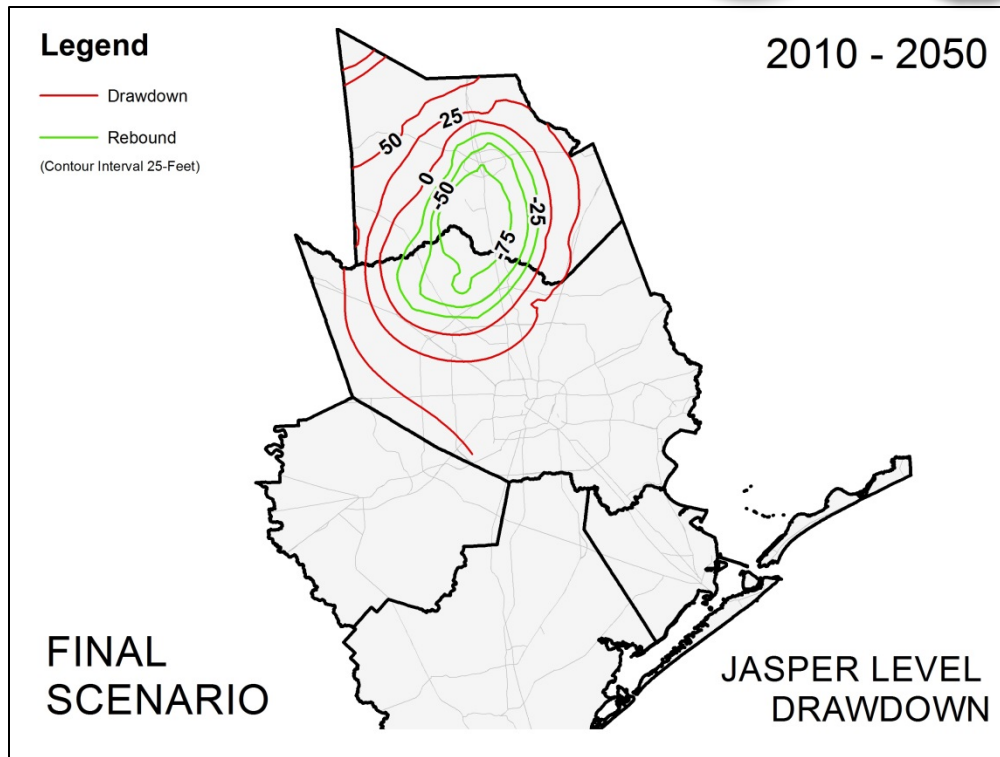


Figure 8. Final Scenario Jasper Drawdown: 2010-2050

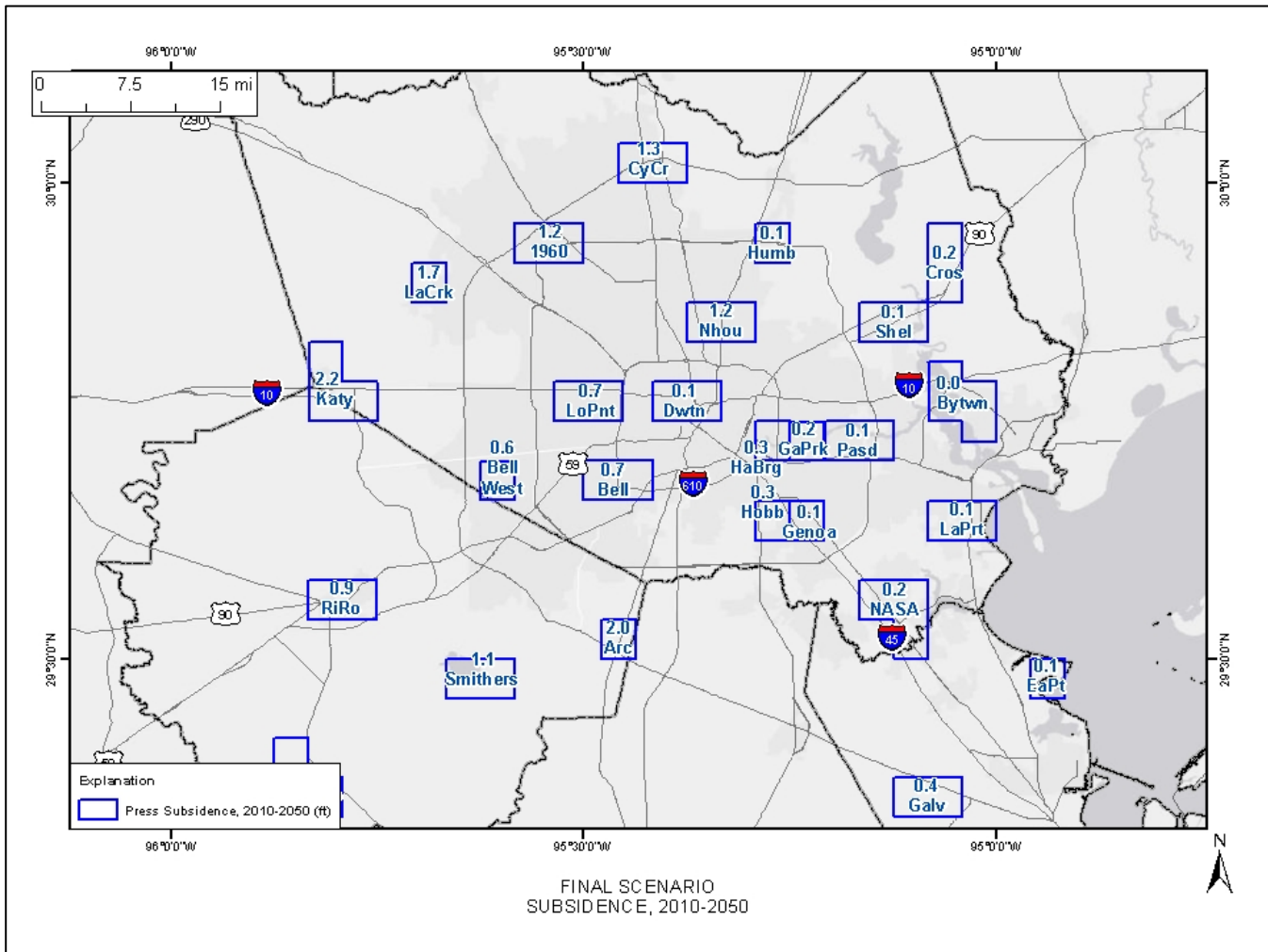


Figure 9. Final Scenario PRESS Subsidence: 2010-2050

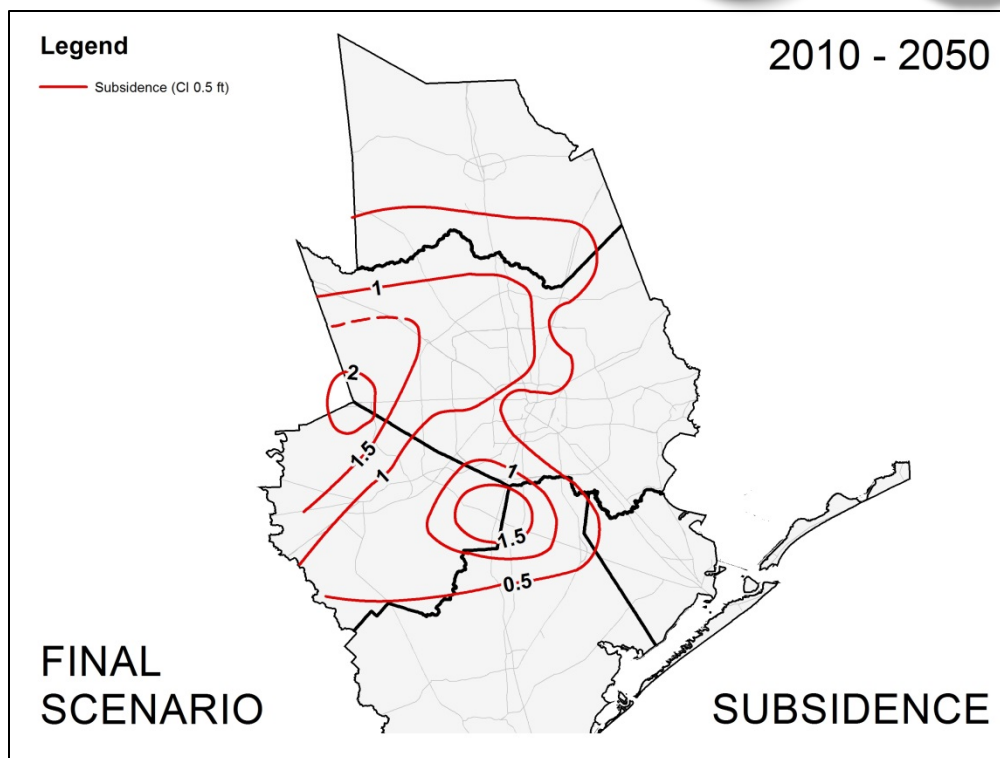


Figure 10. Final Scenario Subsidence: 2010-2050

3.2.3 Impact of Current Regulations

Tables 3-5 provide descriptions, by county, of the impact of regulations on the Chicot, Evangeline, and Jasper aquifers respectively, by comparing water level drawdown predicted with the Final Scenario model with drawdown predicted from the Scenario 1 model. In each of the RGUP partner counties, predicted drawdown is significantly reduced, and in the case of the Evangeline and Jasper aquifers, there is significant rebound in Harris and Montgomery counties.

Table 3. Chicot Water Level Drawdown Comparison: 2010-2050

	Scenario 1	Final Scenario
Fort Bend	Max 200 ft. drawdown near the Harris County border	Generally 0-25 ft. drawdown. Max 50 ft. in northwest
Galveston	Max 150 ft. drawdown near the Harris County border	Max 50 ft. drawdown near Friendswood
Harris	Generally 50-100 ft. drawdown. Up to 250 ft. in the southwest.	Generally 0-25 ft. drawdown. Max 50 ft. near Pearland and also near Montgomery County
Montgomery	50-100 ft. drawdown in southern county	Max 50 ft. drawdown in southwest



Table 4. Evangeline Water Level Drawdown Comparison: 2010-2050

	Scenario 1	Final Scenario
Fort Bend	Generally 50-200 ft. drawdown. Isolated area of 350 ft. in north.	75 ft. rebound near Cinco Ranch. Drawdown limited to 75 ft. in localized area in north.
Galveston	Max 100 ft. drawdown in far northwest near Pearland	Max 50 ft. drawdown at border with Brazoria County
Harris	Max 250 ft. drawdown in central and southwest	150 ft. rebound in north. Max 50 ft. drawdown
Montgomery	Max 300 ft. drawdown in The Woodlands area	200 ft. rebound in The Woodlands. Max 50 ft. drawdown elsewhere.

Table 5. Jasper Water Level Drawdown Comparison: 2010-2050

	Scenario 1	Final Scenario
Fort Bend	200-300 ft. drawdown in north, contours radiating from southern Montgomery Co	Max 50 ft. drawdown
Galveston	None	None
Harris	300-500 ft. drawdown in west and north, contours radiating from southern Montgomery Co.	75 ft. rebound in north
Montgomery	Max 550 ft. drawdown in The Woodlands	75 ft. rebound in The Woodlands. Max drawdown 50 ft.

Table 6 provides a description, by county, of the impact of regulations on subsidence. Predicted subsidence under Scenario 1 conditions is generally very low in eastern Harris County and Galveston County; i.e. in HGSD Regulatory Areas 1 and 2, where significant subsidence occurred in the past and where conversion to nearly 100% surface water has already occurred. Future growth on groundwater in these areas is not expected to produce significant additional subsidence since water level drawdowns would have to exceed levels experienced prior to groundwater reduction regulations (i.e. drop below the preconsolidation head). Additional subsidence under Scenario 1 conditions is greatest in HGSD Regulatory Area 3, which converted 30% in 2010, and Fort Bend County, where there has been no conversion to date.

Generally, current regulations are predicted to significantly reduce 2010-2050 subsidence to one foot or less throughout most of the four-county area; the exceptions are the Katy area and the northern Brazoria County/Pearland area. The Katy area is growing rapidly but is not currently scheduled to receive surface water in any of the existing Groundwater Reduction



Plans (GRPs), although its conversion is taken care of in the West Harris County Regional Water Authority GRP.

Brazoria County does not have any groundwater reduction regulations in place. The City of Pearland, while not required to reduce groundwater withdrawals, is voluntarily developing surface water supplies, and is committed to limiting groundwater use to no more than 50 percent of total demand starting in 2016. The City of Pearland planned surface water use is accounted for in the Final Scenario model, but the model is still showing up to 1.5 ft. of subsidence in northern Brazoria County.

Table 6. Land-Surface Subsidence Comparison: 2010-2050

	Scenario 1	Final Scenario
Fort Bend	Regional peak of subsidence is 5 ft. in western Harris and northern Fort Bend (Katy area and east). Fort Bend subsidence decreases as you go south.	Regional peak is again in the Katy area, but much smaller: 2 ft. is predicted fairly local to Katy. Generally 1 ft. or less everywhere else, except eastern part of county near Pearland, where 1.5 ft. is predicted.
Galveston	1-2 ft in the northwest.	0.5 ft. or less predicted
Harris	Regional peak in the west near Katy of 5 ft. Up to 1 ft in the eastern county.	0-2 ft., with peak near Katy
Montgomery	1-3 ft. in the southern part of county	Less than 1 ft. predicted.



Appendix A

Interim Studies and Reports

Technical Memorandum: Groundwater Model Update and Improvements. LBG-Guyton, May 2011. (pp. 1-15)

Technical Memorandum: Evaluation of Exempt Groundwater Use from Registered Wells Within the Harris-Galveston Subsidence District, Fort Bend Subsidence District and Lone Star Groundwater Conservation District. LBG-Guyton, May 2011. (pp. 16-32)

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