

Joint Regulatory Plan Review

Comprehensive Report

July 2025

HARRIS-GALVESTON



SUBSIDENCE
DISTRICT



FORT BEND
SUBSIDENCE DISTRICT

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List of Attachments

- Attachment 1. Task A: Projected Water Needs Evaluation Technical Memorandum
- Attachment 2. Task B: Alternative Water Supply Availability Report
- Attachment 3. Task C: PRESS Calibration Verification
- Attachment 4. Task D: Scenario Development and Testing
- Attachment 5. Task E: Stakeholder Meeting Presentations

List of Abbreviations

ASR	aquifer storage and recovery
AWS	alternative water supplies
CBP	County Business Patterns
CSUB	Skeletal Storage, Compaction, and Subsidence
DOR	drought of record
FBSD	Fort Bend Subsidence District
GAM	Groundwater Availability Model
GCD	Groundwater Conservation District
GMA	Groundwater Management Area
GPCD	gallons per-capita per day
GPM	gallons per minute
GRP	groundwater reduction plan
GULF 2023	Gulf Coast Land Subsidence and Groundwater-Flow Model
HAGM	Houston Area Groundwater Model
HGSD	Harris-Galveston Subsidence District
JRPR	Joint Regulatory Plan Review
MGD	million gallons per day
MODFLOW	modular finite-difference flow model



OPCC	opinion of probable construction cost
PDSI	Palmer Drought Severity Index
PRESS	Predictions Relating Effective Stress to Subsidence
PWS	Public Water System
RGUP	Regional Groundwater Update Project
RHWPG	Region H Water Planning Group
RO	reverse osmosis
RWP	Regional Water Plan
SAM-Houston	Small Area Model-Houston
SJRA	San Jacinto River Authority
TWDB	Texas Water Development Board
UH	University of Houston
USGS	United States Geological Survey
WUS	Water Use Survey

Water Measurements

Acre-foot (ac-ft) = 43,560 cubic feet = 325,851 gallons

Acre-foot per year (ac-ft/yr) = 325,851 gallons per year = 893 gallons per day

Gallon per minute (gpm) = 1,440 gallons per day = 1.6 ac-ft/yr

Million gallons per day (mgd) = 1,000,000 gallons per day = 1,120 ac-ft/yr

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EXECUTIVE SUMMARY

PROJECT PURPOSE

The Harris-Galveston Subsidence District (HGSD) and Fort Bend Subsidence District (FBSD) (collectively the Districts) were created to prevent subsidence in Harris, Galveston, and Fort Bend counties in southeast Texas through the regulation of groundwater withdrawals. Each District maintains its own Regulatory Plan that is reviewed on a regular basis to ensure that the goals of preventing subsidence based on updated water demand projections and the latest aquifer science and subsidence modeling methodology are still achieved. The last review, known as the Regional Groundwater Update Project (RGUP), was completed in 2013 and resulted in an updated Regulatory Plan for each District. In 2020, HGSD and FBSD initiated the Joint Regulatory Plan Review (JRPR) to estimate future changes in population and water demand, assess the availability of future alternative water supplies, review and update predictive subsidence models, and evaluate the impacts of planned regulatory requirements on future subsidence rates. Subsequently, each District may decide to modify its Regulatory Plan based on the results of the JRPR analyses.

APPROACH AND TASKS

The purpose of the JRPR is to complete several distinct technical evaluations based on the latest available science and present the results to the Board of Directors of each District and to stakeholders.

The JRPR objectives were divided into the following tasks:

Task A – Develop population and water demand projections.

Task B – Conduct an alternative water supply assessment.

Task C – Develop the Gulf Coast Land Subsidence and Groundwater Flow Model (GULF 2023).

Task D – Evaluate regulatory scenarios.

Water demand projections are necessary for evaluation of potential subsidence impacts in various scenarios, as projected groundwater pumping is a primary input to the GULF 2023 model. Population growth projections are used to predict growth in municipal water demands, which are combined with industrial, agricultural, and mining water demands to determine total water demand. A portion of



this demand is allocated toward groundwater based on historical use patterns and regulatory requirements; this portion of the demand becomes the input to the GULF 2023 model. The remaining projected demand must be met by alternative water supplies. The alternative water supply assessment evaluates various strategies to meet this remaining demand.

The GULF 2023 model was used to evaluate various scenarios to answer questions about how variations in demand and other factors could impact potential subsidence outcomes over a near-term period (2025 to 2050) and a long-term period (2050 to 2100).

STUDY RESULTS

Fort Bend County

Overall, groundwater demand for all use types in Fort Bend County is expected to increase by nearly 110% from 2020 to 2100. Demand is largely associated with municipal demand that grows with population and, to a lesser degree over time, agricultural demand.

The most likely alternative water supply (AWS) to supplement existing supply is surface water development. Additional AWS strategies such as seawater desalination and centralized non-potable reclaimed water treatment could result in significant additional supply. Overall results demonstrate availability of AWS to provide for implementation of the FBSD Regulatory Plan in Fort Bend County.

Subsidence modeling indicates that the current regulations of FBSD, including a requirement within Area A that groundwater withdrawals comprise no more than 40% of total water demand by 2027, will result in subsidence between 3 and 6 inches over the period from 2025 to 2050. In the following 50 years (2050 to 2100), additional subsidence of 12 to over 18 inches is predicted, varying by location within the county.

Harris and Galveston Counties

Overall, groundwater demand in Harris County is expected to decrease by nearly 28% from 2020 to 2100 based on projected growth under the current Regulatory Plan. A larger reduction in groundwater demand is expected by 2035 as water providers in Regulatory Area 3 within Harris County convert to using 80% AWS in accordance with the HGSD Regulatory Plan, after which groundwater use is expected to grow gradually as total demand continues to grow. Demand is largely

driven by population and industrial water use. Galveston County groundwater demand is expected to increase by nearly 29% from 2020 to 2100.

The most likely AWS to supplement existing supply is surface water development. Additional AWS strategies such as seawater desalination and centralized non-potable reclaimed water treatment could result in significant additional supply. Overall results demonstrate availability of AWS to provide for implementation of the HGSD Regulatory Plan in Harris and Galveston counties.

Subsidence modeling indicates that under the current regulations dictated by HGSD, including a requirement within Area 3 that groundwater withdrawals comprise no more than 40% and 20% of total water demand by 2025 and 2035, respectively, subsidence of varying magnitudes may occur across the HGSD jurisdiction. Predicted subsidence varies from less than 3 inches up to 12 inches between 2025 and 2050, and another 12 or less inches up to 18 inches is predicted in the period from 2050 to 2100. The lowest magnitudes of additional subsidence predicted from 2025 to 2100 are in the central portion of Harris County, with the greatest values generally occurring in northern and eastern Harris County.



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SECTION 1 – INTRODUCTION

1.1 PROJECT BACKGROUND AND OBJECTIVES

The Harris-Galveston Subsidence District (HGSD) and Fort Bend Subsidence District (FBSD) (collectively the Districts) were created to prevent subsidence in Harris, Galveston, and Fort Bend counties in southeast Texas through the regulation of groundwater withdrawals. Each District maintains its own Regulatory Plan that is reviewed on a regular basis to ensure that the goals of preventing subsidence based on updated water demand projections and the latest aquifer science and subsidence modeling methodology are still achieved. The last review, known as the Regional Groundwater Update Project (RGUP), was completed in 2013 and resulted in an updated Regulatory Plan for each District. In 2020, HGSD and FBSD initiated the Joint Regulatory Plan Review (JRPR) to estimate future changes in population and water demand, assess the availability of future alternative water supplies (AWS), review and update predictive subsidence models, and evaluate the impacts of planned regulatory requirements on future subsidence rates. The purpose of the JRPR is to complete several distinct technical evaluations based on the latest available science and present the results to the Board of Directors of each District and to stakeholders. Subsequently, each District may decide to modify its Regulatory Plan based on the results of the JRPR analyses.

The JRPR objectives were divided into the following tasks:

Task A – Develop population and water demand projections.

Task B – Conduct an alternative water supply assessment.

Task C – Develop the Gulf Coast Land Subsidence and Groundwater Flow Model (GULF 2023).

Task D – Evaluate regulatory scenarios.

1.1.1 PROJECT TEAM AND KEY STAKEHOLDERS

The project team included multiple technical consultants working in coordination with HGSD and FBSD staff to accomplish each objective. The United States Geological Survey (USGS) was also a significant collaborator. The roles of each team member are described in **Table 1-1**.

Table 1-1: JRPR Project Team Members and Roles

Team Member	Role(s)
HGSD / FBSD	Project partners
United States Geological Survey (USGS)	Development of new subsidence and groundwater flow prediction model
Texas Water Development Board (TWDB)	Collaborator on development of new subsidence and groundwater flow prediction model and adoption of an updated Northern Gulf Coast Groundwater Availability Model (GAM) for GMA-14

Communication and coordination with stakeholders in the region were a critical part of the JRPR process. Key stakeholders include:

- Regulated community, including municipalities, utility districts, regional water authorities, other wholesale water providers, and other well owners
- Groundwater Management Area 14 (GMA 14)
- Groundwater conservation districts
- Region H Water Planning Group (RHWPG)
- River authorities

1.2 HISTORY OF SUBSIDENCE PLANNING

Subsidence is the gradual sinking of the earth's surface due to changes in the subsurface. In the greater Houston region, subsurface extraction, namely from hydrocarbon production, resulted in land surface subsidence in 1918 along with the appearance of surficial fissures (Johnson and Pratt, 1926). Later, in the 1940s, research conducted by local universities, the State of Texas, and the U.S. Geological Survey began to identify the correlation between groundwater withdrawal for municipal, industrial, and agricultural supply and subsidence. Then in 1961, Hurricane Carla made landfall causing devastating storm surges and flooding. Another notable instance of damaging subsidence impacts was the loss of the Brownwood neighborhood in Baytown after numerous floods in the early 1970s and a final declaration from FEMA in 1983 after Hurricane Alicia stating that the neighborhood was unsuitable for human habitation. As a result, local area governments began to analyze the severe impacts subsidence could have on the region's economic growth and began to determine how best to reduce the reliance on groundwater. In response, the Texas Legislature established HGSD in 1975 and FBSD in 1989.

1.2.1 CURRENT REGULATORY PLANS

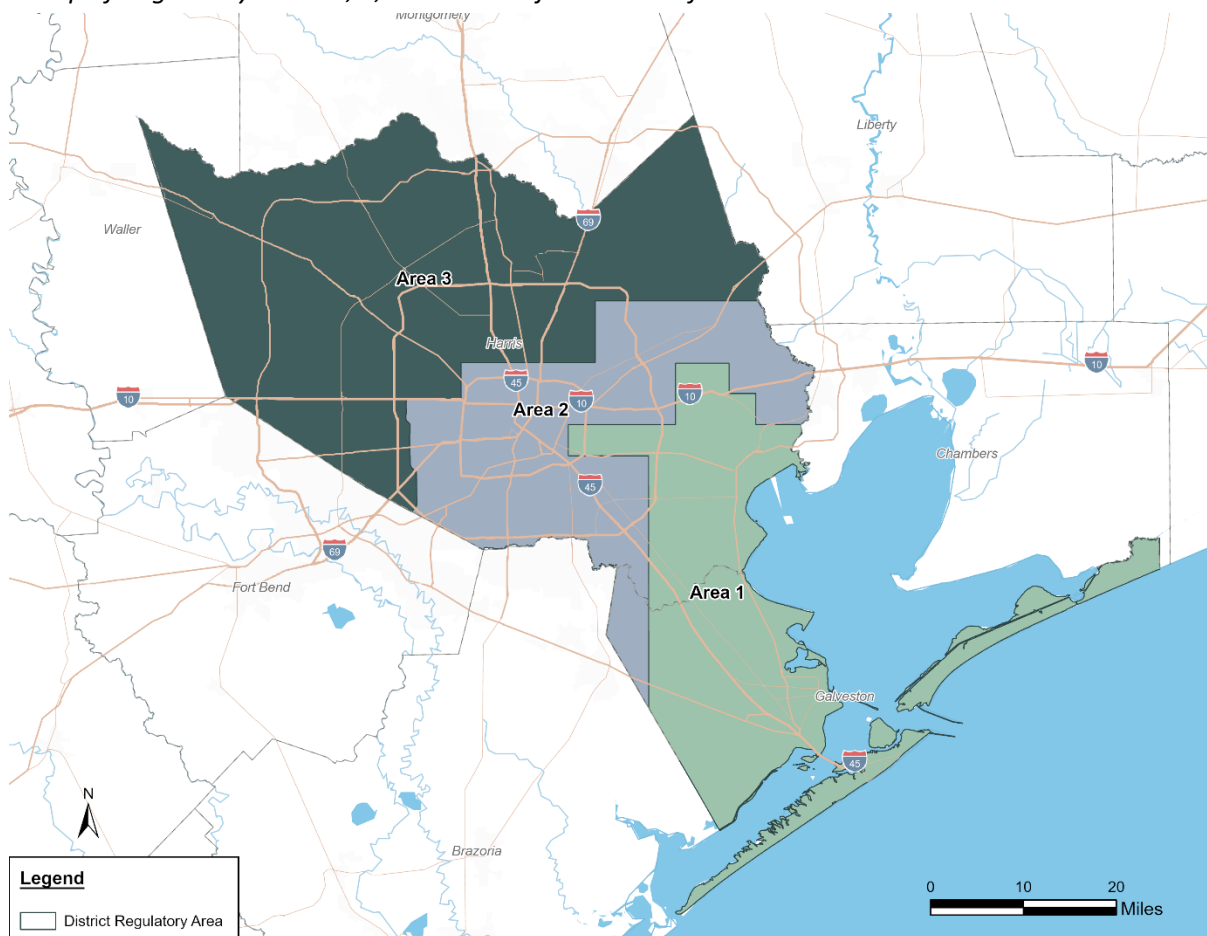
At the time of this review, the Regulatory Plans for the Harris-Galveston and Fort Bend Subsidence Districts were adopted in 2013 and were later amended in 2021 and 2022, respectively. The regulatory areas governed by the HGSD and FBSD are shown in **Figure 1-1** and **Figure 1-2**.

Harris-Galveston Subsidence District

The HGSD 2013 Regulatory Plan aims to reduce groundwater reliance to only 10% of total water demand in Area 1 and only 20% in Areas 2 and 3. Within Areas 1 and 2, the groundwater demand goal has been achieved. Area 3 is currently undergoing conversion to reduce groundwater use. Here, groundwater users must reduce usage to not more than 40% of total demand by 2025 and then to 20% by 2035. This Plan provides rules for exemptions to groundwater reduction.

Figure 1-1: Regulatory Areas in HGSD

Map of Regulatory Areas 1, 2, and 3 in the jurisdiction of the Harris-Galveston Subsidence District.

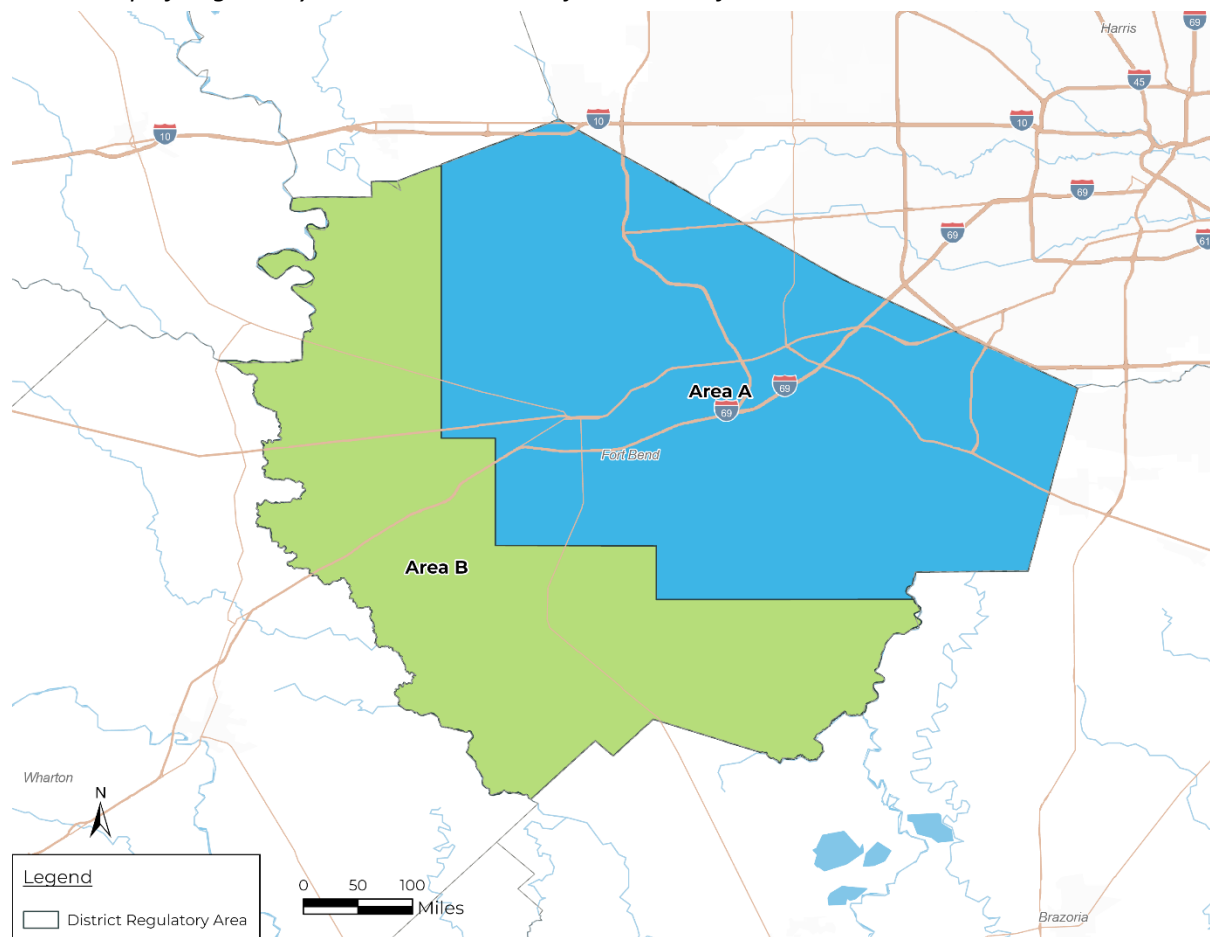


Fort Bend Regulatory Subsidence District

The FBSD 2013 District Plan aims to reduce groundwater reliance to only 40% of total water demand within Area A. Currently, Area A is required to limit groundwater use to no more than 70% of total demand, although conversion to reduce groundwater use to no more than 40% is scheduled to occur by 2027. Area B is not subject to groundwater reduction requirements at this time. Currently, groundwater demand in Fort Bend County comprises approximately 45% of total water demand (Greuter, 2025). This Plan provides rules for exemptions to groundwater reduction.

Figure 1-2: Regulatory Areas in FBSD

Map of Regulatory Areas A and B in the jurisdiction of the Fort Bend Subsidence District.



1.3 BOARD PROCESS

The information generated from the JRPR was evaluated by the HGSD and FBSD Boards and was used to evaluate the effectiveness of the currently adopted Regulatory Plans for controlling future subsidence within Fort Bend, Galveston, and Harris counties. The results of the study have been reviewed and considered in the course of numerous Committee meetings and public workshops of the two boards and subject to stakeholder input through that process.

1.4 STAKEHOLDER PROCESS

Stakeholder engagement is critical to successful implementation of the Regulatory Plans and is highly valued by HGSD and FBSD. Multiple stakeholder meetings have been hosted throughout the JRPR process (**Table 1-2**).

In addition to the stakeholder meetings listed below, HGSD and FBSD collected data from stakeholders for use in the development of population and water demand projections. Feedback from stakeholders on draft population projections was used to refine the projections. More information on stakeholder involvement in the development of population and demand projections is provided in **Attachment 1**. Presentation materials from the public stakeholder meetings are provided in **Attachment 5**.

Table 1-2: JRPR Public Workshops and Stakeholder Meetings

Meeting Date	Meeting Topics
May 20, 2020	Stakeholder Meeting 1 / Stakeholder Advisory Forum 1 • Project overview • Introduction to groundwater flow and numerical groundwater flow modeling • Study area • Planned approach, including model properties and model features • Observations and a request for relevant data to support the model • Proposed schedule
September 30, 2020	Stakeholder Meeting 2 • Proposed methodology for Tasks 1, 2, 3 • 2013 Regulatory Plan Post Audit
December 10, 2020	Stakeholder Meeting 3 / Groundwater Availability Modeling Stakeholder Advisory Forum 2 • Update on alternative water supply analysis • TWDB presentation on groundwater availability modeling • USGS update on GULF 2023 groundwater model development
June 8, 2021	Stakeholder Meeting 4 • Detailed methodology for population and demand projections, including plan for stakeholder involvement • Preliminary findings of alternative water supply analysis
December 14, 2021	Stakeholder Meeting 5 • TWDB presentation on groundwater availability modeling • USGS update on GULF 2023 groundwater model development
September 8, 2022	Stakeholder Meeting 6 • Review of population projections
September 11, 2024 (HGSD) October 10, 2024 (FBSD)	HGSD and FBSD JRPR Workshops • Update on the status of the JRPR: population and demand projections, alternative water supply assessment, groundwater scenario development, and initial baseline results from GULF-2023
June 11, 2025 (HGSD) June 25, 2025 (FBSD)	HGSD and FBSD JRPR Workshops • Overview of final elements of the JRPR: population and demand projections, alternative water supply assessment, and results from groundwater scenario evaluations from GULF-2023

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SECTION 2 – PROJECTED WATER NEEDS

2.1 OVERVIEW

Water demand projections are necessary for evaluation of potential subsidence impacts in various scenarios, as projected groundwater pumping is a primary input to the GULF 2023 model. Demand projections also inform the need for alternative water supplies. For the JRPR, water demand projections were developed for each decade in the period 2020 through 2100. These projections include demands for retail municipal (e.g., residential, institutional, and commercial served by public water systems), industrial, agricultural, mining, and exempt (e.g., single-family dwellings) water users. Additional information can be found in **Attachment 1**.

2.2 METHODOLOGY

To develop water demand projections, decadal population projections were developed for each Public Water System (PWS) and for non-PWS areas; these were interpolated to estimate future population in each planning year. A typical level of per-capita demand was estimated for each PWS and for domestic users in gallons per-capita per day (GPCD), which was then applied to the population projections. Draft manufacturing demand projections estimated by the Texas Water Development Board (TWDB) for use in the 2026 RWP were used to develop industrial and mining demands. Agricultural demands were developed using a methodology employing data from the Districts and TWDB.

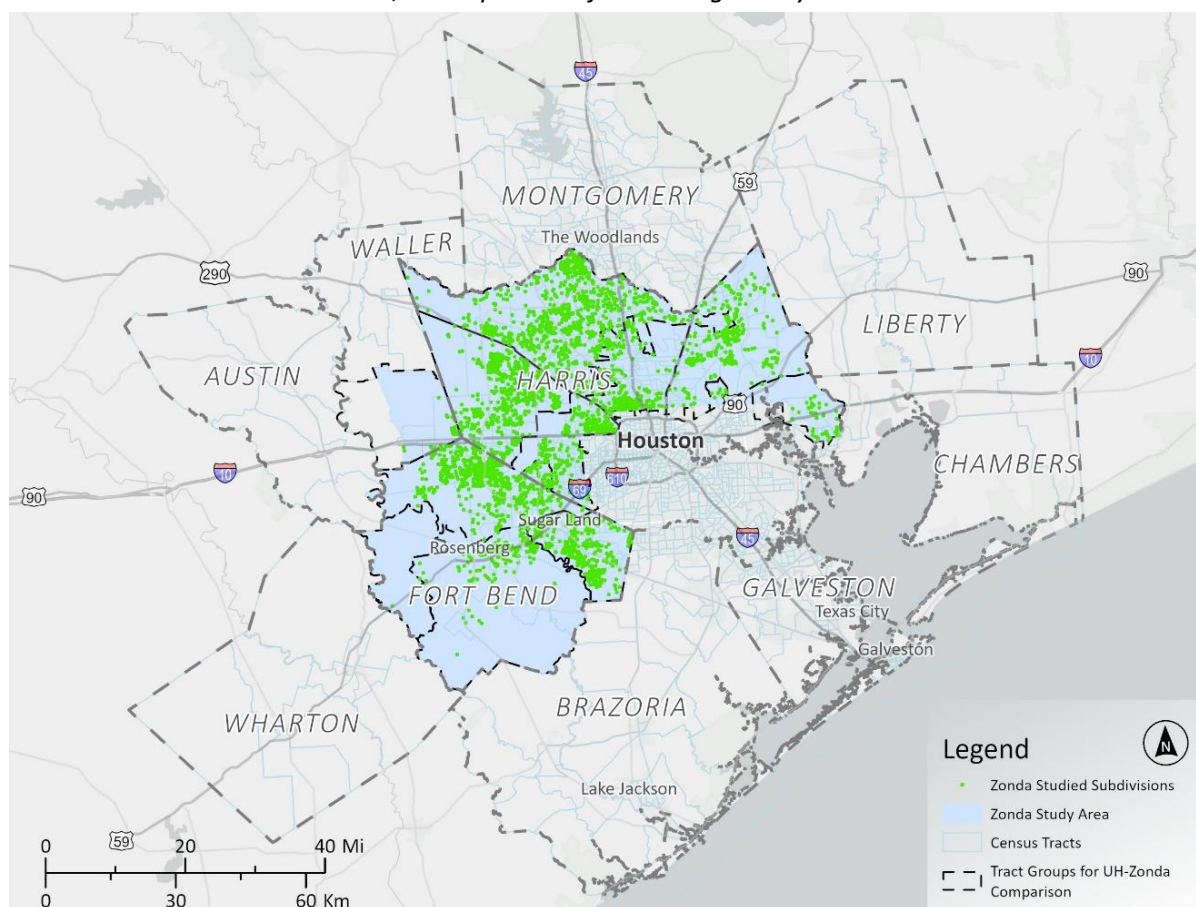
2.2.1 POPULATION PROJECTIONS

Population estimates from the 2020 Census were used as the baseline for the period of 2030 to 2100. Long-term decadal projections (spanning from 2030 to 2100) were developed by the University of Houston (UH) using the Small Area Model-Houston (SAM-Houston model). Near-term projections of growth between 2020 and 2030 were developed by Zonda for Fort Bend County, southeastern Waller County, a portion of HGSD Area 2, and the entirety of HGSD Area 3 (**Figure 2-1**). The results for 2030 projections developed by both methodologies were then compared and aligned to a single near-term projection.

Tract-level projections from Zonda and UH were disaggregated to smaller census blocks to provide a higher resolution of the study area. The process of disaggregation considered factors such as land use, proximity to transportation corridors, proximity to floodplains and wetlands, and proximity to other developments. Service area boundaries for PWS were obtained from the TWDB and were modified based on feedback from stakeholders. Boundaries were also adjusted to include areas that are anticipated to develop new PWSs in the future. These PWS boundaries were then used to reaggregate population projections from the census block level.

Figure 2-1: Study Area for Near-Term Detailed Forecasts by Zonda

Zonda developed population growth projections for years 2021 through 2030 for individual subdivisions and Census tracts in Fort Bend County, southeastern Waller County, HGSD Regulatory Area 3, and a portion of HGSD Regulatory Area 2.



2.2.2 MUNICIPAL DEMAND PROJECTIONS

Examining historical water use data provided a basis to develop municipal demand projections. This data was provided by individual JRPR stakeholders. If a stakeholder was unable to provide historical

data, other sources were used, including HGSD and FBSD pumping records, the TWDB Water Use Survey, and Texas Drinking Water Watch. Annual per-capita use from 2010 to 2020 was estimated based on historical water use data and population estimates, and estimates were compared to drought index data to account for variations in demand due to dry or wet conditions. A baseline per-capita demand was developed for each water system that is representative of demand in a typical year based on historical per-capita use and drought index data. Baseline per-capita demand was multiplied by projected population to develop total municipal demand projections for each PWS.

Exempt Domestic Water Use Estimation

Exempt wells are those that are registered with a groundwater conservation district (GCD) or subsidence district but are unpermitted. Wells that are less than a five-inch casing diameter that serve single-family dwellings are exempt from groundwater reduction requirements in the HGSD and FBSD Regulatory Plans. Projected population at the census block level that is outside of a PWS service area was assigned a baseline per-capita demand value of 100 GPCD based on the per-capita use rate assigned to rural domestic usage in the historical pumping estimates for the GULF 2023 model.

2.2.3 NON-MUNICIPAL DEMAND PROJECTIONS

Non-municipal demand was separated into industrial demand, mining demand, and agricultural demand.

Industrial Demand Projections

Draft manufacturing water demand projections developed by TWDB for the 2026 RWP were utilized for the JRPR. The TWDB projections span 2030 through 2080. For purposes of the JRPR, demands were assumed to remain constant from 2080 through 2100. A brief description of the TWDB methodology (TWDB, 2022) is presented below:

1. TWDB developed an estimated demand level for 2020 based on the highest annual manufacturing water use from years 2015-2019. Here, the 2020 demand level represents a base year projection and not actual use in the year 2020. Source data included the TWDB Water Use Survey (WUS) and estimates of non-surveyed water use based on TWDB data and the US Census Bureau's 2010-2019 County Business Patterns (CBP).



2. The statewide historical growth rate of water use from 2010 to 2019 in the TWDB WUS (0.96% annually) was applied to escalate 2020 manufacturing water demand to the year 2030.
3. Demand for 2040 through 2080 was escalated from 2030 using the statewide growth rate (0.37% annually) of manufacturing establishments cataloged in the 2010-2019 CBP.
4. Projected demand for 2080 was assumed to remain constant through 2100 in the JRPR.

Projected groundwater use was estimated by using the historical percentage of manufacturing water demand from groundwater in each county.

Mining Demand Projections

Most mining activity in the study area is aggregate mining. Demand projections in the JRPR for mining also used draft demand projections developed by TWDB for the 2026 RWP. TWDB mining projections were based on a 2022 study by the Bureau of Economic Geology (Reedy and Scanlon, 2022). The TWDB projections span 2030-2080; the JRPR held the 2080 values constant through 2100. Groundwater demands were estimated by using historical groundwater demand percentage by county.

Agricultural Demand Projections

Agricultural activity in the study area can be categorized as livestock production, cropland, or rice production, with rice production being the most water intensive. A brief description of the methodology for livestock and rice production demand projection is provided below.

Livestock

Species headcounts and per-head water demand rates were used to develop historical water use estimates for livestock production. Historical (2010-2019) livestock headcounts for the study area were evaluated for any trends. However, no clear trends emerged, so the 5-year average livestock water use was used as the baseline demand, which was held constant for 2030-2100 for each county.

Irrigation

For Harris and Galveston counties, average irrigation pumping from 2010-2020 in HGSD records was used as a constant annual projected irrigation groundwater demand for 2030-2100. Projected irrigation groundwater demand in Fort Bend County was based on historical FBSD irrigation pumping data, but a declining trend was applied from 2020 to 2100 based on historical declines in irrigation water use in the county. For the counties not regulated by either HGSD or FBSD, the average of calibrated irrigation pumping from 2010-2018 in the GULF 2023 model was utilized to maintain continuity for this study. Non-groundwater irrigation demand was based on TWDB historical irrigation water use estimates.

2.2.4 DROUGHT SCENARIO DEVELOPMENT

In addition to the baseline demand scenario, which assumes constant baseline per-capita demand for each PWS over the prediction period, a drought scenario was developed for alternative predictive modeling. In this scenario, a repeating ten-year cycle of summer average Palmer Drought Severity Index (PDSI), based on historical PDSI in 2011-2020, was used to create a time series of fluctuating per-capita demand for each system. The calculated GPCD time series were then applied to population projections to develop total water demand. This additional scenario provides insight into the sensitivity of groundwater levels and subsidence to varying demands under different climate conditions. Additional information on this scenario can be found in **Section 4.4.2**.



2.3 RESULTS

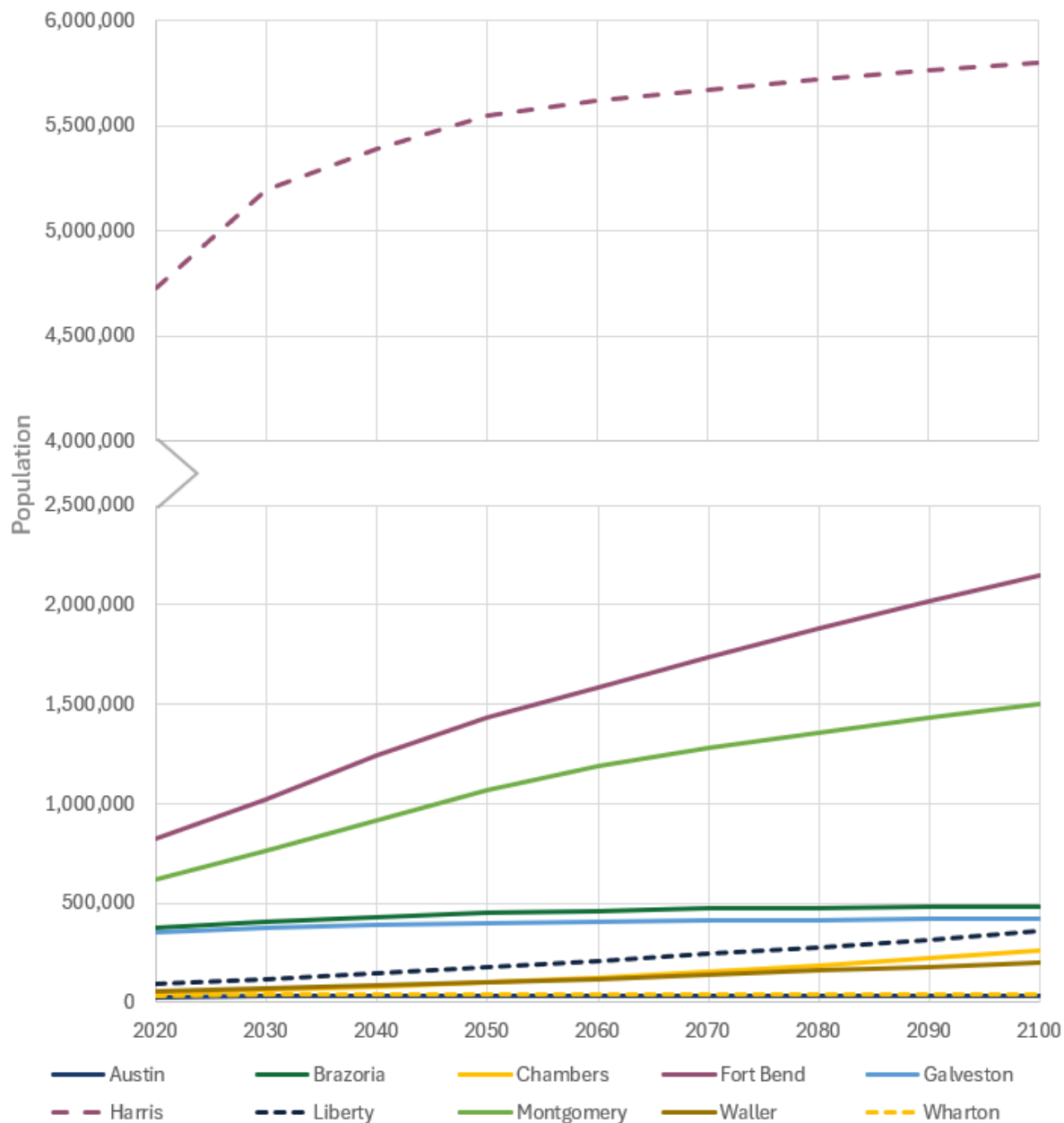
Overall, groundwater demands for the regulated areas are expected to increase by nearly 5% from 2020 to 2100. However, change in groundwater demand varies by regulatory area and includes near-term decreases with conversion and a long-term trend of increase as total demand in the region grows. This growth is largely driven by municipal development, followed by agriculture and industrial activities. Groundwater demand for unregulated counties is expected to increase by over 100%.

2.3.1 PROJECTED POPULATION GROWTH

Population projections from 2030 through 2100 were developed following the method described in **Section 2.2.1**. Growth in Harris County is expected to be focused in the urban core until approximately 2050. After 2050, population growth is projected to shift toward adjoining areas including outer Harris County and surrounding counties. Growth rates in suburban Fort Bend and Montgomery counties are expected to be high in the near and long-term. **Figure 2-2** summarizes the population projections by county.

Figure 2-2: 2020 Census Population and 2030-2100 JRPR Population Forecast by County

JRPR population forecasts were developed for decades 2030 through 2100 and were based on 2020 Census population counts.





2.3.2 MUNICIPAL DEMAND PROJECTIONS

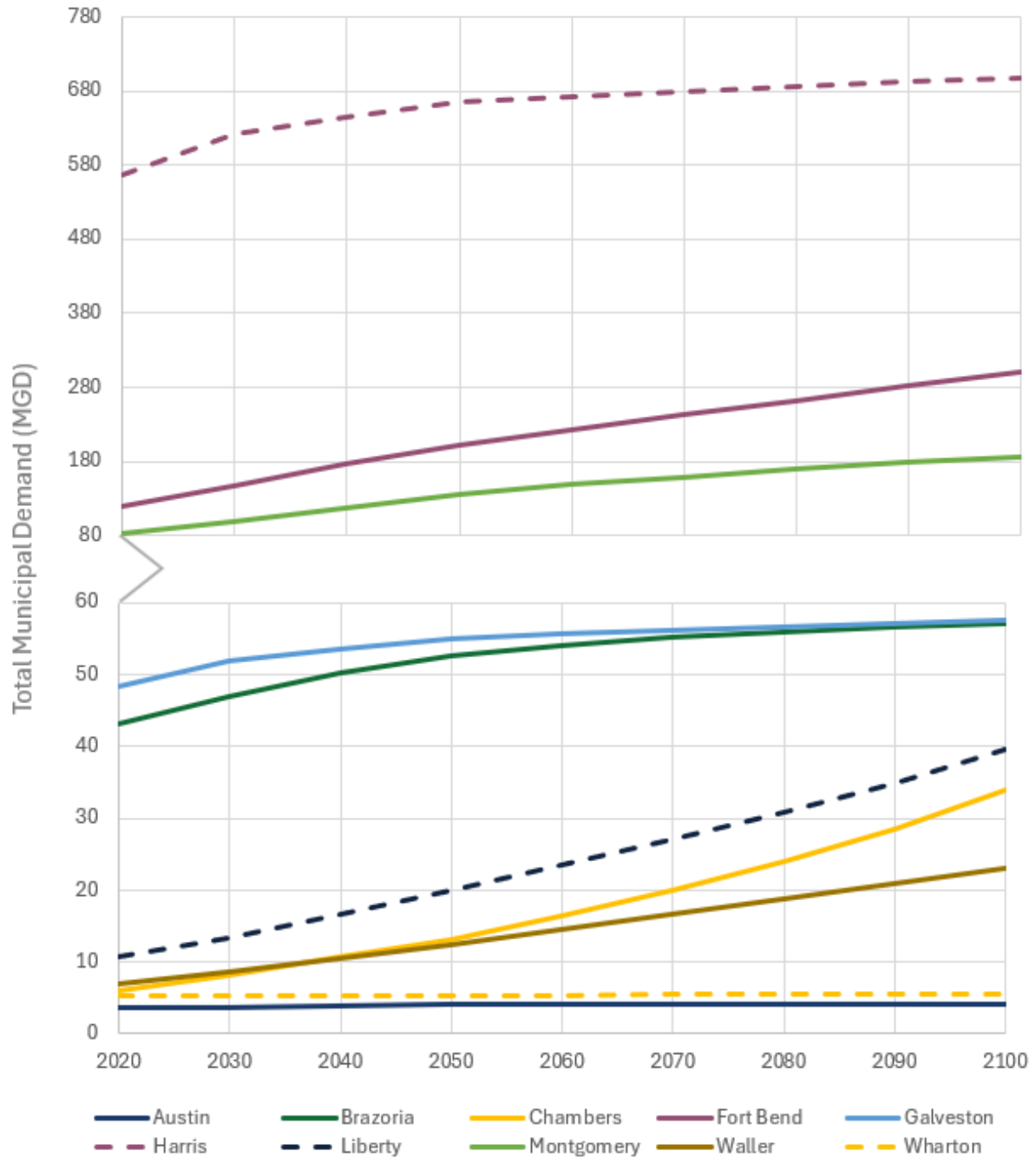
Per-capita demand varies depending on a number of factors but is especially sensitive to climate impacts such as rainfall and temperature. A methodology was devised and applied to analyze historical GPCDs using a regression analysis and historical drought index data. Regression models for each PWS were used to determine a baseline per-capita demand for median historical climate conditions. The baseline per-capita demand for each water system was applied to the population projections to develop total municipal demand. Total municipal demand (regardless of potential supply source) is summarized below. Allocation of municipal demand to groundwater pumping is discussed further in **Section 4**.

- **Fort Bend County:** Total municipal demand (regardless of source of supply) in Fort Bend County is expected to increase by more than 120% from 2020 to 2100.
- **Harris and Galveston counties:** Total municipal demands in Harris County and Galveston County (regardless of source of supply) are expected to increase by approximately 26% and 23%, respectively, from 2020 to 2100.

Projected municipal demand by county is shown in **Figure 2-3**.

Figure 2-3: JRPR Projections of Total Municipal Demand

JRPR projections of municipal water demand for years 2020 through 2100 are based on 2020 Census population, long-term projected populations, and a baseline per-capita demand value for each public water system that reflects median historical climate conditions.





2.3.3 INDUSTRIAL DEMAND PROJECTIONS

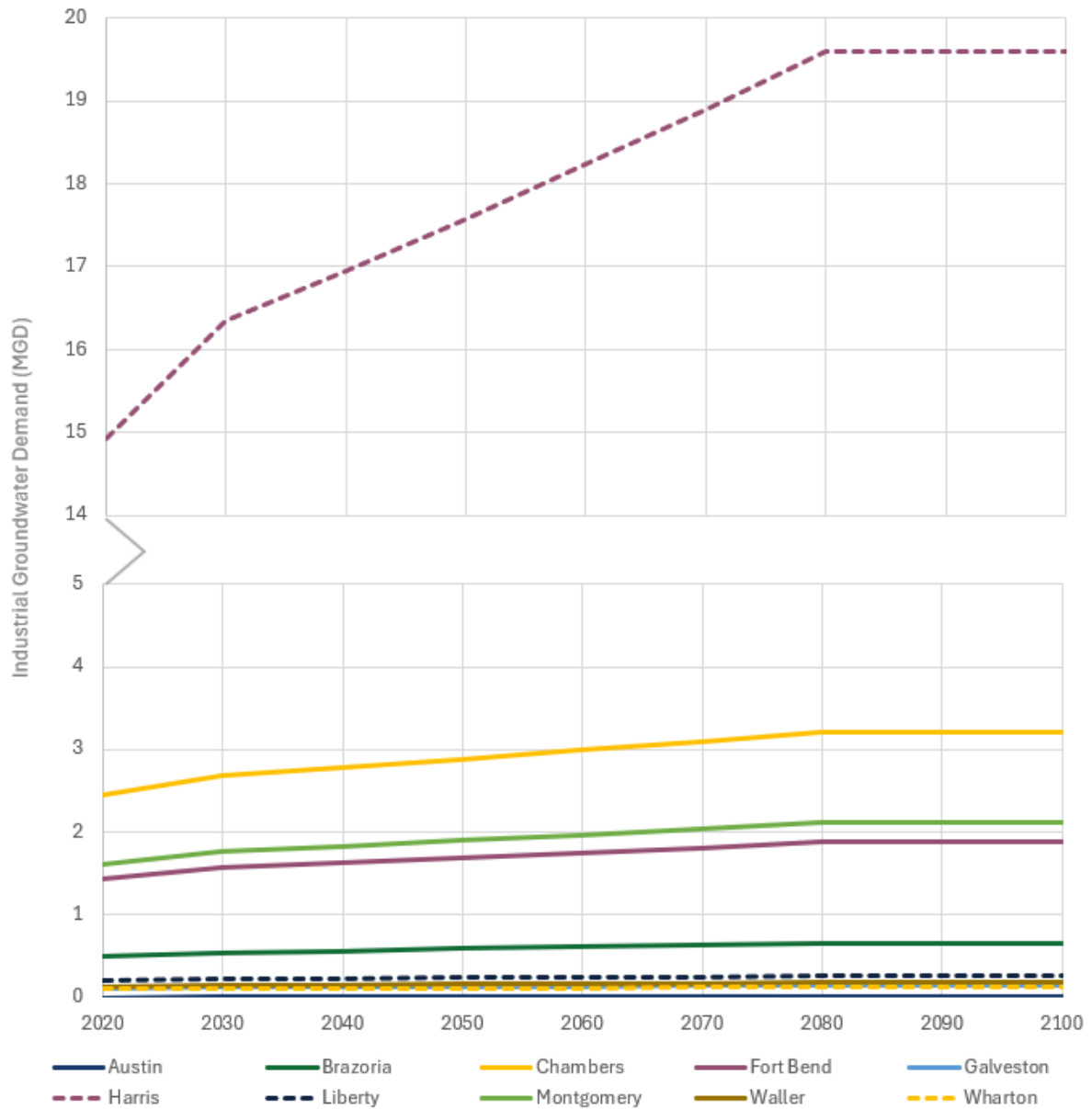
Projections of groundwater demand for industrial use were developed based on TWDB projections of total industrial water demand and historical data on the portion of demand met by groundwater.

- **Fort Bend County:** Industrial groundwater demand in Fort Bend County is expected to increase by nearly 31% from 2020 to 2100.
- **Harris and Galveston counties:** Most of the industrial zones in this study area are contained within Harris County followed by Galveston County. Industrial groundwater demand is expected to increase by nearly 31% from 2020 to 2100.

Projected industrial groundwater demand by county is shown in **Figure 2-4**.

Figure 2-4: JRPR Projections of Industrial Groundwater Demand by County

JRPR projections of industrial groundwater demand for years 2020 through 2100 were developed for all counties in the JRPR study area. Industrial groundwater demands are projected to increase by 31% in Fort Bend County and 31% in Harris and Galveston counties between 2020 and 2100.



2.3.4 MINING DEMAND PROJECTIONS

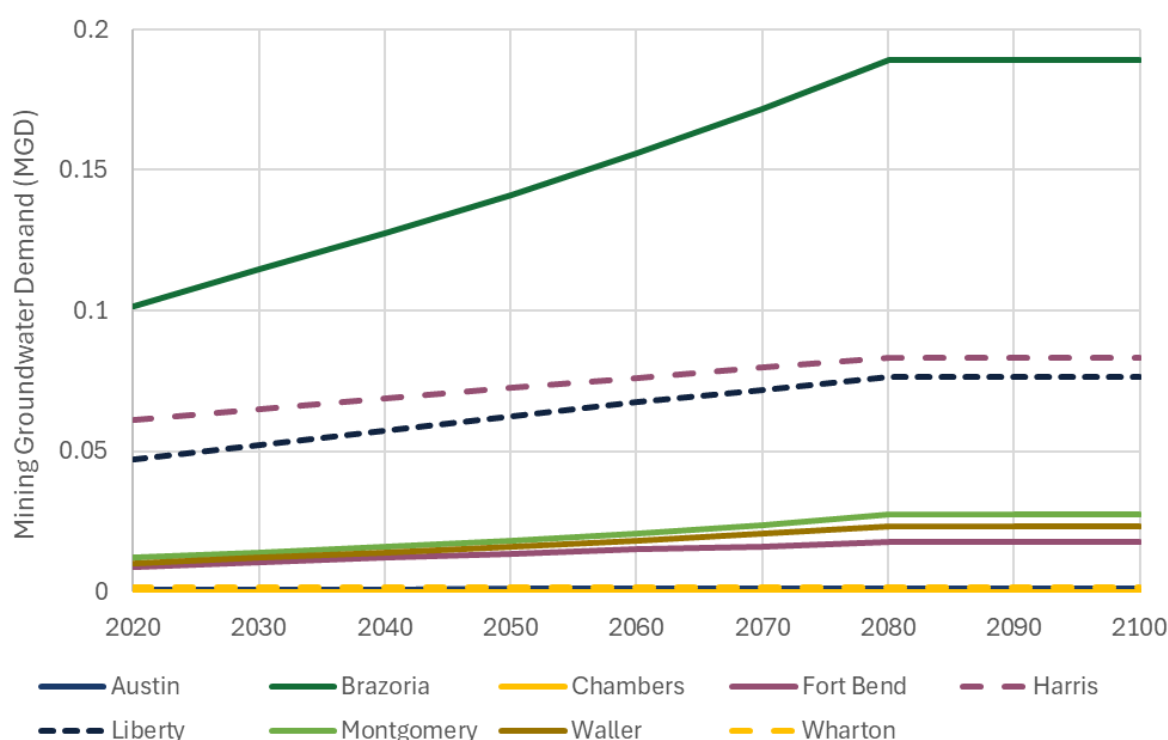
Projections of groundwater demand for mining use were developed based on TWDB projections of total water demand for mining and historical data on the portion of demand met by groundwater.

- **Fort Bend County:** Mining groundwater demand in Fort Bend County is expected to increase by nearly 100% from 2020 to 2100.
- **Harris and Galveston counties:** Mining demand in Harris County is expected to increase by nearly 36% from 2020 to 2100. Mining activities in Galveston County are extremely limited and are not expected to change.

Projected groundwater demand for mining use by county is shown in **Figure 2-5**.

Figure 2-5: JRPR Projections of Groundwater Demand for Mining Use by County

JRPR projections of groundwater demand for mining use in years 2020 through 2100 include increases in demand in most counties. The magnitude of groundwater demand for mining use is small compared to other water use types in the region.



2.3.5 AGRICULTURAL DEMAND PROJECTIONS

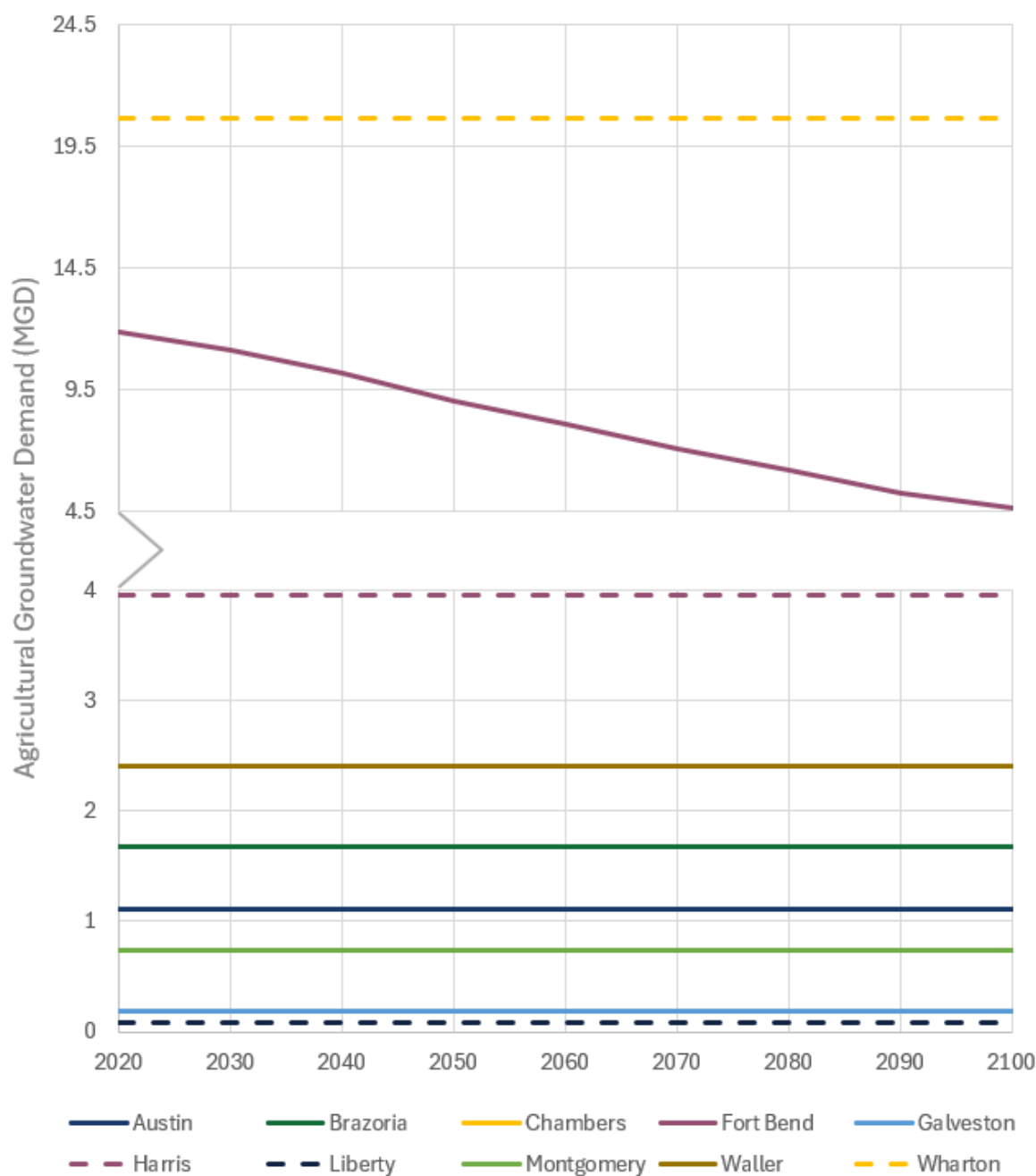
Projections of agricultural groundwater demand include pumping projections for both irrigation and livestock. These demand projections are based on historical data and are held constant for all decades, with the exception of irrigation demands in Fort Bend County, which is expected to continue a recent trend of decline.

- **Fort Bend County:** Agricultural groundwater demands in Fort Bend County are expected to decrease by nearly 61% from 2020 to 2100.
- **Harris and Galveston counties:** Agricultural groundwater demands in Harris County and Galveston County are assumed to remain constant from 2020 to 2100.

Projected agricultural groundwater demand by county is shown in **Figure 2-6**.

Figure 2-6: JRPR Projections of Agricultural Groundwater Demand by County

JRPR projections of groundwater demand for irrigation and livestock uses were developed for years 2020 through 2100. Demands are assumed to remain constant from 2020 through 2100 in all counties except Fort Bend County, in which demands are projected to decrease.



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SECTION 3 – ALTERNATIVE WATER SUPPLIES

3.1 OVERVIEW

The Districts' Regulatory Plans require groundwater users to reduce reliance on groundwater through alternative water supplies (AWSs). The JRPR identified different AWSs and evaluated each for cost, timeline for implementation, resiliency to climate change, and the potential amount of supply available. Additional information can be found in the [Alternative Water Supply Availability Report](#) or in **Attachment 2**.

3.2 ALTERNATIVE WATER SUPPLY OPTIONS

The JRPR identified over 20 different AWS options which were investigated with a desktop analysis. Of the 20 options initially identified, the HGSD and FBSD refined the analysis to seven as listed below:

- Surface Water Development
- Seawater Desalination
- Centralized Reclaimed Water Treatment
- Decentralized Reclaimed Water Treatment
- Brackish Groundwater Desalination
- Aquifer Storage and Recovery (ASR)
- Demand Management through Water Conservation

Surface Water Development

This AWS would involve the creation of new surface water supply through either the construction of new reservoirs, inter-basin transfers, or the optimization of existing water supply. This alternative generally yields large volumes of water but involves a large planning effort and substantial construction time and cost. It should also be noted that this alternative is sensitive to drought and climate change.

Seawater Desalination

Seawater desalination treats high-salinity water for potable use, most commonly through reverse osmosis (RO). The resulting brine from this process is then returned to the ocean. This method can



be employed either onshore or offshore, as the Gulf of Mexico provides virtually unlimited supply. This AWS is generally successful when regional collaboration with other entities is considered due to high capital and maintenance costs.

Centralized Reclaimed Water Treatment

This AWS involves the extended treatment of wastewater to either non-potable or potable use. In this option, a large regional plant would either provide reclaimed water to a purple pipe distribution network, send reclaimed water directly to a water treatment plant for further treatment, or provide water to bodies of water (surface or groundwater) for subsequent diversion and use. This AWS has the potential to provide reliable, drought resistant supply but requires planning effort to map out customers and rates of purchase.

Decentralized Reclaimed Water

Similar to the previous AWS, this option involves treating wastewater for either potable or non-potable use. However, this alternative does not involve a regional facility, but instead relies on smaller and more numerous facilities, such as lift stations, to treat wastewater onsite. This strategy is advantageous because it does not rely on extensive purple pipe networks and supply can be made available near the point of use.

Brackish Groundwater Desalination

This alternative is similar to saltwater desalination but instead uses brackish groundwater as a source of water. Brackish groundwater may either be treated through RO or be blended with another water source to increase volume of supply. This option has the potential to take advantage of local aquifers with brackish groundwater that have some resistance to drought. However, it should be noted that this option does have the potential to cause subsidence in some situations. Additionally, there may be additional treatment needed for brackish water and the resulting brine due to co-contaminants.

Additionally, it should be noted that under the current Regulatory Plans, brackish groundwater is not formally recognized as an AWS, as applications within the regulated areas of the Districts have not been demonstrated to avoid compaction and subsidence.

Aquifer Storage and Recovery

This AWS describes the strategy of recharging aquifers during low demand periods to act as reservoirs. The water that is recharged into an aquifer may be surface water, stormwater, or reclaimed water after some form of treatment. This AWS is not seen as subsidence neutral, since there is some possibility of compaction due to the pumping required to recover the previously stored water. While this option is generally thought of as drought resistant, the hydrologic conditions of the aquifer will greatly impact the efficacy of recovery. As with brackish groundwater desalination, ASR will require partnership between project sponsors and the Districts to ensure viability as a subsidence-avoidant alternative.

Demand Management/Conservation

This option is the management of water demand through various techniques to decrease consumption of an existing or future supply. This management technique is inherently drought resistant and does not have the potential to negatively affect subsidence. Although this option is heavily dependent on public participation, it may be updated and refined as needed.

3.3 SUMMARY OF AVAILABLE ALTERNATIVES

The options listed previously were evaluated across 10 different criteria: implementation approach, regulatory area(s) served, anticipated users, estimated magnitude of supplies, budgetary cost estimates, implementation timelines, water quality considerations, permitting and legal considerations, vulnerability to climate change, and subsidence impacts. A comprehensive analysis of each criterion is provided in **Attachment 2**.

3.3.1 SUPPLY MAGNITUDE

The analysis conducted found that existing supply plus additional supply generated from AWSs would be sufficient for the projected future demands. The total projected 2070 supplies from the AWSs are shown in **Table 3-1**.

Table 3-1: AWS Magnitude of Supplies Summary

Alternative Water Supply	Potential 2070 AWS Magnitude (MGD)
Surface Water Development	~700
Seawater Desalination	100
Centralized Reclaimed Water Treatment	160
Decentralized Reclaimed Water Treatment	13
Brackish Groundwater Desalination	24
Aquifer Storage and Recovery	20 ^a
Demand Management through Water Conservation	73 ^b

a – ASR requires treated surface water as a supply source. It is assumed that this surface water supply would be derived from interruptible rights that are not reflected in the magnitude of surface water development of this table.

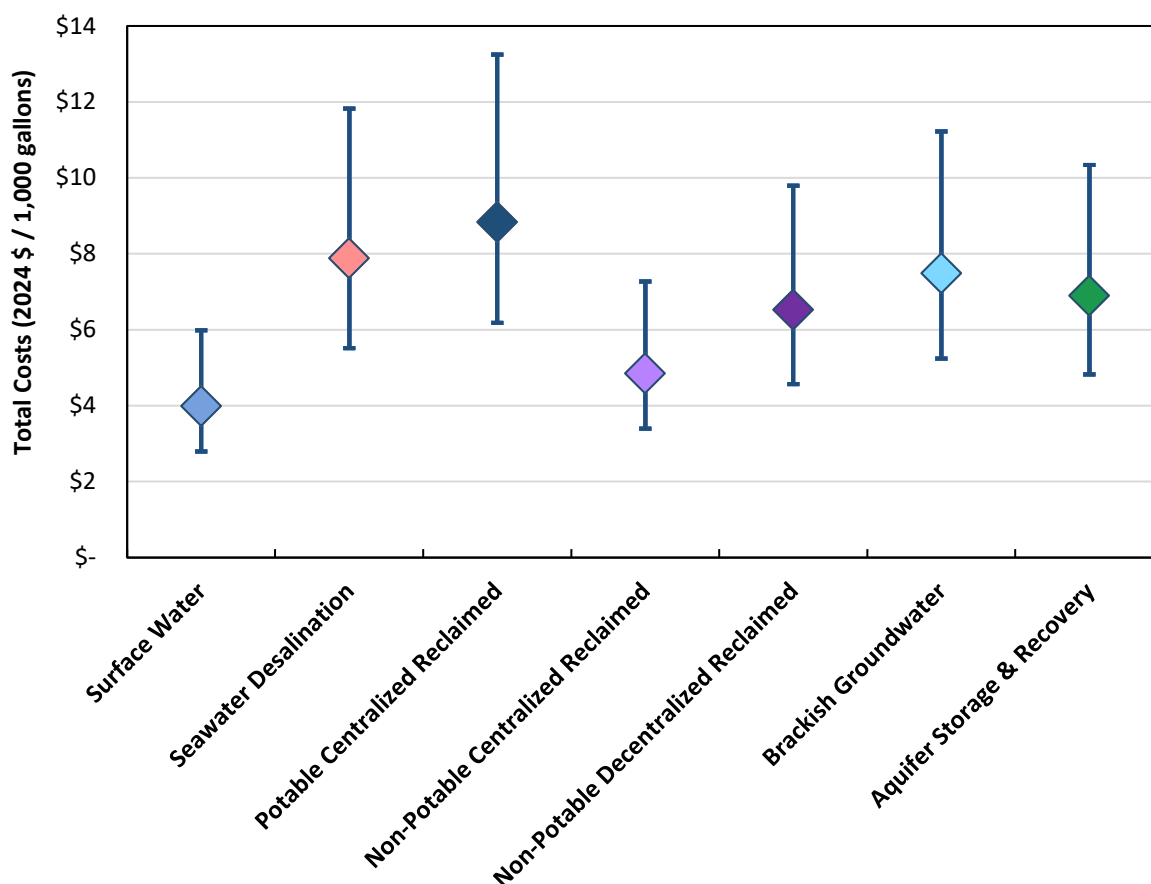
b – Demand management is not a supply option. Rather, the listed magnitude represents a reduction in water demands.

3.3.2 COSTS

Costs for each AWS were developed in 2021 dollars and consider the capital for implementation, annual operations and maintenance, and debt service for implementation. The costs shown in **Figure 3-1** are presented in dollars per thousand gallons, and were developed at the magnitudes discussed in the previous section. The costs are presented alongside a range of -30% to +50% from the opinion of probable construction cost (OPCC).

Figure 3-1: Estimated Cost of Alternative Water Supply Options

Estimated cost ranges of each AWS option are shown in 2024 dollars per thousand gallons.

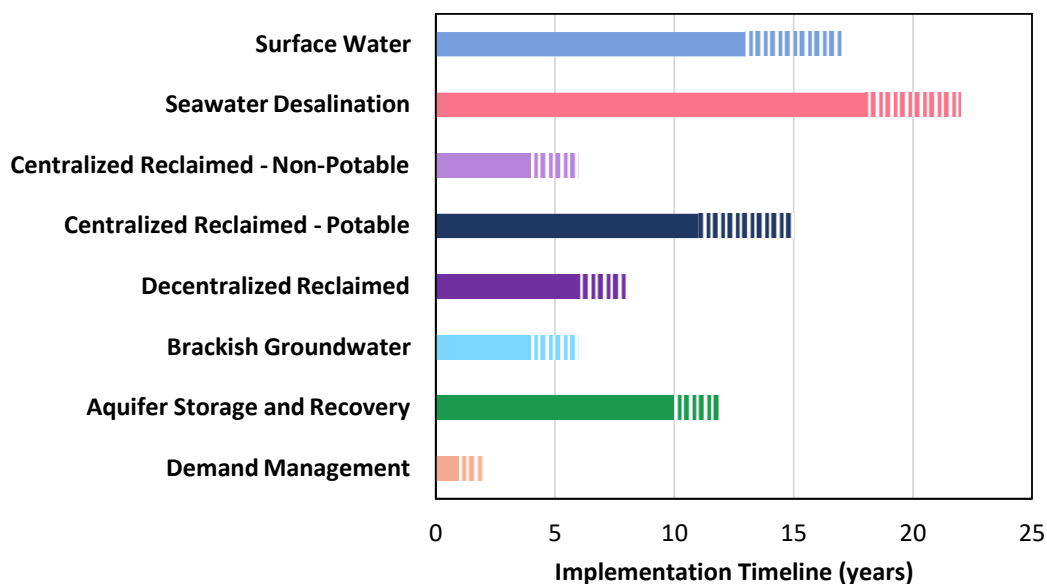


3.3.3 IMPLEMENTATION TIMELINES

The implementation timelines developed consider the planning, permitting, design, and construction phases of each AWS. It should be noted that the timelines shown in **Figure 3-2** are generalized, and that actual project timelines will be impacted by numerous aspects and drivers. However, considering the recent developments with the Luce Bayou Inter-Basin Transfer Project and Northeast Water Purification Plant Expansion, surface water supply will likely be the predominant AWS strategy in use by 2070 within the HGSD regulatory areas. Additional AWS implementation will be needed for the FBSD regulatory areas, which could include the Allens Creek Reservoir and/or seawater desalination.

Figure 3-2: Potential Implementation Timeline of Alternative Water Supply Options

Alternative water supply options vary in the amount of time required for implementation, which includes planning, permitting, design, and construction. Generalized timelines to implement AWS options are shown in number of years.



3.3.4 CLIMATE CHANGE AND SUBSIDENCE CONSIDERATIONS

As discussed in **Section 3.2**, some of the AWS options are more sensitive to climate change than others or present greater subsidence impacts than others.

Table 3-2 provides a summary of each AWS option's vulnerability to climate change and impacts to subsidence. Subsidence impacts are possible with both ASR and brackish groundwater desalination; however, neither of these AWS has a high vulnerability to climate change. Surface water development exhibits the highest vulnerability to climate change.

Table 3-2: Climate Change and Subsidence Considerations for Alternative Water Supply Options

AWS Option	Vulnerability to Climate Change	Subsidence Impacts
Surface Water Development		None
Seawater Desalination		None
Centralized Reclaimed Water Supply		None
Decentralized Reclaimed Water Treatment		None
Brackish Groundwater Desalination		Moderate
Aquifer Storage and Recovery with Surface Water		Moderate
Demand Management – Basic and Advanced Conservation		None

-  – High vulnerability
-  – Moderate vulnerability
-  – Low vulnerability

3.4 CONCLUSIONS

From the analysis presented in previous sections, the most viable AWS option to supplement existing supply is surface water development. Additionally, seawater desalination and centralized non-potable reclaimed water treatment could result in significant additional supply.



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SECTION 4 – SUBSIDENCE MODELING AND EVALUATION

4.1 OVERVIEW

The GULF 2023 model was used to evaluate various scenarios to answer questions about how regulations, variations in demand, and other factors could impact potential subsidence outcomes over a near-term period (2025 to 2050) and a long-term period (2050 to 2100). First, a series of analytical subsidence models, Predictions Relating Effective Stress to Subsidence (PRESS), were validated against historical data. Baseline results from the PRESS models were then compared to GULF 2023 subsidence outputs using the same hydrologic data to verify the calibration of the GULF 2023 model. Then, groundwater demand datasets were developed for a baseline scenario and subsequent scenarios in which variations from the baseline scenario represent alternative pumping conditions. The verification with PRESS, the development of each scenario, and the modeled subsidence results are discussed in the following sections.

4.2 DEVELOPMENT OF THE GULF 2023 MODEL

In collaboration with HGSD, FBSD, and TWDB, USGS has developed a new groundwater flow and subsidence model for the northern portion of the Gulf Coast Aquifer System, which encompasses the portion of the aquifer system from Jackson County and Lavaca County in the southwest to Newton County and Orange County in the northeast (Ellis et al., 2023). This model improves on the previous model for the region, known as the Houston Area Groundwater Model (HAGM), which was used in the 2013 RGUP and has been used as the TWDB-approved Groundwater Availability Model (GAM) for various planning purposes since 2012, including Joint Planning by GMA-14. The new model, referred to as the Gulf Coast Land Subsidence and Groundwater-Flow Model (GULF 2023), improves on the HAGM by including the following updates to data and methodology:

- Recompletion and extension of the model groundwater-use dataset from 1890 – 2018
- Use of the USGS’s modular finite-difference flow model (MODFLOW), MODFLOW-6 Skeletal Storage, Compaction, and Subsidence (CSUB) code to simulate subsidence, including use of residual compaction due to delayed drainage



- Update and expansion of subsidence and water level calibration dataset
- Update to spatially distributed recharge using the Soil-Water-Balance code
- Update to model layers including the addition of the Catahoula Sandstone and the ability of compaction within the Jasper Aquifer
- Use of ensemble-based modeling methods to quantify uncertainty in model parameters and simulated outputs of interest

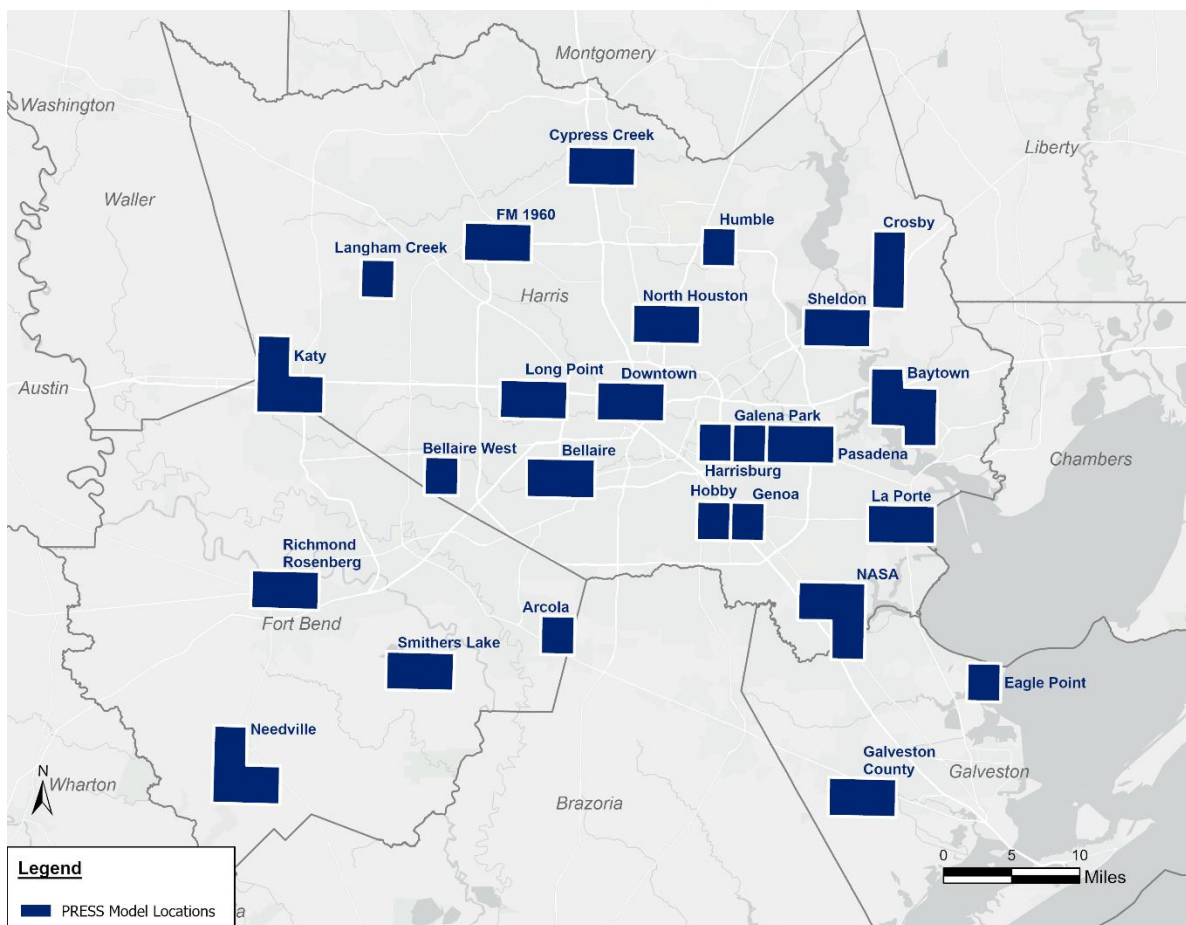
The GULF 2023 model was used throughout the JRPR effort for the evaluation of subsidence in various scenarios. This model was adopted by TWDB as the official Northern Gulf Coast GAM for use in Joint Groundwater Planning when it was released in February 2024.

4.3 PRESS CALIBRATION VERIFICATION

In addition to subsidence projections provided from the GULF 2023 model, subsidence for the Baseline Scenario was also computed using the PRESS site models, which were developed to model subsidence in the Subsidence Districts' jurisdictions. By using head values output from a groundwater model, the PRESS model uses Terzaghi one-dimension consolidation theory to predict consolidation of clay layers and has served as the primary subsidence-modeling tool for HGSD and FBSD in prior rounds of planning. An individual PRESS model, developed based on either a single or dual aquifer model, has been created for each of the 26 PRESS locations identified in **Figure 4-1**.

Figure 4-1: PRESS Model Locations

Map of locations of analytical subsidence models, known as Predictions Relating Effective Stress to Subsidence (PRESS).



Upon the initial development of the Baseline Scenario and execution in the GULF 2023 model, simulated heads associated with each PRESS site were exported to the PRESS models to determine projected subsidence. Simulated subsidence from the GULF 2023 model was compared to these results to confirm the consistency of the historically utilized PRESS models to the new GULF 2023 model using its CSUB Package.

Trends in observed groundwater and subsidence data for each site since 2010 were also compared to the PRESS model predictions of subsidence for the observed water level changes. Overall, the majority of sites were considered to have a “Good” calibration. The Galveston County site was considered to have a “Fair” calibration. No sites were found to have “Poor” calibration. A complete list of model sites and respective calibrations is provided in **Attachment 3**.

4.4 BASELINE AND REGULATORY SCENARIO DEVELOPMENT

Scenario testing began with the development of a Baseline Scenario that represents current regulations and anticipated demands over the planning horizon. From that point, scenario testing involved identifying and modeling various questions to aid in the JRPR process. Several permutations of various scenarios were created and evaluated. This report will focus on the final iterations, which seek to understand the potential impacts to subsidence due to higher-than-normal usage of groundwater or alternative approaches to regulation:

1. Maximum Allowable
2. FBSD Area B Regulation in 2050
3. No New Conversions
4. FBSD Delay to 2030

It should be noted that that in all scenarios, the period of analysis was 2025 to 2100, with subsidence impacts being evaluated for 25-year changes (2025-2050) and long-term changes (2050-2100).

Attachment 4 provides a detailed description of the development and testing of the scenarios.

4.4.1 BASELINE SCENARIO

A baseline scenario was developed to represent current regulations and anticipated groundwater demands, including adjustments of recent under- and over-conversions by regulated entities to the planned conversion levels. The baseline scenario assumes a constant per-capita demand for each municipal or domestic water user over the planning horizon, which represents expected per-capita demand for that specific water user in typical climate conditions. As such, changes in groundwater demand over time in the baseline scenario are driven by long-term growth (or in some cases, decline) in population, anticipated growth or decline in non-municipal demand, and regulated deadlines for conversion to lower levels of groundwater use. Assumptions about future groundwater use outside of HGSD and FBSD jurisdictions were tailored to conditions in each county. The primary assumptions in the development of the baseline scenario are listed below:

1. Non-municipal Demands

- a. Industrial and mining users were assumed to continue using groundwater to meet the same percentage of total demand as the average percentage groundwater from 2010 to 2019. Thus, groundwater demand grows with total demand, but historical over-conversions (such as in HGSD Regulatory Area A) are maintained.
- b. Groundwater demand for agricultural water users was estimated by using historical pumping data from HGSD and FBSD and by assuming that historically available average surface water supplies would continue to be used.

2. Domestic Water Demand

- a. Projected population outside of the service area of a public water system (PWS) and that is not expected to be served by future new or expanding PWSs is assumed to use groundwater from private wells to meet domestic water demand.

3. Regulated Retail Municipal Water Users (Fort Bend, Galveston, and Harris counties)

- a. Entities that have historically under-converted (i.e., have used more groundwater than allowed under regulations) were assumed to under-convert at a historical level.
- b. Entities that have historically over-converted (i.e., have used more alternative water and less groundwater than required by Regulatory Plan) were assumed to continue over-converting at recent levels until the next conversion deadline, at which point they are assumed to complete additional conversion to meet but not exceed regulations.
- c. The baseline scenario represents water management behavior based on the Regulatory Plans and does not reflect individual providers' water management strategies that deviate temporarily from the Regulatory Plan. For example, the utilization of credits to delay conversion is not considered within the baseline scenario.
- d. An exception to this approach was applied to the City of Houston. The City of Houston has a large service area which encompasses portions of multiple regulatory areas in three counties. Houston has historically over-converted within HGSD Regulatory Area 2 and expects to continue over-converting within this area. Based on discussions with the City of Houston, the baseline scenario assumes that the percentage of Houston's demand met by groundwater within HGSD Regulatory Area 2 will not exceed 15%.



4. Retail Municipal Water Users in Brazoria County
 - a. The City of Pearland began operating a new surface water treatment plant in October of 2024, which will reduce its dependence on groundwater supplies. Rather than using historical percentage groundwater data, the baseline scenario assumes that the City of Pearland will meet one third of its water demands with groundwater and the remaining two thirds with alternative water supplies beginning in 2024.
 - b. Six other entities in Brazoria County currently use a blend of groundwater and surface water. The historical percentage of demand met by groundwater is maintained throughout the study period in the baseline scenario.
 - c. All other entities in the county are assumed to meet 100% of demands with groundwater.
5. Retail Municipal Water Users in Montgomery County
 - a. Multiple utilities in Montgomery County use a blend of groundwater and surface water. In the baseline scenario, groundwater demand increases over time for these entities based on the assumption that they will continue to use approximately the same volume of alternative water supply every year without increasing alternative water supplies.
 - b. Other entities are assumed to meet 100% of demands with groundwater.
6. Retail Municipal Water Users in Other Counties
 - a. Water users in Austin, Chambers, Liberty, Waller, and Wharton counties are assumed to use the same percentage of groundwater as observed historically.

4.4.2 ALTERNATIVE PREDICTIVE SCENARIO DEVELOPMENT

Four scenarios were developed to consider alternative applications of the prescribed Regulatory Plans. These explored how subsidence may be impacted by higher-than-normal usage of groundwater or alternative approaches to regulation.

Maximum Allowable

This scenario illustrates the impacts to subsidence if all groundwater users were to produce the maximum allowable volume of groundwater per the current Regulatory Plans. The departure of this scenario from the Baseline is most apparent in HGSD Regulatory Area 1 where current groundwater use is currently below the maximum level of 10% of total water demand.

FBSD Area B Regulation in 2050

This scenario tests the impacts of implementing conversion to AWS in FBSD Regulatory Area B beginning in 2050, with a requirement to convert to no more than 60% groundwater.

No New Conversions

This scenario illustrates the impacts to subsidence if no additional conversions to AWS are made within either District after 2025. In this scenario, planned 2025 conversions in HGSD Regulatory Area 3 are accounted for in modeled pumping, with one exception: the conversion to use of AWS by City of Katy in the baseline scenario is assumed not to occur in this scenario. Later conversions in 2027 (FBSD Regulatory Area A) and 2035 (HGSD Regulatory Area 3) do not occur, resulting in higher pumping in all years 2027 through 2100.

FBSD Delay to 2030

This scenario evaluates the impacts of delaying the 2027 conversion in FBSD Regulatory Area A until 2030.

4.5 BASELINE SCENARIO RESULTS

The Baseline scenario was evaluated to predict the amount of subsidence that would be experienced if the regulatory approach of both Districts continued as currently prescribed and patterns of



groundwater usage were to remain the same through 2100 except for conversions to meet regulations.

4.5.1 HGSD JURISDICTION

Short-Term Subsidence Projections | 2025-2050

Model-predicted subsidence in the HGSD jurisdiction for 2025 through 2050 is shown in **Figure 4-2**. For a large portion of Harris and Galveston counties, additional subsidence is predicted to be less than 6 inches by 2050. Areas in central Harris County and coastal Galveston County (Regulatory Areas 2 and 1, respectively) were predicted to experience less than 3 inches while northern Harris County (Regulatory Area 3) was predicted to experience between 6 inches and 1 foot. The northern portion of Regulatory Area 3 is adjacent to Montgomery County, where groundwater production is expected to increase over time, absent a regulatory mandate to convert to alternative supplies. Additionally, Regulatory Area 3 is continuing to undergo conversion for approved groundwater reduction plan (GRP) participants over the coming decades.

Long-Term Subsidence Projections | 2050-2100

The model predictions for 2050-2100 show similar geospatial distributions of subsidence. For a large portion of the HGSD Regulatory Areas, additional subsidence over this period is predicted to be less than 18 inches. Areas in central Harris County and coastal Galveston County (Regulatory Areas 2 and 1, respectively) were predicted to experience less than 1 foot of additional subsidence, while northern Harris County (Regulatory Area 3) was predicted to experience between 18 inches and 30 inches. Additionally, in the northeastern portion of Harris County (Regulatory Areas 2 and 3), 18 to 24 inches of subsidence was projected as this area currently lacks access to alternative water supplies. Model-predicted additional subsidence from 2050 to 2100 is shown in **Figure 4-3**.

4.5.2 FBSD JURISDICTION

Short-Term Subsidence Projections | 2025-2050

Model-predicted subsidence in Fort Bend County for 2025 through 2050 is shown in **Figure 4-2**. For a large portion of Fort Bend County, additional subsidence is predicted to be about 3 inches over the period from 2025 to 2050. A small area on the eastern border of the county is predicted to experience



less than 3 inches of subsidence. The southeastern portion of the county is predicted to experience 6 inches of subsidence.

Long-Term Subsidence Projections | 2050-2100

The model predictions for 2050-2100 show a geospatial expansion in southeast Fort Bend County for moderate subsidence greater than 18 inches. The northern portion of the county is predicted to experience between 12 and 18 inches of subsidence. Model-predicted additional subsidence from 2050 to 2100 is shown in **Figure 4-3**.

Figure 4-2: Baseline: Total Subsidence (2025-2050)

Subsidence projected to occur between 2025 and 2050 in the baseline scenario.

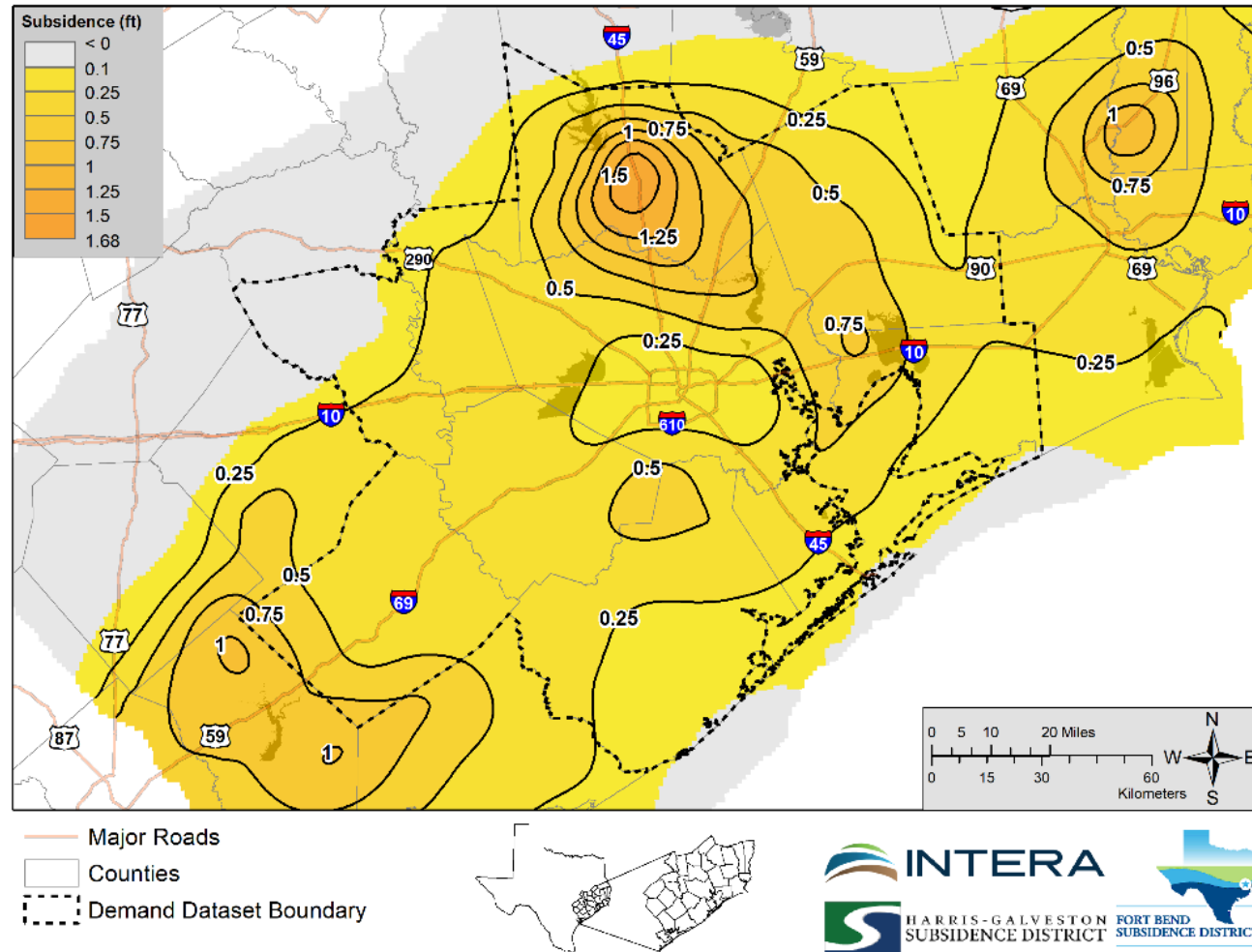
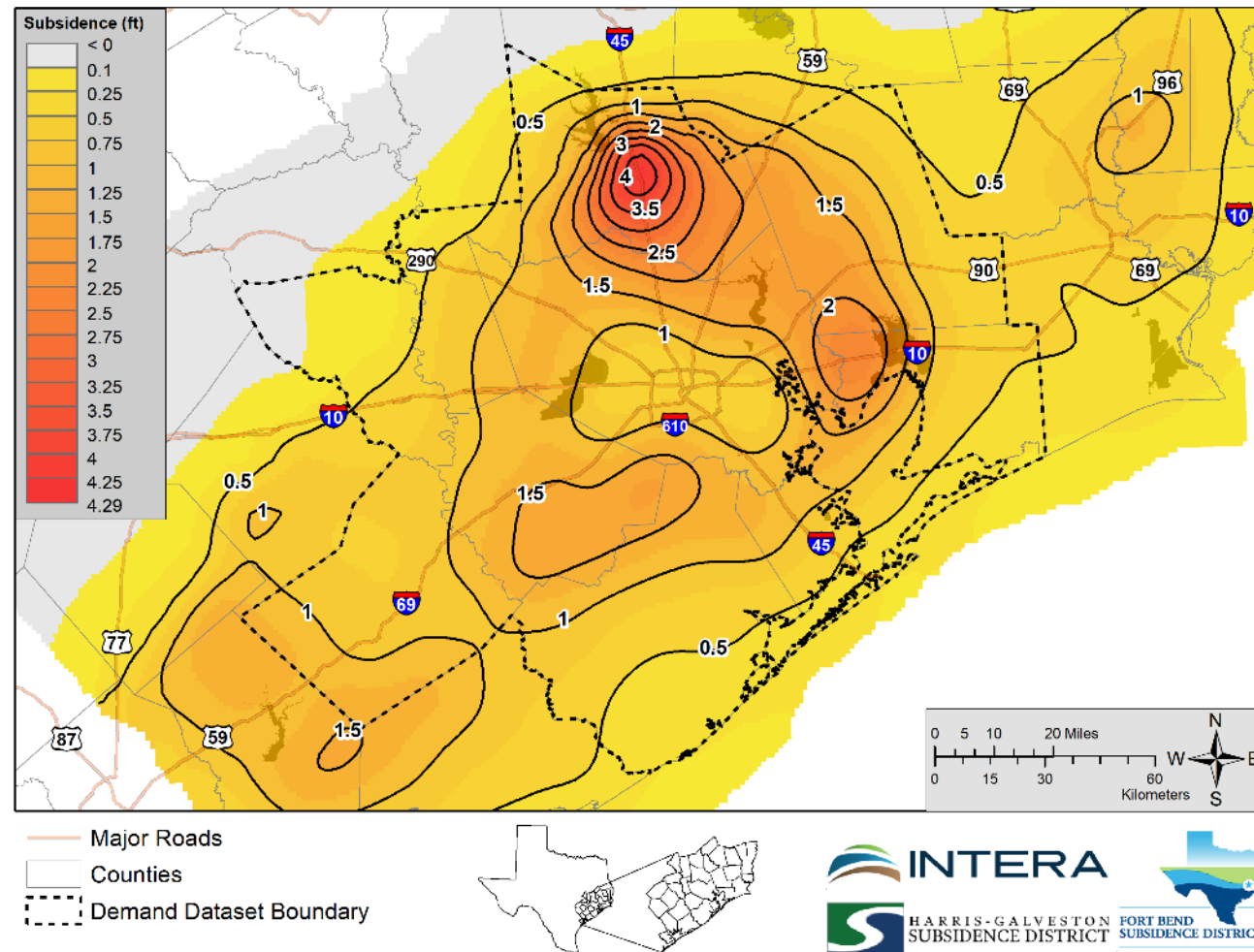


Figure 4-3: Baseline: Total Subsidence (2050 to 2100)

Subsidence projected to occur between 2050 and 2100 in the baseline scenario.



4.6 ALTERNATIVE PREDICTIVE SCENARIO RESULTS

4.6.1 MAXIMUM ALLOWABLE

The Maximum Allowable scenario was evaluated to predict the amount of subsidence that would be experienced if groundwater was produced at maximum rates allowed by the Districts' respective regulations.

HGSD Jurisdiction

For a large portion of the HGSD Regulatory Areas, additional subsidence in this scenario is predicted to be less than 1 foot by 2050. The additional pumping in this scenario is concentrated in HGSD Regulatory Area 1, where Baseline pumping represented historical over-conversion and pumping is increased in the Maximum Allowable scenario to 10% of total demand. The impact of this change is an increase in predicted subsidence, especially in Galveston County and eastern Harris County, where model-predicted subsidence is mostly between 12 and 18 inches. Model-predicted subsidence from 2025 through 2050 is shown in **Figure 4-4**.

The model predictions for 2050-2100 show similar geospatial distributions of subsidence but increased levels of subsidence. In this scenario, predicted subsidence exceeds predictions from the Baseline scenario by as much as 1 foot in eastern Harris County. Model-predicted additional subsidence from 2050 to 2100 is shown in **Figure 4-5**.

FBSD Jurisdiction

For a large portion of Fort Bend County, additional subsidence in the Maximum Allowable scenario is predicted to be less than 1 foot by 2050. The northern and far western areas of the County are predicted to experience the least amount of subsidence. Subsidence is predicted to increase moving easterly across the county, mostly influenced by the additional pumping modeled in HGSD Regulatory Area 1. Model predicted subsidence from 2025 through 2050 is shown in **Figure 4-4**.

The model predictions for 2050-2100 are consistent with the geospatial pattern of subsidence. The northern and western portion of the County is predicted to experience between 12 and 18 inches of subsidence. Moving easterly across the County, subsidence levels are predicted to increase to

between 1.5 and 2 feet. Model-predicted additional subsidence from 2050 to 2100 is shown in **Figure 4-5**.

Figure 4-4: Maximum Allowable: Total Subsidence (2025-2050)

Subsidence projected to occur between 2025 and 2050 in a modeling scenario in which groundwater is produced at maximum rates allowed by the Districts' respective regulations.

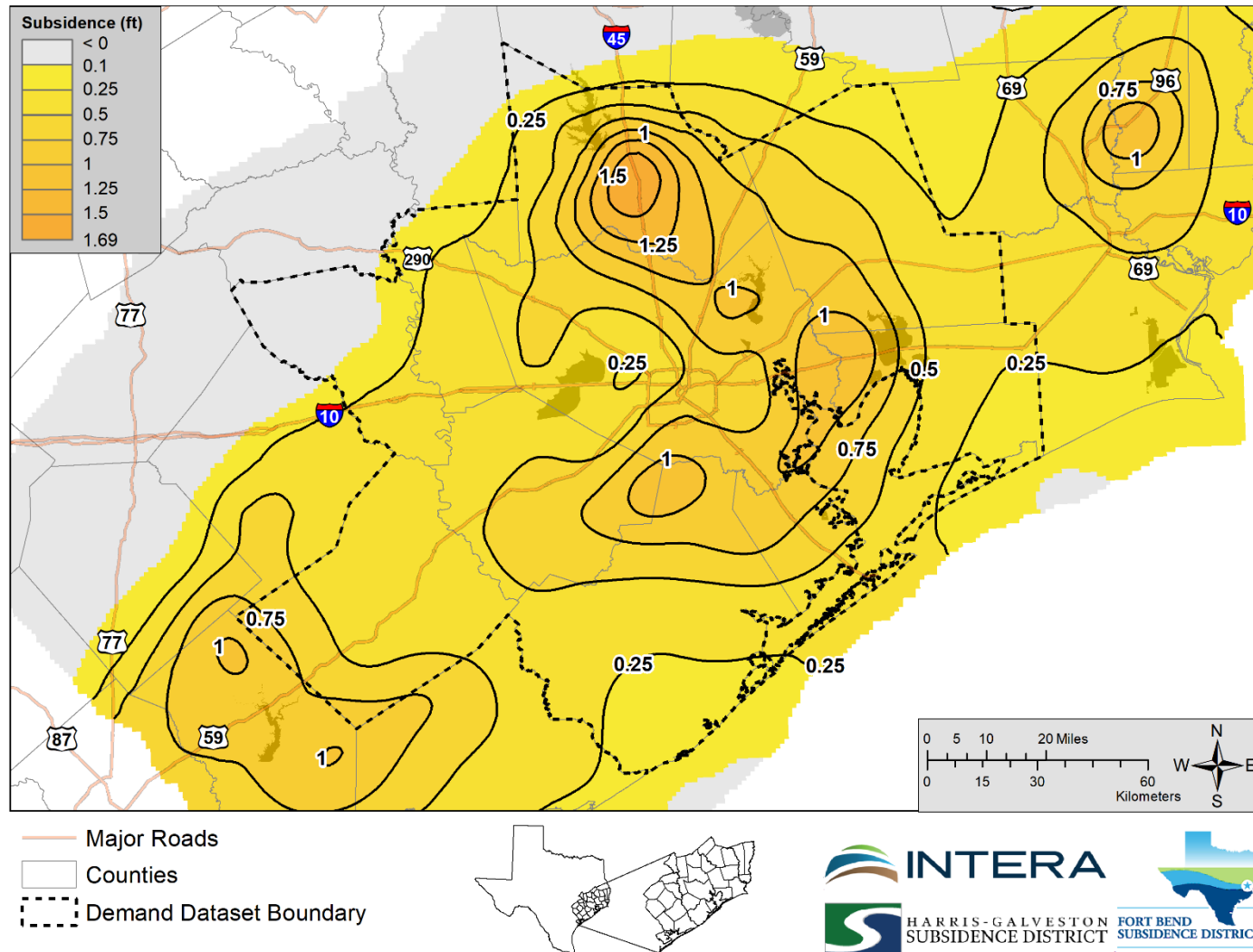
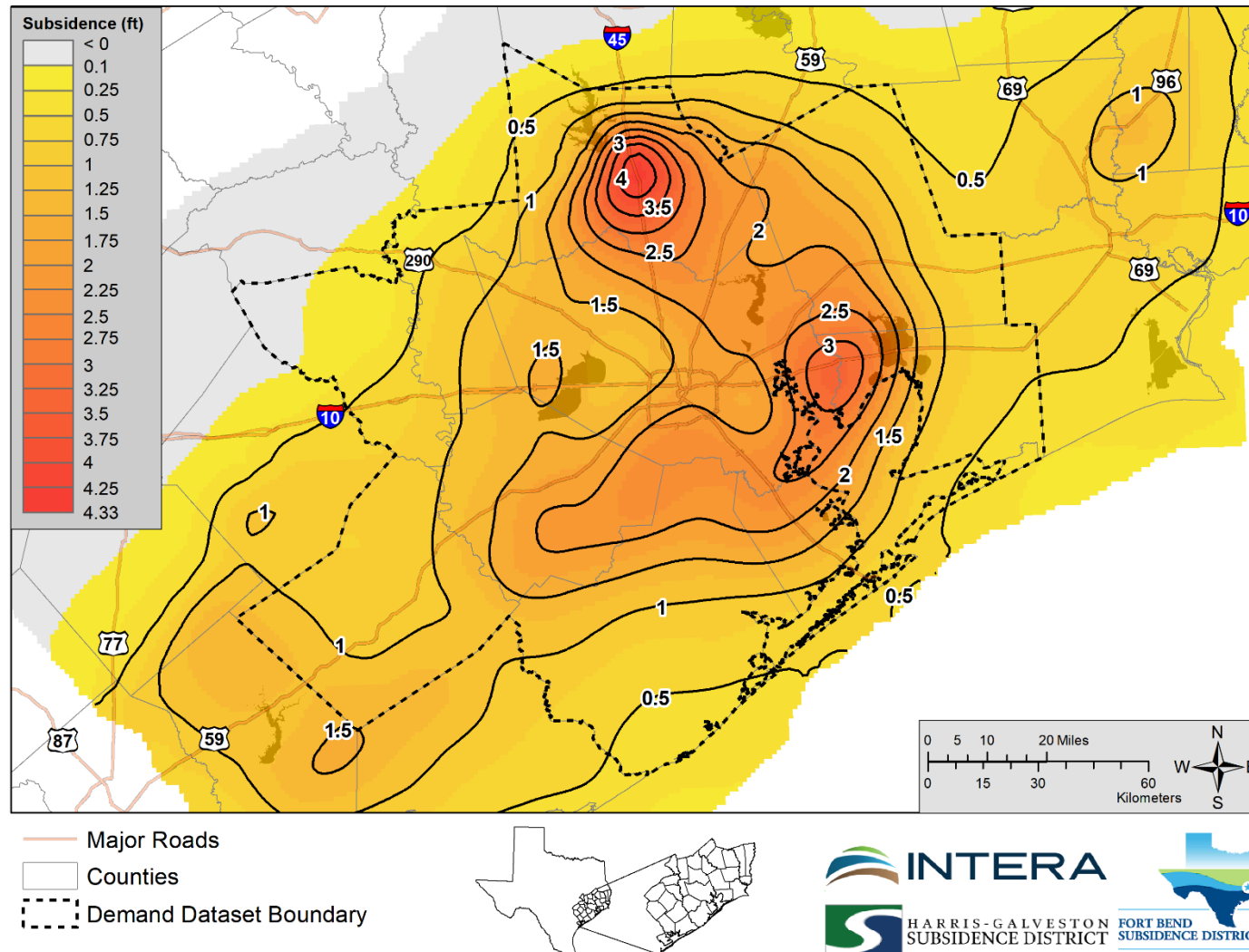


Figure 4-5: Maximum Allowable: Total Subsidence (2050-2100)

Subsidence projected to occur between 2050 and 2100 in a modeling scenario in which groundwater is produced at maximum rates allowed by the Districts' respective regulations.





4.6.2 FBSD AREA B REGULATION IN 2050

This scenario was evaluated to predict the amount of subsidence that would be experienced over the next 25 and 75 years if, in addition to current regulations, a new requirement was implemented to convert to no more than 60% groundwater in FBSD Regulatory Area B beginning in 2050. As this scenario tests a change beginning in 2050, modeling inputs and results for 2020 through 2049 are the same as the baseline scenario.

HGSD Regulatory Areas

Within the HGSD Regulatory Areas, predicted subsidence is similar to the baseline scenario. Model-predicted subsidence through 2050 is shown on **Figure 4-6**, and additional subsidence through 2100 is shown in **Figure 4-7**.

FBSD Regulatory Areas

Model predicted subsidence through 2050 is shown in **Figure 4-6**. The modeled effects of implementing conversion requirements in FBSD Regulatory Area B are a reduction in predicted subsidence in the period from 2050 to 2100 (**Figure 4-7**). Compared to the baseline scenario, the extent of the area in the southeastern part of Fort Bend County with subsidence greater than 1.5 feet is substantially reduced.

Figure 4-6: FBSD Area B Regulation in 2050: Total Subsidence (2025-2050)

Subsidence projected to occur between 2025 and 2050 in a modeling scenario in which FBSD Area B converts to 60% groundwater and 40% alternative supplies beginning in 2050.

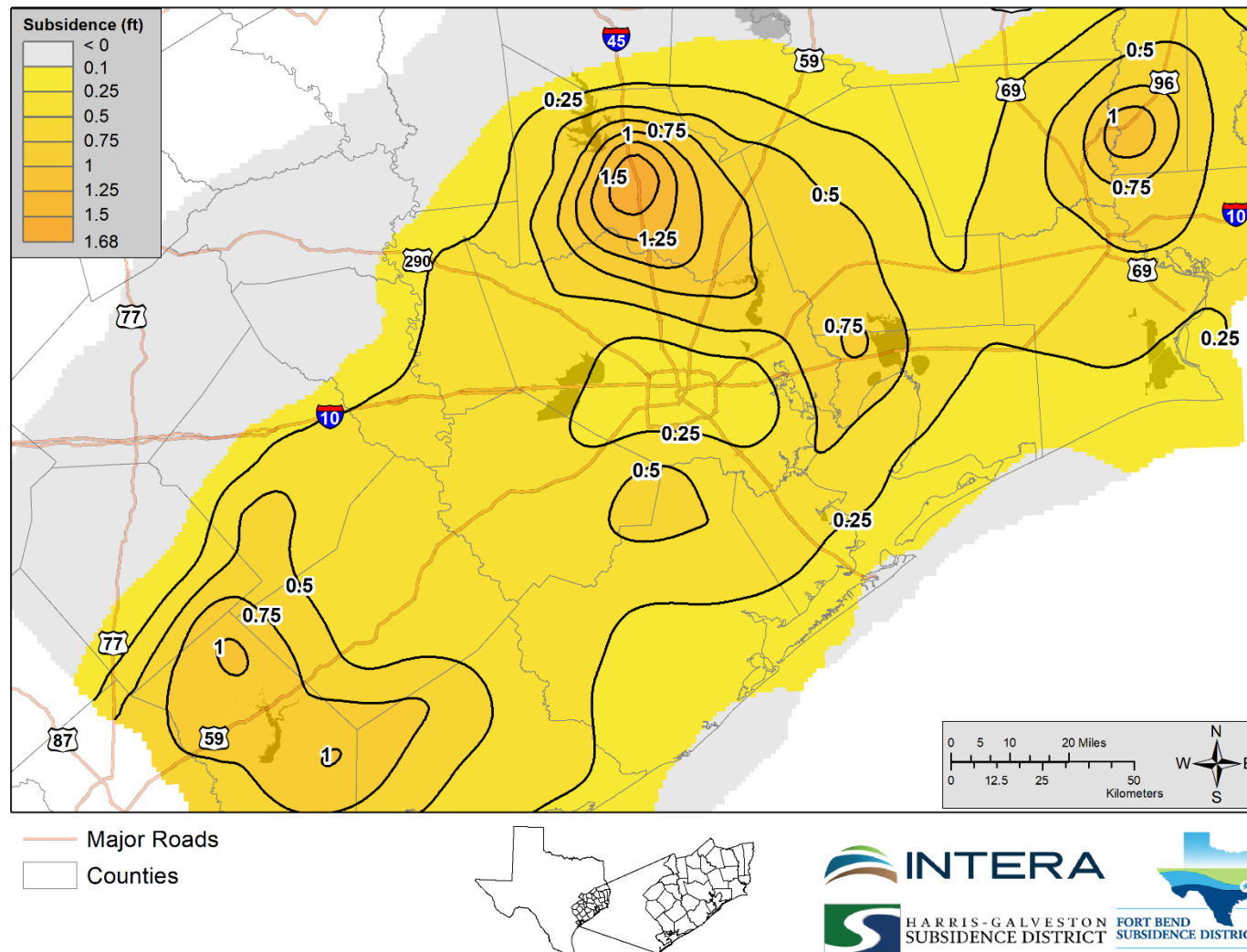
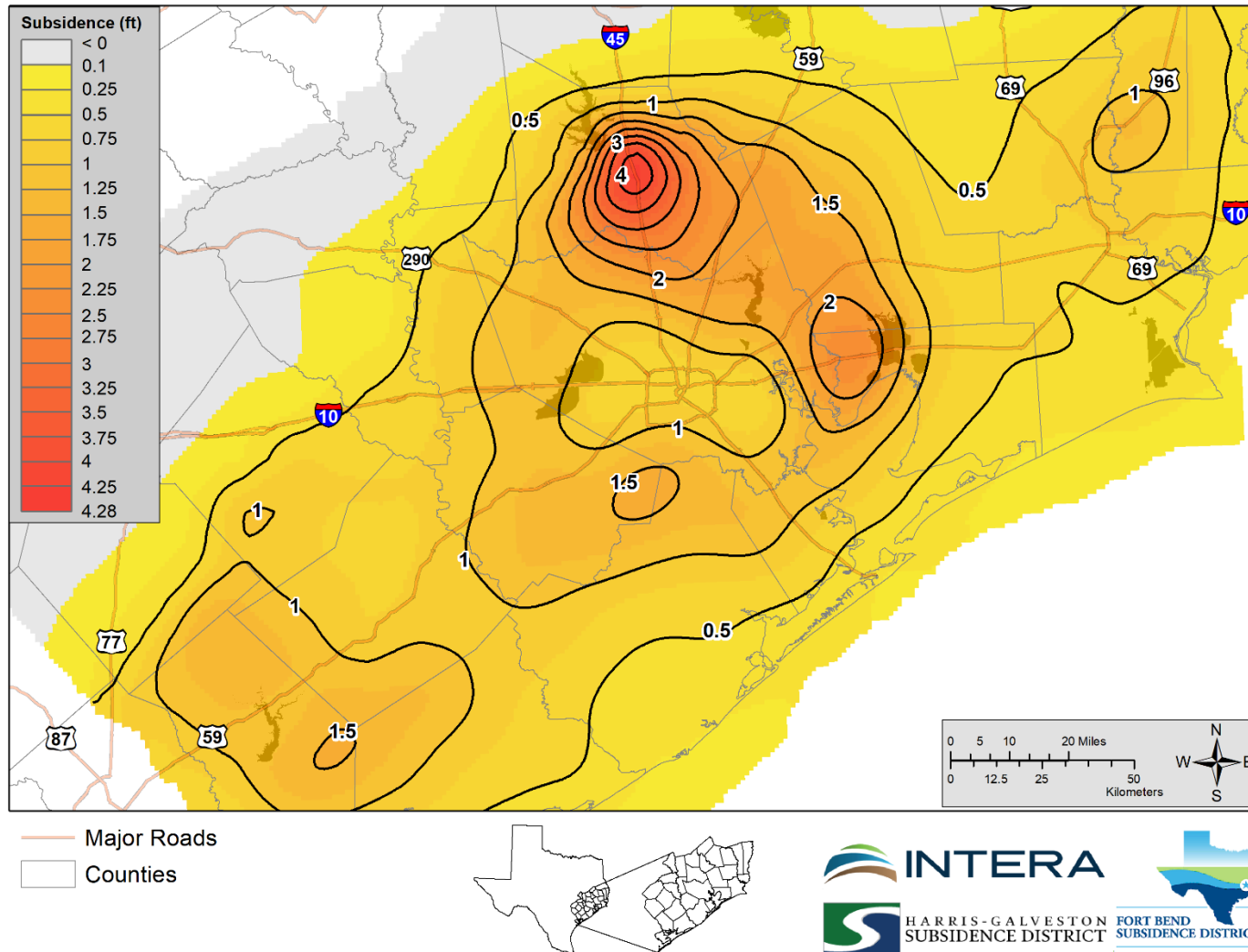


Figure 4-7: FBSD Area B Regulation in 2050: Total Subsidence (2050-2100)

Subsidence projected to occur between 2050 and 2100 in a modeling scenario in which FBSD Area B converts to 60% groundwater and 40% alternative supplies beginning in 2050.



4.6.3 NO NEW CONVERSIONS

This scenario was evaluated to predict the amount of subsidence that would be experienced over the next 25 and 75 years if planned conversions to additional AWS in 2027 (FBSD Regulatory Area A) and 2035 (HGSD Regulatory Area 3) are not implemented. Model-predicted subsidence through 2050 is shown on **Figure 4-8**. Modeled additional subsidence predicted to occur between 2050 and 2100 is shown in **Figure 4-9**.

HGSD Regulatory Areas

Modeling results for this scenario indicate additional subsidence throughout the HGSD jurisdiction. Whereas the baseline scenario indicated maximum subsidence of approximately 1 foot in Regulatory Area 3 between 2025 and 2050, this maximum increases to 1.5 feet in northern Harris County over the same time period. Similarly, the baseline maximum of additional subsidence between 2050 and 2100 was approximately 2.5 feet, but the No New Conversions scenario indicates up to 3.5 feet in the same area.

FBSD Regulatory Areas

Similarly, the highest levels of predicted subsidence in Fort Bend County between 2025 and 2050, which were approximately 6 inches in the baseline scenario, increase to 12 inches in the No New Conversions scenario. Over the later time period from 2050 to 2100, additional model-predicted subsidence in Fort Bend County is less than 24 inches in the baseline scenario but is up to 30 inches in the No New Conversions scenario.

Figure 4-8: No New Conversions: Total Subsidence (2025-2050)

Subsidence projected to occur between 2025 and 2050 in a modeling scenario in which no additional conversions to alternative water supplies are implemented after 2025.

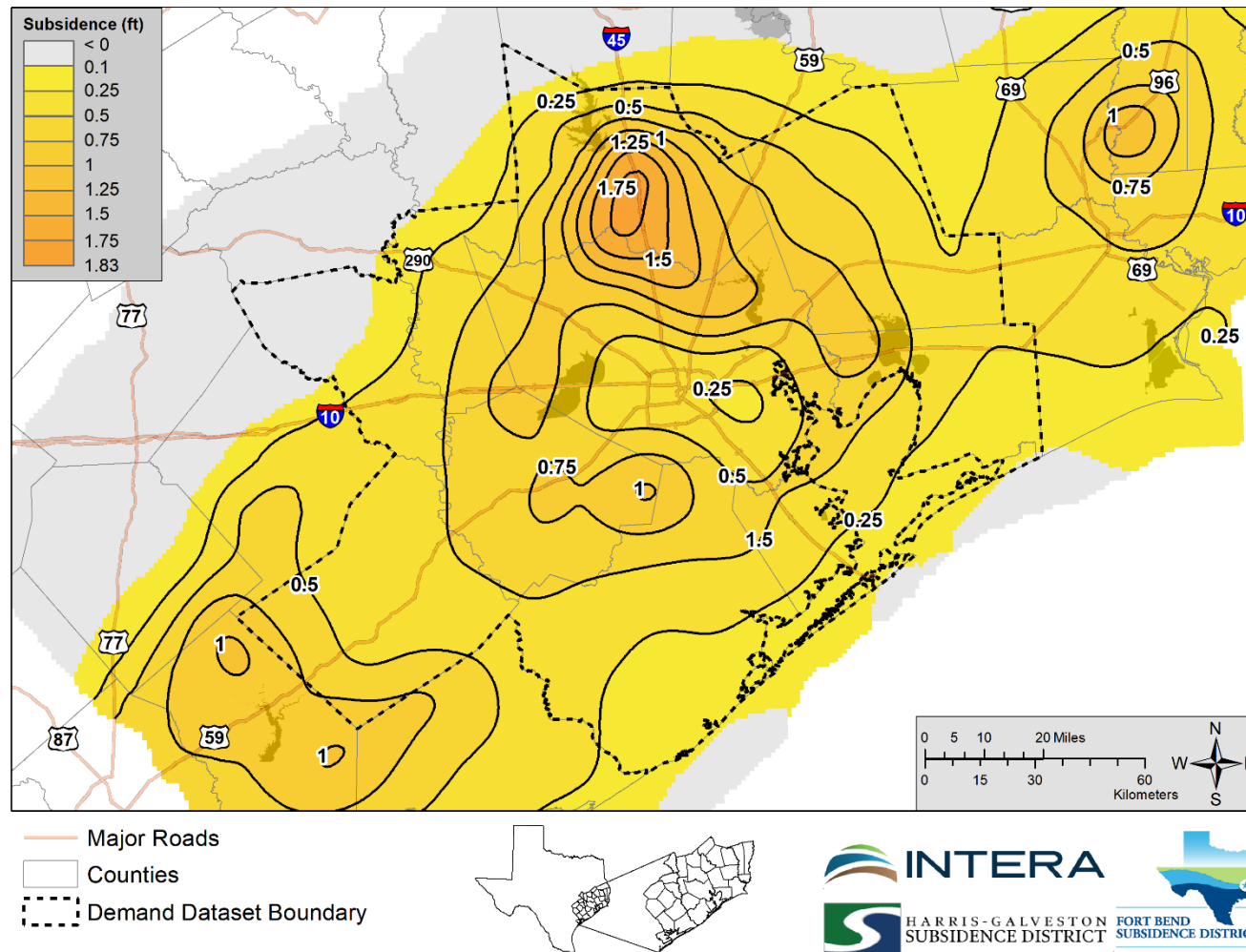
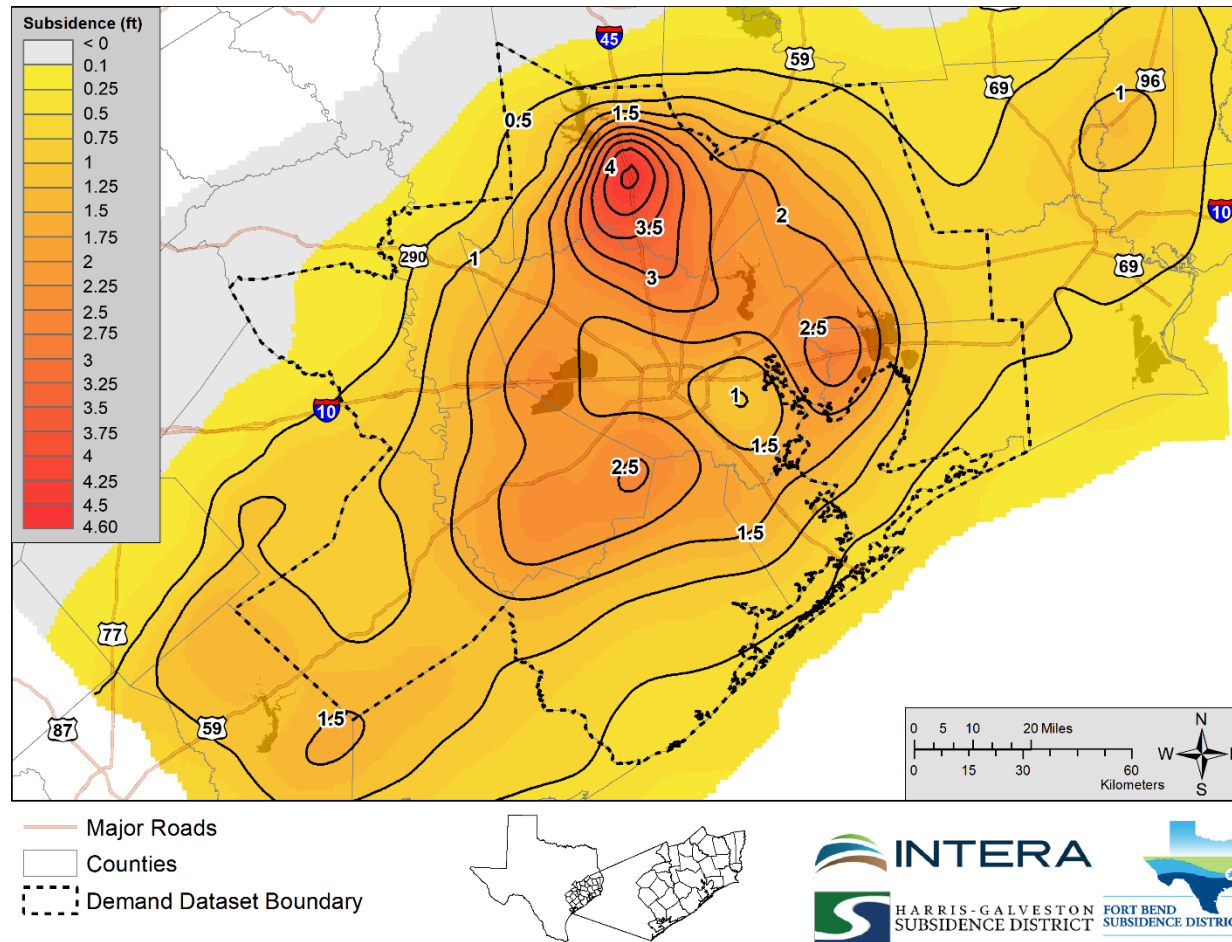


Figure 4-9: No New Conversions: Total Subsidence (2050-2100)

Subsidence projected to occur between 2050 and 2100 in a modeling scenario in which no additional conversions to alternative water supplies are implemented after 2025.





4.6.4 FBSD DELAY TO 2030

This scenario was evaluated to predict the amount of subsidence that would be experienced over the next 25 and 75 years if the 2027 conversion deadline in FBSD Regulatory Area A is delayed until 2030. Model-predicted subsidence through 2050 is shown on **Figure 4-10**. Modeled additional subsidence predicted to occur between 2050 and 2100 is shown in **Figure 4-11**.

HGSD Regulatory Areas

Within the HGSD Regulatory Areas, predicted subsidence is similar to the baseline scenario.

FBSD Regulatory Areas

The delay of the 2027 conversion until 2030 causes some increase in the amount of subsidence predicted by the model within Fort Bend County between 2025 and 2050 compared to the baseline scenario. Predicted subsidence greater than 6 inches only occurred in the eastern portion of the county in the baseline scenario but is also shown in the central portion of the county in this scenario (**Figure 4-10**). The modeled conversion delay scenario predicts similar amounts of additional subsidence predicted to occur between 2050 and 2100 as in the baseline scenario.

Figure 4-10: FBSD Delay to 2030: Total Subsidence (2025-2050)

Subsidence projected to occur between 2025 and 2050 in a modeling scenario in which 2027 conversions in FBSD Regulatory Area A are delayed until 2030.

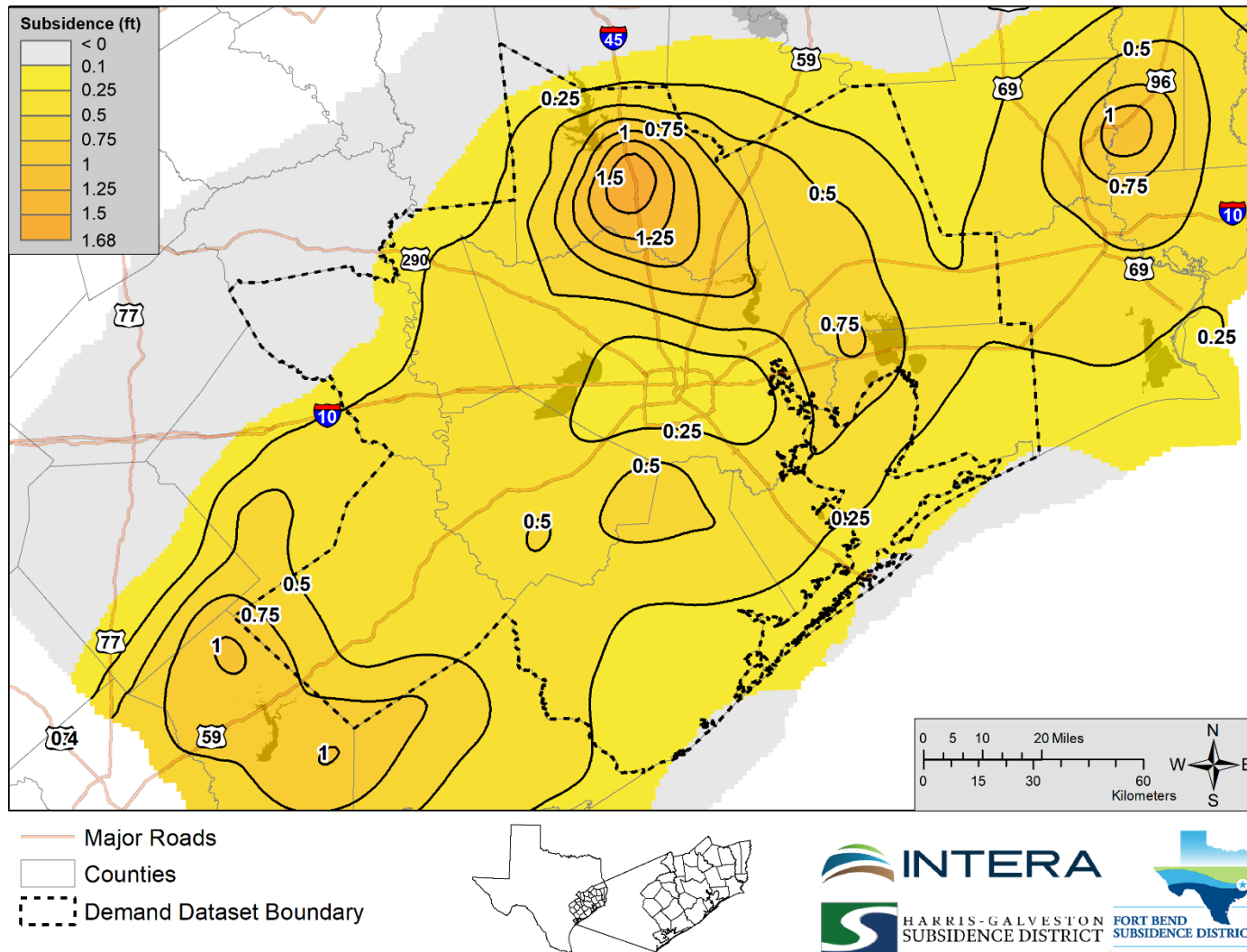
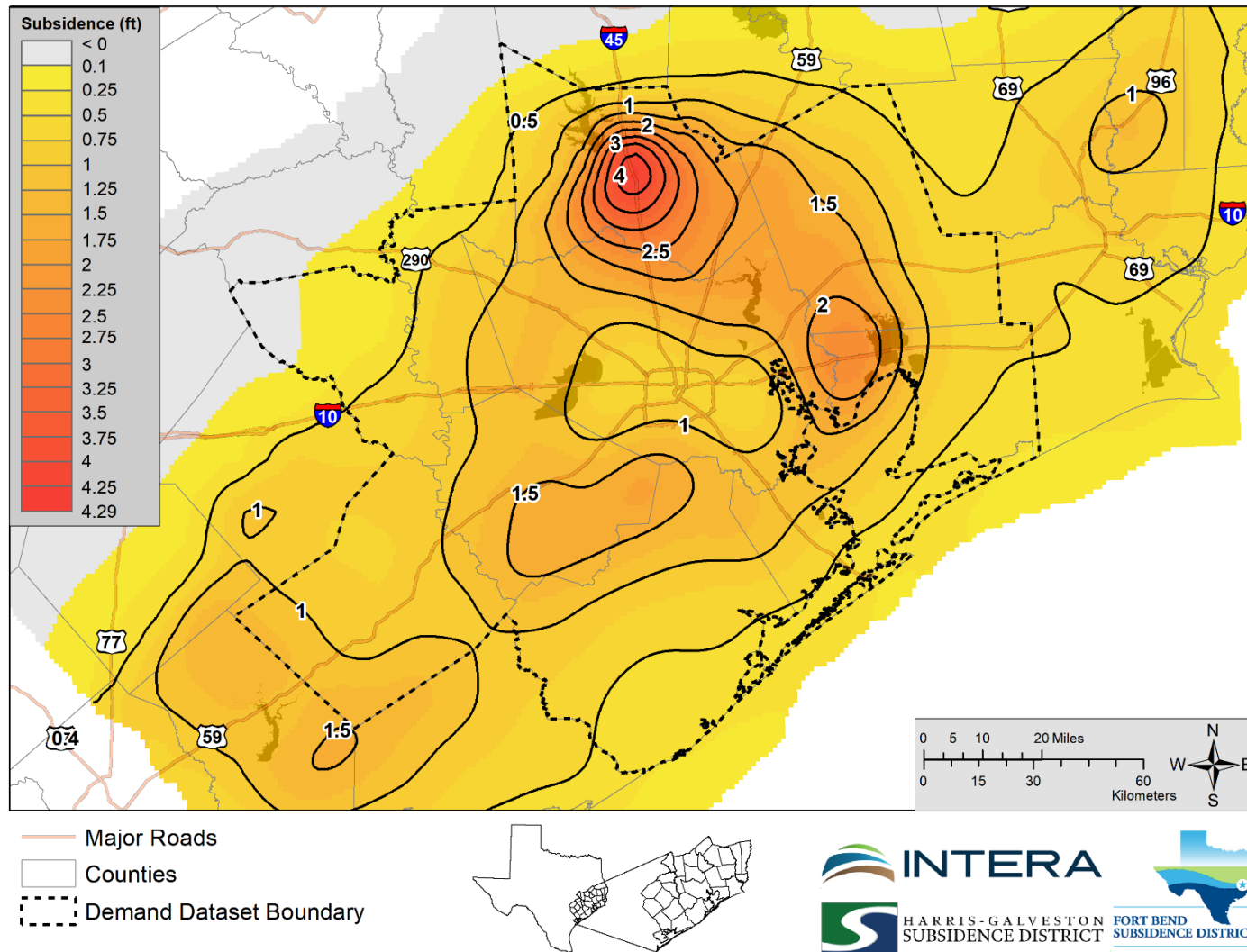


Figure 4-11: FBSD Delay to 2030: Total Subsidence (2050-2100)

Subsidence projected to occur between 2025 and 2050 in a modeling scenario in which 2027 conversions in FBSD Regulatory Area A are delayed until 2030.



4.7 SUMMARY OF MODELING ANALYSIS

The model analysis evaluated expected levels of subsidence with consideration for current District regulations, varying climate conditions, and behaviors of groundwater usage. Under the current regulations set forth by the Districts and current water use behaviors as represented in the baseline scenario, subsidence levels within the Districts' jurisdictions are predicted at up to 12 inches between 2025 and 2050 and up to an additional 30 inches between 2050 and 2100, with significant spatial variation across each county. In addition to the modeled subsidence results within the Districts' jurisdiction, subsidence was also indicated by the modeling results in other areas. In western Chambers and Liberty counties, subsidence of up to 9 inches is predicted in the near-term period (2025-2050), with an additional 2 feet predicted between 2050 and 2100. In Montgomery County, subsidence of up to more than 18 inches is predicted in the baseline modeling scenario in the near-term period (2025-2050), with additional subsidence of another 48 inches between 2050 and 2100. Projected subsidence is also shown in the baseline modeling results in western Wharton County. However, as growth projections in this area are minimal, this prediction is considered to be an effect of model limitations rather than growth in groundwater demand. Sparse historical pumping data, as well as difficulty in simulating irrigation return flows and their effect on aquifer recharge within Wharton and Colorado counties, contribute to uncertainty in the predicted subsidence results within Wharton County.



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SECTION 5 – CONSIDERATIONS FOR FUTURE STUDY

HGSD and FBSD regularly collaborate on research efforts and other activities with one another, other groundwater districts, state agencies, and others. Activities include subsidence monitoring, research projects, conservation programs, audits of past regulatory plans or plan reviews, and more. The evaluations completed as part of the JRPR have led to the identification of additional studies that may be useful in guiding updates to the Regulatory Plans and/or modifications to rules and programs administered by the Districts. Some such future studies are proposed below:

- Evaluation of subsidence impacts associated with the groundwater credit programs administered by each District. These programs are intended to influence responsible water management but are not always tied directly to a benefit in avoiding subsidence. Further evaluation will provide the Districts with more opportunity to evaluate the benefits of such programs and better tailor future programs to achieving the overall missions of both HGSD and FBSD.
- Investigation of options for users in historically under-converted areas to meet regulatory requirements. Although conversion to AWS has been highly successful throughout the region and accomplished in a cost-effective manner, these shifts in water use are still difficult for some disadvantaged areas. This effort would consider options for some isolated areas to economically achieve the Regulatory Plan and benefit the region through conversion to surface water or another viable AWS.
- Evaluation of the economic benefits of groundwater reduction versus the cost of infrastructure to develop alternative water supplies. The conversion to AWS and primarily the introduction of surface water as an alternative to groundwater pumping has come at an economic cost to the region. However, it is also apparent that these measures have been necessary to avoid the continued impacts of subsidence as seen in some areas and the impact on the local economy. This study would consider the potential avoided economic impacts of subsidence on infrastructure, including features relating to public utilities, residential home value, continued industrial and commercial growth, and other key economic factors in comparison to this overall cost of water supply development.



Following are considerations for future efforts undertaken by the Districts:

- Scope of analysis for future study and reviews should begin with an analysis of recent (1-5 years) groundwater pumping data recorded by HGSD and FBSD to identify trends that warrant further, detailed study.
- Consideration of how delays in the Census process may impact overall project schedule.
- Continue to prioritize stakeholder engagement and opportunities for stakeholder feedback.

Regular reviews of the HGSD Regulatory Plan and FBSD Plan are necessary to monitor progress, keep up with the latest science, and adjust recent and future groundwater demand to reflect ongoing growth in the region. Future reviews of the Regulatory Plans should include objectives similar to the JRPR: updates to projections of population growth and water demand, evaluation of demand scenarios and regulatory scenarios for potential subsidence impacts, and assessment of options for alternative water supplies.

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SECTION 6 – REFERENCES

Ellis, J.H., Knight, J.E., White, J.T., Sneed, M., Hughes, J.D., Ramage, J.K., Braun, C.L., Teeple, A., Foster, L., Rendon, S.H., and Brandt, J. (2023). *Hydrogeology, land-surface subsidence, and documentation of the Gulf Coast Land Subsidence and Groundwater-Flow (GULF) model, southeast Texas, 1897–2018 (ver. 1.1, November 2023): U.S. Geological Survey Professional Paper 1877.* <https://doi.org/10.3133/pp1877>.

Greuter, A. (2025). *Determination of Groundwater Withdrawal and Subsidence – Fort Bend County in 2024.* Fort Bend Subsidence District.
https://fbsubsidence.org/wp-content/uploads/2025/06/2024_FBSD_AGR_Final.pdf

Reedy, R.C. and Scanlon, B. R. (2022). *“Water Use by the Mining Industry in Texas, Final Report.”* Prepared for TWDB. Funded by USGS.
<https://www.twdb.texas.gov/waterplanning/data/projections/MiningStudy/index.asp>

Texas Water Development Board. (2022). *Manufacturing Water Demand Projections Methodology for the 2026 Regional and 2027 State Water Plans.* TWDB.
<https://www.twdb.texas.gov/waterplanning/data/projections/methodology/index.asp>