



HARRIS-GALVESTON  
SUBSIDENCE  
DISTRICT

## An All-Inclusive Approach to Successfully Preventing Further Subsidence in the Greater Houston Area

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Presented by:  
**Michael Turco**  
General Manager  
Harris-Galveston Subsidence District

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## Agenda

- District Introduction
- Subsidence in the Houston Area
- Groundwater Regulation
- Subsidence Monitoring
- Regulatory Planning
- Water Conservation Tools & Resources
- Q&A

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## Agenda

District Introduction

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## Harris-Galveston Subsidence District

The Harris-Galveston Subsidence District (HGSD) is a special-purpose district created by the Texas Legislature in 1975 to prevent further land subsidence in Harris and Galveston counties.



### GROUNDWATER REGULATION

- Collaborating with local groundwater conservation districts, regional water providers, and other water agencies to manage groundwater use through water planning and well permitting.

### SCIENCE & RESEARCH

- Utilizing the highest quality data and research to monitor groundwater usage, aquifer characteristics, and land surface changes as well as analyzing the best-available predictive models.

### WATER CONSERVATION

- Equipping permittees, residents, businesses, and educators with water conservation tools and resources to reduce water usage and empower the community to value water.

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# Collaboration



## Local Agencies

- Water providers (cities, MUDs, regional water authorities)
- Groundwater Conservation Districts
- Harris County Flood Control District

## State Agencies

- Texas Department of Transportation
- Texas Water Development Board

## Federal Agencies

- United States Geological Survey
- National Geodetic Survey

## Universities

- University of Houston
- Southern Methodist University
- Conrad Blucher Institute – Texas A&M Corpus Christi

# Agenda

District Introduction

Subsidence in the Houston Area

Groundwater Regulation

Subsidence Monitoring

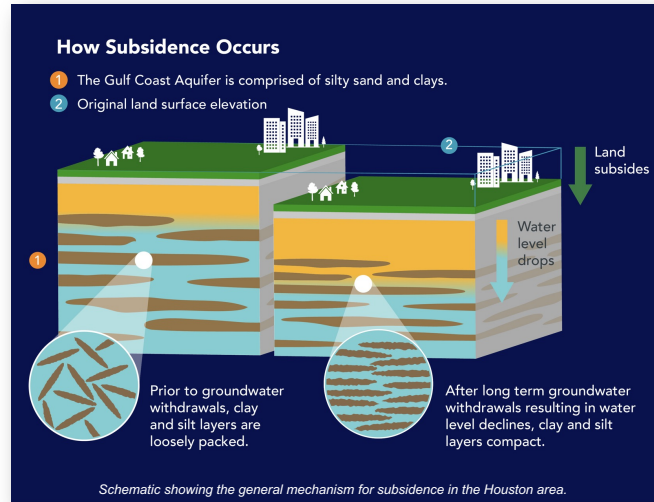
Regulatory Planning

Water Conservation Tools & Resources

Q&A

## Subsidence in the Houston Area

- Subsidence is the lowering of the elevation of land surface over time.
- In Texas' Gulf Coast region, aquifer clay and silt compaction resulting from groundwater withdrawal is the primary cause of land surface subsidence.
- Subsidence can have a wide range of consequences depending on the location of the occurrence and its proximity to surface drainage and coastal zones.



## Impacts of Subsidence in the Houston Area

Reduced well capacity  
and casing damage



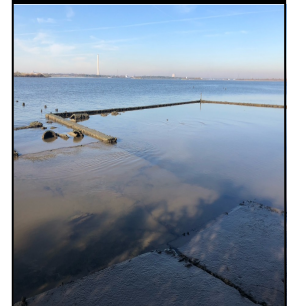
New bridge to allow for  
more freeboard



Flooding from  
Hurricane Harvey



Home foundation  
remnants inundated





## Permanent Inundation Due to Subsidence

### GOOSE CREEK OIL FIELD 1918-1926

- The first documented link between shallow fluid withdrawal, aquifer compaction, and subsidence.
- Nearly three (3) feet of subsidence occurred over an 8-year period.
- Today in San Jacinto Bay, remnants exist as much of the field has been inundated.



Goose Creek Oil Field, 2010



Earth fissures at Goose Creek Oil Field

Source: (U.S. Geological Survey)



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## Brownwood Subdivision in Baytown, TX

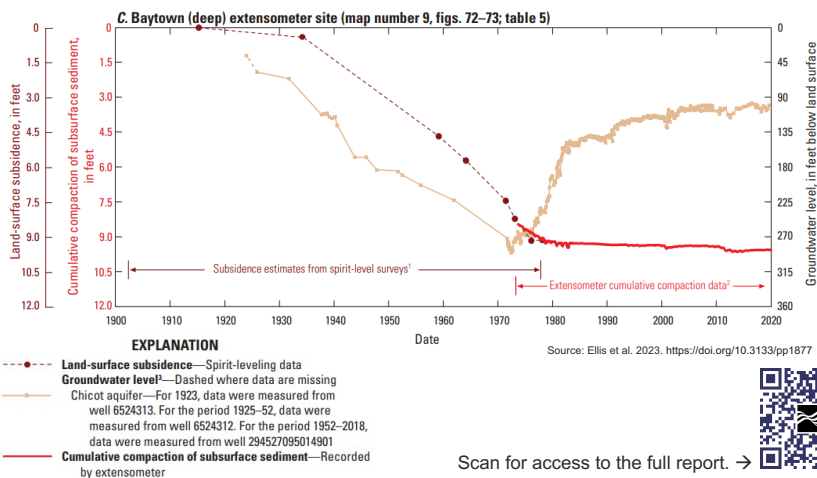
- 1944: Beginning development of infrastructure
- 1953: Many homes have been developed – nice bay front housing
- 1978: Inundation by the bay is extensive due to subsidence in the area
- 1989: Homes and property have been abandoned
- 2016: Baytown Nature Center and Preserve



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# Brownwood Subdivision in Baytown, TX

## Land-surface measurements obtained from benchmark PTS 185



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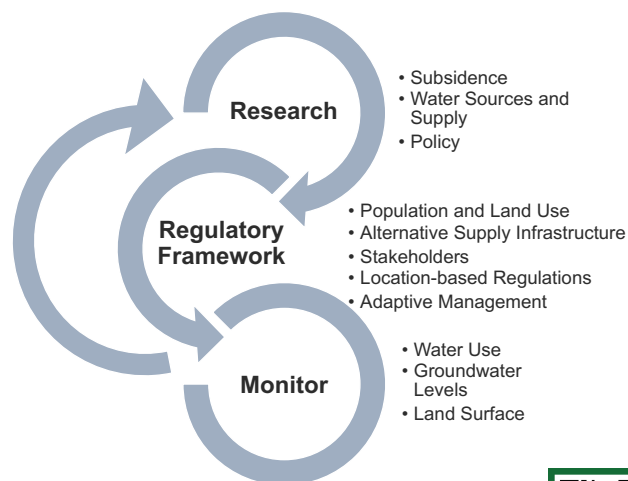
Water Conservation Tools & Resources

Q&A

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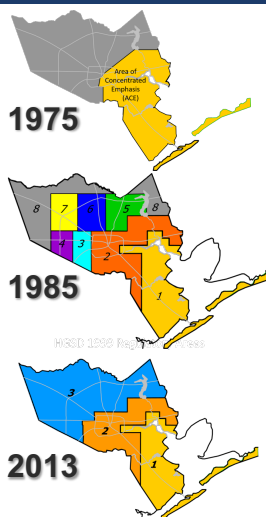
## Science-based Groundwater Regulation

- Conduct research
- Identify where subsidence is occurring
- Communicate with stakeholders
- Establish a regulatory framework
- Implement a monitoring program
- Continue research and outreach



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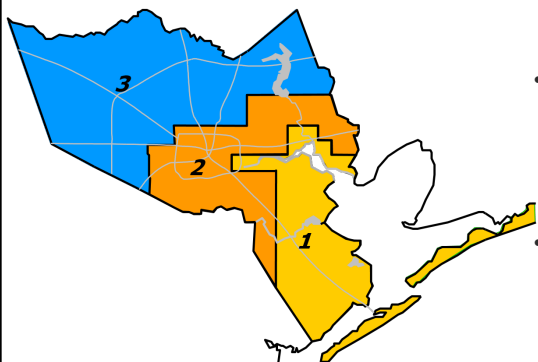
## Groundwater Regulation to Stop Subsidence



- Following the creation of the Harris-Galveston Subsidence District, groundwater regulation began nearest the coast in the Area of Concentrated Emphasis (ACE).
- As the population spread to the north and west and water use increased, numerous regulatory plans were developed and implemented.
- The 1999 Regulatory Plan designated the three regulatory areas that exist today. By 2013, two regulatory areas were fully converted, and Regulatory Area 3 was put on a revised timeline for conversion.

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## HGSD's Regulatory Areas

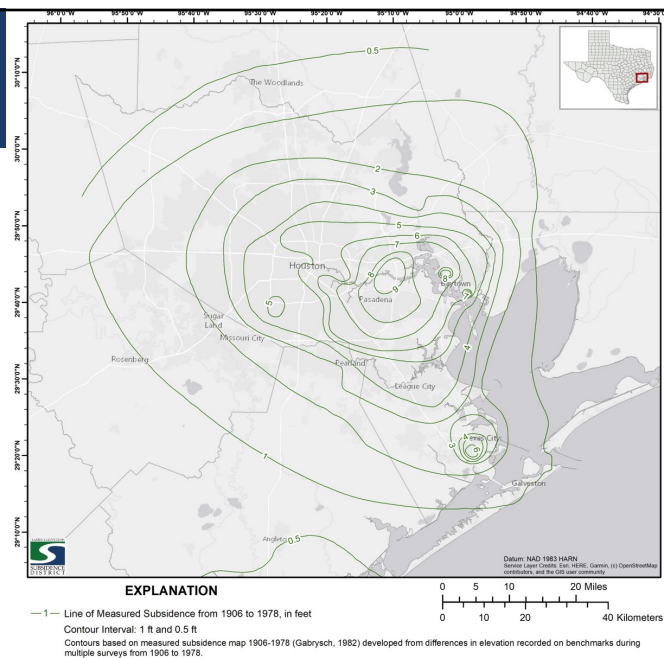


- **Area 1:** no more than 10% of Total Water Demand (TWD) may be sourced from groundwater.
- **Area 2:** no more than 20% of TWD may be sourced from groundwater.
  - Groundwater Reduction Plan (GRP) may be approved with conditions.
- **Area 3:** no more than 20% of TWD may be sourced from groundwater.
  - Permittees operating within an approved GRP have the following requirements:
    - 2010 – reduce groundwater use to no more than 70% of TWD
    - 2025 – reduce groundwater use to no more than 40% of TWD
    - 2035 – reduce groundwater use to no more than 20% of TWD

## Subsidence from 1906 to 1978

- Cumulative subsidence from 1906 to 1978 measured from spirit and first order leveling surveys in the greater Houston region.
- Representation of subsidence prior to the formation of HSGD.

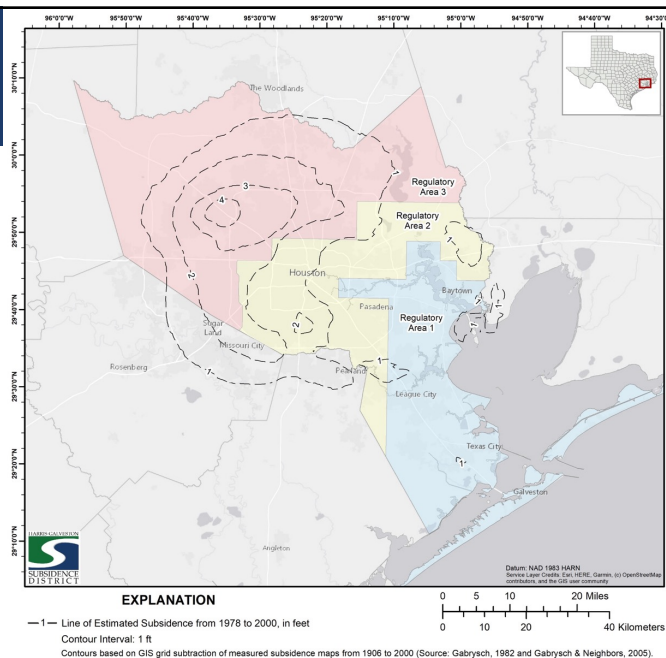
Source: Greuter A., M. J. Turco, C. M. Petersen, and G. Wang, 2021, Impacts of groundwater withdrawal regulation on subsidence in Harris and Galveston counties, Texas, 1978–2020: GeoGulf Transactions, v. 71, p. 109–118.



## Subsidence from 1978 to 2000

- Cumulative subsidence from 1978 to 2000 measured from first order re-leveling surveys in the greater Houston region.
- Representation of subsidence impacts from the implementation of the Regulatory Plan conversion requirements in Regulatory Areas 1 and 2.

Source: Greuter A., M. J. Turco, C. M. Petersen, and G. Wang, 2021, Impacts of groundwater withdrawal regulation on subsidence in Harris and Galveston counties, Texas, 1978–2020: *GeoGulf Transactions*, v. 71, p. 109–118.

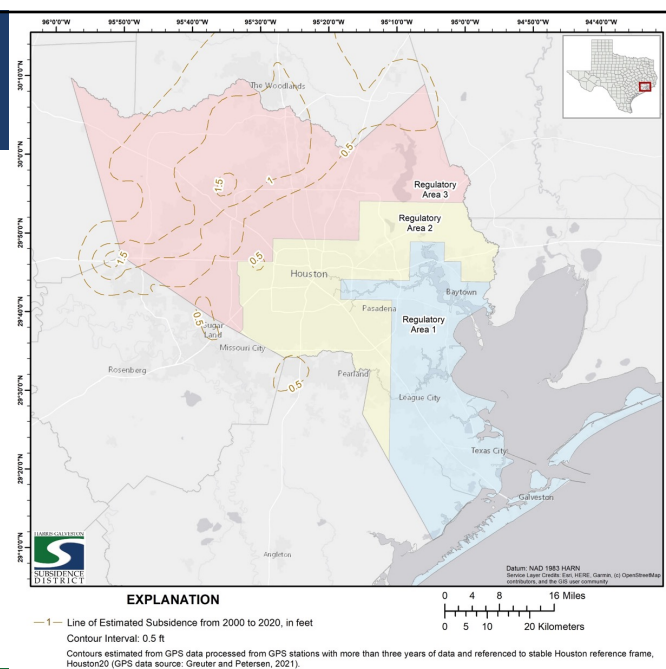


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## Subsidence from 2000 to 2020

- Cumulative subsidence from 2000 to 2020 estimated from GPS data collected periodically and continuously from stations in the monitoring network.

Source: Greuter A., M. J. Turco, C. M. Petersen, and G. Wang, 2021, Impacts of groundwater withdrawal regulation on subsidence in Harris and Galveston counties, Texas, 1978–2020: *GeoGulf Transactions*, v. 71, p. 109–118.



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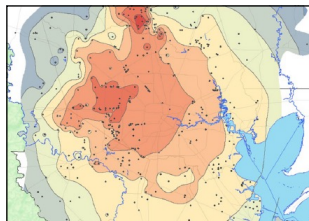
## Subsidence Monitoring

Monitoring the occurrence of subsidence and the impact of pumpage on the aquifer requires the consistent collection of aquifer, water use, and subsidence data. Data improves our understanding of the groundwater system and alternative water availability; and improves our ability to predict subsidence in the future.



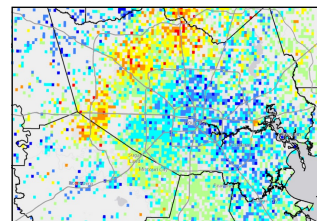
### Water Use Data

- Groundwater Pumpage
- Alternative Water Usage



### Aquifer Data

- Water Levels
- Lithology
- Extensometers



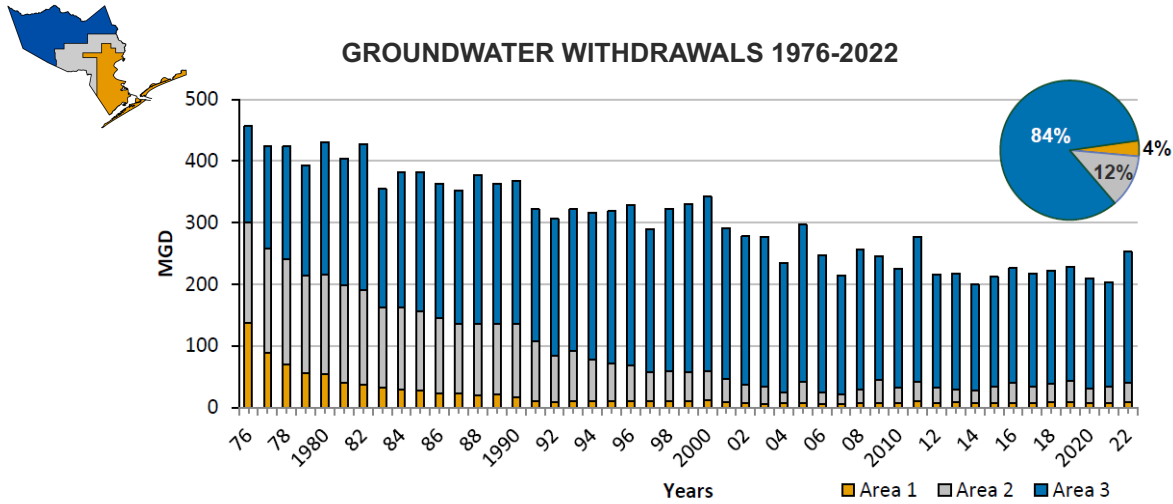
### Land Subsidence Data

- Benchmark Surveys
- GPS Stations
- InSAR



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## Water Use Data



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\*Updated data will be released next Thursday,  
April 25, 2024, during our AGR Public Hearing.

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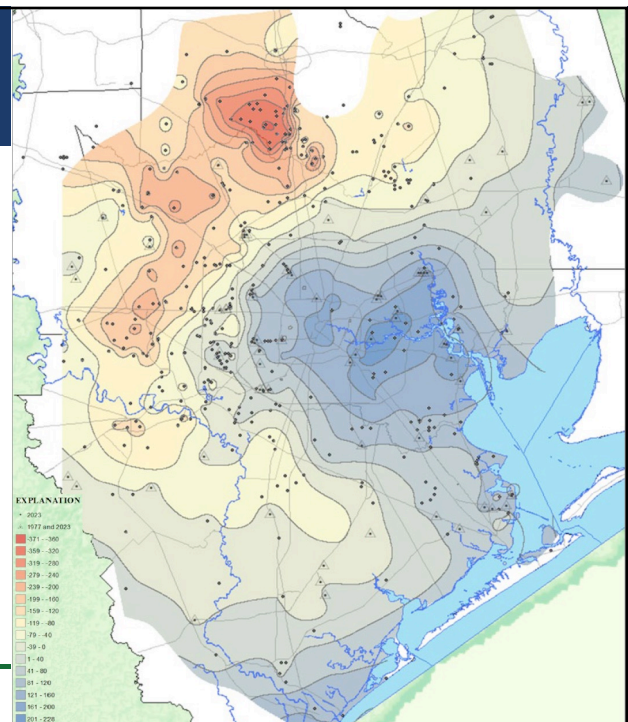
## Aquifer Data

The United States Geological Survey (USGS) monitors over 600 public supply, irrigation, industrial, and observation wells spread across 11 counties in the Houston-Galveston Region.

- Multi-agency effort including the USGS, Subsidence Districts, City of Houston, BCGCD, and LSGCD.

### MAP OF CHICOT AND EVANGELINE (UNDIFF.) WATER-LEVEL CHANGE SINCE 1977

- Highest areas of decline exist in northern and western Harris County, and the south-central portion of Montgomery County.
- Large area of rise in central and eastern Harris County and Galveston County indicative of shift in water supply from groundwater to alternatives.



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## Benchmark Surveys

**HGSD 2022 GNSS Survey**

This map shows benchmarks observed in the Harris-Galveston Subsidence District's 2022 GNSS Survey and validated by the National Geodetic Survey (NGS).

The circles represent a benchmark that was observed using GNSS equipment and processed in NGS's OPUS Projects.

**INSTRUCTIONS:**

- Click on the circle to open a pop-up that contains basic geodetic information, HGSD and NGS datasheets, and photos of the selected benchmark.
- To download the datasheets, scroll to the bottom of the pop-up and click the link.
- To view photos of the benchmark, scroll to the bottom of the pop-up under "Attachments" and click the photo link.
- For a close-up view, select the photo ending in 10.jpg.
- For a general location view, select the photo ending in 11.jpg.




**Additional Map Tools:**

- Select the icons in the upper right panel for the following options from left to right:
  - Legend - description of map icons.
  - Measurement - use to measure distances.
  - Basemap - use to change the background map.
  - Search - enter address to view location on map.

**Benchmark Designations: W 1019**

PID	AW1973
4-CHAR ID	W019
MARK DESIGNATION	W 1019
GENERAL LOCATION	Houston
COUNTY	Harris
LATITUDE [DMS]	29°53'00.76967" (N)
LATITUDE [DD]	29.883547
LONGITUDE [DMS]	095°07'43.06037" (W)
LONGITUDE [DD]	-95.128628
ELLIPSOID HEIGHT [USF]	-60.65
HORIZONTAL DATUM	NAD83 (2011) Epoch 2010.0
GEOID HEIGHT [USF]	-89.68
ORTHOMETRIC HEIGHT [USF]	29.00
ORTHOMETRIC HEIGHT SOURCE	GPS OBS
VERTICAL DATUM	NAVD88
GEOID MODEL	Geoid 18
NORTHING [USF]	1388911.44
EASTING [USF]	3195096.32
SPCS	TXSC 4204
COMBINED SCALE FACTOR	0.999991185
NGS DATASHEET	<a href="#">More info</a>
HGSD DATASHEET	<a href="#">More info</a>

Attachments:  
W019\_10.jpg  
W019\_11.jpg

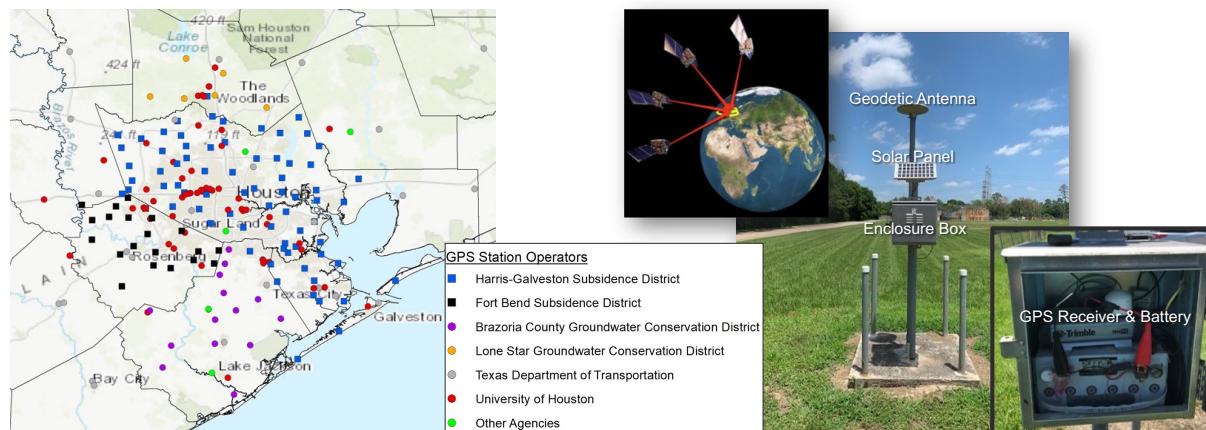




Scan to access survey data. →

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## GPS Measurement Method

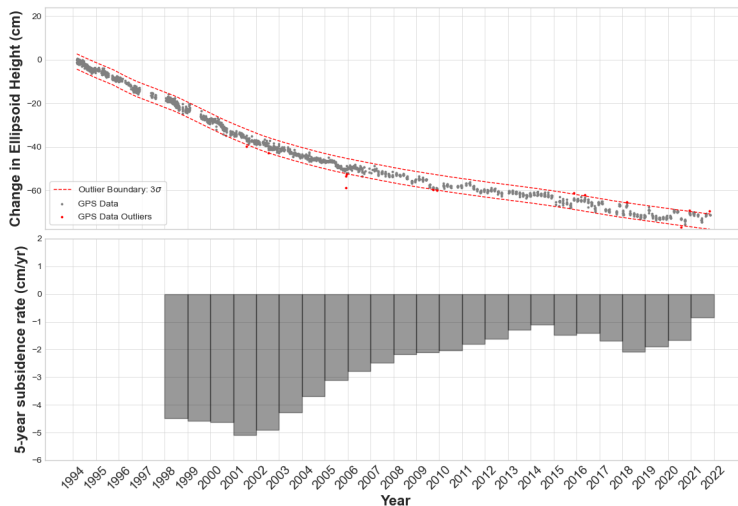
**Our subsidence monitoring network utilizes over 200 Global Positioning System (GPS) stations constructed in the Port-a-Measure (PAM) design and collects GPS data periodically.**



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## GPS Station Period of Record Data

GPS station P001, located near Jersey Village, has measured a total of approximately 71 cm of subsidence since 1994.

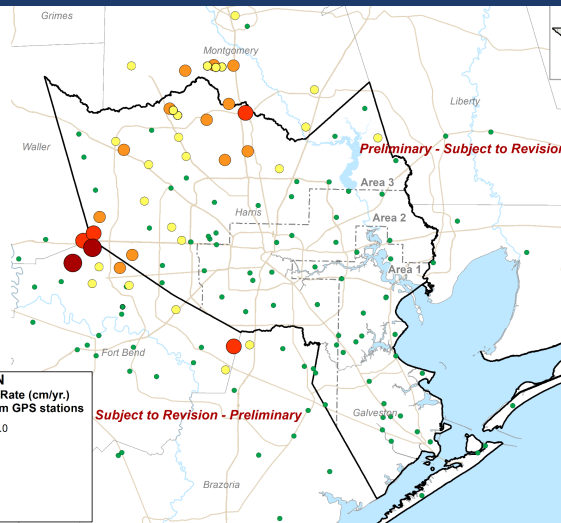
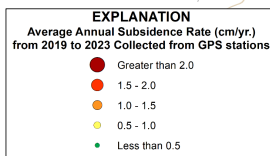


Processed GPS data (source: UH) over a period of record. Processed data (grey circles) located inside the outlier boundary (red dashed lines) are used when calculating subsidence rates. Processed GPS data identified as outliers (red circles) are excluded from subsidence rate calculations and are shown for informational purposes only.

## Subsidence Rates Collected from GPS Stations

### AVERAGE ANNUAL SUBSIDENCE RATES FROM 2019 TO 2023 *PRELIMINARY*

- Fully converted Areas 1 and 2 show the impact groundwater regulation has had on stabilizing subsidence rates.
- Decreased subsidence rates were achieved through the reduction of reliance on groundwater through a collaborative effort to develop infrastructure amongst regional water authorities and the City of Houston.



# Interferometric Synthetic Aperture Radar (InSAR)

- Synthetic aperture radar (SAR) data are generated by transmitting electromagnetic radiation and observing the return signal.
- Satellite SAR can observe Earth's surface during all-weather conditions.
- The phase of the radar wave of the return signal that depends on the distance from the satellite to the ground can be measured accurately.
- Interferometric SAR (InSAR) uses two SAR images of the same area to find the phase difference between them.
- By precisely measuring the phase shift in an InSAR image, the change in distance from satellite to ground can be calculated to an accuracy of centimeters.
- State-of-the-art multi-temporal InSAR (MTI) techniques can be used to suppress the artifacts that plague conventional InSAR methods to achieve an accuracy of millimeters (Qu et al. 2015, 2019).

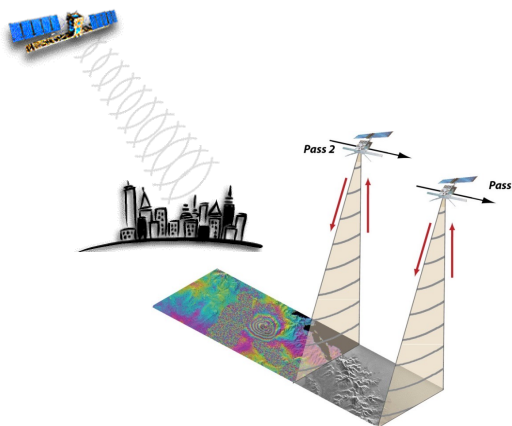
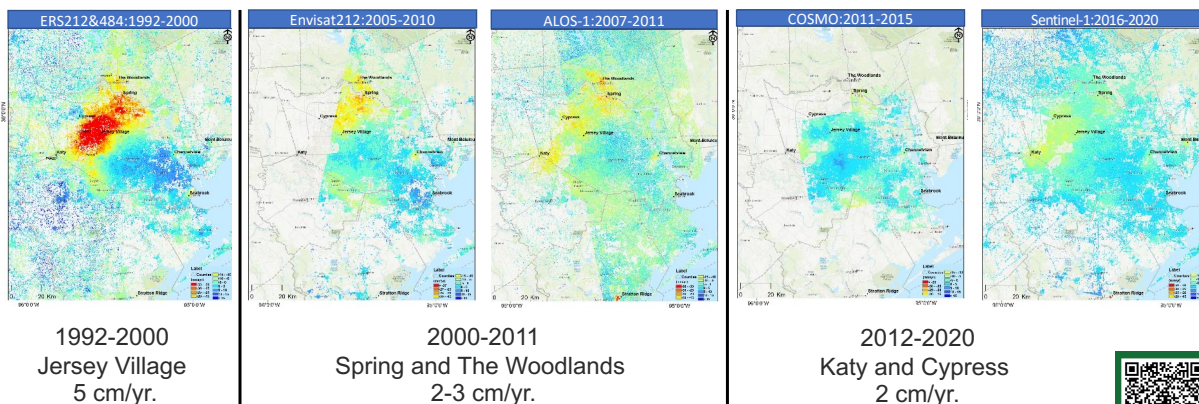


Illustration of how InSAR works  
(Lu & Dzurisin, 2014)

## Land Surface Monitoring Using InSAR

### InSAR-derived surface deformation evolution across the Houston-Galveston Region



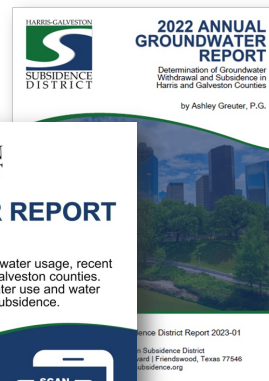
Scan for access to the full report. →



## Annual Groundwater Reports

Each year, the District publishes an annual groundwater report, and a public hearing is held to take testimony concerning the effects of groundwater withdrawals on the subsidence of land within the District during the preceding year and includes information on:

- Precipitation data from weather stations
- Groundwater withdrawals and total water demand
- Groundwater levels in Chicot/Evangeline and Jasper aquifers
- Compaction measurements and GPS data





### ANNUAL GROUNDWATER REPORT

#### Public Hearing

Join us for a public hearing to learn about annual groundwater usage, recent subsidence, and aquifer water level data in Harris and Galveston counties. The report provides context on the impact changes in water use and water sources can have on the occurrence and magnitude of subsidence.

Scan the QR code for more information.

 **APRIL 25, 2024**

 **9:00 AM**

 **1660 W. BAY AREA BLVD.  
FRIENDSWOOD, TX 77546**



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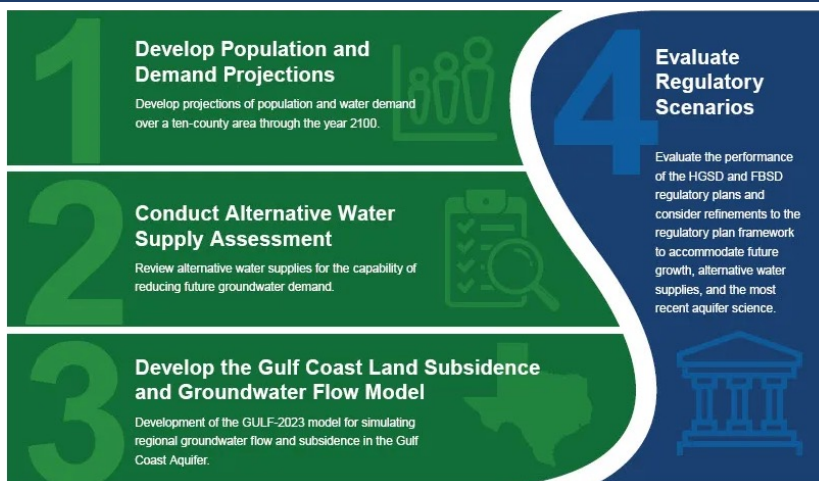
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# Joint Regulatory Plan Review

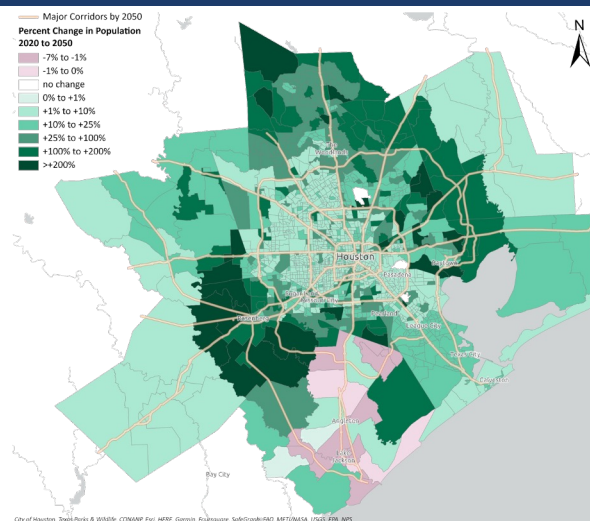


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## Population Growth Forecast 2020 to 2050

### PERCENT CHANGE IN POPULATION BY CENSUS TRACT

	<u>2020</u>	<u>2050</u>	<u>% Change</u>
Austin	30,167	33,366	+11%
Brazoria	372,031	451,031	+21%
Chambers	46,571	102,555	+120%
Fort Bend	822,779	1,431,122	+74%
Galveston	350,682	401,517	+14%
Harris	4,731,145	5,547,593	+17%
Liberty	91,628	176,682	+93%
Montgomery	620,443	1,063,722	+71%
Waller	56,794	101,637	+79%
Wharton	41,570	42,335	+2%



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# Alternative Water Supplies Assessment

## Characterization and Evaluation of Supplies



Estimate Magnitude of Supplies



Prepare Planning Level Cost Estimates



Consider Water Quality and Permitting



Identify Implementation Timelines

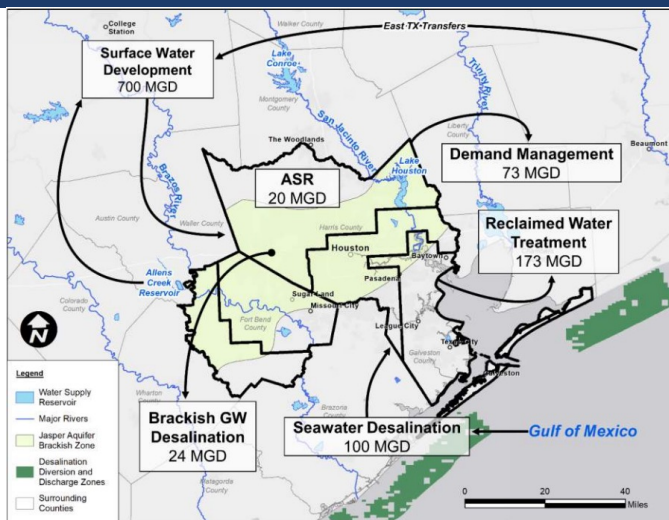


Assess Climate Vulnerability



Evaluate Subsidence Impacts

Scan to access the full report. →



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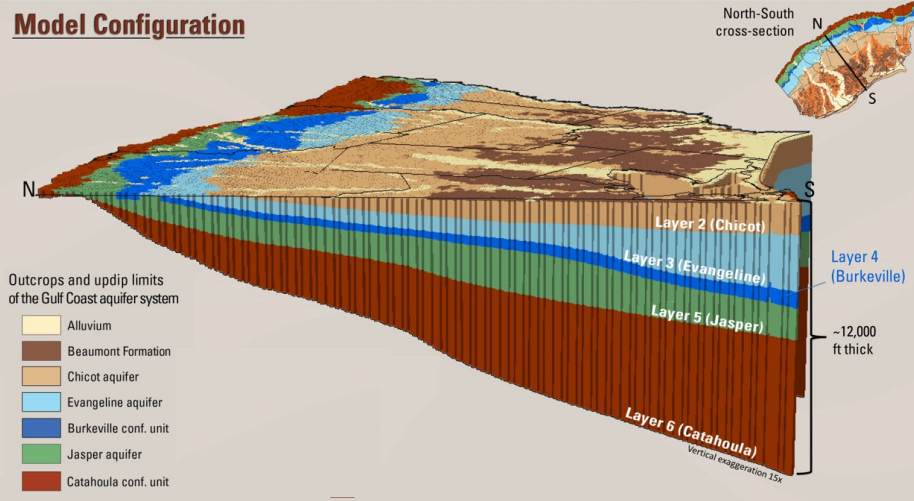
# Groundwater Modeling Updates

- Inclusion of 115 years of water level and subsidence data
- Updated model packages and parameters
- Inclusion of full Gulf Coast Aquifer System
- Enhanced calibration and uncertainty ensembles



Scan for access  
to the full report. →

## Model Configuration



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## Water Conservation Grant Program

Since 2019, the District has provided funds for projects that align with the District's water conservation mission. Projects in the scope of water efficiency, conservation measures, or research are eligible for funding.

### Who can apply?

- A water utility in good standing with the District. A water utility, including a water supply corporation, general law or home-rule city, a special utility district, a municipal utility district or any other entity included in the definition of a retail public utility in Section 13.002, Texas Water Code, whose defined service area, or a majority portion thereof, lies within the boundaries of the District;
- A private entity (industrial, commercial/institutional, residential, agricultural or other) whose property, or a majority portion thereof, is within the District;
- A 501(c) non-profit organization with an environmental purpose located within Harris County or Galveston County;
- A public entity (school district, management district, improvement district or similar entity) whose property, or a majority portion thereof, is within the District; or
- A research university located within the State of Texas.



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## Water Conservation School Program

Since 1994, HGSD has partnered with local cities, regional water authorities, municipal utility districts (MUDs), and other water industry professionals to deliver the Water Conservation School Program to more than 35 local school districts, reaching over 40,000 students annually.

The program equips 3rd-6th grade students in Harris and Galveston counties with quality, age-appropriate, and locally-based water education and each student receives a free water conservation kit.

The District recently launched the new and improved school program, H2O Lab! providing fun, project-based learning to help students understand more about water conservation, water efficiency, water sources, and subsidence.

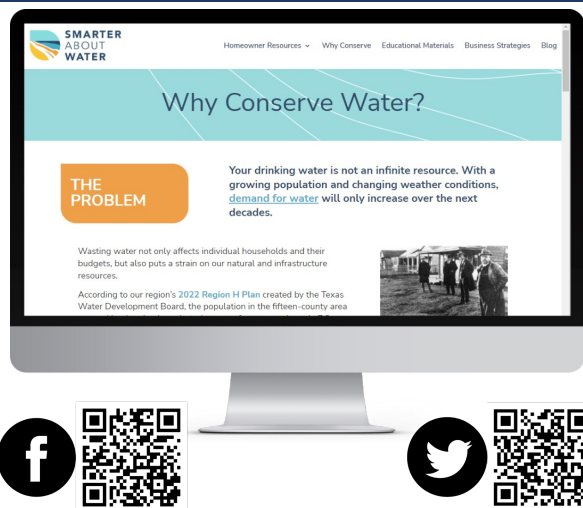


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## Smarter About Water

With a focus on the Gulf Coast and the greater Houston-Galveston region, Smarter About Water tells the community-based story of why we need to conserve water and shares tools on how to make that happen.

- **Website** - SmarterAboutWater.org is a dedicated website that provides water conservation tools and resources for students, teachers, homeowners, business owners, or anyone interested in learning about water efficiency.
- **Blog** - This blog provides water-specific curated content for readers to implement water-saving tips into their everyday lives.
- **Social** - Follow Smarter About Water on your social channels to stay in-the-know or to share your own water-saving tools and resources!



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## EPA WaterSense Partnership

The District utilizes the free tools and resources provided by EPA WaterSense campaigns to promote water conservation and efficient water behaviors.

WaterSense, a voluntary partnership program sponsored by EPA, is a label for water-efficient products, programs, and homes as well as a resource for helping consumers learn ways to save water.



- WaterSense products for maximizing water efficiency.
- Water-saving tips and resources for indoor/outdoor usage, homeowners, businesses, and much more.
- WaterSense for kids includes water-saving information, games and other activities to make saving water fun!



Last October, WaterSense honored Harris-Galveston Subsidence District as a 2023 Partner of the Year Award winner for its substantial efforts in collaborating with other WaterSense partners, like Houston Public Works, and organizations to implement successful water-saving projects.



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## Gulf Coast Water Conservation Symposium

The District hosted the Gulf Coast Water Conservation Symposium on February 22, 2024, where experts provided information on implementing water conservation programs, funding opportunities, engaging customers, and planning for the future. This was the first year for HGSD to host this symposium successfully bringing together 130 local water utility and resource professionals, engineers, educators, students, and community members to learn about water resource management and water conservation.

Stay tuned for details for next year's symposium!

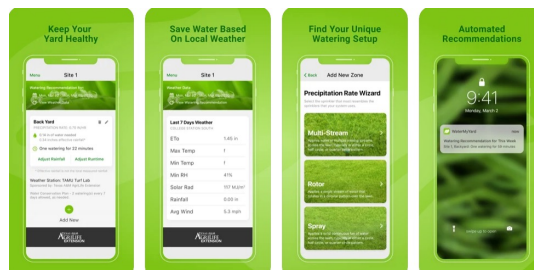


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## Water My Yard

- Over 50% of landscape water is wasted due to overwatering, inefficient watering practices, and broken or poorly maintained irrigation systems.
- Water My Yard is a free tool designed by Texas A&M Agrilife Extension to help homeowners and businesses save water and money by determining an adequate amount of water that is needed to maintain a healthy lawn.
- Users receive automated recommendations via email or text messaging that is customized to their yard utilizing data from a network of evapotranspiration weather stations and user-defined criteria.
- Visit [WaterMyYard.org](http://WaterMyYard.org) for free online access or download the mobile application through your device's app store.

Water<sub>My</sub>Yard 



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# Q&A



Connect with us!



## HARRIS-GALVESTON SUBSIDENCE DISTRICT

### Michael Turco

General Manager

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281-956-1105



mturco@subsidence.org



[www.hgsubsidence.org](http://www.hgsubsidence.org)



1660 W. Bay Area Blvd.  
Friendswood, TX 77546