

HARRIS-GALVESTON



SUBSIDENCE
DISTRICT

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



Presented by:

Michael Turco

General Manager

Harris-Galveston Subsidence District

Agenda

District Introduction

Subsidence in the Houston Area

Groundwater Regulation

Subsidence Monitoring

Regulatory Planning

Water Conservation Tools & Resources

Q&A

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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.

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

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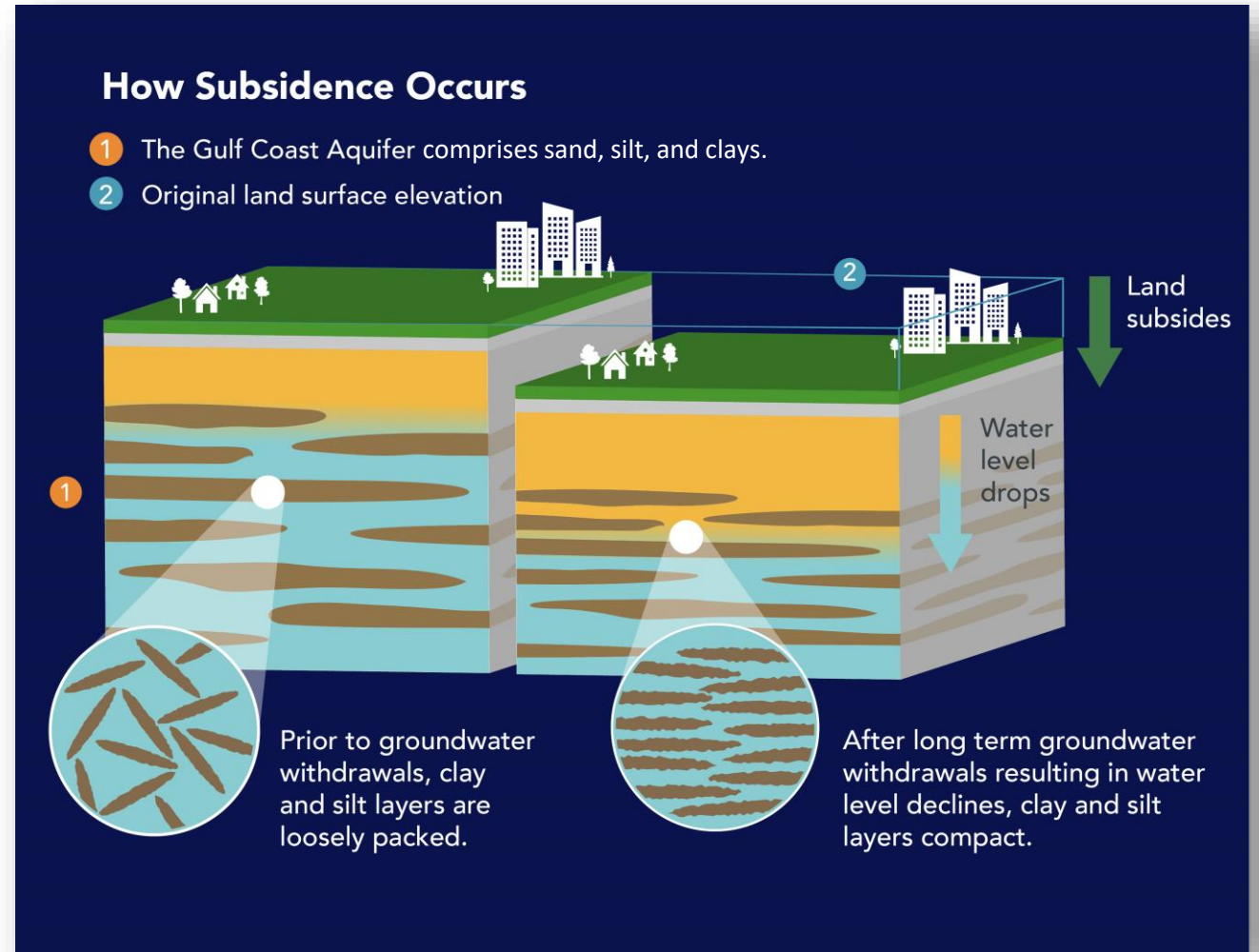
Regulatory Planning

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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



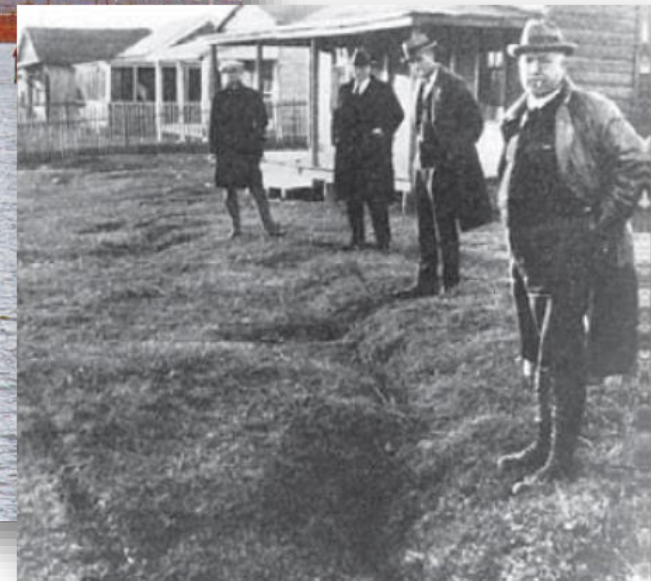
Permanent Inundation Due to Subsidence

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

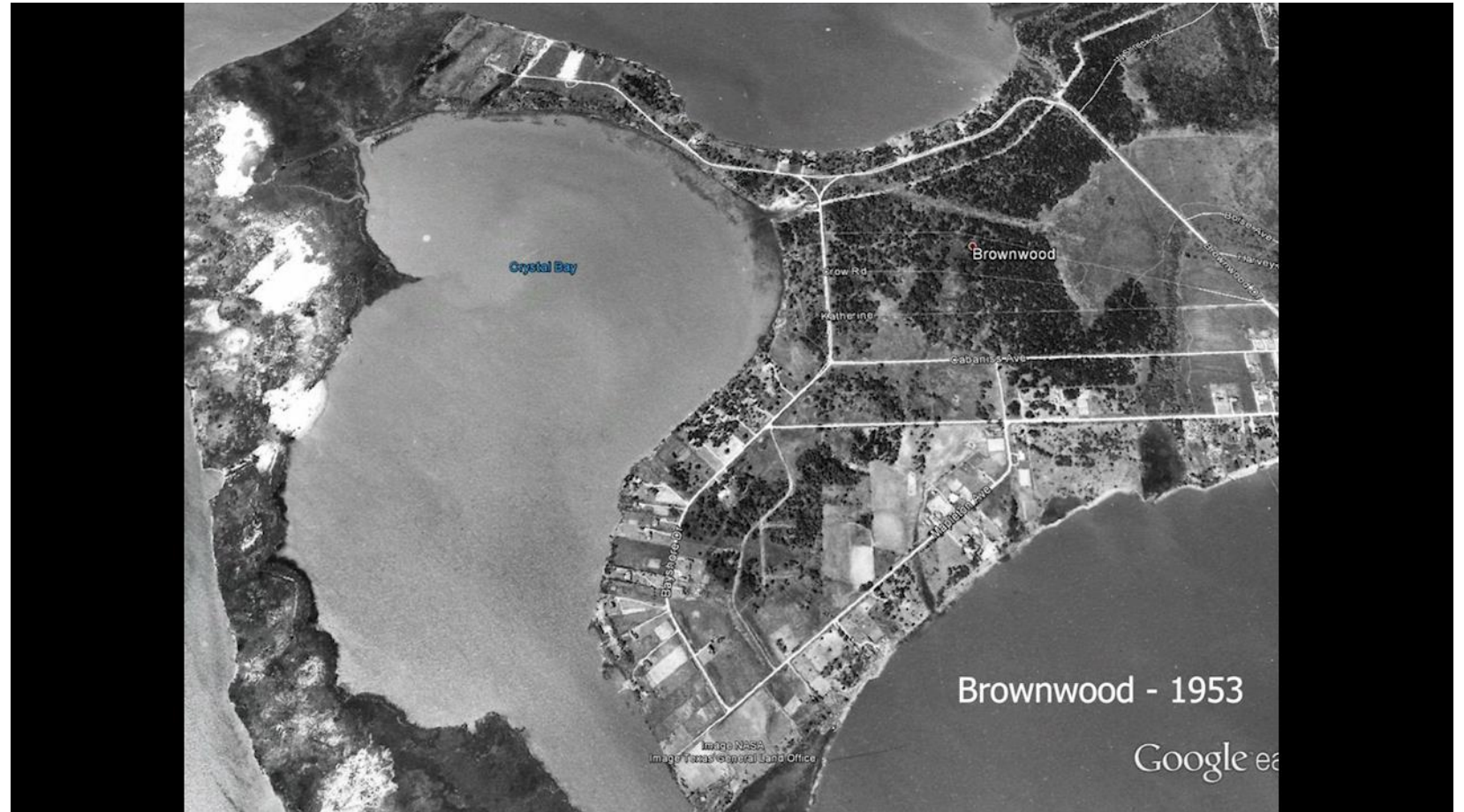


Earth fissures at Goose Creek Oil Field

Source: (U.S. Geological Survey)

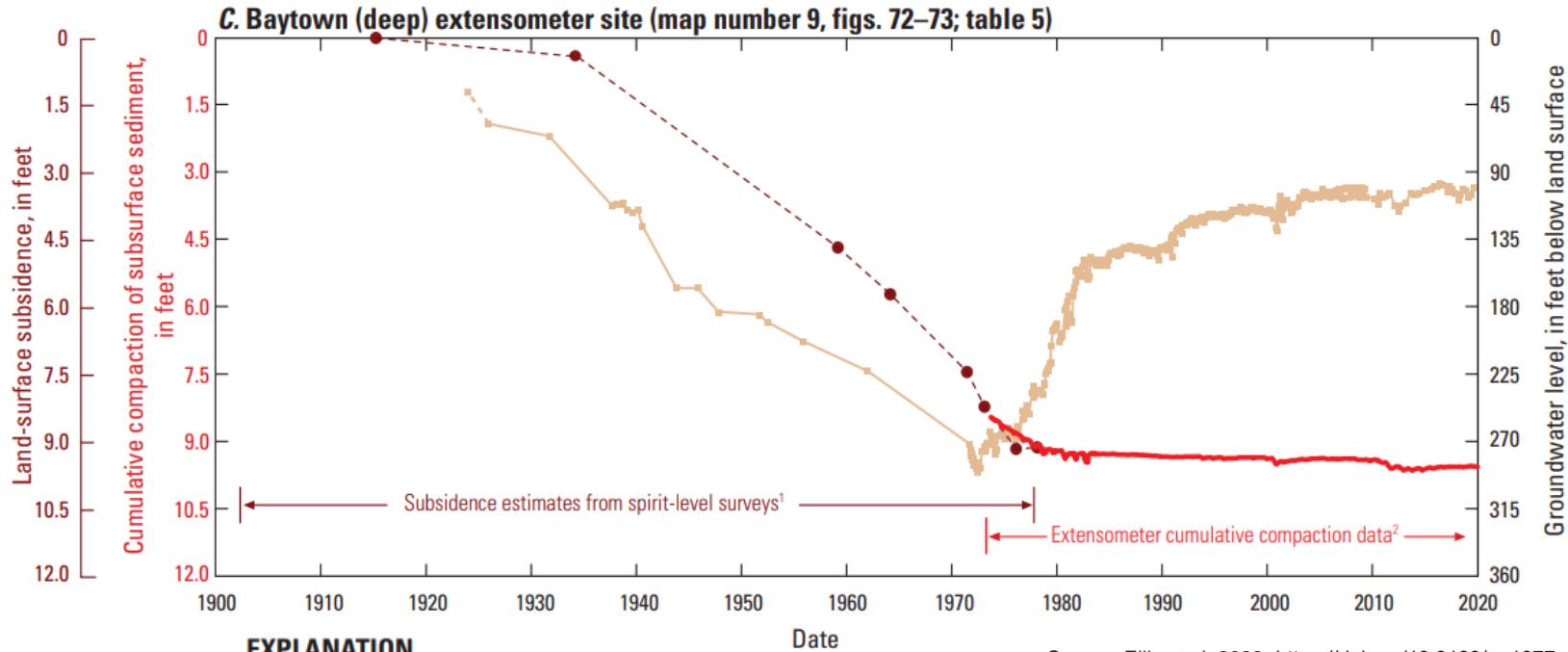
Brownwood Subdivision in Baytown, TX

- 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



Brownwood Subdivision in Baytown, TX

Land-surface measurements obtained from benchmark PTS 185



Source: Ellis et al. 2023. <https://doi.org/10.3133/pp1877>



Scan for access to the full report. →



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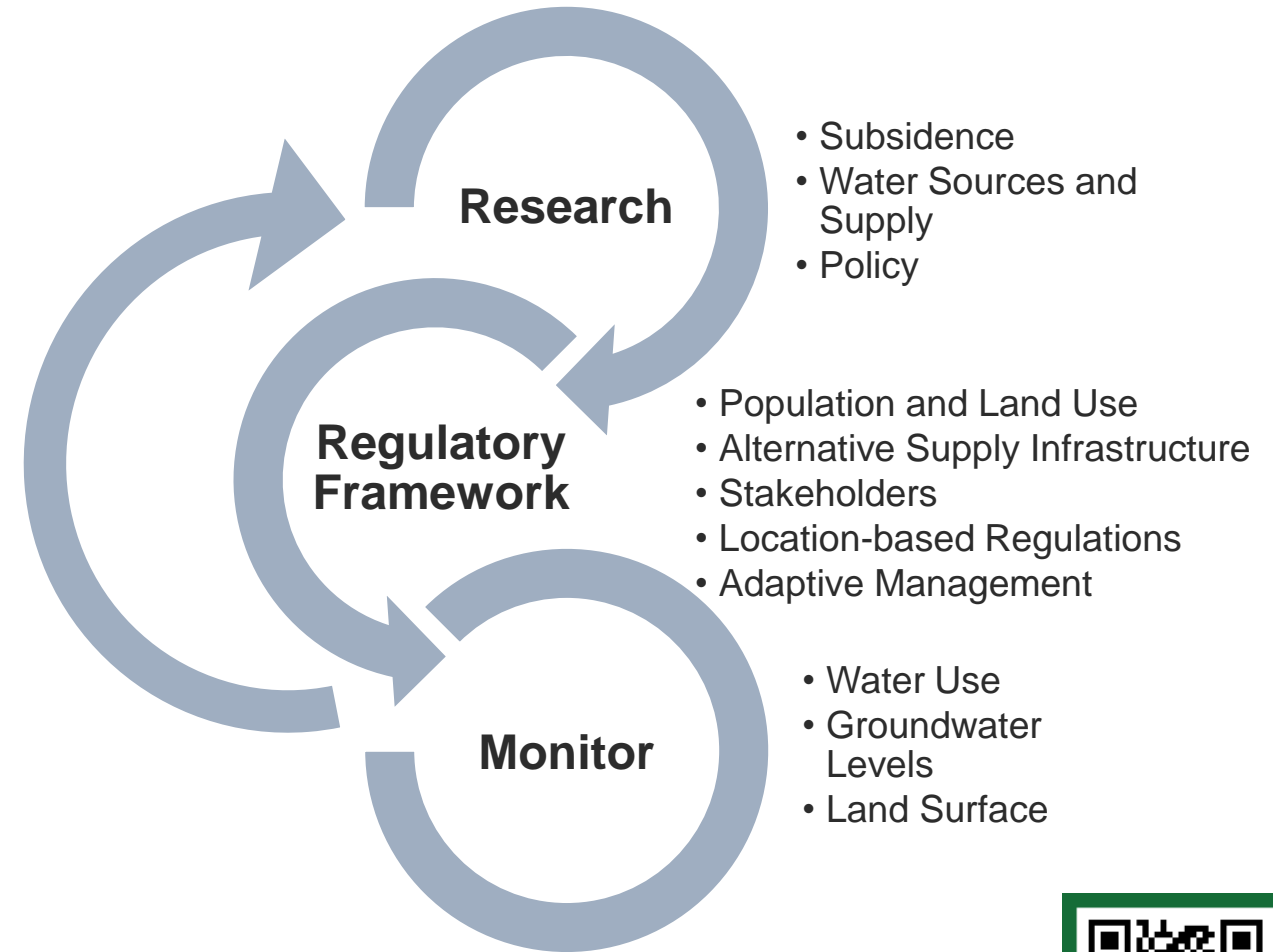
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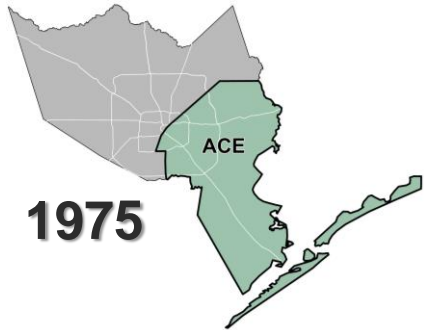
Q&A

Science-based Groundwater Regulation

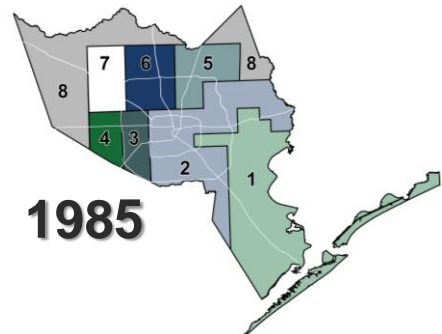
- **Conduct research**
- **Identify where subsidence is occurring**
- **Communicate with stakeholders**
- **Establish a regulatory framework**
- **Implement a monitoring program**
- **Continue research and outreach**



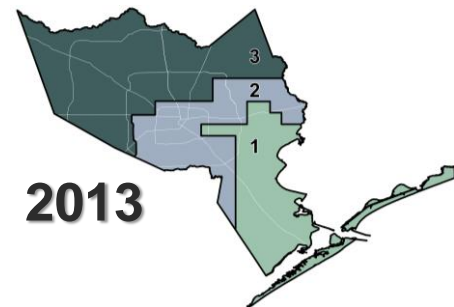
Groundwater Regulation to Stop Subsidence



- Following the creation of the Harris-Galveston Subsidence District, groundwater regulation began nearest to the coast in the Area of Concentrated Emphasis (ACE).

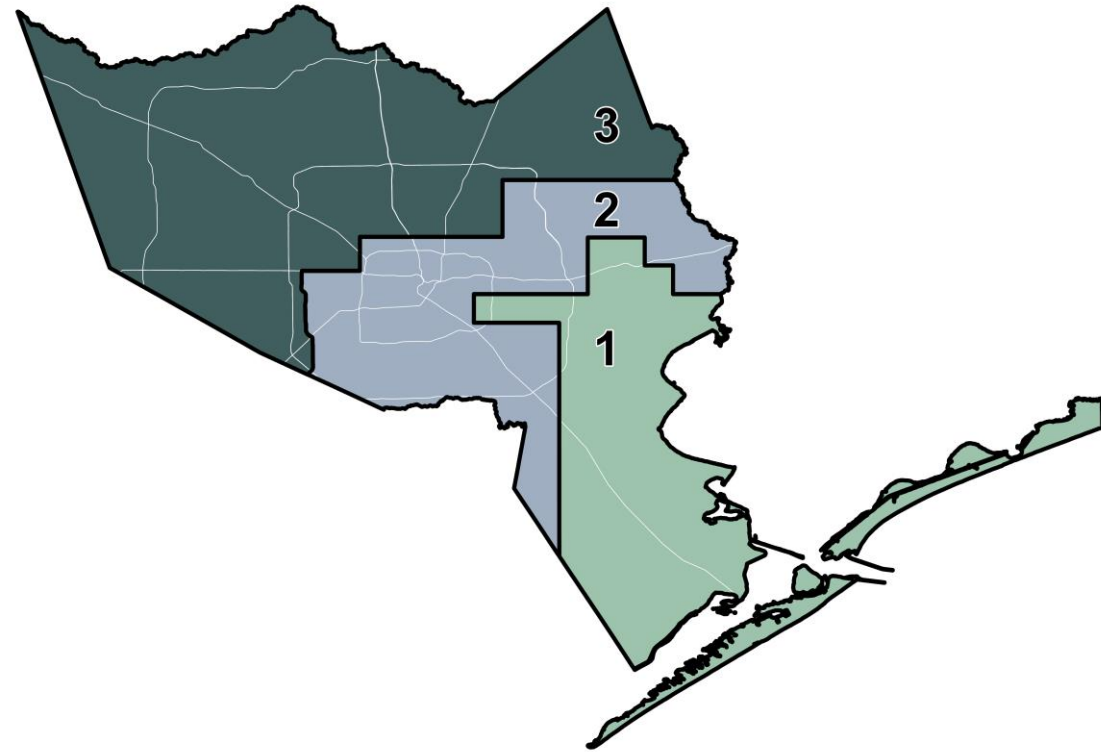


- As the population spread to the north and west and water use increased, numerous regulatory plans were developed and implemented.



- The 1999 Regulatory Plan designated the three regulatory areas that still exist today. By 2013, two regulatory areas were fully converted, and Regulatory Area 3 was put on a revised timeline for conversion.

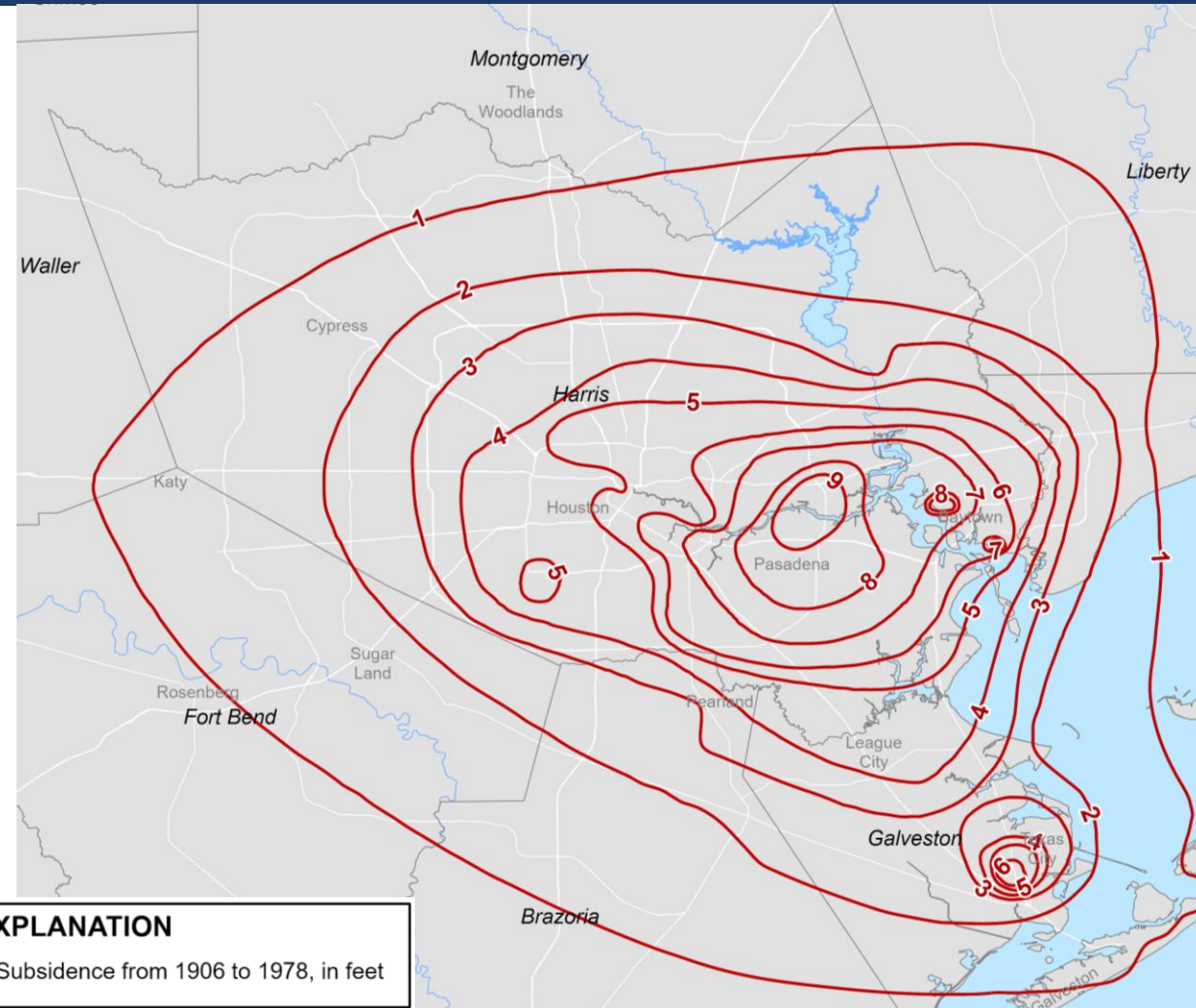
HGSD's Regulatory Areas



- **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

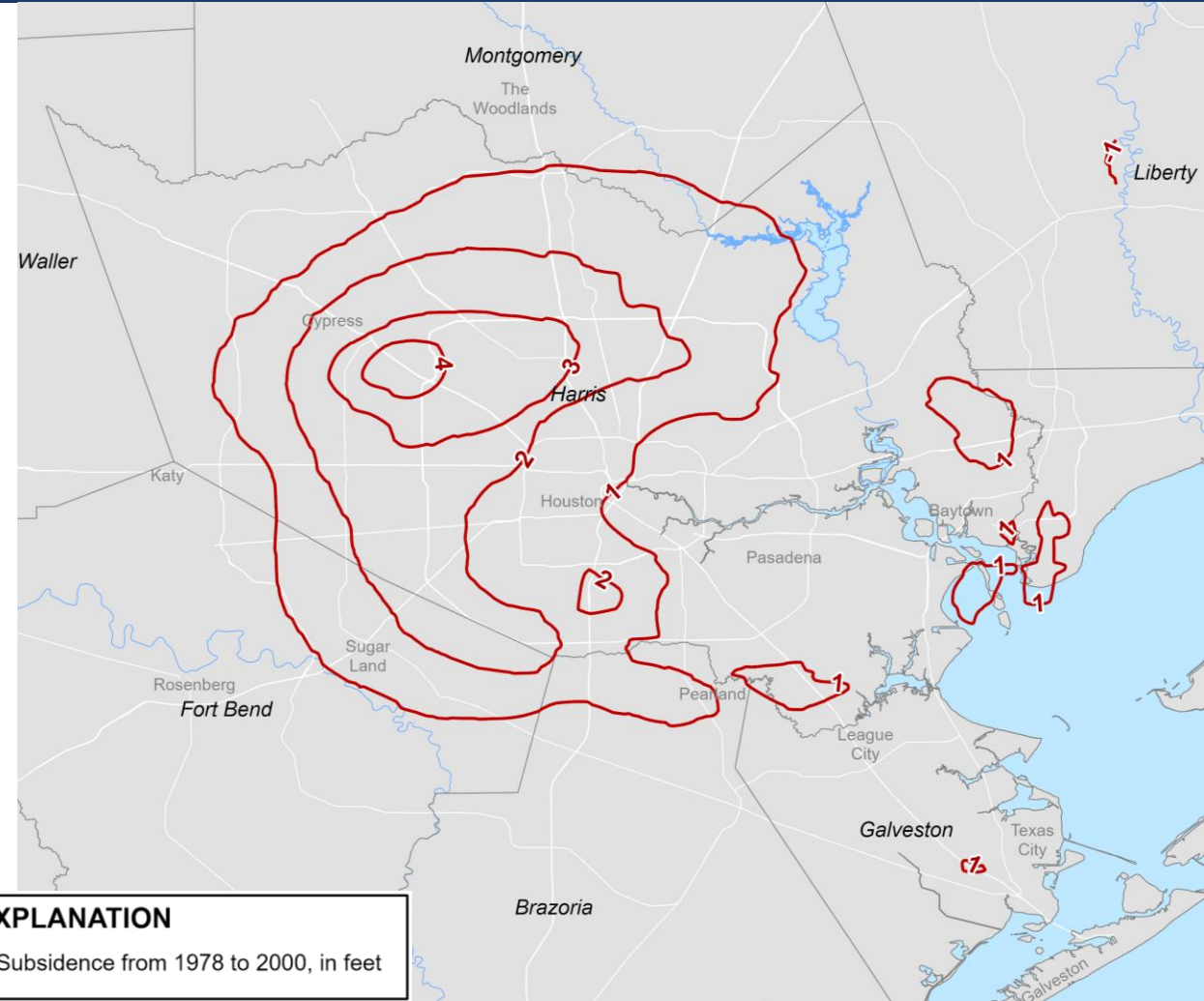
Subsidence from 1906 to 1978

- 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.



Subsidence from 1978 to 2000

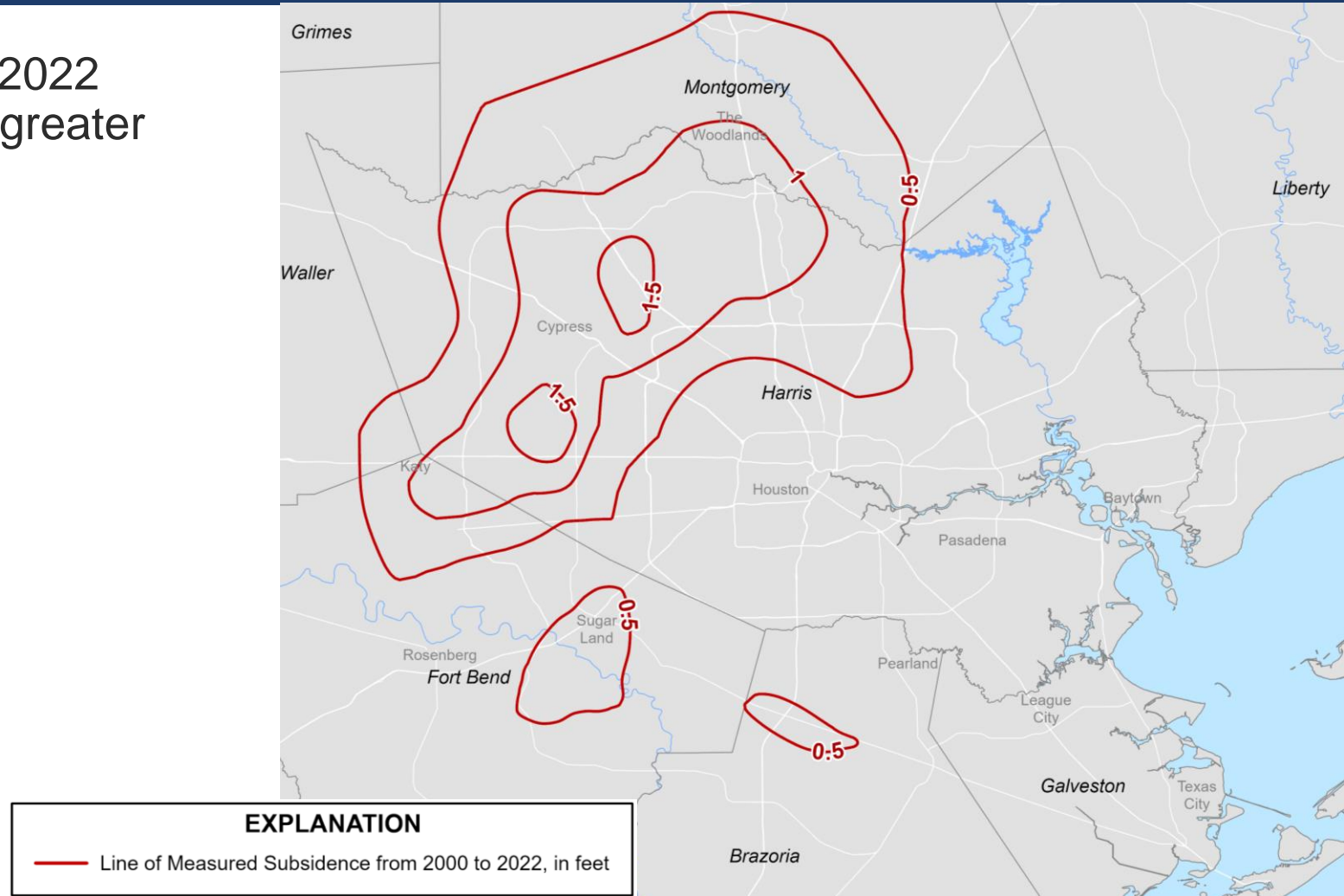
- Cumulative subsidence from 1978 to 2000 measured from first order re-leveling surveys in the greater Houston region.
- Representation of subsidence impacts from the implementation of the Regulatory Plan conversion requirements in Regulatory Areas 1 and 2.



Source: Gabrysch, 1982 (<https://doi.org/10.3133/ofr82571>)

Subsidence from 2000 to 2022

- Cumulative subsidence from 2000 to 2022 measured from GNSS surveys in the greater Houston region.



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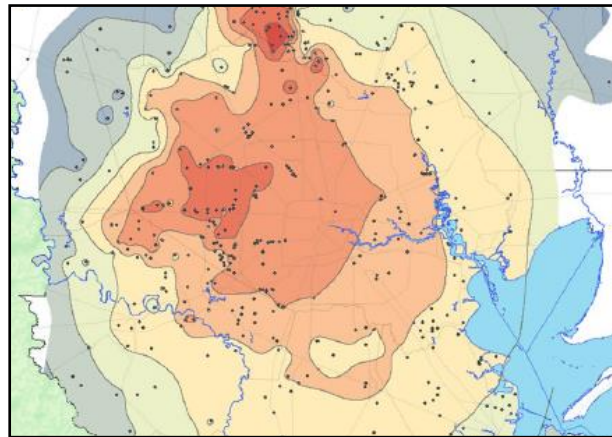
Subsidence Monitoring

Monitoring the occurrence of subsidence and the impact of groundwater withdrawal requires consistent collection of water use data, aquifer data, and land surface data. Together, these data improve our understanding of the groundwater system and our ability to predict subsidence in the future.



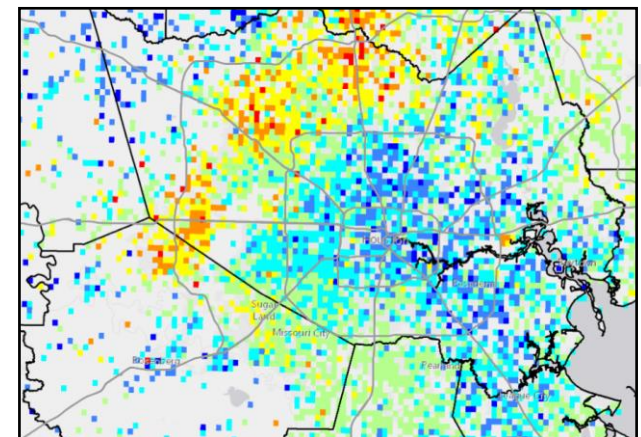
Water Use Data

- Groundwater Pumpage
- Alternative Water Usage



Aquifer Data

- Water Levels
- Lithology
- Extensometers

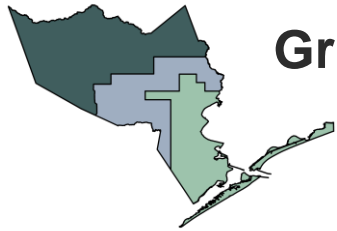


Land Surface Data

- Benchmark Surveys
- GPS Stations
- InSAR

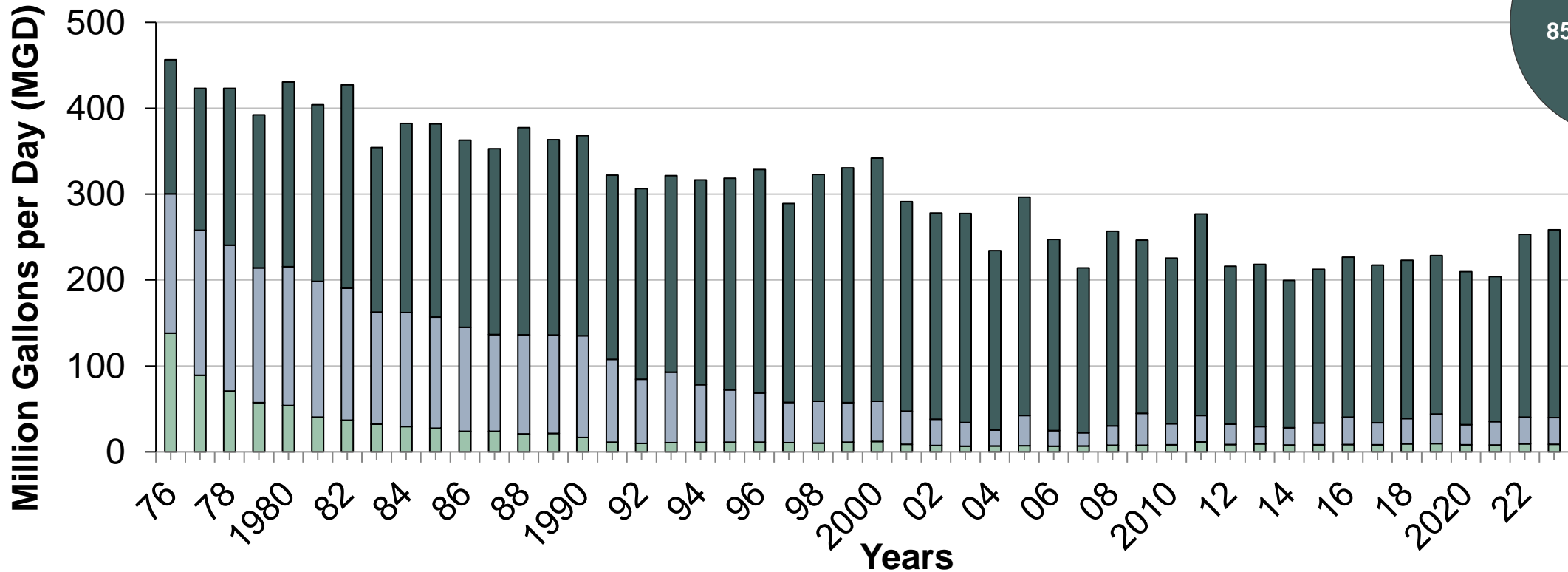


Groundwater Use Data

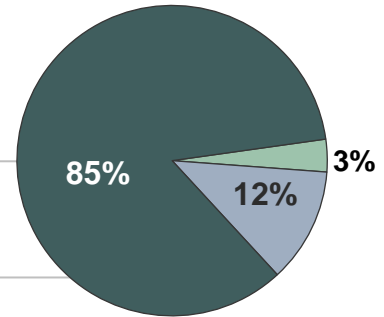


Groundwater Withdrawals Grouped by Regulatory Area

■ Area 1 ■ Area 2 ■ Area 3



2023: 258.6 MGD



Aquifer Data

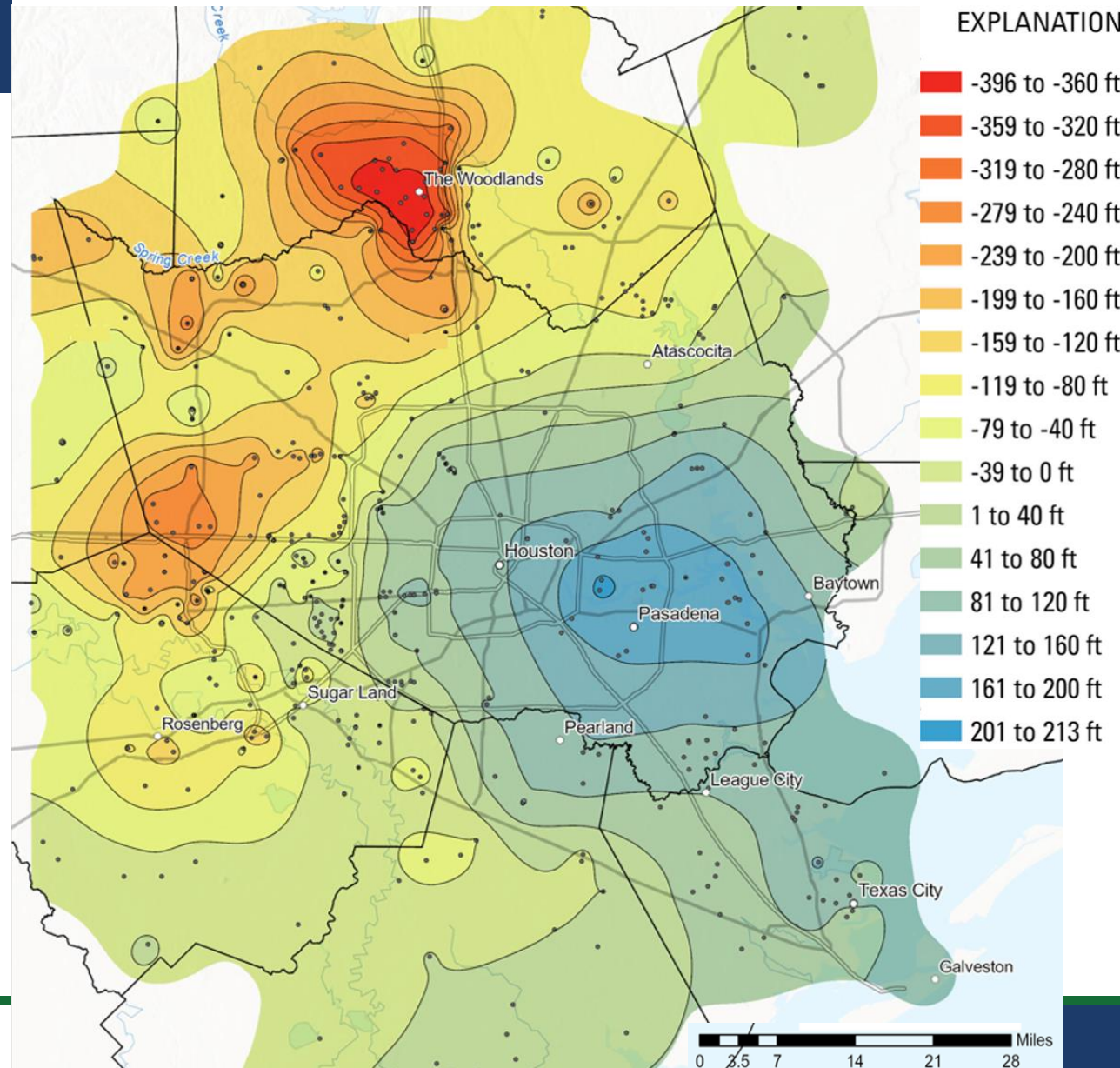
The United States Geological Survey monitors over 550 public supply, irrigation, industrial, and observation wells spread across 11 counties in the Houston-Galveston Region.

- A multi-agency effort with Harris-Galveston Subsidence District, Fort Bend Subsidence District, City of Houston, Bluebonnet Groundwater Conservation District, and Lonestar Groundwater Conservation District.

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 a shift in water supply from groundwater to alternatives.

Chicot and Evangeline (undiff.) Water-Level Change from 1977 to 2024



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).

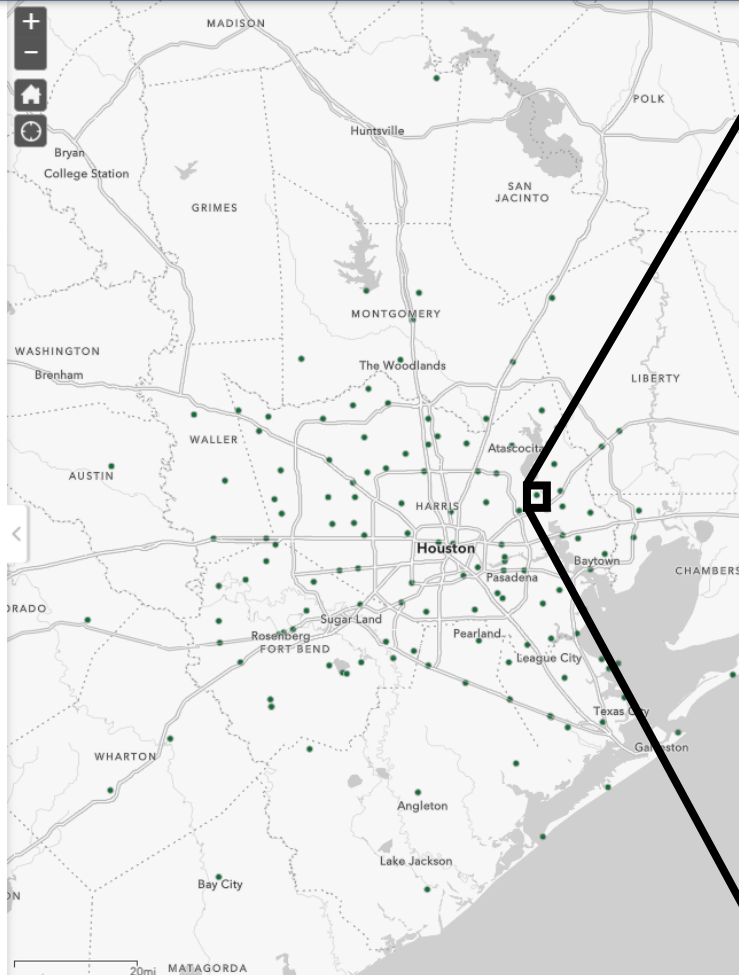
The circles represent a benchmark that was observed using GNSS equipment and processed in NGS's OPUS Projects.

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 Designation: 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 [USft]	-60.65
HORIZONTAL DATUM	NAD83 (2011) Epoch 2010.0
GEOID HEIGHT [USft]	-89.68
ORTHOMETRIC HEIGHT [USft]	29.00
ORTHOMETRIC HEIGHT SOURCE	GPS OBS
VERTICAL DATUM	NAVD88
GEOID MODEL	Geoid 18
NORTHING [USft]	13889111.44
EASTING [USft]	3195096.32
SPCS	TXSC 4204
COMBINED SCALE FACTOR	0.99991185
NGS DATASHEET	More info
HGSD DATASHEET	More info

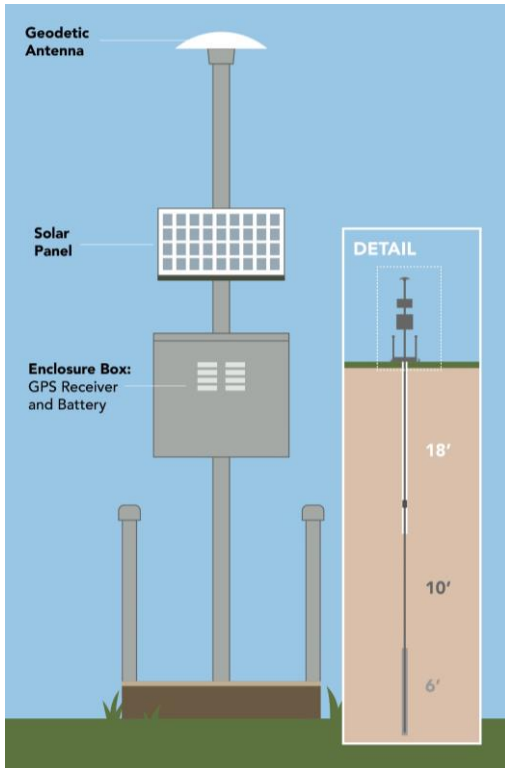
Attachments:
[W019_10.jpg](#)
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Scan to access survey data. →

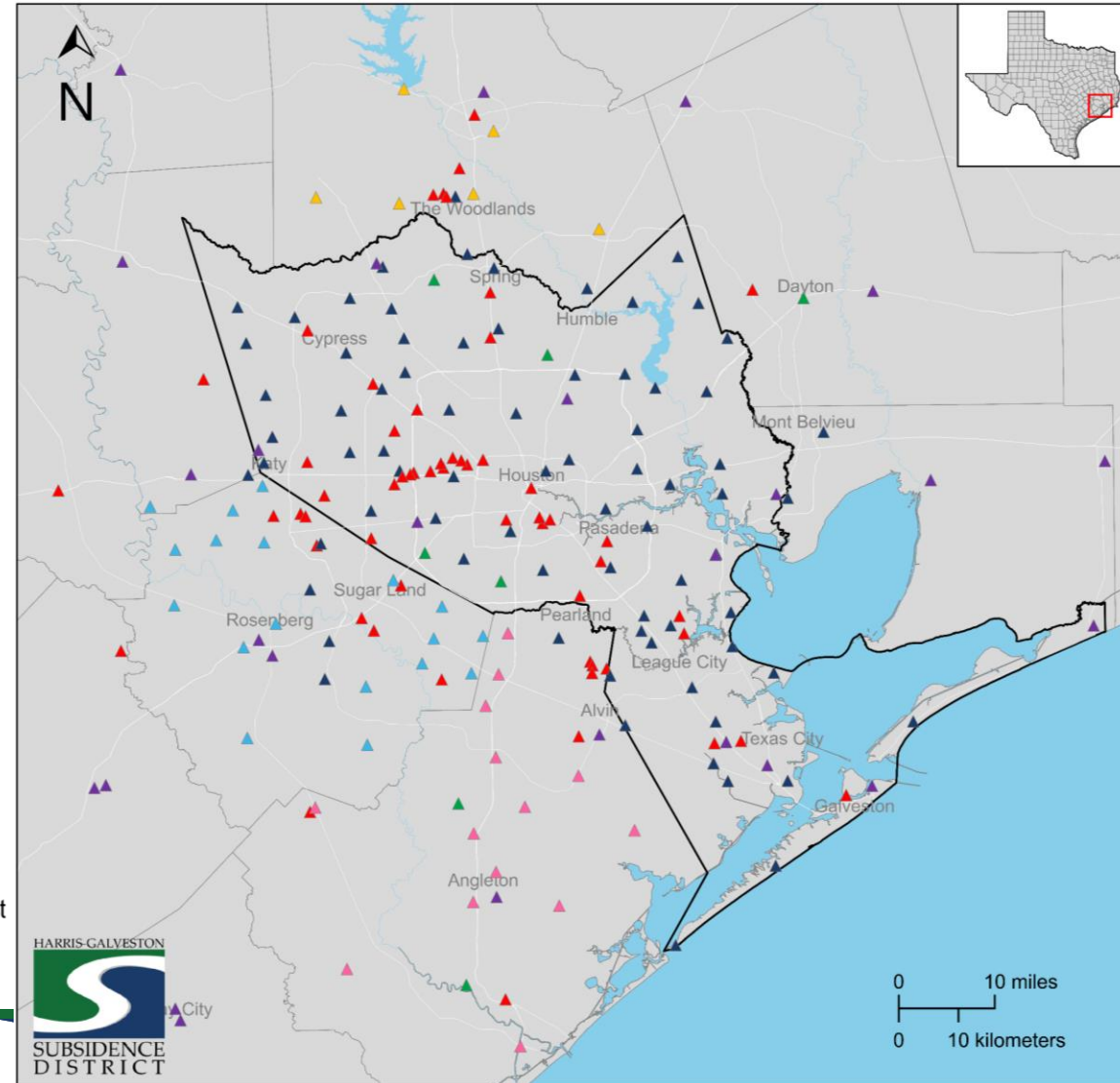
GPS Stations

Our subsidence monitoring network utilizes over 100 Global Positioning System (GPS) stations constructed in the Port-a-Measure (PAM) design that collect GPS data to track changes in the land surface.



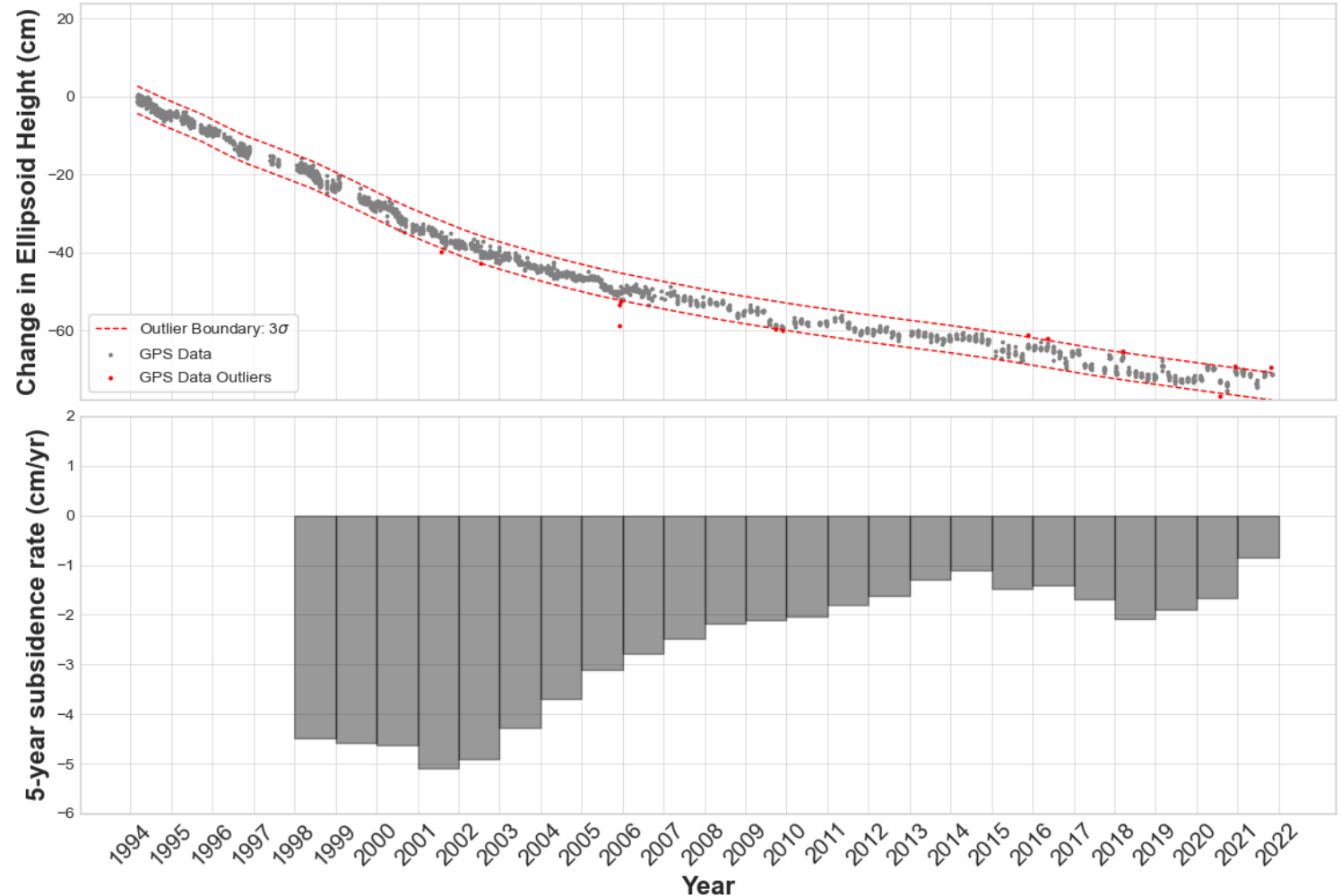
EXPLANATION

-  HGSD Jurisdiction
-  Harris-Galveston Subsidence District
-  Fort Bend Subsidence District
-  University of Houston
-  Texas Department of Transportation
-  Brazoria County Groundwater Conservation District
-  Lone Star Groundwater Conservation District
-  Other Operators



GPS Station Period of Record Data

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

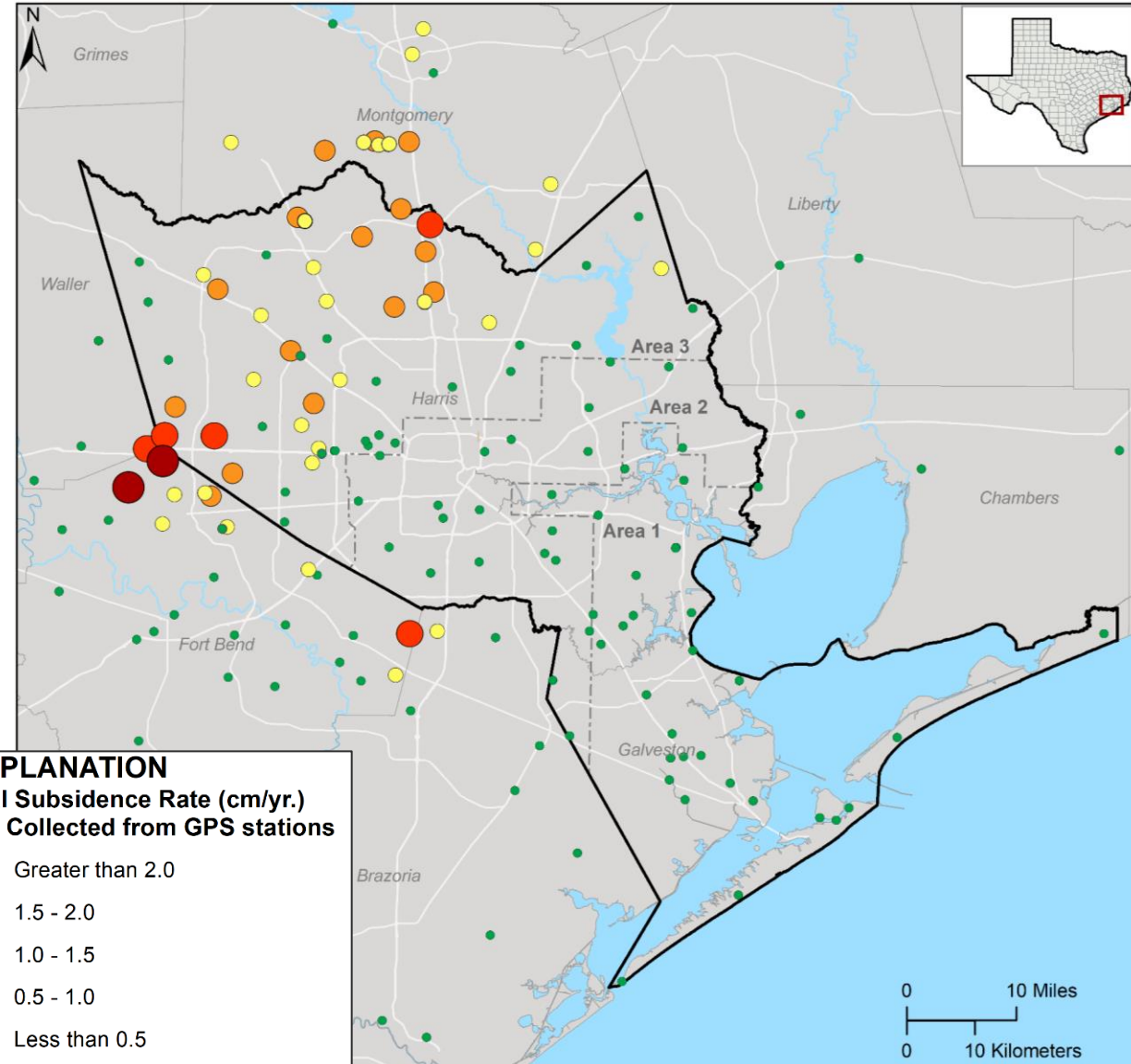


Processed GPS data (source: UH) over a period of record. Processed data (grey circles) located inside the outlier boundary (red dashed lines) are used when calculating subsidence rates. Processed GPS data identified as outliers (red circles) are excluded from subsidence rate calculations and are shown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

Subsidence Rates Collected from GPS Stations

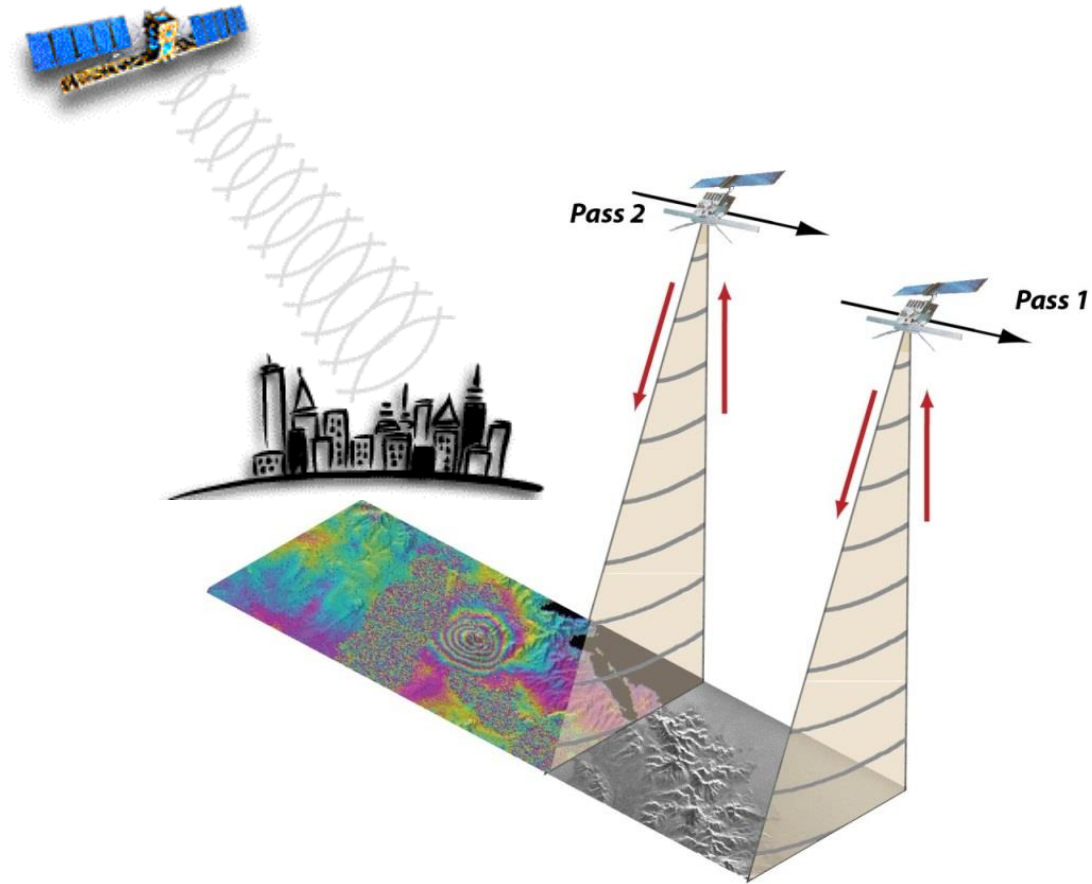
Average Annual Subsidence Rate from 2019 to 2023 Collected from GPS Stations

- Fully converted Areas 1 and 2 show the impact groundwater regulation has had on stabilizing subsidence rates.
- Decreased subsidence rates were achieved by the reduced 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 during all weather conditions.
- 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)*

Annual Groundwater Reports

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



- Precipitation data from weather stations
- Water use from groundwater and alternative sources
- Groundwater levels in Chicot/Evangeline and Jasper aquifers
- Compaction measurements from extensometers
- Land surface deformation from GPS stations



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Joint Regulatory Plan Review

1

Develop Population and Demand Projections

Develop projections of population and water demand over a ten-county area through the year 2100.



2

Conduct Alternative Water Supply Assessment

Review alternative water supplies for the capability of reducing future groundwater demand.



3

Develop the Gulf Coast Land Subsidence and Groundwater Flow Model

Development of the GULF-2023 model for simulating regional groundwater flow and subsidence in the Gulf Coast Aquifer.



4

Evaluate Regulatory Scenarios

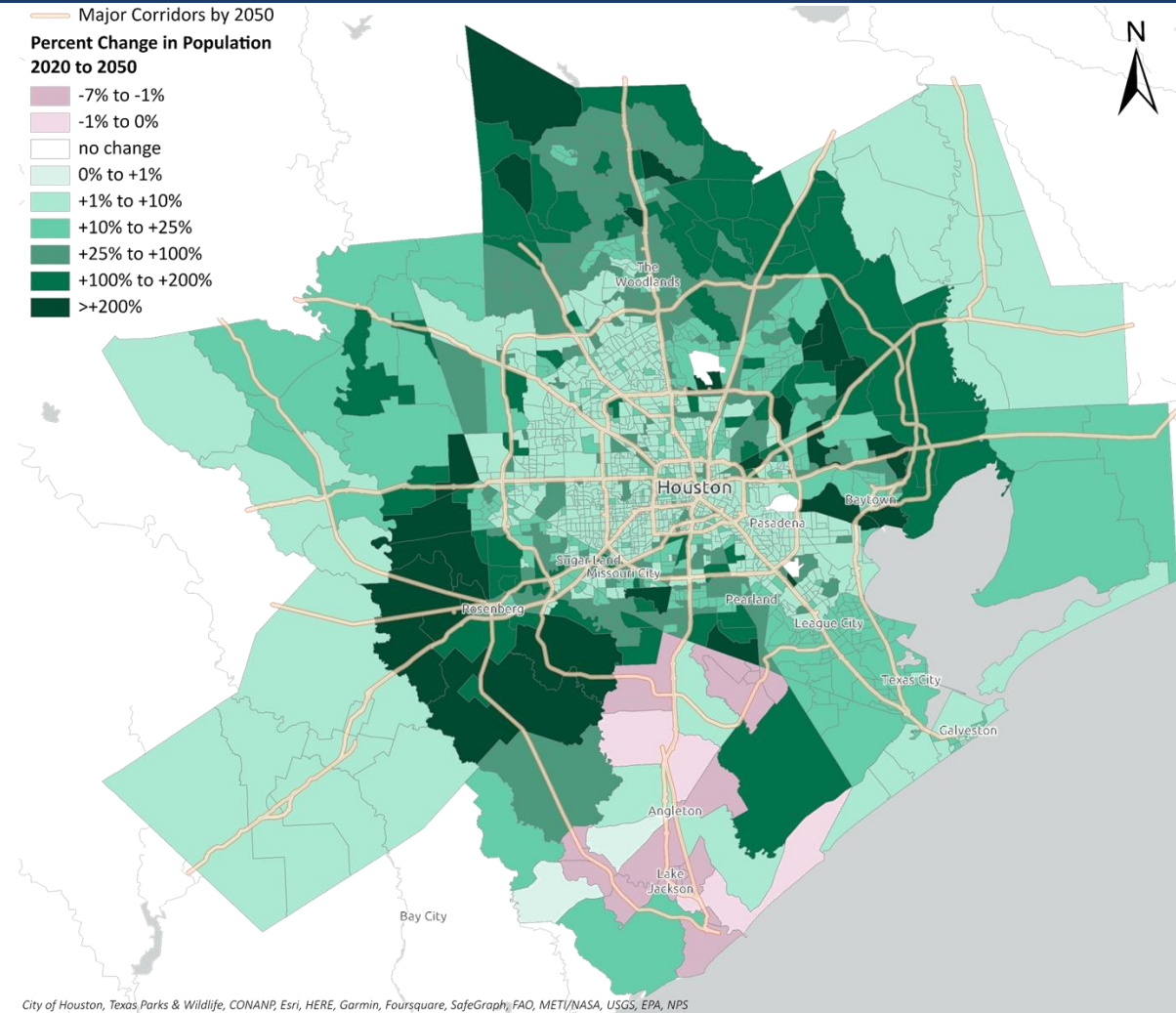
Evaluate the performance of the HGSD and FBSD regulatory plans and consider refinements to the regulatory plan framework to accommodate future growth, alternative water supplies, and the most recent aquifer science.



Population Growth Forecast 2020 to 2050

Percent Change in Population by Census Tract

County	2020	2050	% Change
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%

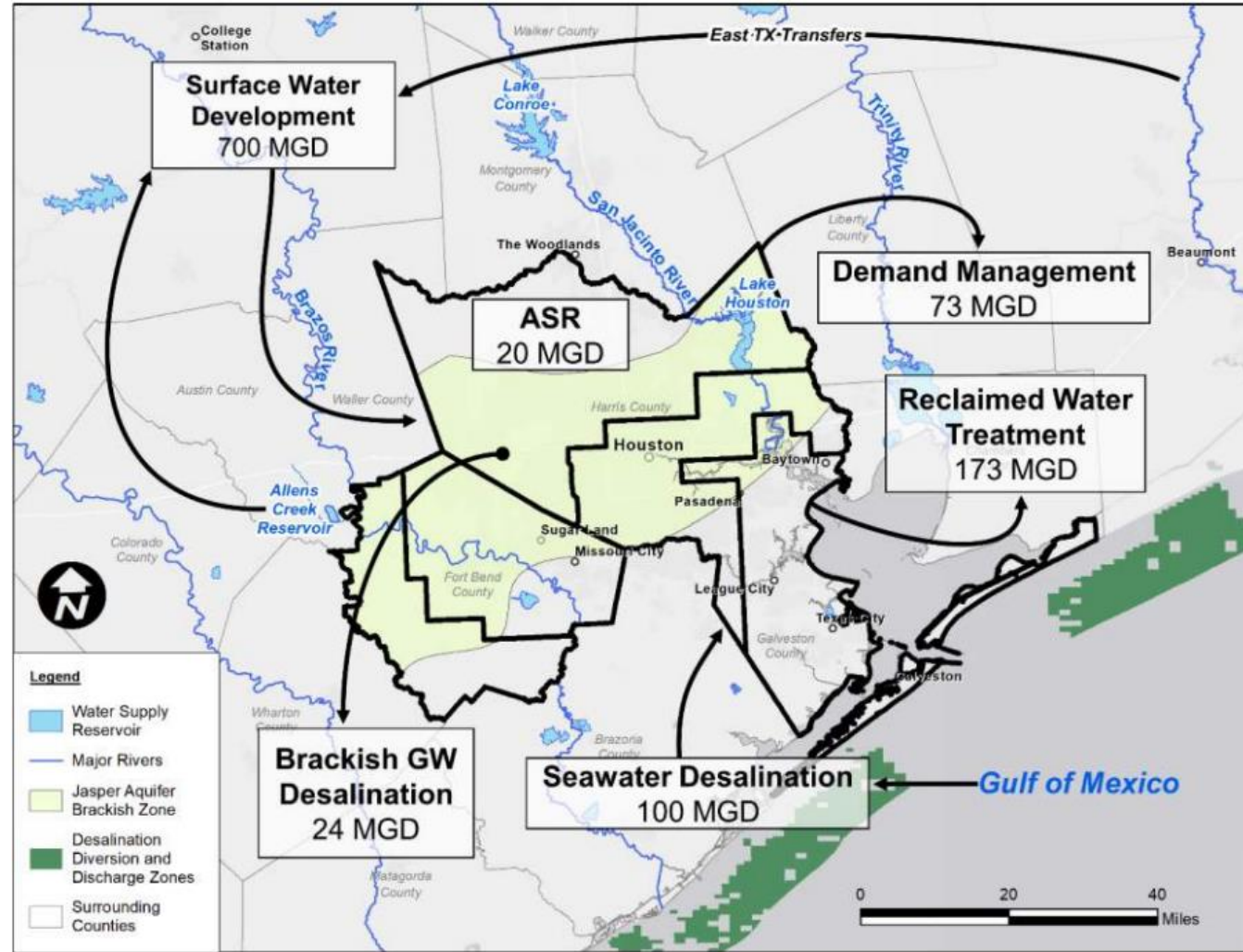


Alternative Water Supplies Assessment

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. →



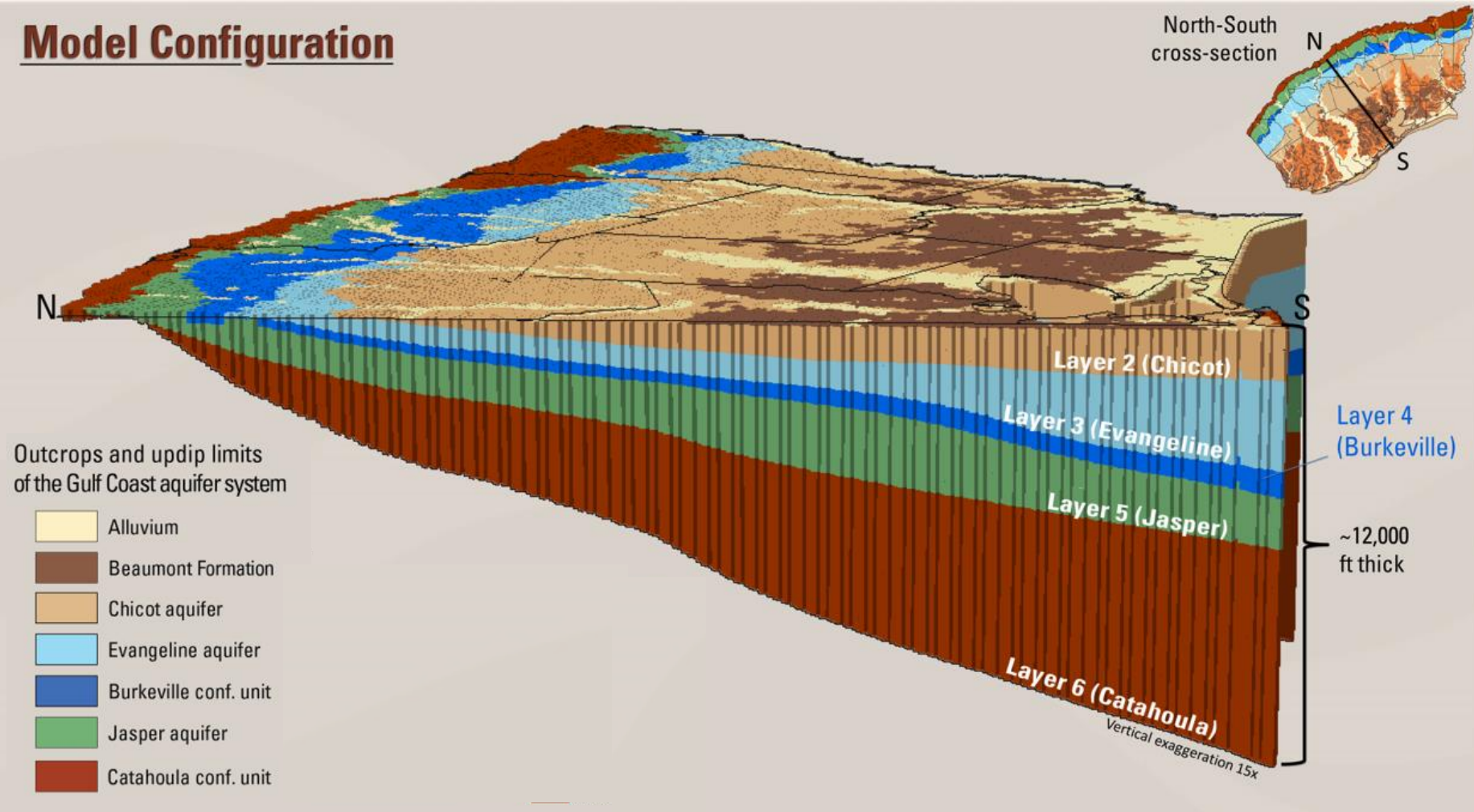
Groundwater and Subsidence Modeling Updates

- 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.



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 local school districts through sponsorships.

The program is **FREE** for 3rd-6th grade classrooms and includes:

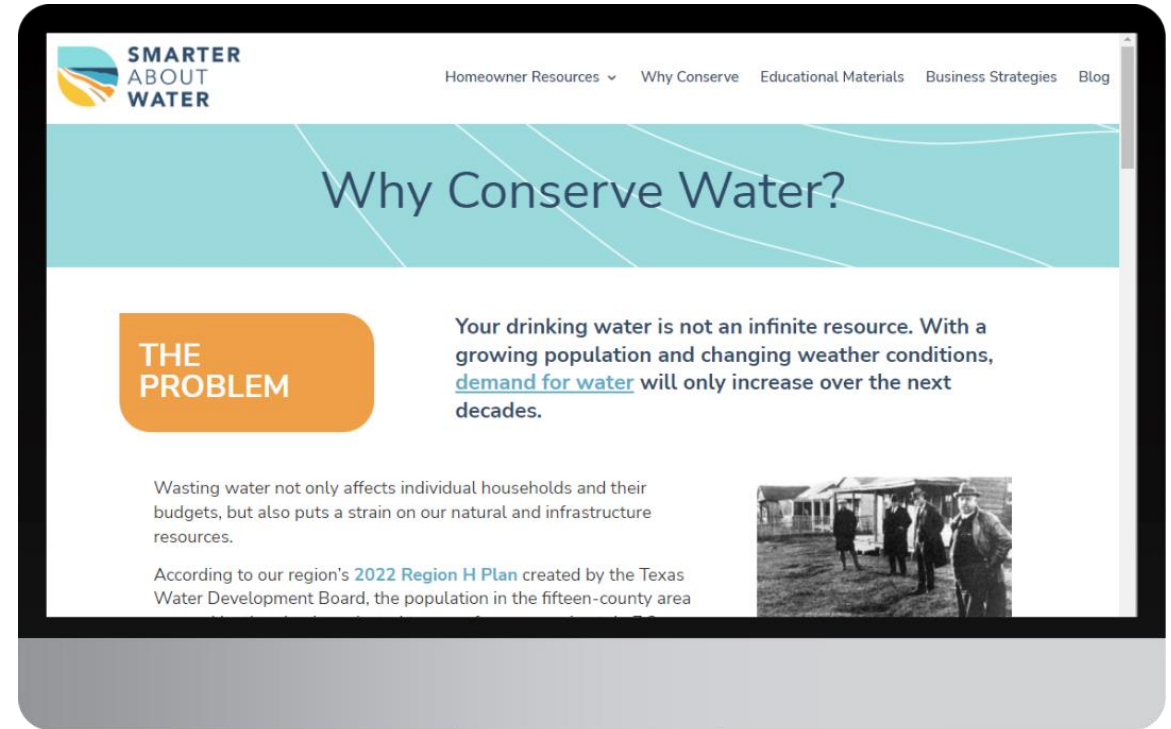
- Quality and locally-based water curriculum that's aligned with TEKS and is offered digitally with printed workbooks.
- Take-home water conservation kit for each student.
- Student contests for awards, prizes, and recognition.
- In-class presentation provided by HGSD staff which includes a subsidence demonstration.



Smarter About Water

With a focus on Texas' 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!



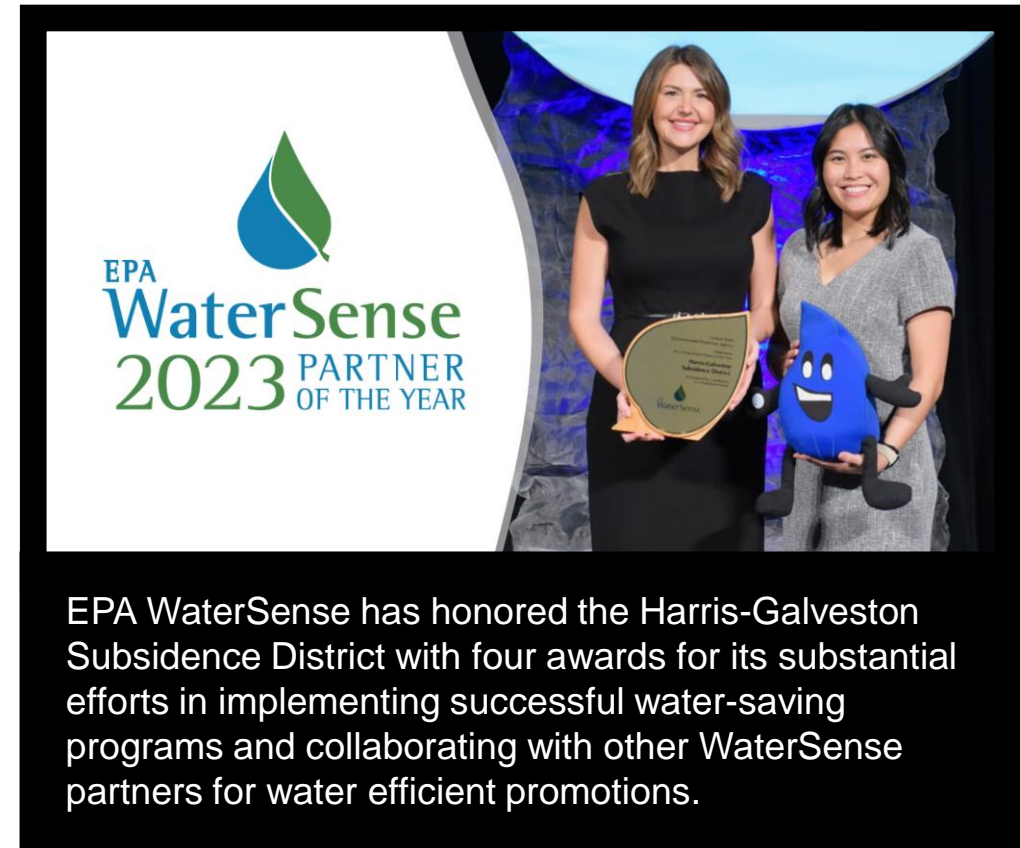
EPA WaterSense Partnership

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!



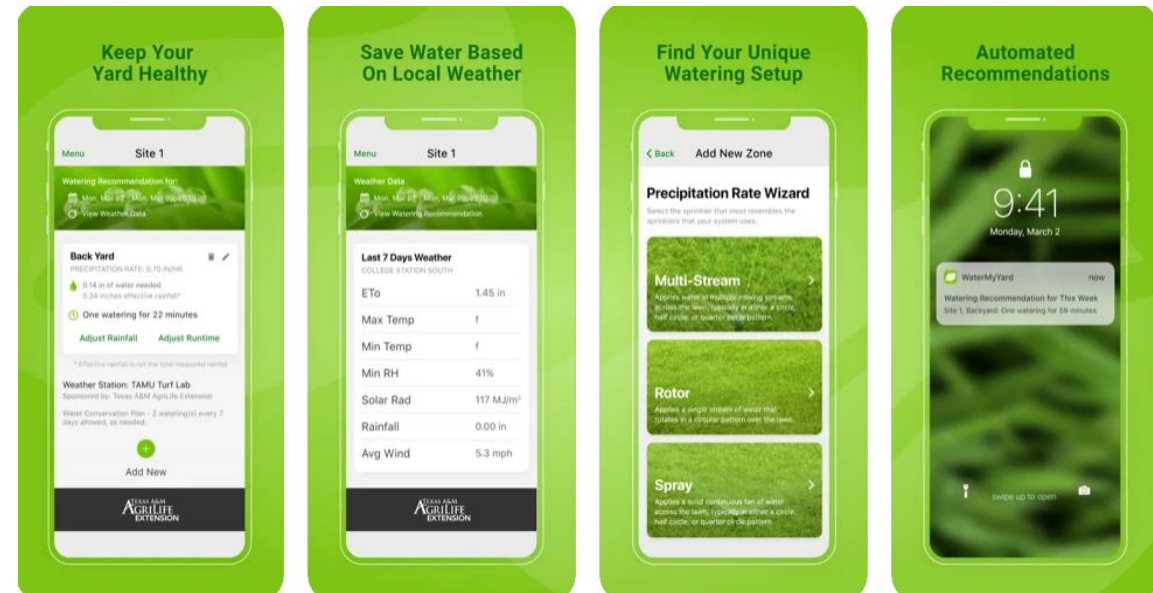
EPA WaterSense has honored the Harris-Galveston Subsidence District with four awards for its substantial efforts in implementing successful water-saving programs and collaborating with other WaterSense partners for water efficient promotions.



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 for free online access or download the mobile application through your device's app store.

Water_{My}Yard



Gulf Coast Water Conservation Symposium

2025 GULF COAST WATER CONSERVATION *Symposium*

This symposium brings together local water utility and resource managers, engineers, architects, educators, communicators, and community members to learn about water resource management and water conservation. The one-day program will provide information on implementing successful water conservation programs, funding opportunities for water conservation projects, engaging customers, and planning for the future.



#GCWCS25



May 21, 2025



Marriott at George Bush Intercontinental Airport



www.eventcreate.com/e/gcwcs25



SCAN
ME 

Water Conservation Tools for Our Region

Water Conservation School Program



Since 1994, the District has partnered with local cities, regional water authorities, municipal utility districts (MUDs), and other permittees to deliver water resource and conservation education to our local schools.

The program is active in over 200 schools for third, fourth, fifth, and sixth-grade students.

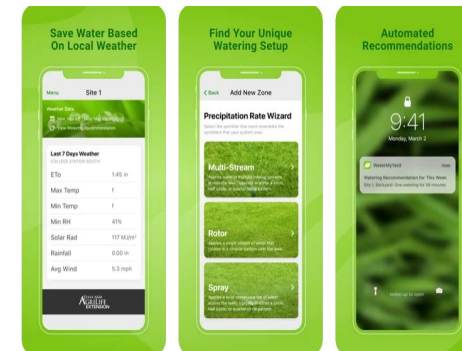
Smarter About Water



Visit [SmarterAboutWater.org](https://www.SmarterAboutWater.org) and follow us on social media for water conservation resources that help homeowners, teachers, students, and businesses in the Gulf Coast Region.



Water My Yard



The **Water My Yard** program helps homeowners and businesses save water and money through specifically designed recommendations for lawn irrigation that are customized per user.

Sign up for FREE watering recommendations by downloading the app on your smartphone or subscribing online at [watermyyard.org](https://www.watermyyard.org).

Water Conservation Grant Program



The District provides grants for projects that can achieve quantifiable water reduction through water loss control measures, water efficiencies, or research.



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SUBSIDENCE DISTRICT

Michael Turco

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Connect with us!



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www.hgsubsidence.org



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