HARRIS-GALVESTON SUBSIDENCE DISTRICT

A History of Groundwater Regulation and Subsidence in the Houston Area

HGSD's Continued Mission to Prevent Subsidence in Harris and Galveston Counties

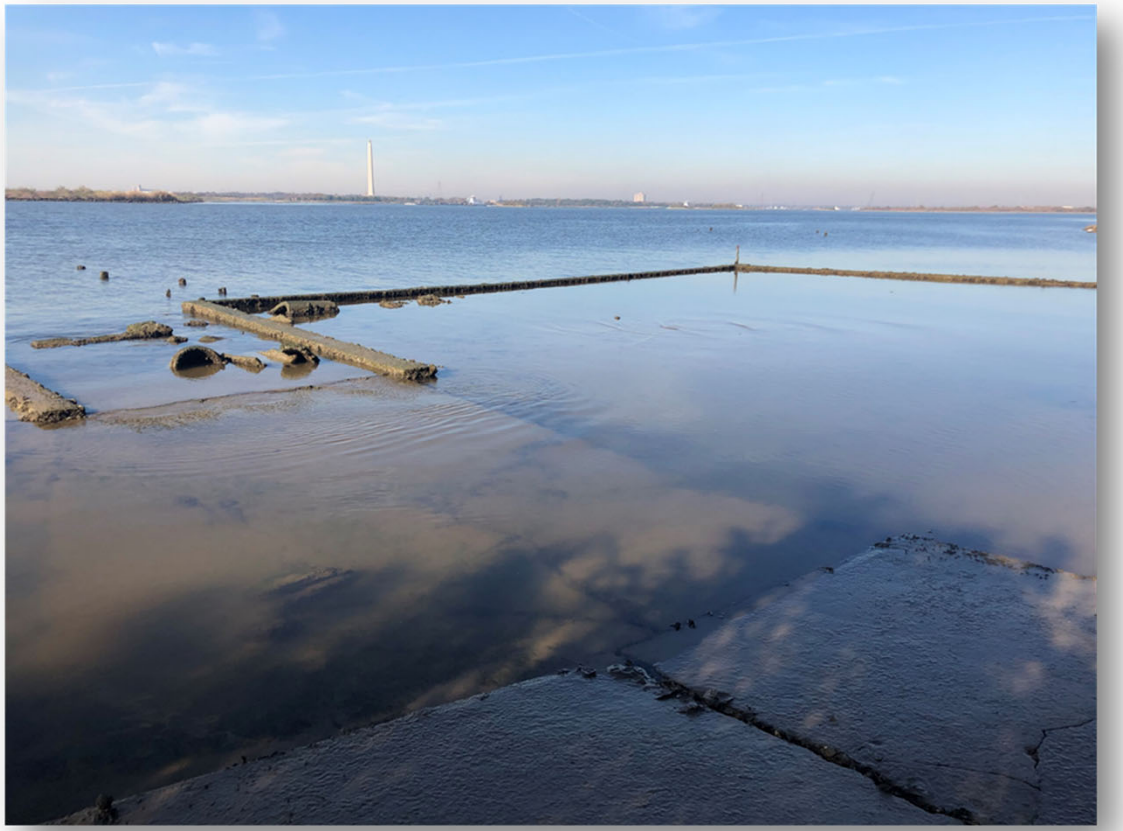
Michael Turco
General Manager

Agenda

- Introduction
- Regulatory Planning Overview
- Subsidence Monitoring and Impacts
- Joint Regulatory Plan Review
- Water Conservation Tools & Resources

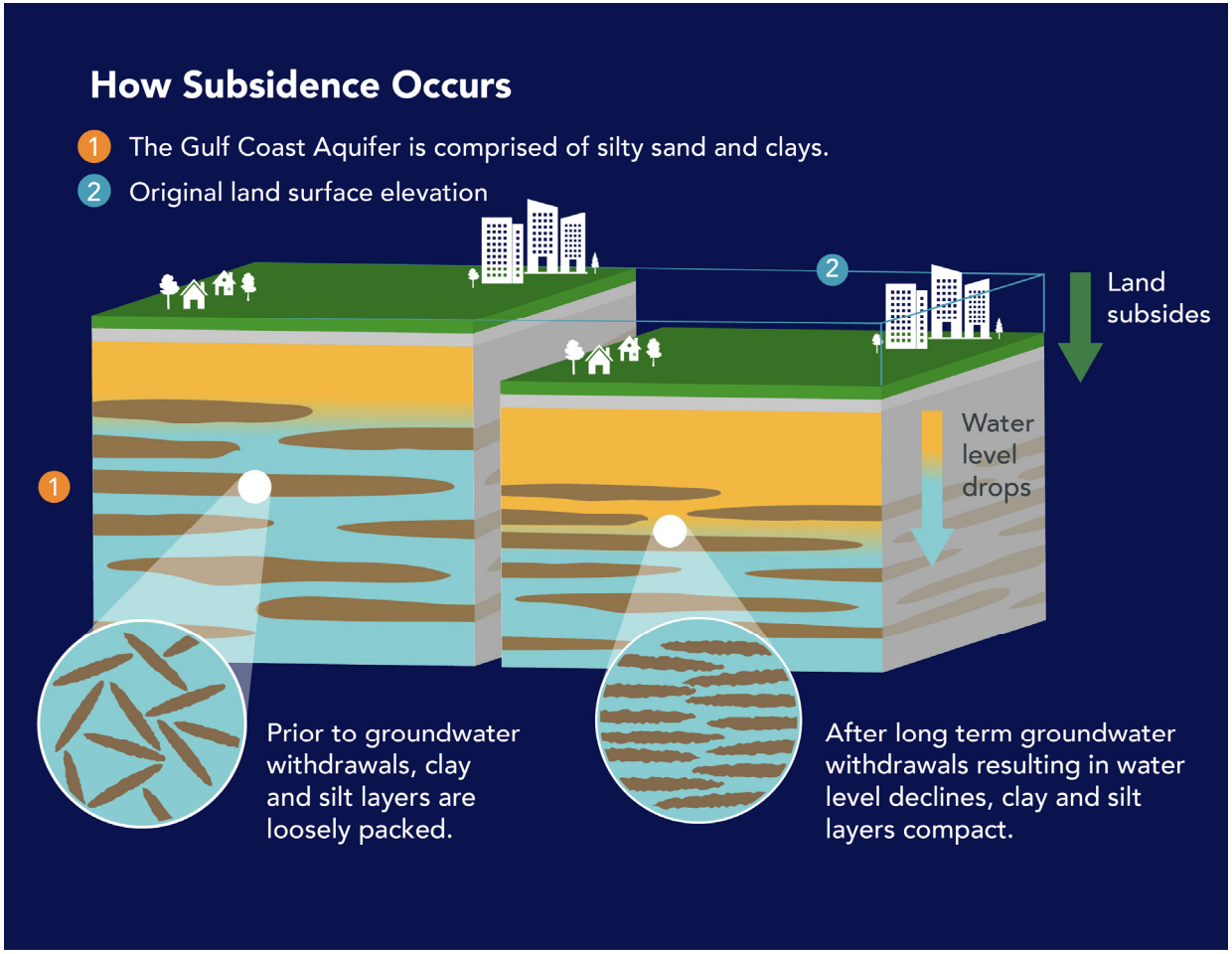
Harris-Galveston Subsidence District

- 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 through the regulation of groundwater.
- Efforts to prevent subsidence by the District and the regulated community have required significant investment to create a more resilient infrastructure while securing reliable water sources for future needs.



What is Subsidence?

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



Schematic showing the general mechanism for subsidence in the Houston Region.

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 feet of subsidence occurred due to shallow fluid withdrawal.
- Today, in San Jacinto Bay, remnants exist as much of the field has been inundated.

Goose Creek Oil Field, 2010

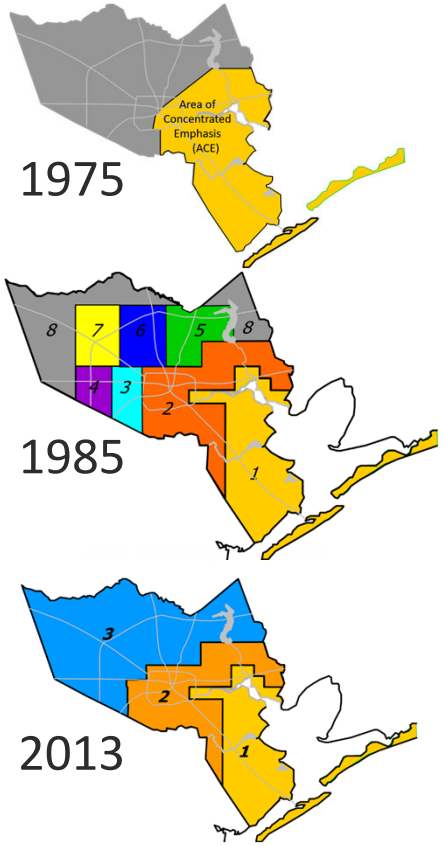
Earth fissures at Goose Creek Oil Field

Source: (U.S. Geological Survey)

Case Study: Brownwood Subdivision in Baytown, TX

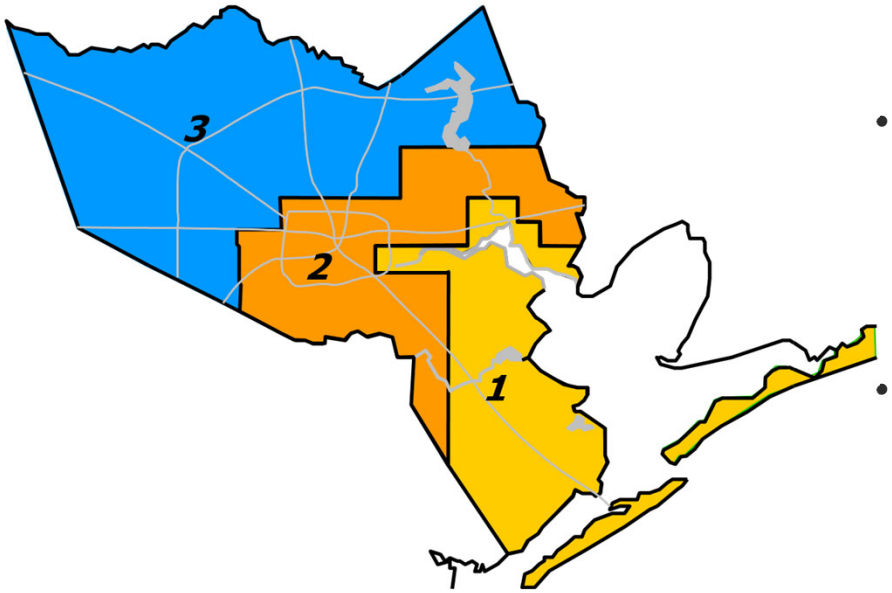
- 1944: Beginning development of infrastructure
- 1953: Many homes have been developed – nice bay front housing
- 1978: Inundation by the bay is extensive due to subsidence in the area
- 1989: Homes and property have been abandoned
- 2016: Baytown Nature Center and Preserve

Regulating Groundwater to Stop Subsidence



- Following the creation of the District, groundwater regulation began nearest the coast in the Area of Concentrated Emphasis (ACE).
- As population spread to the north and west and water use increased, numerous regulatory plans were developed and implemented.
- The 1999 Regulatory Plan designated the 3 Regulatory Areas that exist today.

Regulating Groundwater to Stop Subsidence



- **Area 1**: no more than 10% of total water demand may be sourced from groundwater.
- **Area 2**: no more than 20% of total water demand may be sourced from groundwater.
  - Groundwater Reduction Plans may be approved with conditions.
- **Area 3**: no more than 20% of total water demand may be sourced from groundwater.
  - Permittees operating within an approved Groundwater Reduction Plan 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

Data Collection

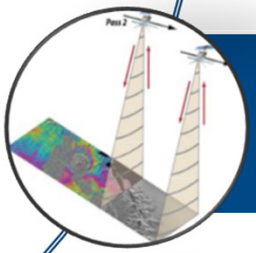
- Monitoring the occurrence of subsidence and the impact of pumpage on the aquifer requires the consistent collection of aquifer, water-use, and subsidence data.
- Collaboration with multiple local, state, and federal agencies including:
  - U.S. Geological Survey
  - Texas Water Development Board
  - Harris County Flood Control
  - Groundwater Conservation Districts
  - River Authorities
  - Regional Water Authorities
- Data improves our understanding of the groundwater system, alternative water availability, and improves our ability to predict subsidence in the future.

Aquifer Data

- Water Levels
- Lithology
- Extensometers

Water Use Data

- Groundwater Pumpage
- Alternative Water Usage

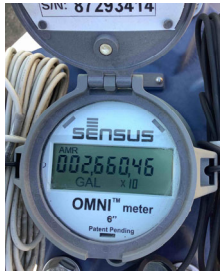


Land Subsidence Data

- GPS
- InSAR
- Benchmark Surveys

Decades of Data Collection

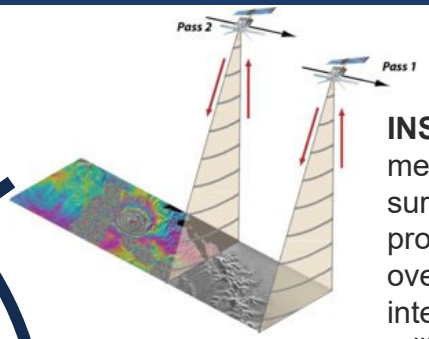
Groundwater Use – Reported annually by all permittees and verified by District Enforcement staff.



Surface Monitoring – GPS data measurement of benchmark movement at permanent monitoring stations.

Benchmark Monitoring – Discrete GPS Surveying of Benchmarks vertical motion over time.

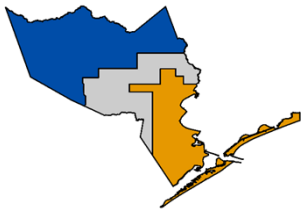
The District's data collection program includes the measurement of aquifer water use, impact on water-level, and subsidence.



INSAR – Satellite measurement of land surface deformation provides dense data over multiple time-intervals at the millimeter scale.

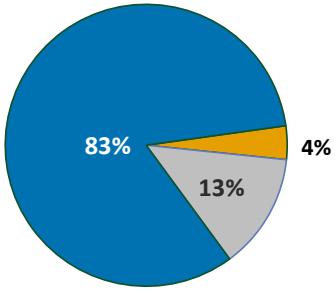
Aquifer Water Level Measurement – Measurement of potentiometric water level in the primary aquifers in the region

Groundwater Withdrawals

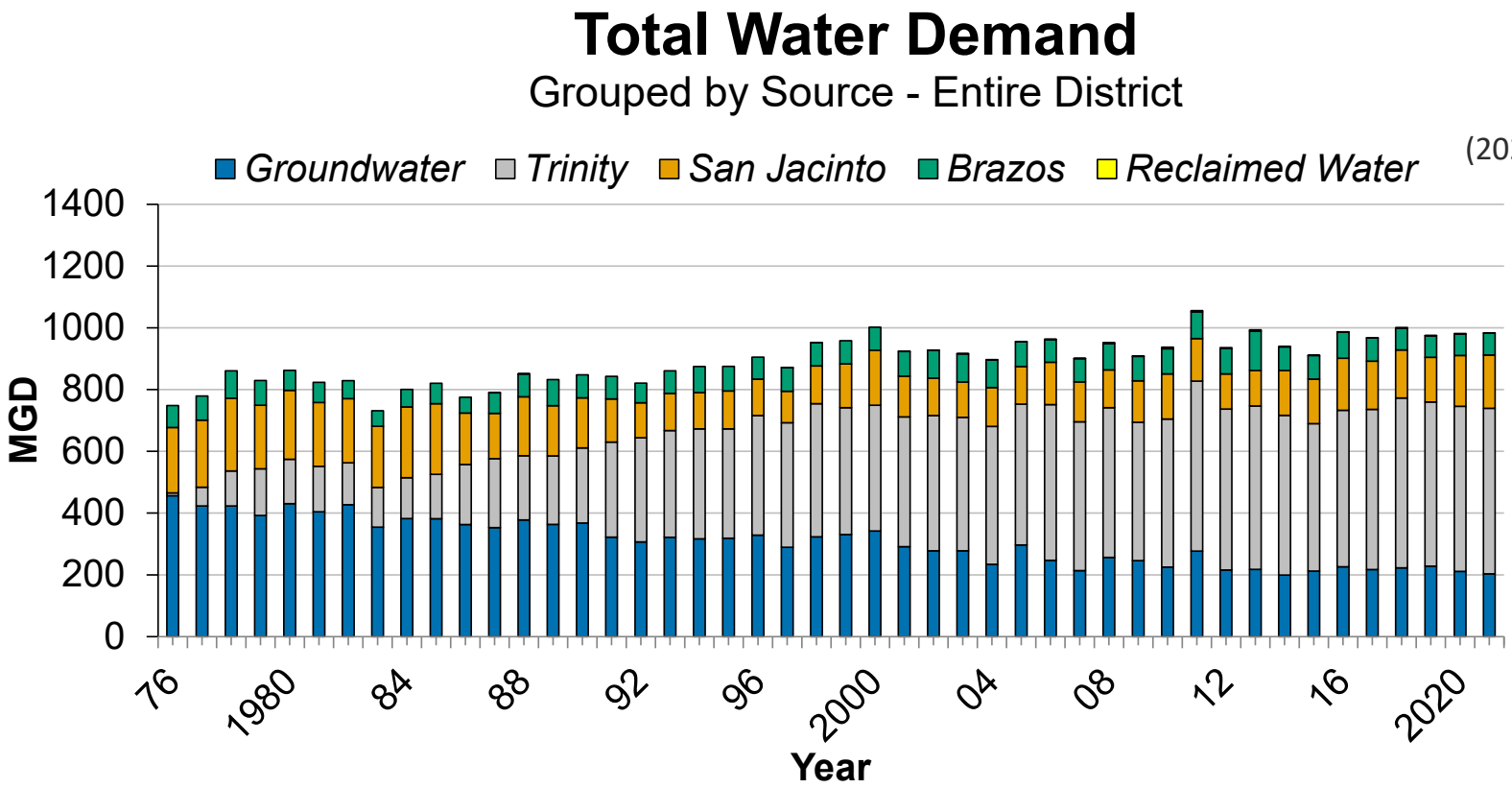


2021 - 203.6 MGD

(2020 – 211.4 MGD; -4% change)

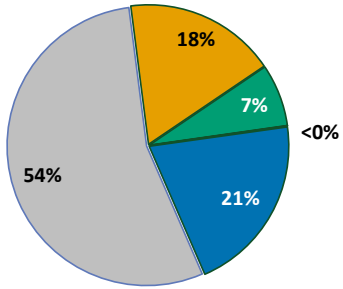


Total Water Demand



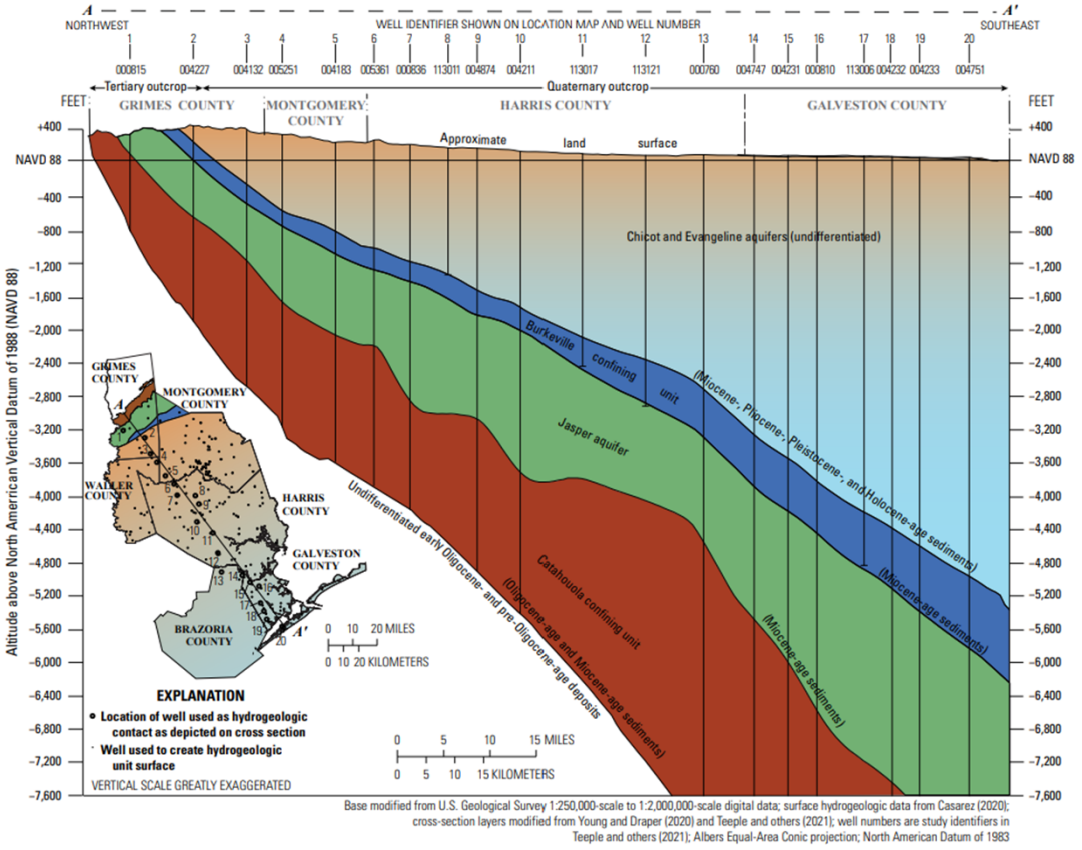
2021 - 983.4 MGD

(2020 – 981.9 MGD; 0.2% change)



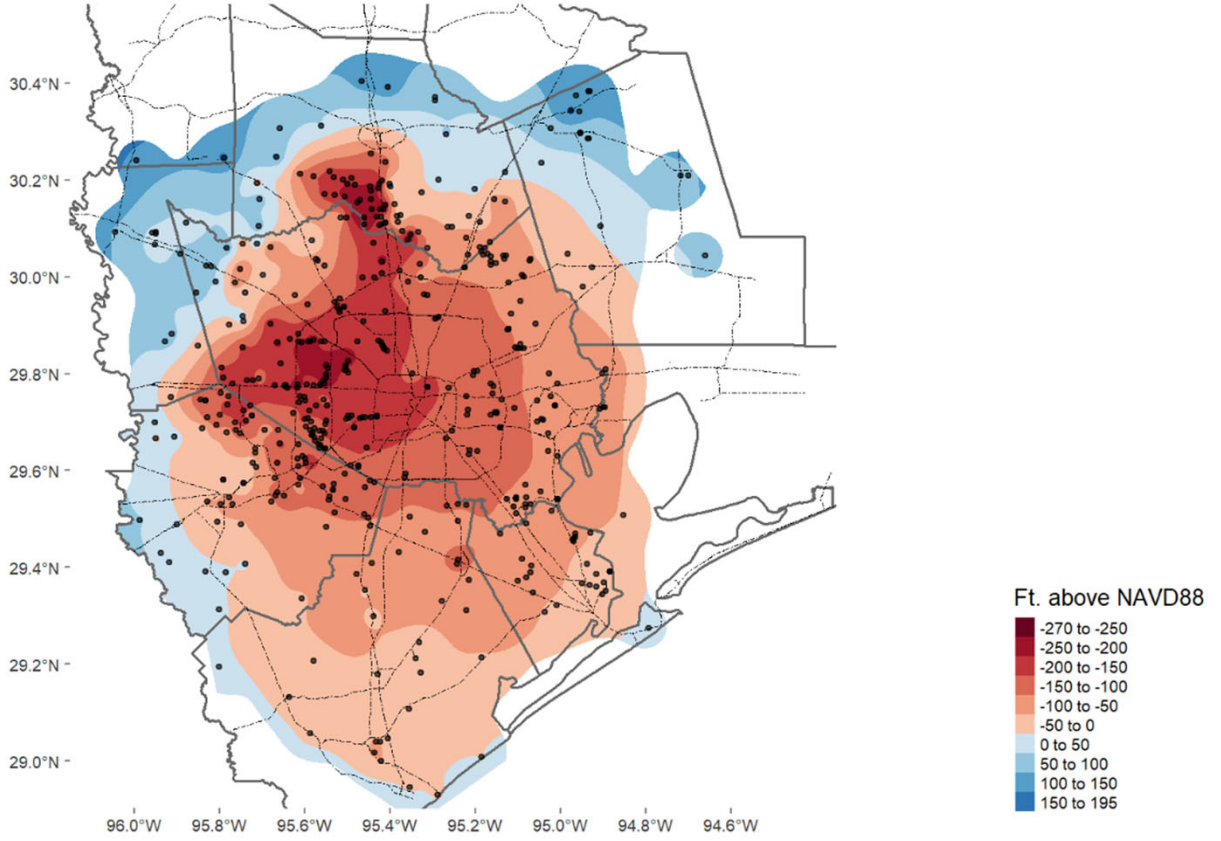
USGS Water Level Measurements

- United States Geological Survey (USGS) monitors over 600 public supply, irrigation, industrial, and observation wells spread across 11 counties in the Houston-Galveston Region
  - Strong collaboration with local well owners, municipalities, municipal utility districts, public utility districts, special utility districts
  - Multi-agency effort including the USGS, Subsidence Districts, City of Houston, BCGCD, and LSGCD
- The potentiometric water-level is measured in wells screened in the primary aquifers of the Guld Coast Aquifer System:
  - Chicot – Evangeline aquifer
  - Jasper aquifer



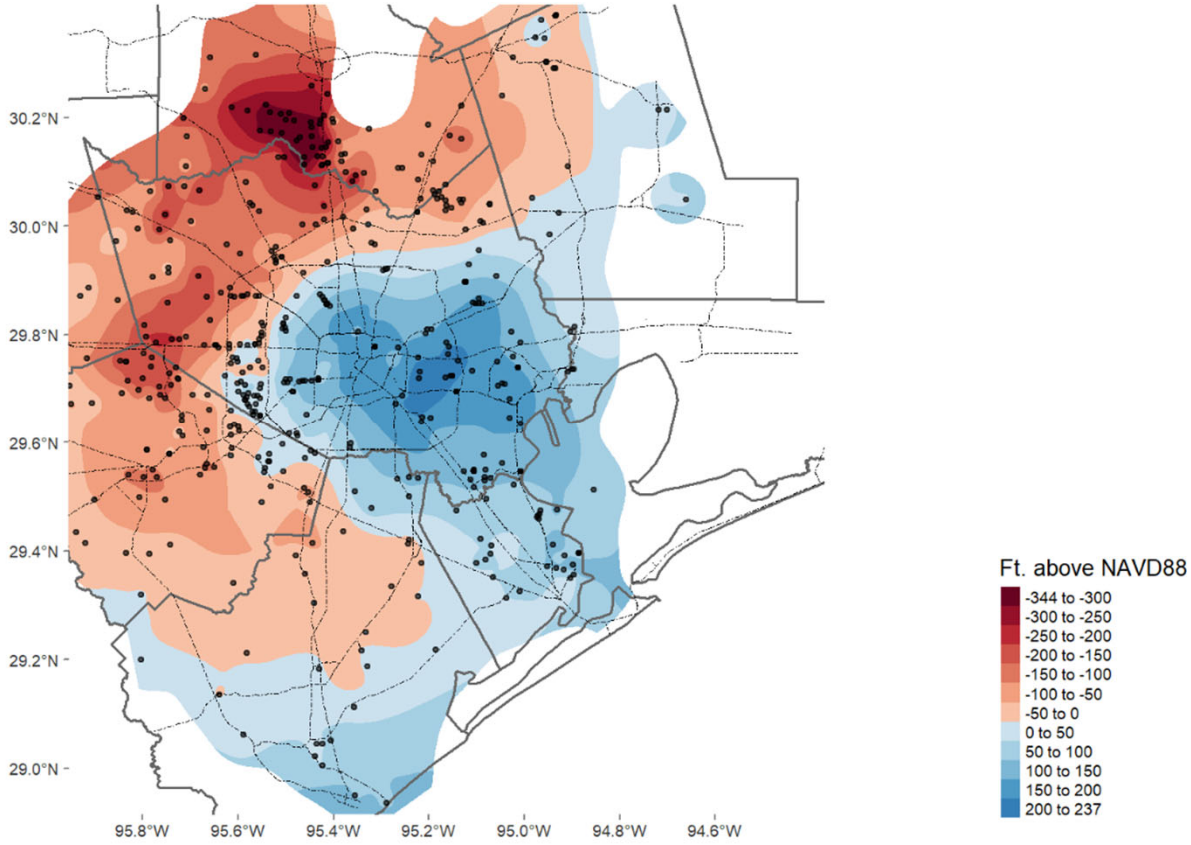
2022 Chicot and Evangeline (Undifferentiated) Water-Level Altitude

- Data summary:
  - Min: **-270**
  - Mean: **-42**
  - Max: **195**
- Highest areas of usage in western Harris County, and the south-central portion of Montgomery County.



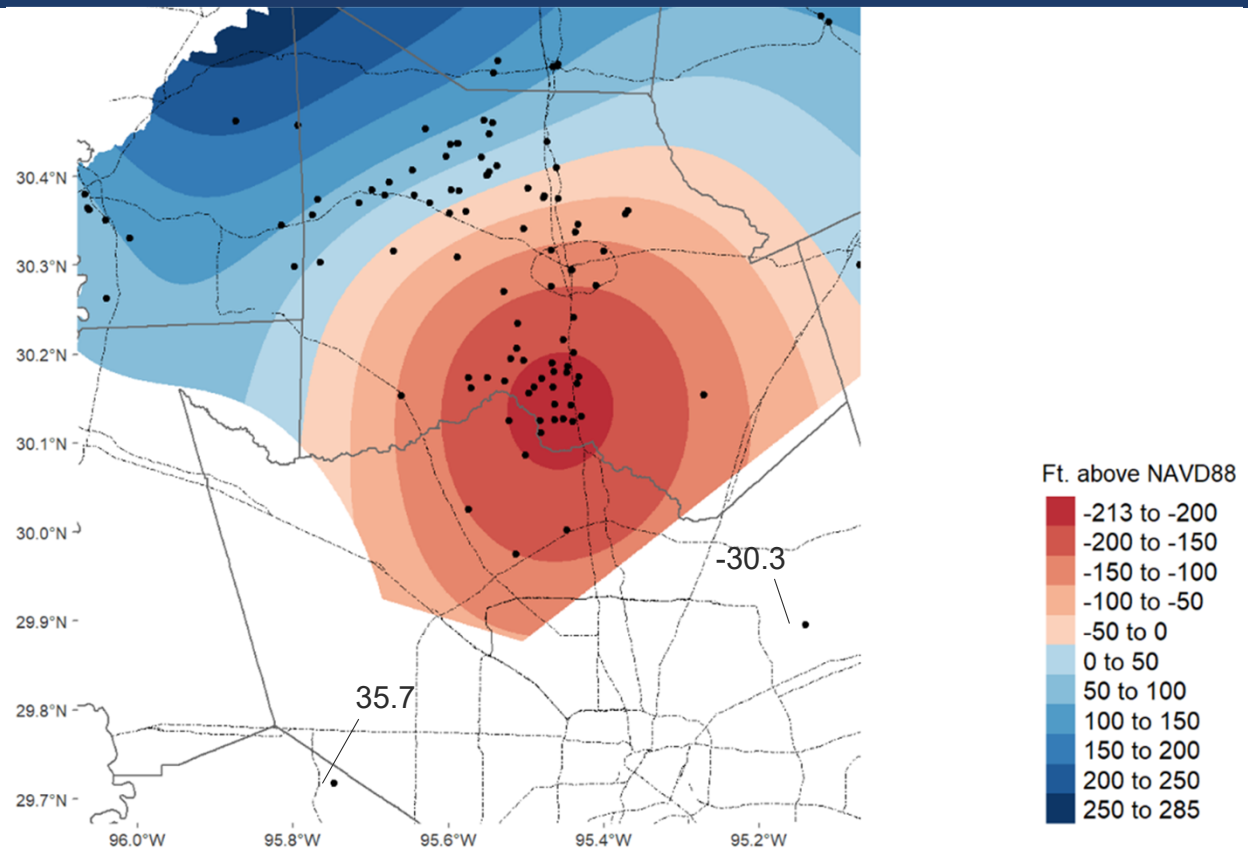
Chicot and Evangeline (Undifferentiated) Water-Level Change Since 1977

- Data summary:
  - Min: **-344**
  - Mean: **-7**
  - Max: **237**
- Water-level rises across most of central and eastern Harris County as well as Galveston County.
- Water-level declines in the northern part of Fort Bend County, NW portions of Harris County, and most of Montgomery County.



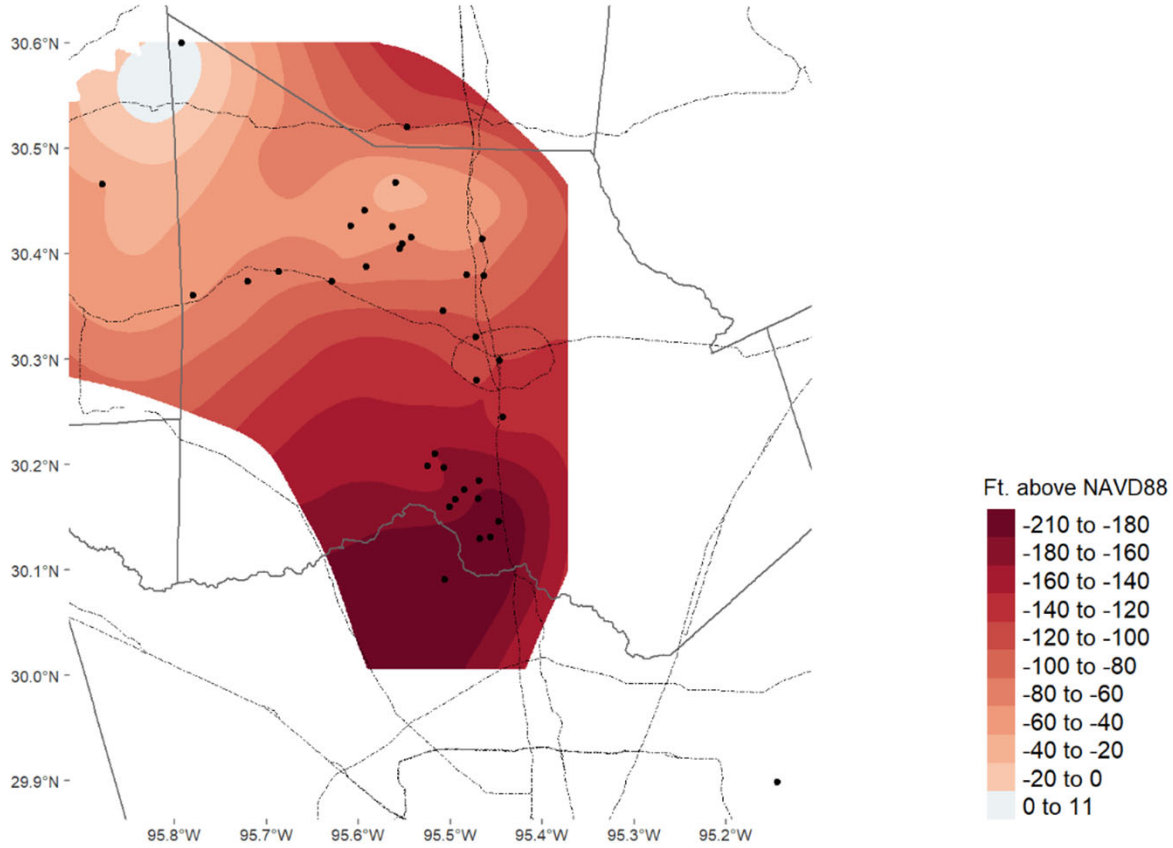
2022 Jasper Aquifer Altitude

- Data summary:
  - Min: **-213**
  - Mean: **10**
  - Max: **285**
- General trend of deepening water levels in downdip (NW-SE) direction.
- Deepest water levels in south-central Montgomery County near border with Harris County.



Jasper Aquifer Water-Level Change Since 2000

- Data summary:
  - Min: **-210**
  - Mean: **-98**
  - Max: **11**
- General trend of declining water levels in downdip (NW-SE) direction.
- Area with greatest declines along Harris – Montgomery County border.

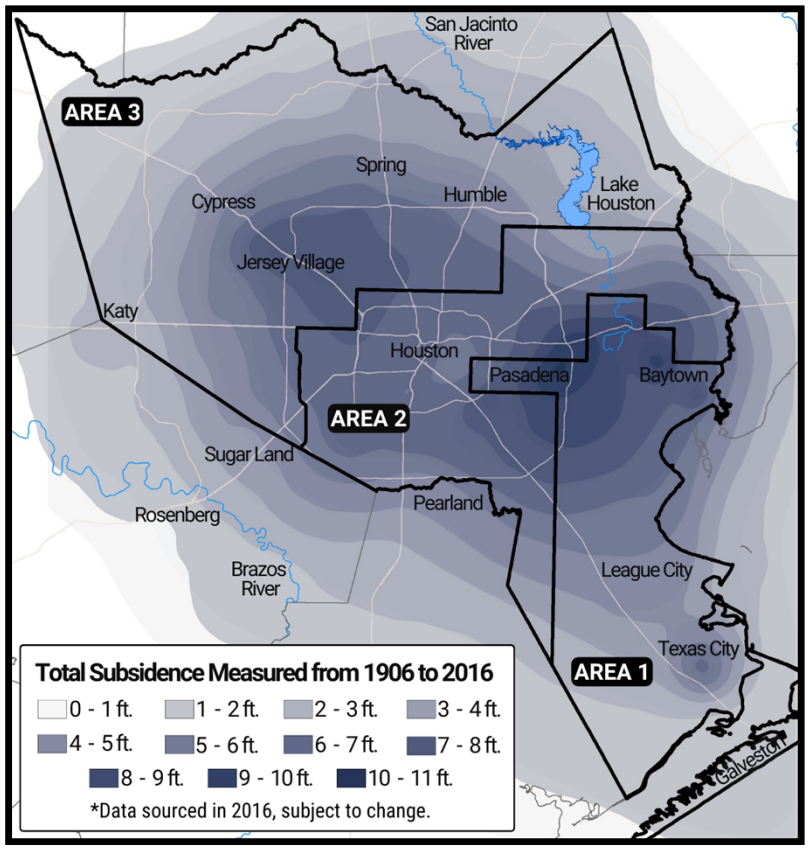


Subsidence and Compaction Measurements

- Since the mid 1990s, the District has been utilizing Global Positioning Stations (GPS) to monitor subsidence in the area.
- Over 200 GPS subsidence monitoring locations (e.g., PAMs and CORs) operated by multiple agencies, including:
  - Harris-Galveston Subsidence District
  - Fort Bend Subsidence District
  - University of Houston
  - Lone Star Groundwater Conservation District
  - Brazoria County Groundwater Conservation District
- 13 USGS extensometer locations to measure compaction
- Remote sensing methods (InSAR) monitoring land surface deformation
- Traditional surveying of benchmarks

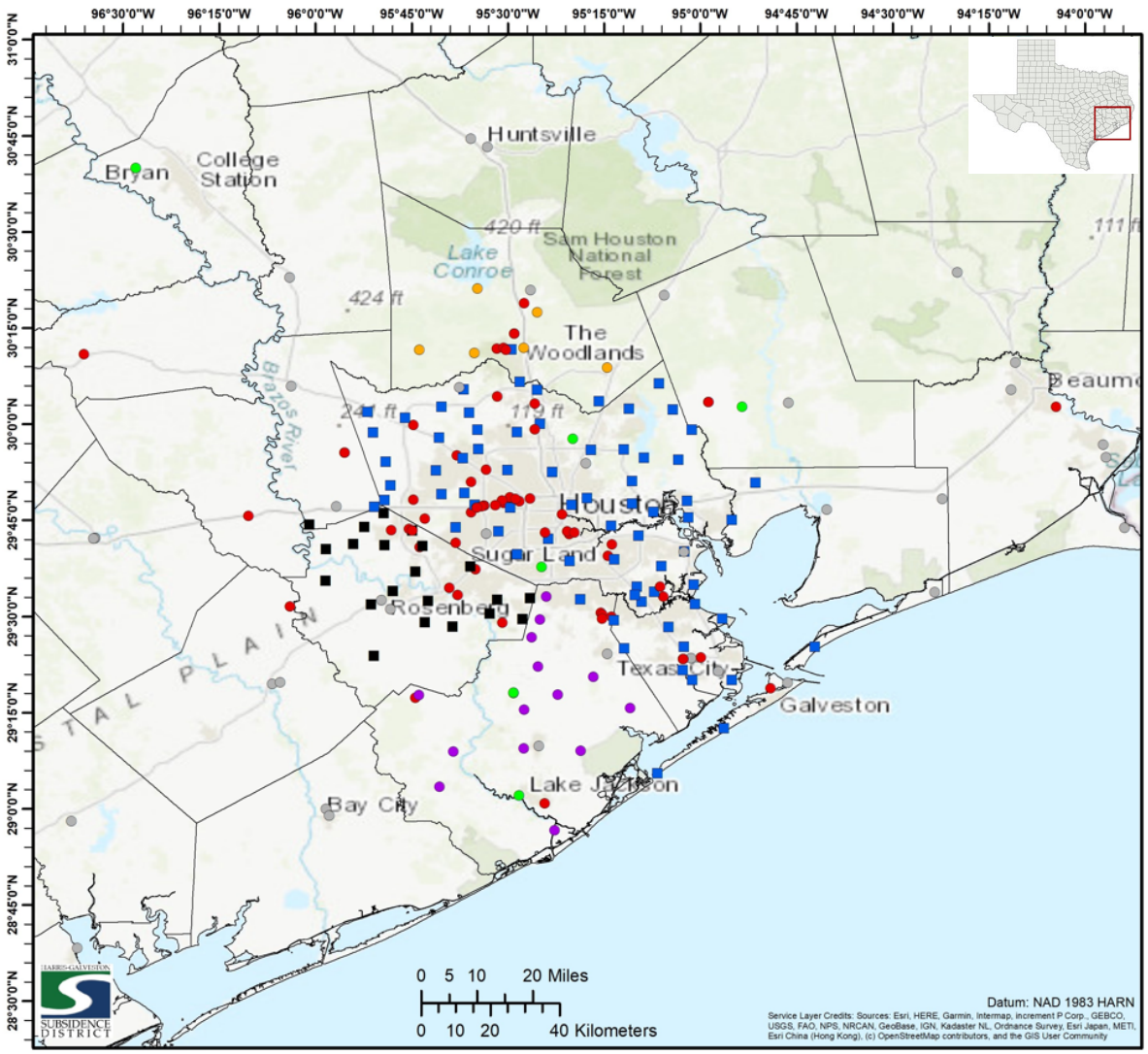
Estimated Total Subsidence 1906-2016

- Total subsidence over the period of development has been estimated based on traditional benchmark surveying from 1906-2000 and the calculated subsidence rates from measured GPS vertical movement data from sites active in 2016 with more than three years of vertical movement data.
- The largest magnitude of historical subsidence has occurred in the ship channel area of Eastern Harris County.



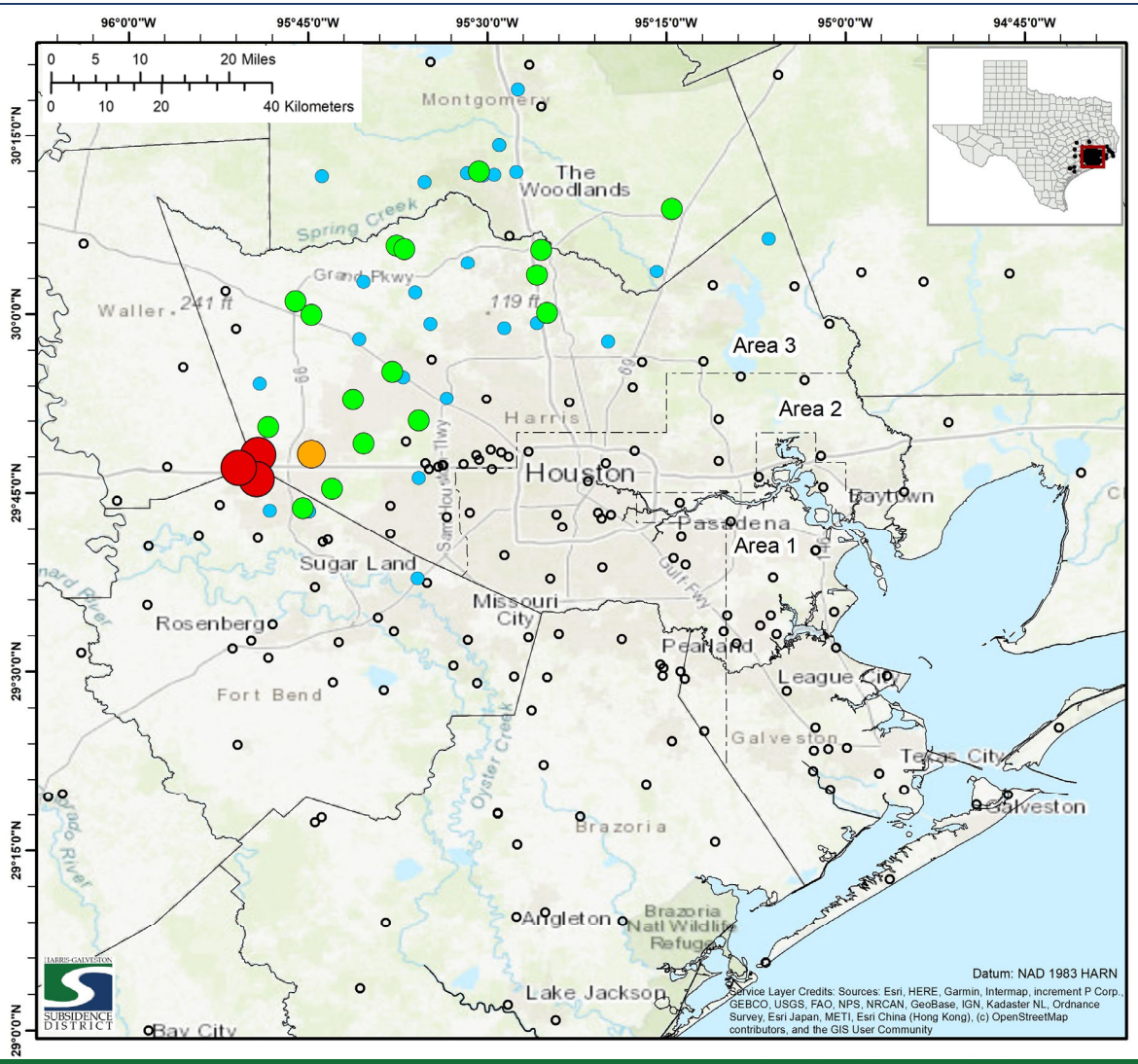
Subsidence Monitoring Network

Location and operator of GPS stations that monitor land-surface deformation periodically or continuously within the greater Houston-Galveston region 2021.



2017-2021 Subsidence Rates

Annual subsidence rate, in centimeters per year (cm/yr), measured at GPS stations with three or more years of GPS data in Harris and surrounding counties, from 2017 to 2021.



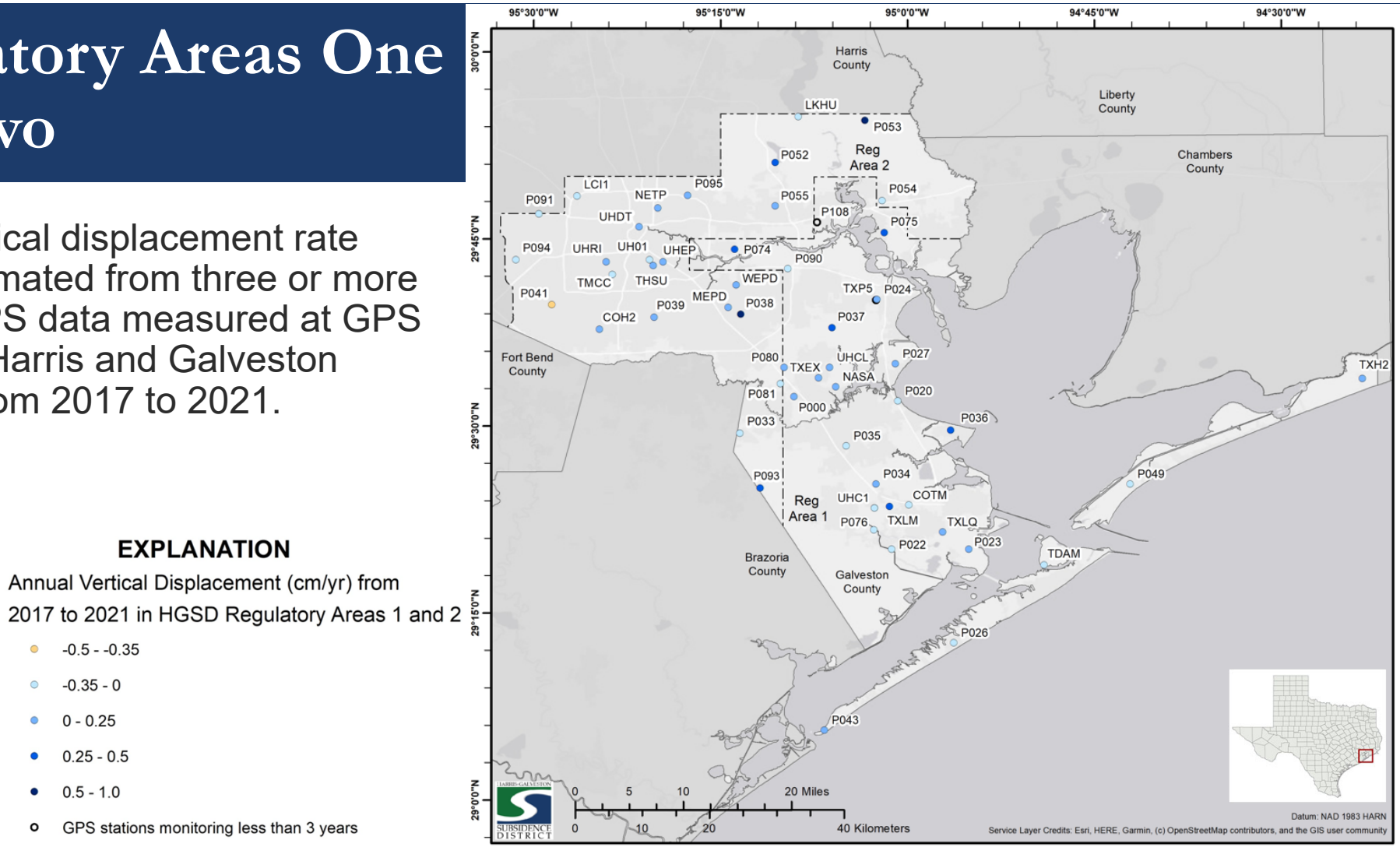
EXPLANATION

Annual Subsidence Rate (cm/yr) from 2017 to 2021

- Greater than 2.0
- <2.0 - 1.5
- <1.5 - 1.0
- <1.0 - 0.5
- Less than 0.5 or period of record less than 3 years

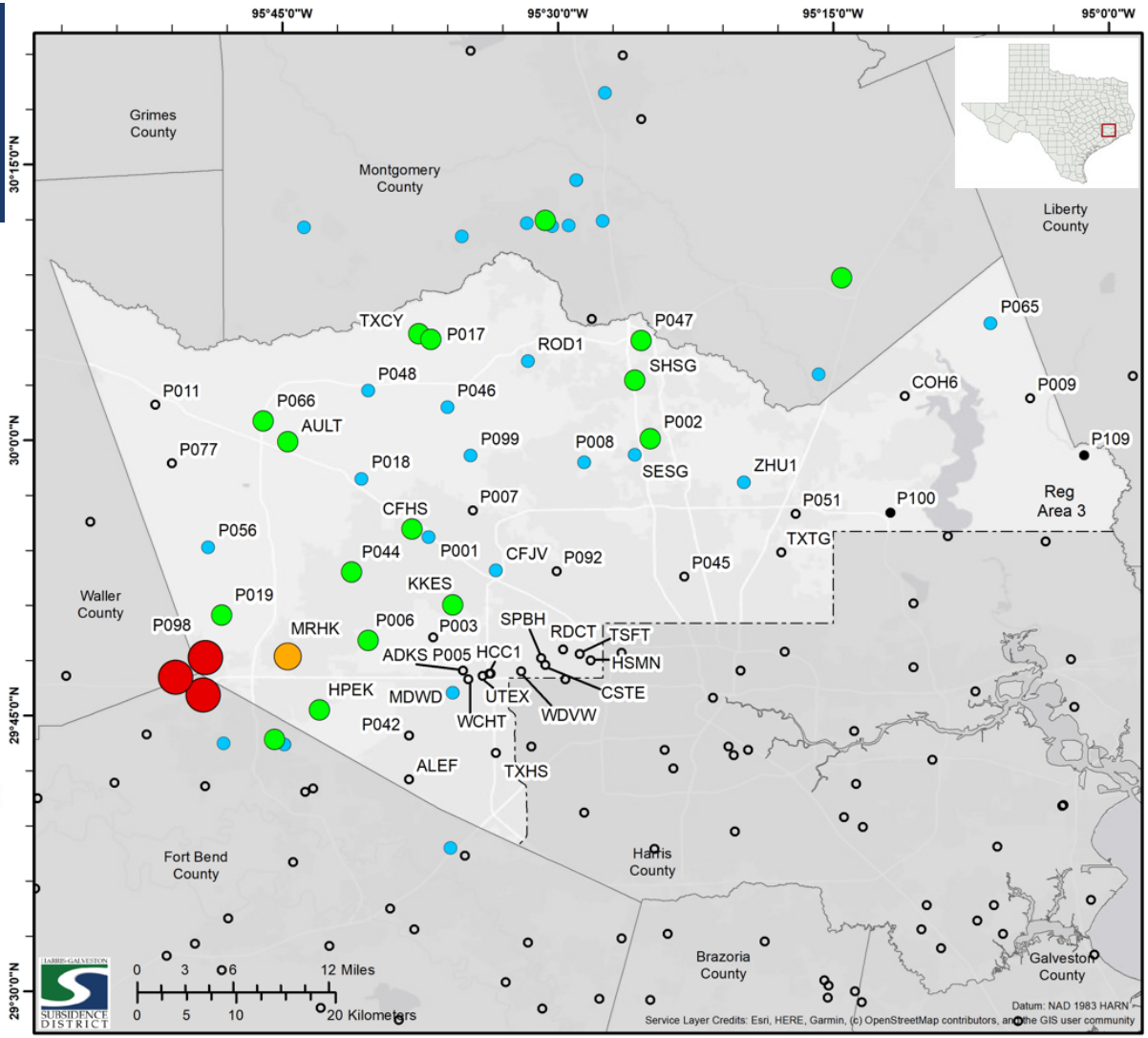
Regulatory Areas One and Two

Annual vertical displacement rate (cm/yr) estimated from three or more years of GPS data measured at GPS stations in Harris and Galveston counties, from 2017 to 2021.



Regulatory Area Three

Annual subsidence rate (cm/yr) estimated from three or more years of periodic or continuous GPS data measured at GPS stations in Harris County, Texas, from 2017 to 2021.



EXPLANATION

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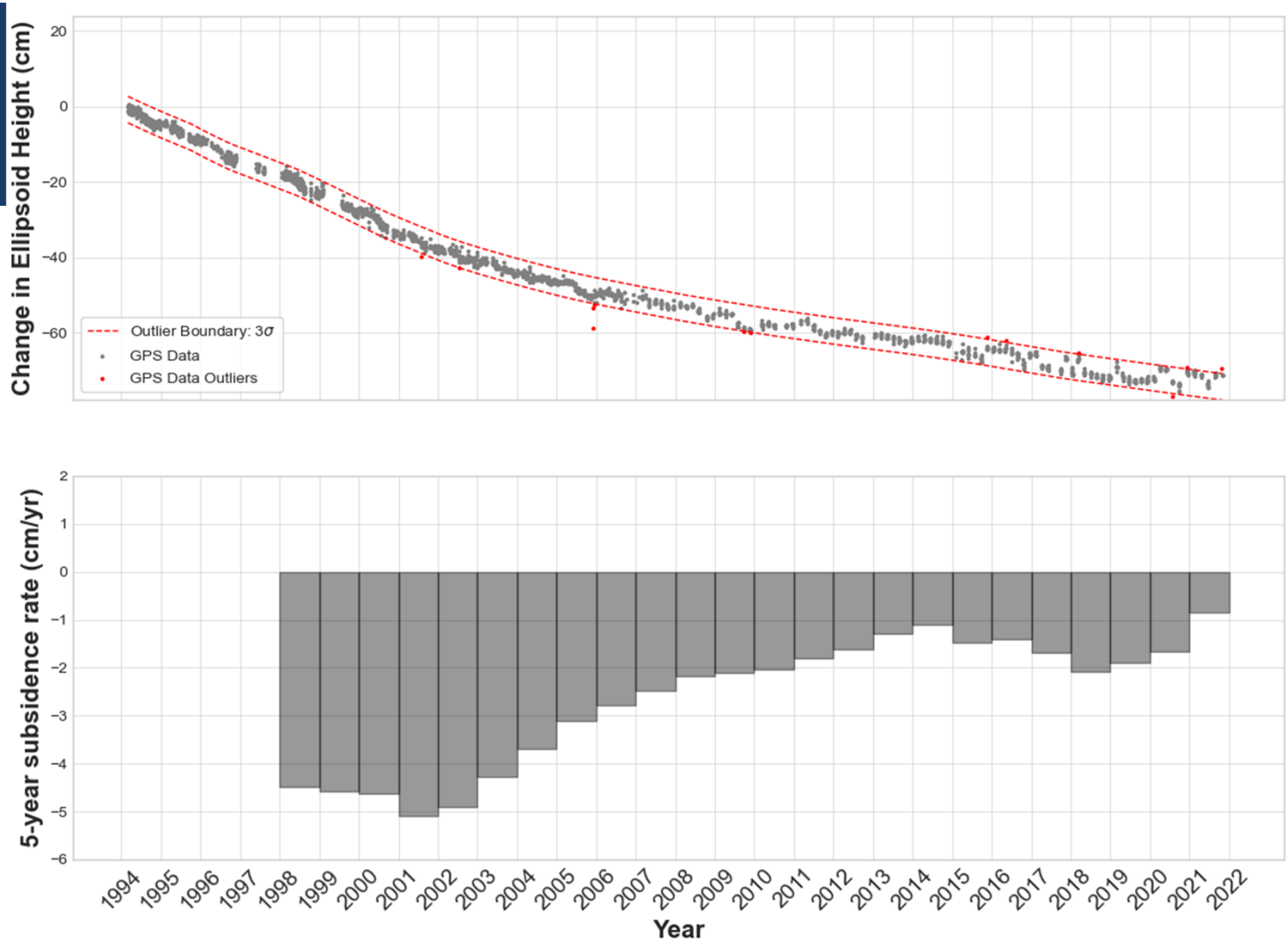
P001 POR Plot

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



Processed GPS data (source: UH) over 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.

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).

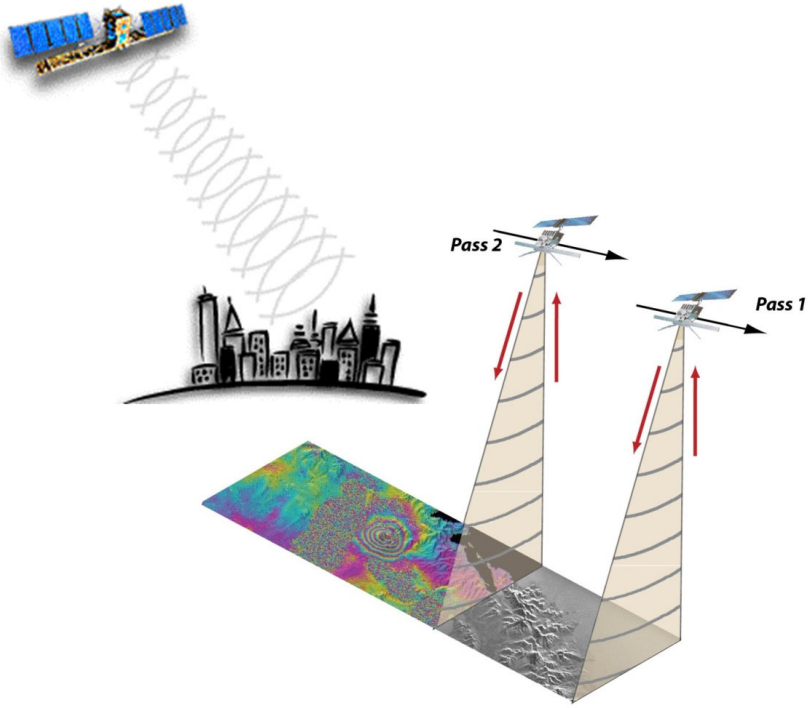
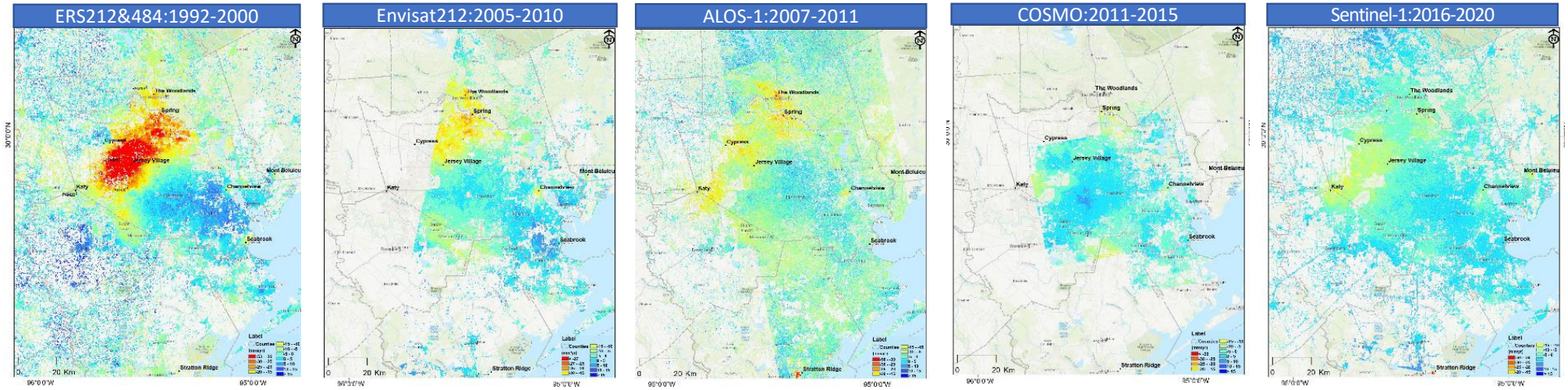


Illustration of how InSAR works (Lu & Dzurisin, 2014)

SMU

Subsidence Monitoring Using InSAR

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



1992-2000
Jersey Village
5 cm/yr

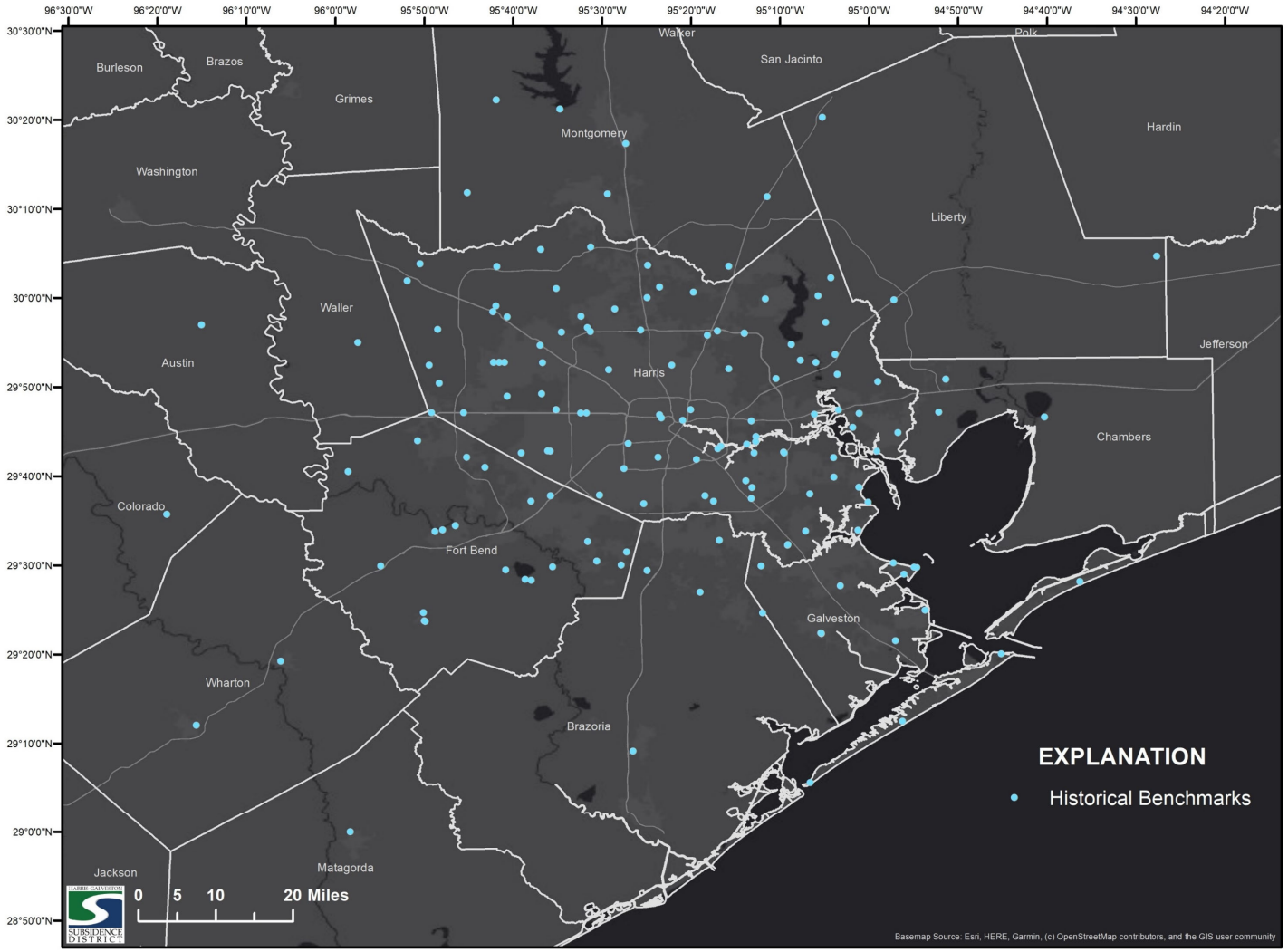
2000-2011
Spring and The Woodlands
2-3 cm/yr

2012-2020
Katy and Cypress
2 cm/yr

2022 GNSS Survey

Goals include:

1. Obtain 2022 elevations for over 150 benchmarks that were historically surveyed by the HGSD in 1978, 1987, 1995, 2000, and 2007.
2. Validate benchmarks within the National Geodetic Survey (NGS) database for community use.
3. Verify projections in other research projects.



HARRIS-GALVESTON SUBSIDENCE DISTRICT

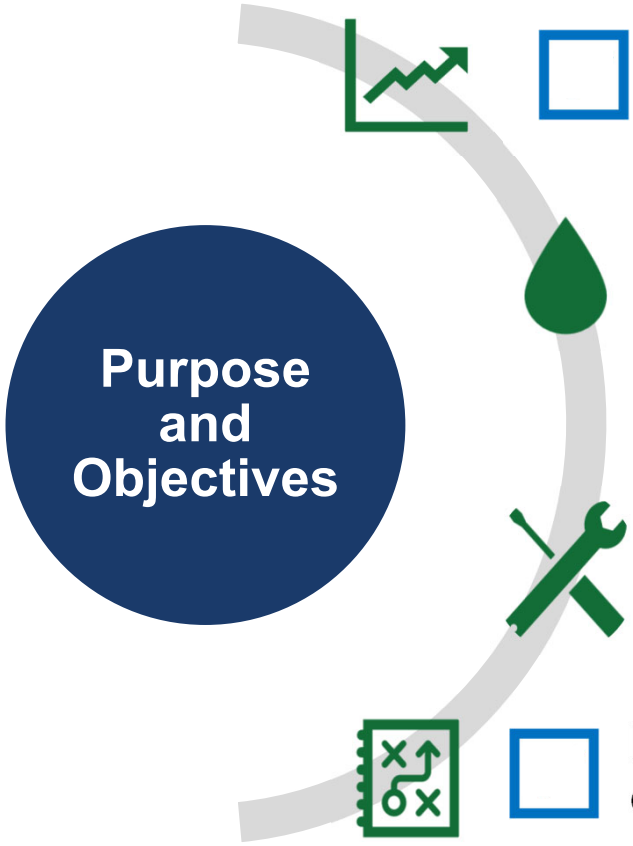
Annual Groundwater Report

- To fulfill the requirements of the District's enabling legislation, each year HGSD's Board of Directors shall hold a public hearing to take testimony concerning the effects of groundwater withdrawals on the subsidence of land within the District during the preceding year.

- The Annual Report includes information on:
  - Precipitation data from weather stations throughout the Houston area
  - Groundwater withdrawals and total water demand
  - Groundwater levels in Gulf Coast Aquifer system
  - Aquifer compaction measurements and subsidence data

- Next hearing will be held on April 27, 2023 at 9:00am at HGSD's Office.

JOINT REGULATORY PLAN REVIEW

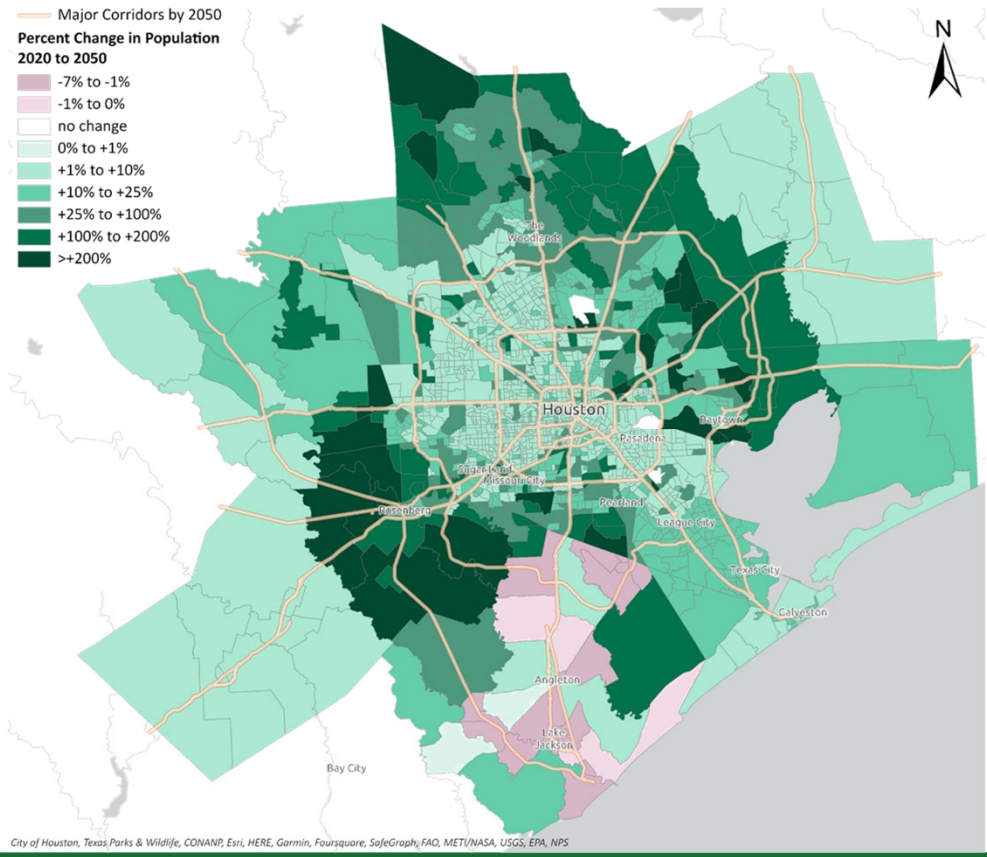


- ☐ Refresh population and per-capita water demand projections within and surrounding the Regulatory Areas.
- ☑ Improve the understanding of future alternative source waters – Report available on website.
- ☑ Update and improve predictive tools – USGS GULF-2023 Model has been released.
- ☐ Evaluate regulatory and climatic scenarios versus the occurrence of subsidence through 2100.

Population Growth Forecast 2020 to 2050

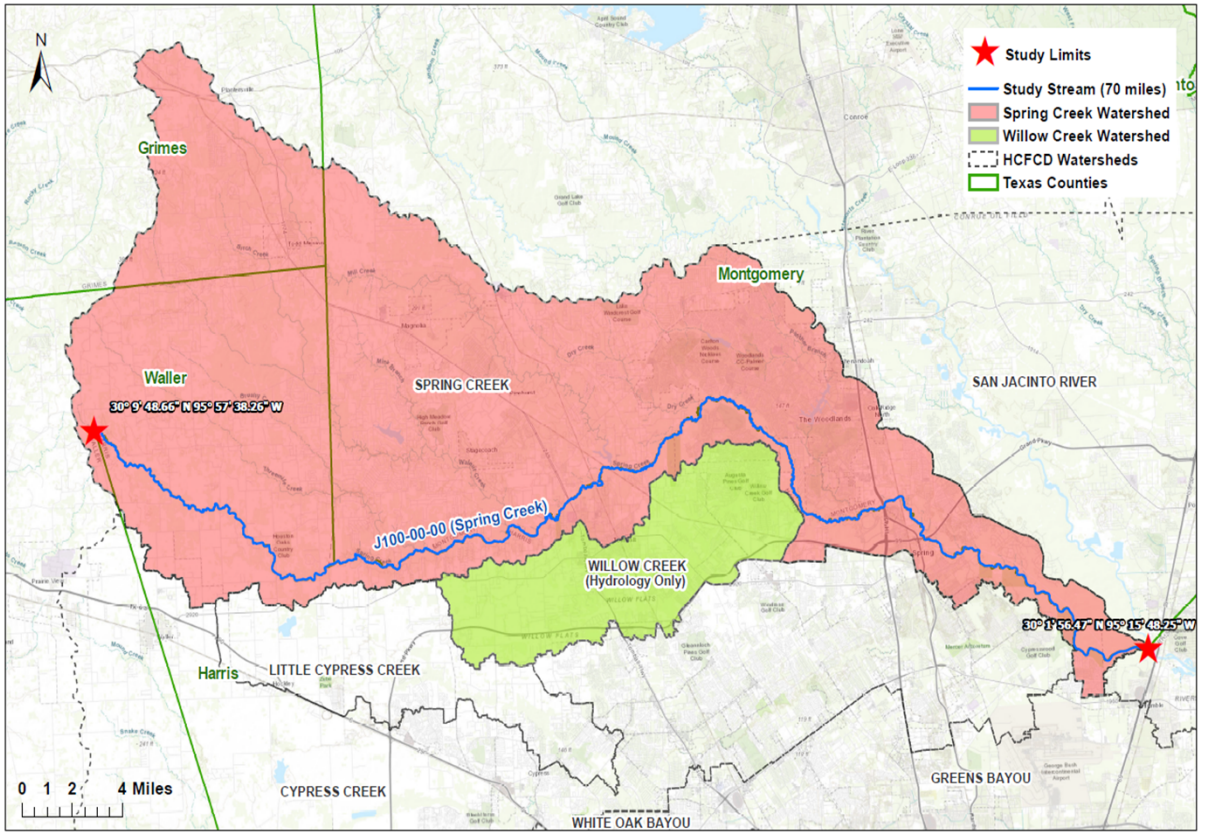
Percent Change in Population by Census Tract

	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%



Evaluation of Subsidence Impacts in the Spring Creek Watershed

- Collaborative work with the Harris County Flood Control District.
- Utilize recent measured data in Montgomery County and projected subsidence in Harris County.
- Evaluates the impact of potential increased subsidence within the basin on flooding.
- Expected release in 2023.



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 water industry professionals to deliver the Water Conservation School Program to our local schools.

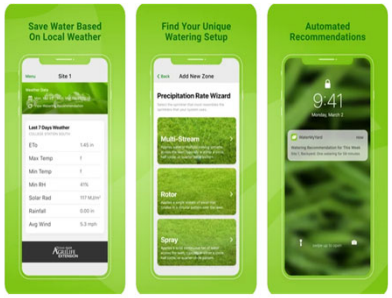
The program is now active in over 35 school districts, reaching over 45,000 area third, fourth, fifth, and sixth-grade students annually.

Smarter About Water

Visit SmarterAboutWater.org or follow us on social media for water conservation resources that help homeowners, teachers, students, and businesses in the Gulf Coast region.

EPA WaterSense 2022 PARTNER OF THE YEAR

Water My Yard



The Water My Yard app not only helps homeowners and businesses save water and money, but also helps local communities make current resources go further, keeping water affordable for all.

Sign up for free watering recommendations and check out other water conservation resources for homes and businesses.

Water Conservation Grant Program

The District provides grants for projects that can achieve quantifiable water conservation, especially those projects and programs that correlate to implementing irrigation best management practices, water loss control measures, and water efficiency measures.

HARRIS-GALVESTON
SUBSIDENCE DISTRCT

Michael Turco

General Manager

281-956-2184

mturco@subsidence.org

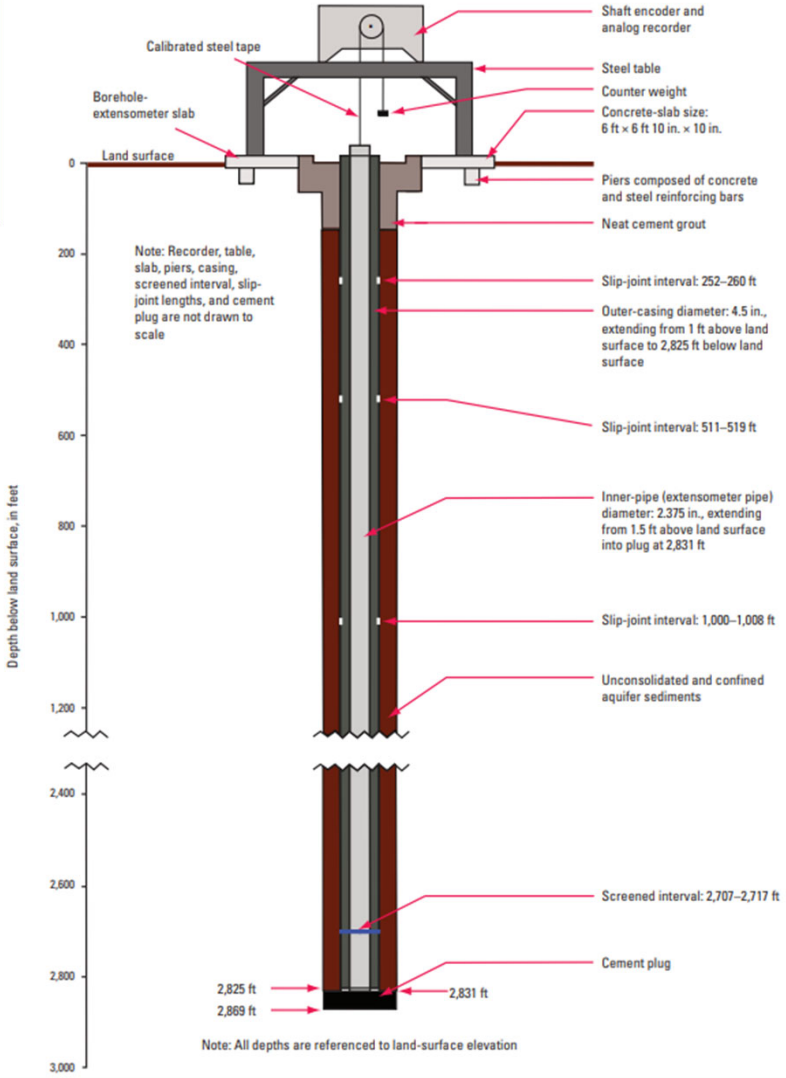
www.hgsubsidence.org

1660 W. Bay Area Blvd.
Friendswood, TX 77546

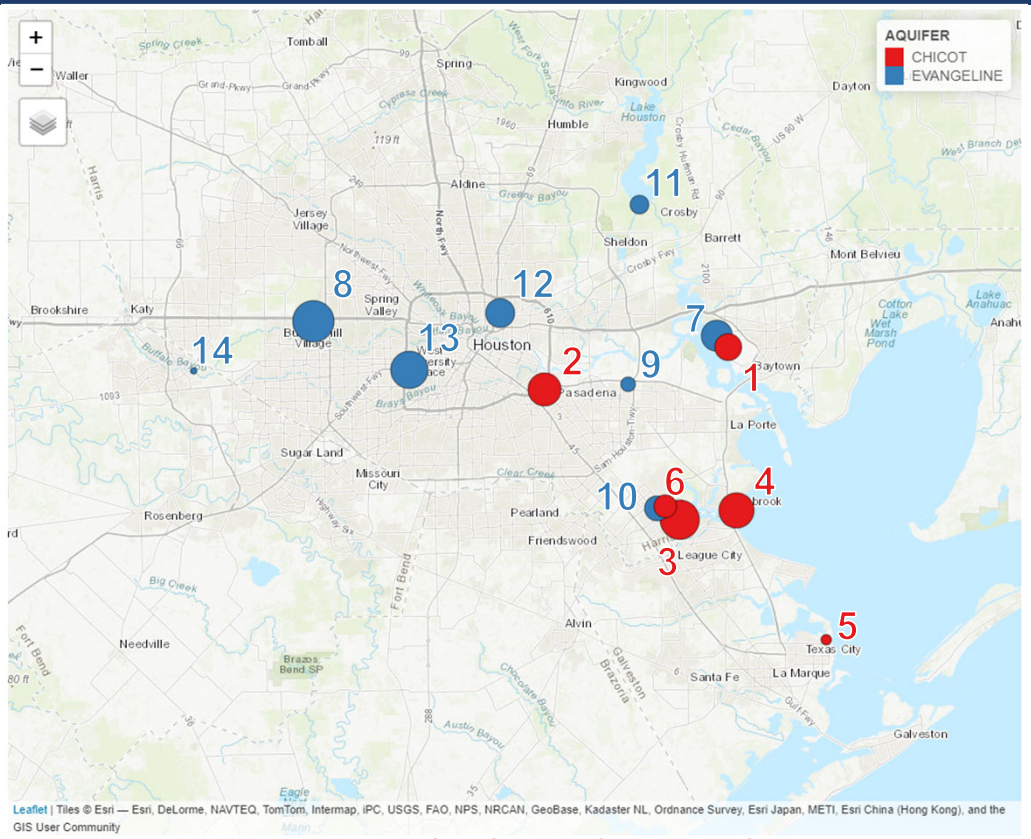
Connect with us!

USGS Extensometers

- First installed in the 1970s to measure aquifer compaction
- As of 2022, USGS operates 14 extensometers:
  - 11 in Harris County
  - 2 in Galveston County
  - 1 in Fort Bend County



Cumulative Compaction Recorded at Extensometers as of December 2021



Size of symbol reflects amount of total cumulative compaction

Chicot Aquifer

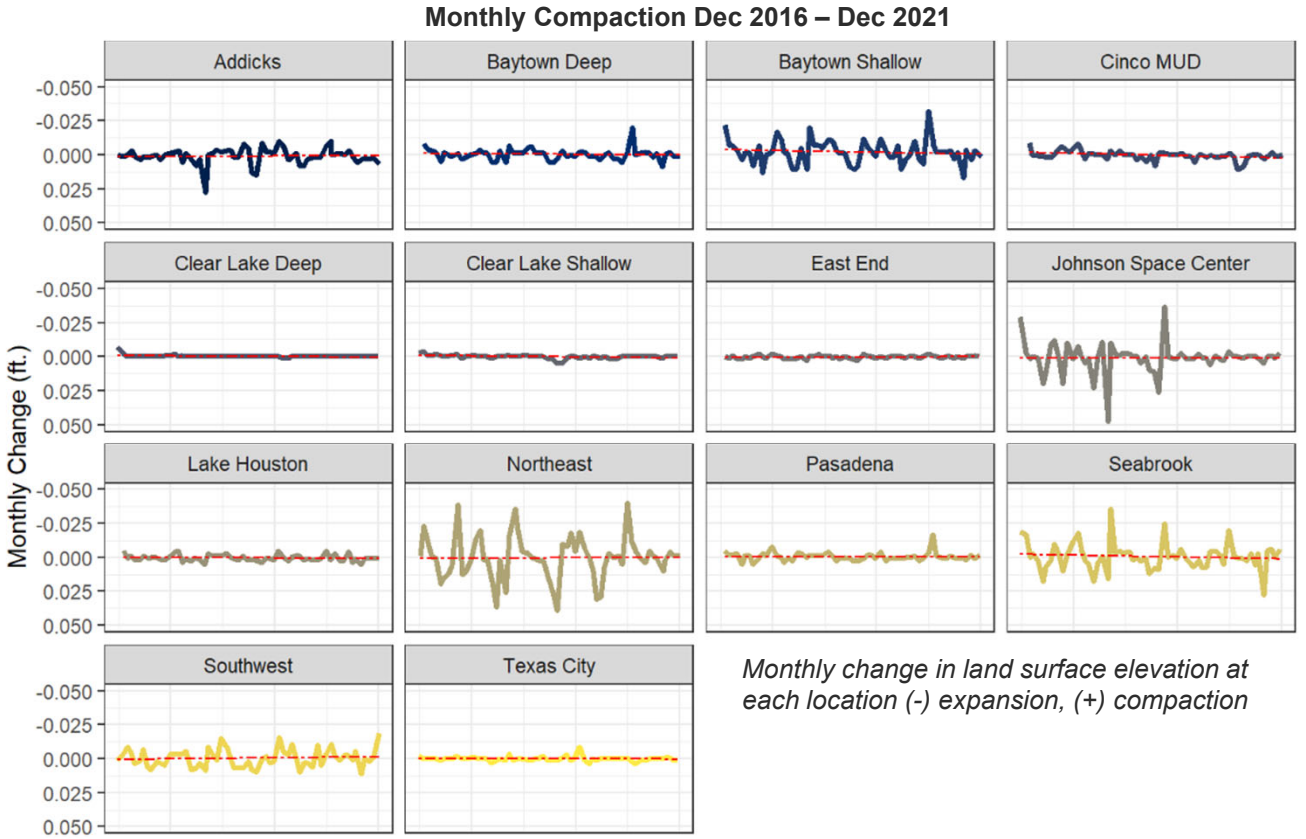
1. 1973 | Baytown Shallow – 0.874 ft.
2. 1973 | East End – 1.350 ft.
3. 1973 | Johnson Space Center – 2.580 ft.
4. 1973 | Seabrook – 1.570 ft.
5. 1973 | Texas City – 0.091 ft.
6. 1976 | Clear Lake Shallow – 0.686 ft.

Evangeline Aquifer

7. 1973 | Baytown Deep – 1.110 ft.
8. 1974 | Addicks – 3.780 ft.
9. 1975 | Pasadena – 0.458ft.
10. 1976 | Clear Lake Deep – 0.705 ft.
11. 1980 | Lake Houston – 0.636 ft.
12. 1980 | Northeast – 1.000 ft.
13. 1980 | Southwest – 1.680 ft.
14. 2017 | Cinco MUD – 0.014 ft.

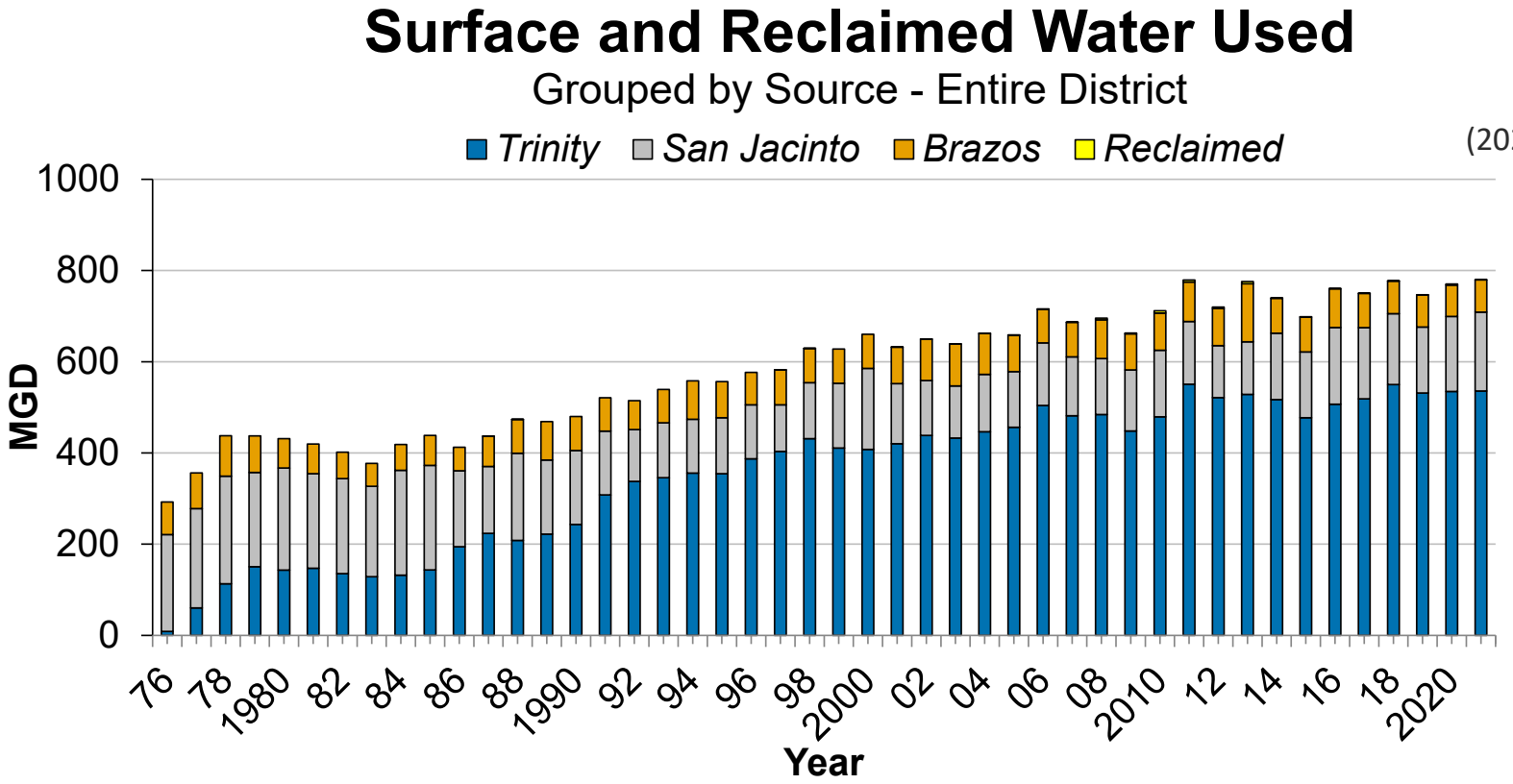
Compaction 5-Year Monthly Changes

- Slight increase in trend (compaction)
  - Baytown Shallow
  - Cinco MUD
  - Seabrook
- Slight decrease in trend (expansion)
  - Southwest



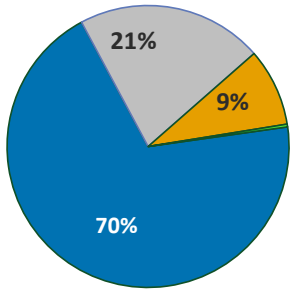
Monthly change in land surface elevation at each location (-) expansion, (+) compaction

Alternative Water Utilized



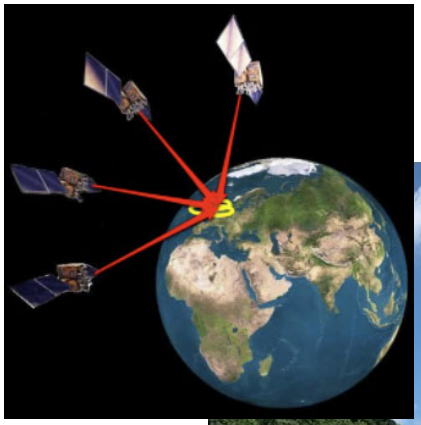
2021 - 779.9 MGD

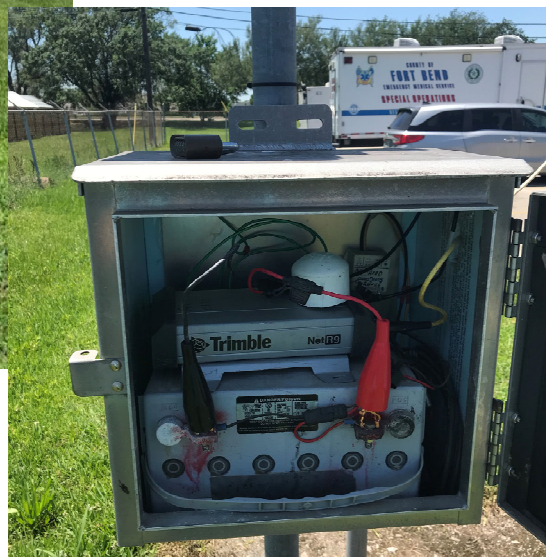
(2020 – 770.5 MGD; 1% change)



GPS Measurement Method

Global positioning system (GPS) stations are constructed in the Port-a-Measure (PAM) design and collect GPS data periodically.





Links

Harris Galveston 2021 Annual Report

https://hgsubsidence.org/science-research/district-research/annual-groundwater-reports/

USGS Water Level Altitude and Extensometer Data

https://txpub.usgs.gov/houston_subsidence/viewer/index.html