SUBSIDENCE 101

28 JANUARY 2025

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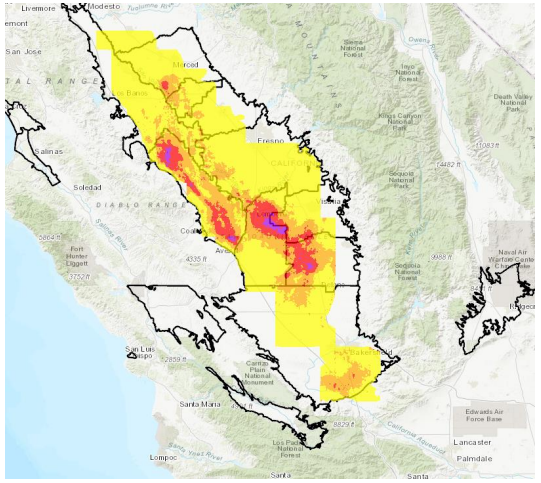
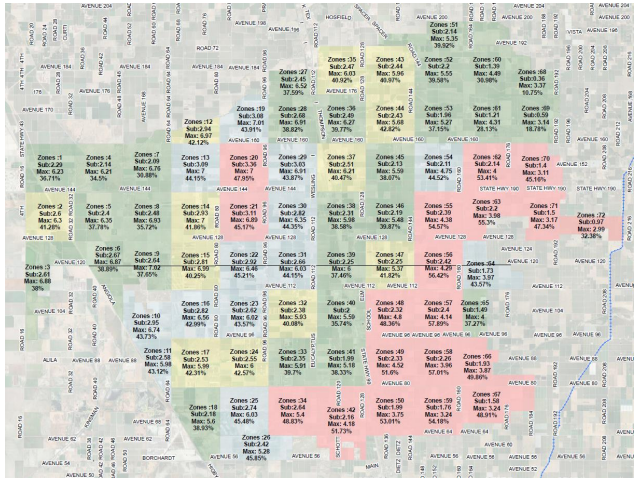
Est. 1989

35 Years Making an Impact

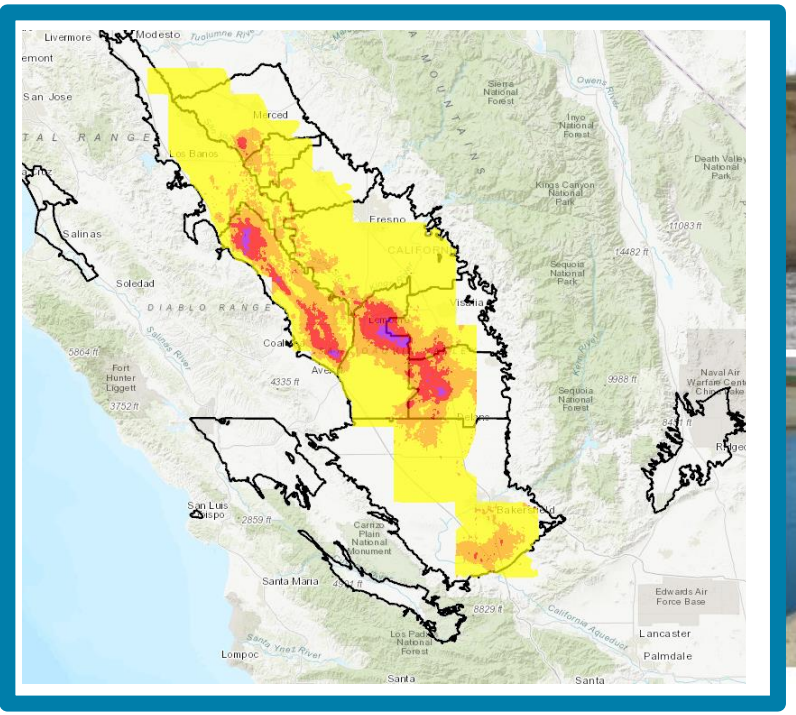
PRESENTATION OVERVIEW

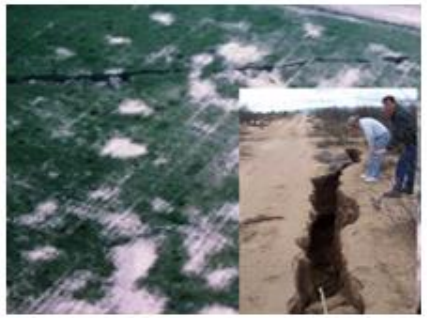
- Background on Subsidence
- Subsidence in the Tule Subbasin
- SGMA Implications for LTRID / PID GSAs

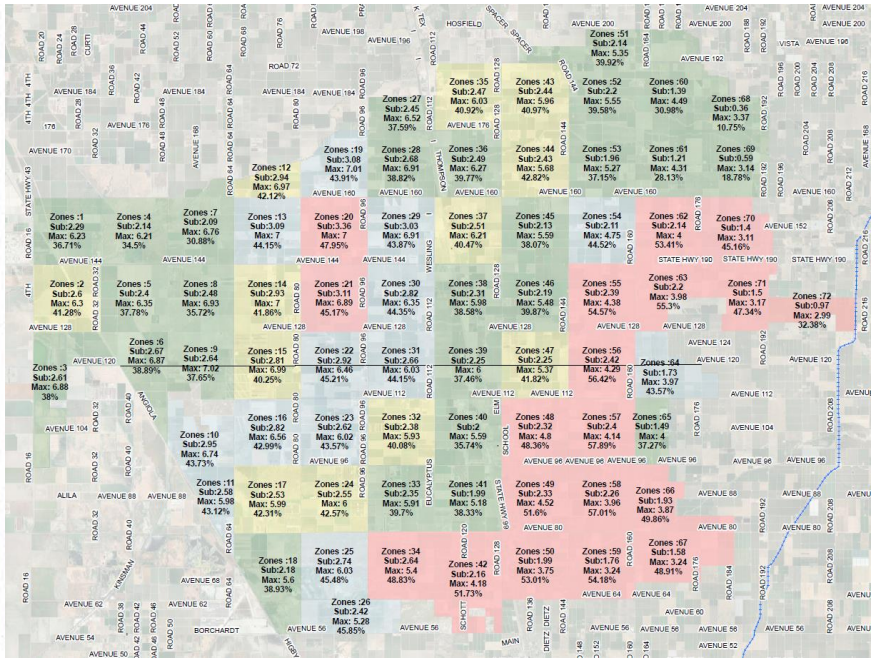




BACKGROUND ON SUBSIDENCE

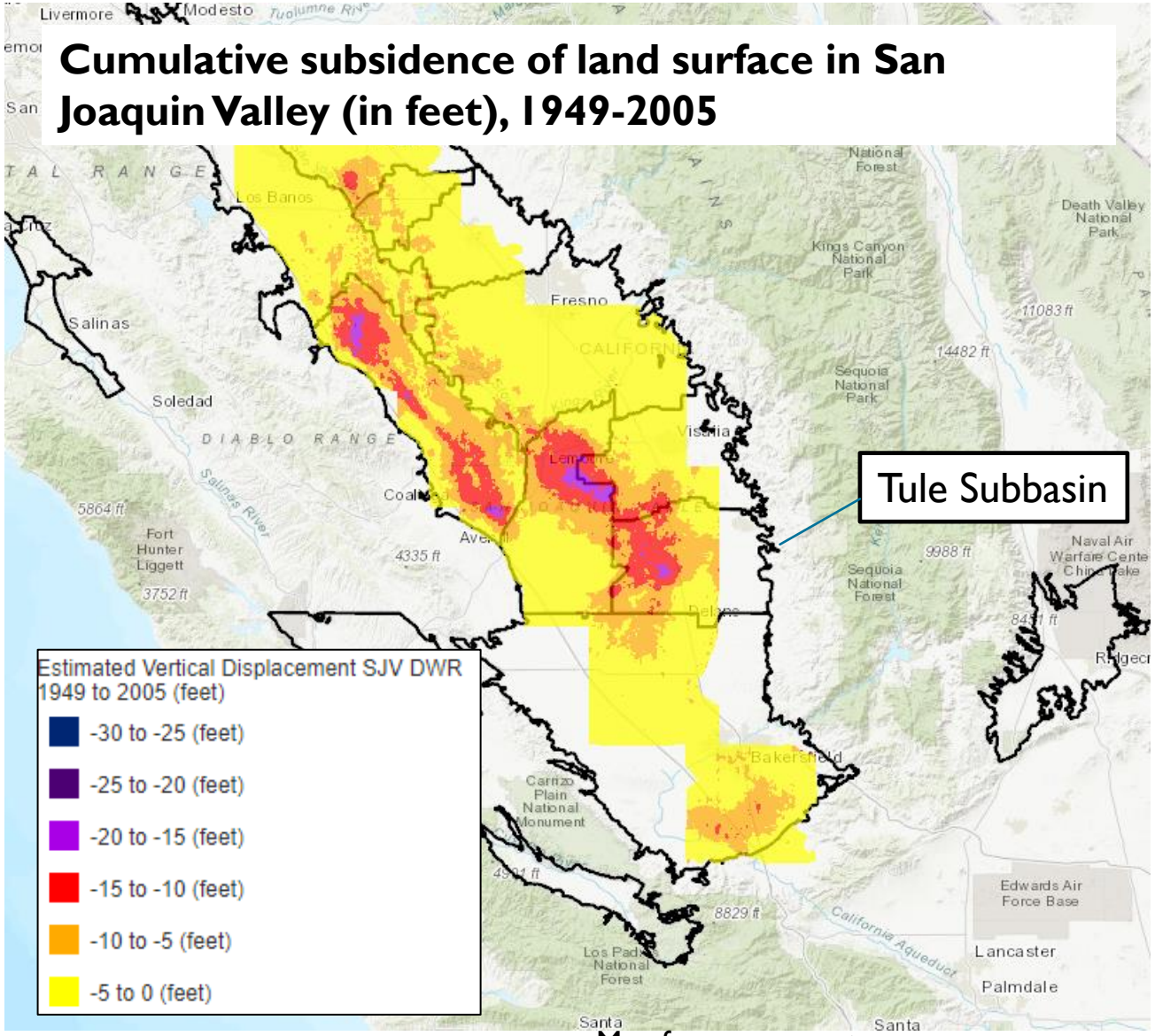






SUBSIDENCE IN THE CENTRAL VALLEY

- Subsidence is occurring throughout the Central Valley because of aquifer compaction.
- Up to ~20 feet of subsidence has been observed in the Tule Subbasin since 1949.



Map from sgma.water.ca.gov

WHAT IS SUBSIDENCE?

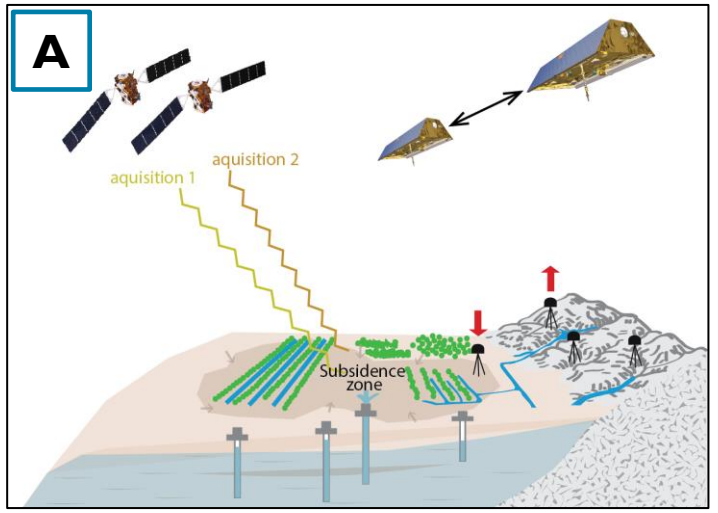
- Subsidence is the "*gradual settling or sudden sinking of the Earth's surface due to subsurface movement of earth materials*."
- 80% of the subsidence in the United States is a consequence of human impacts on subsurface water (USGS, 2000).
  - Aquifer system compaction (the single largest cause of subsidence in the U.S.).
  - Drainage and oxidation of organic soils.
  - Collapse of underground cavities (sinkholes).
- Other causes of subsidence can include:
  - Underground mining (i.e., oil and gas extraction).
  - Hydro-compaction (near surface subsidence).
  - Natural consolidation.
  - Thawing permafrost.

TWO TYPES OF SUBSIDENCE – ELASTIC AND INELASTIC

- ***Elastic Subsidence*** – aquifer materials compress as pore pressure decreases (groundwater levels decline) and expand as pore pressure increases (groundwater levels increase). This process is reversible.
- ***Inelastic Subsidence*** – occurs when sediments are compressed beyond their previous maximum effective stress.
  - This generally occurs when groundwater levels decline below historical lows.
  - This process is **irreversible** and results in permanent loss of aquifer storage.

HOW IS SUBSIDENCE MEASURED?

- ***Interferometric Synthetic Aperture Radar (INSAR)*** – satellite-based radar that collects high density land surface elevation measurements over broad areas at different times then compares measurements to determine subsidence.
- ***Continuous GPS (CPGS) stations*** – provide a continuous record of land surface elevation measurements to determine subsidence at one location.
- ***Extensometers*** – measure change in thickness of a specified depth interval at one location.



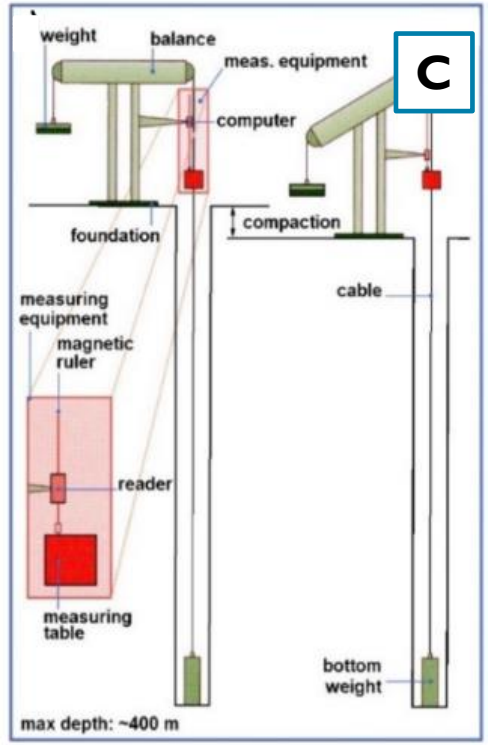
Source: C. Faunt (USGS)

Sources/Usage: Public Domain. View Media Details

A: Schematic showing how INSAR acquires multiple measurements over time in a given area to determine the degree of subsidence.

B: Example CPGS station.

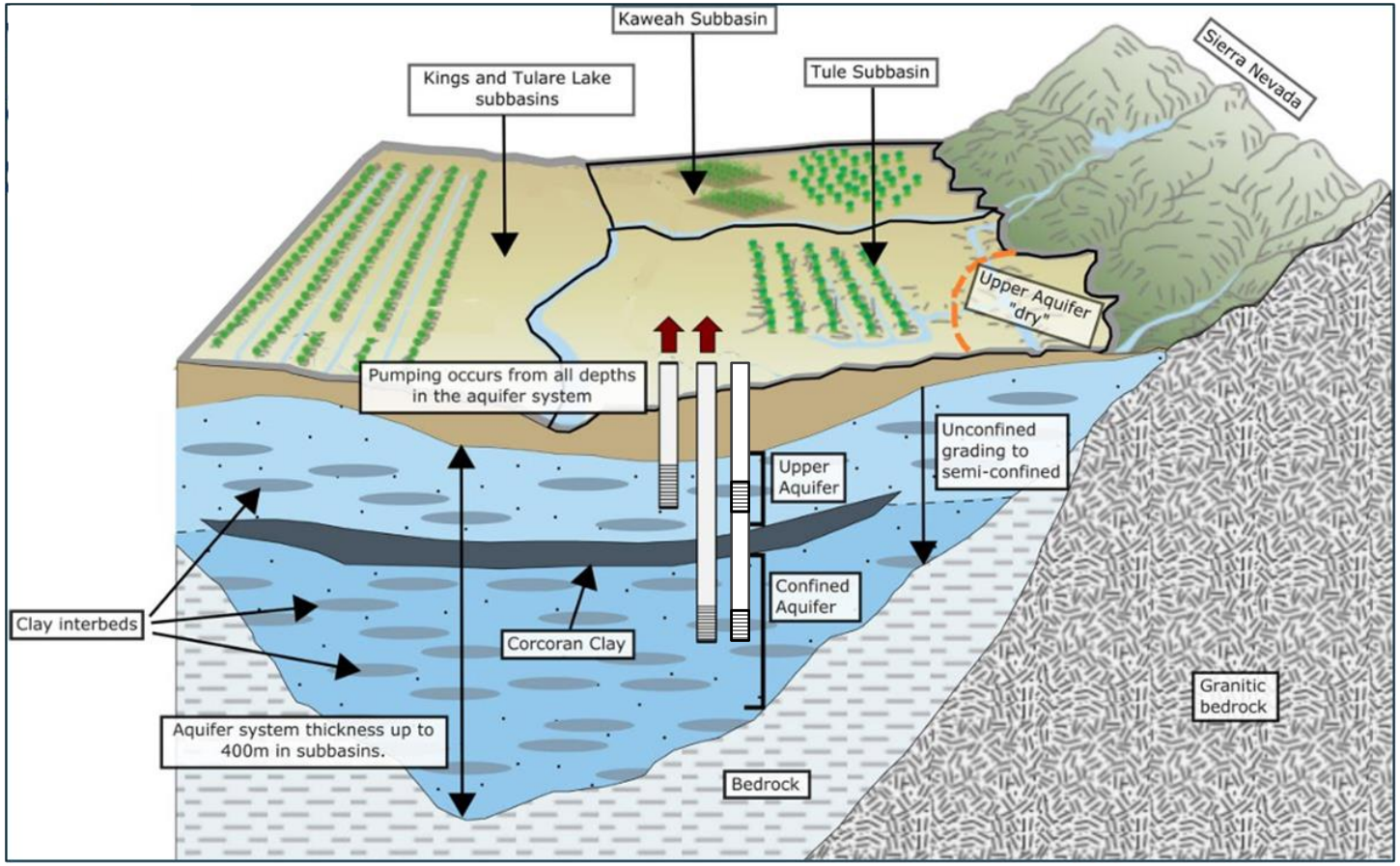
C: Schematic describing how extensometers monitor compaction.



Source: The Groundwater Project

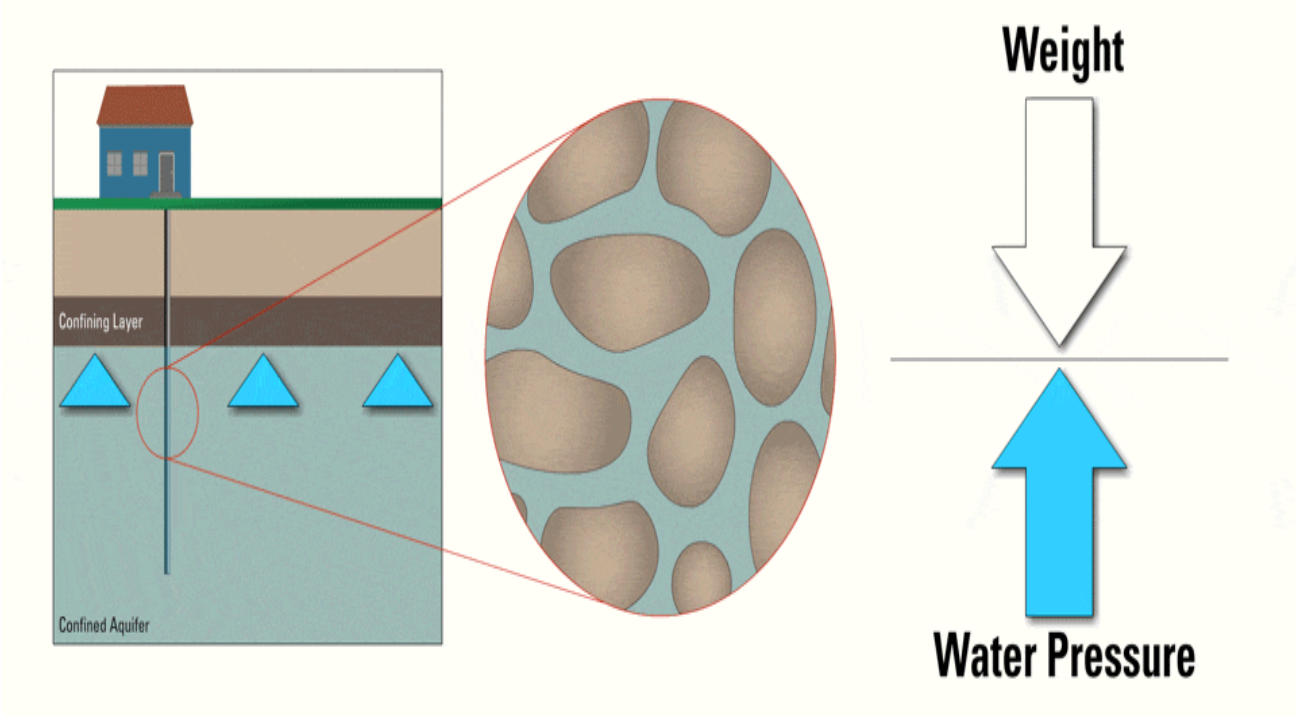
CONNECTION BETWEEN AQUIFER STRUCTURE AND SUBSIDENCE

- The Corcoran Clay is a regionally extensive low-permeability unit that separates the upper unconfined aquifer from the deeper confined aquifer.
- Land subsidence is primarily driven by groundwater pumping in the deeper confined aquifer.



IMPORTANCE OF LOCAL AND REGIONAL INFLUENCES

- Groundwater levels & subsidence are a result of both local and regional withdrawals.



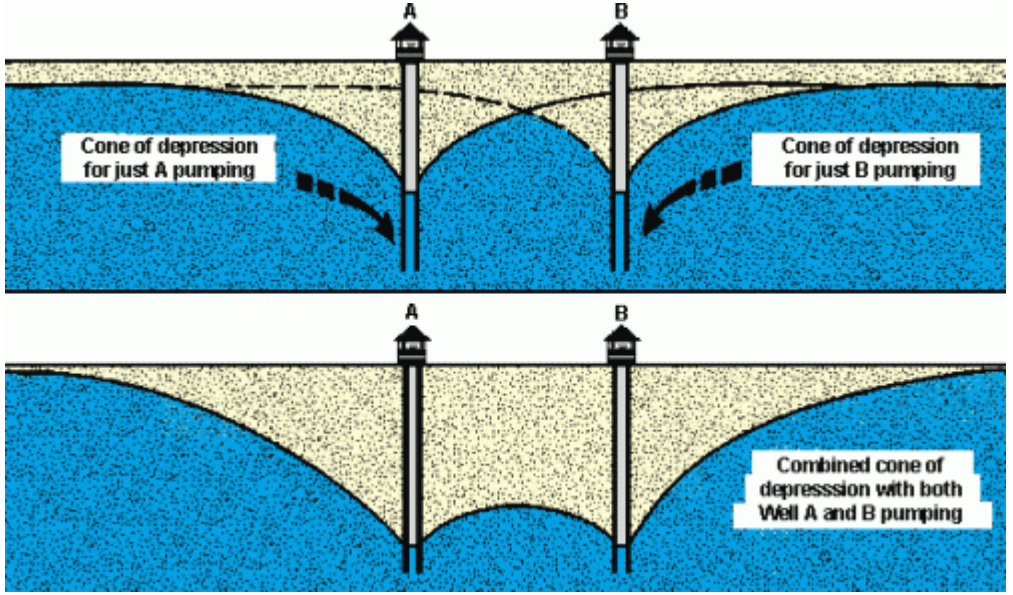


Image from Raymond, 1989

USGS produced animation, August 1, 2022.

LOWER AQUIFER COMPACTION DRIVES SUBSIDENCE

- Head fluctuations in the Lower Aquifer below historical lows drive subsidence.
- Compaction in the Lower Aquifer has accounted for over 90% of subsidence in the San Joaquin Valley in the last 20 years (Lees et al. 2022).
- Compaction in the Upper Aquifer drove some subsidence historically but has declined in significance.

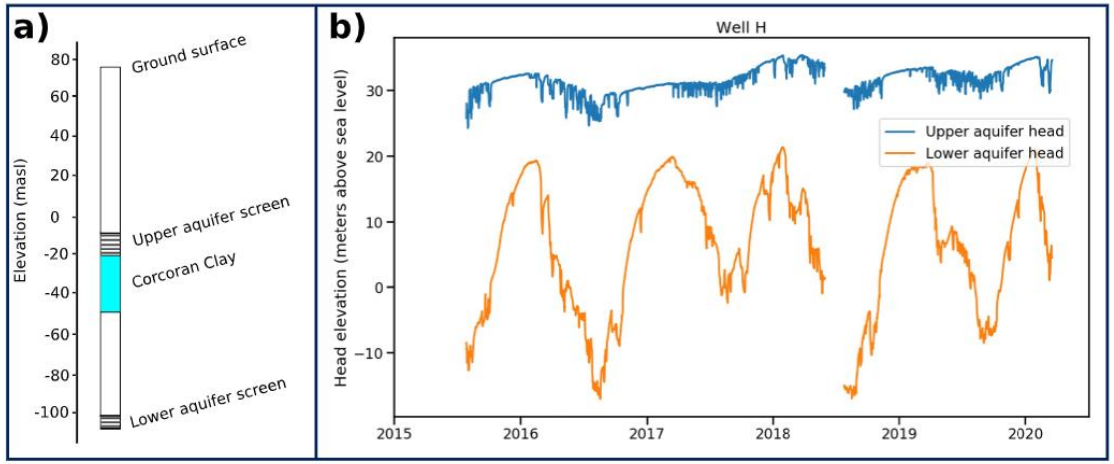


Figure 3. (a) The relationship between the Corcoran Clay and the screened intervals in Well H and (b) the continuously monitored head records from Well H. These two head time series show clear and distinct head values and trends between the two aquifers. The data from Well H were provided by Kings County Water District, who installed and operate the well.

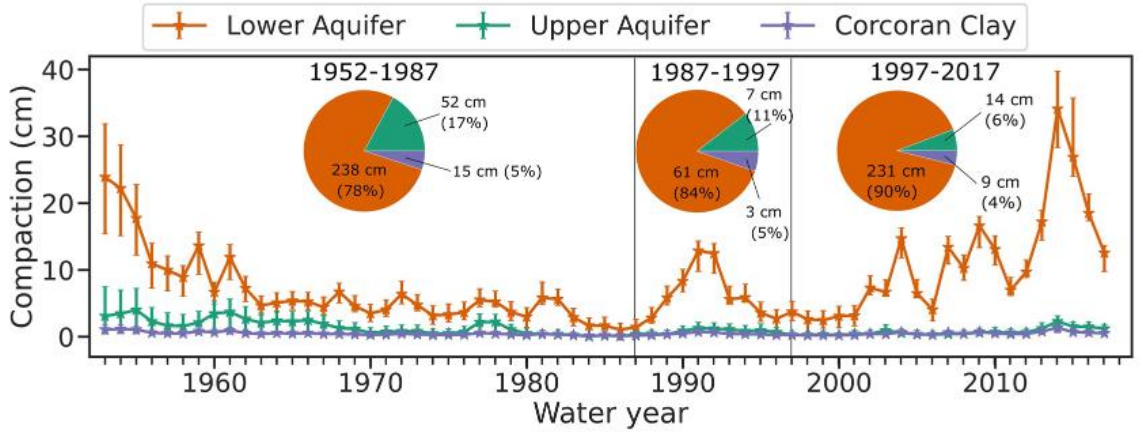
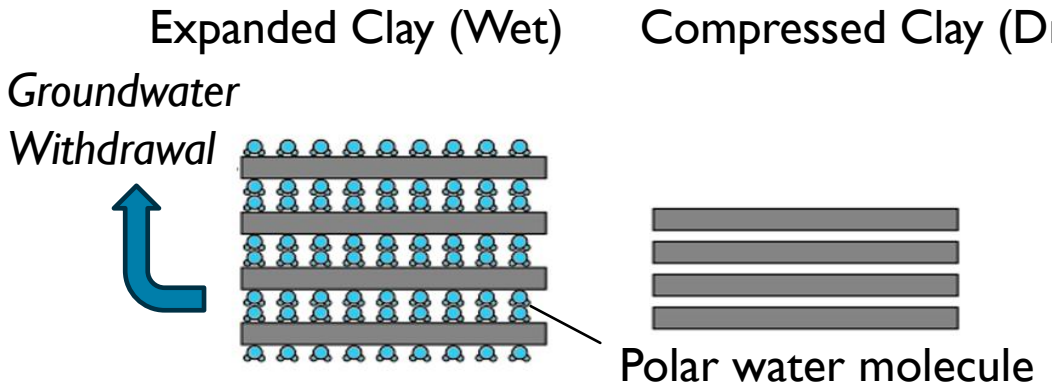


Figure 11. The partitioning of compaction between the upper aquifer, the lower aquifer, and the Corcoran Clay over time.

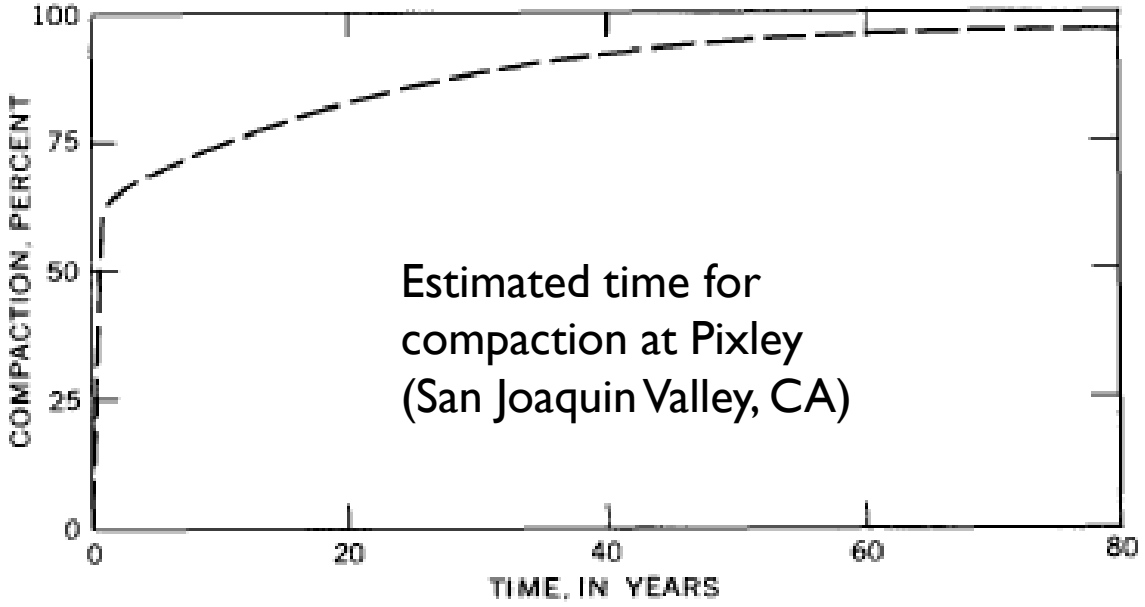
Study area included Tulare Lake and Kaweah Groundwater Basins. Figures from Lees et al. 2022.

DELAYED COMPACTION CAN OCCUR FOR DECADES

- Time-delay to complete compaction depends upon:
  - Ability of water to move out of clay.

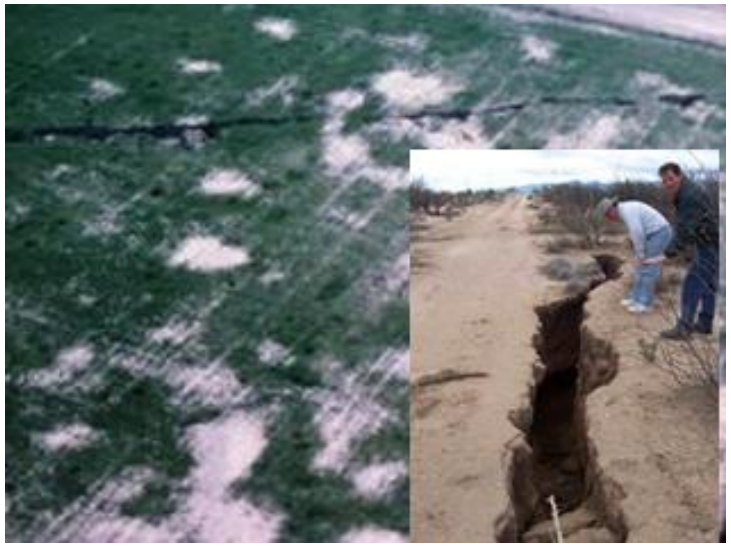


  - Volume of water that must be expelled from clay to increase density enough to withstand additional stress.

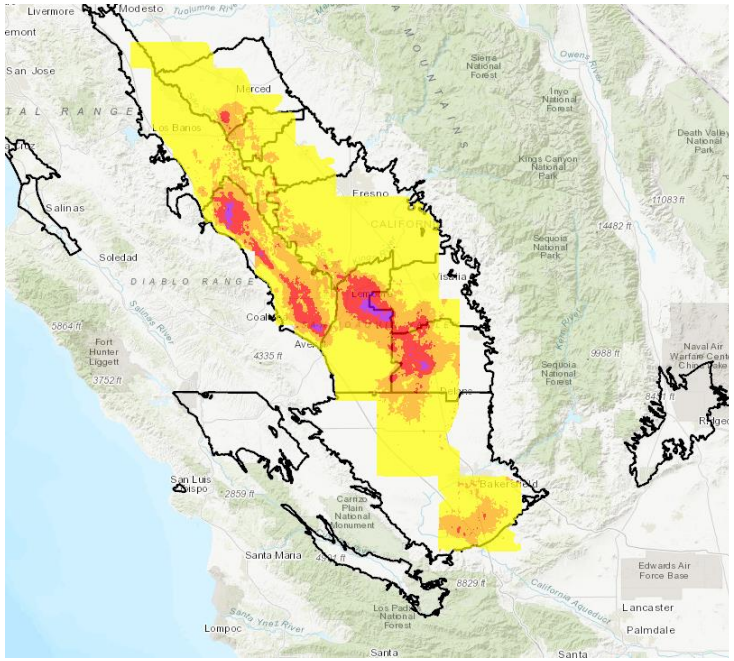


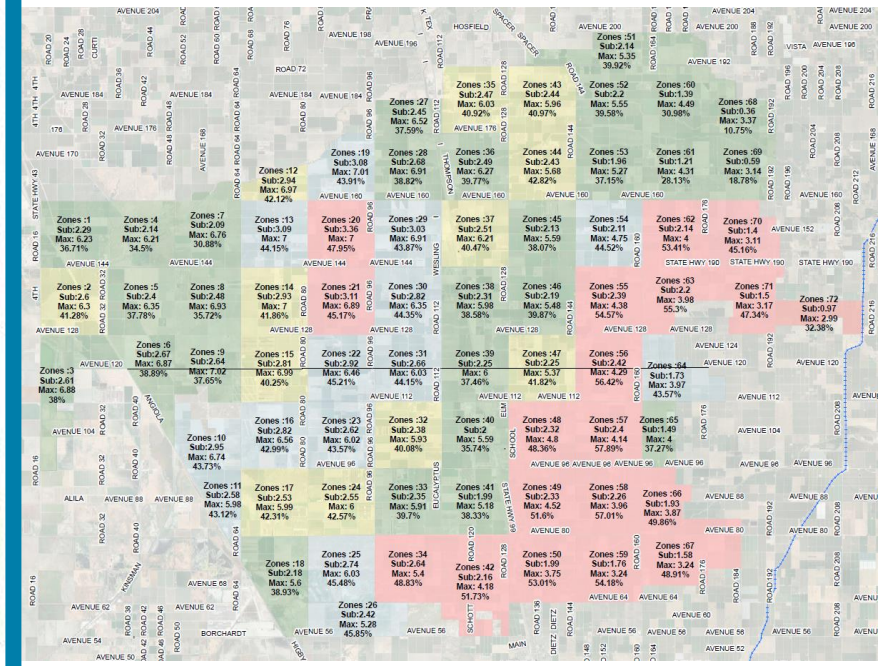
IMPACTS / RISKS OF SUBSIDENCE

- Structural damage to dams, levees, canals, and wells
- Reduction in capacity for canals, intakes
- Damage to water delivery pipelines
- Impacts to flood control infrastructure – increased flooding risk
- Ground fissures



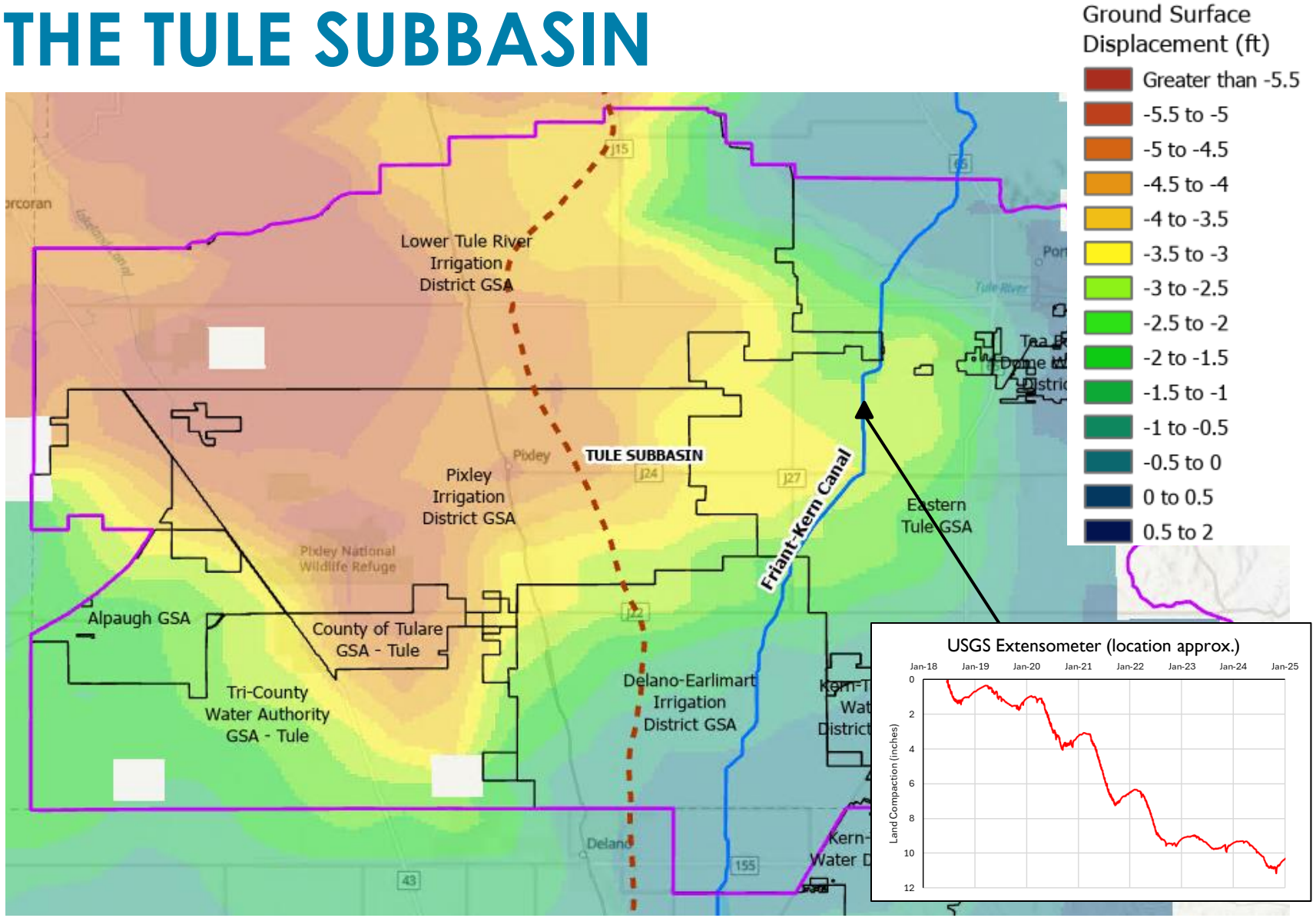
SUBSIDENCE IN THE TULE SUBBASIN





SUBSIDENCE IN THE TULE SUBBASIN

- Satellite measurements (INSAR data) show subsidence in the Tule Subbasin is widespread and significant.
- Up to ~5 feet decline in land surface elevation since 2015 in LTRID GSA and PID GSA.



INSAR Subsidence Data showing Extent of Subsidence, 2015-2024

RELATIONSHIP BETWEEN SUBSIDENCE AND WATER LEVEL DECLINE IN CONFINED AQUIFER

- Groundwater level declines in the confined (deep) aquifer drive declines in land surface elevation.

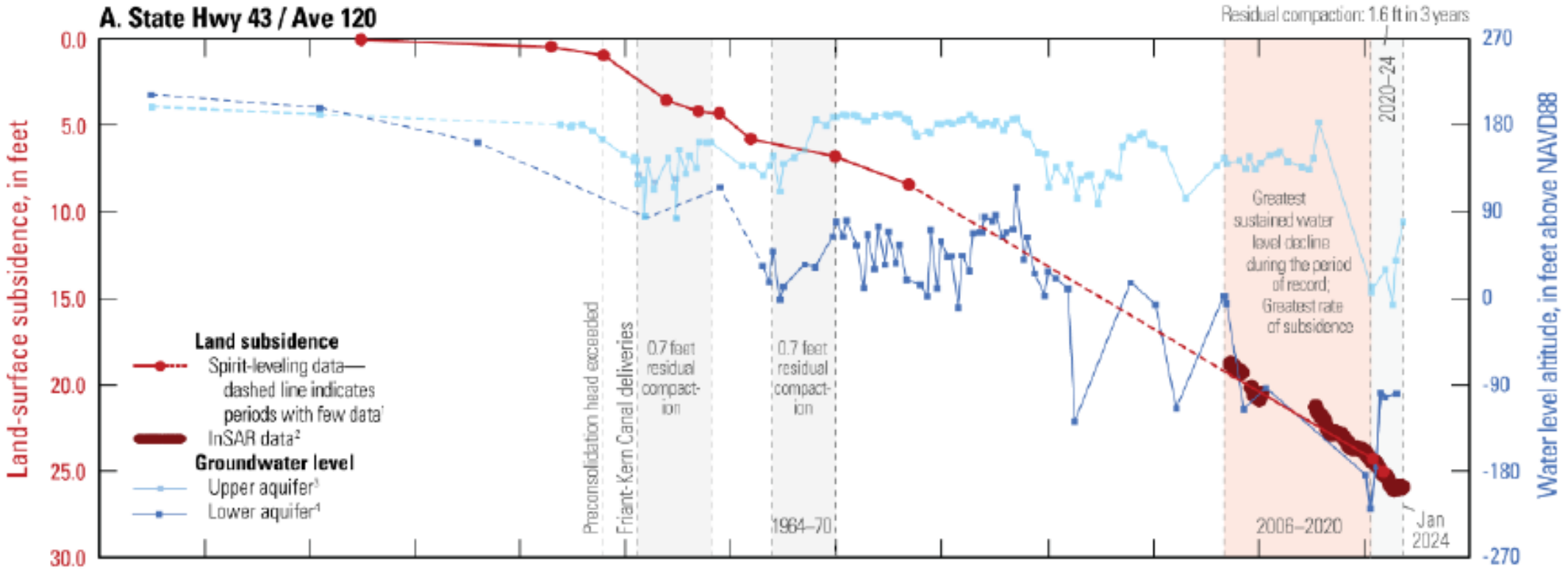
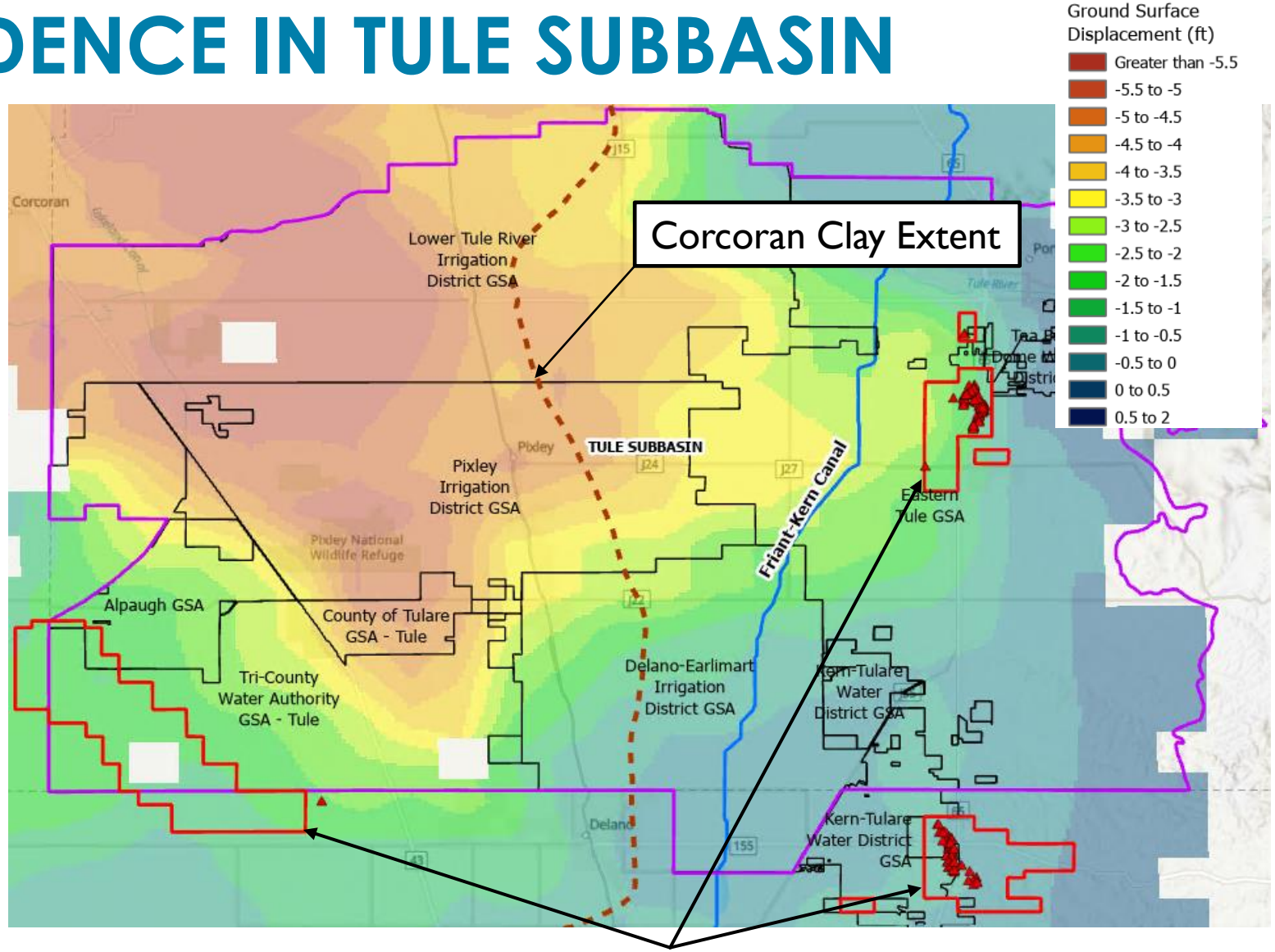


Image from DEID GSP (2024)

CAUSES OF SUBSIDENCE IN TULE SUBBASIN

- The primary cause of land subsidence within PID/LTRID is groundwater withdrawals.
- Oil and gas extraction is limited in the Tule Subbasin and is not co-located with the areas of greatest subsidence.



EXTENT OF CLAYS IN TULE SUBBASIN

- Tule Subbasin comprised of series of coalescing alluvial fans that merge with lacustrine deposits of the Tulare Lakebed to the west, including the Corcoran Clay (CC).
- The CC thickens to the west, under the PID and LTRID GSAs.
- Other relatively localized confining beds are present east of the CC.
- Subsidence is greatest where the CC is present but also occurs east of the CC where other localized confining beds exist.

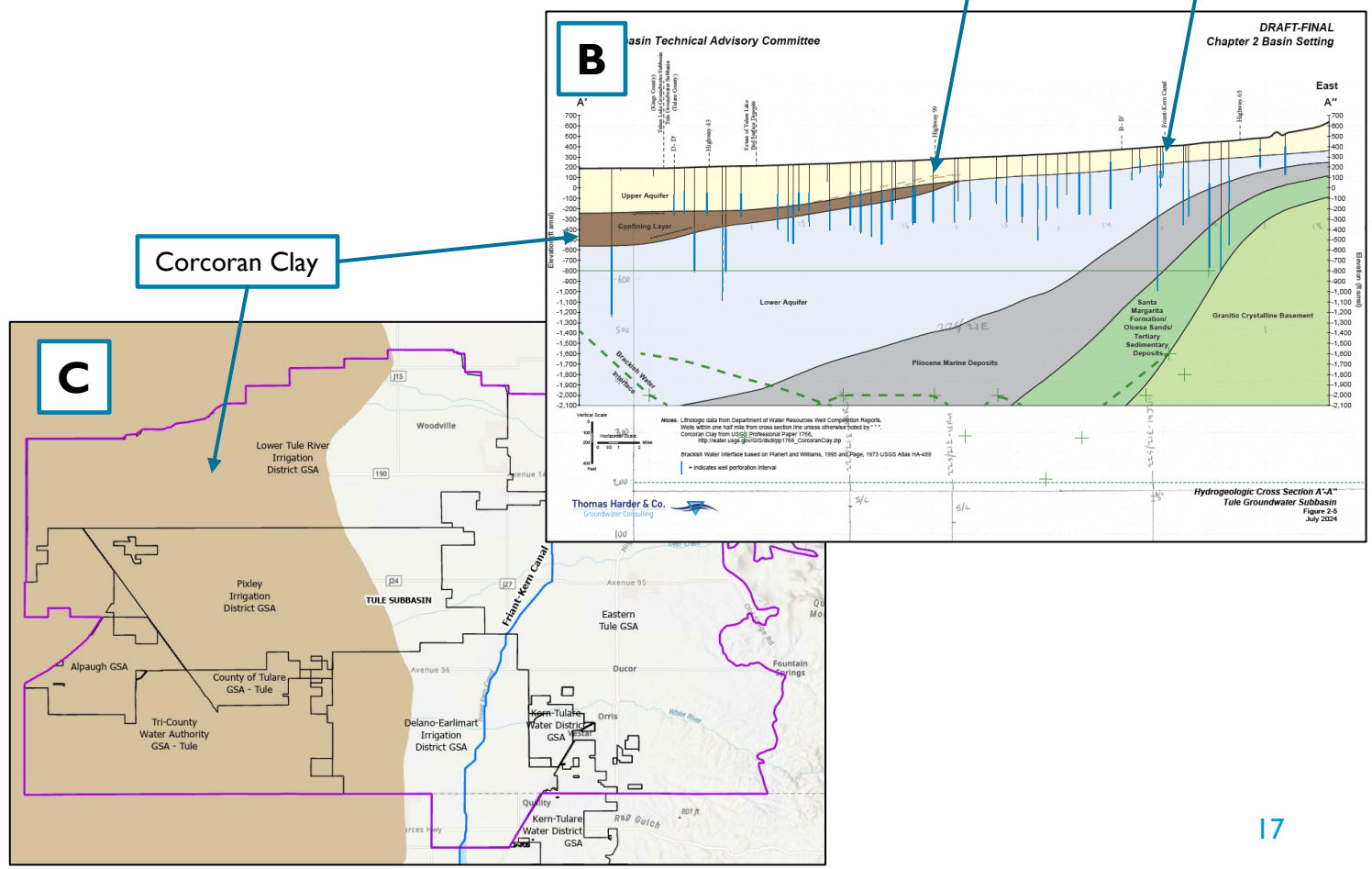
A: Text from DEID Tule Subbasin Setting.
B: Cross-section of Tule Subbasin from GSP.
C: Extent of Corcoran Clay taken from USGS, 2012, modified from Page, 1986.

A

Subbasin Setting DRAFT-FINAL July 2024

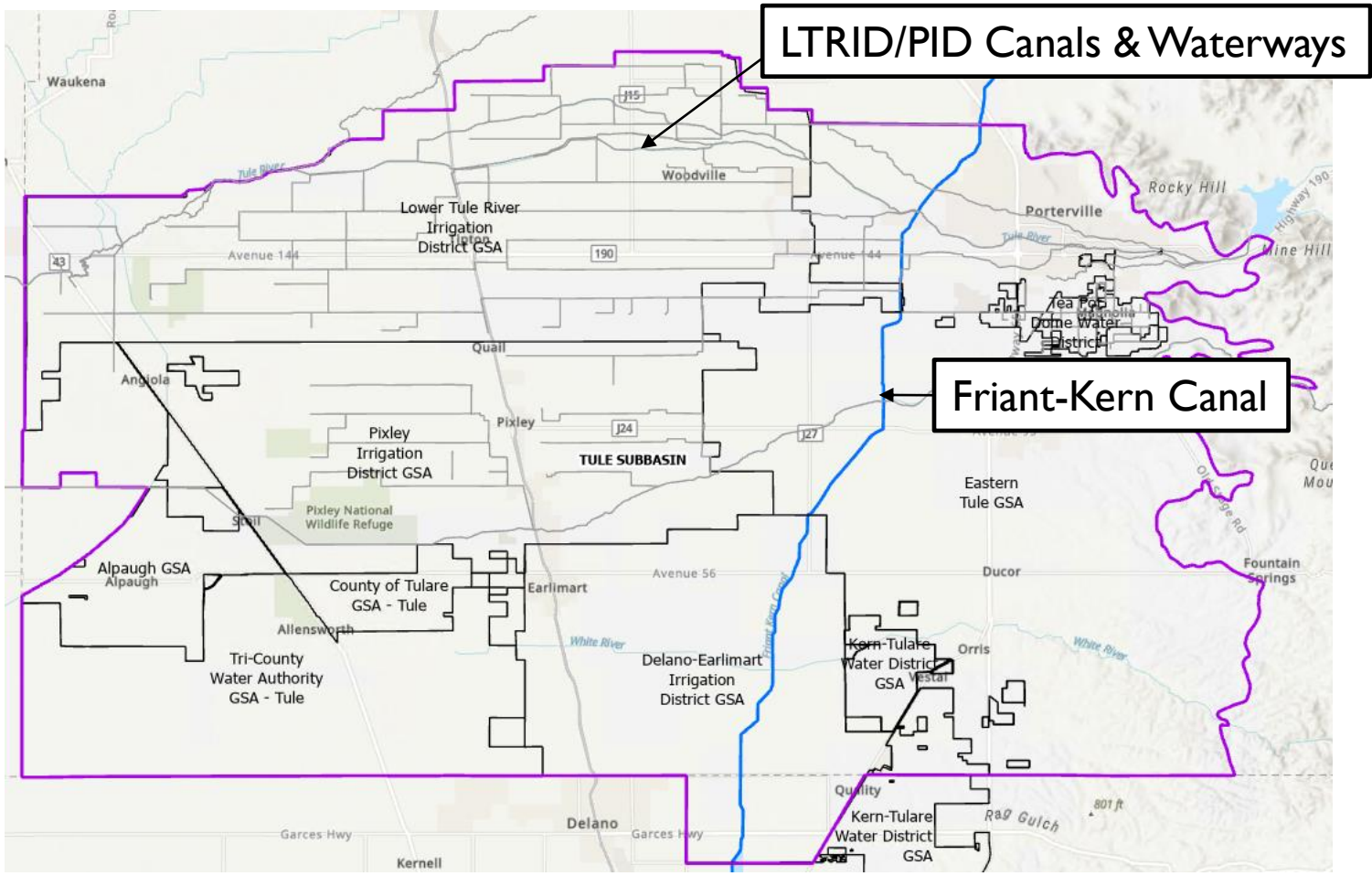
2.1.7.3 Geologic Structures that Affect Groundwater Flow §354.14 (b)(4)(C)

East of the Corcoran Clay, other localized confining beds are present that separate the upper aquifer from the lower aquifer.



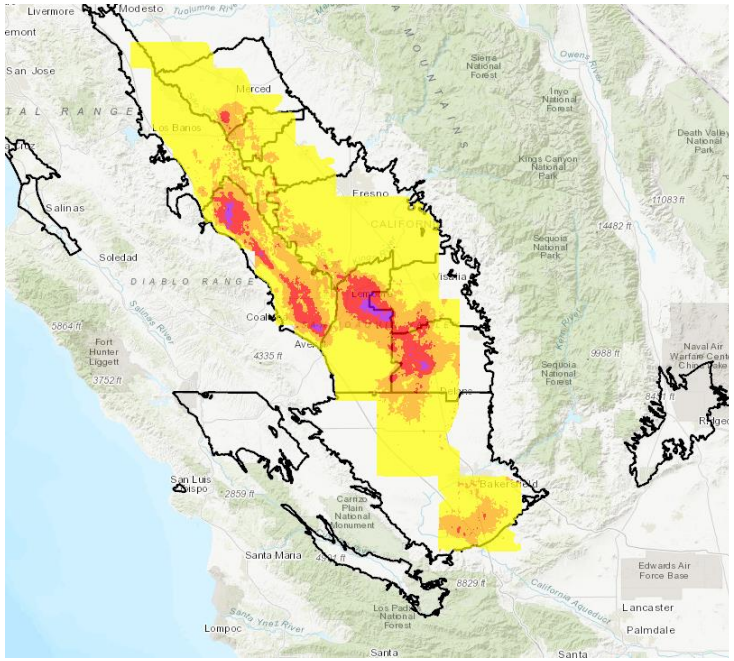
CONCERN: IMPACTS TO CRITICAL INFRASTRUCTURE

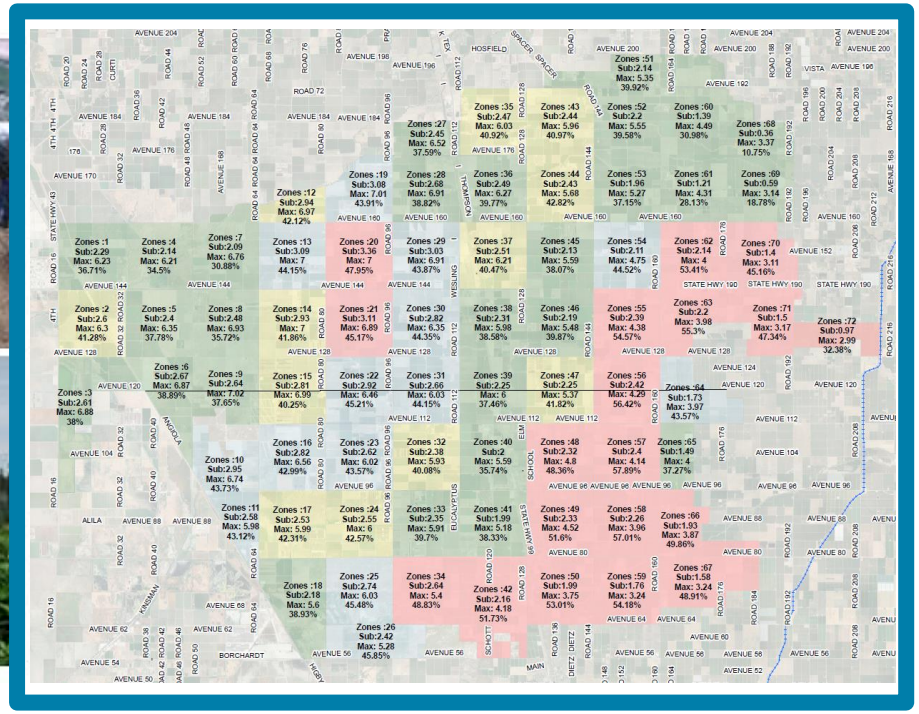
- Reduced capacity in Friant-Kern Canal.
- Canals, waterways, and pipeline systems serving agricultural users.
- Increased pressure on DEID pipelines.
- Roadways and flood control infrastructure.



Canals & Waterways in other GSAs not shown

SGMA IMPLICATIONS FOR LTRID / PID GSAs





INTENT OF SGMA

- Per CWC 10720.1(e), in enacting SGMA it is the "intent of the legislature to… avoid or minimize subsidence."
- California Department of Water Resources (DWR) has stated that they have a "zero tolerance" for subsidence beyond 2040.

SWRCB FINDINGS

- On 17 September 2024, the SWRCB put the Tule Subbasin in probation (Resolution No. 2024-0030), finding that, regarding subsidence, the Tule Subbasin GSPs:
  - "…do not clearly describe subsidence conditions that would reasonably be expected to cause undesirable results."
  - "The GSAs did not set Minimum Thresholds in accordance with DWR Regulations."
  - "The GSPs do not provide adequate implementation details and are not on track to avoid serious impacts to the Friant-Kern Canal."
  - "The GSPs do not address undesirable results caused by land subsidence after 2040 and instead allow for residual subsidence to continue after 2040."

IMPLICATIONS OF PROBATION

- SWRCB Fees and Reporting:
  - All groundwater extractions for non-domestic purposes must be metered and reported, with fees associated with metering and extraction.
  - Specific, state-approved flowmeters must be used for extractions within the Friant-Kern Canal Management Area.
- DEID GSA and Kern-Tulare GSA were exempted from fees.
- LTRID GSA and PID GSA requested exemption from fees, citing intent to develop their own GSPs and develop a Subsidence Mitigation Plan. *SWRCB is still considering this request.*

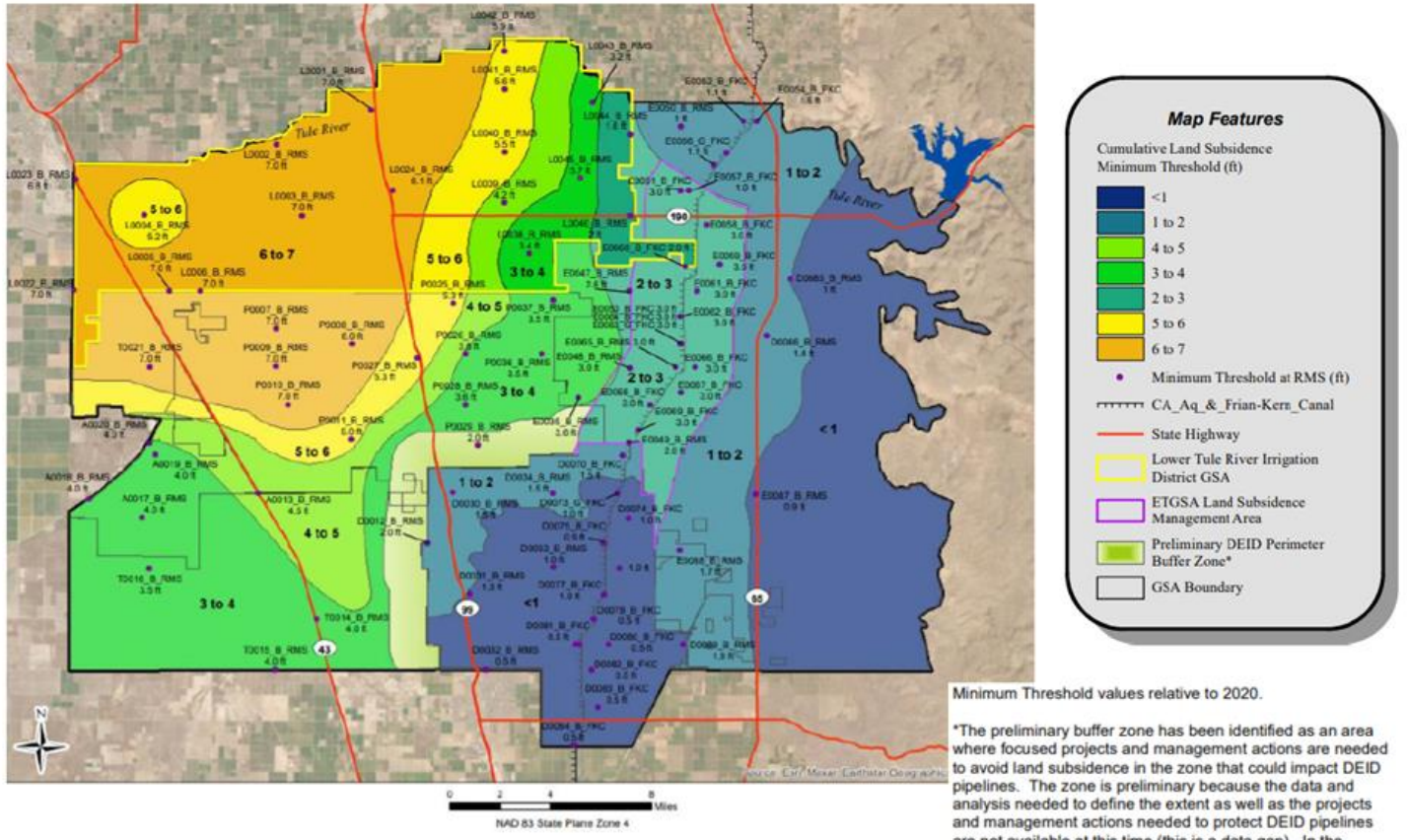
PID/LTRID STATUS UPDATE

- Tea Pot Dome Water District and Vandalia Water District filed to be GSAs in July 2024.
- Developed Revised GSPs for LTRID, PID, Tea Pot Dome, and Vandalia.
- GSPs included:
  - Revised SMCs for groundwater levels and subsidence.
  - Established new SMCs for lower aquifer groundwater levels.
  - Subsidence Management Plan.
  - Revised Transitional Allocation Ramp Down.
- LTRID and PID have developed a GSP Impact Mitigation Plan to mitigate impacts to groundwater levels, groundwater quality, and land subsidence from GSP/GSA authorized activities

REVISED SUBSIDENCE MINIMUM THRESHOLDS (MTs) FOR PID/LTRID

- Quantitative values for significant and unreasonable subsidence to FKC, local canals, pipelines, and other infrastructure were used to establish Subsidence SMCs.
- MTs range up to 7 feet of cumulative subsidence.
- DEID has expressed concern about MTs at their border with PID GSA.

Distribution of Cumulative Land Subsidence Minimum Thresholds



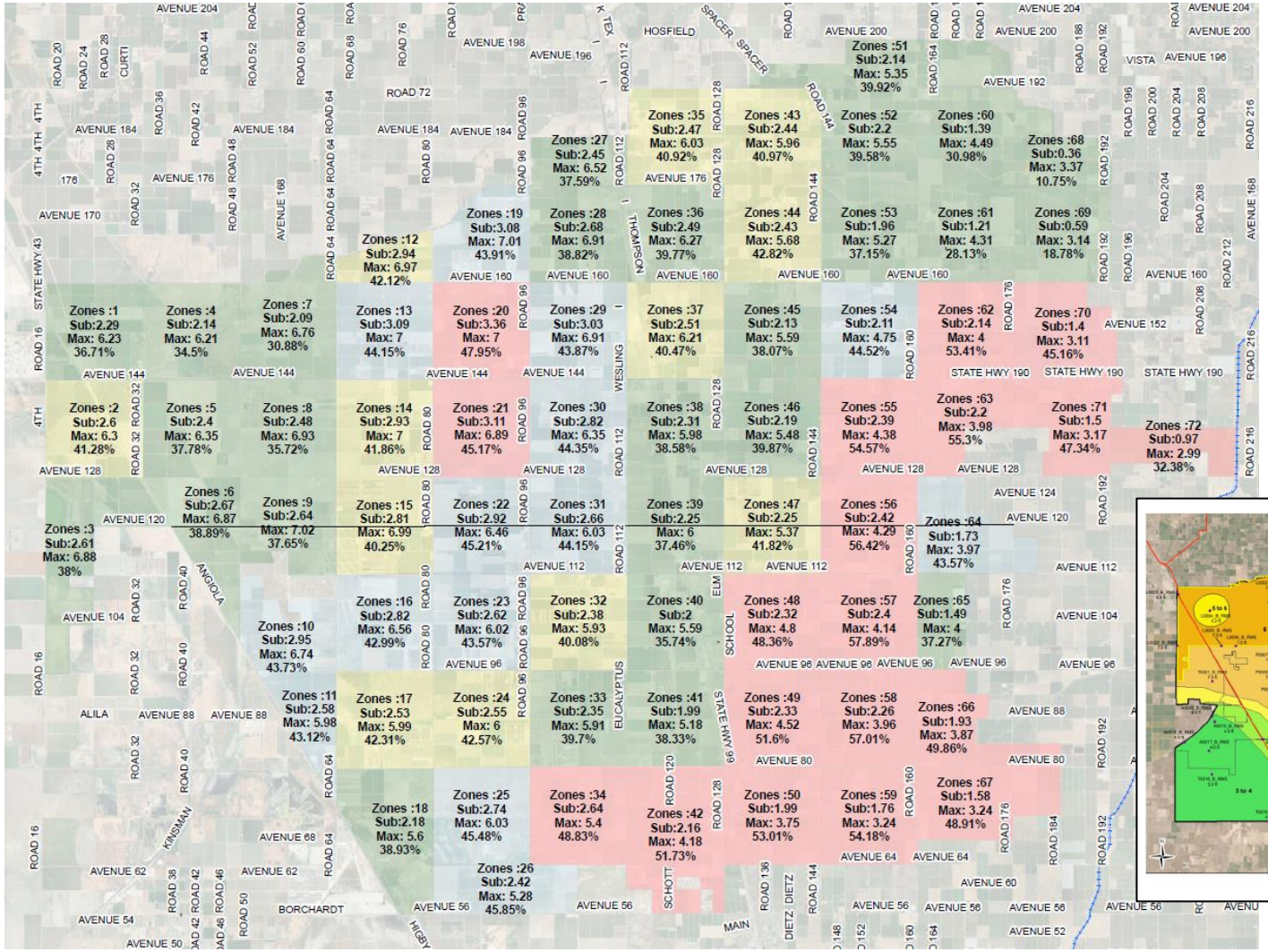
Minimum Threshold values relative to 2020.

*The preliminary buffer zone has been identified as an area where focused projects and management actions are needed to avoid land subsidence in the zone that could impact DEID pipelines. The zone is preliminary because the data and analysis needed to define the extent as well as the projects and management actions needed to protect DEID pipelines are not available at this time (this is a data gap). In the meantime, the GSAs are coordinating to implement more frequent land subsidence monitoring as well as implementing a land subsidence management plan to avoid impacts to DEID's pipelines until the analysis can be completed.

Figure 3-9. Cumulative land subsidence minimum thresholds.

LAND SUBSIDENCE HIGH RISK SMMZs – LTRID/PID

GSAs designate zones based on percentage of MT used up to date, and base management actions on degree of risk.



LTRID/PID SUBSIDENCE MITIGATION PLAN

- Landowner Regulatory Actions
  - The High Risk SMMZs identified in October 2024 required to register and meter wells *by January 2025*.
  - GSAs decided to categorize all zones as high-risk and plans to phase in metering *by end of 2025*.
- District Actions
  - Focus surface water deliveries, recharge projects and land fallowing in specific zones.
  - Initiate aquifer storage and recovery projects for the Deep Aquifer.
  - Mitigate impacts to key infrastructure.
  - Implement Corrective Subsidence Management Order if subsidence thresholds are surpassed – ***additional reductions in pumping***.
  - GSAs will notify well owners within 30 days if it is determined that their well(s) are driving exceedances.

DEID'S REVISED 2024 GSP

- DEID asserts it is the only GSA in the Subbasin that is a net recharger of groundwater and does not contribute to:
  - Declines in storage/groundwater levels.
  - Land subsidence.
- DEID has invested heavily in infrastructure (surface water distribution system and recharge facilities).
- DEID identified its at-risk pipelines by comparing current static pressure heads to the pipelines' rated pressures. Where static pressure heads exceed rated pressures, pipelines are at risk for failure.
- DEID asserts that negative impacts due to subsidence result from overdraft pumping in adjacent GSAs (e.g., PID).

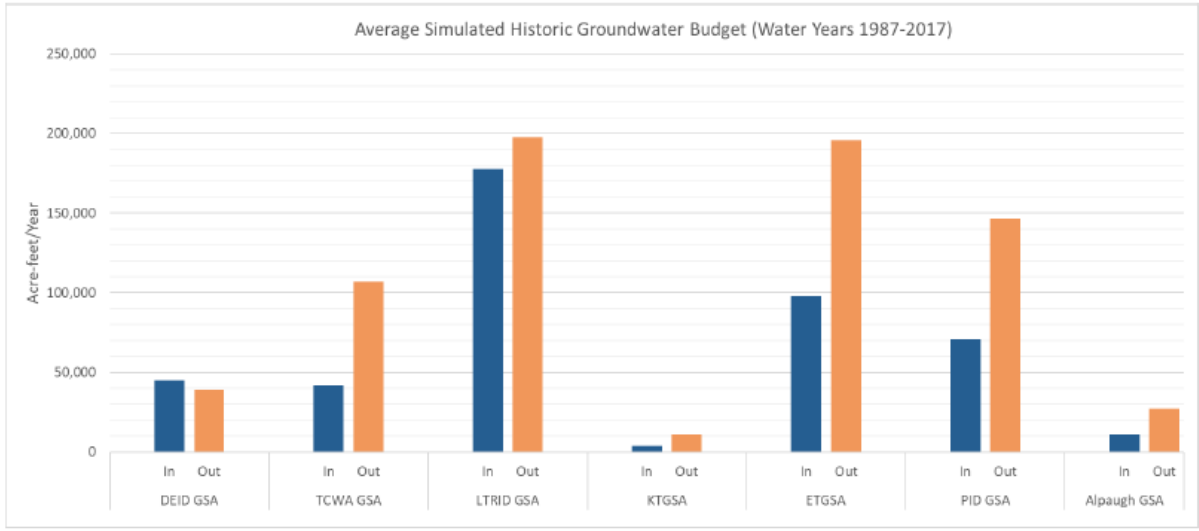


Figure 0-8: The groundwater budget for the Tule Subbasin from 1987 – 2017 shows that DEID is the only GSA in a net-positive position

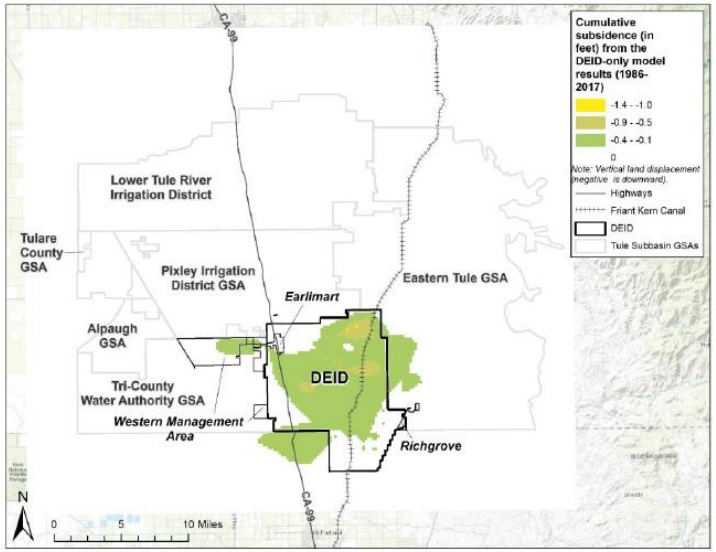


Figure 0-16: Model results show only minimal subsidence (less than 1 foot) is attributable to DEID during 1986 – 2017

RELATED SUBBASIN EFFORTS

- Pursuing exit from SWRCB probationary status.
- 2025 Subsidence Study to look at apportionment of subsidence impacts within DEID.
- 2025-2026 Subbasin-wide model update.
- On-going SGMA implementation.

EKI'S ROLE

- Providing technical support for LTRID/PID on Tule Subbasin efforts.
- Providing technical support for implementation of the LTRID/PID Subsidence Management Plan.
- Initial steps EKI plans to take include:
  - Review of the existing Subbasin groundwater flow model.
  - Conduct evaluation of conditions in LTRID/PID – refine understanding of where low-permeability materials exist relative to production wells/pumping centers and critical infrastructure.
  - Evaluation of possible District actions – assess the specifics of proposed actions to determine if they will effectively address subsidence in PID/LTRID.

TAKEAWAYS

- Subsidence is a critical focus of SGMA.
- SWRCB expects significant commitments toward eliminating subsidence to avoid probation/fees.
- While focus has been on ETGSA, the lense is expanding to PID and LTRID.
- Other GSAs (e.g., DEID) are also focused on subsidence impacts caused by PID/LTRID.
- LTRID/PID GSAs/GSPs have made significant commitments to address subsidence.
- Expect that significant action will be needed to address/minimize subsidence.
- Your input and participation will be critical to local and Subbasin success.

QUESTIONS

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35 Years Making an Impact