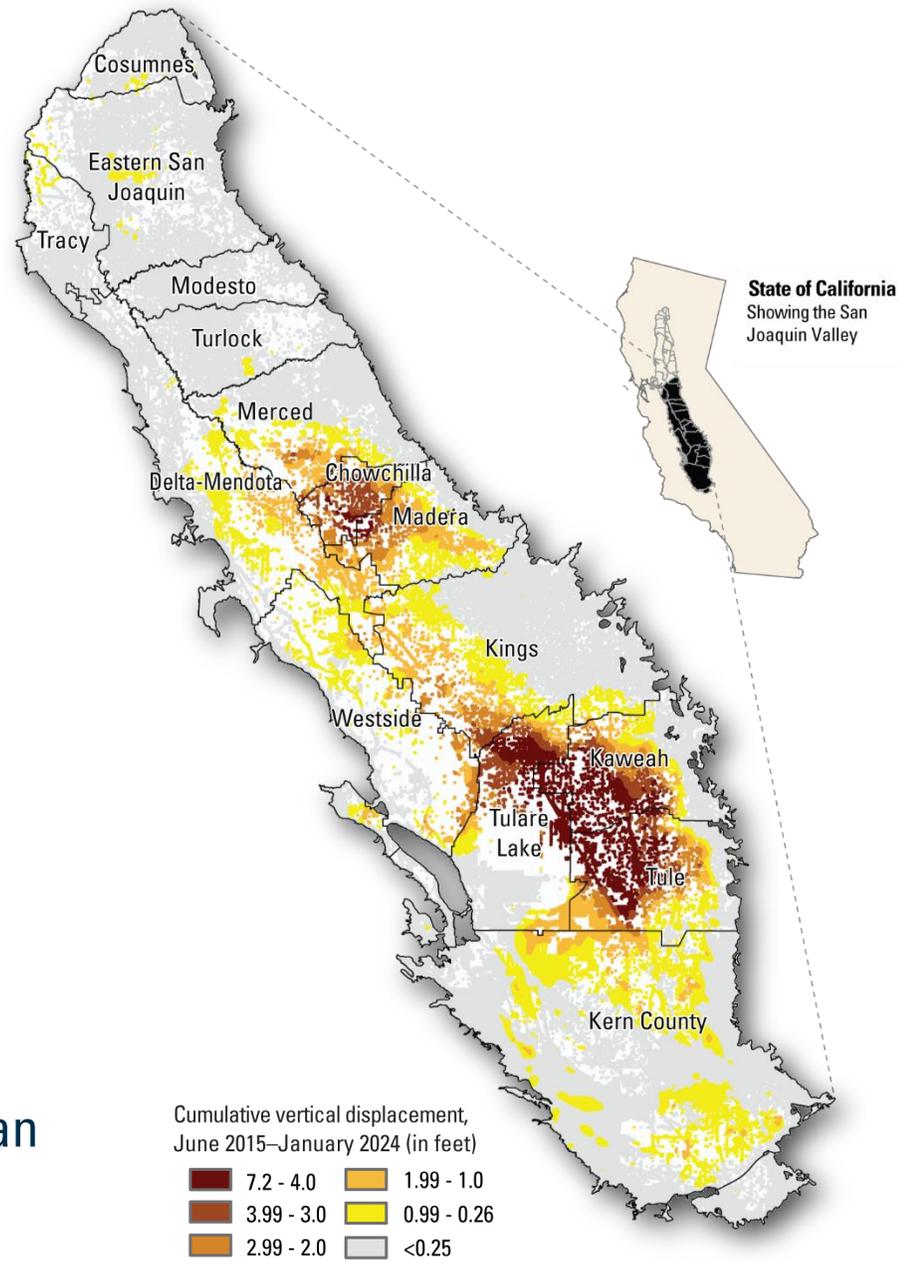


# Looking Back to Look Forward:

## What Happens if We Don't Manage Water Levels?

Leila Saberi

with collaborators John Ellis, Jeremy White, Marisa Earll, Spencer Jordan



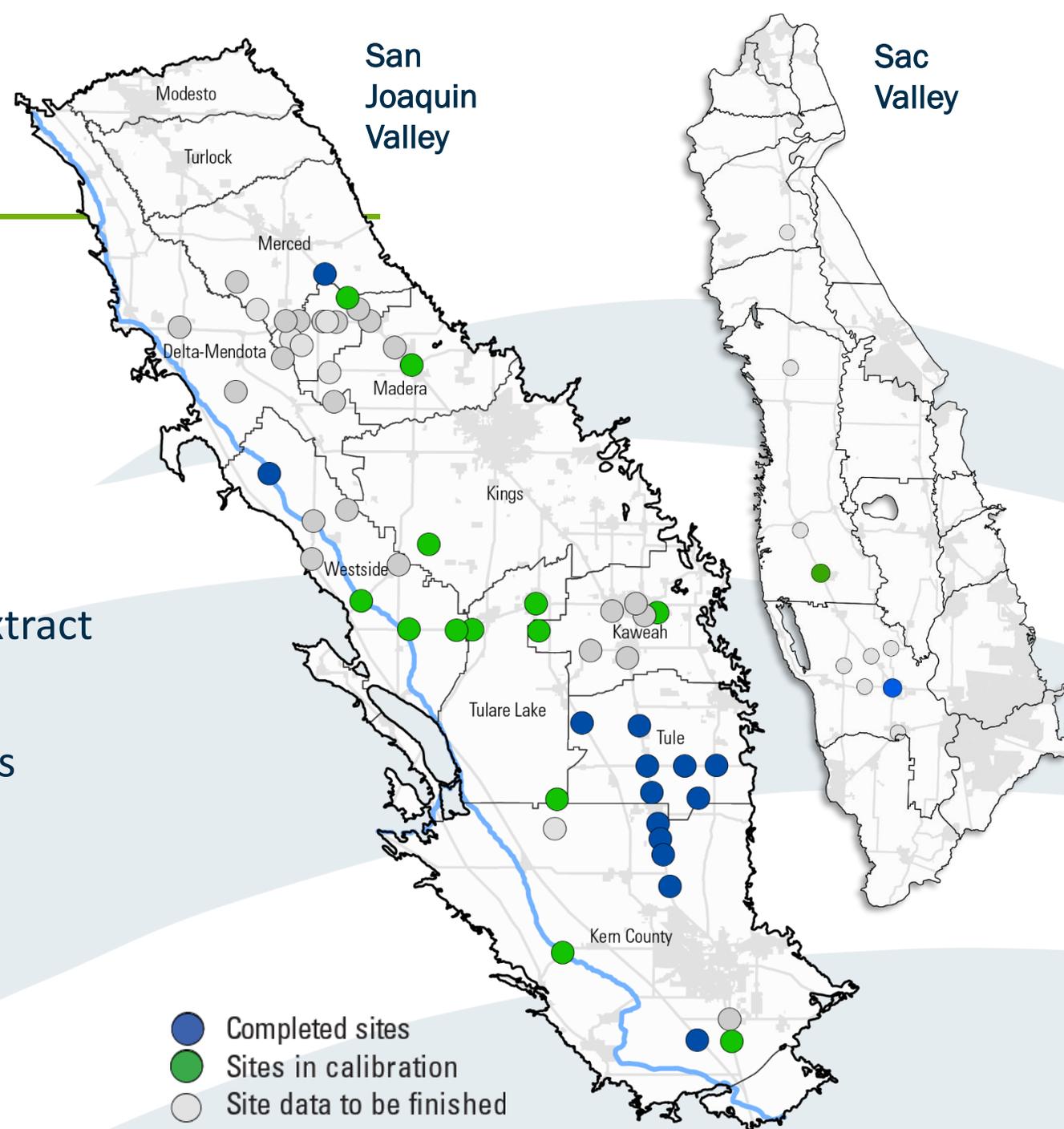
# Workflow

## Data Collection and Analysis

- Subsidence Data
- Water Level Data

## Modeling

- Calibrate models to long-term data and extract critical head from the subsidence package
- Run a range of scenarios on the 1D models



# Modeling Approaches

---

## Integrated Modeling (3D Regional Models)

- Central Valley Hydrologic Model (CVHM2)
  - MODFLOW-OWHM – SUB Package
  - Head-Based Formulations
- California Central Valley Groundwater-Surface Water Simulation Model (C2VSim)
  - IWFM-based
  - Delay bed added to version 5, not tested though

## 1D Modeling

- Focused, vertical-only analysis
- Both Head-Based and Effective-Based Formulations
- Can be standardized across multiple locations

# Model Parameterization

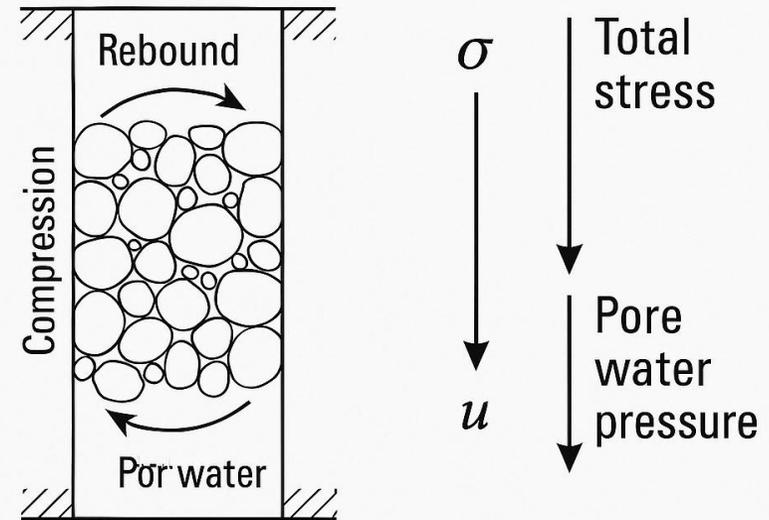
Terzaghi theory of 1D vertical compaction

$$\uparrow \sigma' = \sigma - u \downarrow$$

where:

- $\sigma'$  = effective stress
- $\sigma$  = total stress =  $\rho_b g z$
- $u$  = pore water pressure =  $\rho_w g h$

## Terzaghi's theory



$$\sigma = \gamma z$$

Total stress

$$u = \gamma_w z$$

Pore water pressure

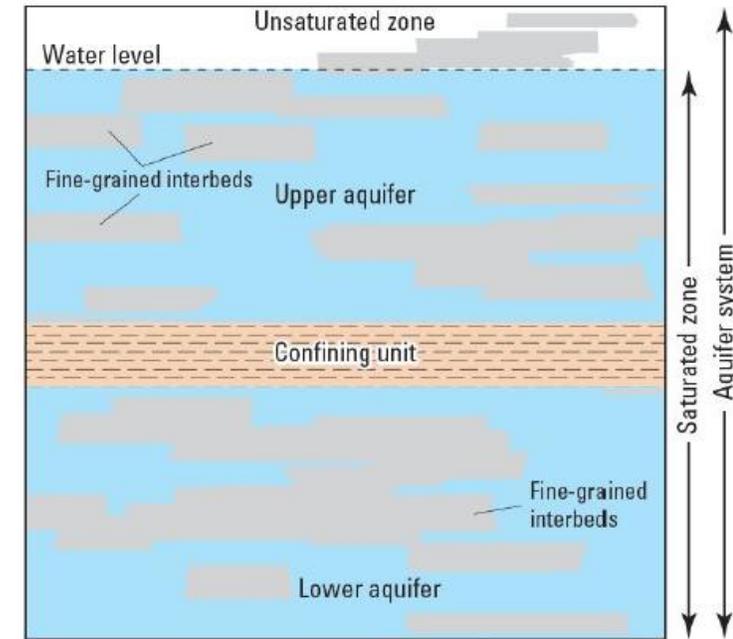
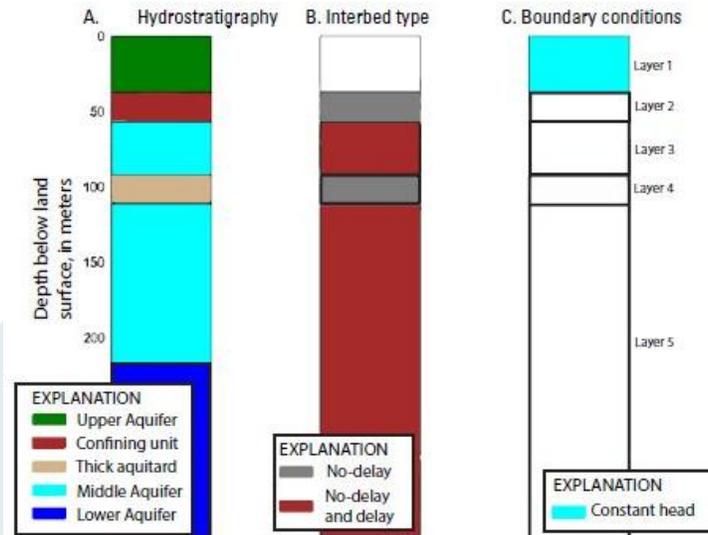
# MODFLOW6 (MF6) + CSUB Package

## MODFLOW 6

- Simulating head

## CSUB Package

- Instantaneous subsidence (layer 1)
- Delayed subsidence (remaining layers)
- Simulates elastic and inelastic subsidence
- Tracks compaction by layer
- Tracks pre-consolidation head



From Hughes and others (2022)

# Model Inputs & Conceptualization

- Lithology:
  - Aquifer/Aquitard thickness and % clay content

- Observed Groundwater Levels

- Pre-consolidation Head

Elastic subsidence:  $\sigma' >$  Pre-consolidation Stress

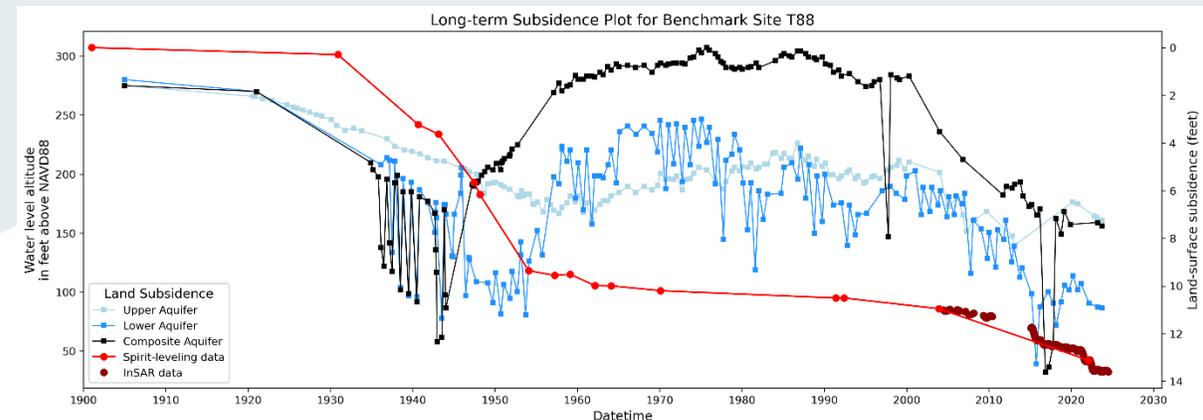
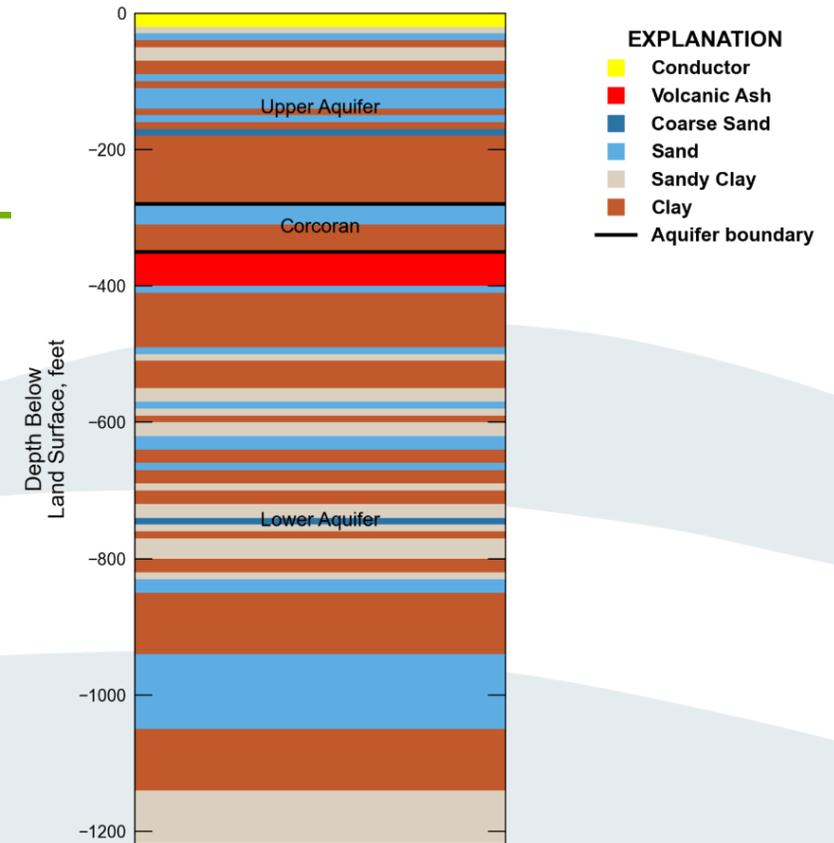
In-elastic subsidence:  $\sigma' <$  Pre-consolidation Stress

- GHBs

- Added noise (std: 15ft)
- 5 ft offset

- Cumulative subsidence time-series

- Leveling, InSAR, extensometer, GPS
  - Added noise (std 0.15 to 0.05 ft)



# Model Workflow—Calibration

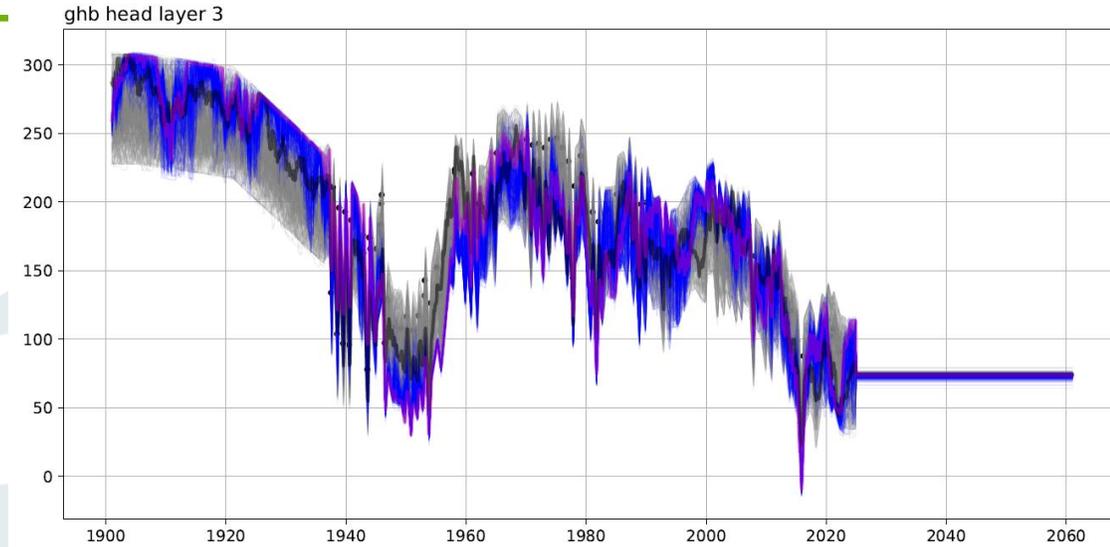
## PEST Interface Setup

### CSUB Properties:

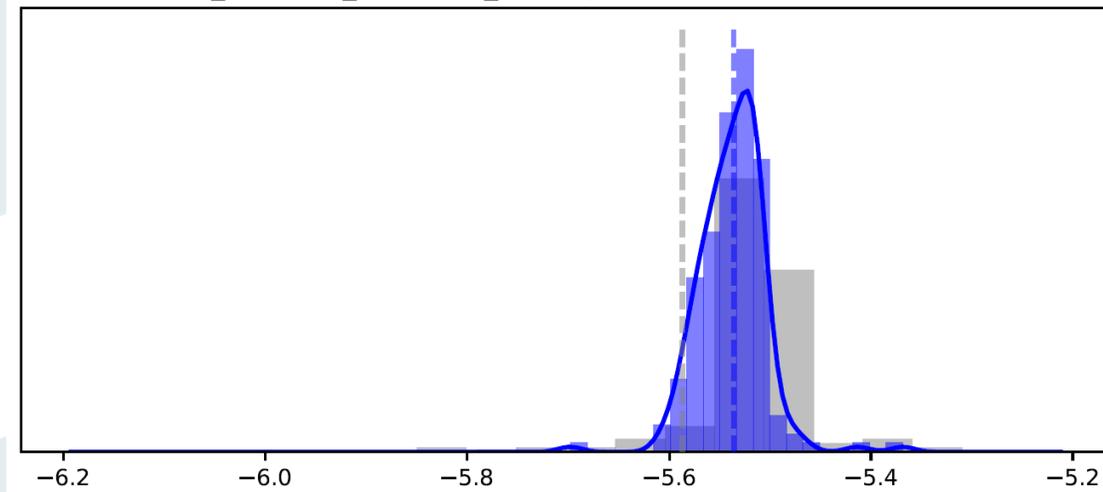
- Pre-consolidation head
  - SSV
  - SSE
  - Porosity
  - Interbed Kv
- Number of clay beds
- Thickness of each bed

### GWF Properties:

- Kh
- Kv
- SS
- GHB

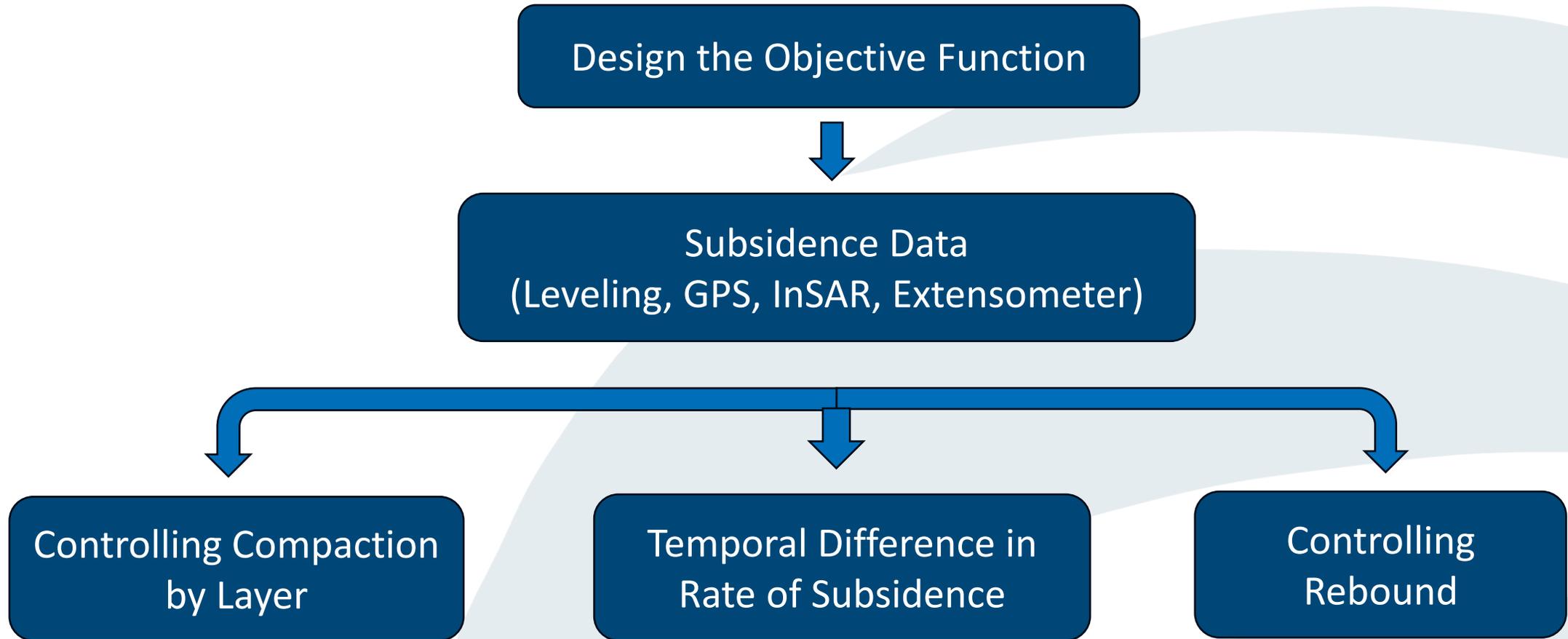


oname:listobs\_otype:lst\_usecol:kv\_k:2 (log10)



# Model Workflow—Calibration

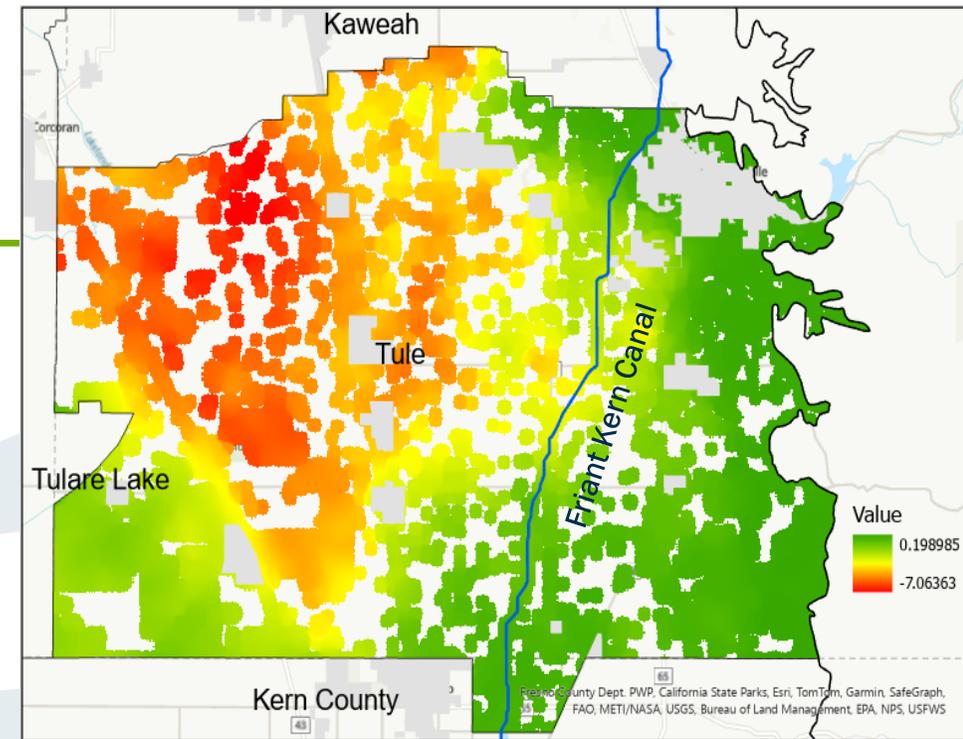
---



# Subsidence in Tule Subbasin

## Focus area: Tule subbasin

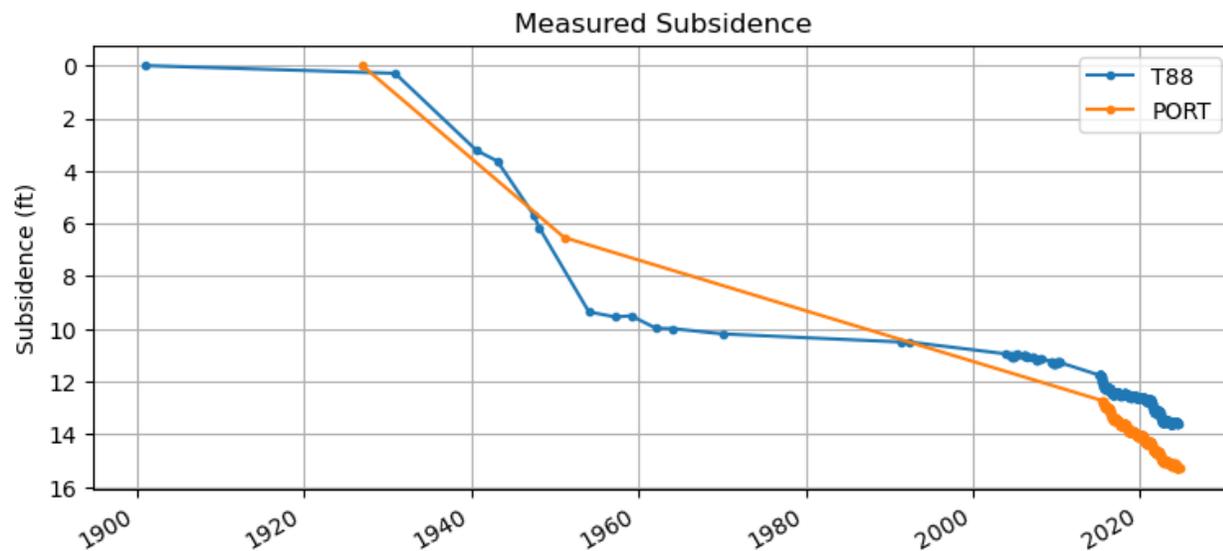
- Under SGMA, the Tule Subbasin is classified as a critically overdrafted basin.
- The Tule Subbasin has experienced some of the fastest rates of subsidence in the Central Valley, with areas sinking over 1 foot per year in recent years.
  - Cumulative subsidence since the 1920s has exceeded 20 to 28 feet in some locations.
- Subsidence has significantly affected the Friant-Kern Canal (FKC), a critical water delivery system in the region:
  - The canal has lost 60% of its carrying capacity due to deformation caused by subsidence.



# Subsidence in Tule Subbasin

## Subsidence: critical infrastructure impacts

- About 15 feet of subsidence at sites PORT and T88
- Friant-Kern Canal conveyance reduced substantially due to subsidence
- Newly constructed canal segments subsiding more rapidly than planned due to sustained water level declines



# Take away

---

- What happens if we don't manage water levels?

**Subsidence doesn't wait.**

**Without intervention, we sink – and we sink fast in some areas**

# Thank You!

---

Leila Saberi

[Lsaberi@INTERA.com](mailto:Lsaberi@INTERA.com)