Extrapolating Subsidence Temporally and Spatially from 1D Models

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Acknowledgements

- Kaweah Subbasin Groundwater Sustainability Agencies
- Stanford University Geophysics Dept – Matthew Lees, Rosemary Knight

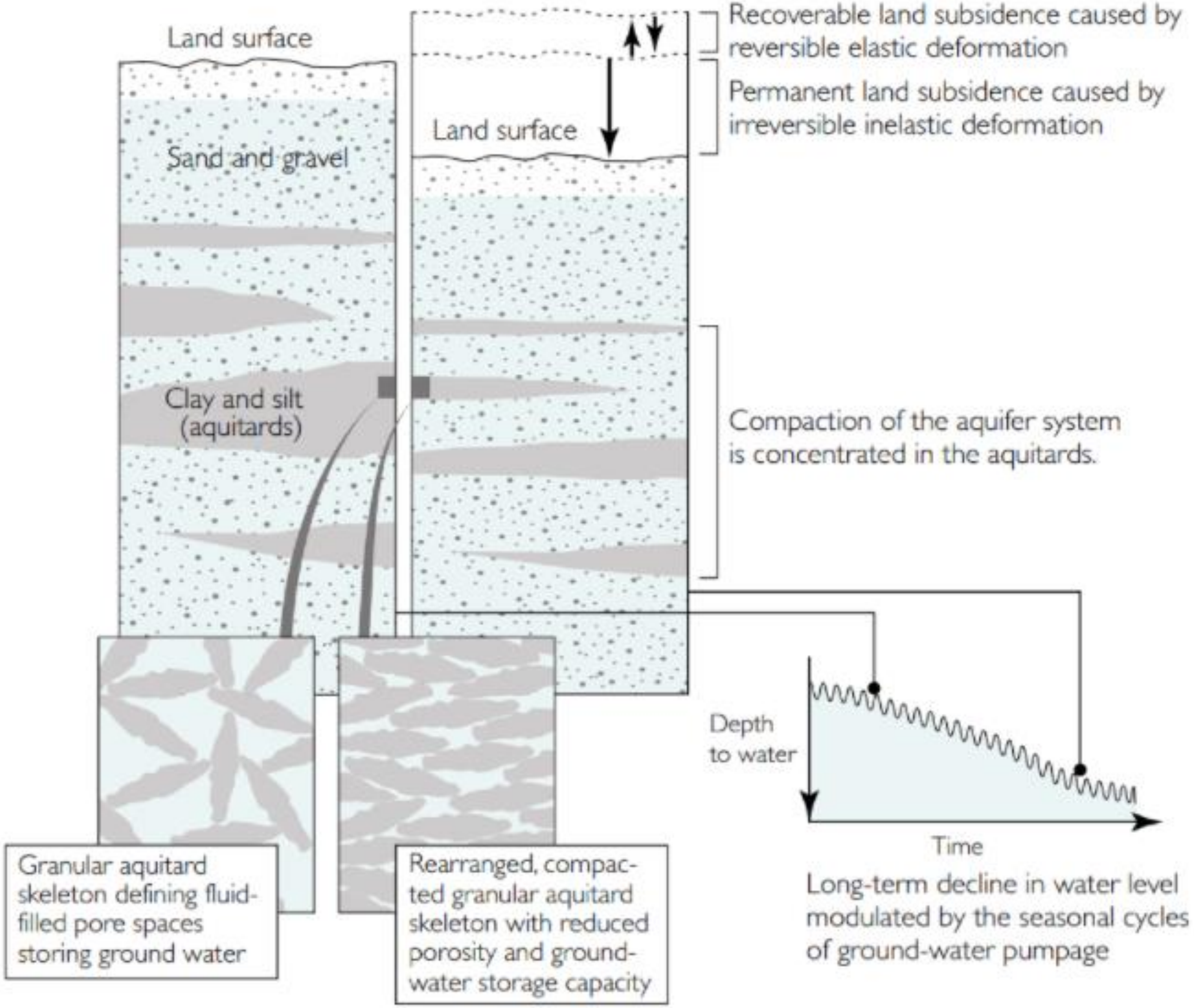
Presentation Overview

- Provide study background
- Introduce Stanford 1D subsidence model
- Show steps to develop and calibrate spreadsheet tool
- Demonstrate how tool is used to evaluate potential subsidence impacts
- Summarize next steps for further study

Background

Subsidence Background

- Groundwater overdraft and clay compaction is the primary cause of subsidence in Central Valley
- Some subsidence is instantaneous
  - Elastic subsidence is reversible
  - Inelastic subsidence is permanent
- Residual subsidence can occur long after overdraft due to gradual head decline in low conductivity clays

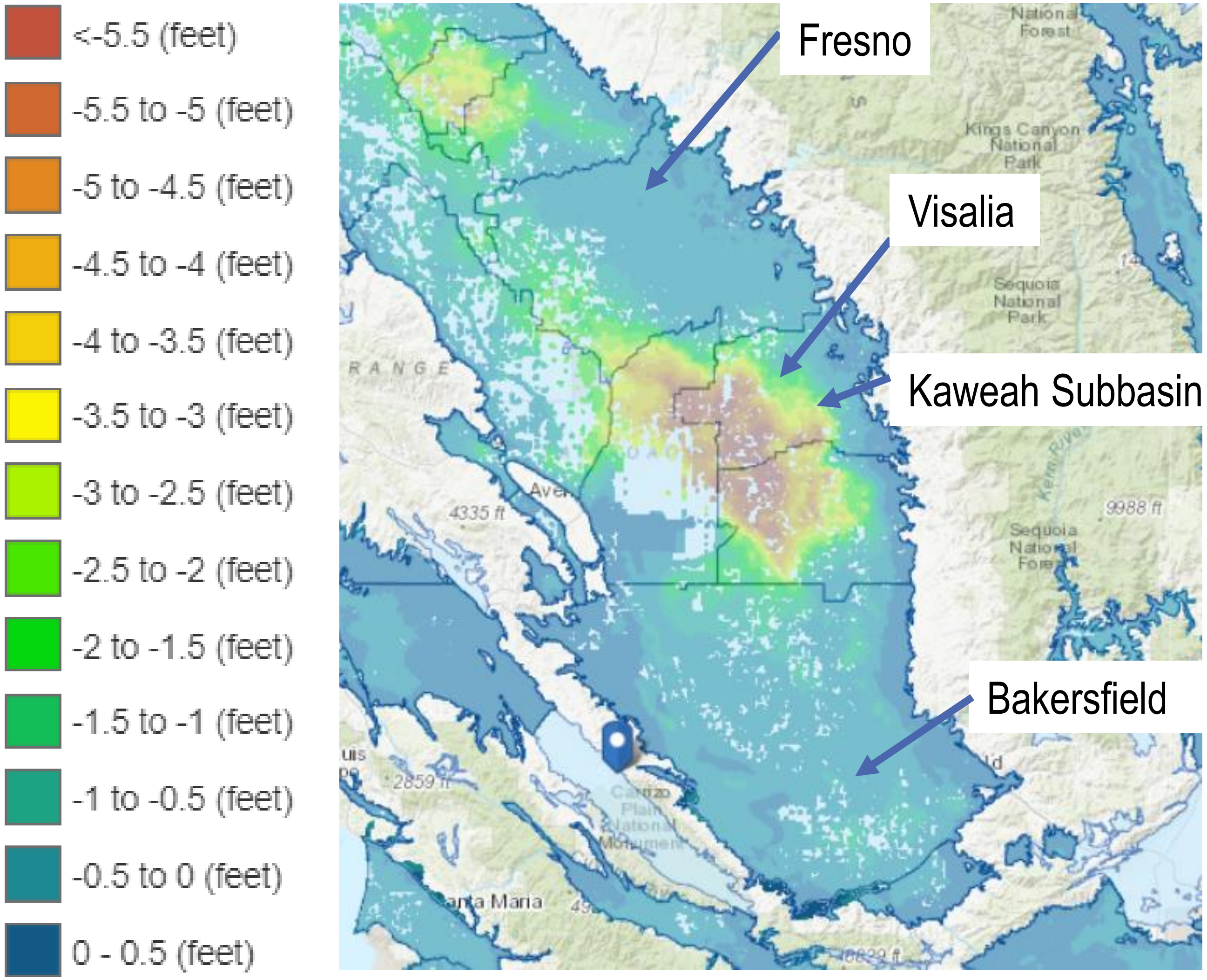


https://www.usgs.gov/media/images/aquifer-compaction

Project Background

- Kaweah Subbasin subsidence impacts analysis for 2022 GSP Revision
    - Groundwater model with subsidence package not developed yet
    - 1D compaction models for 2 sites prepared by Stanford
    - Extrapolated 1D results using spreadsheet curve fitting approach to develop SMC

2015 to 2023 Cumulative InSAR Subsidence



1D Compaction Model

Stanford 1D Compaction Model Development

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ARTICLE

Development and Application of a 1D Compaction Model to Understand 65 Years of Subsidence in the San Joaquin Valley

View article page

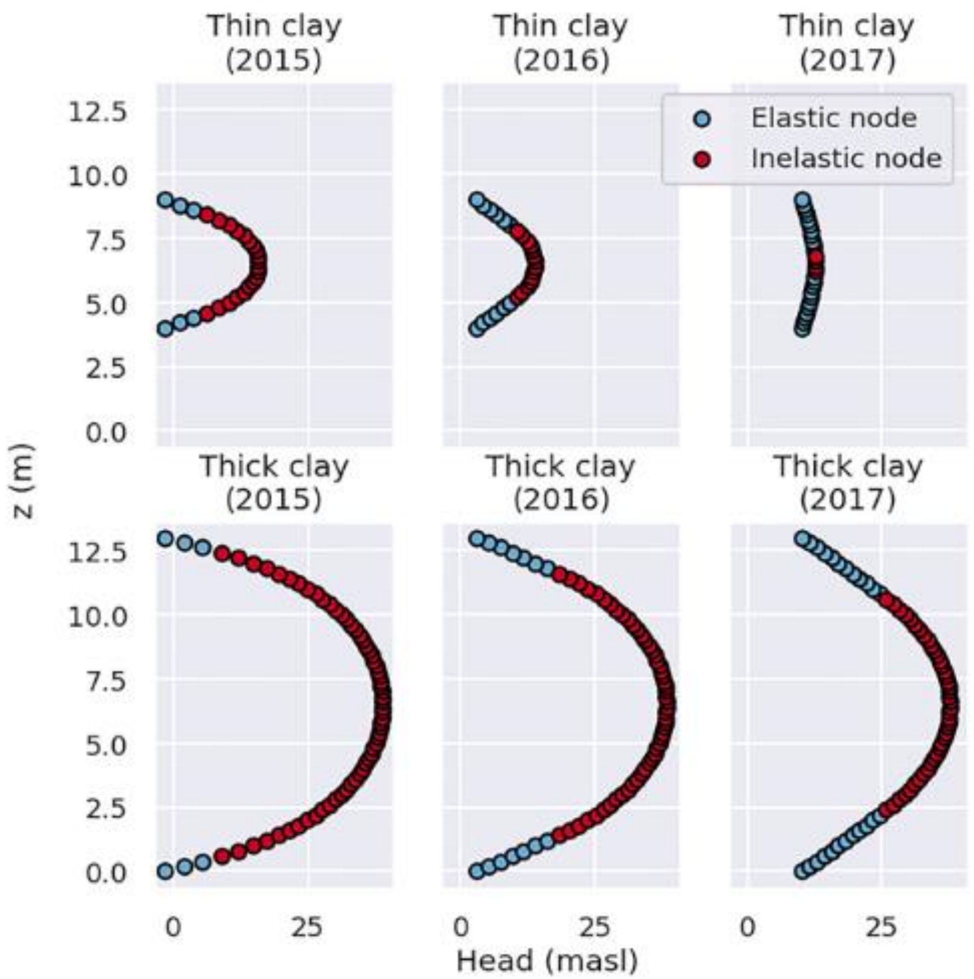
Matthew Lees, Rosemary Knight, Ryan Smith

https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2021WR031390

- 1D compaction model simulates subsidence based on head and aquifer properties
- Calibrated using historical groundwater and subsidence data from 1954-2017
- Models for 2 sites in San Joaquin Valley
- Published results for 1 site (South Hanford) in Water Resources Research

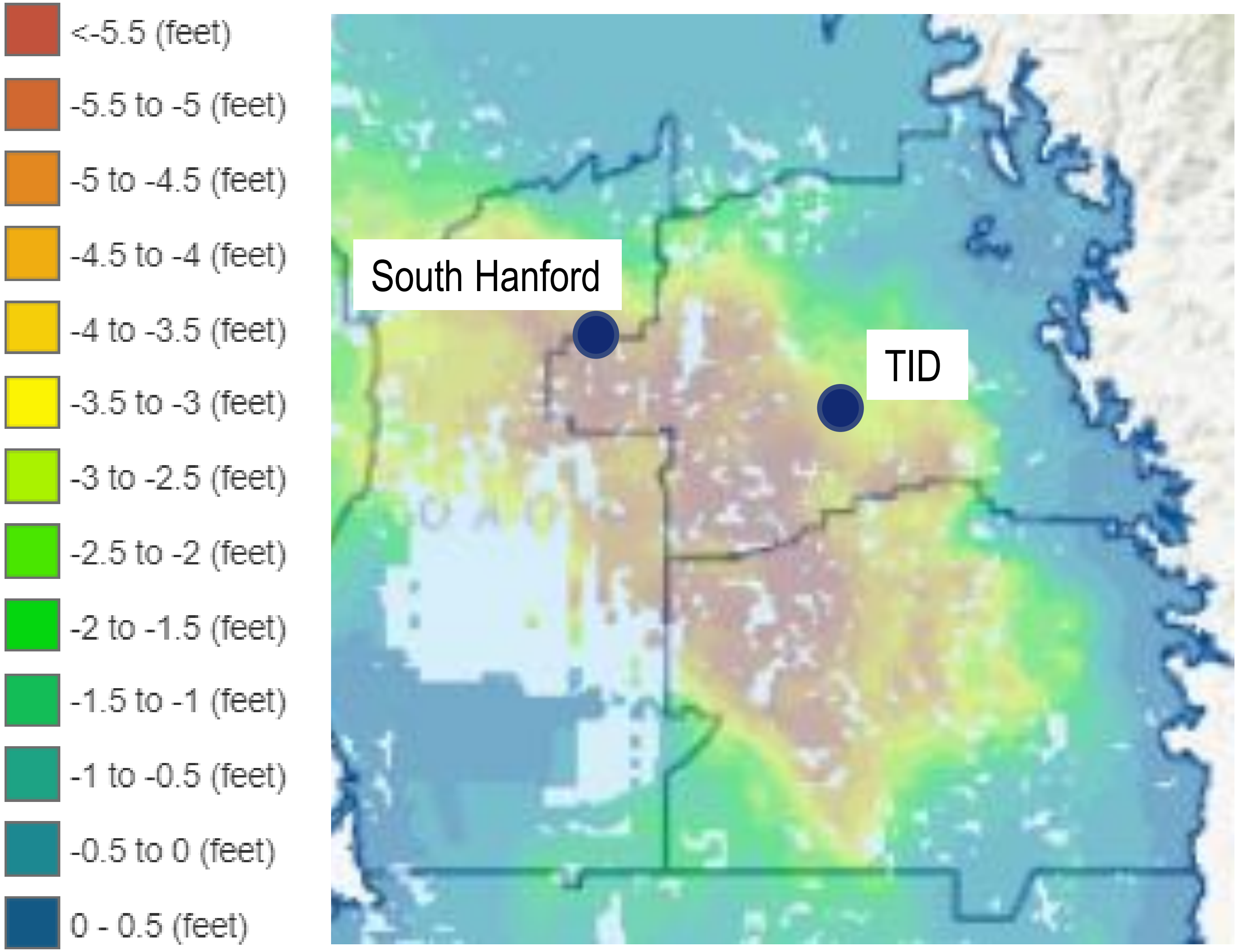
1D Model Main Takeaways

- Most subsidence (~90%) related to lowering groundwater levels below Corcoran Clay
- Subsidence occurs in Corcoran Clay and other thick clay layers below
- Residual subsidence is important and can take more than 50 years to equilibrate



1D Model Application for Kaweah Subbasin 2022 GSP Revisions

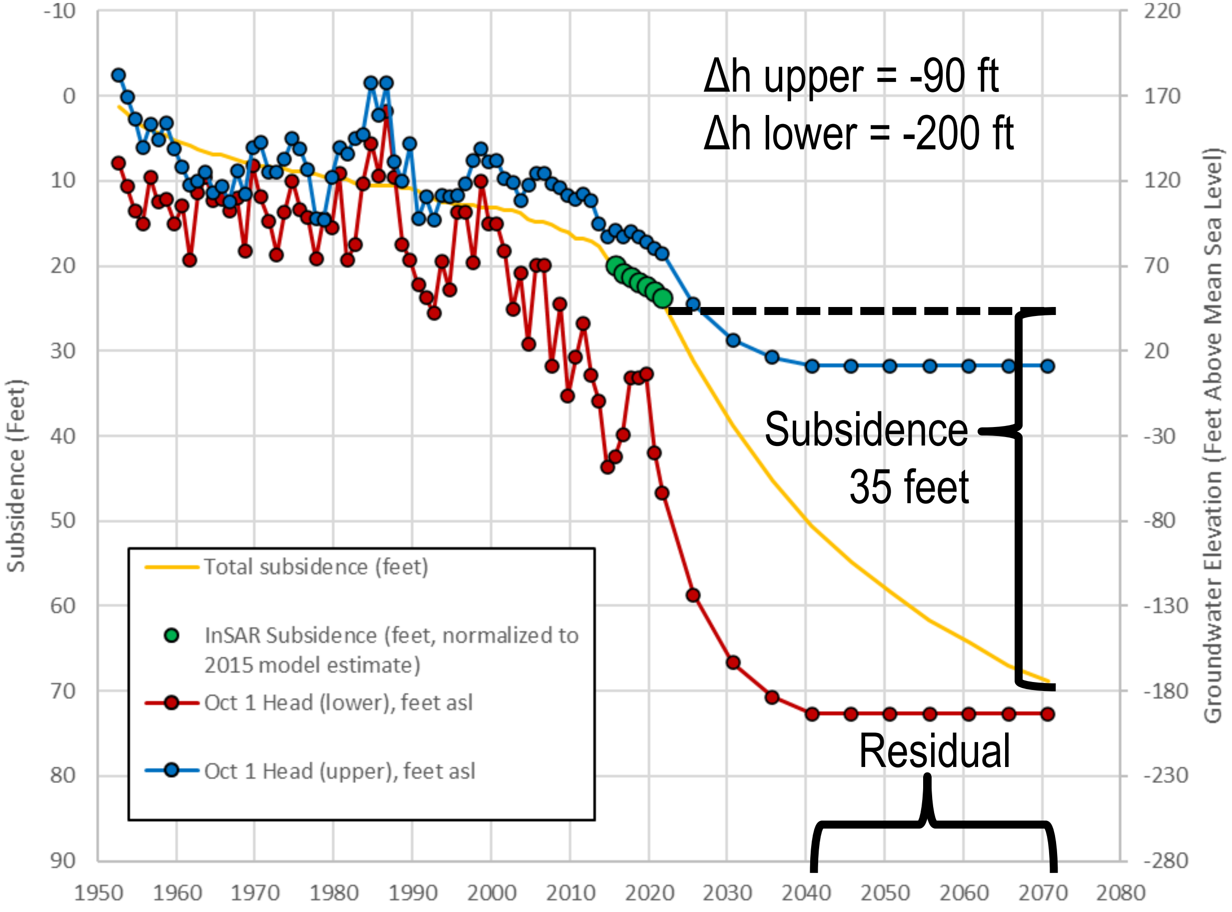
1D Model Locations on 2015-2023 InSAR Map



- Ran 1D models forward to project subsidence at groundwater level sustainable management criteria

Projected Subsidence at Groundwater Level Minimum Thresholds

South Hanford



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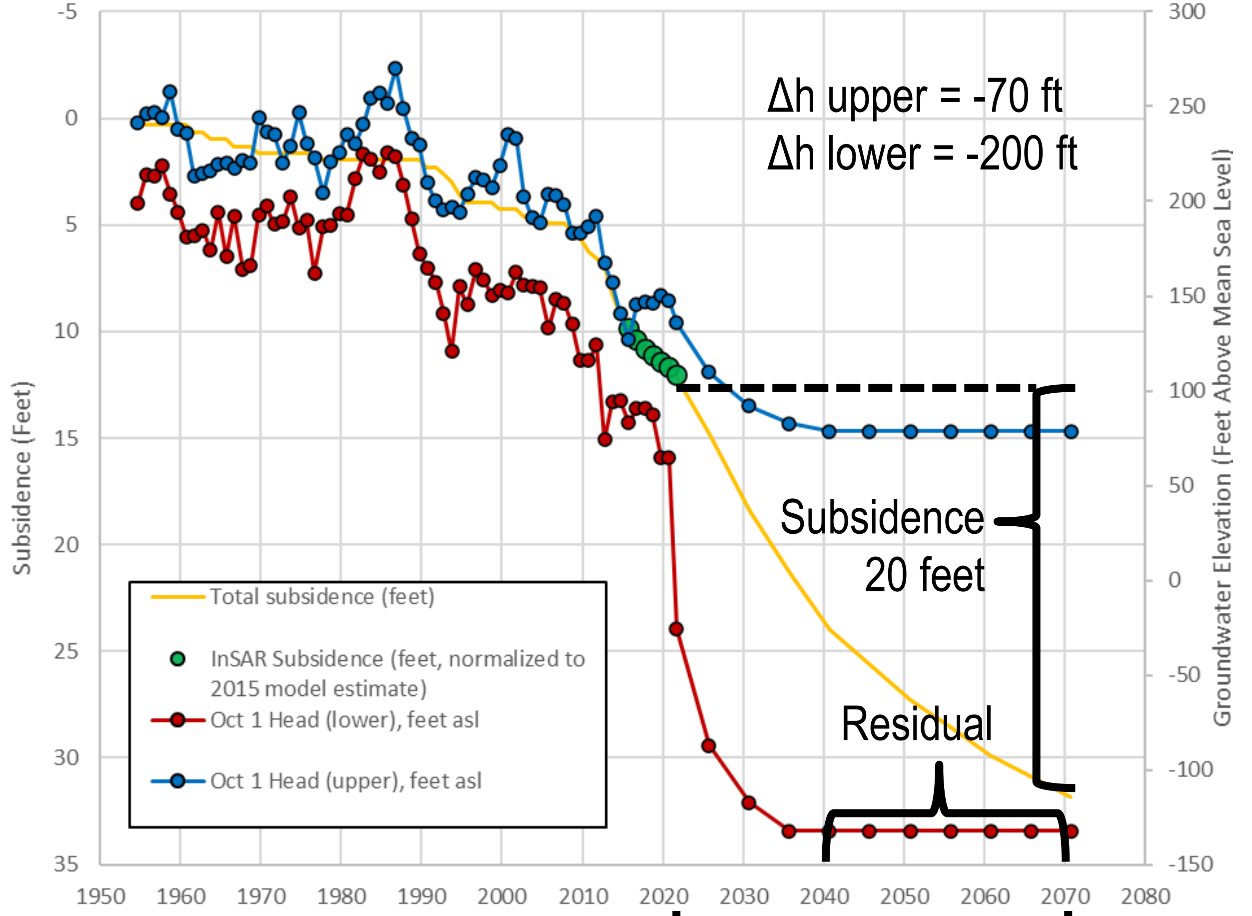


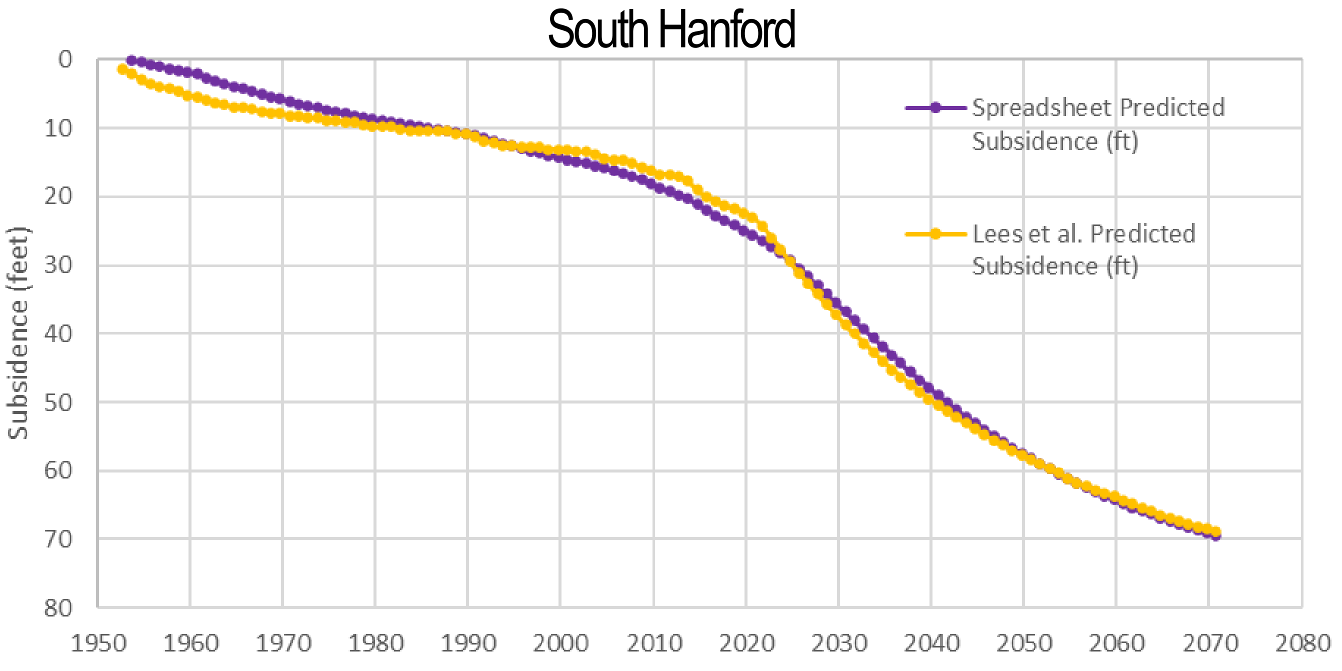
50 year GSP planning and implementation horizon

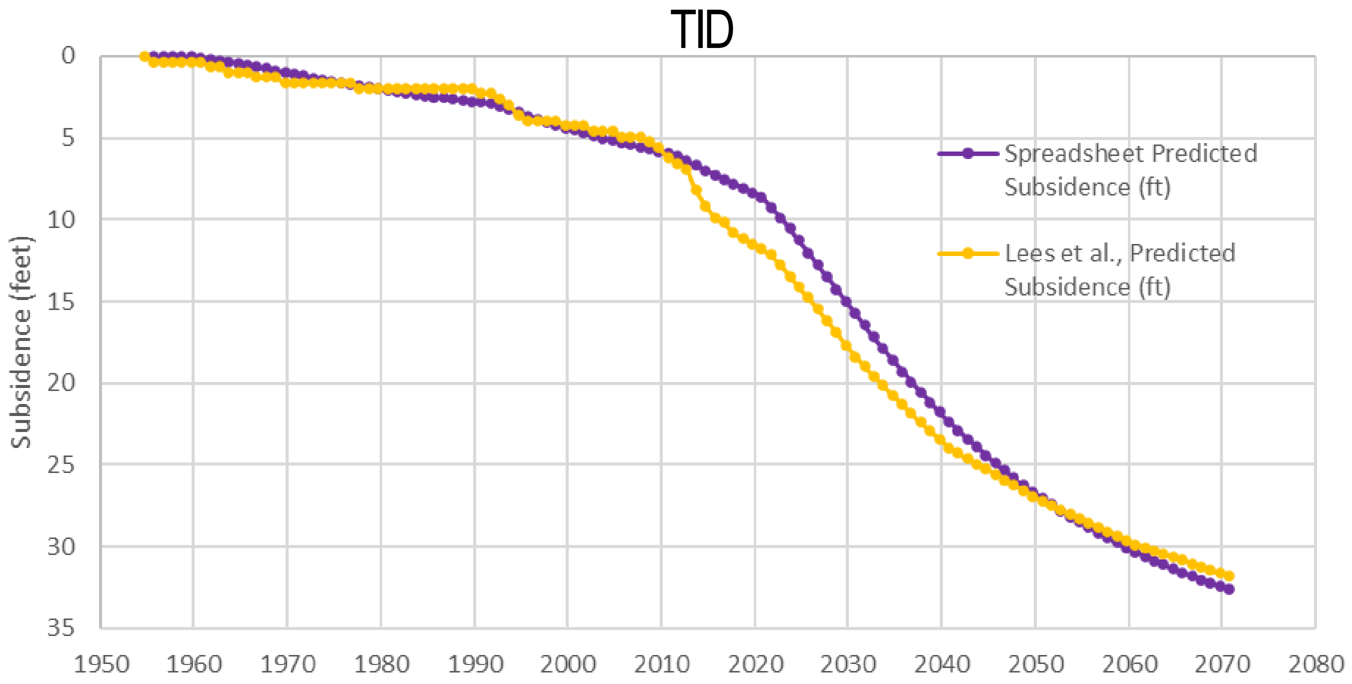
50 years

Spreadsheet Tool to Extrapolate 1D Model Results

Spreadsheet Tool Development

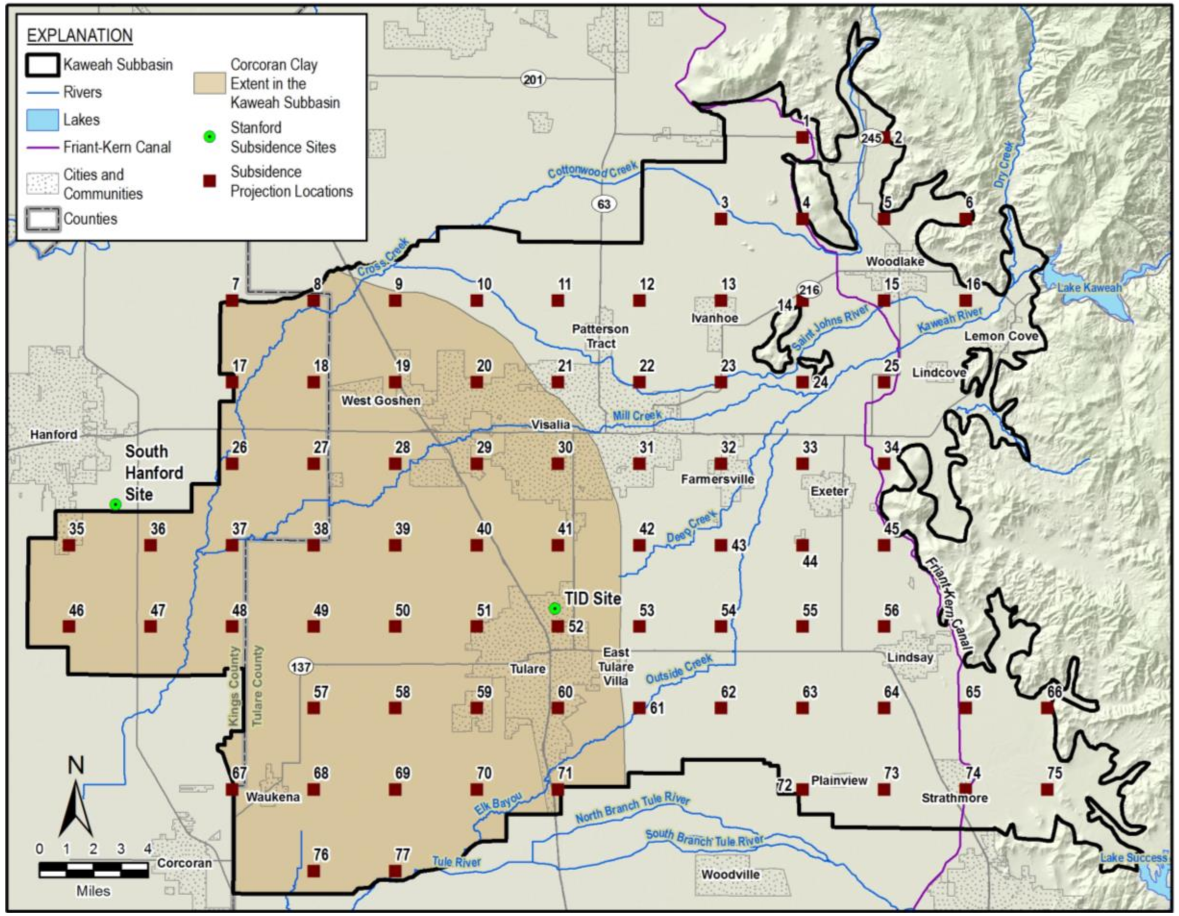
- Created simplified set of equations, inputs, and parameters in Excel spreadsheet to fit the 1D model results
- Inputs - variable
  - Groundwater levels above and below Corcoran Clay
  - Clay thickness from geophysical logs
- Parameters - constant
  - Active subsidence as proportion of overdraft
  - Residual subsidence tailing
  - Unique scaling factors for depths above and below Corcoran Clay





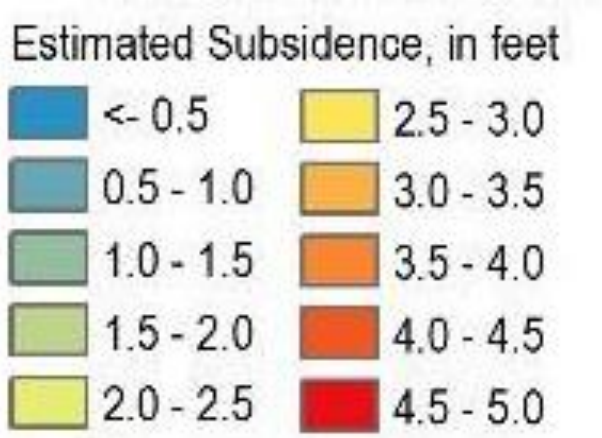
Estimating Subsidence Spatially

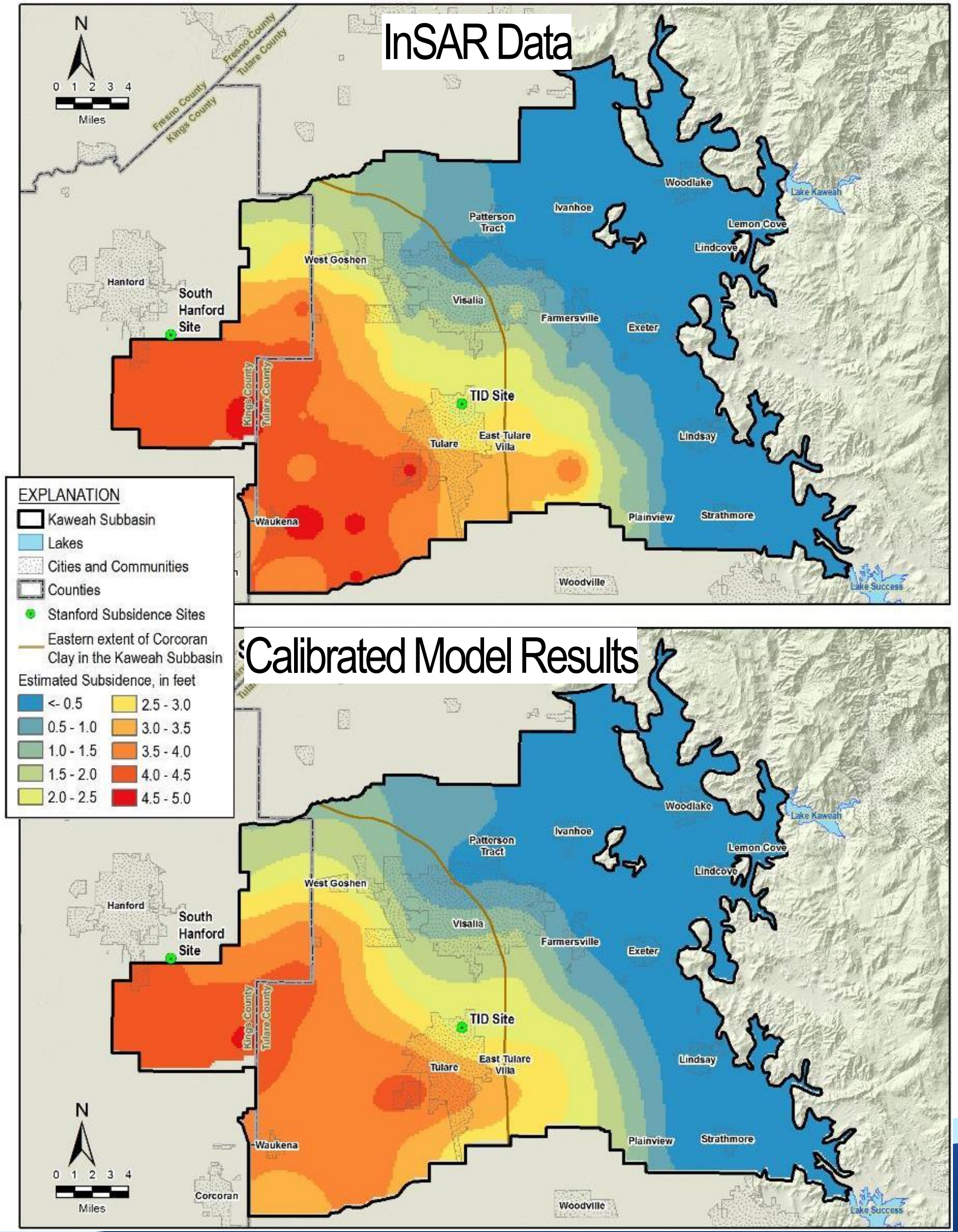
- 1D to 2D extrapolation (77 points at 2 mi spacing)
- Estimated subsidence at each point
  - Governing equations
  - Historical groundwater levels from subbasin groundwater model and management criteria (MT and MO)
  - Approximate clay thickness from CVHM
- Interpolated subsidence results in GIS



Calibrating Spreadsheet Clay Thickness Using InSAR Data

- Used 2015-2021 subsidence data from InSAR to calibrate spreadsheet grid
- Calibrated input - clay thickness





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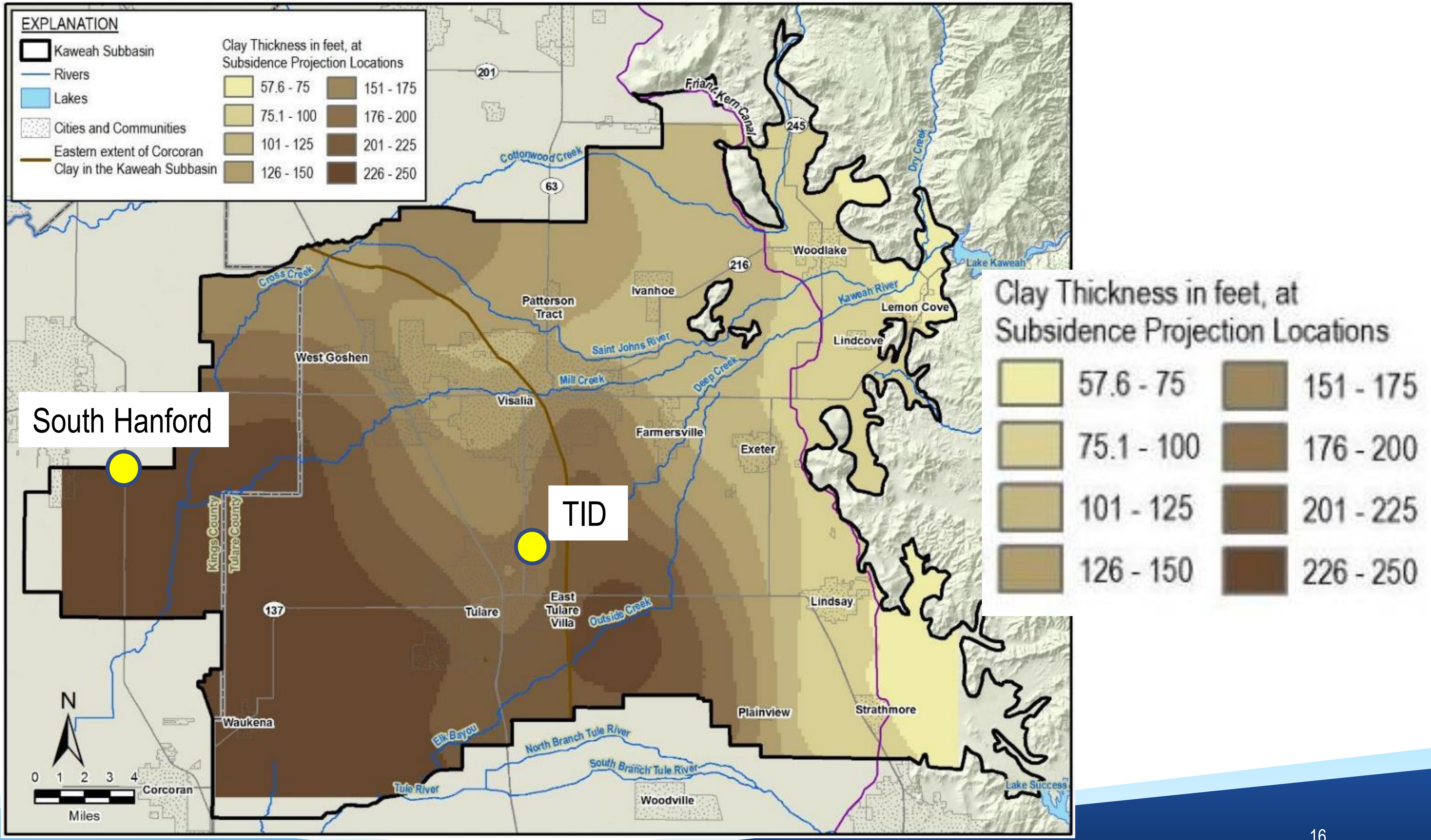
Calibrated Clay Thickness



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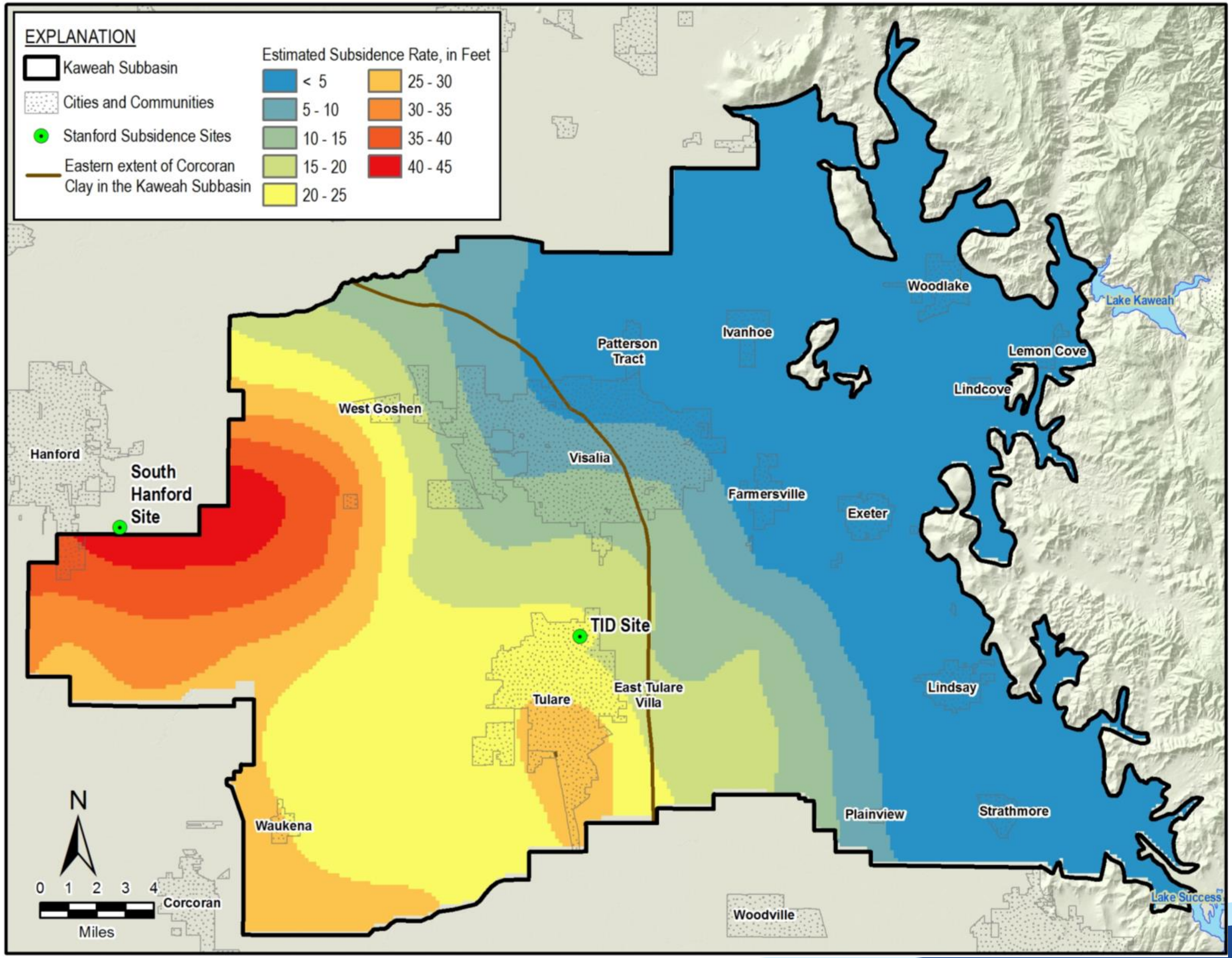
Analyzing Subsidence Results

Subsidence at Groundwater Level Minimum Threshold

- Results show worst case scenario for impacts analysis
- Residual subsidence adds up: >40 feet of total subsidence and >20 feet residual subsidence could occur by 2070
- Clay matters: 0 to 20 feet subsidence projected to east of Corcoran Clay

Projected 2020 to 2070 Subsidence at Minimum Threshold



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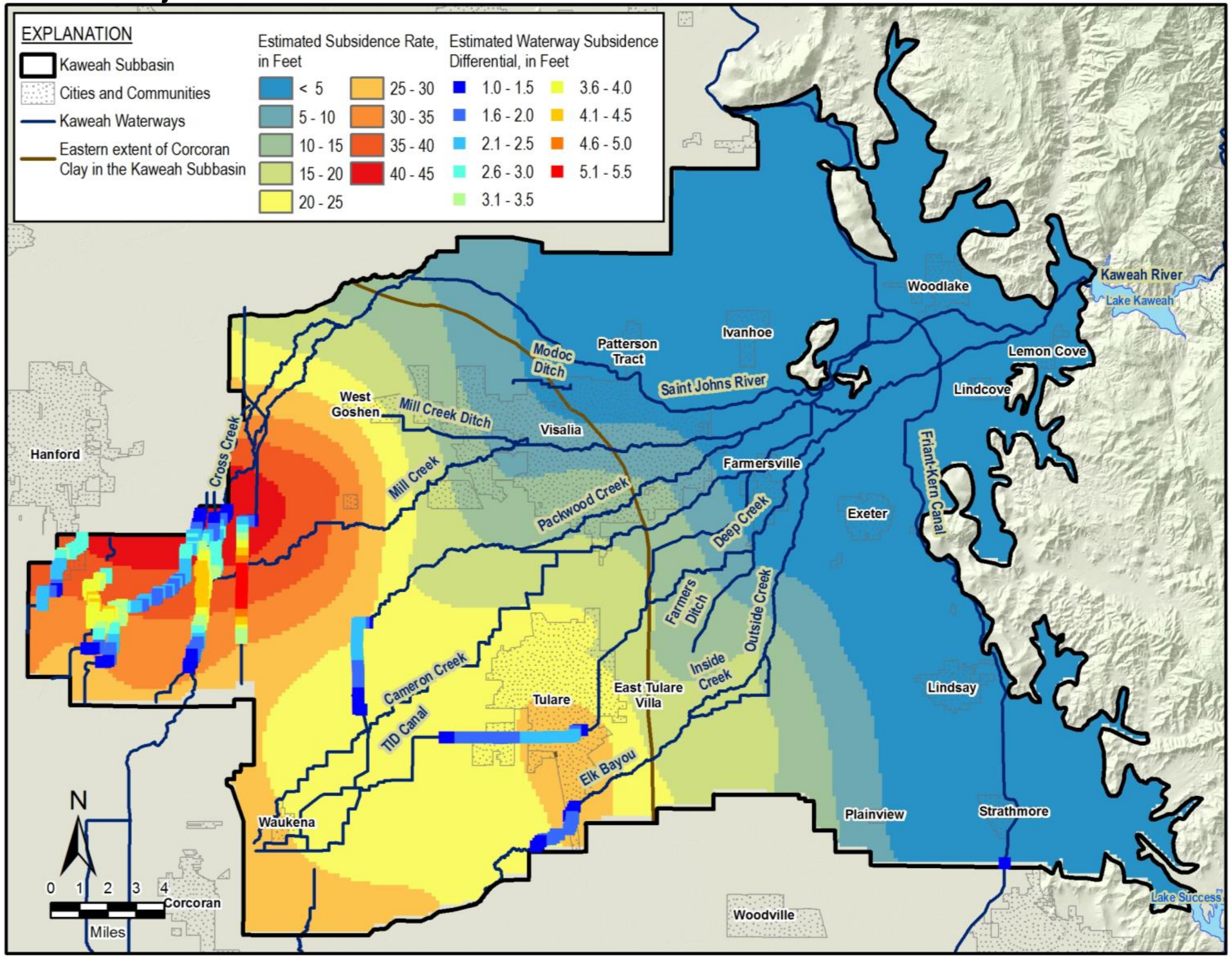
Differential Subsidence Impacts Analysis

- Estimate differential subsidence on canals and waterways
- Significant and unreasonable differential subsidence = 1 ft / 1.5 mile

Projected 2020 to 2070 Differential Subsidence at Minimum Threshold



Estimated Subsidence in Feet		Estimated Waterway Subsidence Differential, in Feet	
< 5	25 - 30	1.0 - 1.5	3.6 - 4.0
5 - 10	30 - 35	1.6 - 2.0	4.1 - 4.5
10 - 15	35 - 40	2.1 - 2.5	4.6 - 5.0
15 - 20	40 - 45	2.6 - 3.0	5.1 - 5.5
20 - 25		3.1 - 3.5	

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Summary and Discussion

Summary

- Developed spreadsheet tool for projecting subsidence using simplified set of equations, inputs, and parameters
- Extrapolated for spatial and temporal analysis
- Calibrated using clay thickness and InSAR observations
- Projected subsidence and locations of infrastructure impacts under various management scenarios and timescales
- Created flexible approach that could be used in other areas with historical groundwater level and subsidence data but no numerical model for subsidence

Discussion and Potential Research Questions

- What is ultimate compaction of compressible clays and will it be reached???
- Does spreadsheet tool work as well to east of Corcoran Clay where not as well constrained with 1D model data???
- Would spreadsheet tool equations work outside of San Joaquin Valley???
- How does the spreadsheet calibrated clay compare to AEM data???
- How does the spreadsheet projected subsidence compare to MODFLOW or other numerical models???