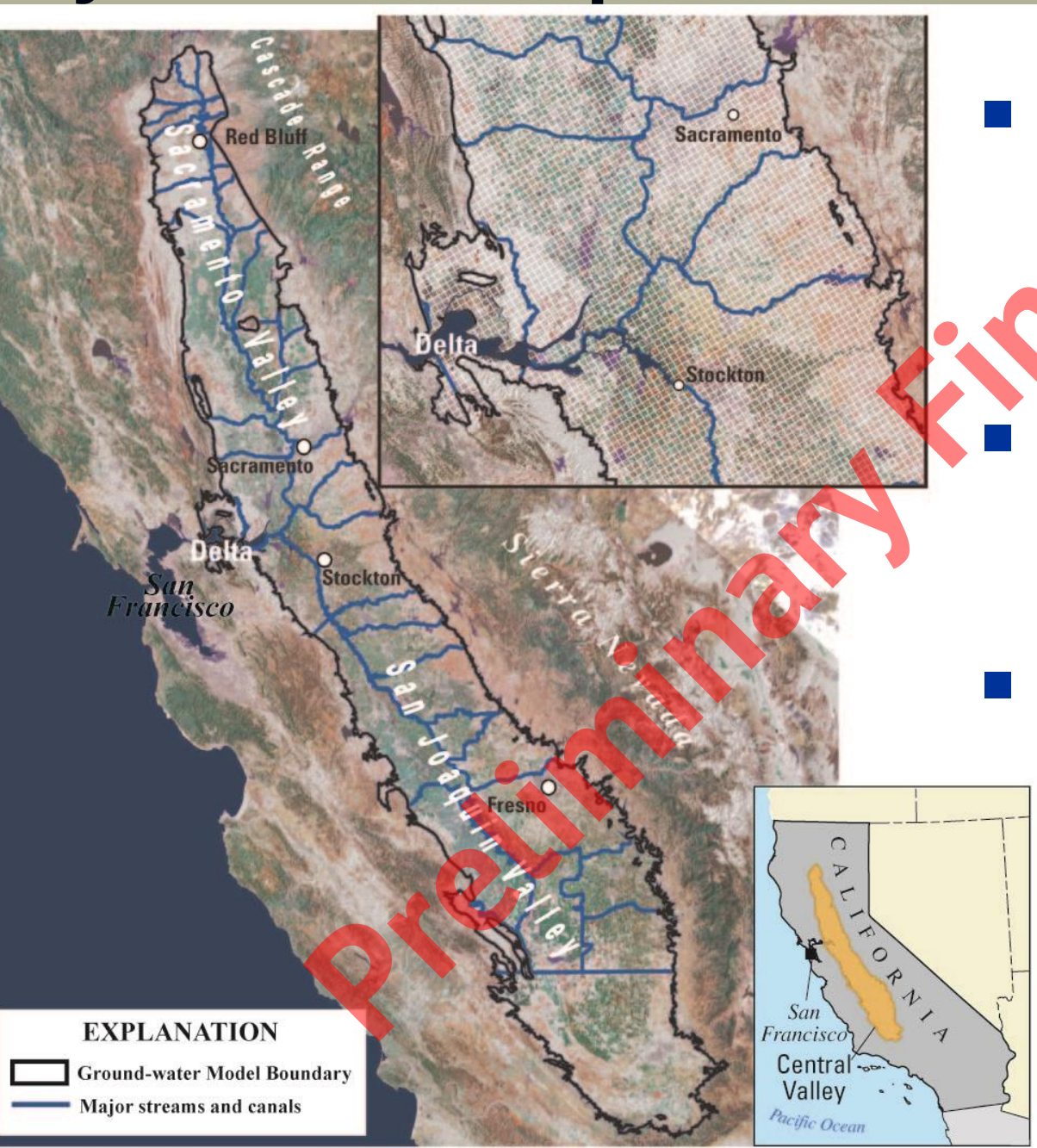
Central Valley Hydrologic Model (CVHM)

- A Regional Integrated Hydrologic Model of California's Central Valley
- USGS Groundwater Resources Program
- Focus on groundwater availability and changes in storage
- Updates in conjunction with Reclamation focusing on subsidence issues

Preliminary Findings

USGS

System Conceptualization:



- Approx. 20,000 mi^2 (50,000 km^2) sediment filled structural trough
- Average thickness of sediments = 2,400 feet (732 m)
- Generally surrounded by relatively impermeable rock (except Delta)

Preliminary Findings

CVHM Components

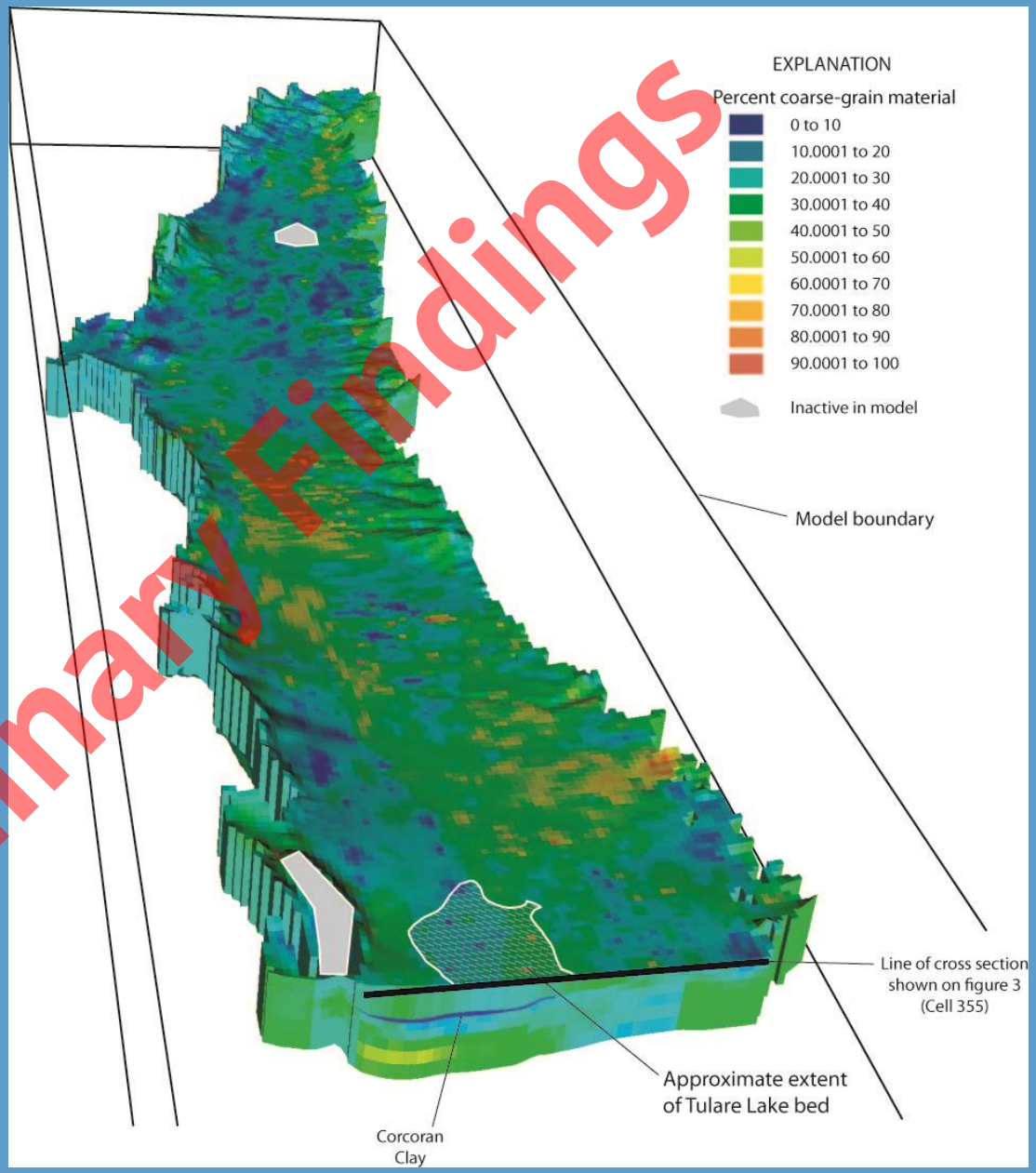
- TEXTURE ANALYSIS: Describe the sediment characteristics of the aquifer system to estimate hydraulic properties.
- FARM PROCESS: Develop an approach for systematically estimating water budget components for an aquifer system in an area dominated by irrigated agriculture.
- HYDROLOGIC MODEL: Develop a model of the Central Valley aquifer system capable of being accurate at scales relevant to water management decisions.

Preliminary Findings

Texture Analysis:

3D model

- Based on 8,500 drillers logs
- Interpolated to one-mile spatial grid at 50 foot depth intervals
- Defines sediment characteristics of the aquifer



Preliminary Findings

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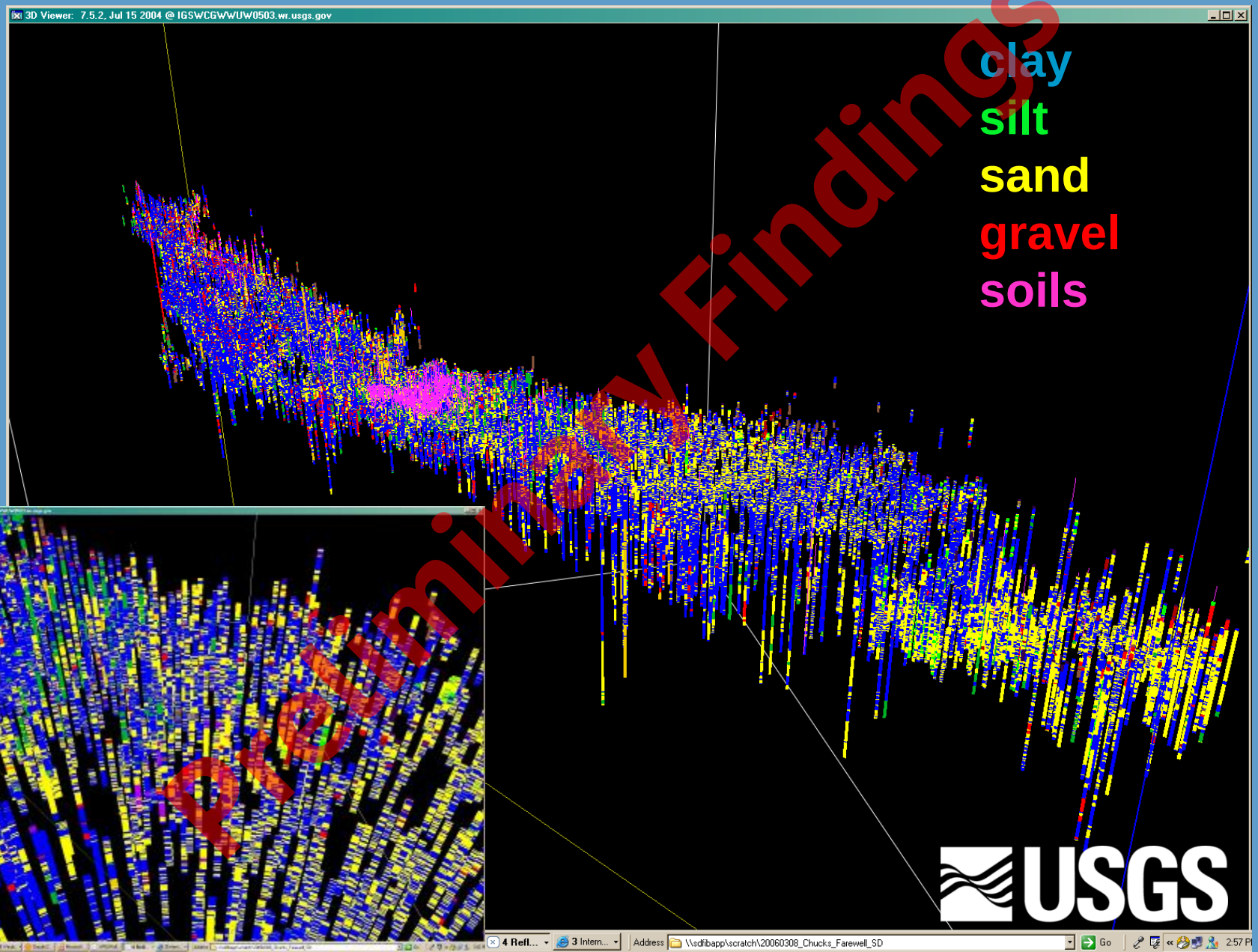
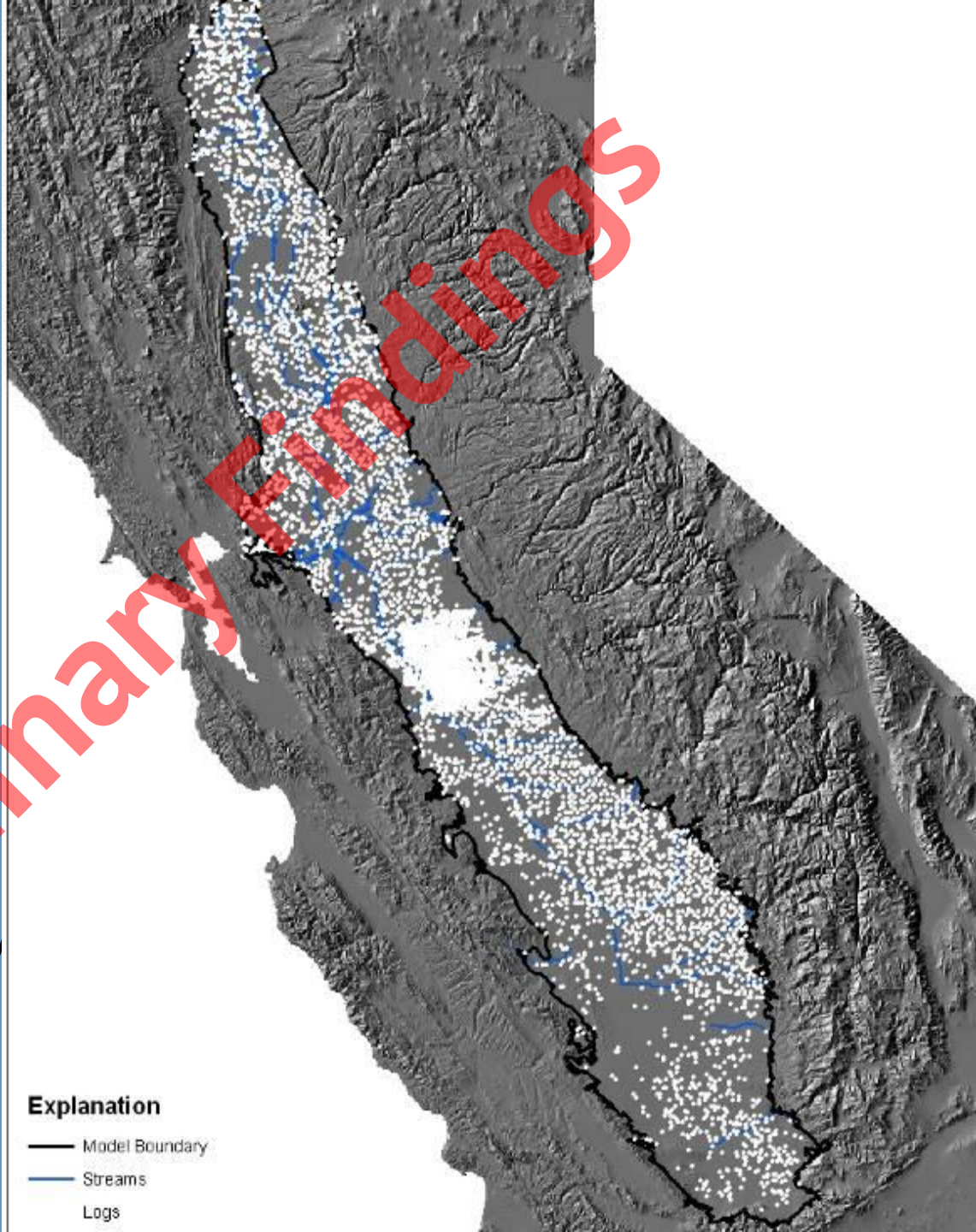
Central Valley well logs - lithology



Data Analysis and Post Processing

Three-dimensional kriging (ISATIS)

- 50 foot depth intervals
- 1 mile spatial grid
- Coarse near river channels
- Finer in low energy environments (Corcoran Clay)



Preliminary Findings

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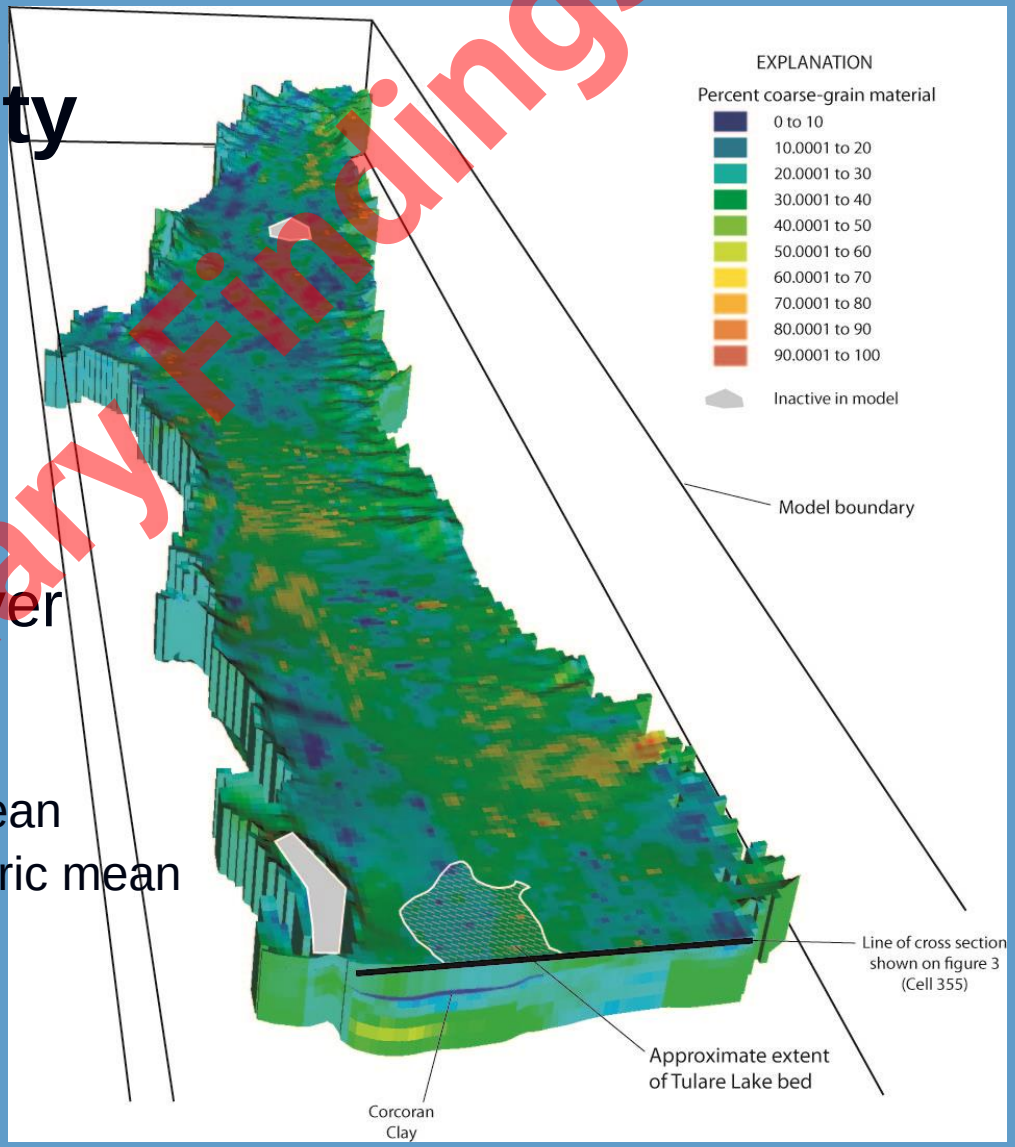
Texture based approach for hydraulic properties:

Hydraulic conductivity is a function of

- **Stratigraphy**
  - 3D geologic model
- **Texture**
  - Percent coarse each layer
    - Hydraulic conductivity
      - Power mean

        Horizontal – arithmetic mean

        Vertical – approx. geometric mean
    - Subsidence (% fine)



Preliminary Findings

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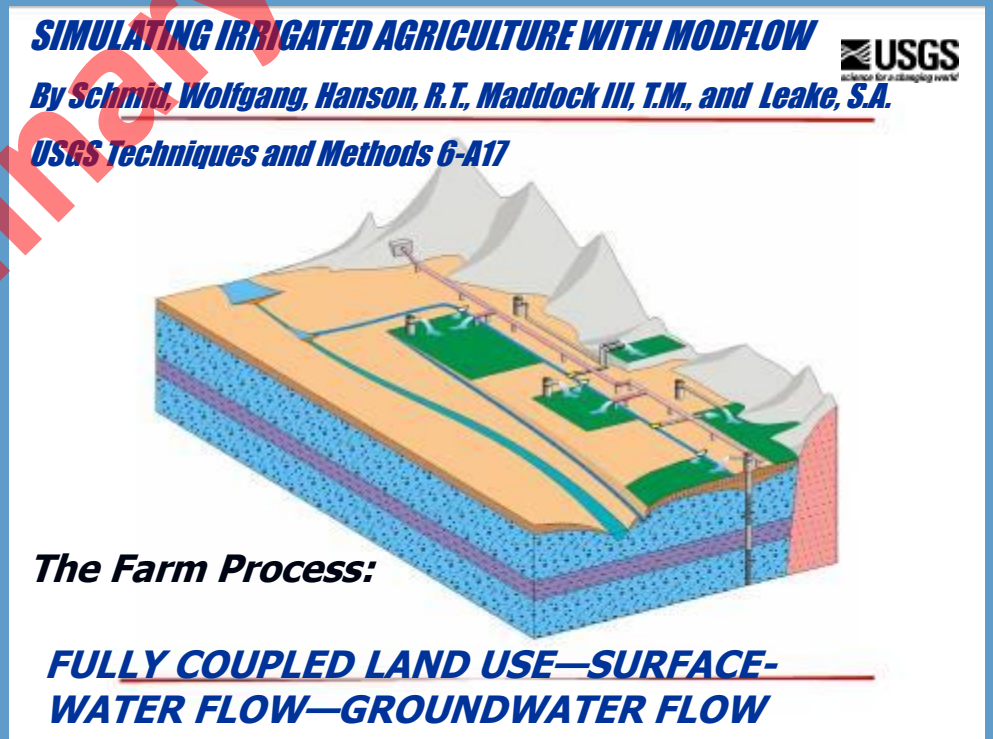
Farm Process:

- Systematic approach for estimating water-budget components
- Based on:
  - the consumptive use of water by plants
  - available surface-water deliveries

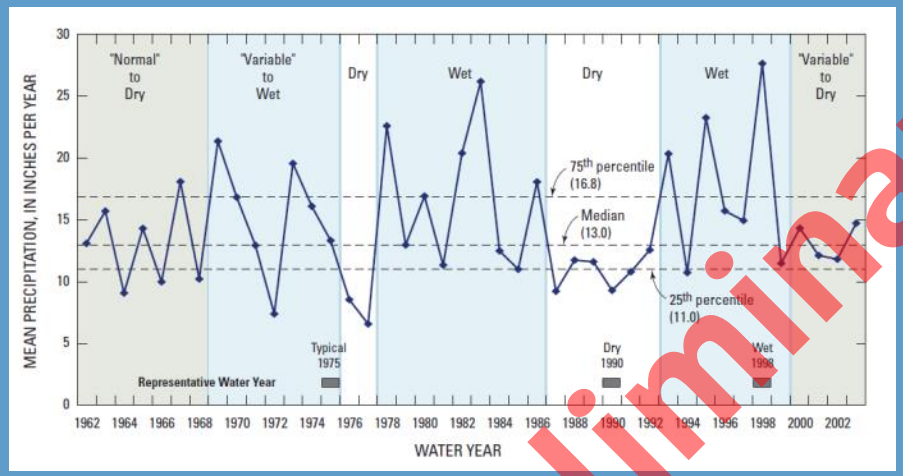


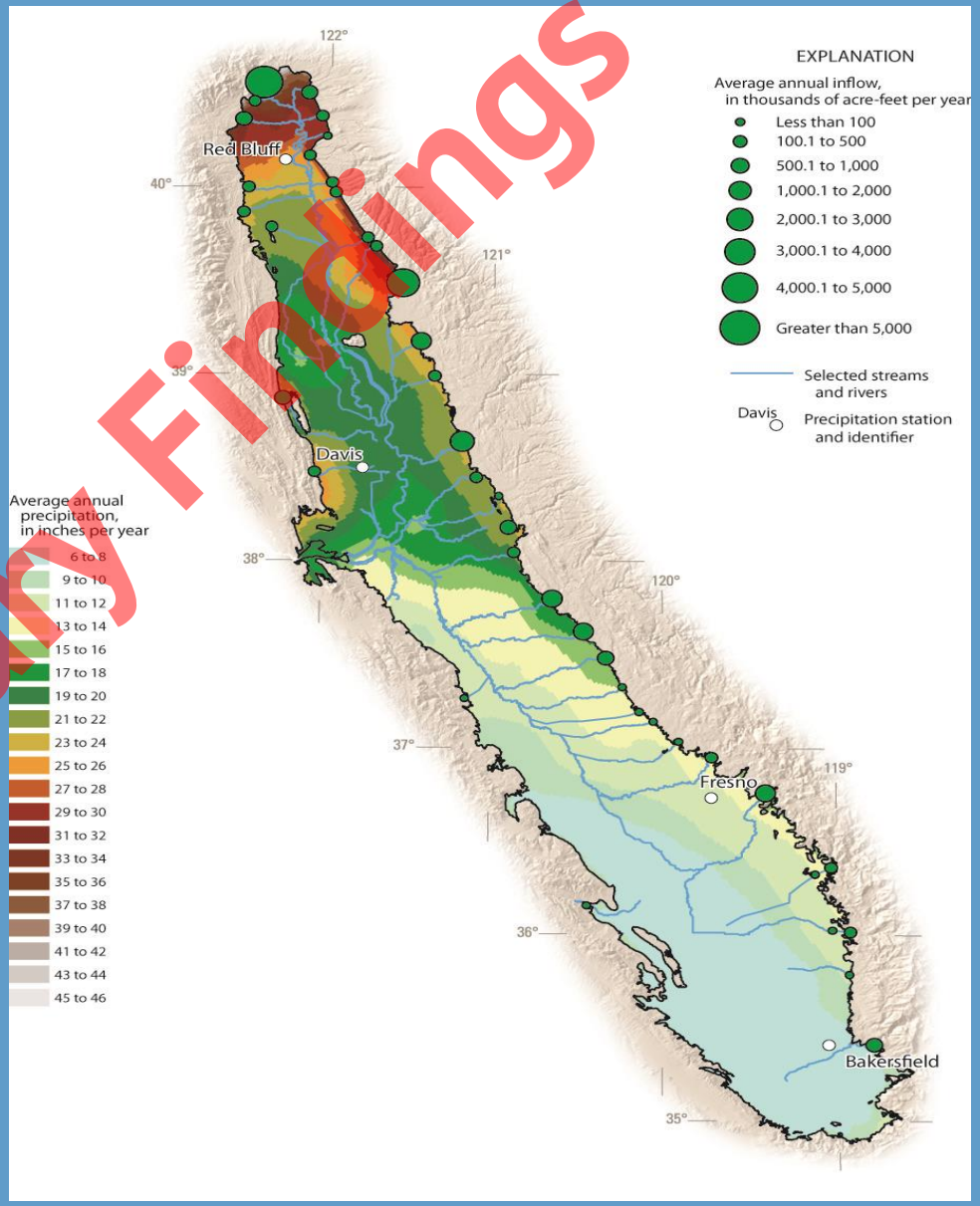
Preliminary Findings

USGS

Climate: Precipitation and Inflows

- Vary Geographically
- Vary with Time
  - Annually
  - Seasonally



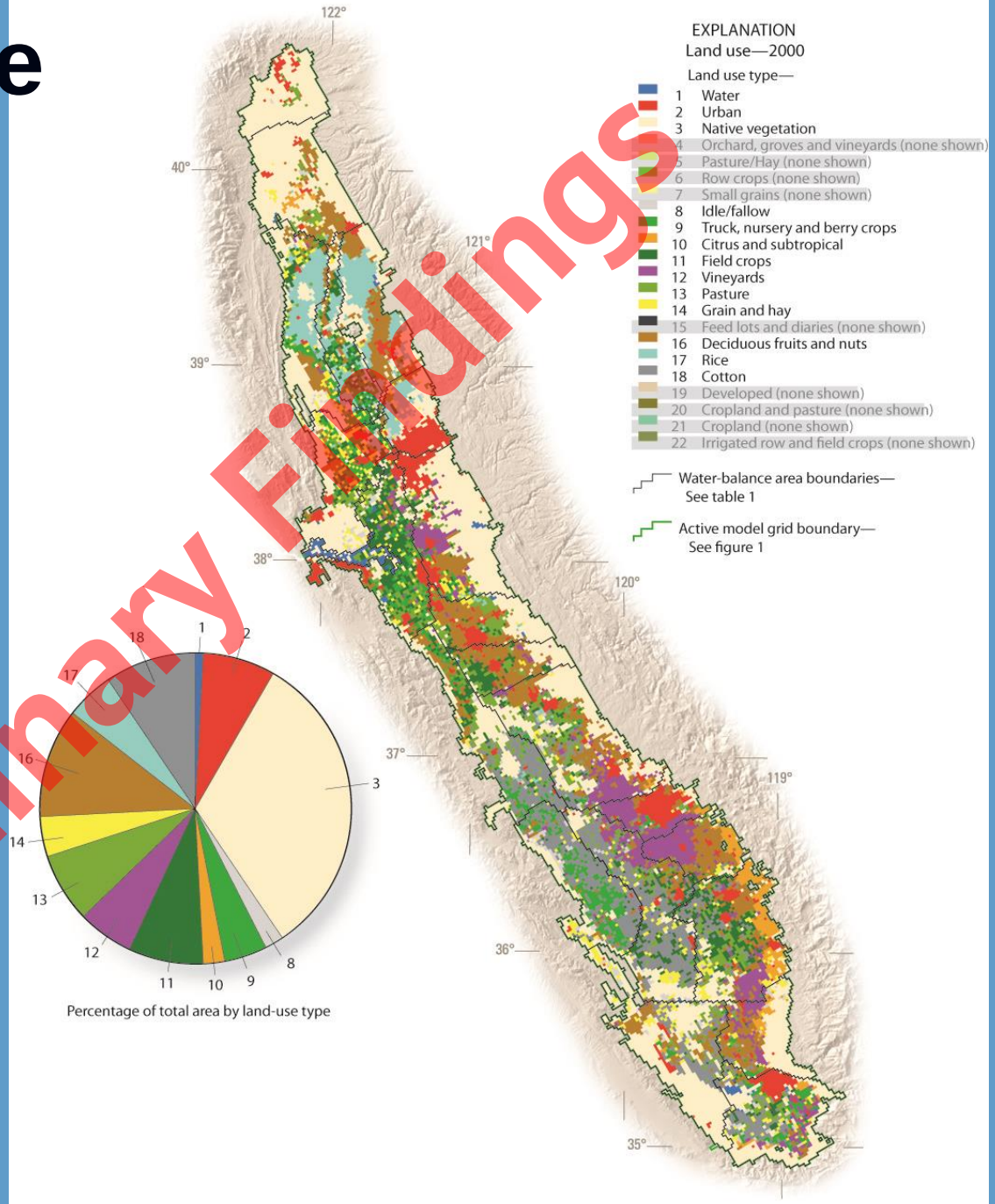


Preliminary Findings

USGS

Water-balance regions and Landuse

- 21 regions
  - CA-DWR collaboration
- 1962-2003
- Landuse categories:
  - Urban
  - Native
  - Crops

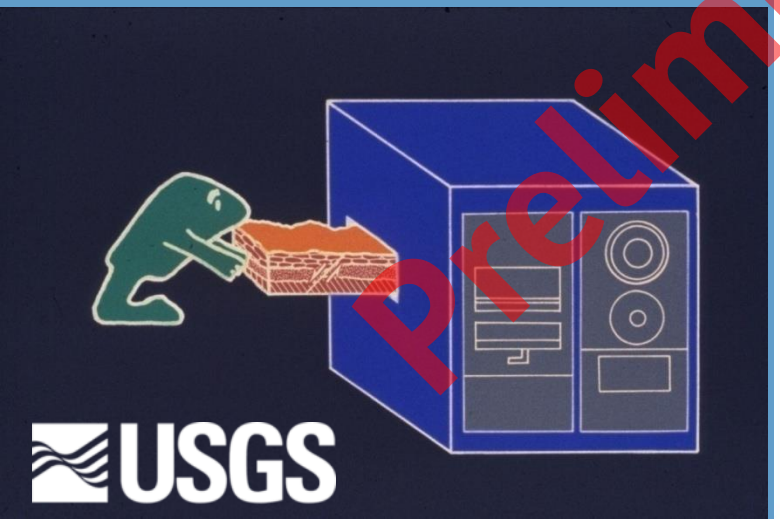


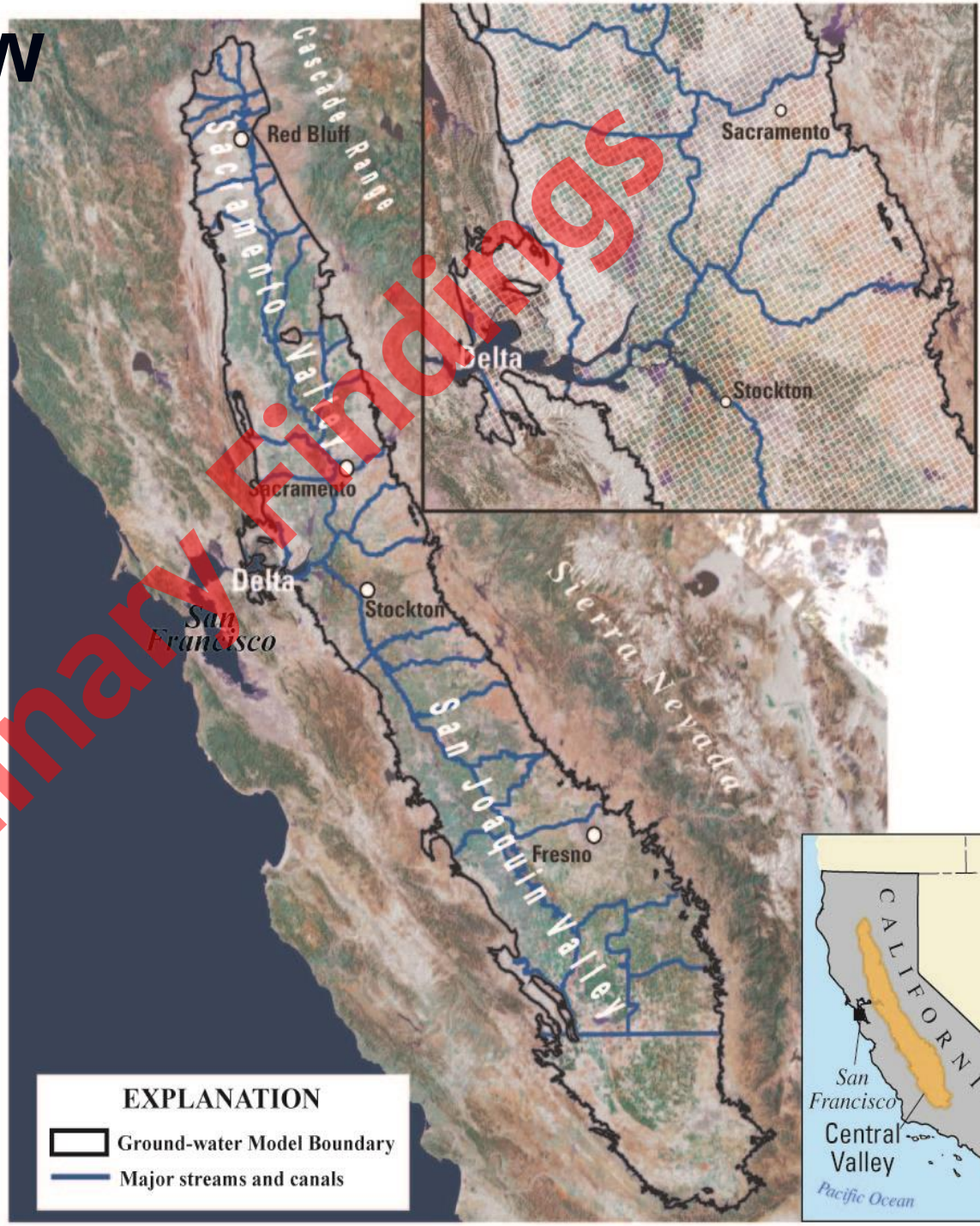
Preliminary Findings

USGS

Model overview

- Uniform one sq. mile cells
- Water years 1962 – 2003 (monthly stress periods)
- MODFLOW-2000 with Farm Process (FMP)
  - Stream flow routing (SFR)
  - Wells (MNW) (municipal/ farm)
  - Subsidence (SUB)
  - Flow barriers (HFB)
- Sensitivity Analysis and Calibration with Parameter Estimation (UCODE/PEST)

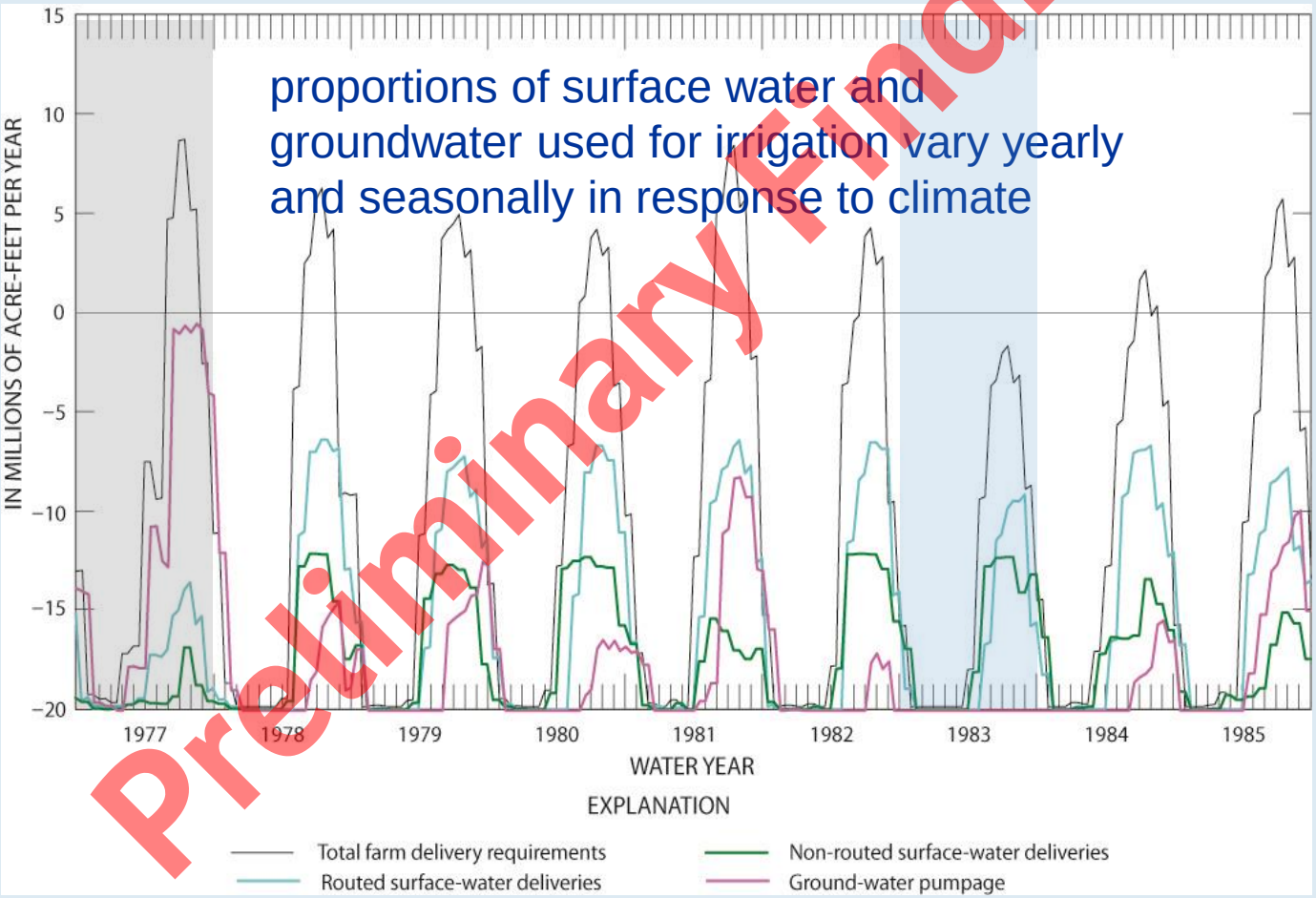




Preliminary Findings

CVHM Simulation of Climate Change/Variability

- ***Early in growing season, dominantly surface water deliveries***
- ***Later in growing season, surface-water shortfall made up by groundwater pumpage***
- ***Drought '77 (high pumping all growing season)***
- ***Wet Period '83 (lower delivery, mostly surface water)***



Preliminary Findings

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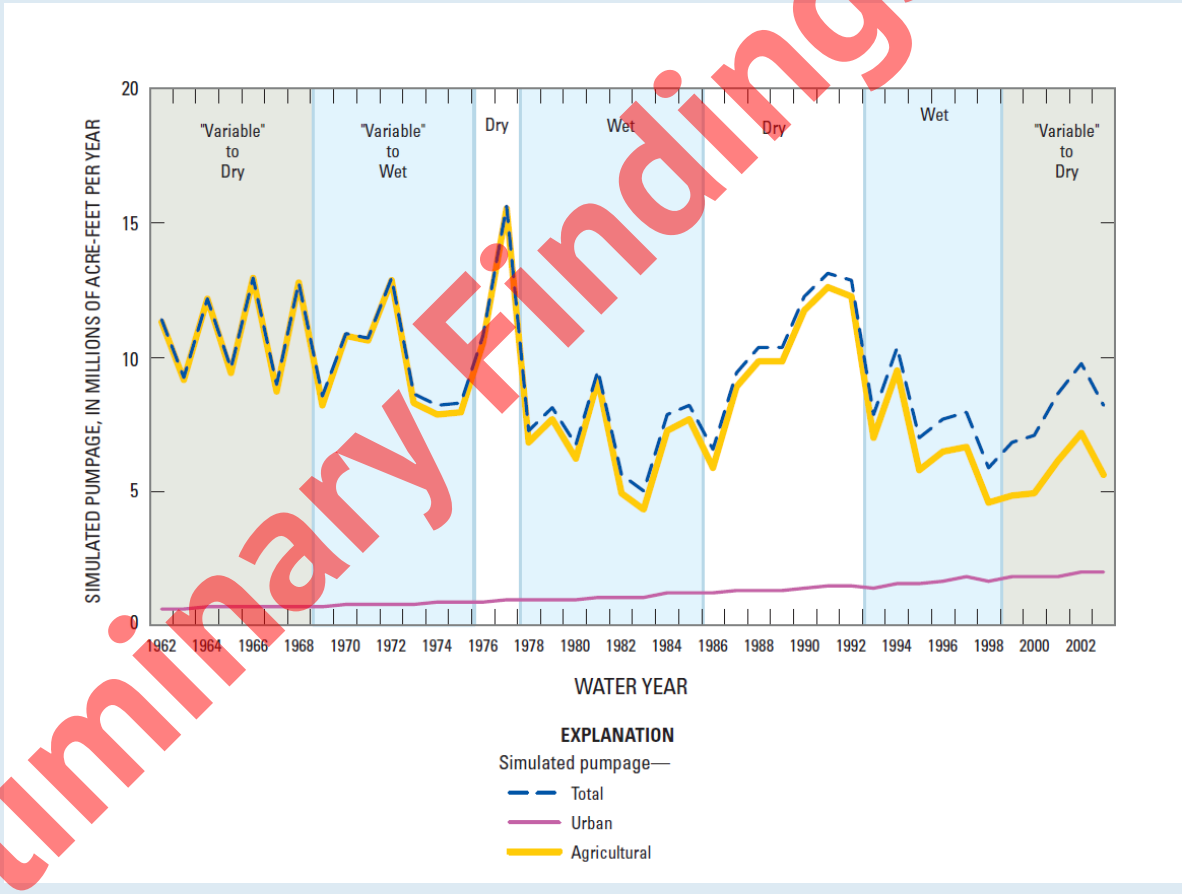
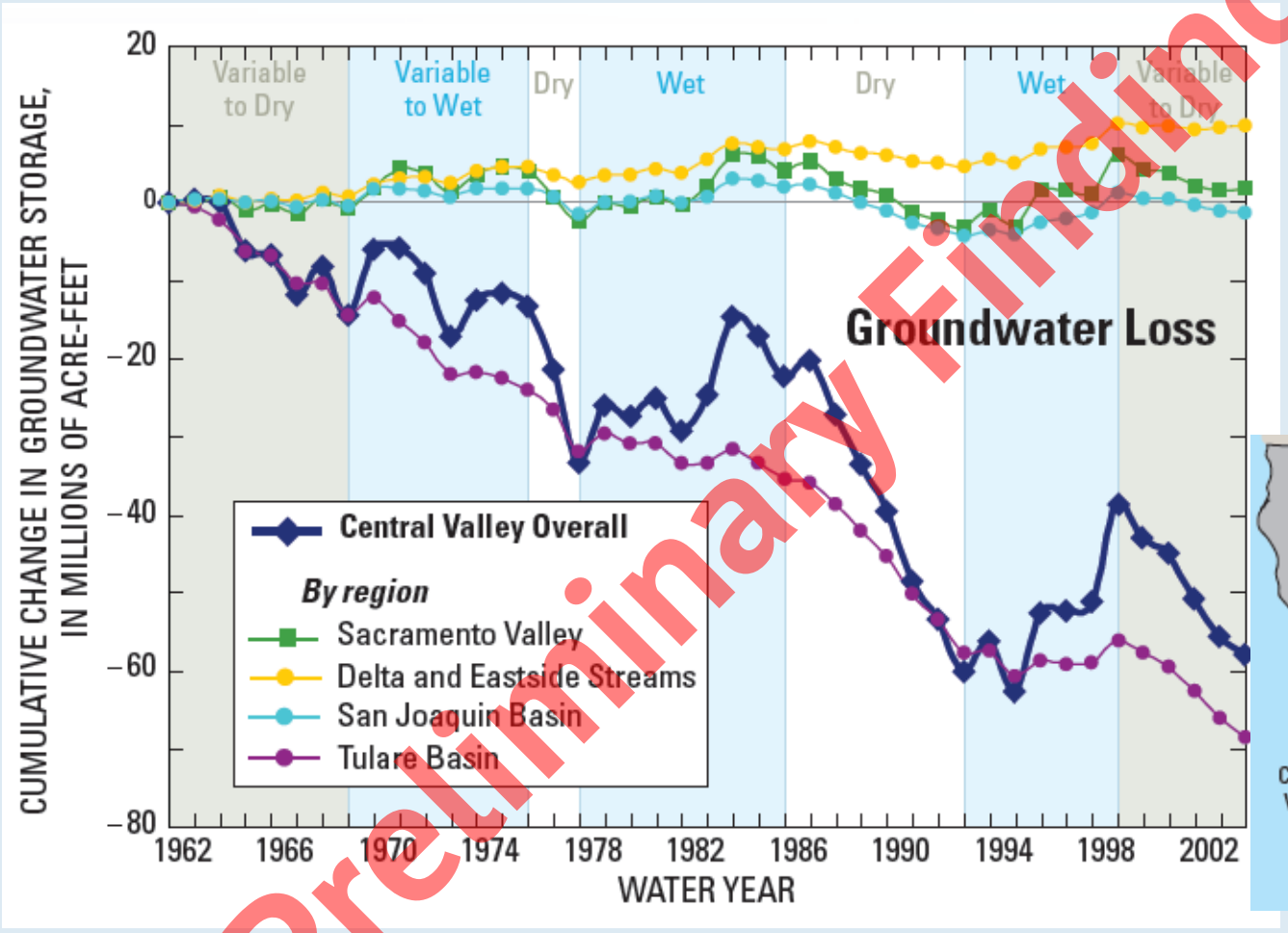
Simulated Pumpage:

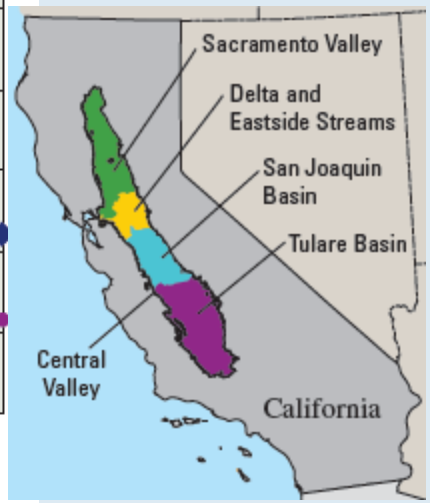
- Surface-water delivery system in place in early 1970s
- Except during droughts, general decrease in total amount of groundwater pumped
- General increase in proportion of groundwater pumped used for urban purposes



Preliminary Findings

Change in Storage with time



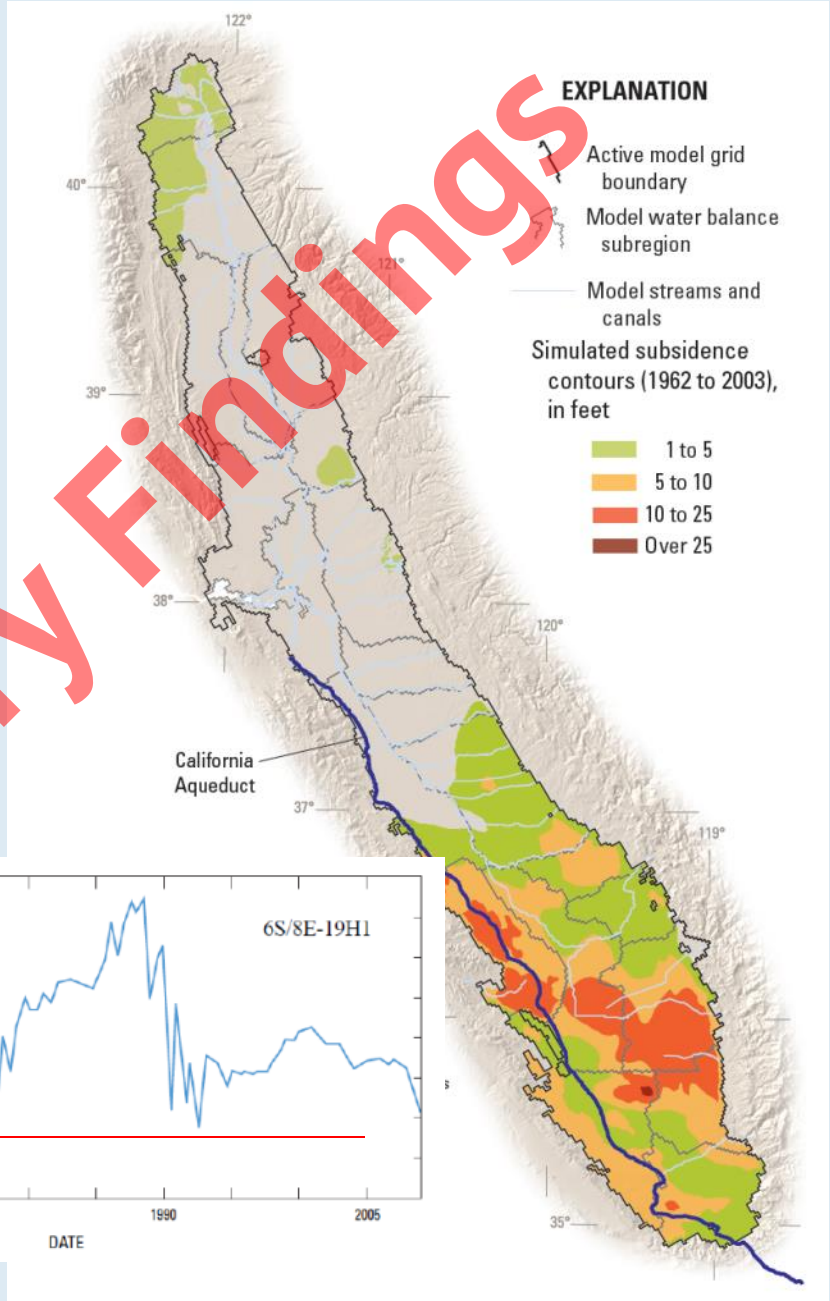


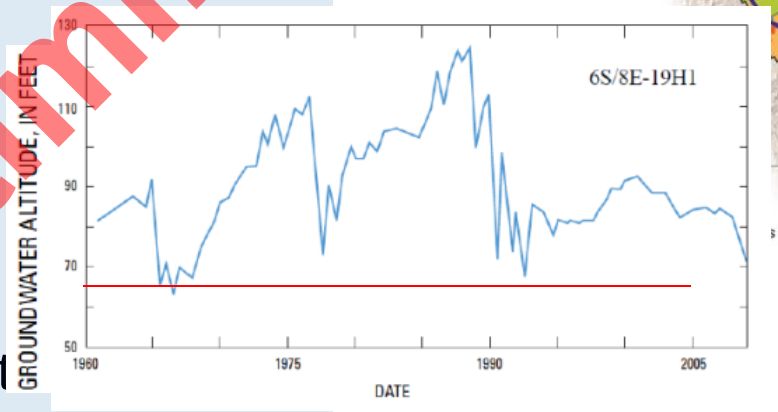
Preliminary Findings

USGS

Subsidence:

- In1960s, groundwater pumping caused water levels to decline
- Water-level declines cause compaction of fine-grained deposits, which results in subsidence
- Surface-water deliveries since the late 1960s have reduced the dependence on groundwater
- In 2009, water levels were again reaching their historic lows and subsidence was renewed
- Management constraint

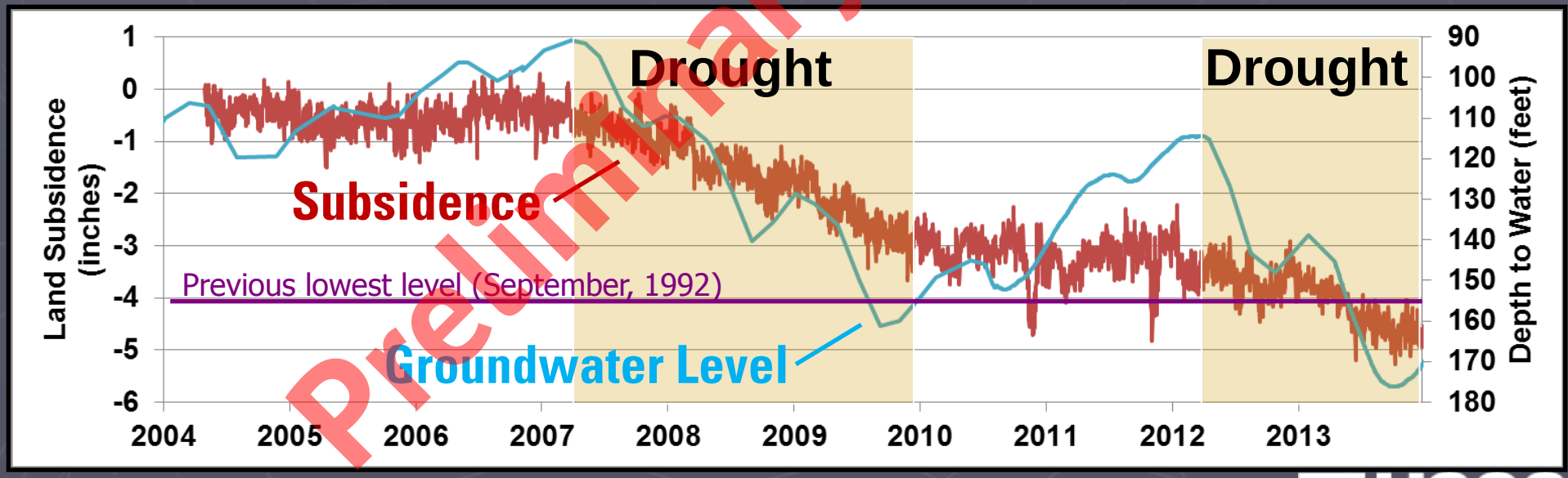




Preliminary Findings

Recent Subsidence

- Renewed subsidence concern during 2007-09 drought, and now, the current drought
  - Reduced surface water importation
  - More reliance on the groundwater resources
  - As it turns out…this is not just a problem during droughts for some areas without surface-water access



Preliminary Findings

P304 data from UNAVCO; 2004-10 water-level data from Luhdorff and Scalmanini Consulting Engineers

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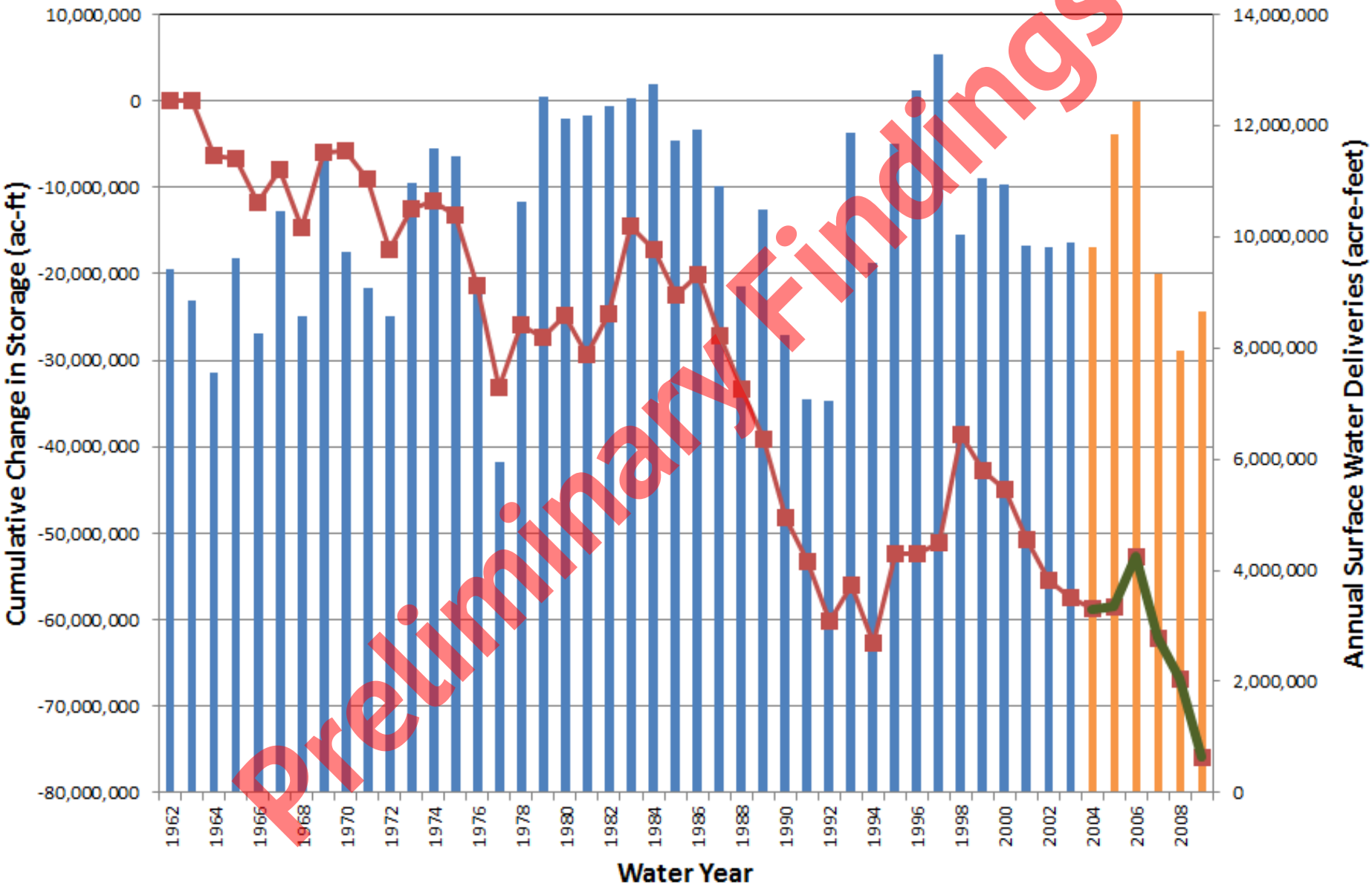
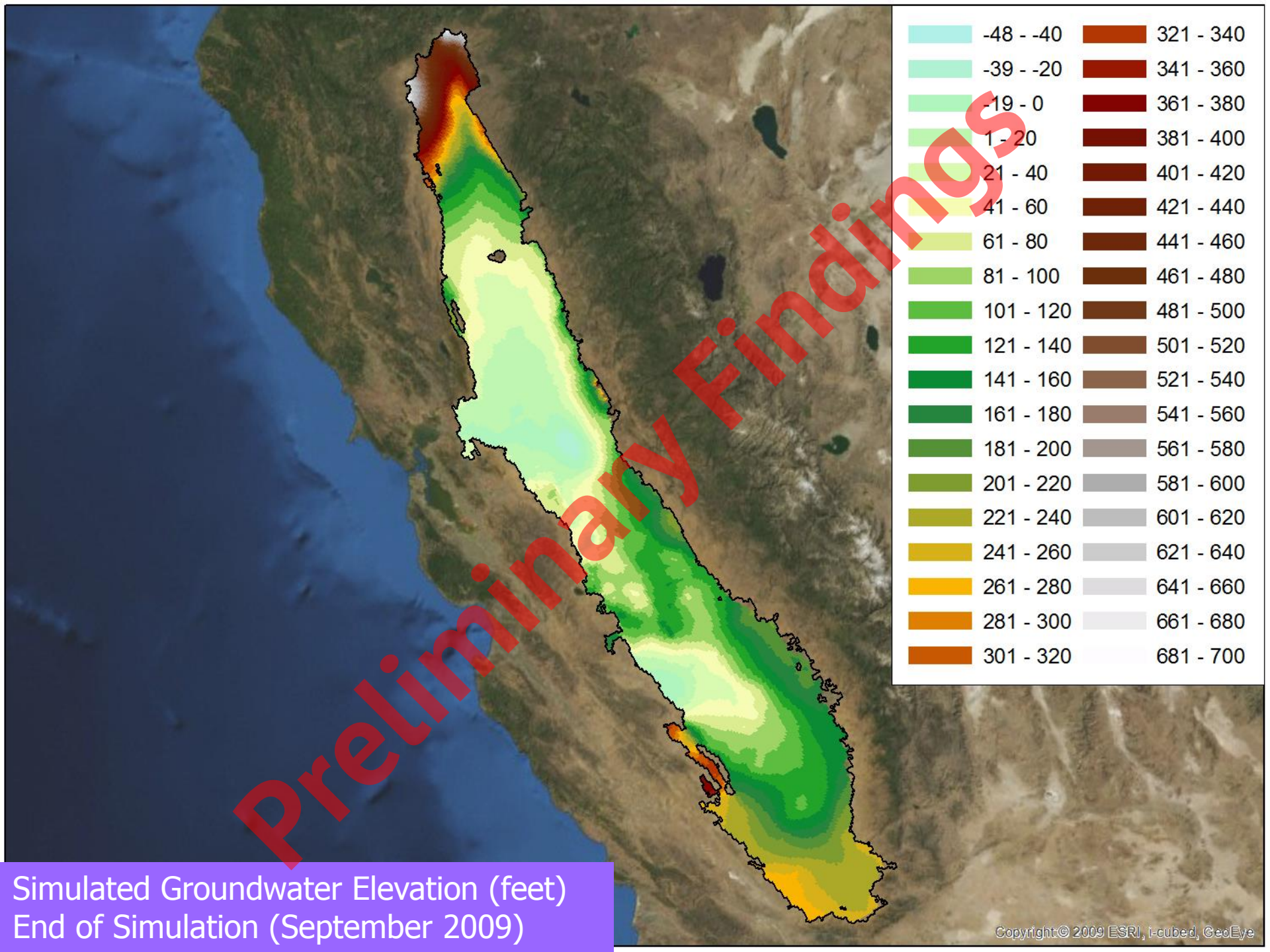
Updates and Refinements to CVHM

- **Model Code Changes**
- **Data Updates**
  - Extend the model simulation period
    - through 2009 (Reclamation)
    - through 2013 (USGS drought initiative)
  - Update land use
  - Update surface water delivery data
  - Increase the resolution in western San Joaquin Valley
- **Recalibration**
- **Preliminary Results**
- **Working to incorporate current drought**

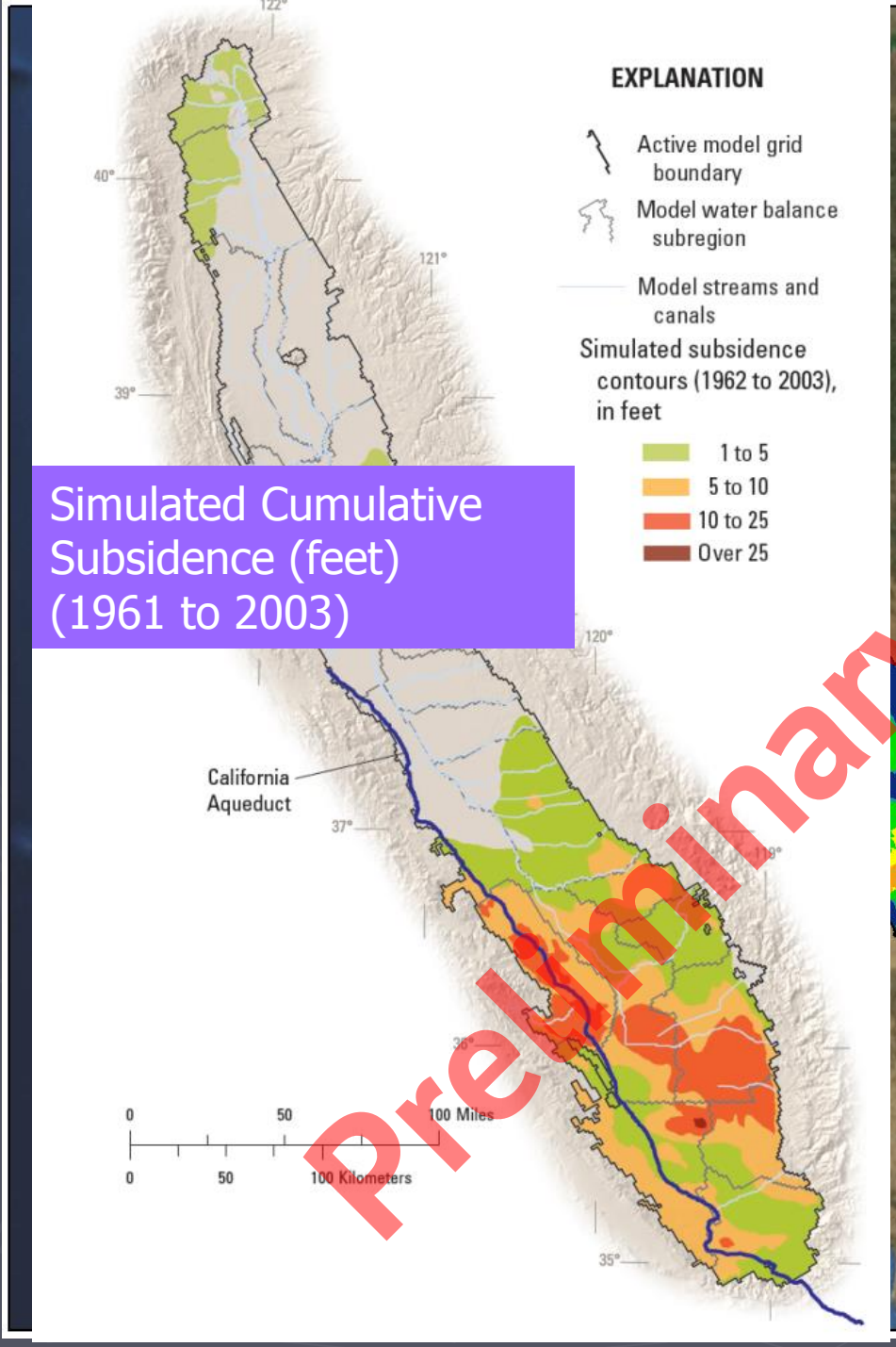
Preliminary Findings

Cumulative Change in Storage and Annual Surface Water Deliveries

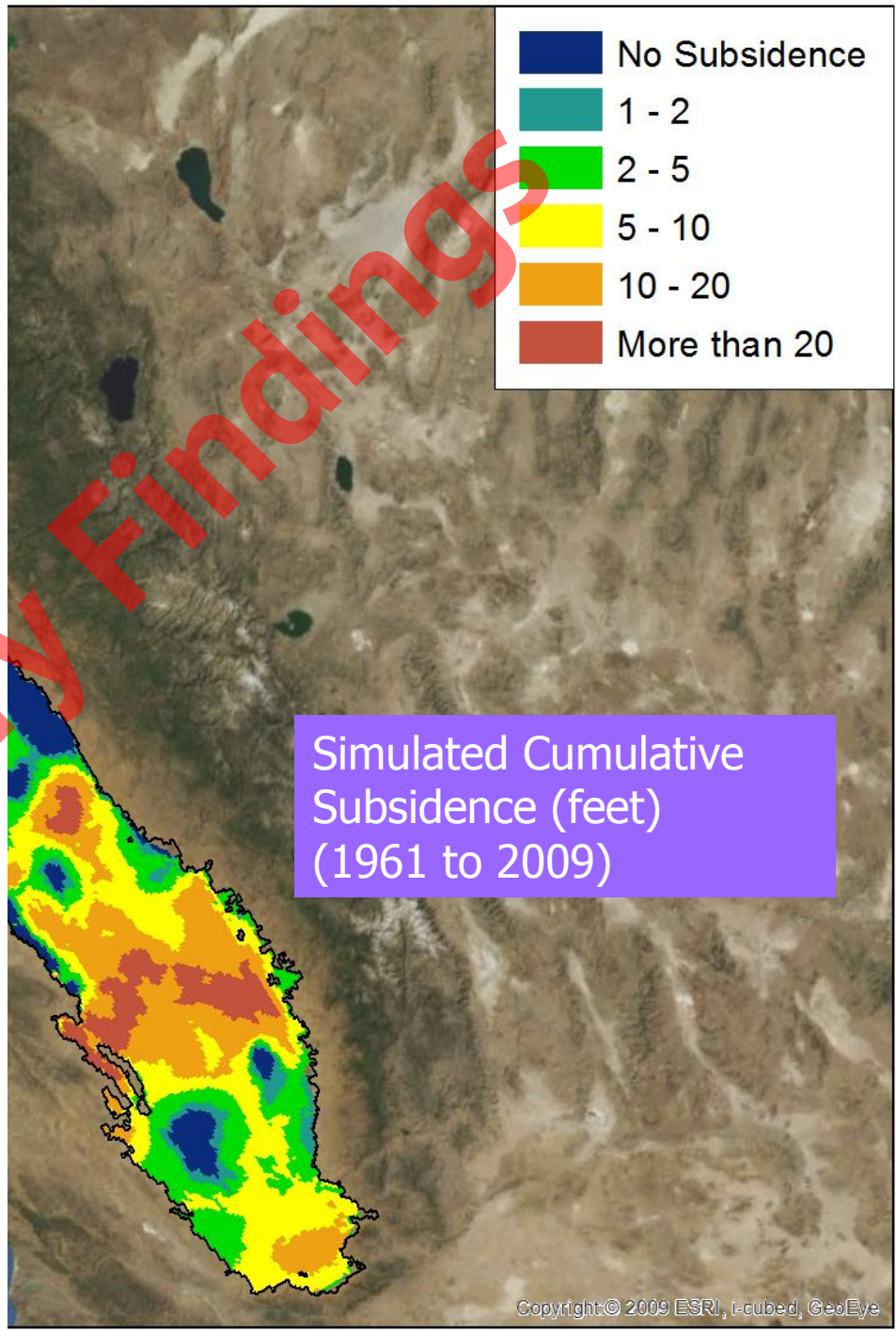




Simulated Groundwater Elevation (feet)
End of Simulation (September 2009)



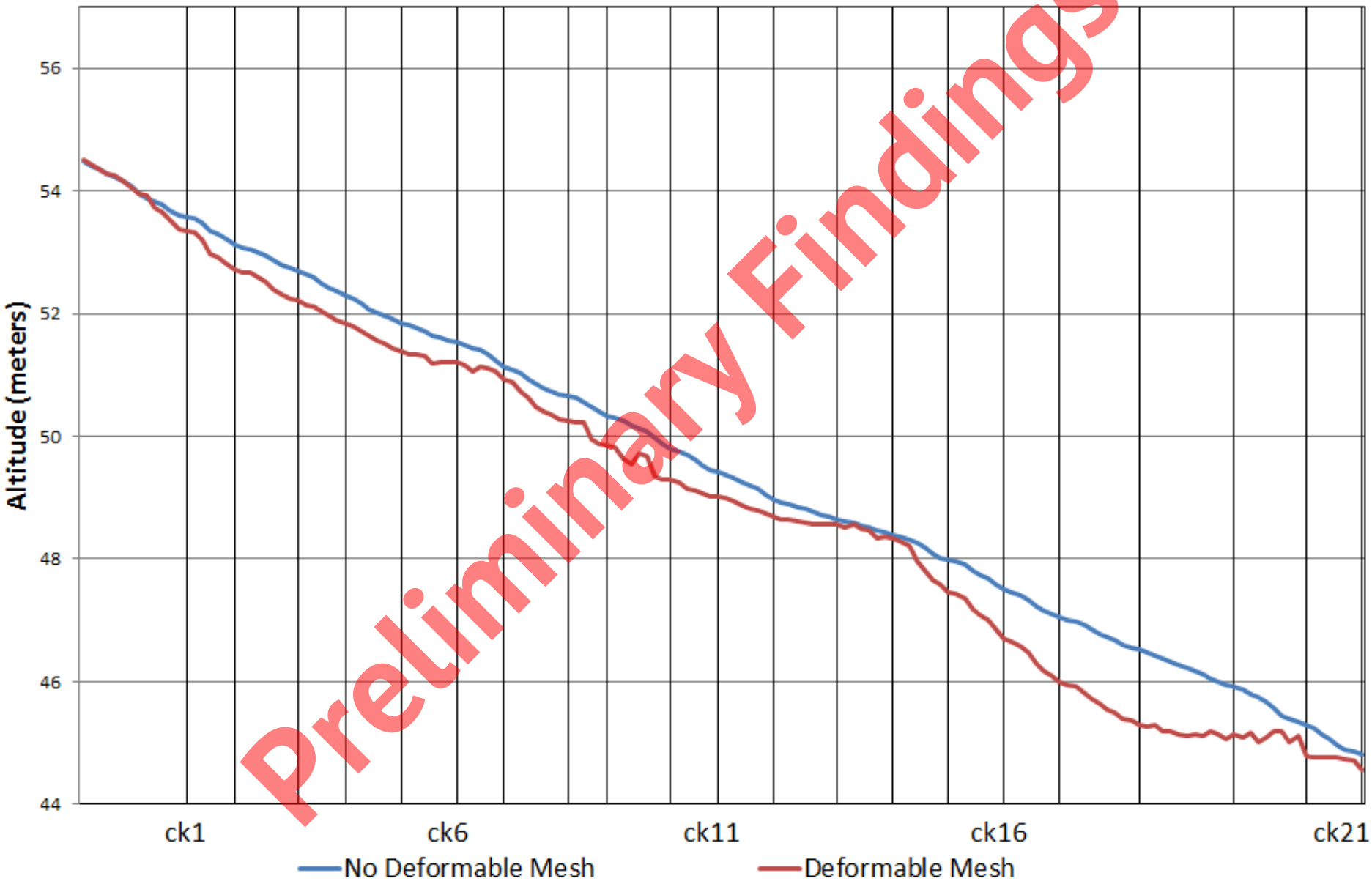
Simulated Cumulative Subsidence (feet) (1961 to 2003)



Simulated Cumulative Subsidence (feet) (1961 to 2009)

Preliminary Findings

Delta-Mendota Canal Altitudes Simulated with CVHM



Preliminary Findings

Model Applications

- Predict groundwater elevations
- Predict location and amount of land subsidence
- Simulate future scenarios including
  - Extended drought
  - Climate change
  - Reduced surface water deliveries
- Provide boundary conditions for local scale models
- USGS is always looking for cooperators would like to apply CVHM in their studies

Preliminary Findings

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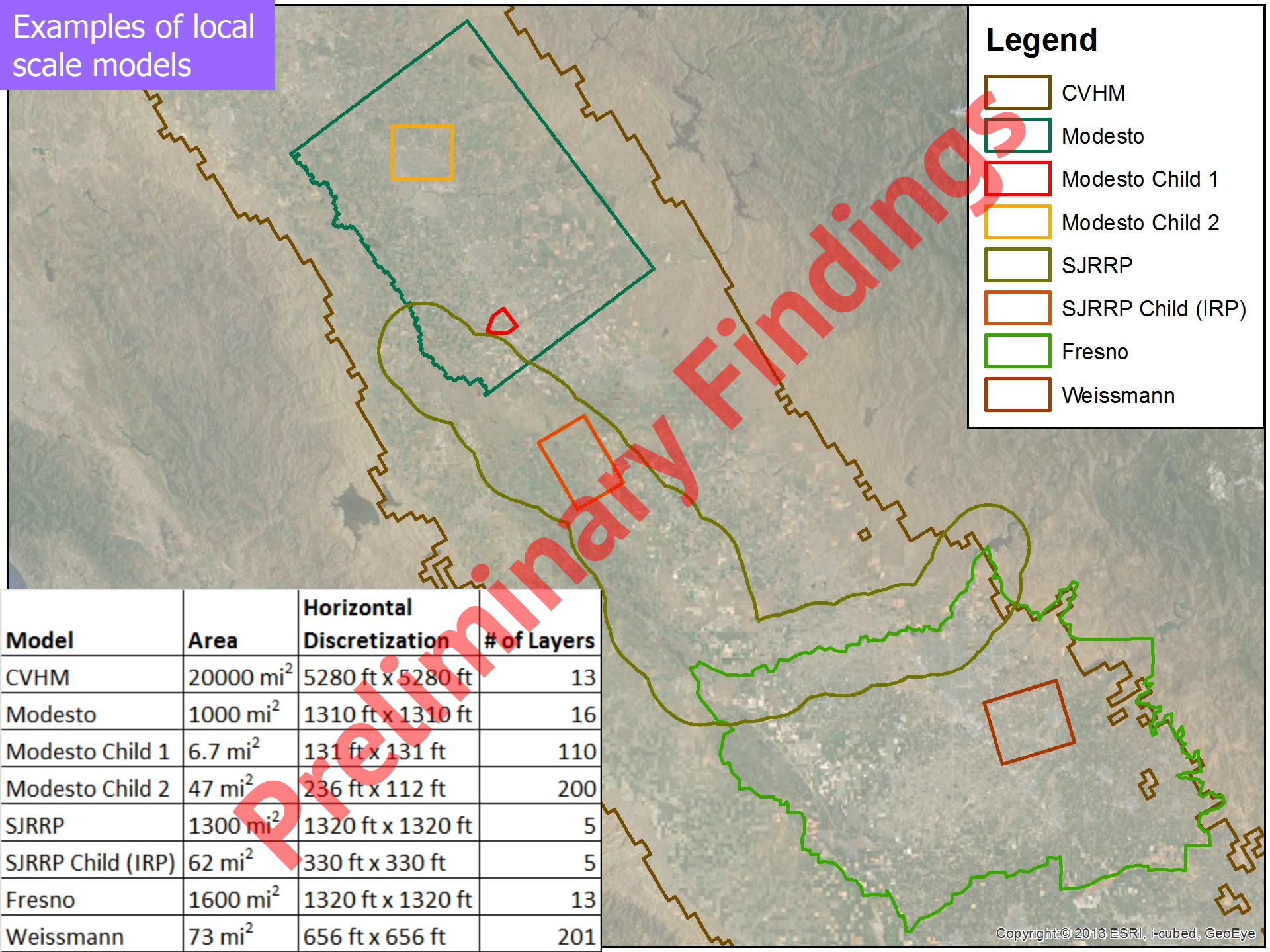
Examples of local scale models



Model	Area	Horizontal Discretization	# of Layers
CVHM	20000 mi^2	5280 ft x 5280 ft	13
Modesto	1000 mi^2	1310 ft x 1310 ft	16
Modesto Child 1	6.7 mi^2	131 ft x 131 ft	110
Modesto Child 2	47 mi^2	236 ft x 112 ft	200
SJRRP	1300 mi^2	1320 ft x 1320 ft	5
SJRRP Child (IRP)	62 mi^2	330 ft x 330 ft	5
Fresno	1600 mi^2	1320 ft x 1320 ft	13
Weissmann	73 mi^2	656 ft x 656 ft	201

Preliminary Findings

Summary and Conclusions

- Recent modifications to MODFLOW will help the CVHM to better characterize the entire hydrologic system
- Updated data sets and recalibrated model
  - will provide a detailed analysis of changes in hydrologic system and subsidence
  - will help us better understand water resources and the interaction of groundwater with subsidence
- Updated model being built to more accurately forecast the anticipated locations and magnitudes of water level declines and/or subsidence based on alternative future scenarios

Preliminary Findings

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What Can Be Done About It?

CVHM is a useful tool to forecast information based on alternative scenarios

- Predict groundwater elevations and subsidence
- Simulate scenarios including
  - Extended drought/climate change/variability
  - Reduced surface water deliveries
  - Pumping (Reclamation)
  - Artificial Recharge
- Provide boundary conditions for local scale models (SJRR)

Long-term monitoring of water levels and subsidence is needed to track groundwater conditions

- Groundwater levels in the context of historical levels
- Track groundwater levels and subsidence in shallow and deep systems separately

Preliminary Findings

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PUBLICATIONS:

- **Professional Paper:**

Faunt, C.C., ed., 2009, Groundwater Availability of the Central Valley Aquifer, California: U.S. Geological Survey Professional Paper 1766, 225 p. Available at http://pubs.usgs.gov/pp/1766/

- **Fact Sheet:**

Faunt, C.C., Hanson, R.T., Belitz, Kenneth, and Rogers, Laurel, 2009, California's Central Valley Groundwater Study: A Powerful New Tool to Assess Water Resources in California's Central Valley: U.S. Geological Survey Fact Sheet 2009-3057, 4 p. Available at http://pubs.usgs.gov/fs/2009/3057/

- **Journal Article:**

Faunt, C.C., Belitz, Kenneth, and Hanson, R.T., 2009, Development of a three-dimensional model of sedimentary texture in valley-fill deposits of Central Valley, California, USA, Hydrogeology Journal, DOI: 10.1007/s10040-009-0539-7. Available at http://www.springerlink.com/content/5q5736403v144648/

- **Web Site:**

http://ca.water.usgs.gov/projects/central-valley/index.html

Preliminary Findings