Central Valley Hydrologic Model

Version 1

Datasets Workshop

Claudia Faunt and Randy Hanson

U.S. Geological Survey

Today's Agenda:

<u>Part 1 - Hydrogeologic Framework (with quick overview)</u>

9:30-10:30 Overview of Geologic Framework (Claudia Faunt, USGS)

- Geologic Units, Drillers Logs Database, Development of Texture Model

10:30-10:45 Break

10:45-11:15 Hydraulic Properties (Claudia Faunt)

11:15-11:30 Storage and Subsidence (Randy Hanson, USGS)

- Storage Properties and Delay, Critical Heads

11:30-12:00 Discussion

<u>Part 2 - Surface Water and Climate</u>

1:00-2:00 Surface Water and Flux from Adjacent Basins (Claudia Faunt/Randy Hans

- Inflows, Routed Network, Stream Properties, Diversions in Relation to Network, Gaged and Un-gaged Inflows from Surrounding Basins

2:00-2:15 Break

2:15-3:00 Climate Data (Randy Hanson)

- Precipitation, Reference Evapotranspiration , Scripts/Tools, Climate

3:00-3:30 Website Overview (Claudia Faunt)

3:30-4:00 Discussion

A Regional Hydrologic Model of California's Central Valley

Claudia Faunt, Randy Hanson, Ken Belitz
and many others
California Water Science Center
U.S. Geological Survey

USGS

A Regional Hydrologic Model of California’s Central Valley

- USGS Groundwater Resources Program
- Focus on groundwater availability and changes in storage
- Developed in consultation with CA-DWR

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/**

- 3 chapters

- ## 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/**

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CVHM APPLICATIONS/ COLLABORATIONS:

- Compare CVHM with previously developed models and water budgets (CA-DWR)
- Evaluate climate-change on Central Valley Hydrologic System (NOAA California Application)
- Utilize CVHM to examine impacts of San Joaquin River Restoration flows on Central Valley aquifer system (BOR)
- Modify CVHM to examine impacts of Bay Delta Conservation Plan (BDCP) as part of EIS/EIR (BOR/CA-DWR)
- Utilize CVHM to analyze potential water-level declines and subsidence along canals (BOR)

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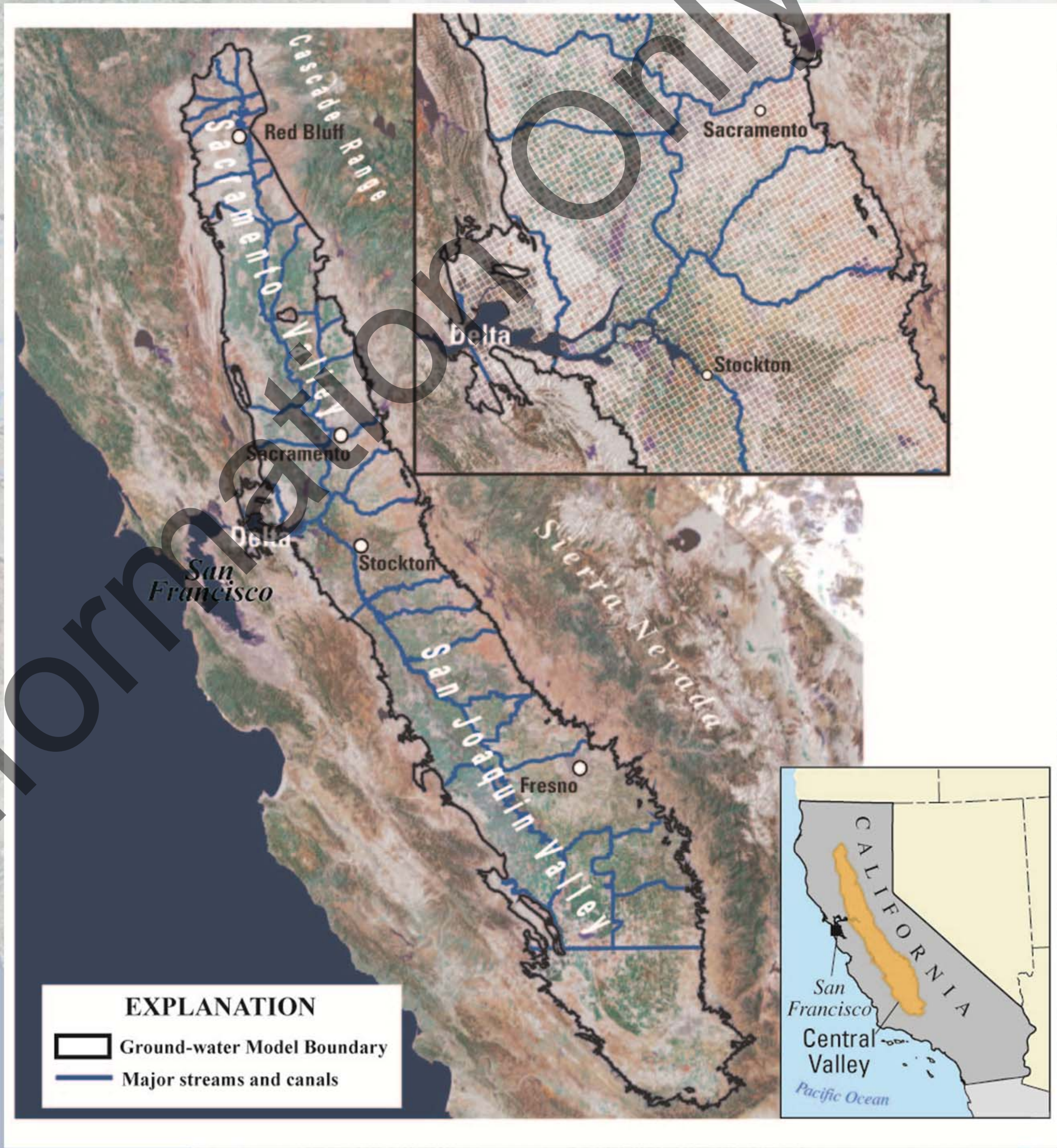
Objectives:

- **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.
- **GROUNDWATER MODEL**: Develop a model of the Central Valley aquifer system *capable of being accurate* at scales relevant to water management decisions.

Central Valley Facts:

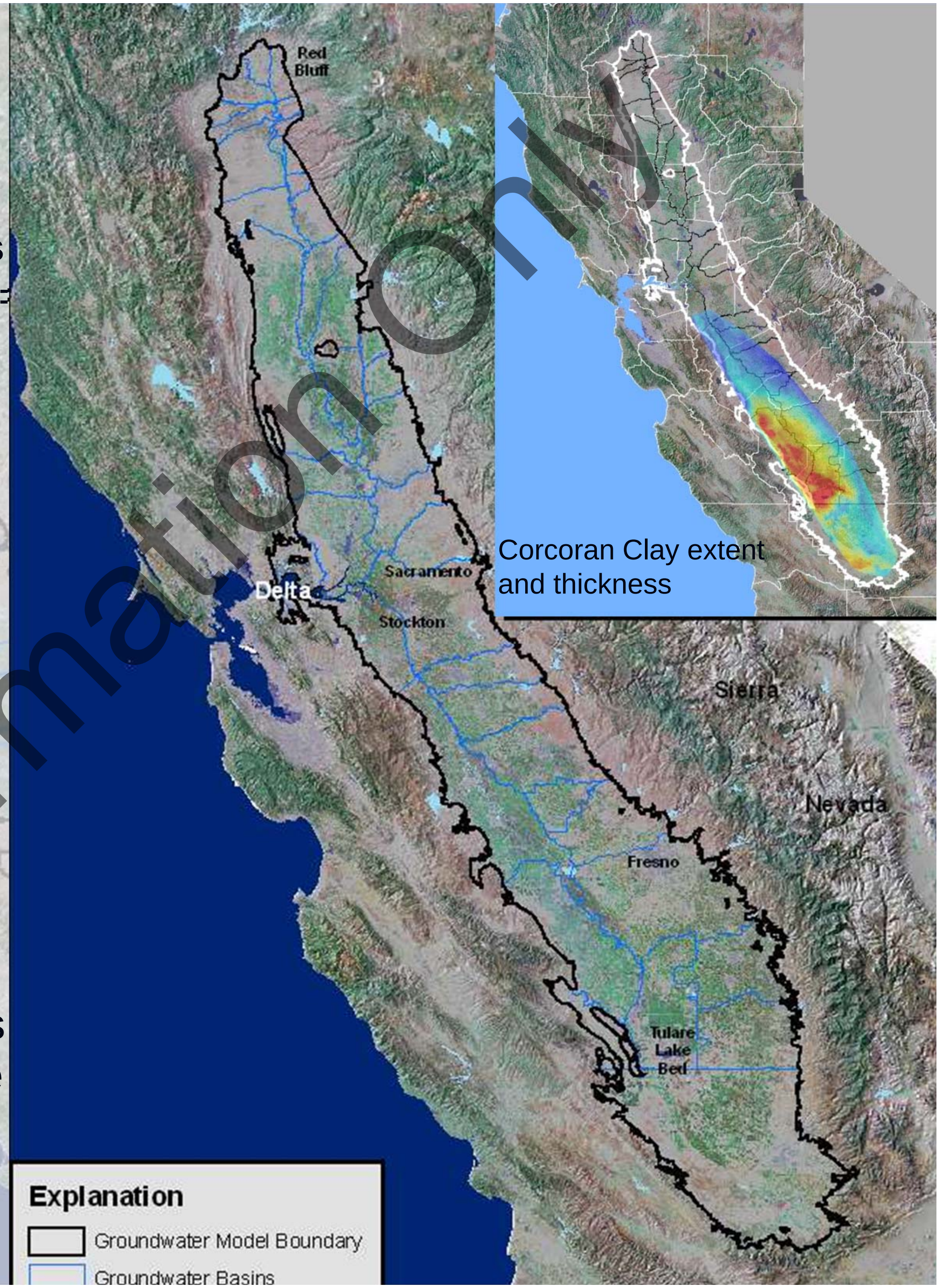
- 20,000 square miles
- More than 250 different crops with an estimated value of $17 billion /year
- Approximately 25% of the table food consumed in the US is grown in the Central Valley
- Approximately 17% of the Nation's irrigated land is in the Central Valley
- Approximately 20% of the Nation's groundwater pumpage is from the Central Valley aquifer system



System Conceptualization:

FRAMEWORK

- **Structural trough filled with sediments**
  - Average thickness of sediments = 2400 feet
  - Vertical head differences throughout
  - > 50% of sediments are fine-grained lenticular deposits
    - Discontinuous
    - Distributed throughout the area and section
  - One system with varying properties and stratigraphic controls
    - Units such as Corcoran Clay (forms major confining unit)
- **Generally surrounded by relatively impermeable rock (except Delta)**
  - East – generally crystalline rocks
  - West – generally less permeable marine deposits



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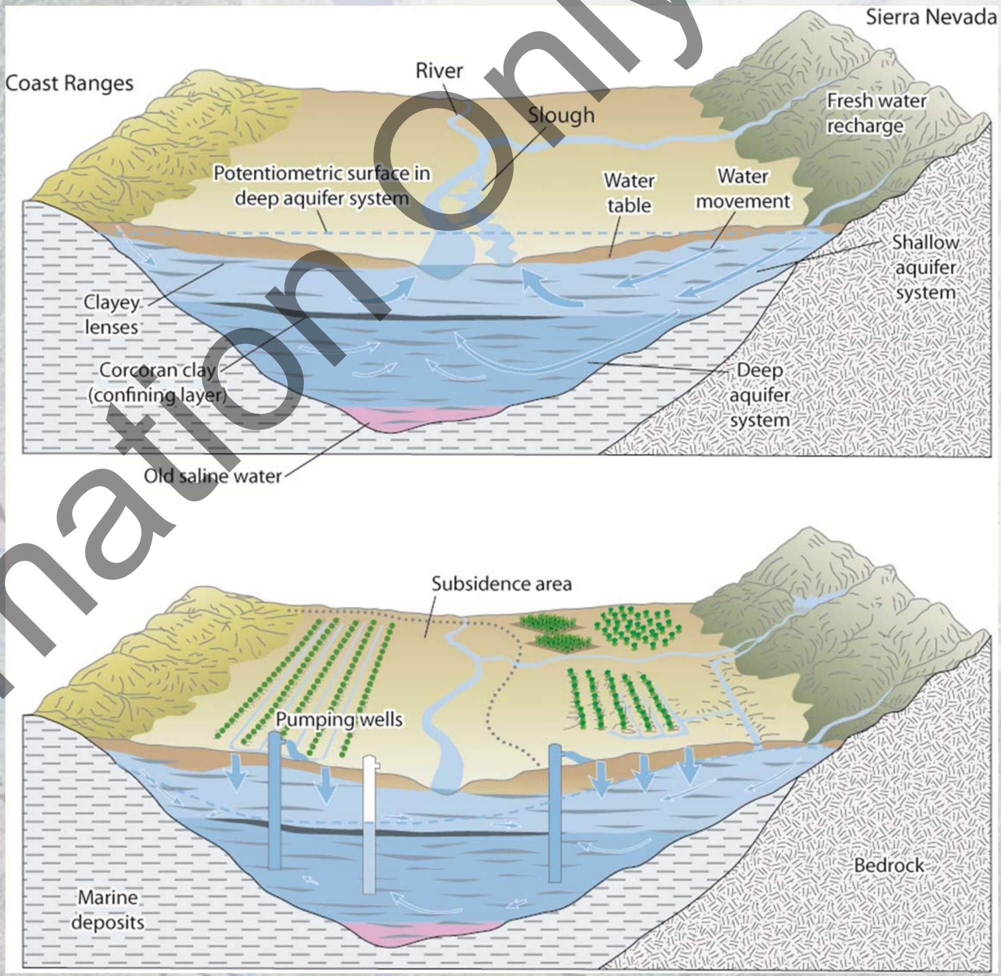

Types of Hydrogeologic Frameworks

- ***Sequence Stratigraphic Models***

  Strictly honors Sequence/Structural boundaries
- ***Hydro-Stratigraphic Models***

  Honors Formational Boundaries but may combine some sequences into composite hydrologic units
- ***Textural Models***

  Layering is partly arbitrary and Texture is estimated locally and combined into larger composite features

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Hydrogeologic Frameworks

- **Stratigraphic and Fault Surfaces ➔ Sides of Volumes (Spline Interpolation)**
- **Distribution of Properties/Surfaces within Volumes (Kriging Interpolation)**

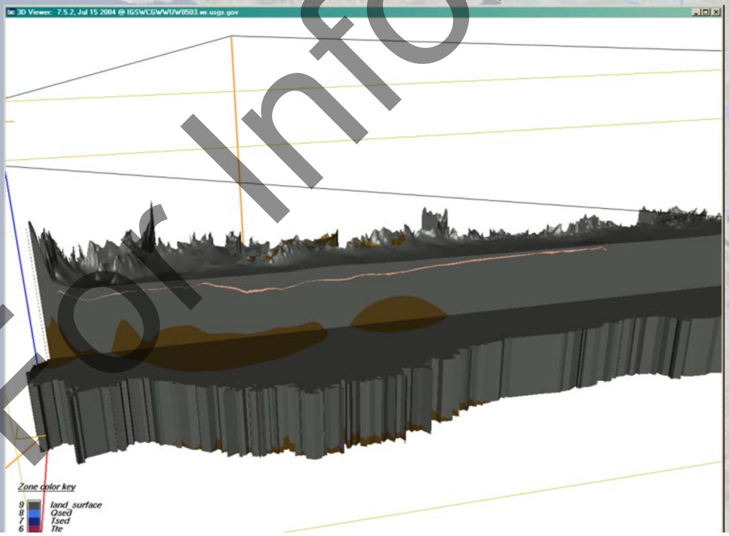
VOLUMETRIC BOUNDARIES

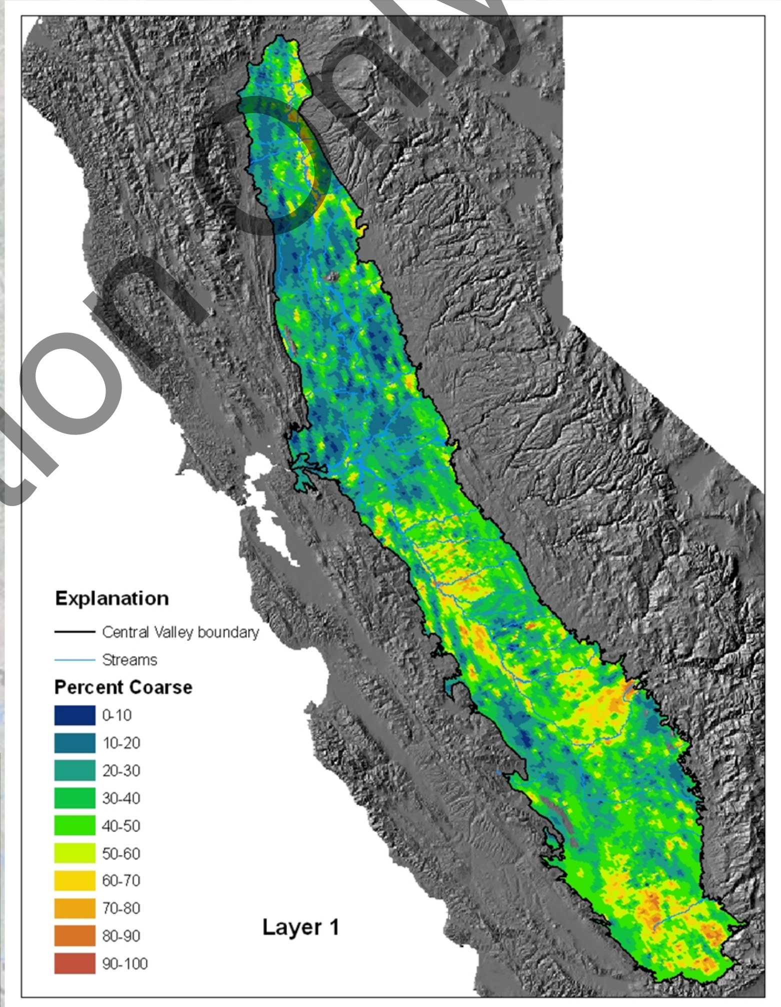
(1) LATERAL – FAULTS, PINCH OUTS, & OUTCROPS

(2) VERTICAL – UNCONFORMITIES, PINCH OUTS, & OUTCROPS

Hydrogeologic Framework

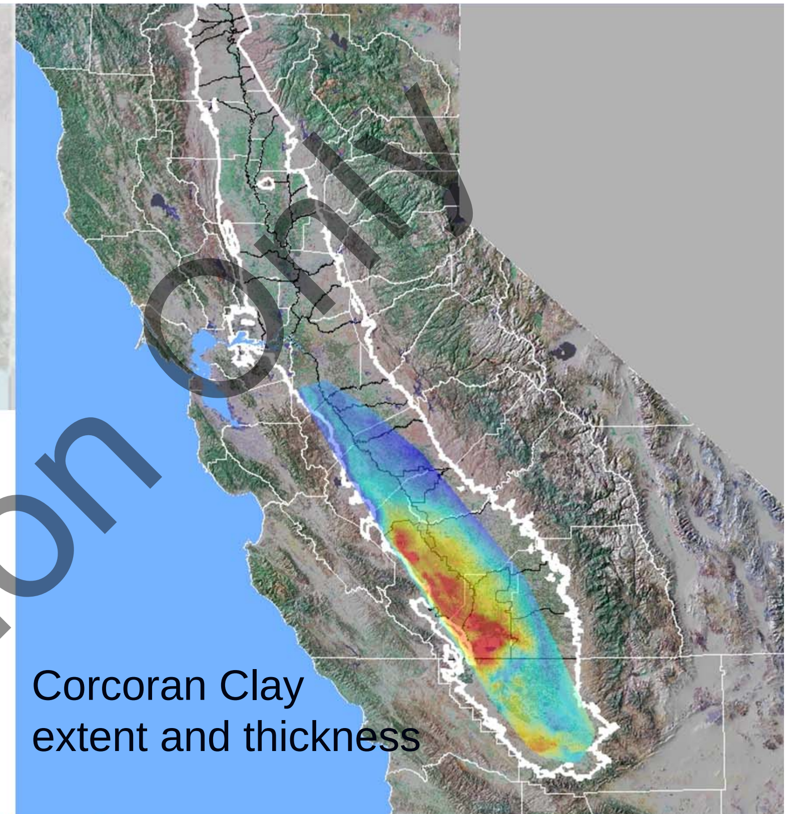
- Geologic/Stratigraphic units
  - Undifferentiated sediments
  - Corcoran Clay
  - San Joaquin Formation
  - Bedrock
- Undifferentiated sediments and Corcoran clay have varying properties related to percent coarse grained deposits

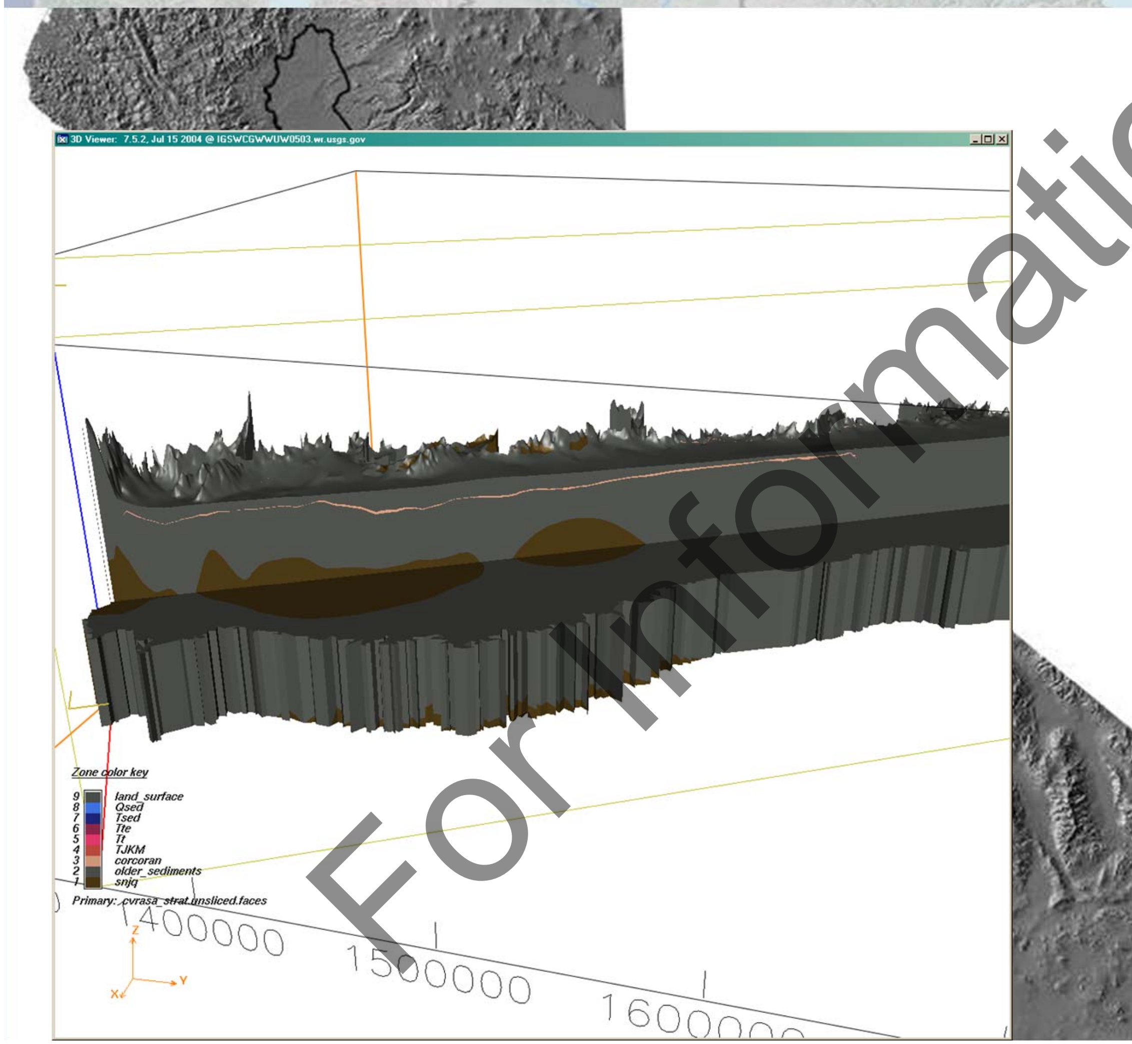


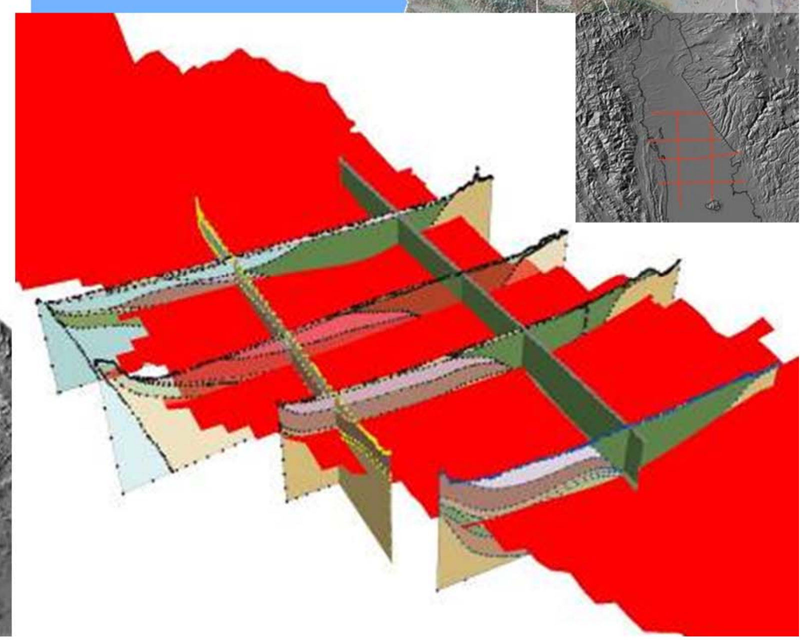


Stratigraphy

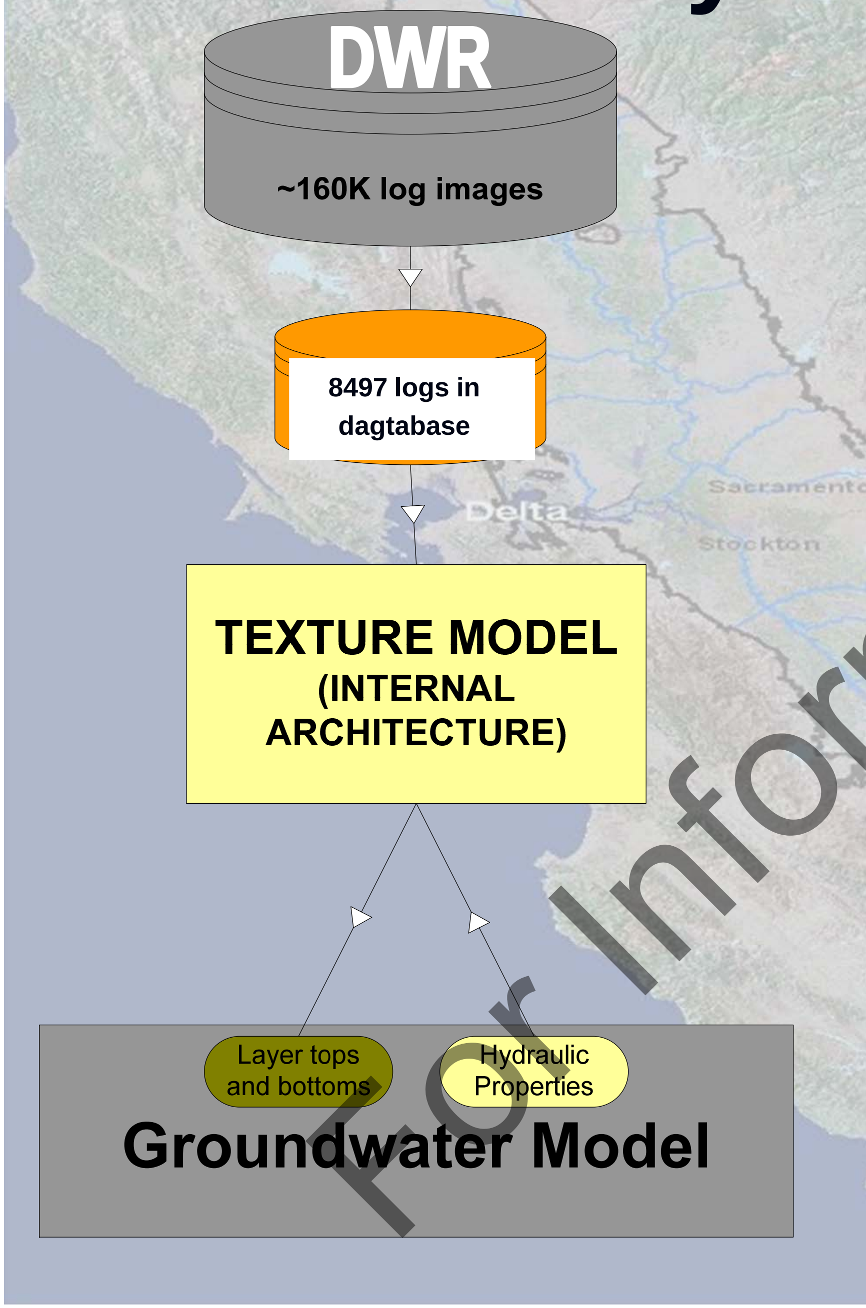
- Some layers modified to conform to Corcoran clay
- Stratigraphy in Sacramento Valley

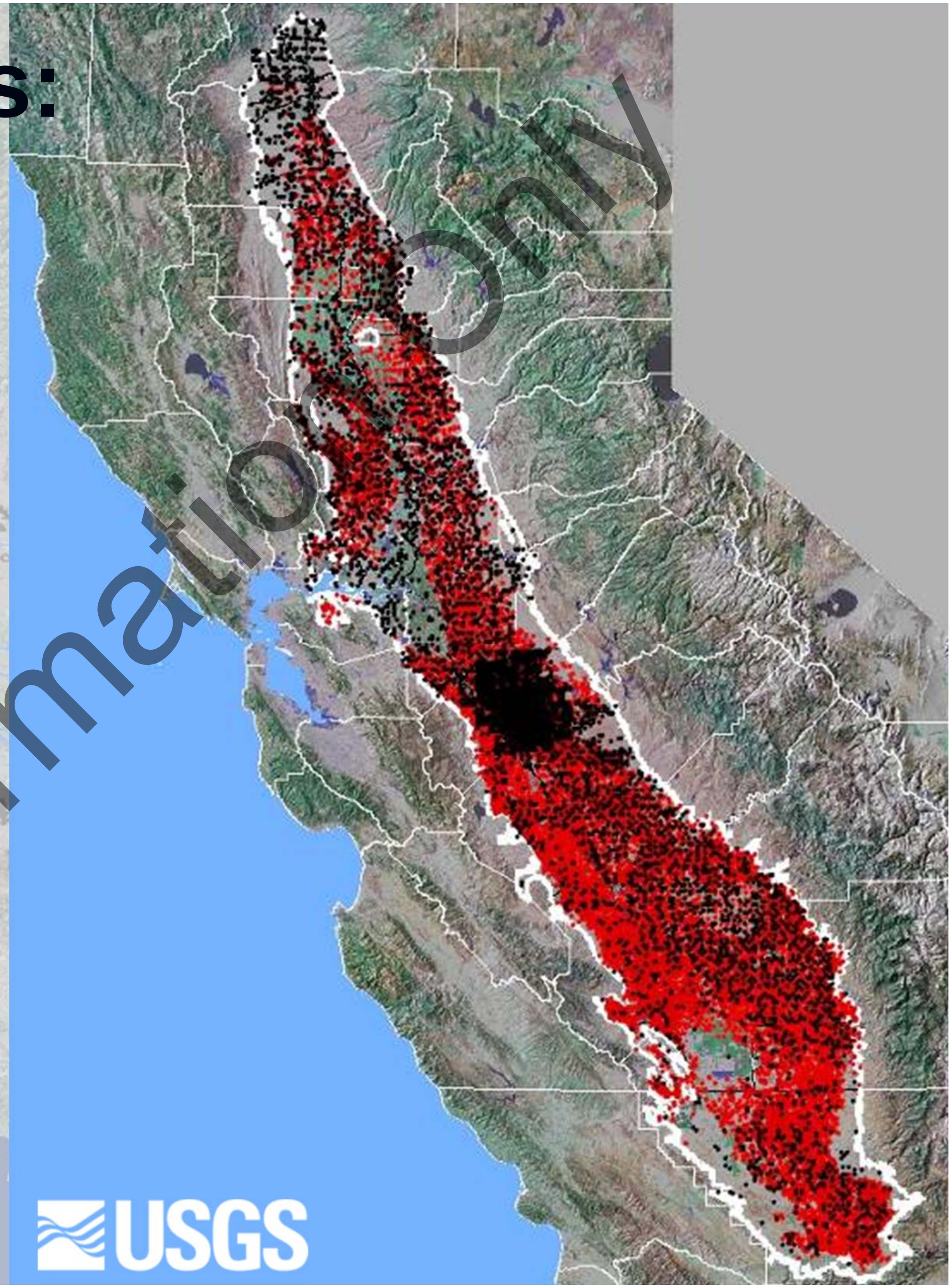






Texture Analysis:

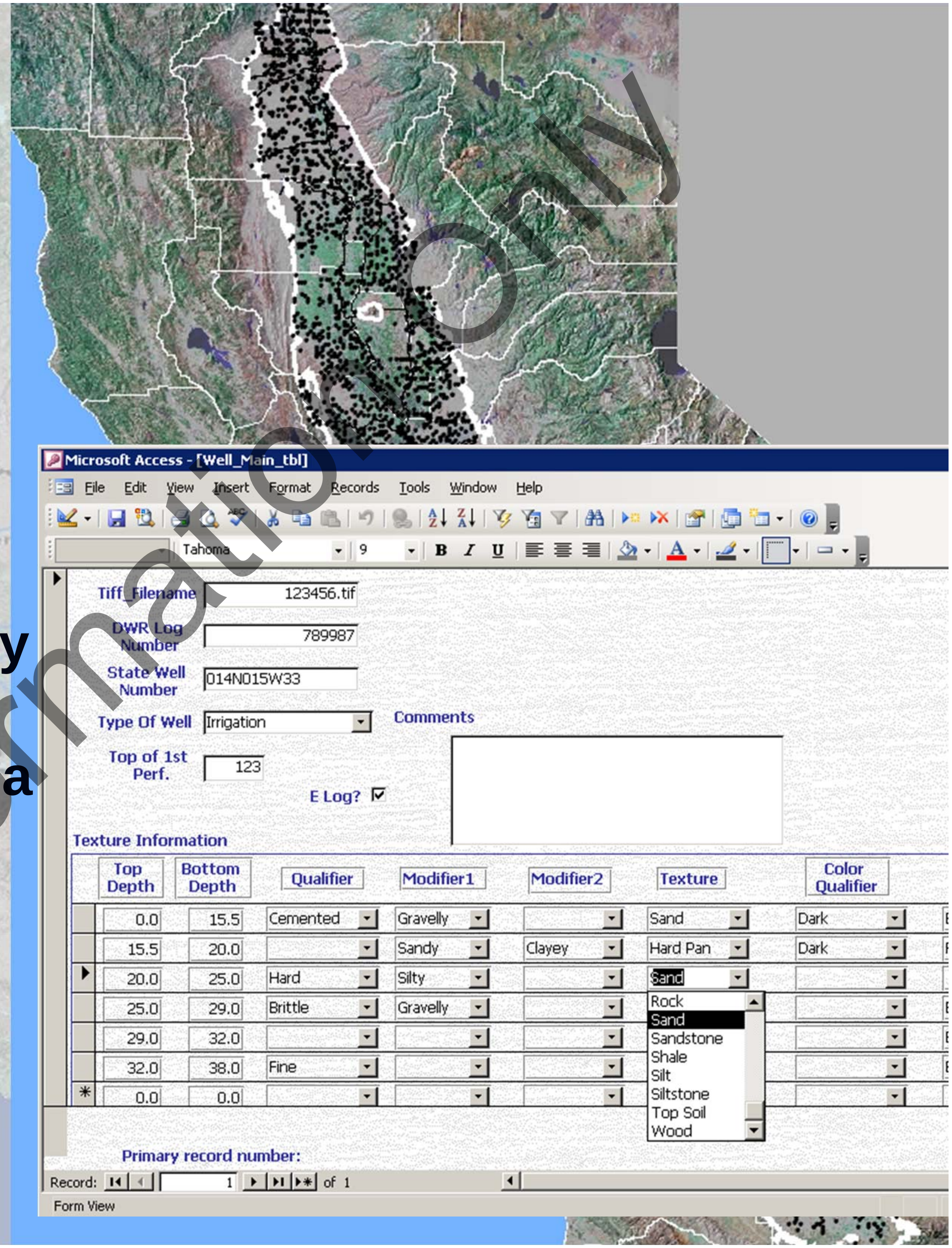




Well database:

Properties within stratigraphy based on textural analysis

Digitized DWR well logs
8497 logs digitized
2598 in Stanislaus county (Burow and others work)
5899 in rest of model area



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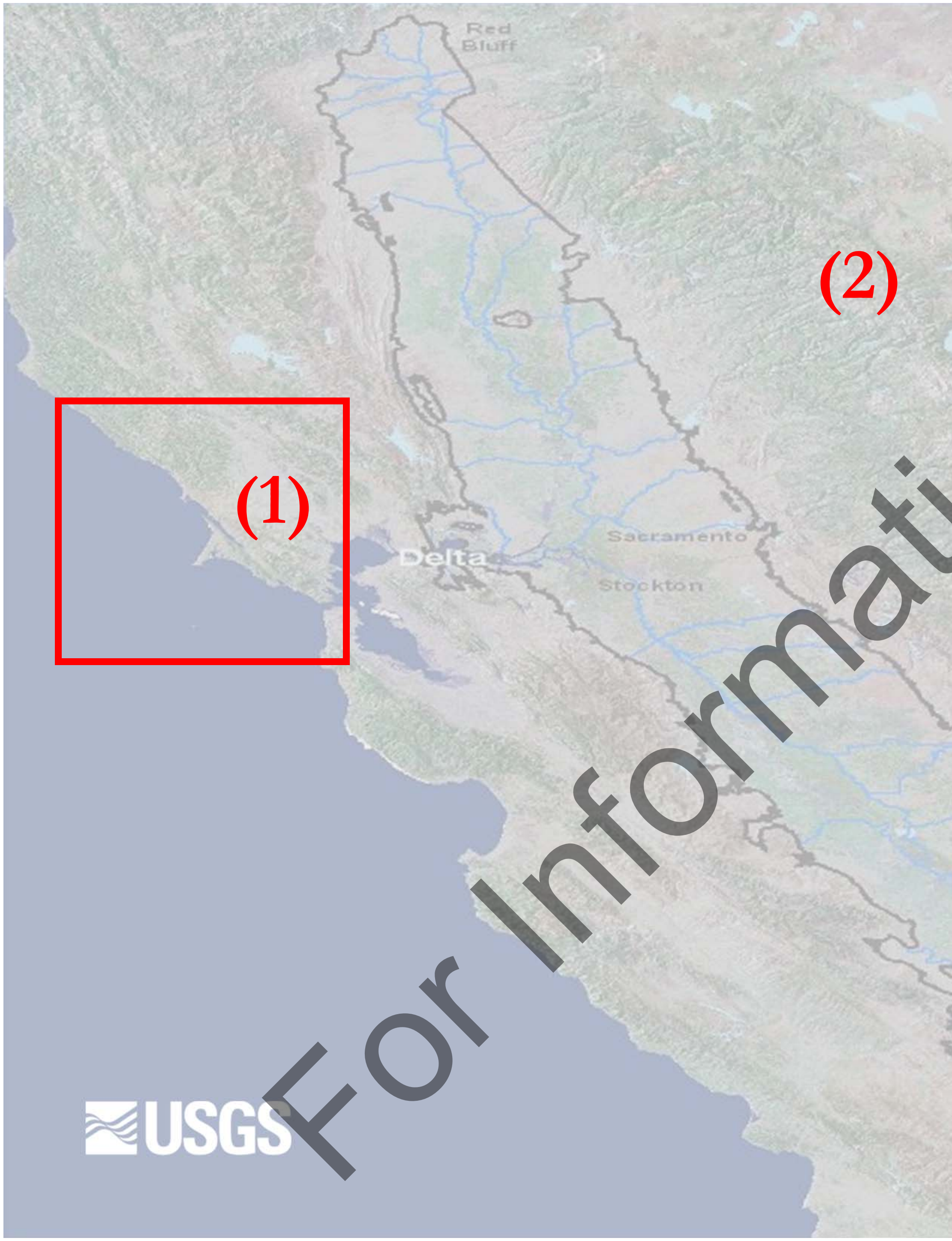
Screening Algorithm

- **Assess overall log quality on a pass or fail basis.**
  - If it lacks location information, has poor lithologic descriptions, or is illegible it immediately fails and is skipped.
- **If passed on overall quality a location score is determined.**
  - 4 pts are given to logs with the best location information (¼ ¼ info, plus legible map or written directions with distances).
  - 3 pts are given to logs with just a map or written directions with distances.
  - 2 pts are given to logs with only a street address or intersection.
- **Each ¼ of a township is complete when 8 or more pts worth of well logs have been identified in it.**



High Quality Well Log

Well log screening attempts to identify logs which contain:

1) **Adequate location information**

2) **Fair to excellent lithologic descriptions, preferably with modifiers such and gravelly/silty/sandy and qualifiers such as hard/soft/cemented.**

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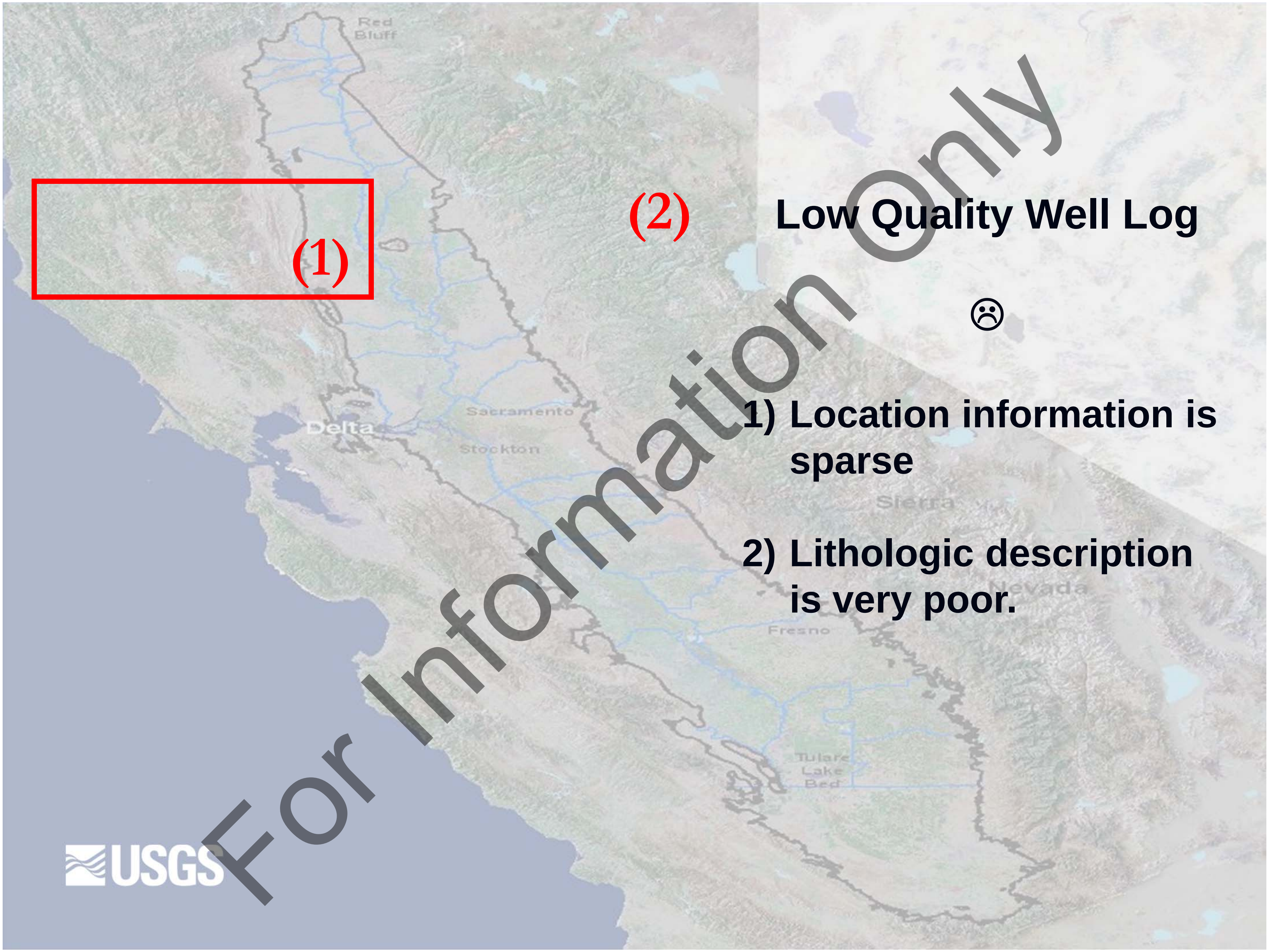


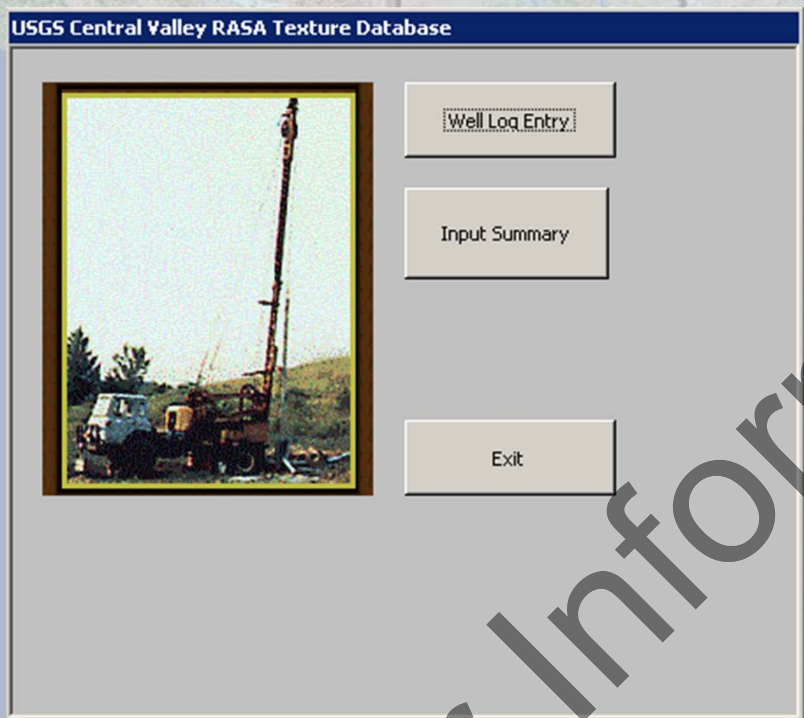
(2) **Low Quality Well Log**

☹

1) **Location information is sparse**

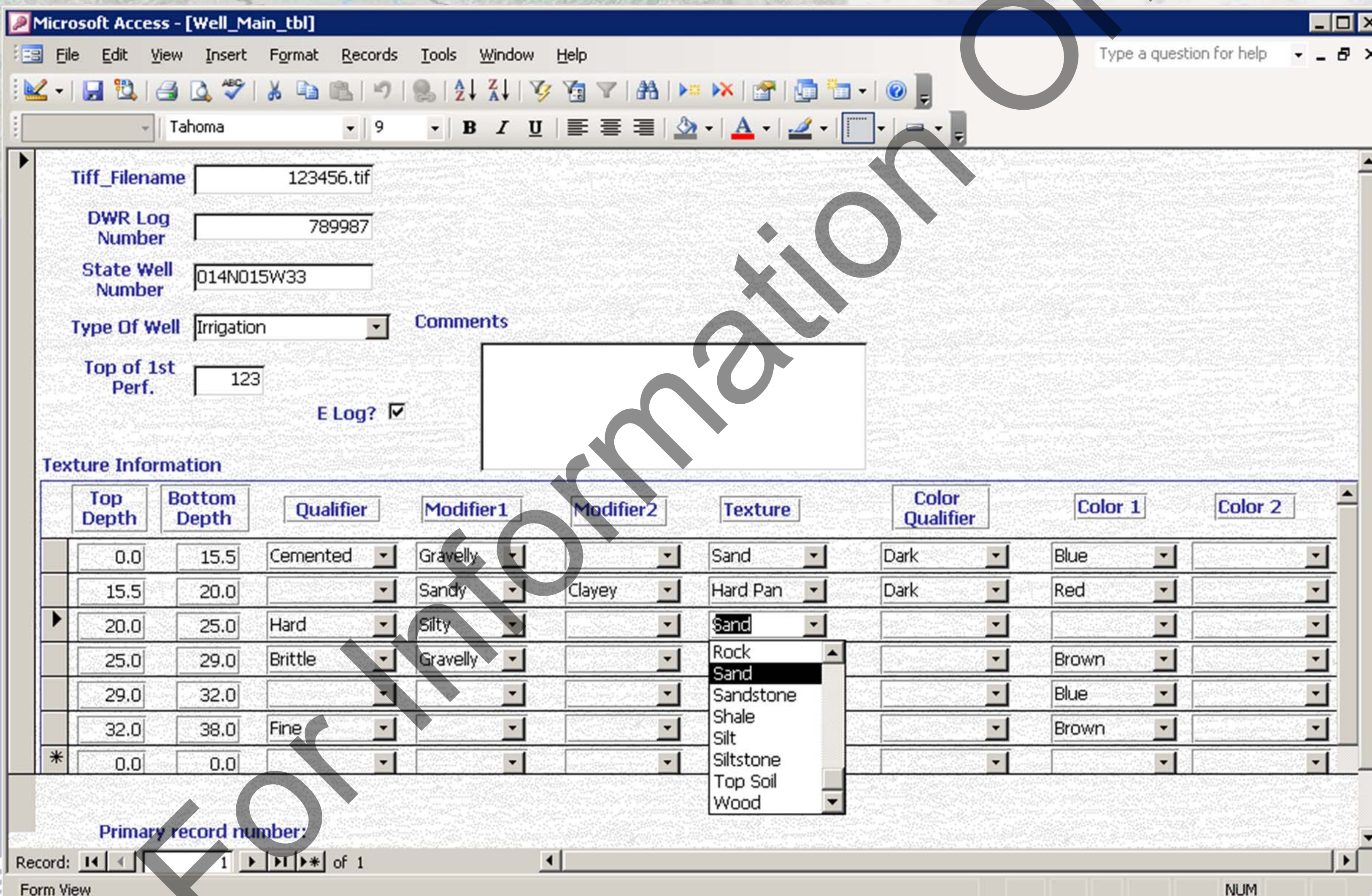
2) **Lithologic description is very poor.**

Database Entry

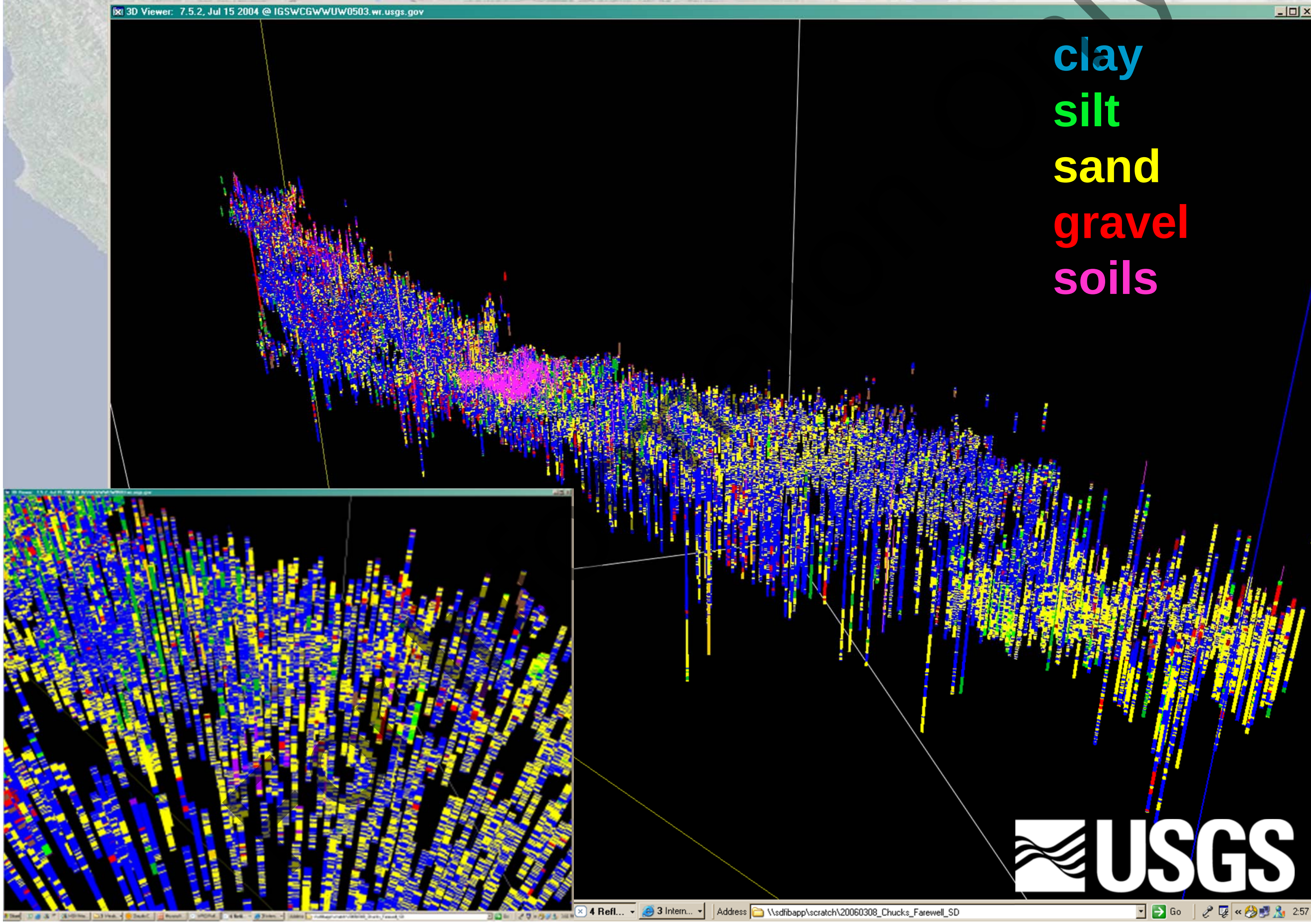


- After the well logs have been screened they are entered into the texture database.
- Location based on TRS

Database Well Log Entry Screen

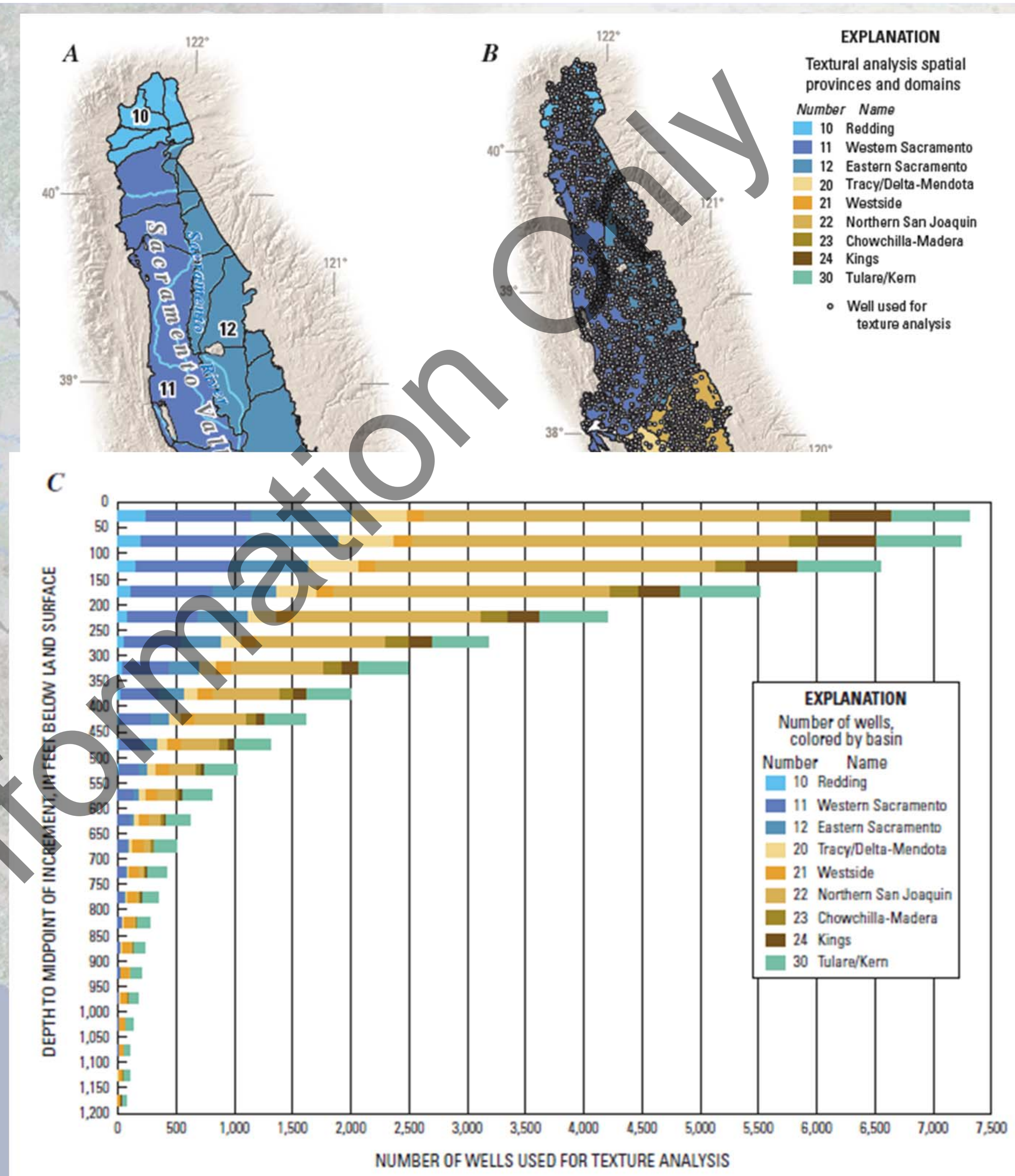


Central Valley well logs - lithology



Provinces based on groundwater basins and sub-basins

- Three-dimensional kriging (ISATIS) by provinces
- Data distribution by province and depth



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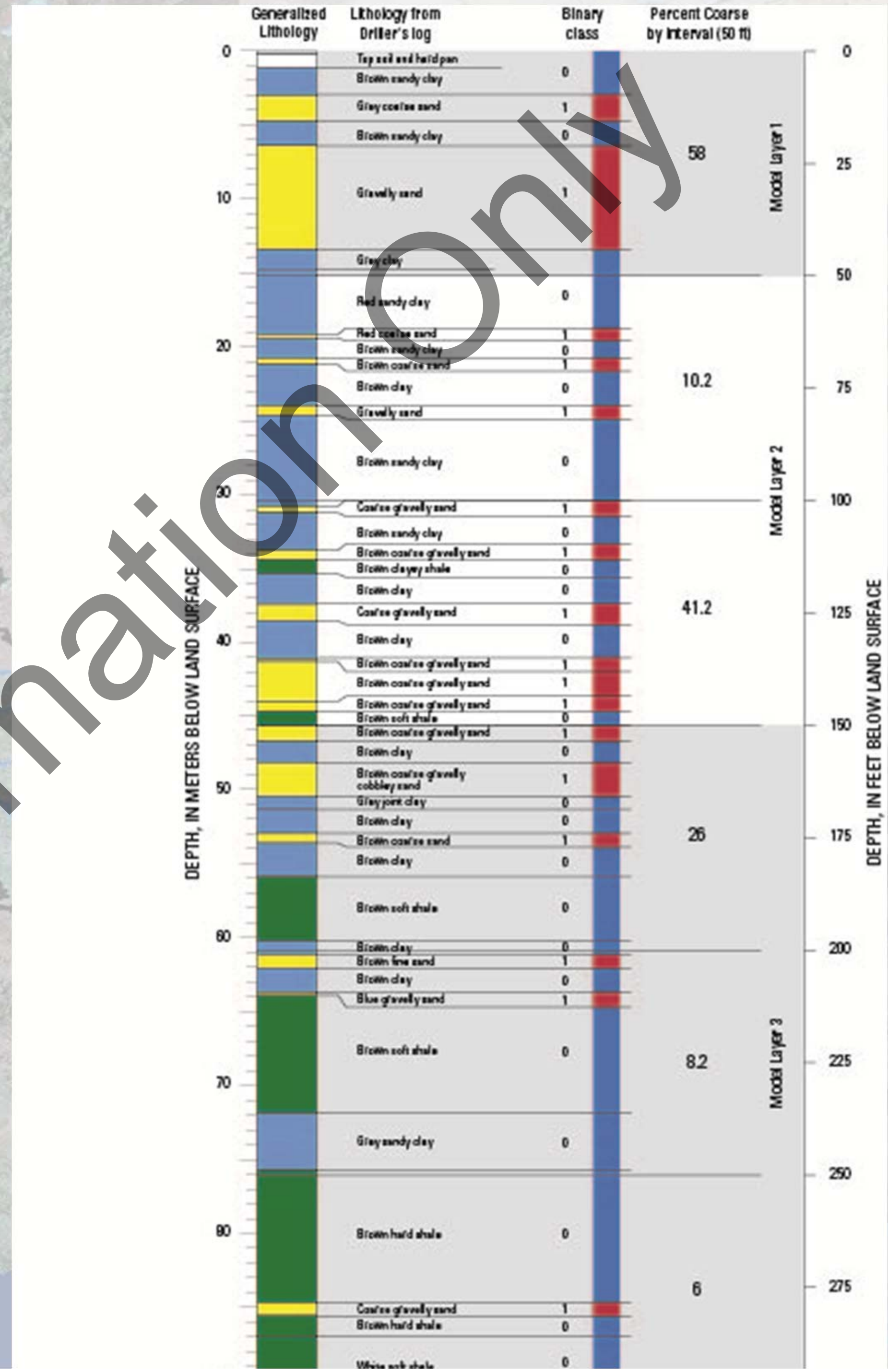
Drillers log

- Lithology
- Binary Classification
- Percent Coarse – 50 foot increments



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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)

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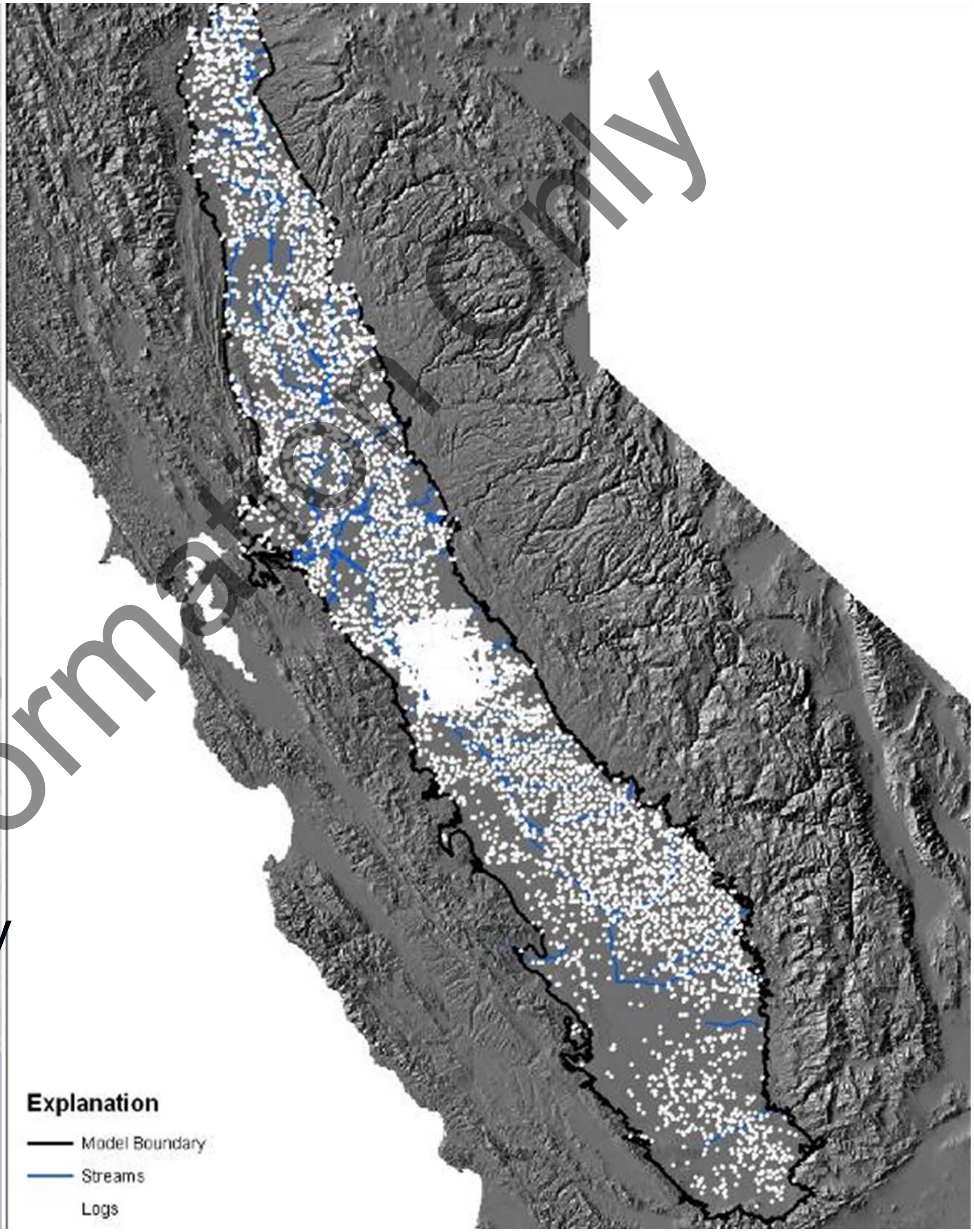
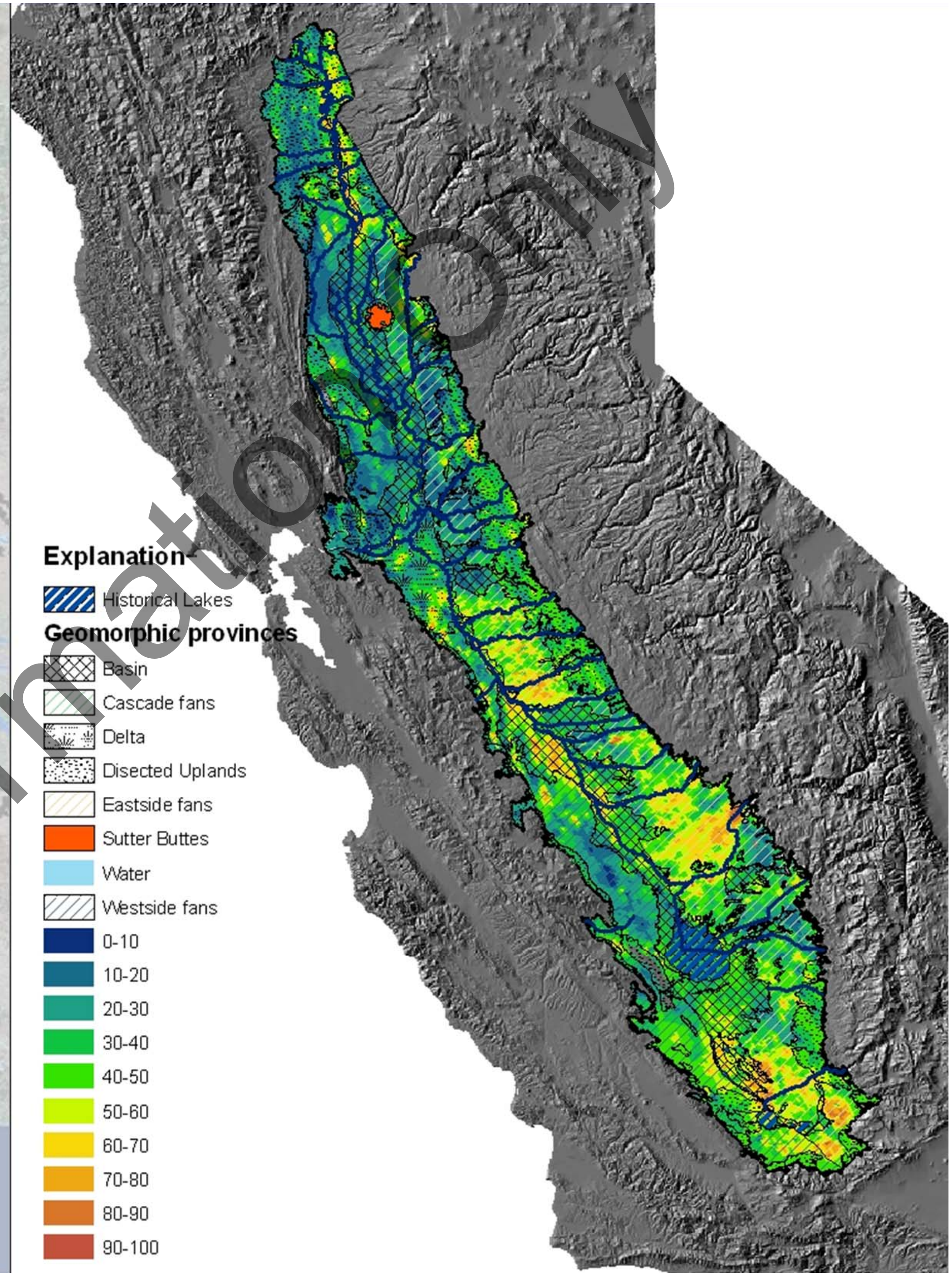


Geomorphology

- Based on existing water supply papers and maps
- Correlates with texture model



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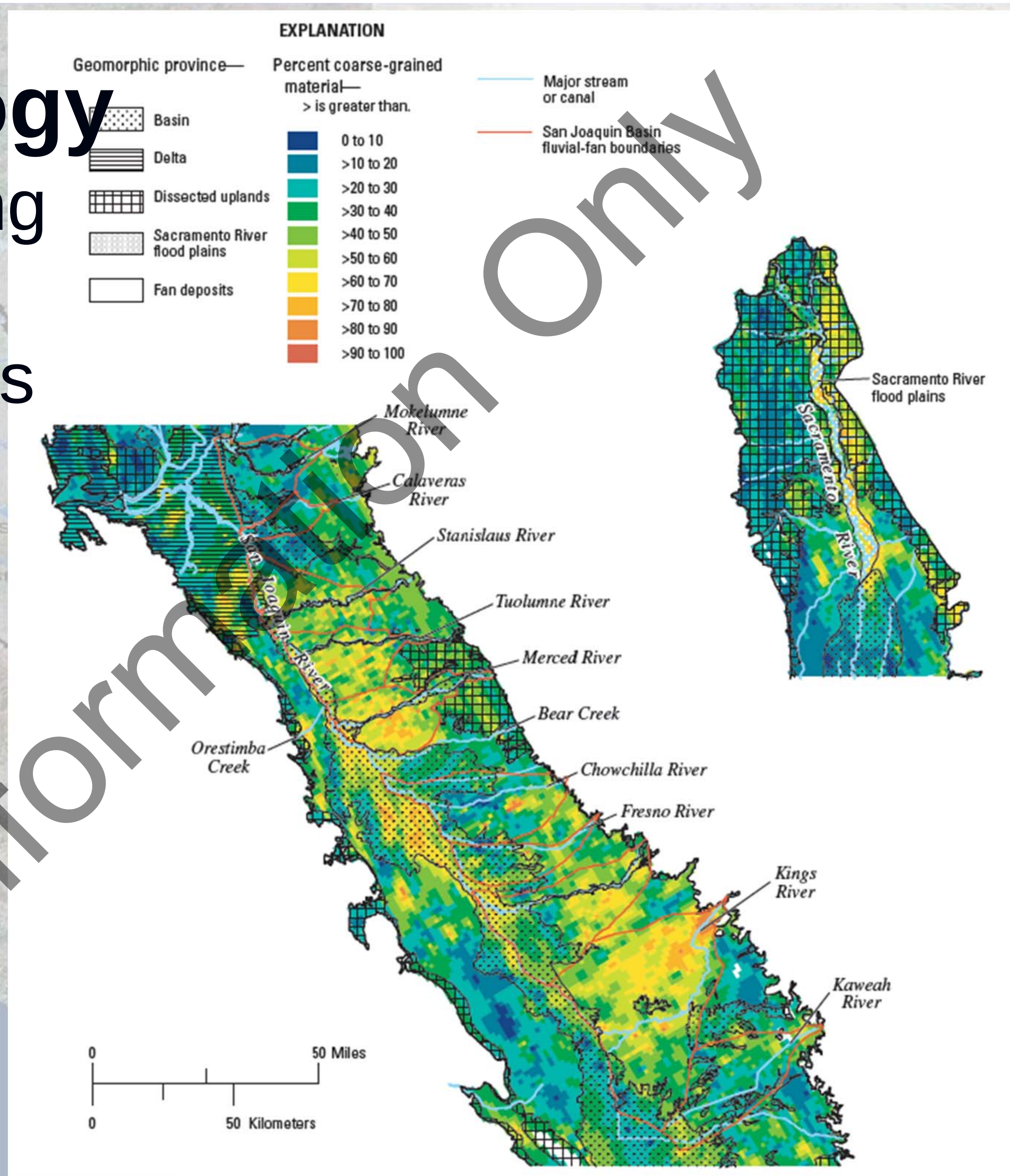
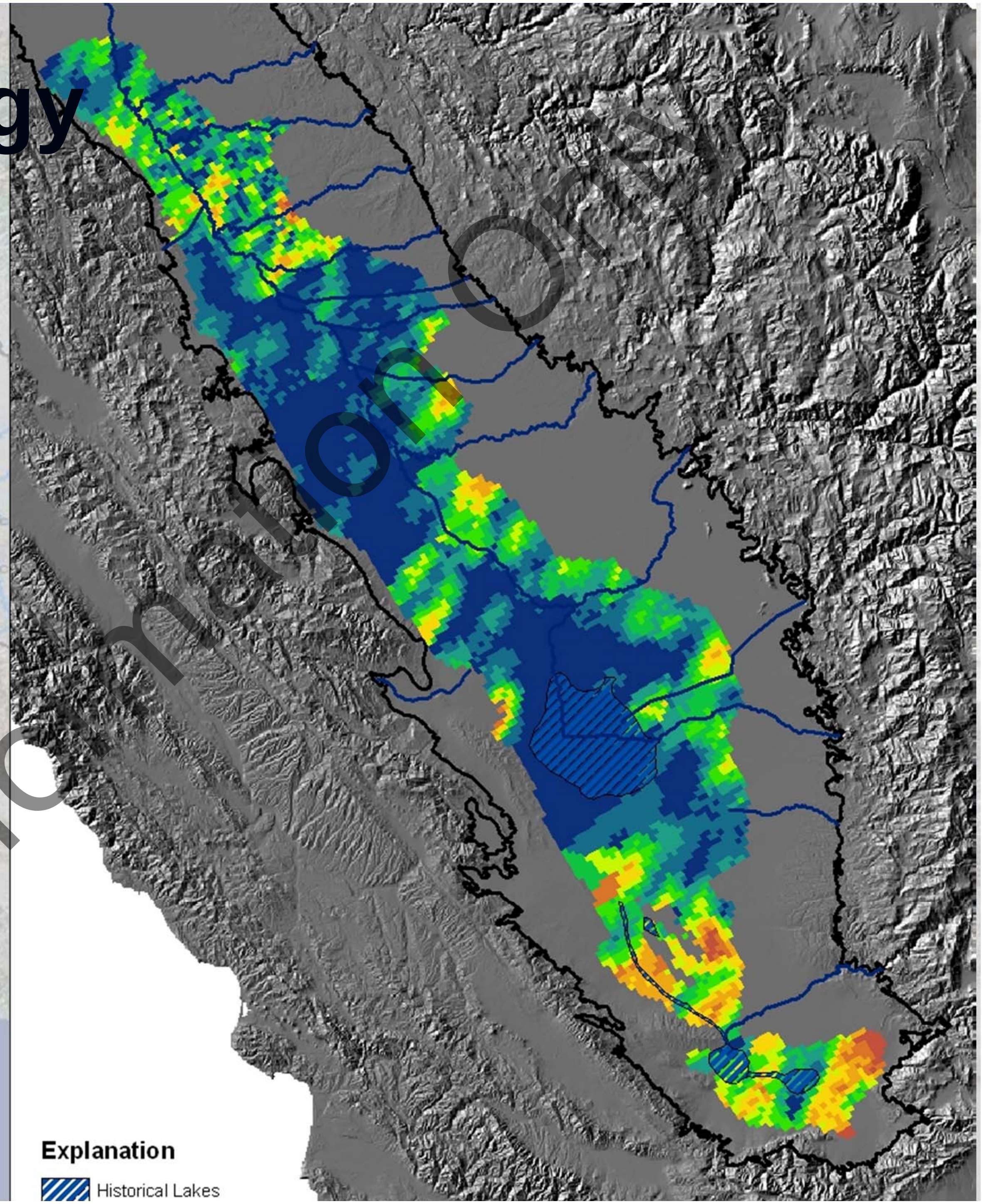


Geomorphology

- San Joaquin

Valley area

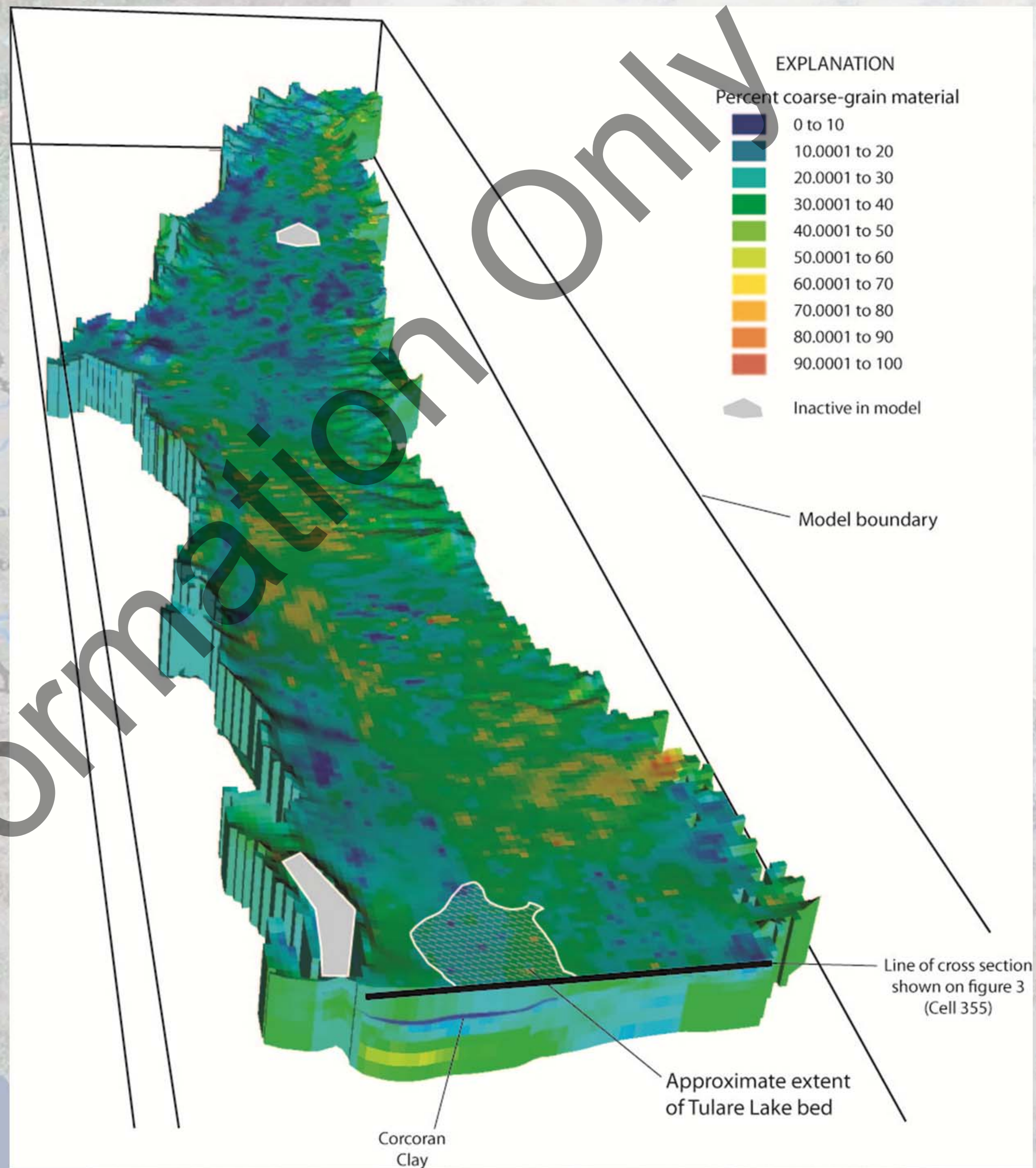
- *Corcoran clay*



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



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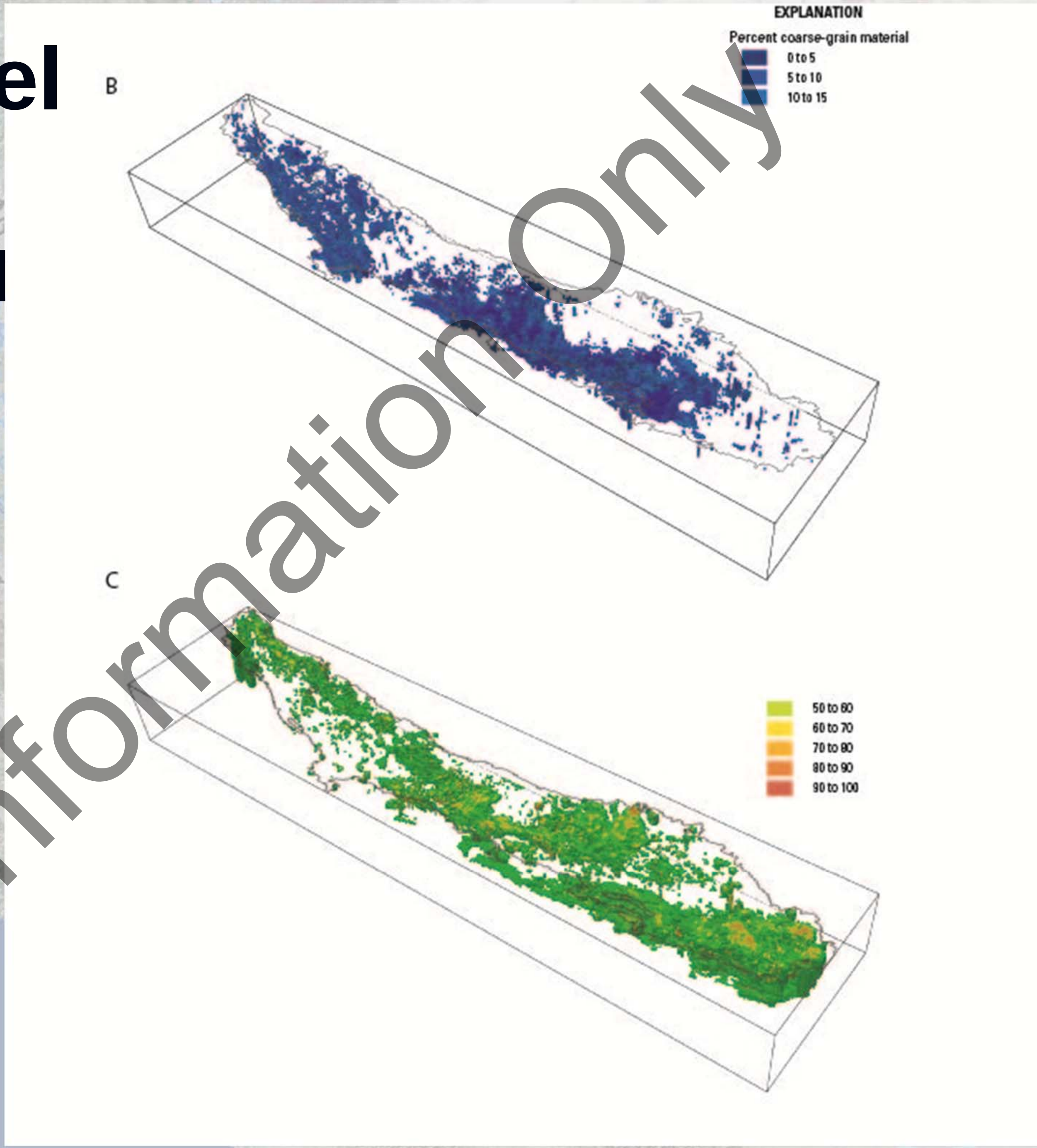
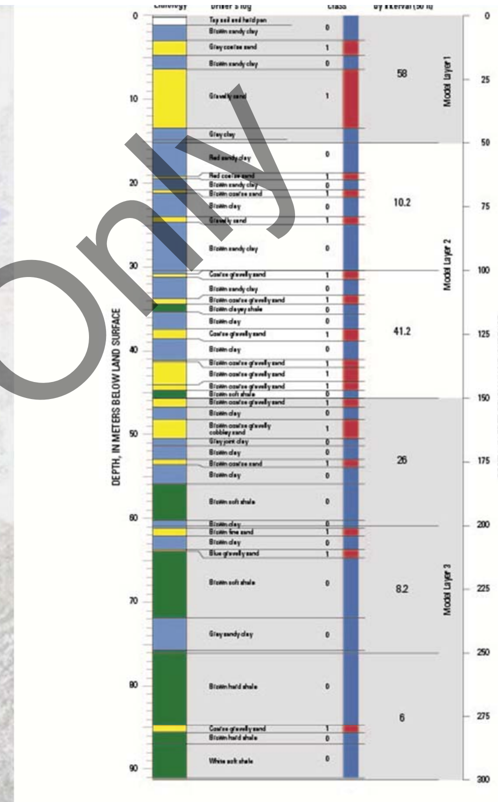
Texture Model

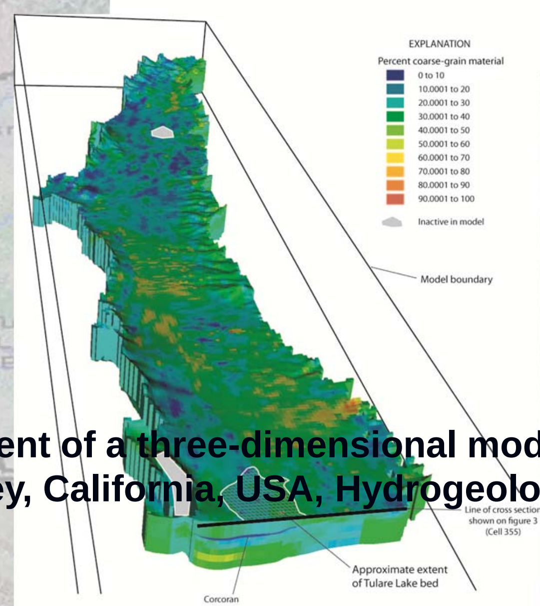
- Fine-grained
- Coarse-grained



Datasets available:

- Driller’s logs proprietary
  - Access Database proprietary
- Journal article – data sets
  - Table of Percent Coarse on 50 foot depth increments at each Well (location based on TRS)
  - Texture Model Percent Coarse at Lattice Points
    - 50 foot depth increments
    - One square mile grid





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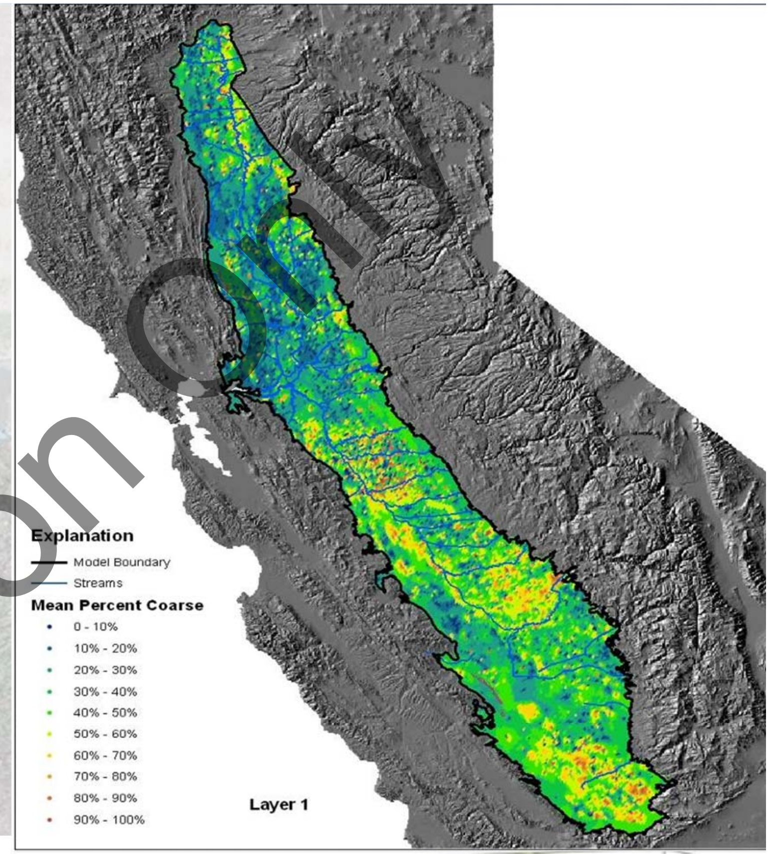
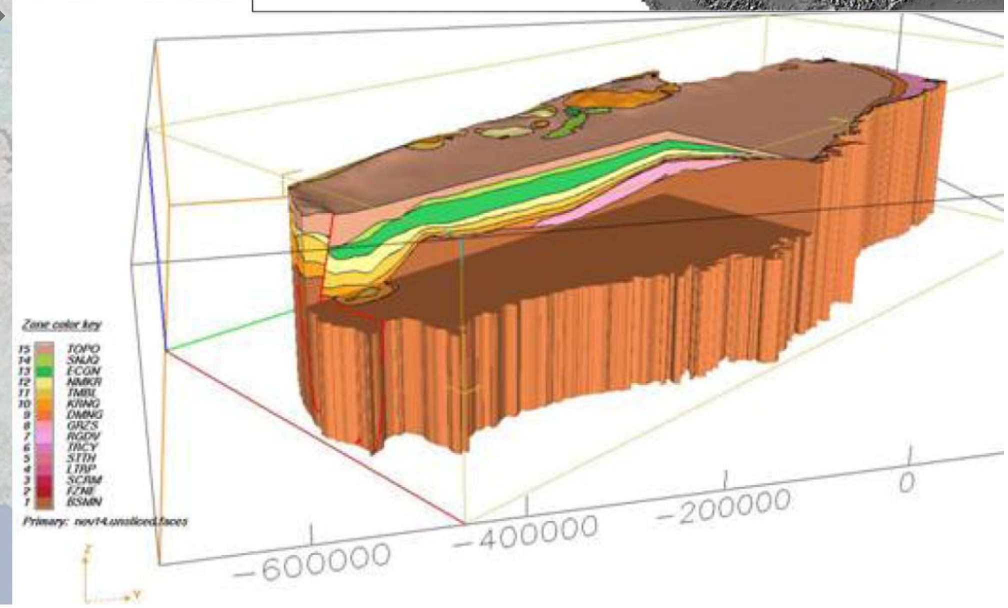
Texture based approach for hydraulic properties:

- Hydraulic properties
  - K is a function of
    - Texture
    - Geologic unit
- 3D geologic model
  - Stratigraphy
- Texture Data
  - DWR well logs
  - Screen and code DB
  - 3D texture model





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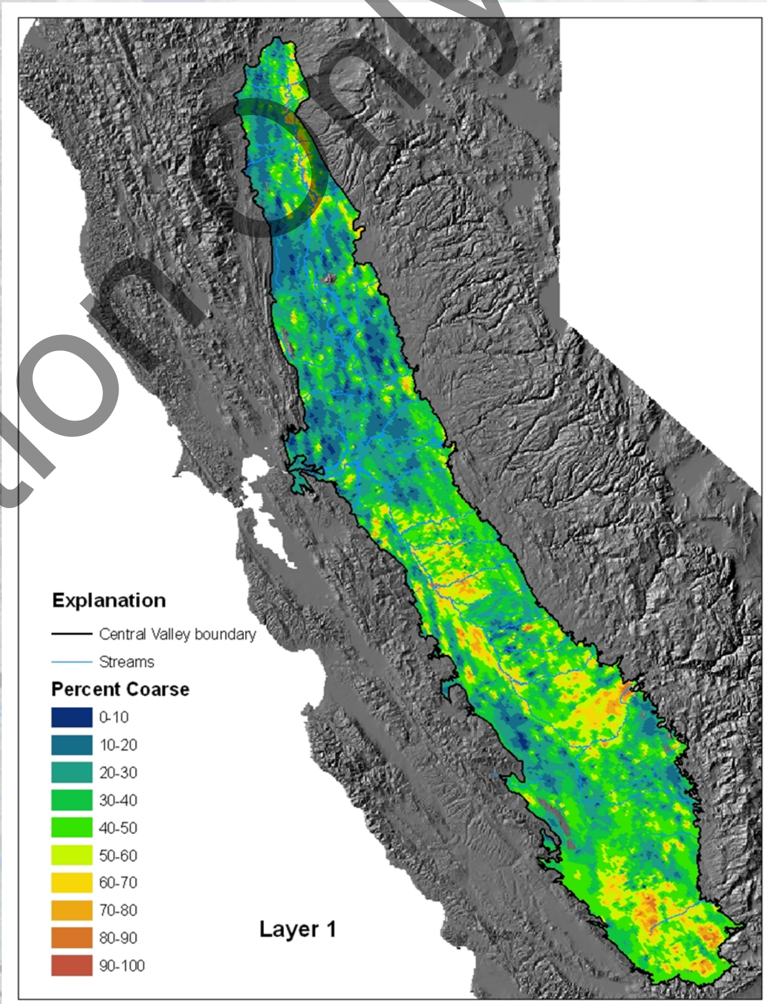
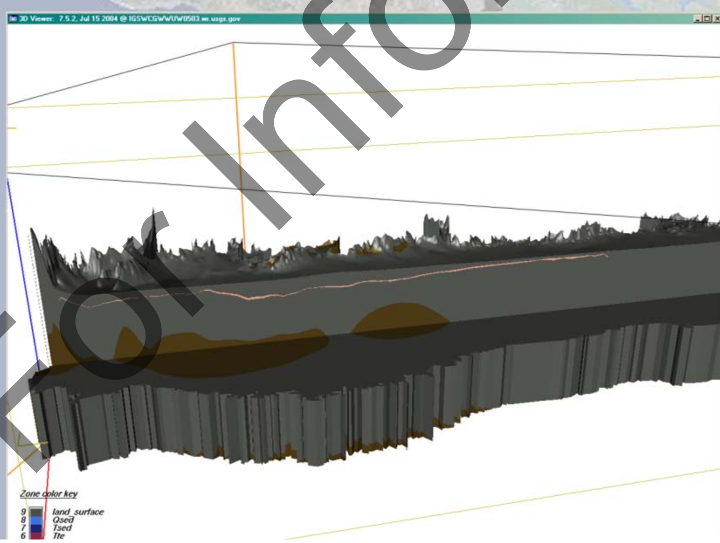
Texture Data into Flow Model

- Geologic/Stratigraphic units
  - Corcoran Clay
  - San Joaquin Formation
  - Sacramento stratigraphy
- Percent coarse each layer
  - Hydraulic conductivity
  - Storage





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Discretization

- 10 layers
- Thinner near surface
- Generally equal thickness in multiples of 50 ft increments
  1. 50
  2. 100
  3. 150
  4. Upper Corcoran Clay
  5. Lower Corcoran Clay
  6. 200
  7. 250
  8. 300
  9. 350
  10. 400
- Total Thickness Outside Corcoran: 1800 ft (550 m)
- Dummy layers outside Corcoran Clay

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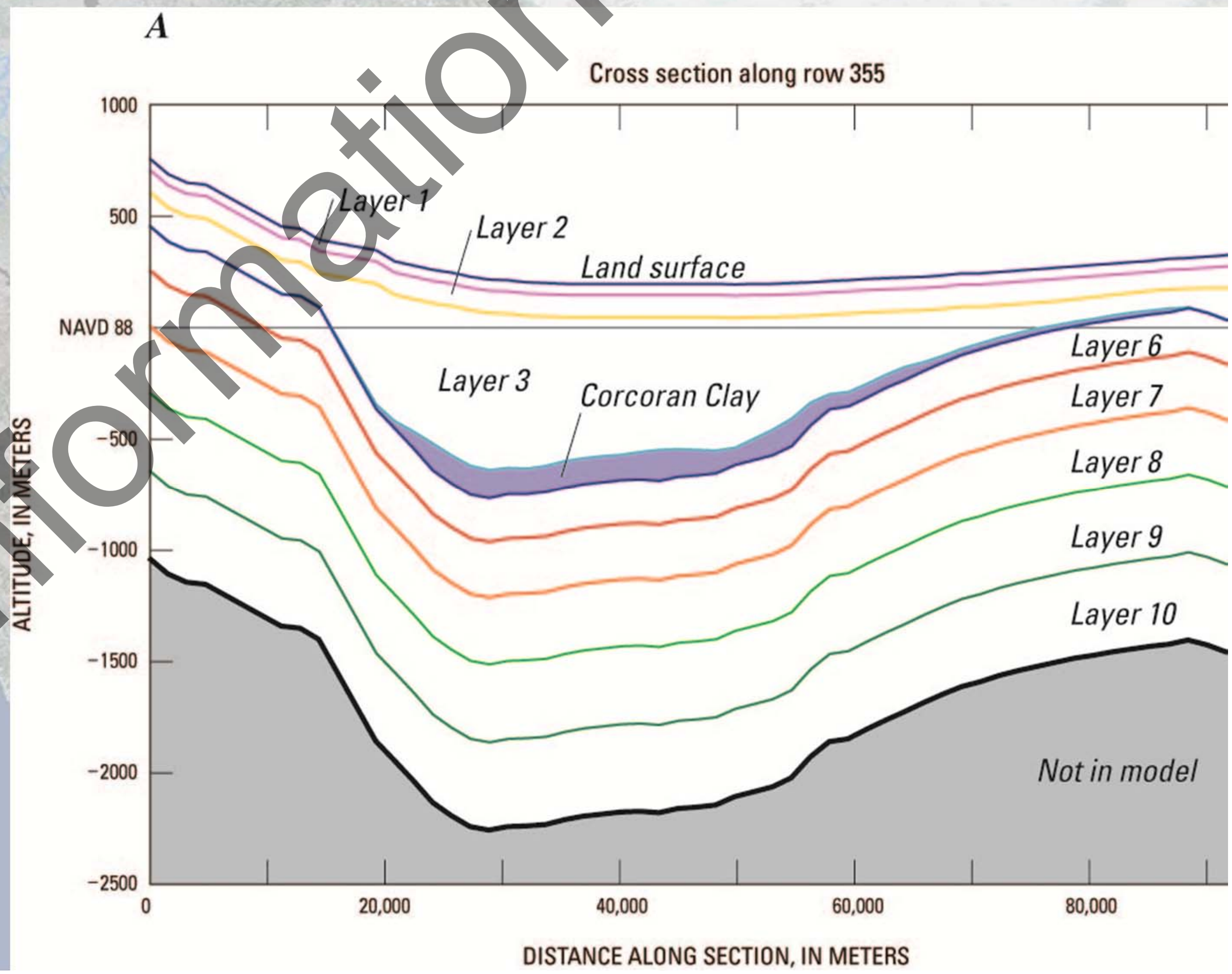


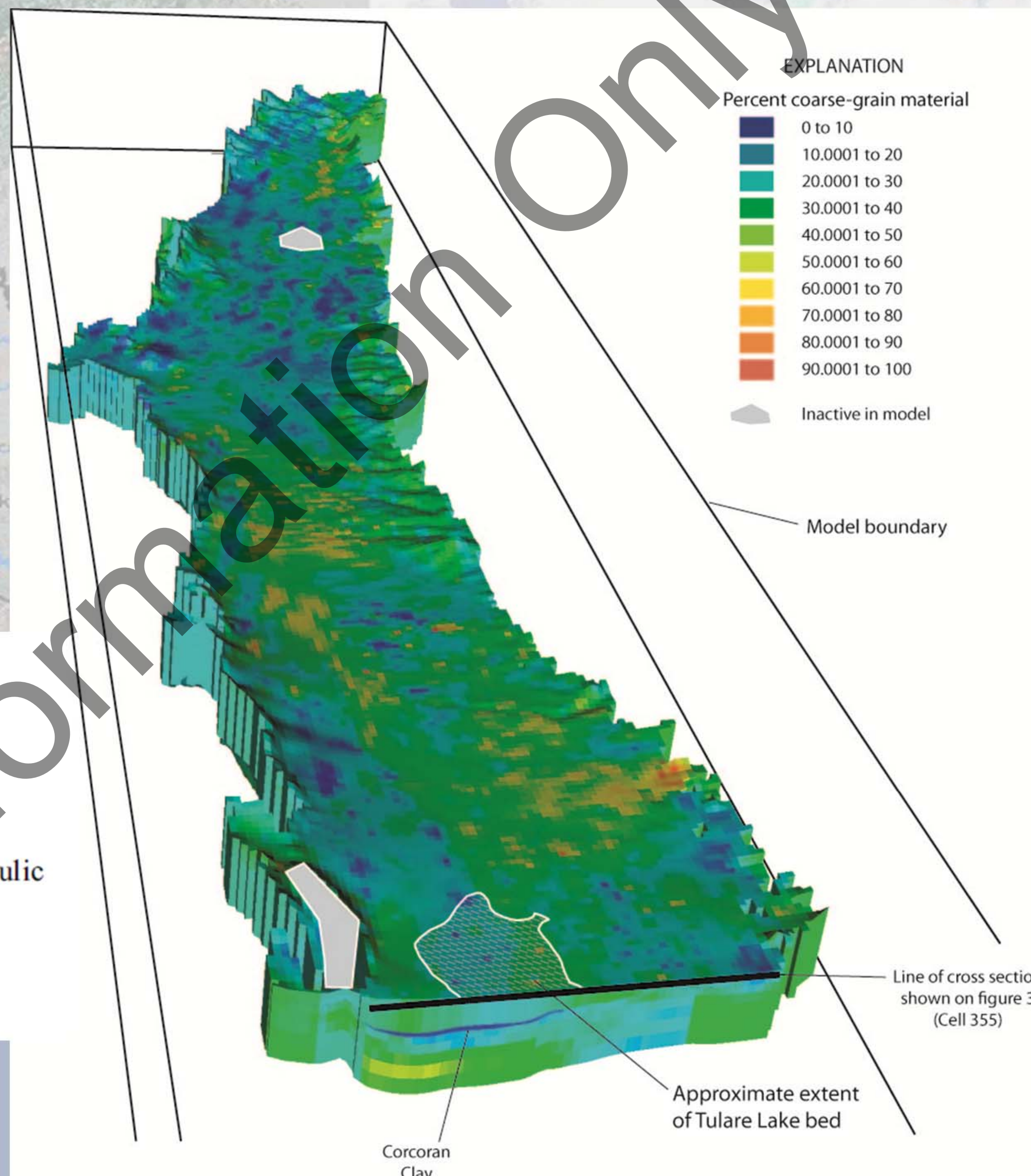
Hydraulic Properties

- **Geologic/Stratigraphic units**
  - Corcoran Clay (zones/layers)
  - San Joaquin Formation (zones)
- **Generally based on texture model (percent coarse)**
- Hydraulic conductivity
  - Power mean

$$M^p(x) = \left(\frac{1}{n}\sum_{k=1}^{n} x_k^p\right)^{1/p},$$

where

x is the value being averaged (such as hydraulic conductivity)
p is the averaging power-mean exponent
n is the number of elements being averaged, and
x_k is the kth element in the list.



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Hydraulic Properties

- **Hydraulic conductivity**
  - Power mean
    - Horizontal K
      - p = 1
      - arithmetic mean
      - Kf << Kc, the arithmetic mean largely is influenced by the K fraction of the coarse-grained end member
    - Vertical K
      - p = -1 to 0
        - p = 0 geometric mean
        - p = -1 harmonic mean
      - Both the harmonic and geometric means more heavily weight the fine-grained end members
    - Vertical hydraulic conductivities are much lower than the horizontal hydraulic conductivities
- Storage and subsidence
  - uses % fine
    - Elastic
    - Inelastic
    - Compressibility of water

Horizontal Hydraulic Conductivity (K_h)

$$K_{h,i} = \left[K_c F_{c,i} + K_f F_{f,i}\right]$$

where

$F_{c,i}$ is the fraction of coarse-grained sediment in a cell, estimated from sediment texture data, and

$F_{f,i}$ is the fraction of fine-grained sediment in a cell ($1 - F_{c,i}$).

Vertical Hydraulic Conductivity (K_v)

$$K_{v,k+1/2} = \left[F_{c,k+1/2} K_c^p + F_{f,k+1/2} K_f^p\right]^{1/p},$$

where

k represents the layer

$F_{c,k+1/2}$ is the fraction of coarse-grained sediment between layer midpoints, and

$F_{f,k+1/2}$ is the fraction of fine-grained sediment between layer midpoints.

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