# Central Valley Hydrologic Model

## Version 1

# Datasets Workshop

Claudia Faunt, Randy Hanson,
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U.S. Geological Survey

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# Today's Agenda:

**Part 3 - Irrigated Agriculture**

9:00-9:15 Water Budget Subregions (Claudia Faunt/Randy Hanson)

9:15-10:00 Land Use (Claudia Faunt/Randy Hanson)

10:00-10:30 Soils (Randy Hanson)

10:30-10:45 Break

10:45-11:00 Deliveries/Diversions (Claudia Faunt/Randy Hanson)

11:00-11:30 Pumpage (Claudia Faunt/Randy Hanson)

11:30-12:00 Discussion

**Part 4 - Model Observations and Ways to Move Forward**

1:00-1:30 Observation Data (Claudia Faunt)

1:30-2:00 Data Input Networks (Randy Hanson)

2:00-2:15 Break

2:15-4:00 Discussion (possible topics and leads to discussion)

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- Artificial Recharge/Water Banks (ASRs)
- Regions changing through time

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- Crop Properties
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- ASRs
- Allotments

11:30-12:00 Discussion

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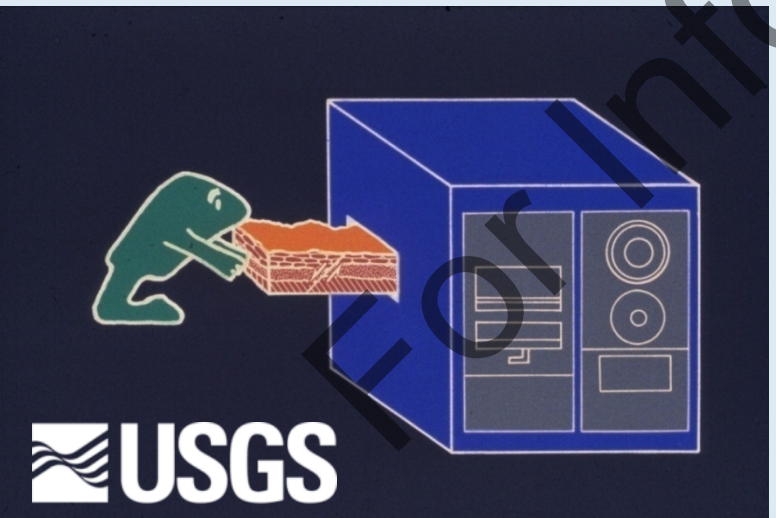
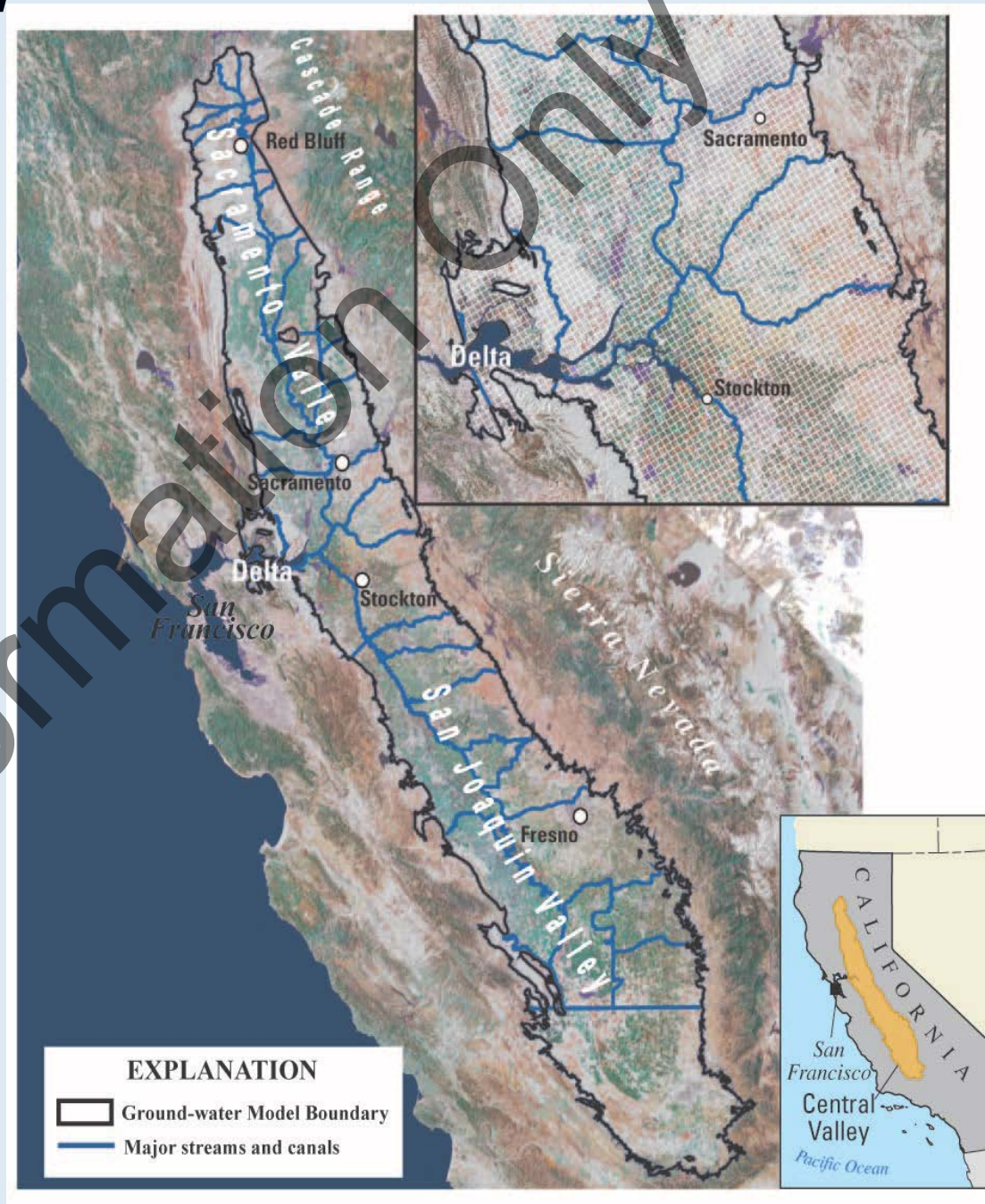
# CVHM overview

- 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)

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# CVHM – emphasis on groundwater availability and changes in storage

## 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.

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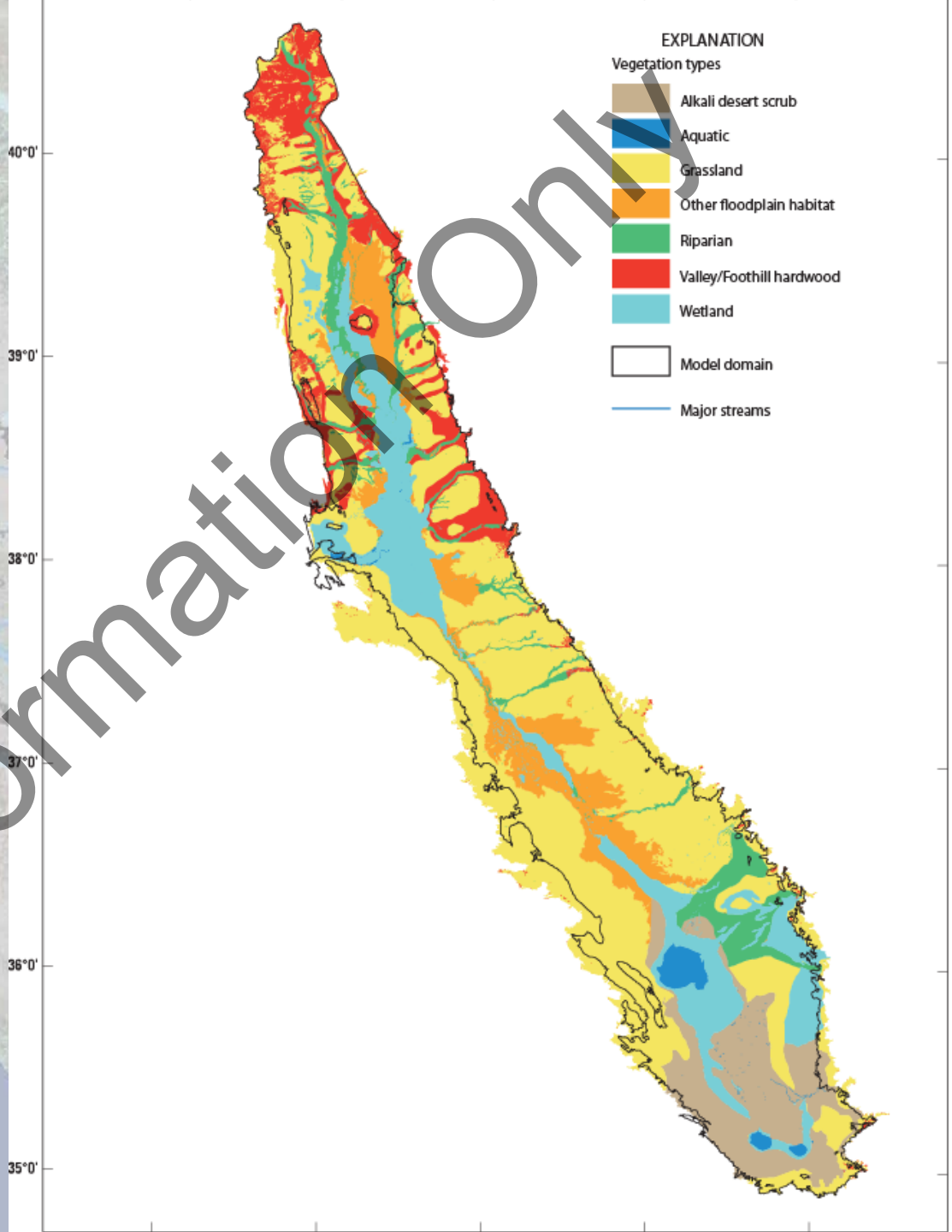
# Water Use:

- Began in 1700s
- 1914 water act addressed surface water
- Groundwater not regulated (local responsibility):

"legally landowner can pump ground water as long as it is put to a reasonable and beneficial use"

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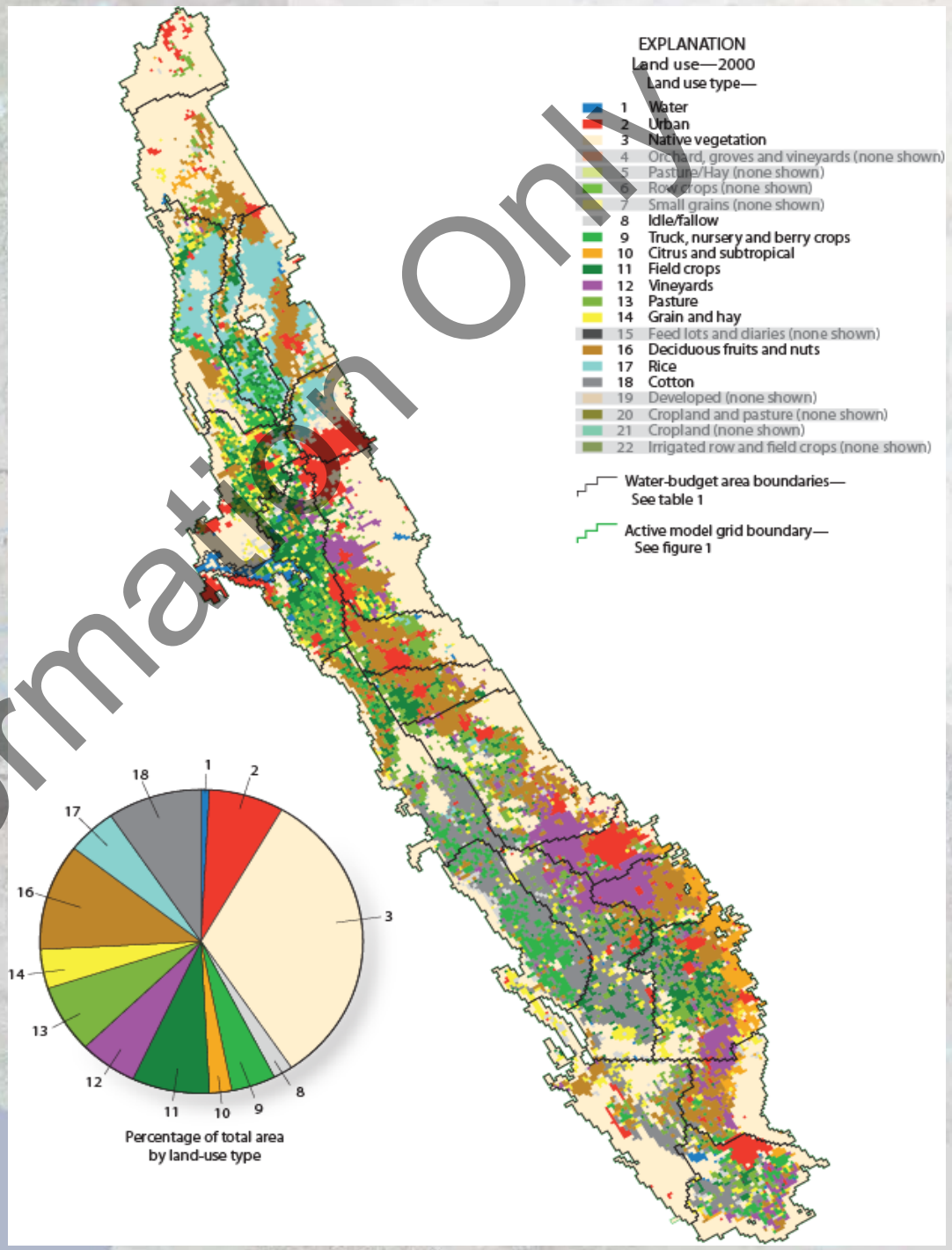
# Water Use:

- Municipal/Industrial (urban)
- Agricultural
  - Measure of the amount of water used to irrigate crops
  - Depends on:
    - Crop type
    - Climate
    - Soils
    - Efficiency
  - Central Valley 7 million acres of irrigated crops
    - Sacramento Valley (2)
    - San Joaquin Basin (2)
    - Tulare Basin have (3)
- Environmental
  - Delta flows
  - San Joaquin River

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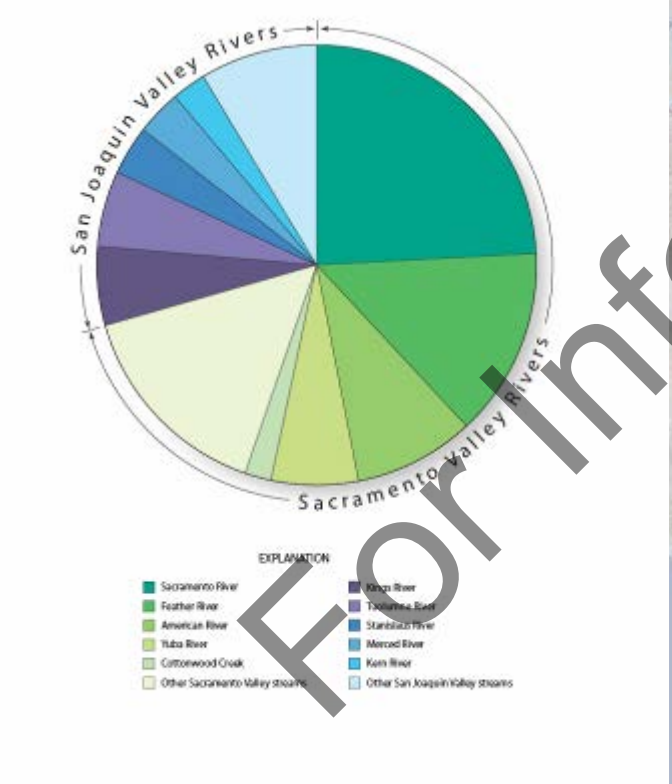
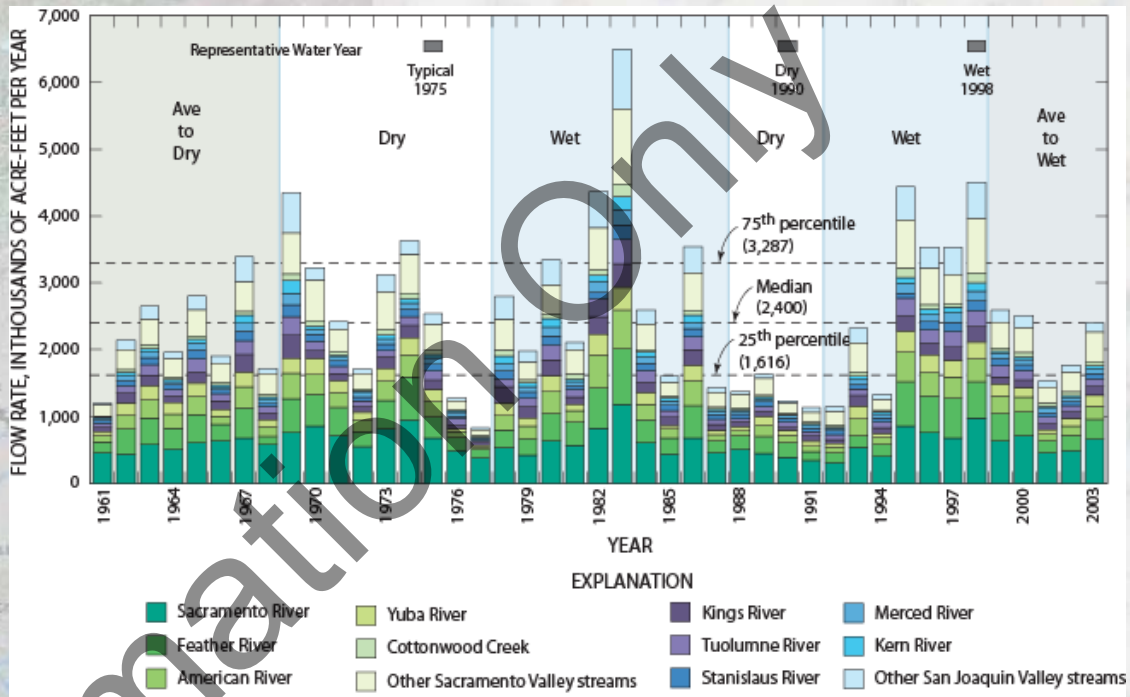
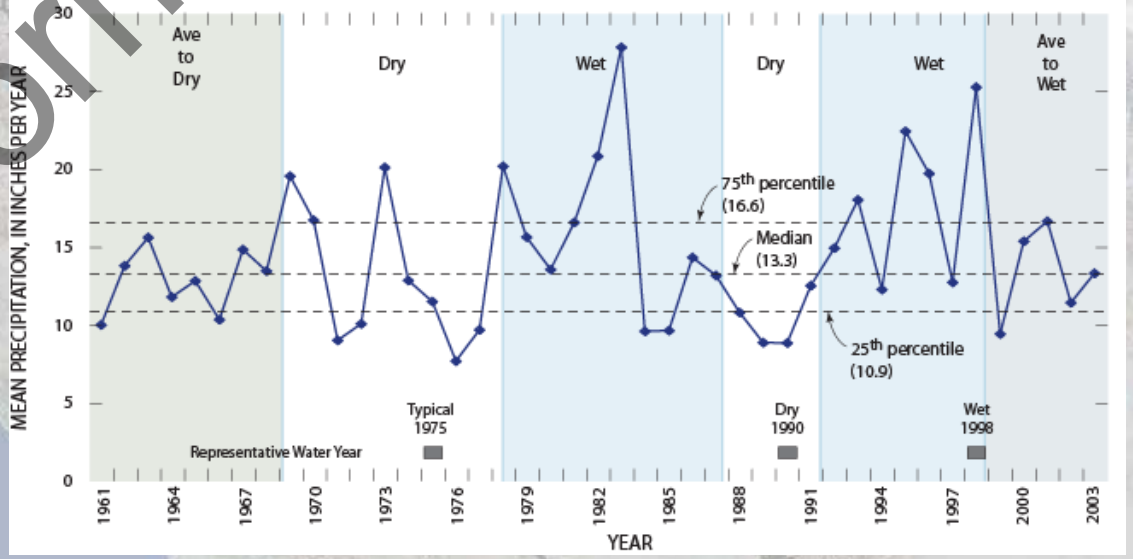
# Water Use:

- **precipitation and runoff not distributed uniformly in space or time**

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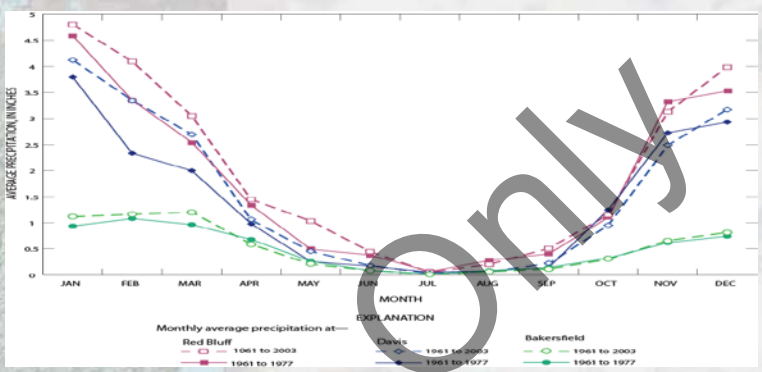
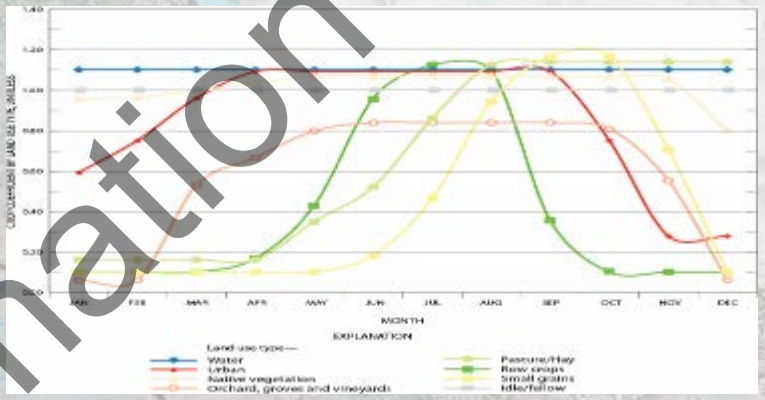
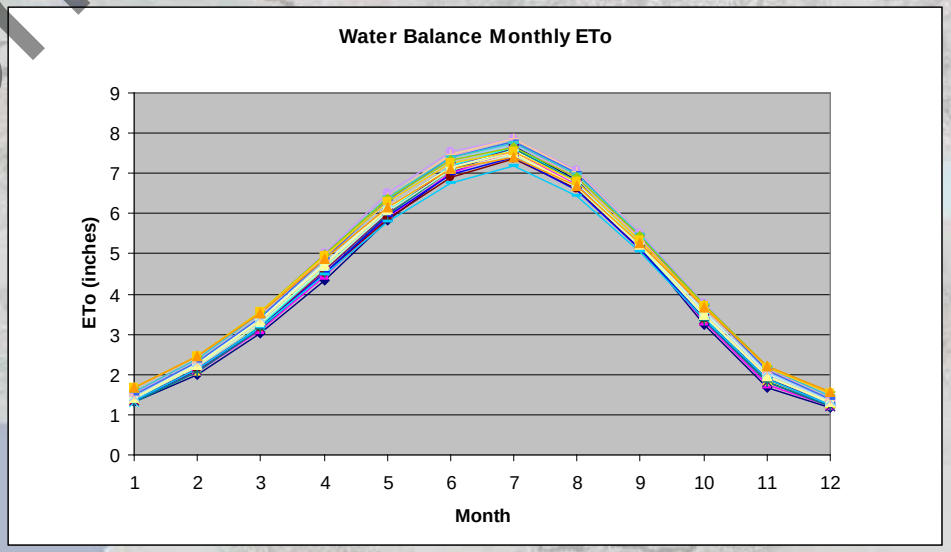
# Water Use:

- **Seasonal**
  - Most of the water is withdrawn and applied during the spring-summer growing season
  - Opposite natural delivery
  - Urban
    - **seasonal fluctuation may change**
    - **use about the same, the timing of these withdrawals may change**

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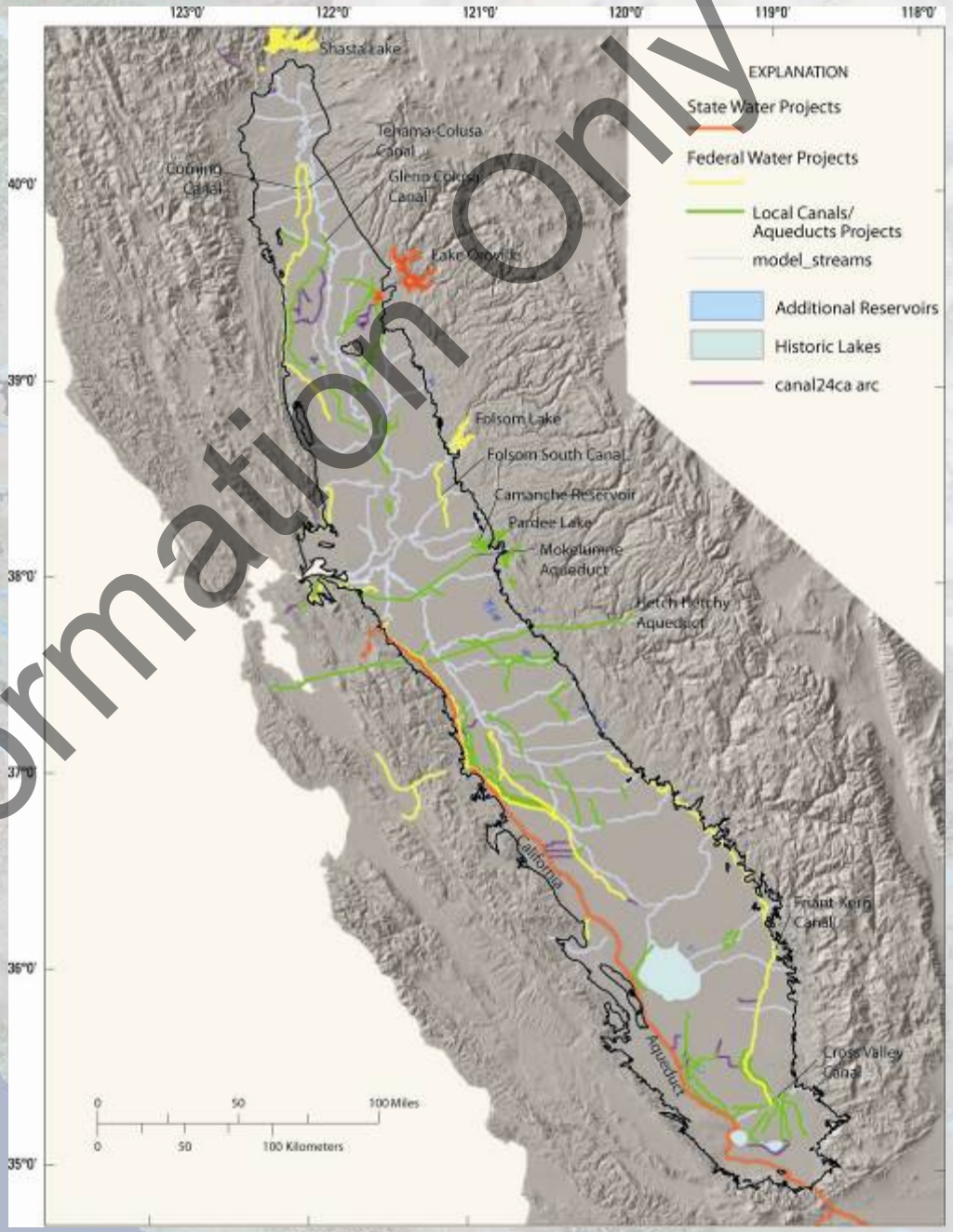
# Water Use:

- Water sources/reservoirs:
  - Snowpack
  - Surface water (dams)
  - Groundwater
- Developed delivery system
  - Federal (CVP)
  - State (SWP)
  - Local

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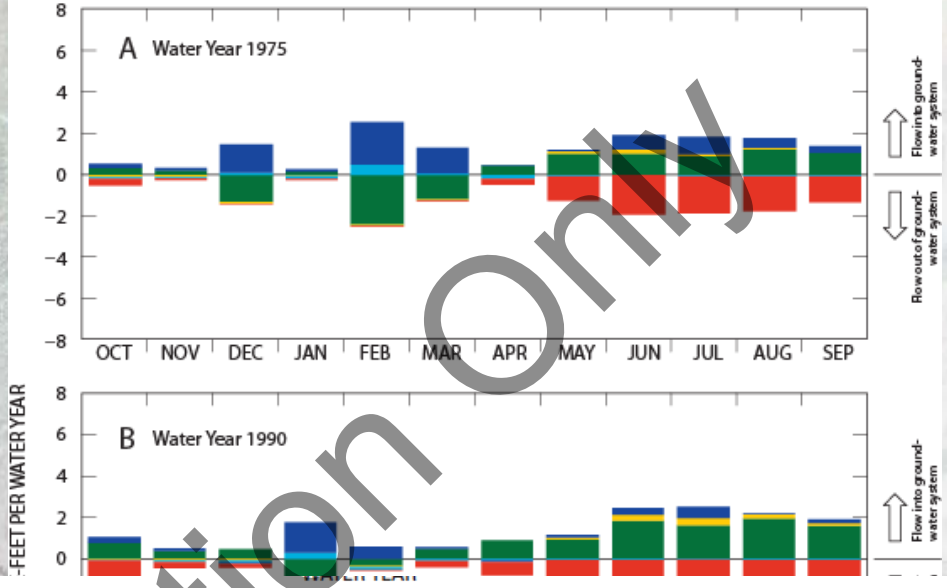
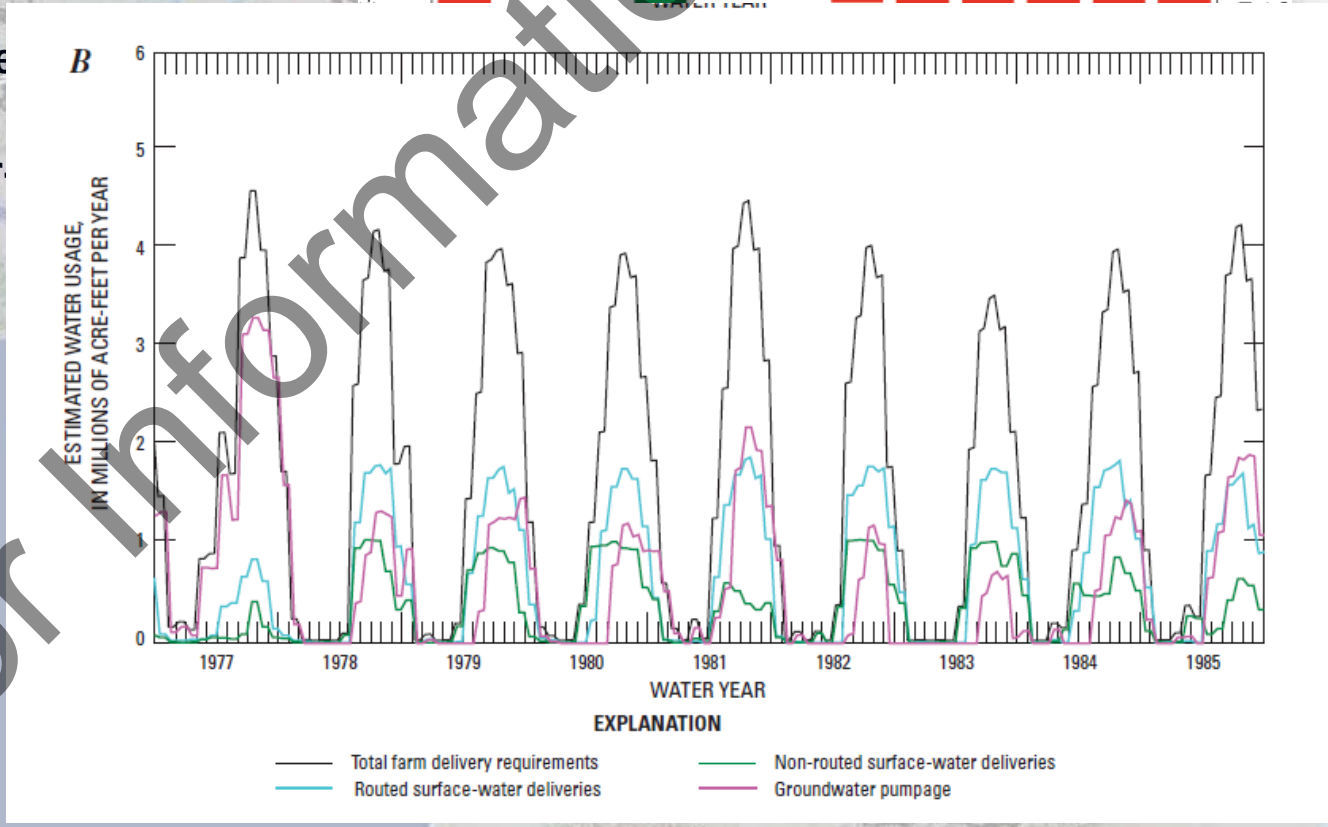
# Water Use:

- **Climatic changes**
  - Droughts
    - **surface water allocation cutbacks from the SWP and the CVP**
    - **Ground-wate increases**
    - **Lower water-**
    - **Allow prime lie fallow.**

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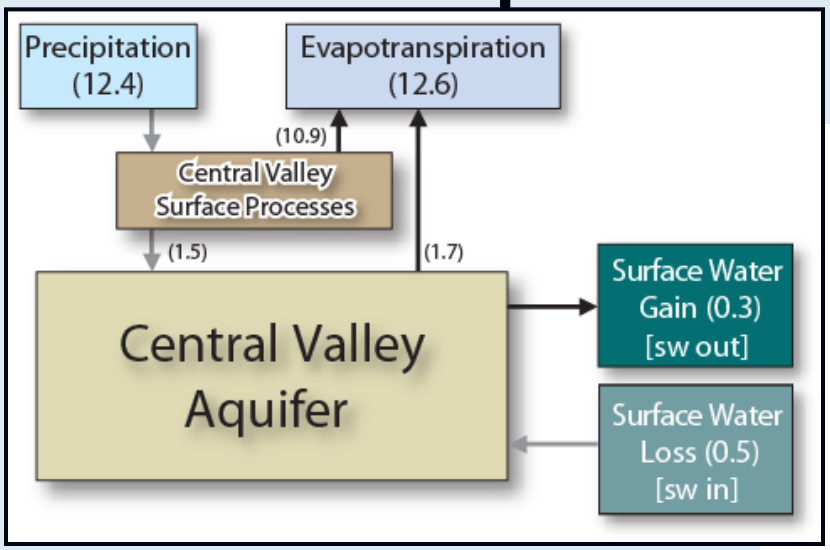
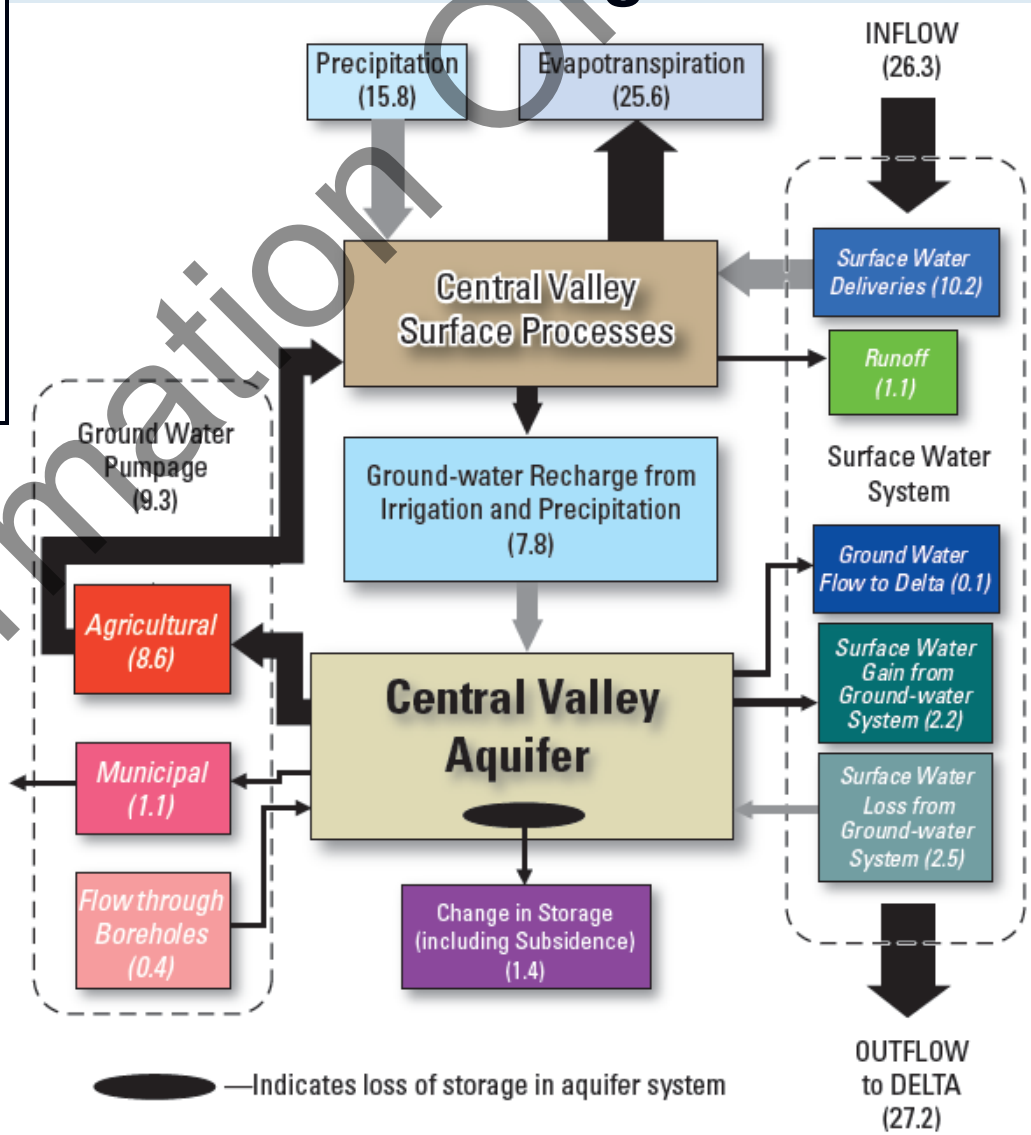
# Pre-development




# 1962-2003/Engineered




**Natural** ➡ **Engineered**

**Simple** ➡ **Complex**

**2 million** acre-feet/year recharge /discharge ➡ **12 million** acre-feet/year recharge /discharge

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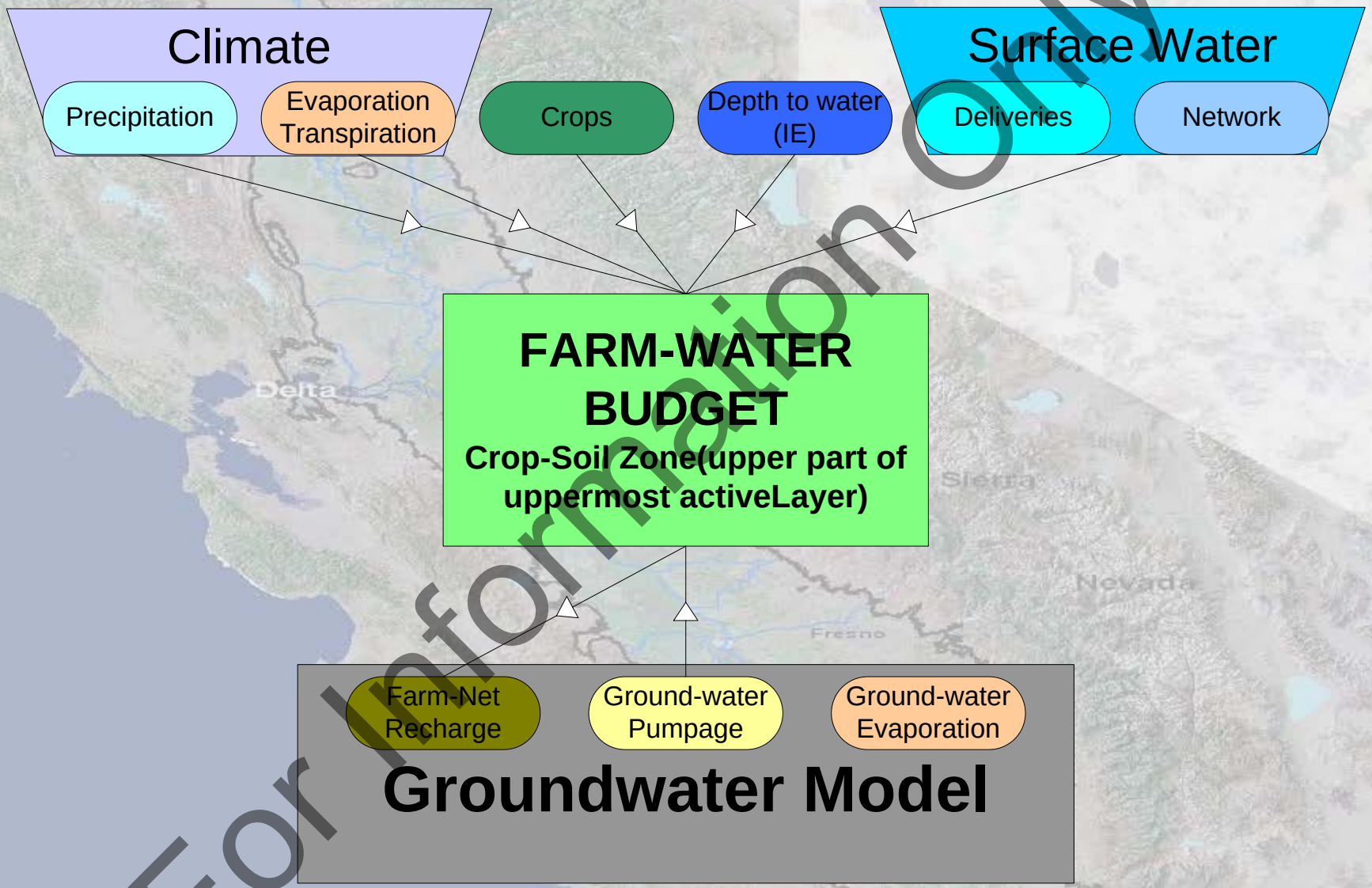
# WATER BUDGET COMPONENTS

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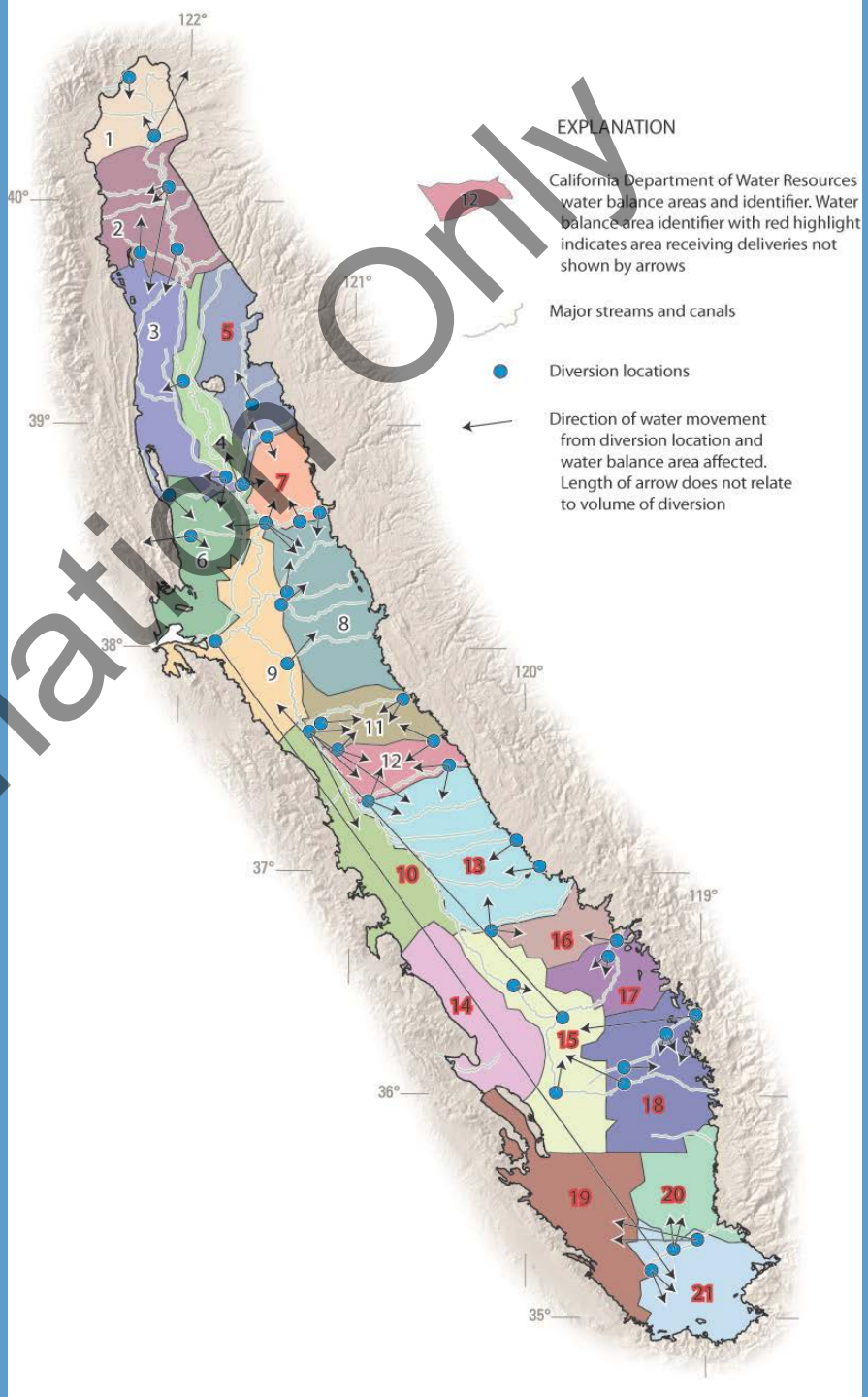
# Water-balance subregions

- 21 subregions
  - CA-DWR collaboration

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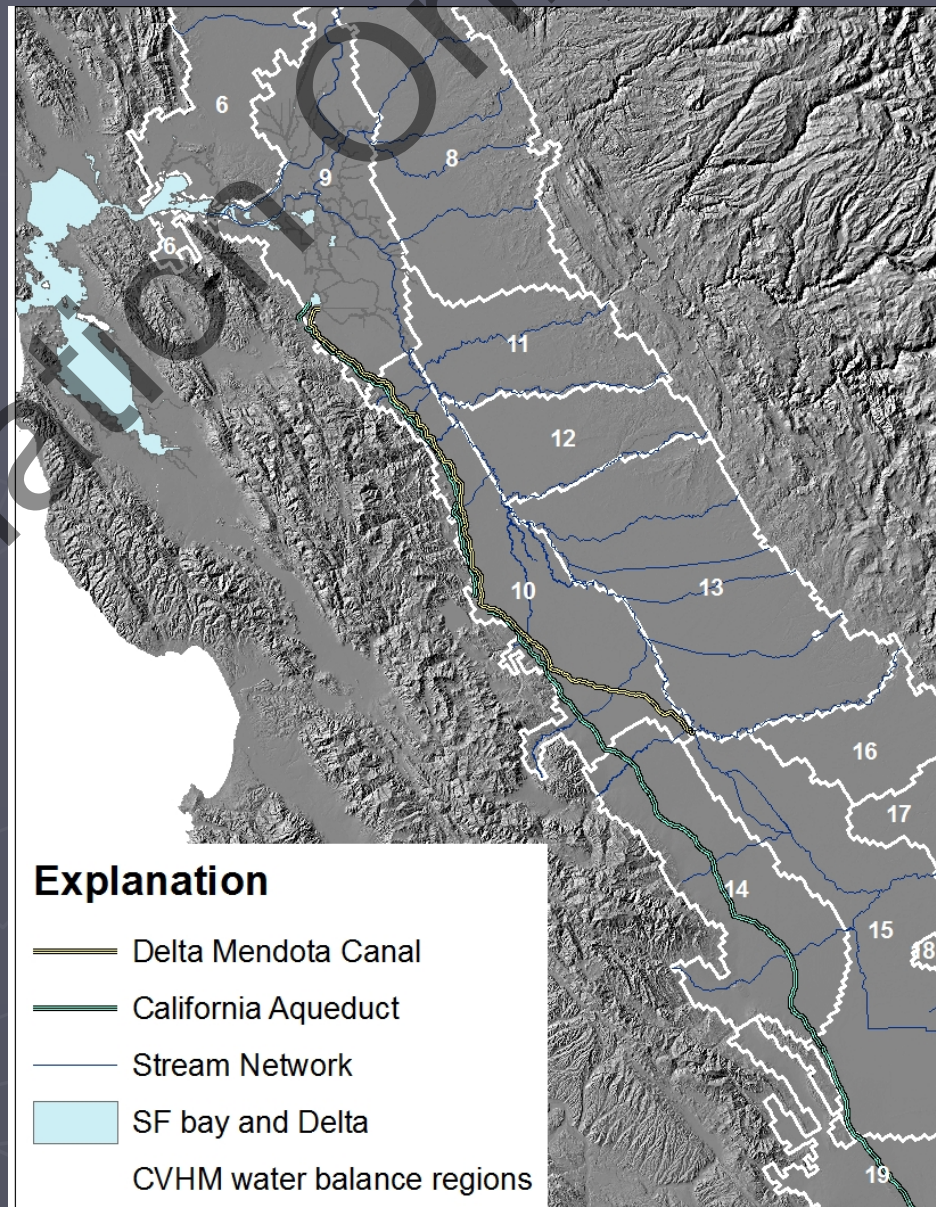
# Water budget areas in the western San Joaquin Valley:

- rediscretize CVHM water-balance subregions into
  - 78 subregions in SLDMWA and
  - 32 in delta area

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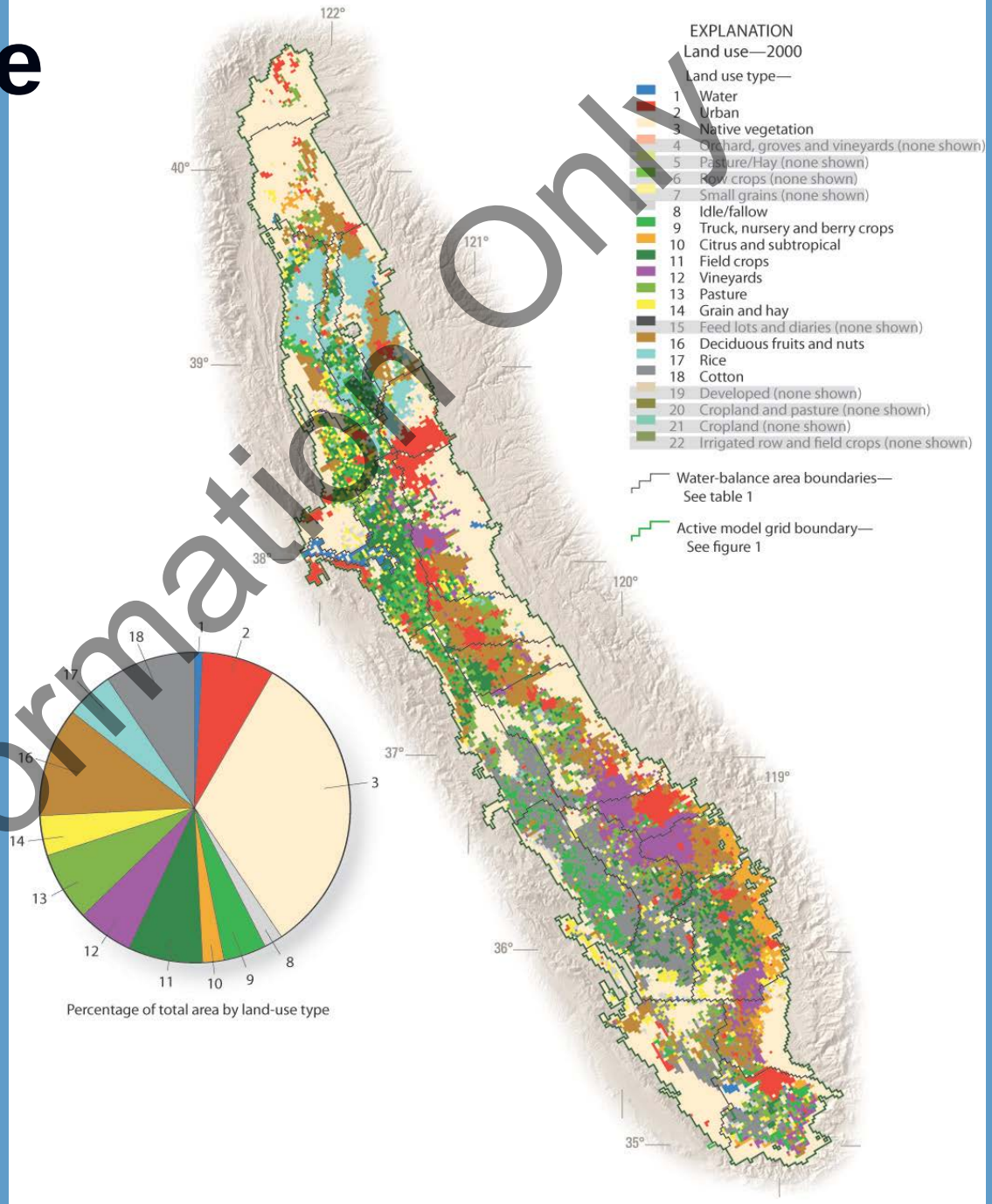
# Water-balance regions and Landuse

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

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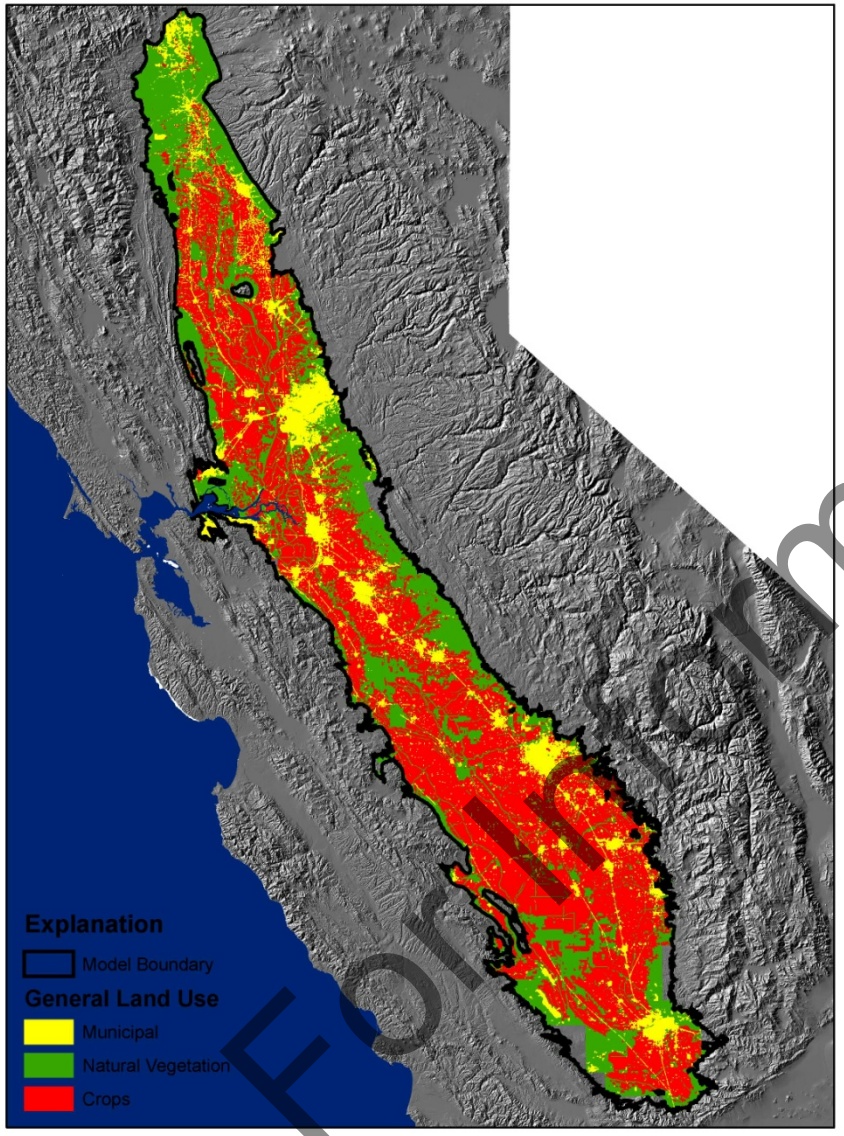
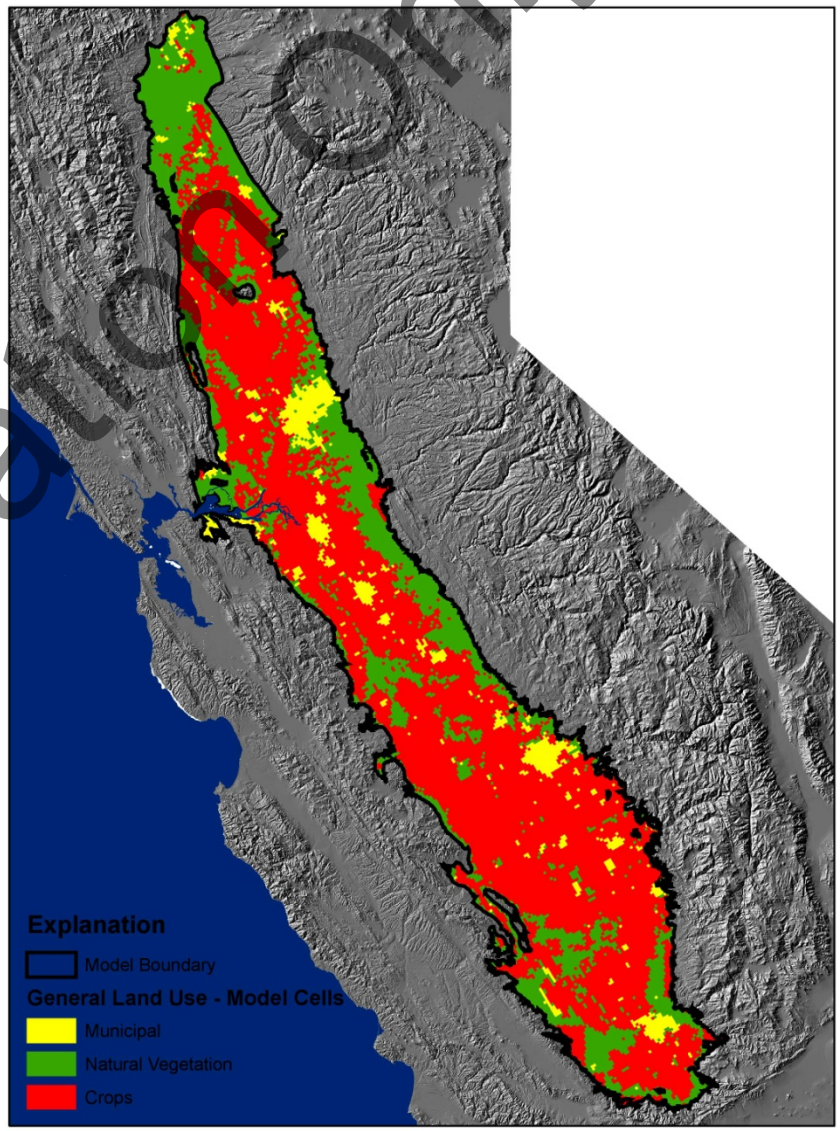
# Detailed DWR Land Use ➔ Simplified Land Use (Crops/Natural/Urban)

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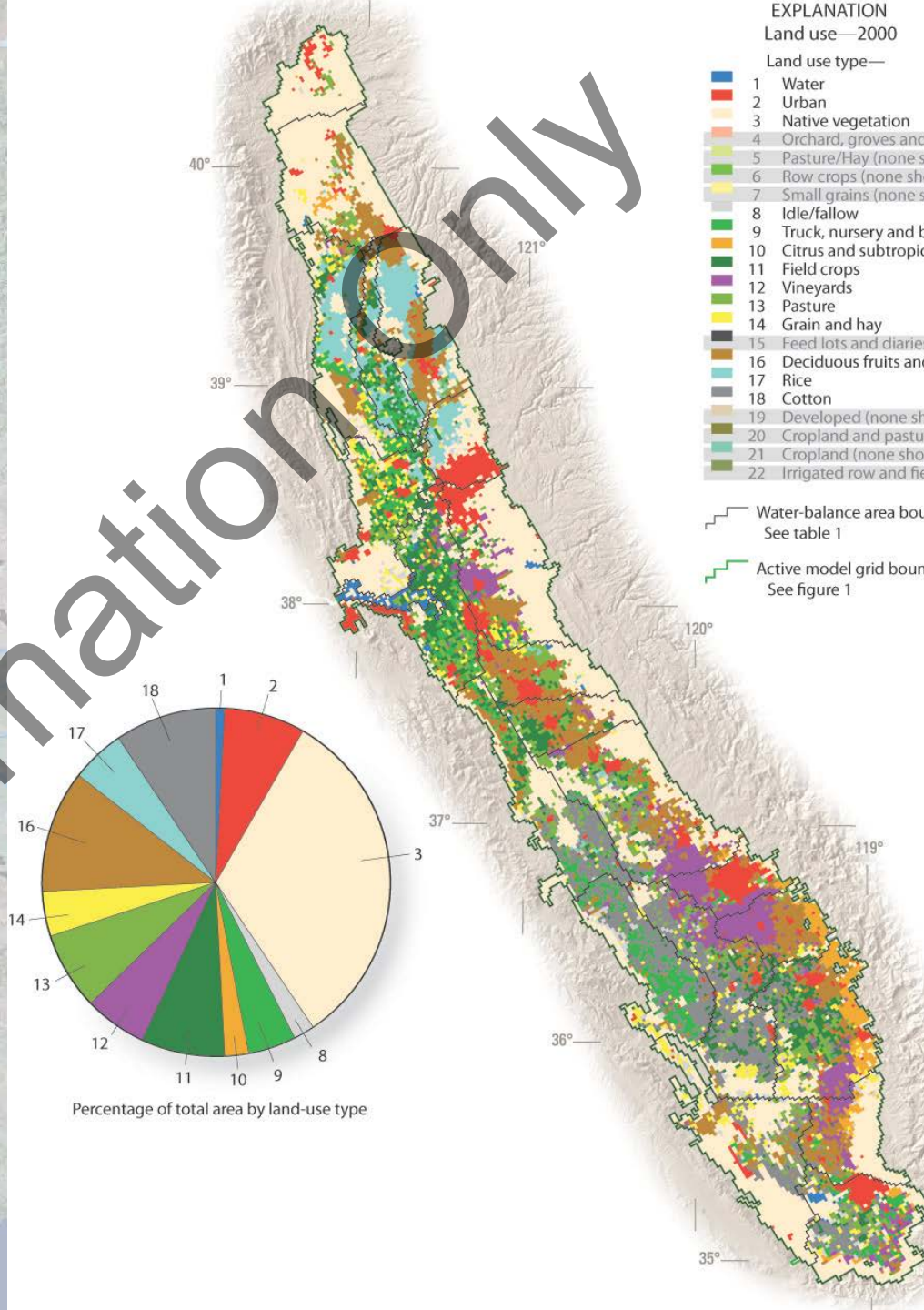
# Virtual Crops

- 2D-Array (GIS) of Crops, with the following attribute:
  - *The sequence and* spatial distribution of the Crop-ID may be random.
  - Other attributes are not represented in a GIS coverage, but as data lists related to Crop-ID

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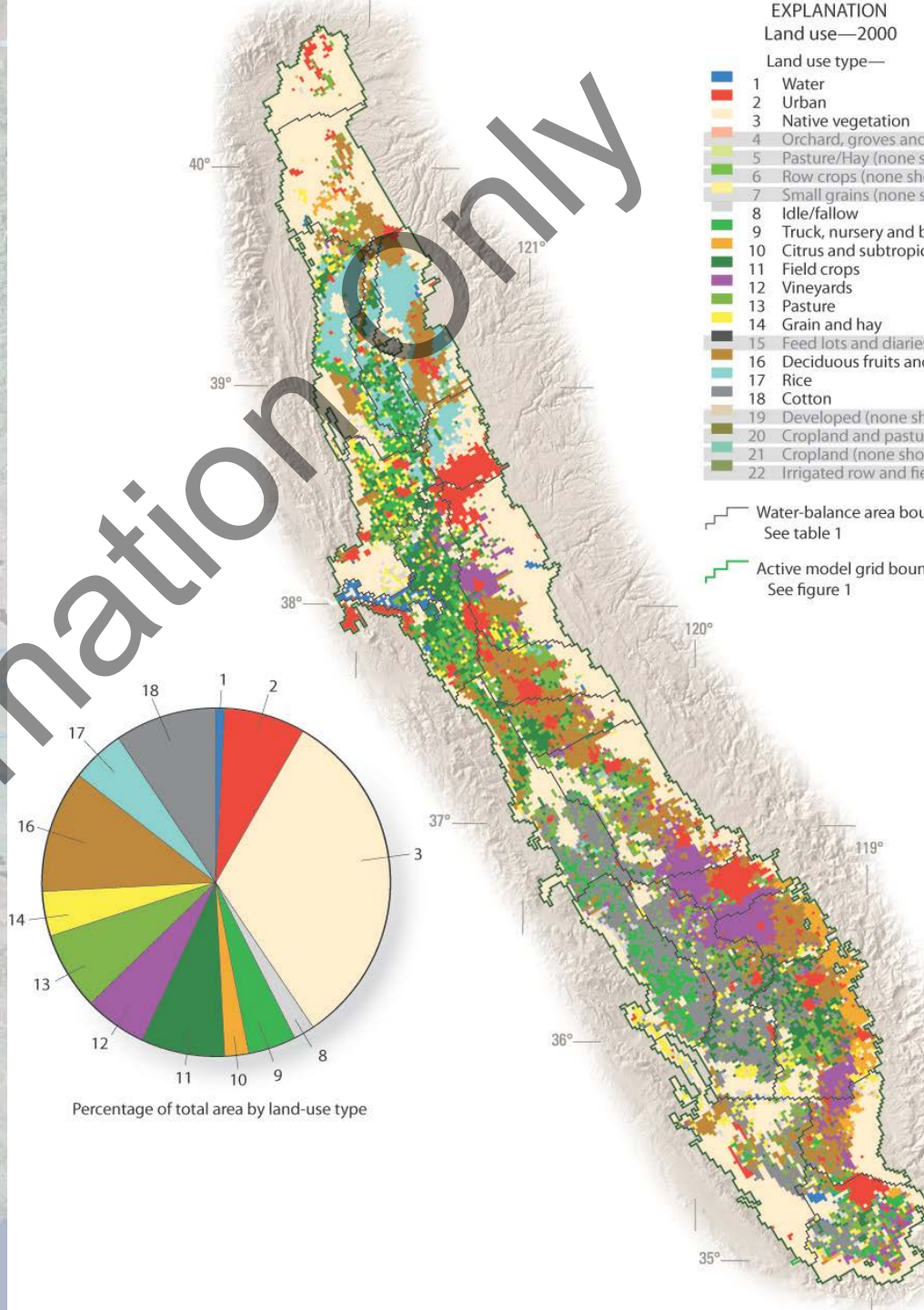
# Virtual Crops

- landuse maps for all stress periods
- Specified for each stress period
- For Central Valley 22 landuse categories
- Base on GIS coverages or imagery

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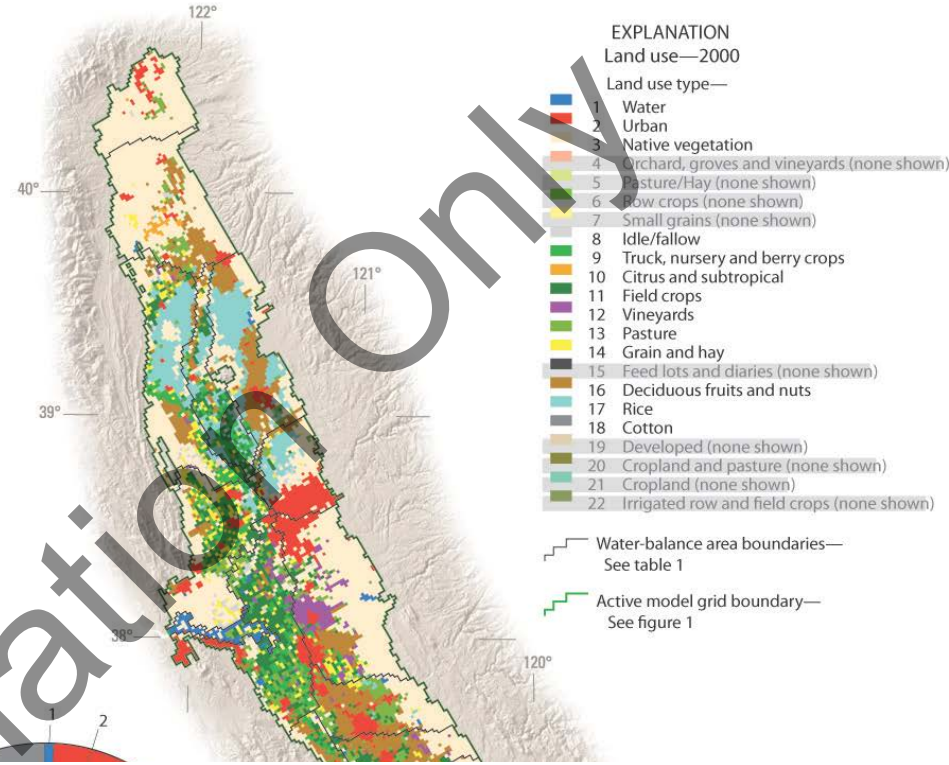
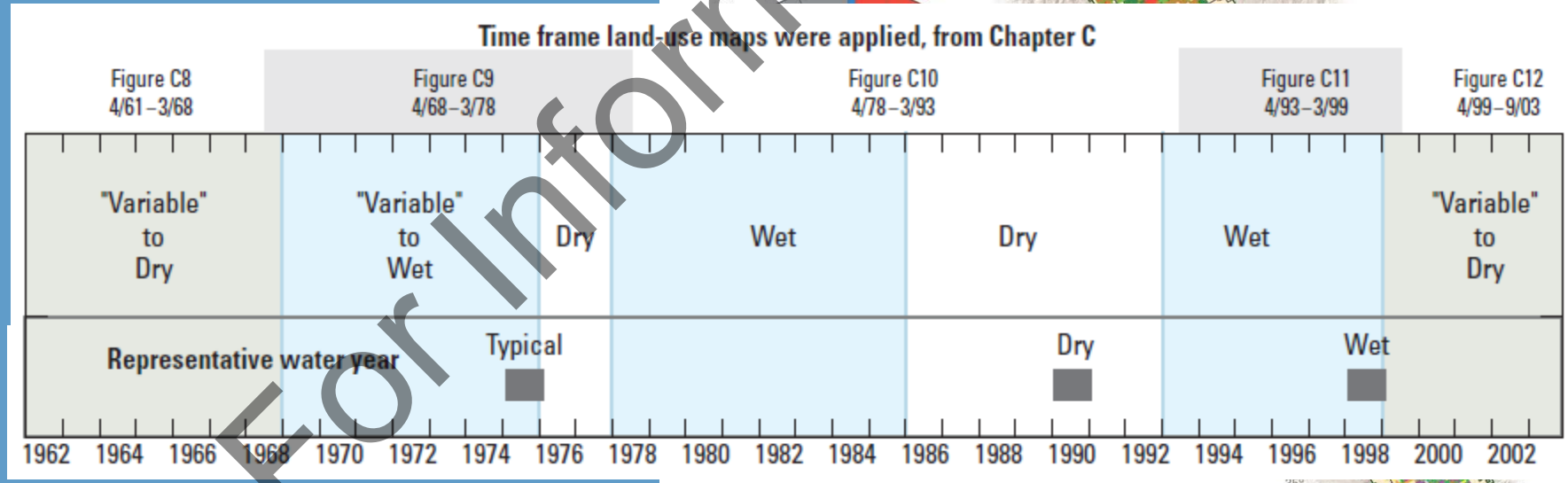
# Landuse

- 5 Snapshots
- Different maps/sources

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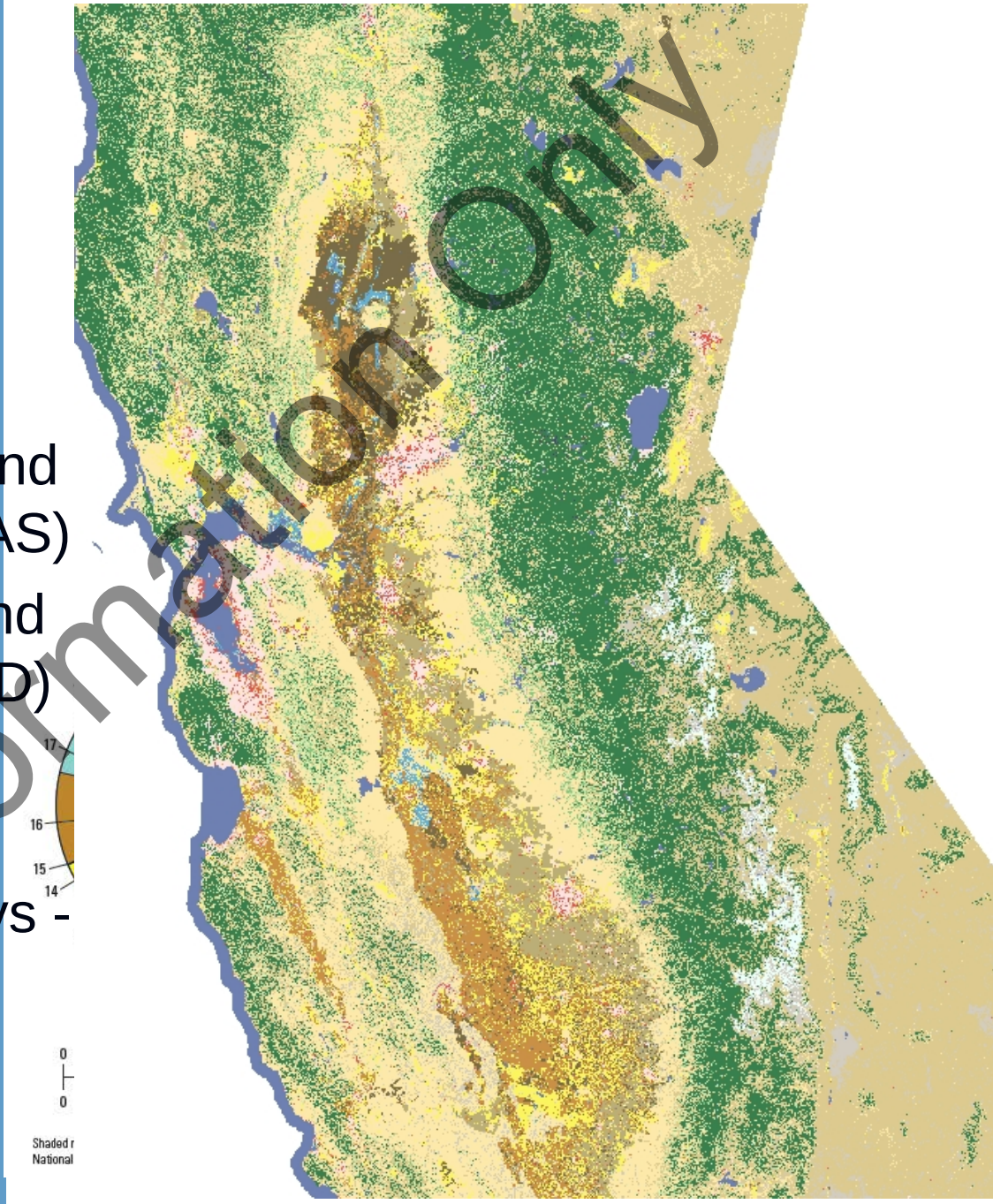
# Landuse

- 5 maps/sources
  - (1) California State University, Chico
  - (2) Geographic Information Retrieval and Analysis System (GIRAS)
  - (3) North American Land Class Data 1992 (NLCD)
  - (4) GAP Analysis
  - (5) DWR composite (county landuse surveys - years around 2000)

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## Remotely Sensed Data ➔Upcoming Approaches to Land and Crop Attributes

(1) Land Use changes
(2) Crop Types
(3) Canopy (FTR)
(4) Crop Coefficients (Spatial/Temporal)
(5) Actual ET for Model Comparison/Input
(6) Soil Moisture
(7) Climate Data – Precipitation/Reference ET

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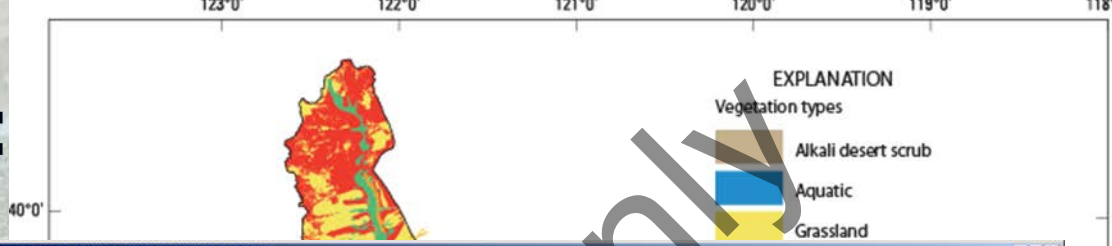
# Initial Conditions:

- Development began in 1800s
- Little data for early development period



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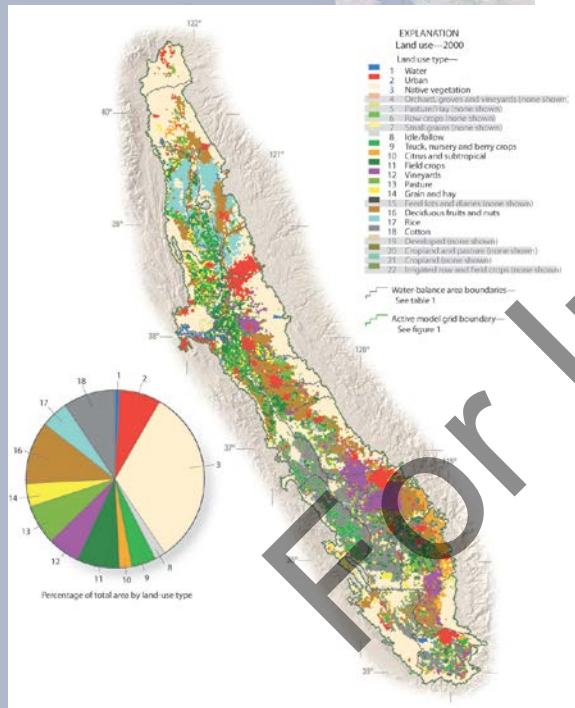
# Consumptive Use:

Consumptive use based on

- Reference Eto
- Crop Coefficient (Kc)
- = ETo * Kc



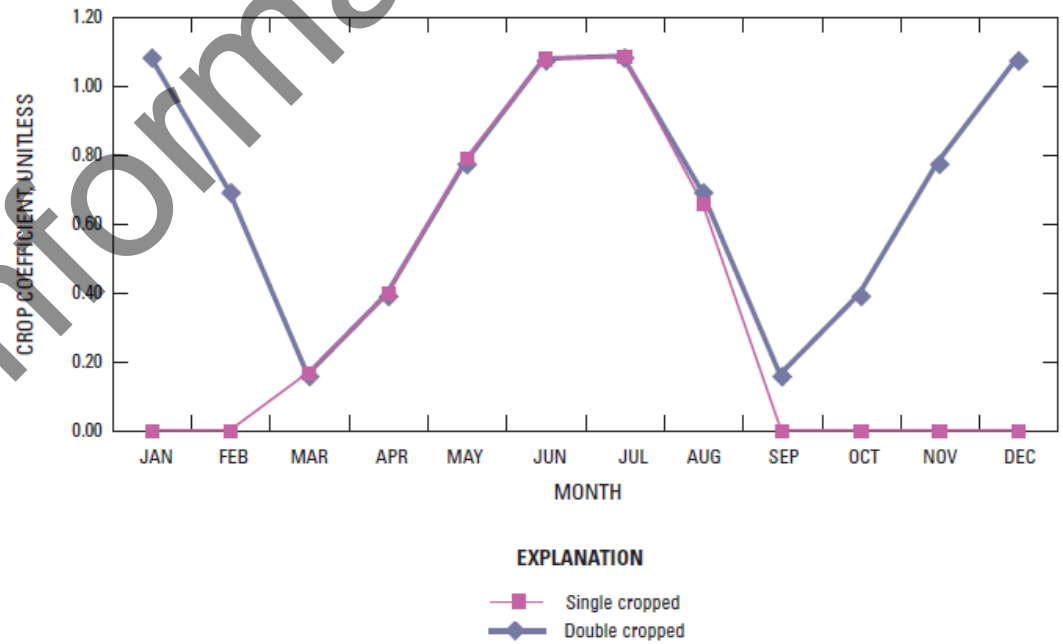




**Figure C24.** Single and double cropped crop coefficient values for truck crops.

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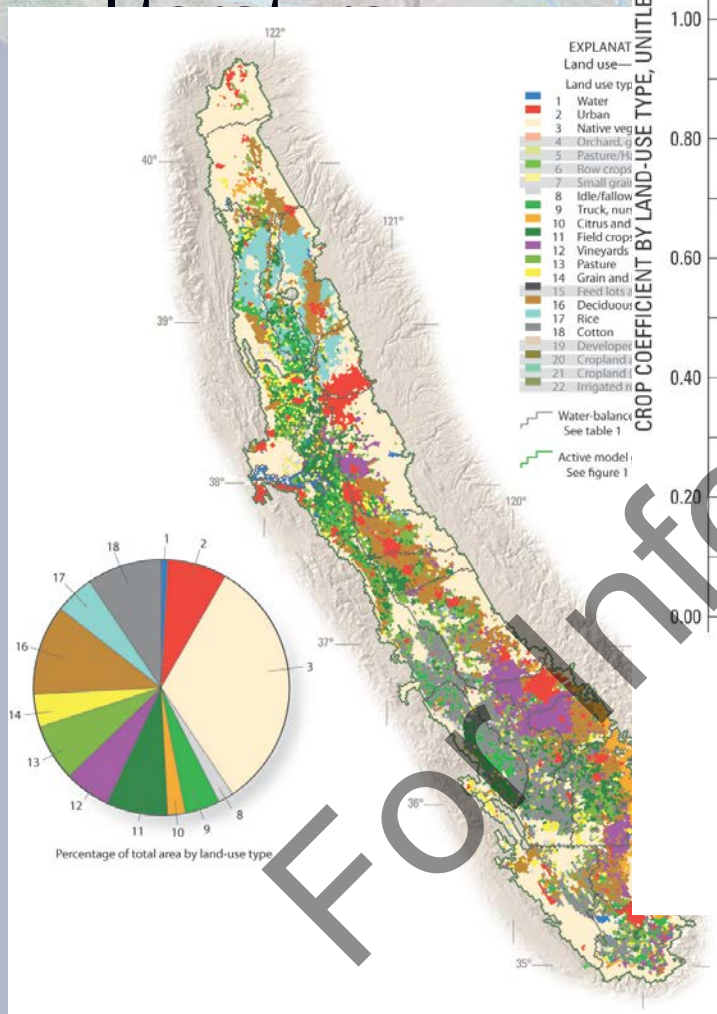
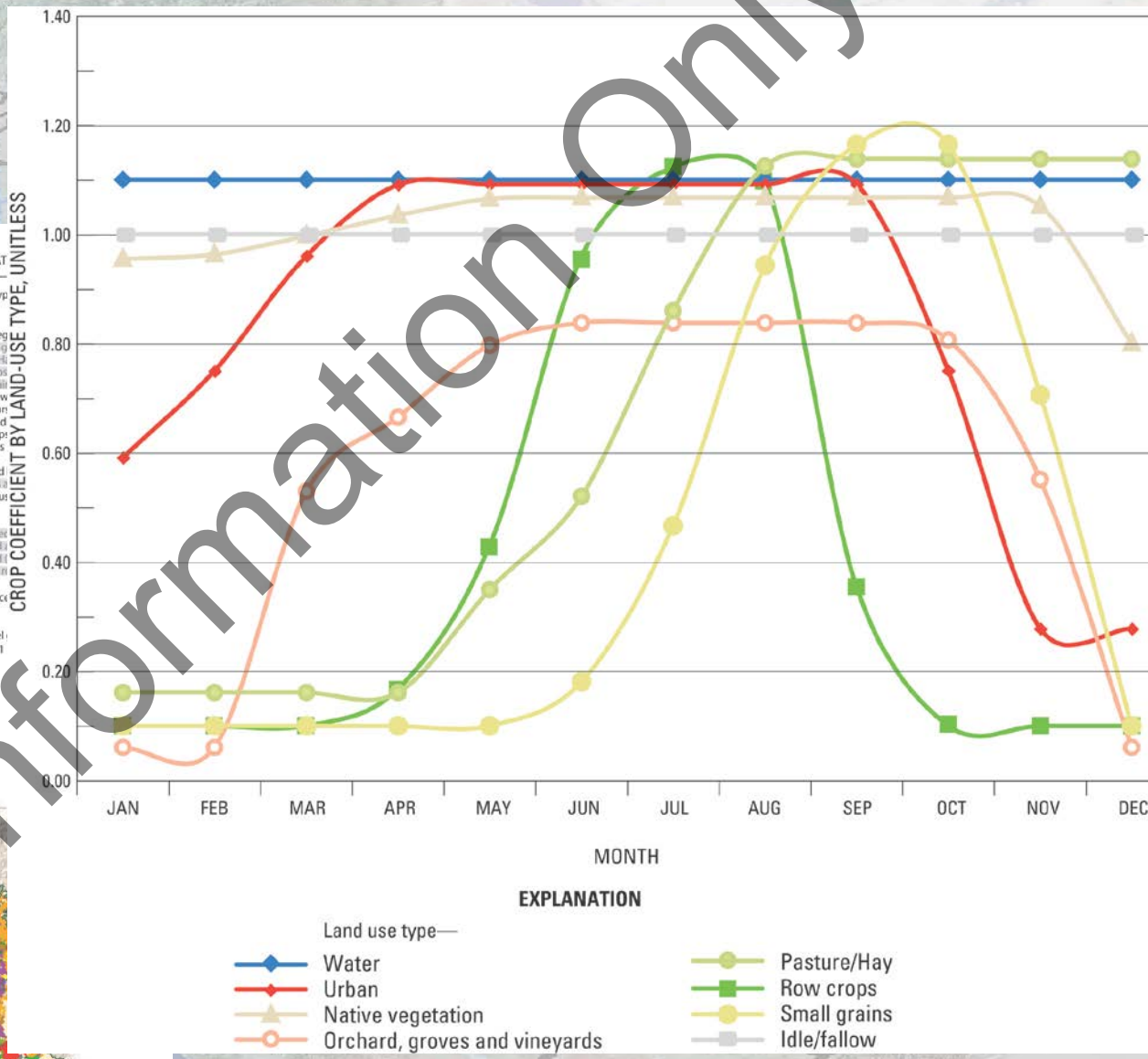
# Crop Coefficient

- Values published in literature

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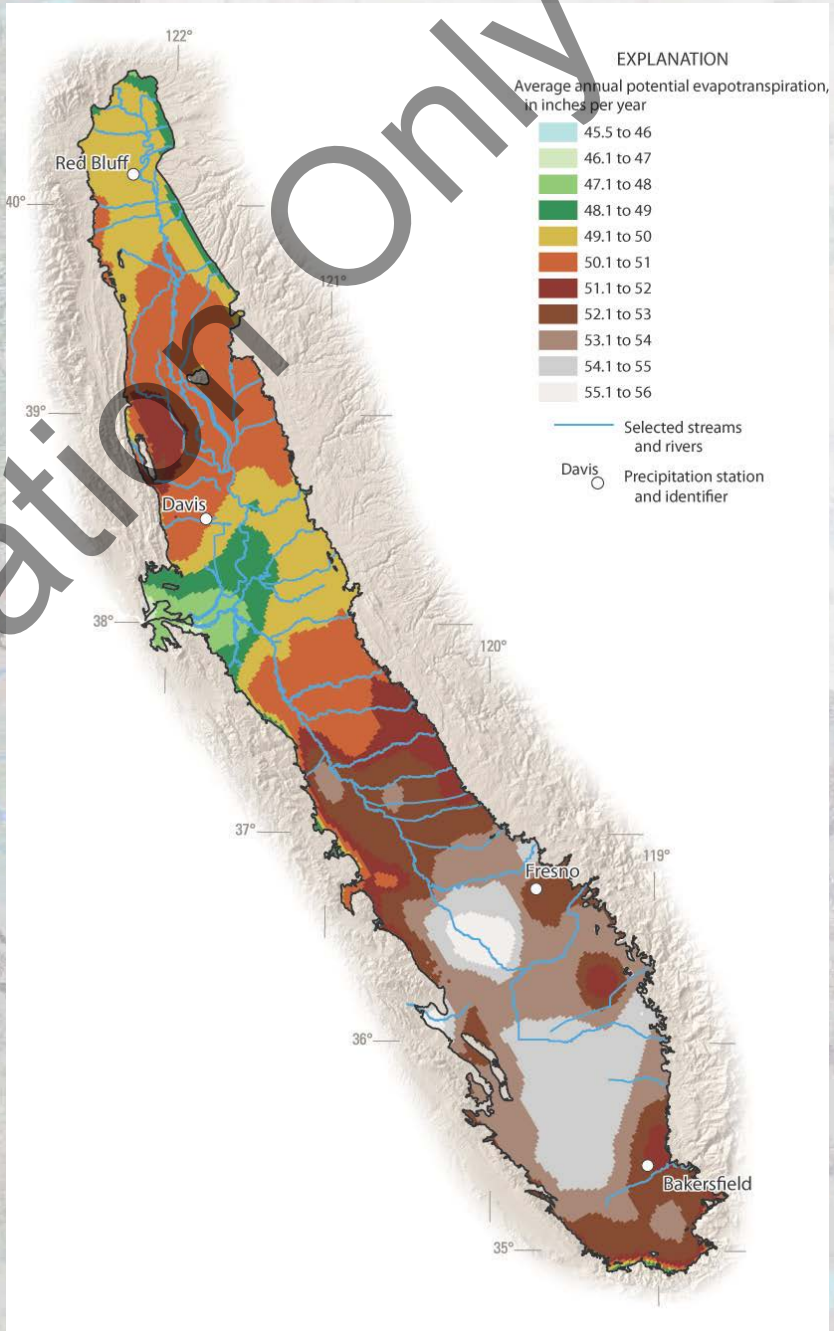
# Reference ET:

- 2D-Array (GIS) of Reference ET for each stress period
- Can be calculated from temperature data
- Data sources:
  - PRISM data
  - CIMIS data

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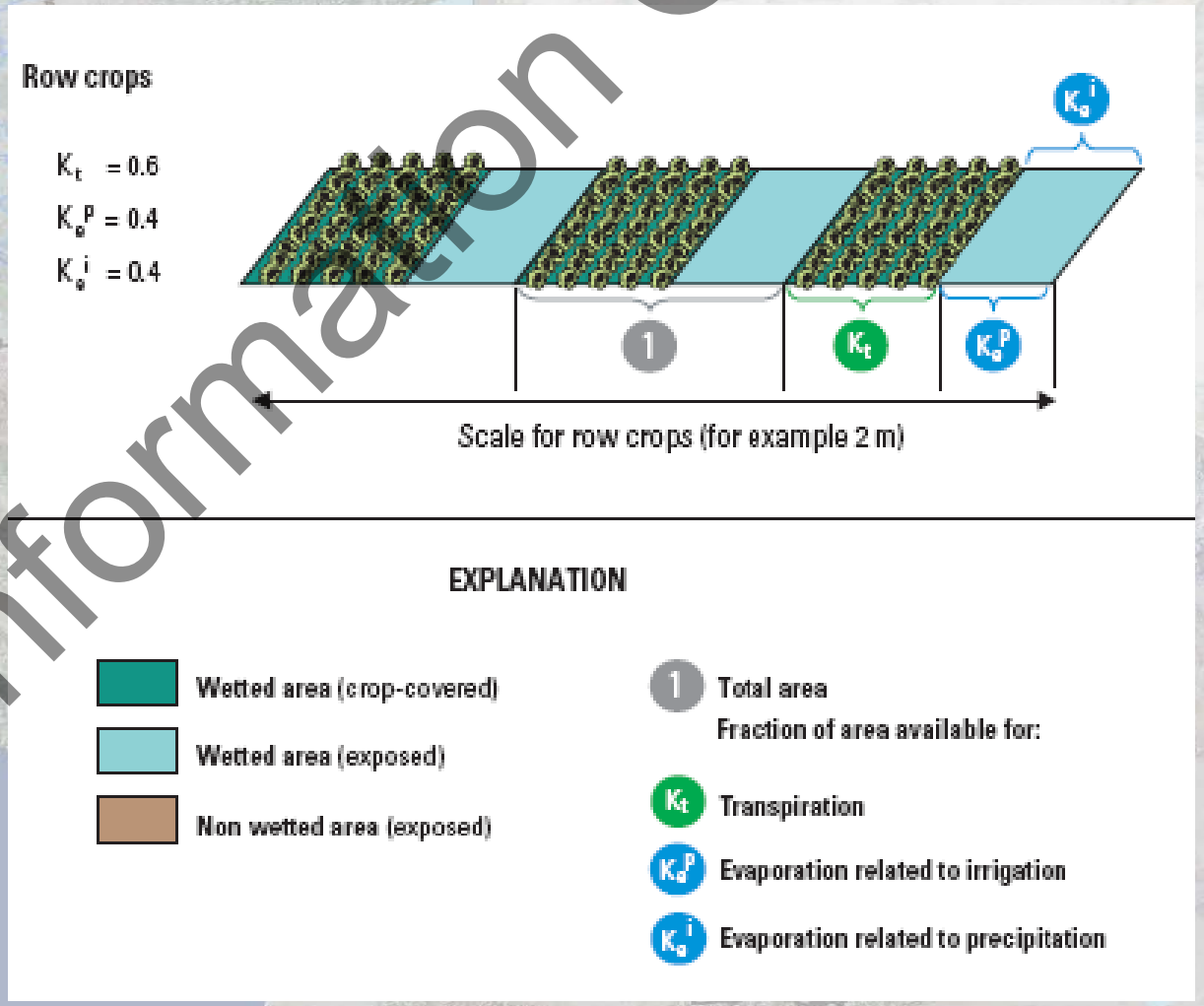
# Fractions of transpiration and evaporation: FTR FEP FEI

External (specified in name file)

FTR -fraction of transpiration

FEP - fraction of evaporation from precipitation

FEI -fraction of evaporation from irrigation

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# Fractions of transpiration and evaporation: FTR FEP FEI

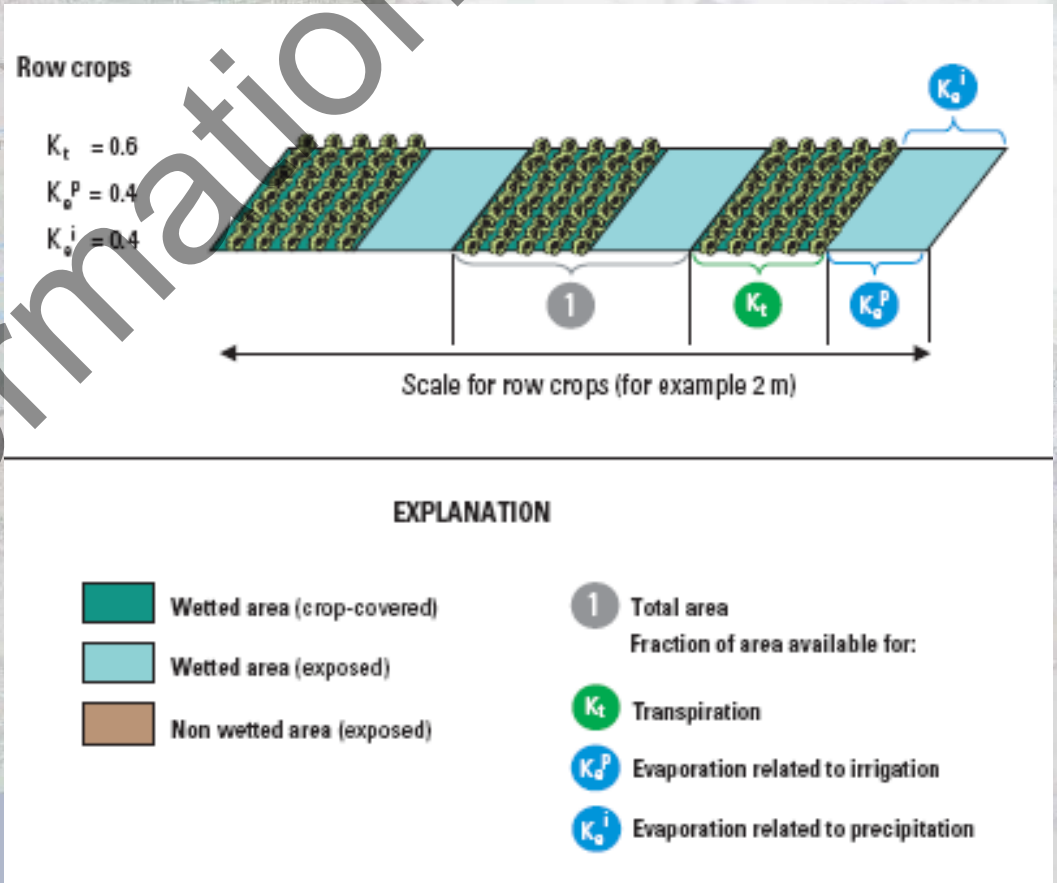
Notes:

FTR plus FEP = 1

FEI must be <= FEP

Function of growth stage:

- vegetation cover reaches close to 100%, then FTR = 1 while FEP and FEI = 0

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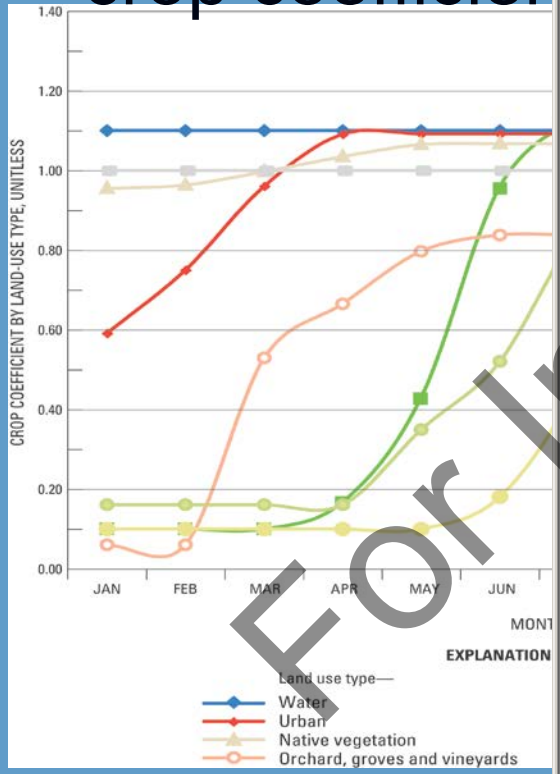
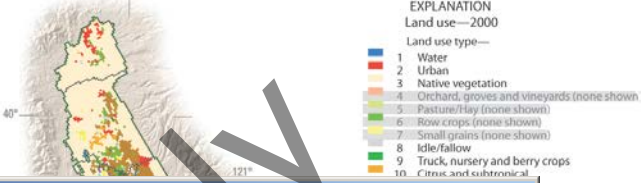
# Landuse and Crops

- Landuse categ
- Virtual crop co
  attributed to vi
- Area-weighted
  crop coefficier



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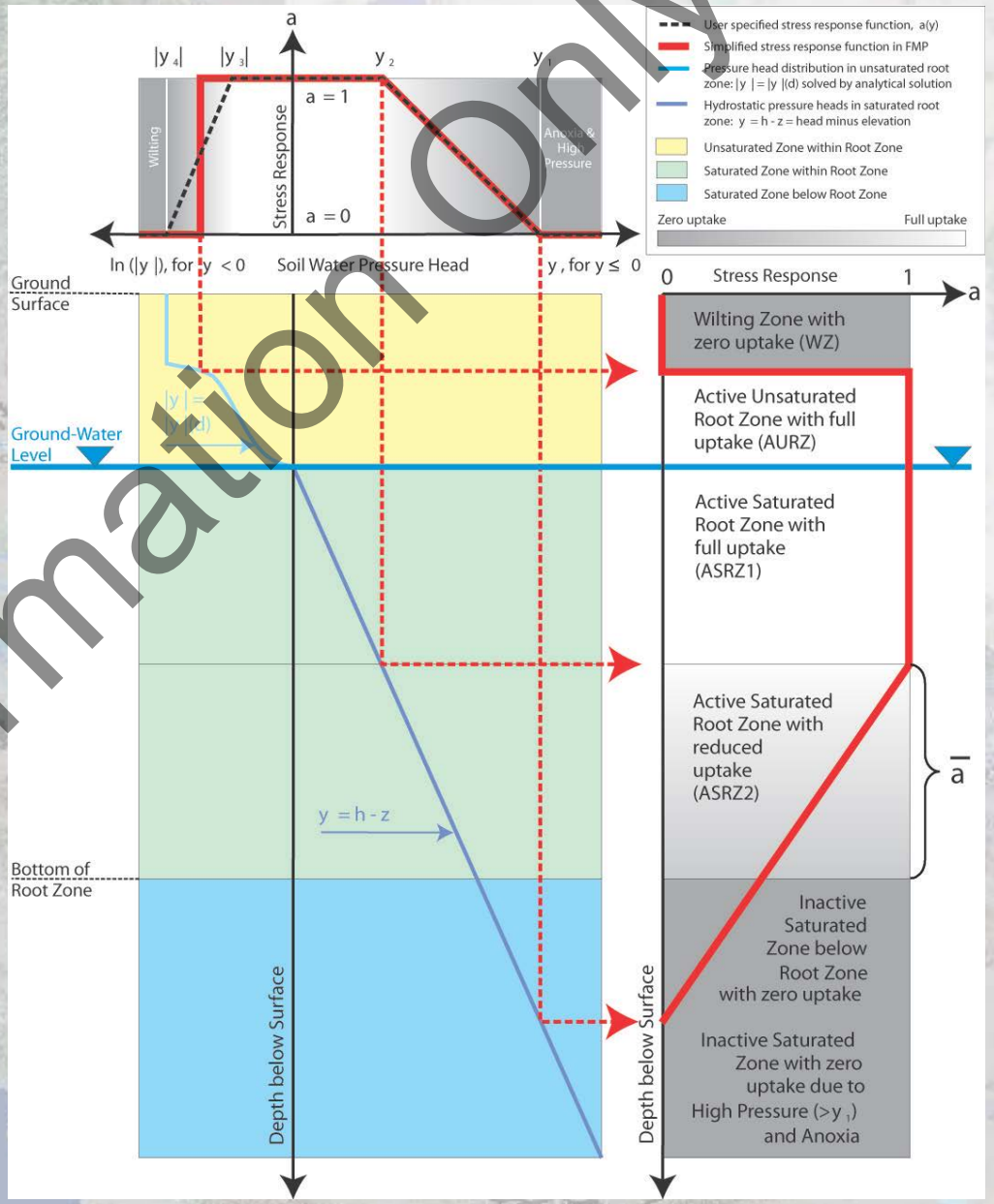
# Root Zone

Root Uptake pressure heads in feet

- Anoxia
- Lower Optimal Range
- Upper Optimal Range
- Wilting

Depth of root zone [L]

List based on literature

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# Runoff

- Fraction of in-efficient losses to surface-water related to precipitation
- Fraction of in-efficient losses to surface-water related to irrigation
- Estimates based on irrigation type and slope of land surface and so on

  (surface water flow sensitive to)

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# Farm Irrigation Efficiency:

External (specified in na

Farm-ID, EFF for each c

Array (header multiplier
period

- Columns = crop
- Rows = farms

Values from local inform

Determines amount of e
(recharge)

**Table C6.** Average area-weighted composite efficiency for each water-balance subregion of the Central Valley, California, through the simulation period.

[Efficiencies in percent]

| Water-balance subregion | 1960s | 1970s | 1980s | 1990s | 2000s |
|---|---|---|---|---|---|
| 1 | 70 | 68 | 73 | 76 | 74 |
| 2 | 70 | 68 | 72 | 75 | 73 |
| 3 | 74 | 74 | 79 | 82 | 83 |
| 4 | 71 | 70 | 74 | 78 | 79 |
| 5 | 73 | 72 | 78 | 80 | 80 |
| 6 | 69 | 69 | 74 | 77 | 77 |
| 7 | 71 | 69 | 73 | 77 | 77 |
| 8 | 69 | 69 | 75 | 78 | 75 |
| 9 | 69 | 70 | 76 | 79 | 78 |
| 10 | 69 | 72 | 78 | 80 | 79 |
| 11 | 70 | 70 | 76 | 78 | 77 |
| 12 | 71 | 70 | 74 | 77 | 76 |
| 13 | 71 | 72 | 77 | 80 | 79 |
| 14 | 68 | 73 | 82 | 86 | 87 |
| 15 | 67 | 69 | 75 | 76 | 76 |
| 16 | 72 | 72 | 78 | 79 | 81 |
| 17 | 72 | 72 | 77 | 79 | 80 |
| 18 | 71 | 72 | 77 | 79 | 79 |
| 19 | 68 | 72 | 78 | 79 | 77 |
| 20 | 72 | 73 | 78 | 81 | 81 |
| 21 | 71 | 73 | 79 | 81 | 81 |

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11:30-12:00 Discussion

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# Soil Type Identity

- 2D-Array (GIS) of Soil types

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# Soils

- Sources:
  - STATSGO
  - SURGO
  - County soil surveys
- 3 types
  - SILTYCLAY
  - SILT
  - SANDYLOAM
- Capillary fringe

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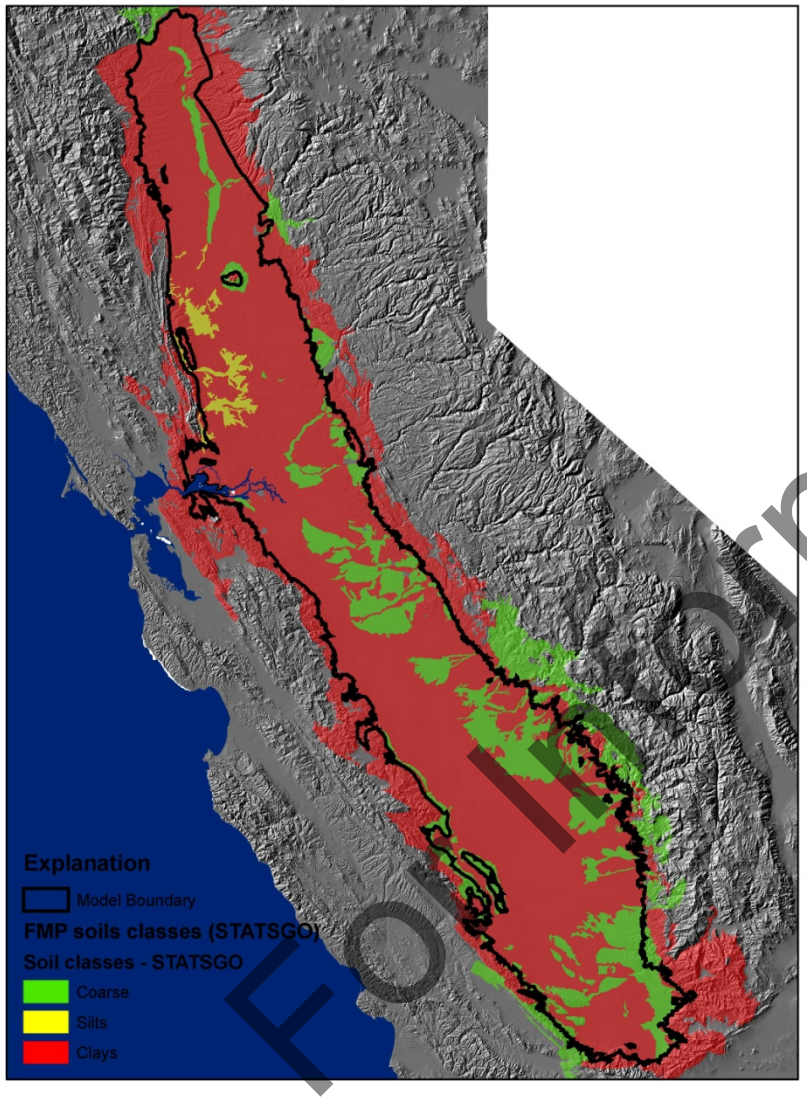
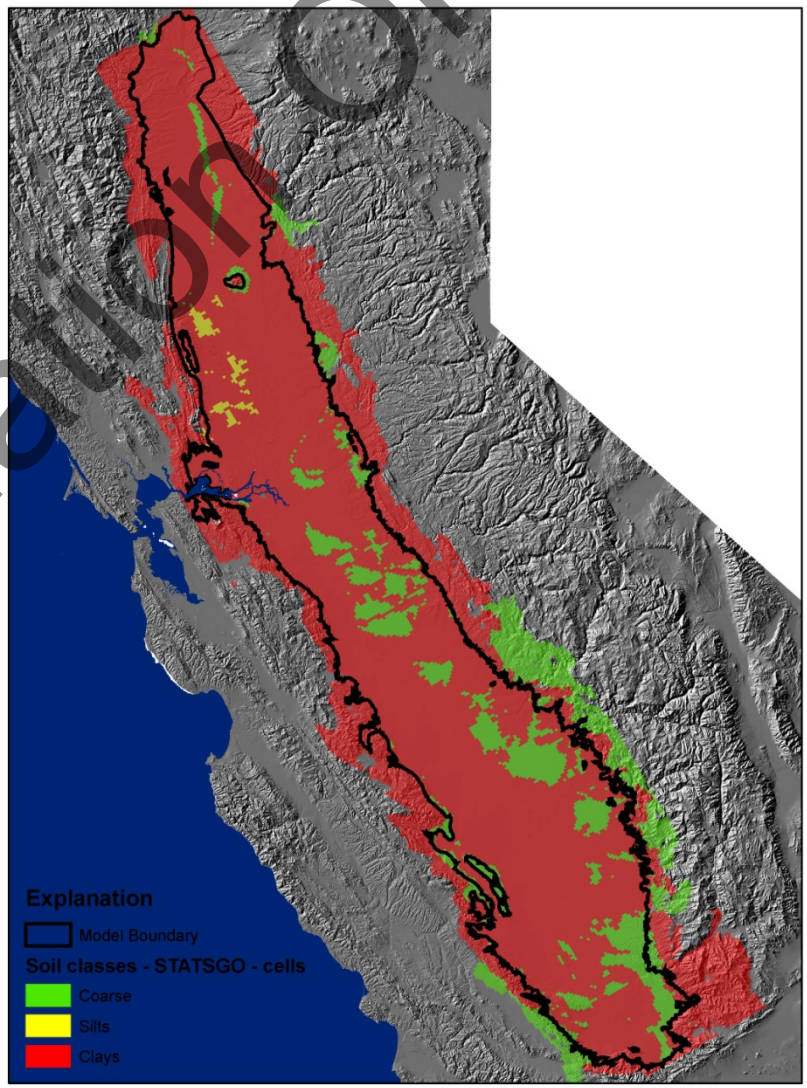
# Detailed Lumped STATSGO Soils ➔ Lumped Majority per cell

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# Today's Agenda:

## Part 3 - Irrigated Agriculture

9:00-9:15 Water Budget Subregions (Claudia Faunt/Randy Hanson)

- CVHM ver. 1 and others
- Artificial Recharge/Water Banks (ASRs)
- Regions changing through time

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- Crop Properties
- Remotely Sensed Data and other new methods

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11:30-12:00 Discussion

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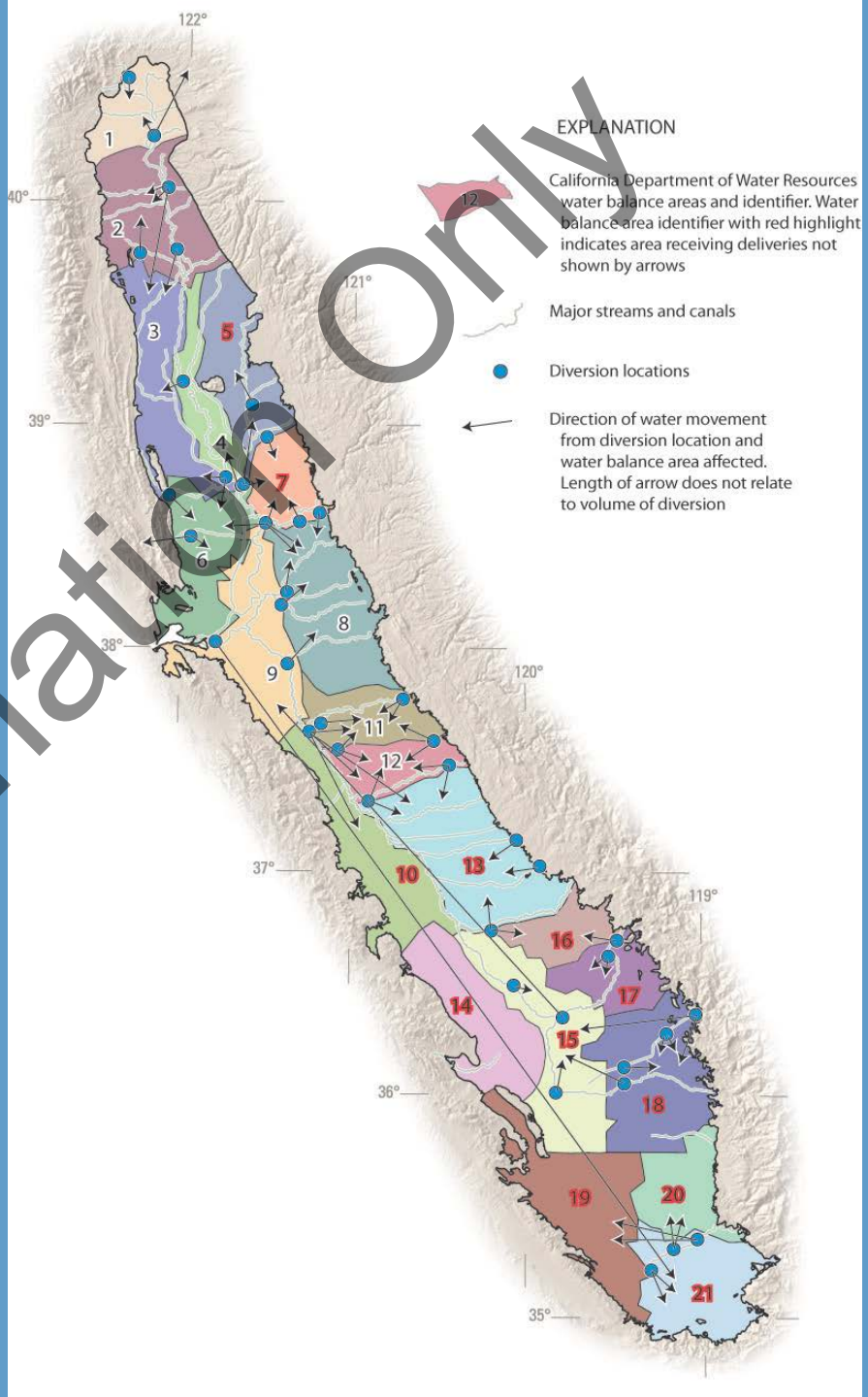
# Stream and Canal Network

- Inflows (43)
- Diversions (110) – Deliveries
  - Source: DWR
  - 66 routed through streams
    - 64 to farm process
    - 2 diverted outside of model
  - 44 non-routed
  - Supply constrained demand

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# Hierarchy Irrigation Sources of Supply-and-Demand Modeling

Overall order of sources of water to satisfy Potential ET ➔

(A) Natural Sources
(1) Precipitation
(2) GW-uptake
(B) Surface-water Sources
(1) NRDs
(2) SRDs
(C) Groundwater Sources
(1) ASR wellfields (if used)
(2) FMP wells & FMP-MNW wells

From MF-FMP Documentation (Schmid and others, 2006; Schmid and Hanson, 2009)

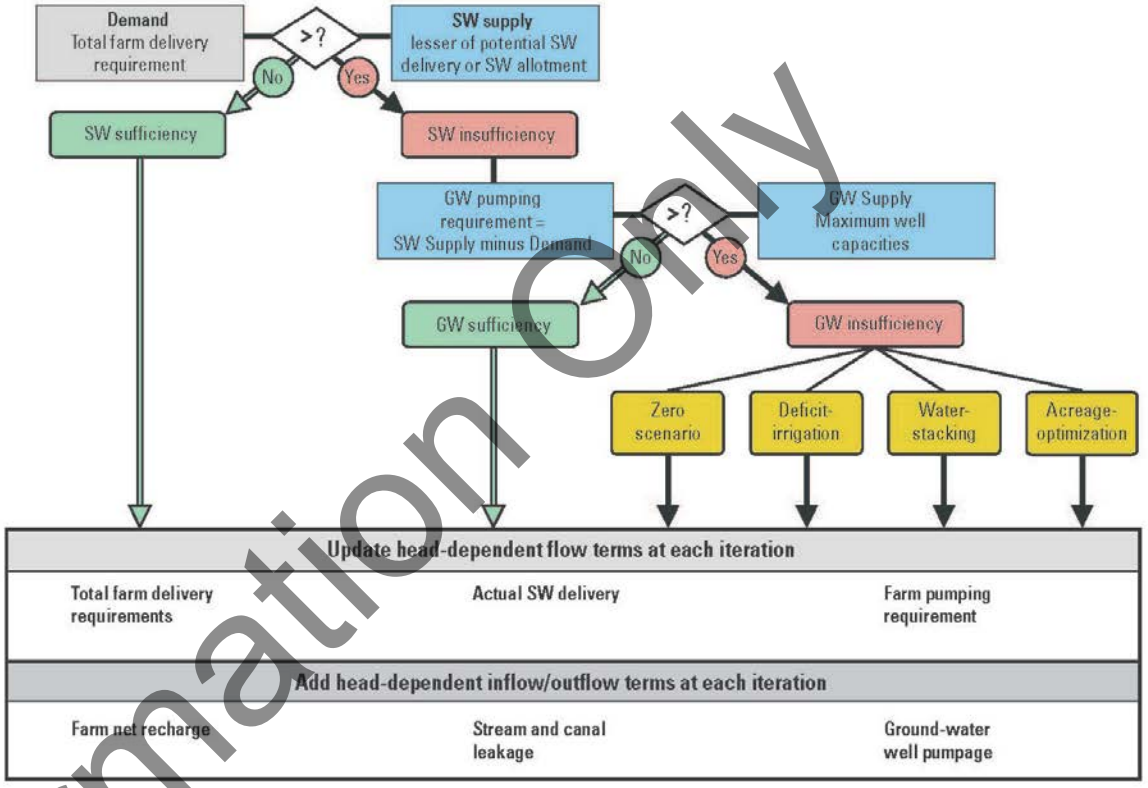


**Figure 4.** Cases of sufficiency and insufficiency of irrigation water supply in a surface-water dominated irrigation setting.

When using MF2K with the FMP1, this process dynamically integrates the following terms for a farm unit (*fig. 3*):

- Farm irrigation delivery requirement (irrigation demand), which depends on changing climate (evapotranspiration and precipitation) and variable aquifer head;
- Actual surface-water delivery to the farm, which is driven by irrigation demand, but limited to canal stream inflow at the farm's diversion head gate, limited by water-rights allotments, or nonrouted deliveries;
- Supplemental ground-water pumpage, which is the difference between the irrigation demand and the actual surface-water delivery, but limited by a specified maximum capacity for all of the wells associated with a farm; and
- Net recharge to ground water, which is the excess of irrigation and of precipitation minus surface-water runoff and minus evapotranspiration from ground water.

In general, the FMP1 provides four improvements compared to previous approaches of integrated surface-water/ground-water modeling:

- Dynamic dependency of crop water demand on changing climate and variable aquifer head;
- Analytical steady state approximation of unsaturated flow (confirmed with HYDRUS2D simulations for several typical soil types) underlying the derivation of crop water demand and in-excess farm net recharge;
- Allocation of surface-water and ground-water supply driven dynamically by crop water demand, and allowing for the estimation of historic and future ground-water pumping supplemental to surface-water supply; and

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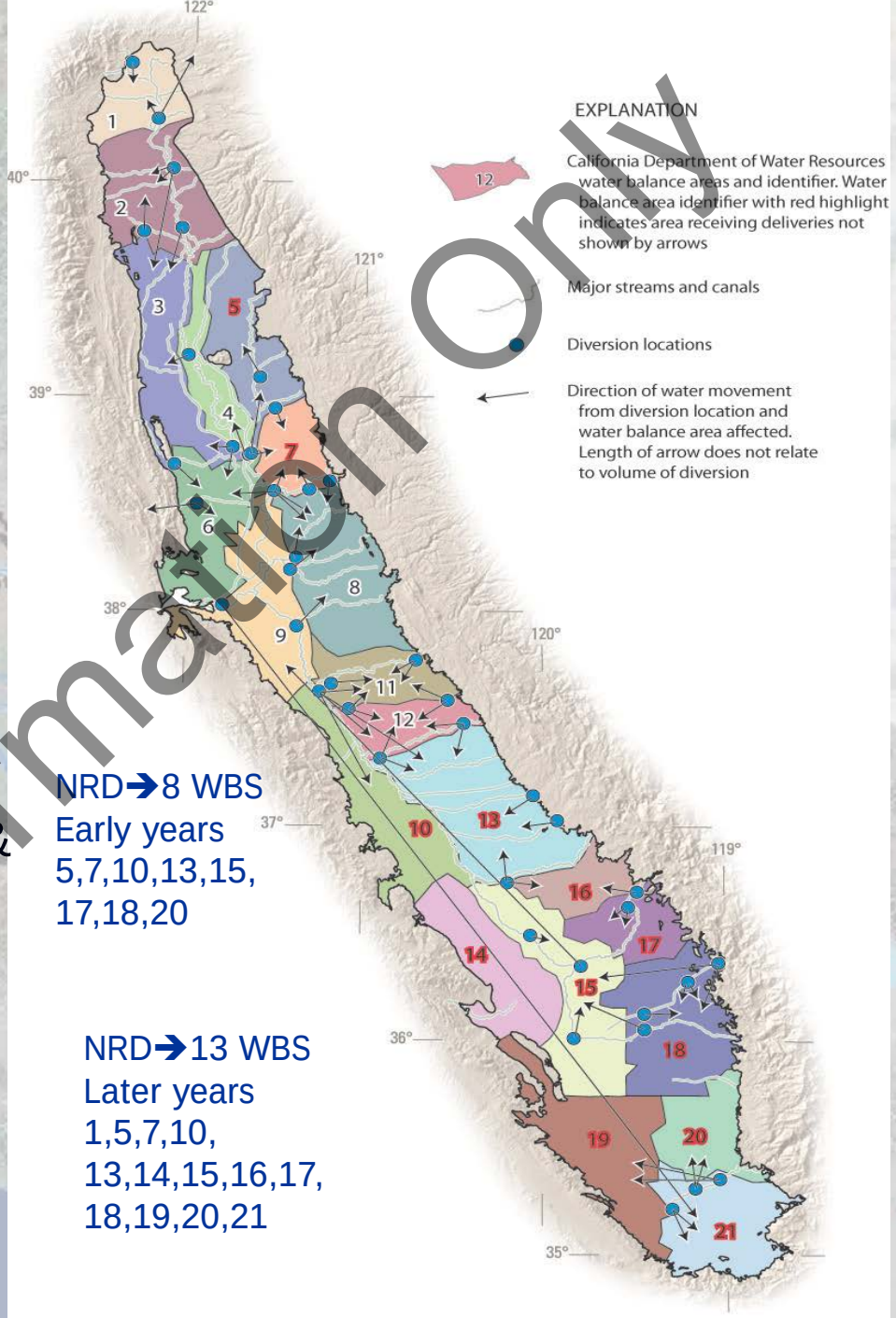
# Non-routed Deliveries

- Surface-water delivery (Volume for each month) without simulation of conveyance that change through time
- Multiple NRDs that represent different sources of water deliveries to WBS ➔ Up to 7 potential sources
- Pre-processing pgm assembly of NRD inputs
- Allows for Supply-constrained & Demand-driven surface-water deliveries
- Only delivers part of volume needed to satisfy TFDR after precipitation/gw-uptake & before SRD's




NRD➔8 WBS
Early years
5,7,10,13,15,
17,18,20

NRD➔13 WBS
Later years
1,5,7,10,
13,14,15,16,17,
18,19,20,21

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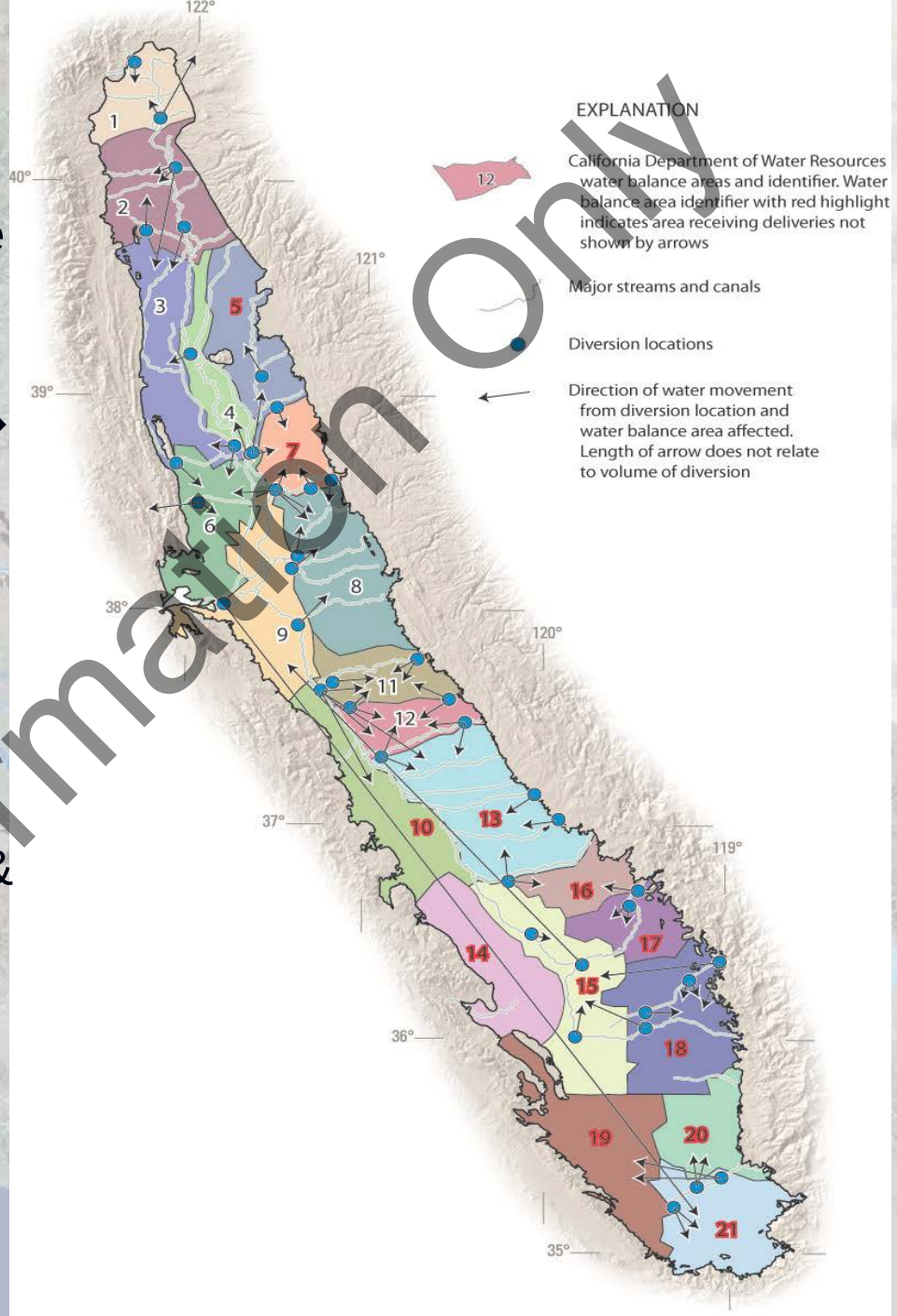
# Semi-routed Deliveries

SFR routing modified to include SRD delivery and returnflow segments

If multiple diversions to WBS ➔ "collected" into collector segment added to SFR network & SRD delivered to WBS

GIS tool to help with SFR modifications

Allows for Supply-constrained & Demand-driven surface-water deliveries

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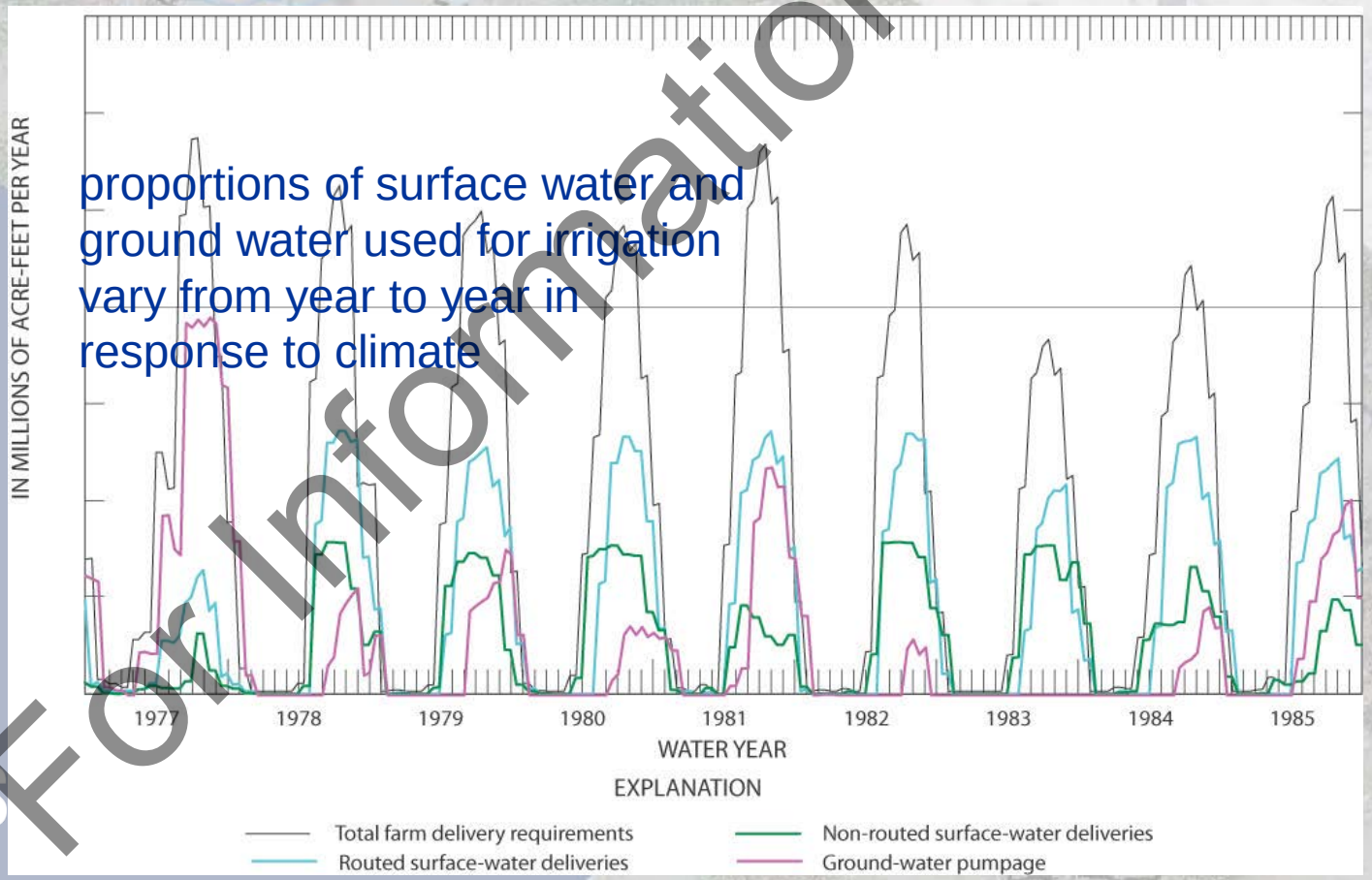
# Example of FMP and Response of Climate Changes built into CVHM

- *Drought '76-'77, '88-'92*
- *Wet Period '83, '99*




proportions of surface water and ground water used for irrigation vary from year to year in response to climate

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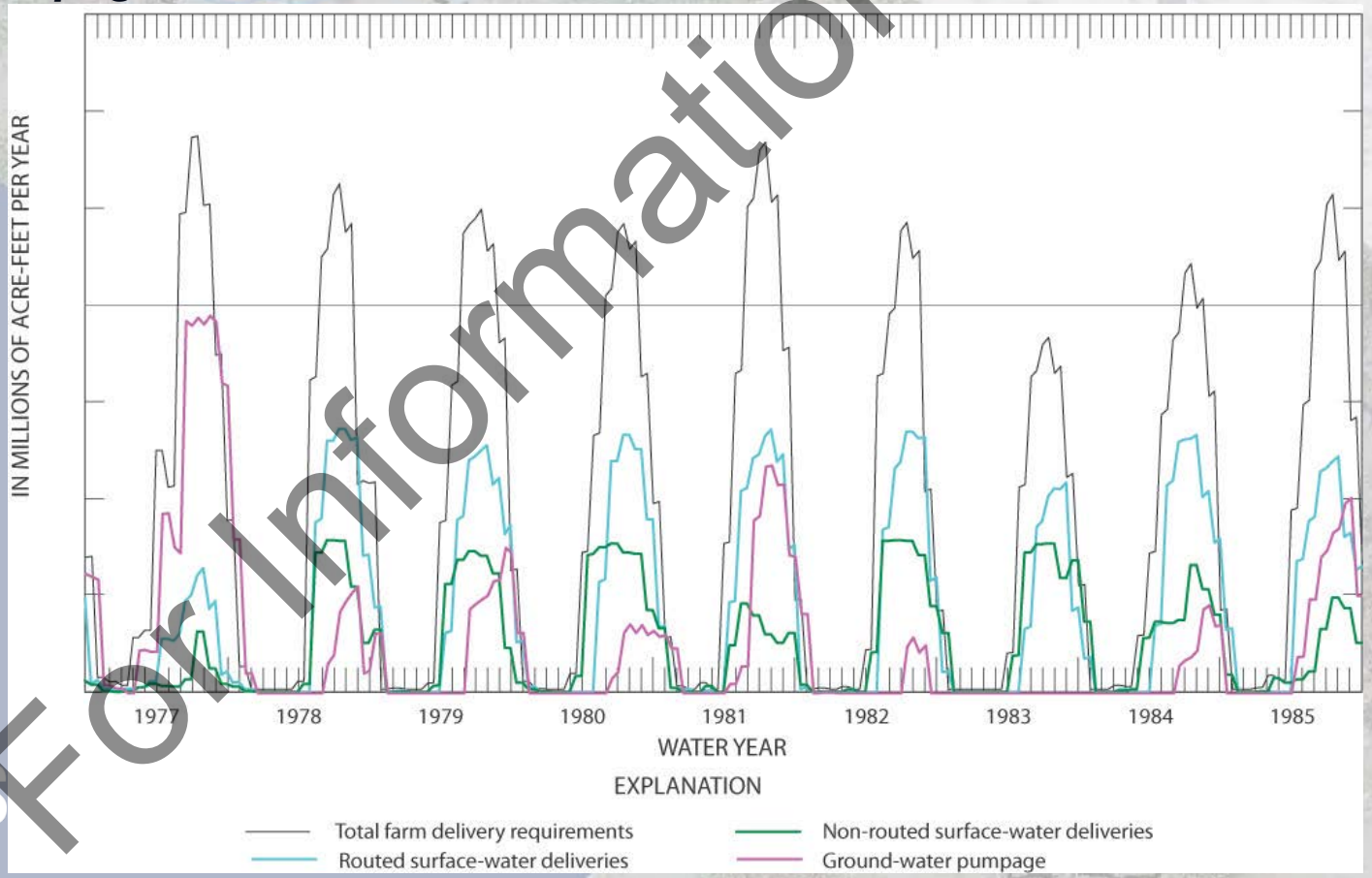
# Example of FMP Seasonal Changes

- *Drought ’77*
  - *High pumping all growing season*
- *Typically*
  - *Early in growing season dominantly surface water deliveries*
  - *Later in growing season, surface-water shortfall made up by ground-water pumpage*

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# Example of FMP

- *Change of Dominant Water Source*
- *Non-routed Water Transfers start in late 60s*

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# Example of FMP Seasonal Changes

**TFDR ➔ Total Farm Delivery Requirement**

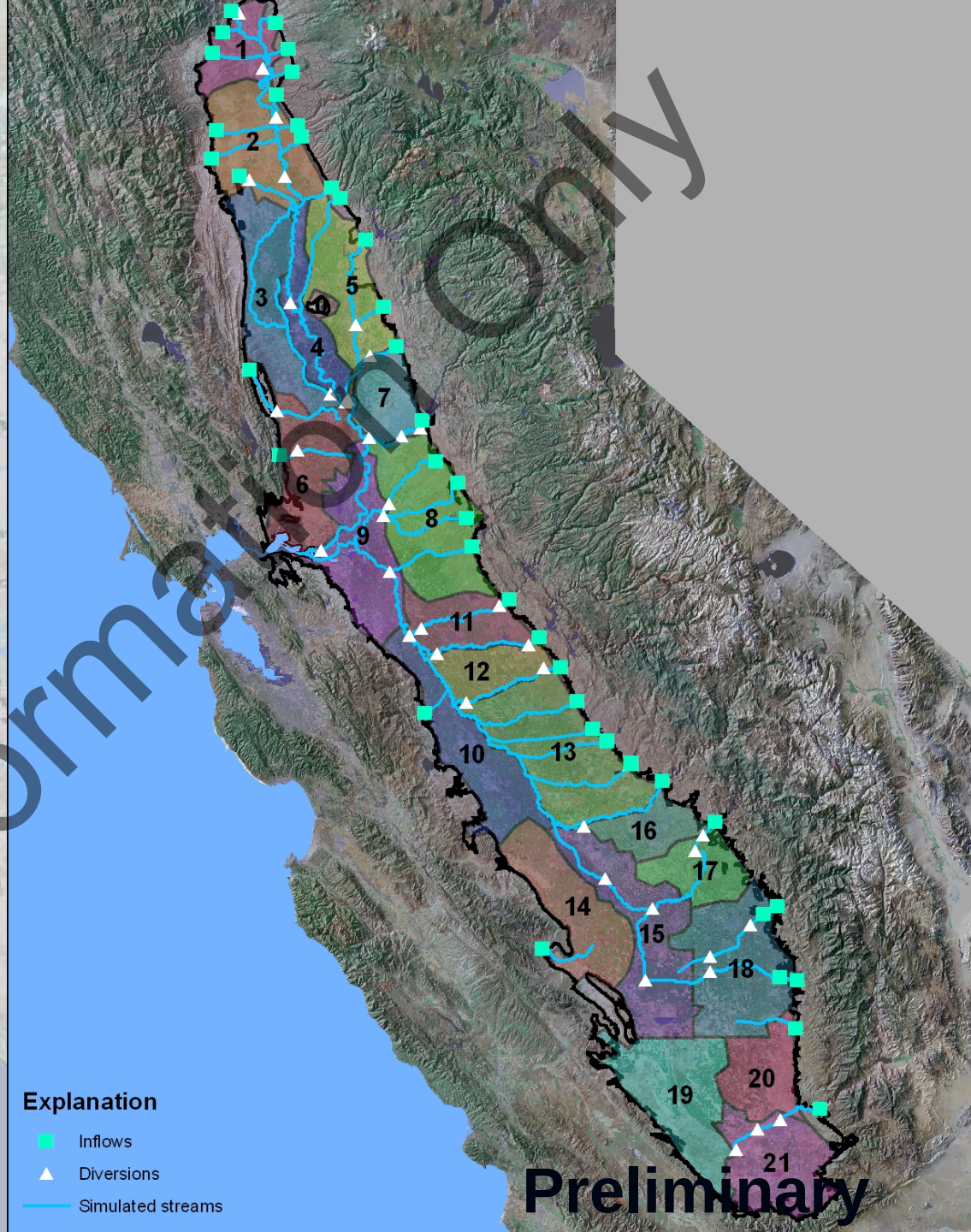
**----- Subregion FMP Net Pumpage**
**WaterBalance Region Example**

R-SWD➔ Semi-routed Surface-Water Deliveries (from 2 Diversions)

NR-SWD ➔ Nonrouted Surface-water Delivery to Subregion (very small)

SWD early in season

Pumping increases and SWD decrease later in season

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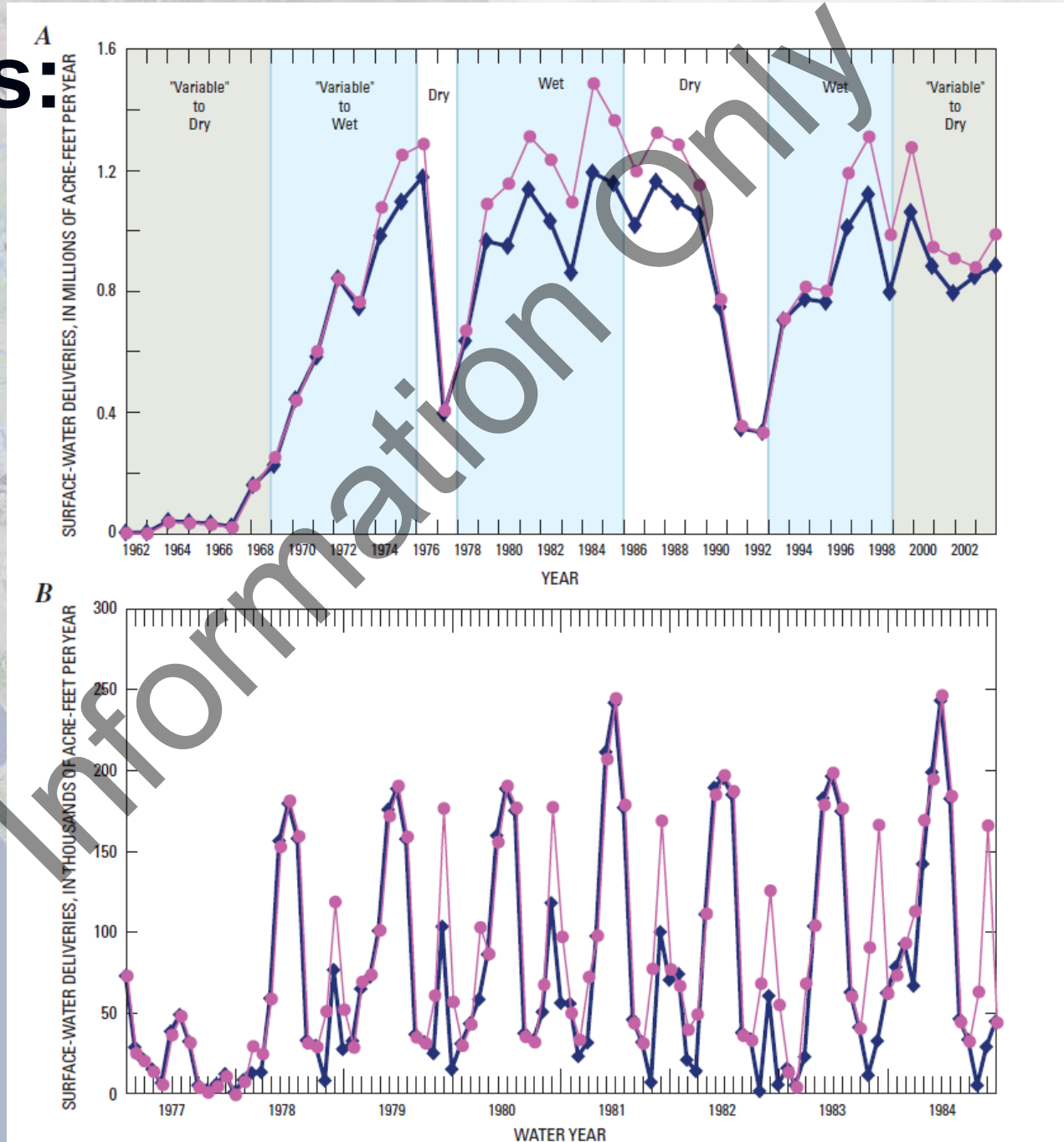
Preliminary

# Deliveries:

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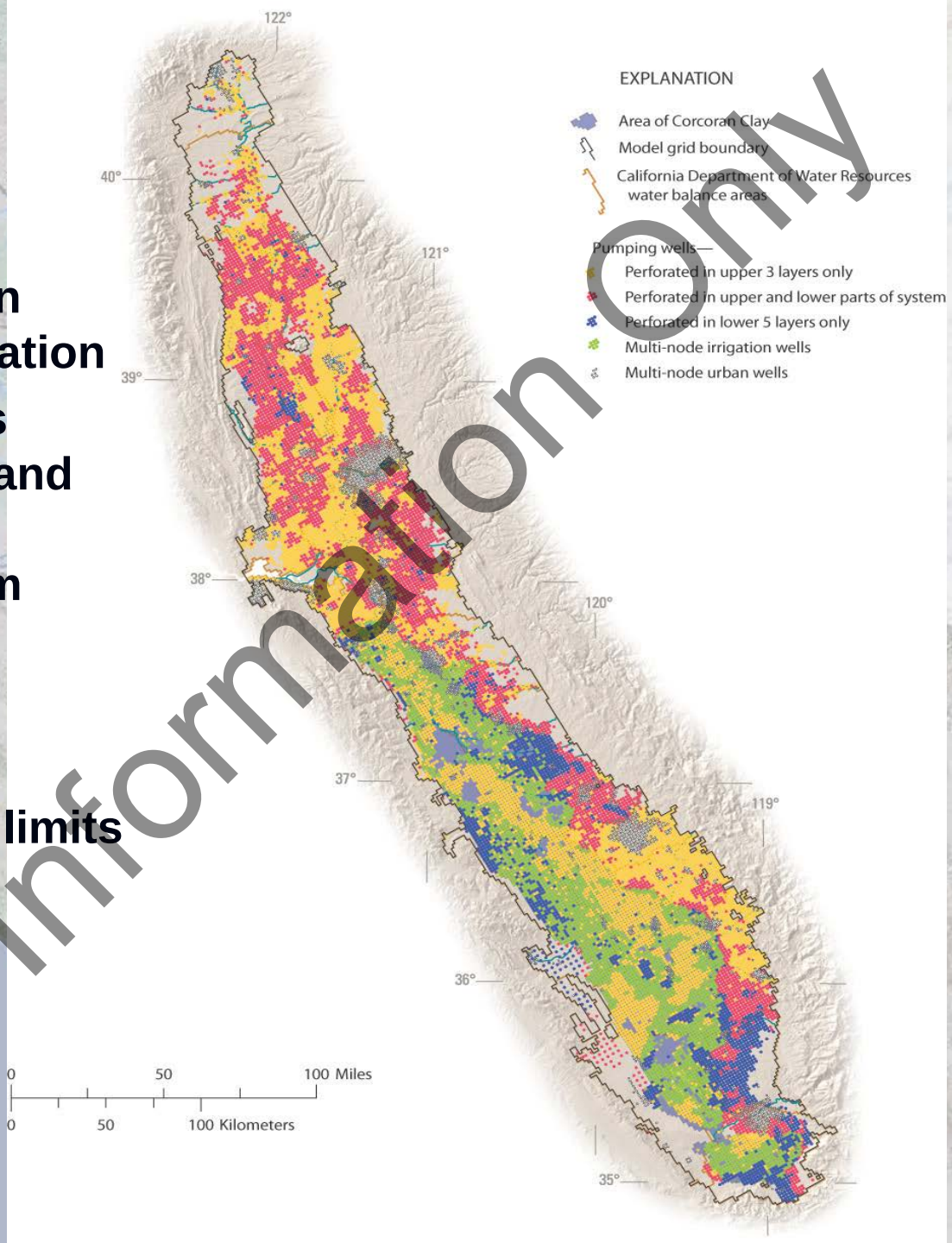
# Wells

- Virtual wells
- Perforation based on construction information
  - Where none was available upper and lower interval interpolated from closest wells
  - Wells crossing Corcoran Clay
- Maximum pumpage limits

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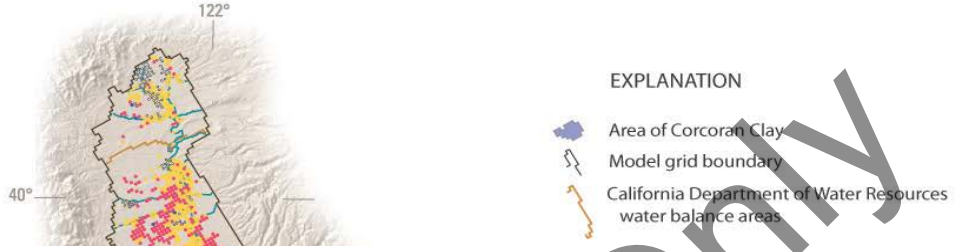
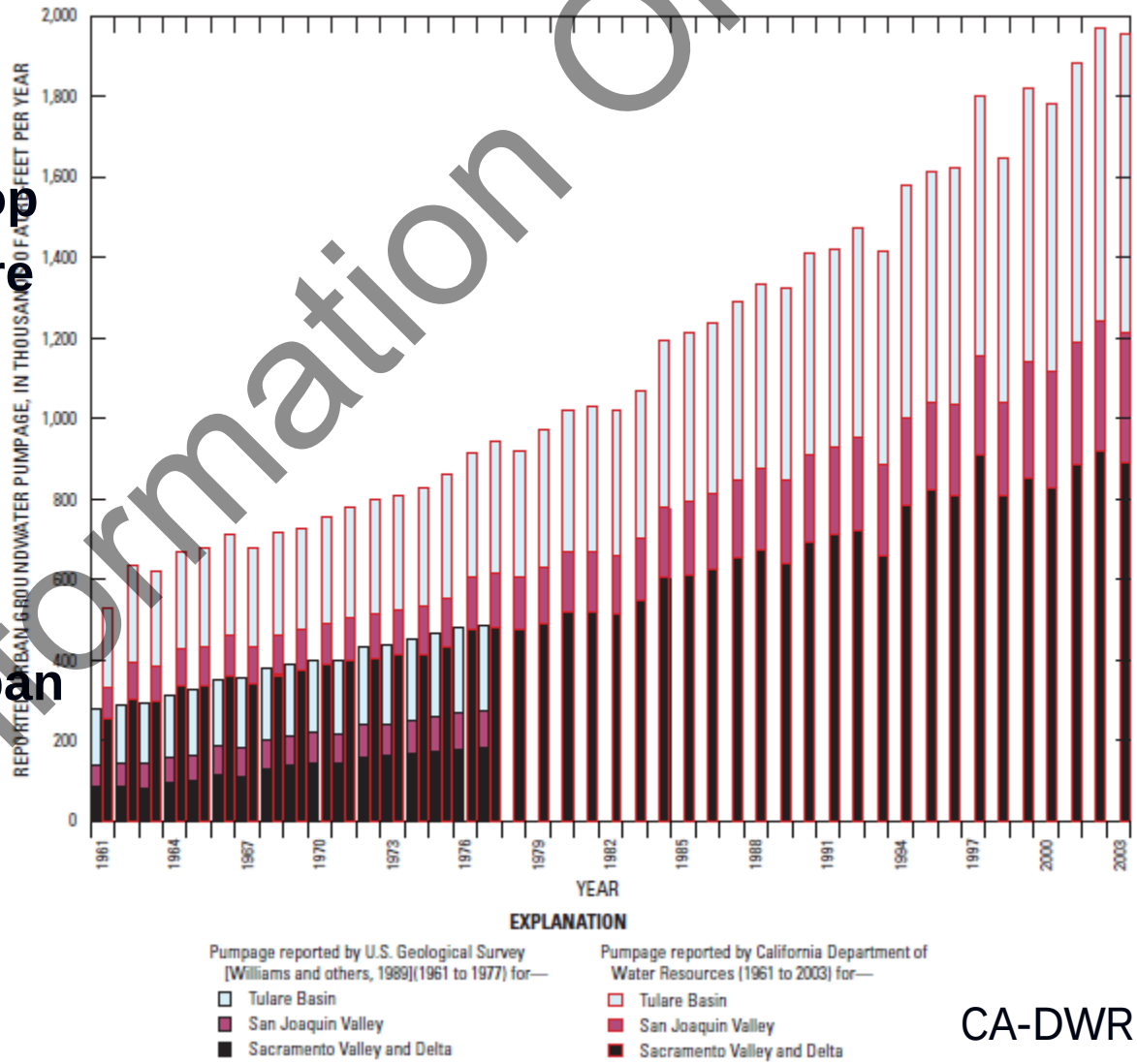
# Wells

- Well types
  - Irrigation
    - Well in each cell with irrigated crop
    - Many areas where wells cross corcoran-clay (non-linearity)
  - Municipal
    - Well in each cell with majority urban land use
    - Wells cross multiple layers




CA-DWR

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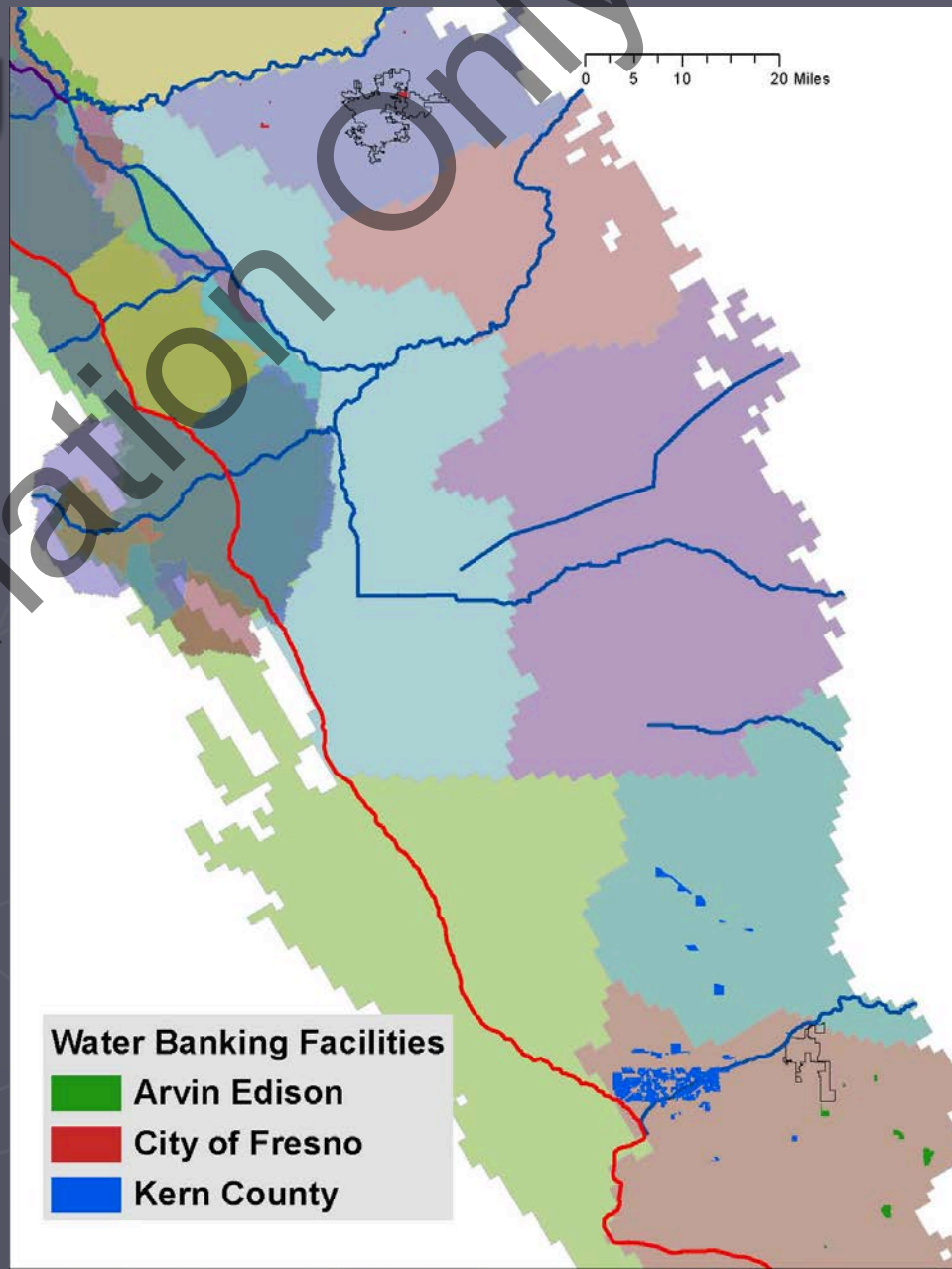
# Recharge from water banking

:

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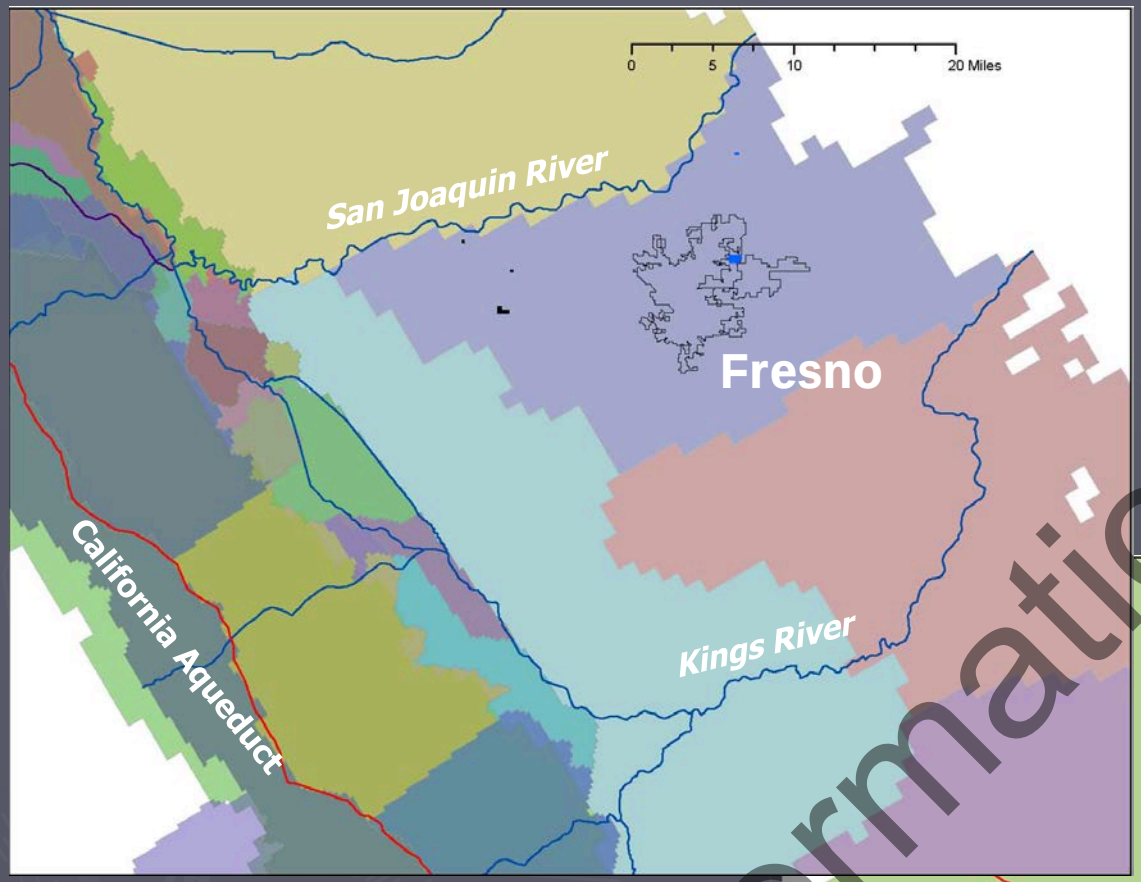


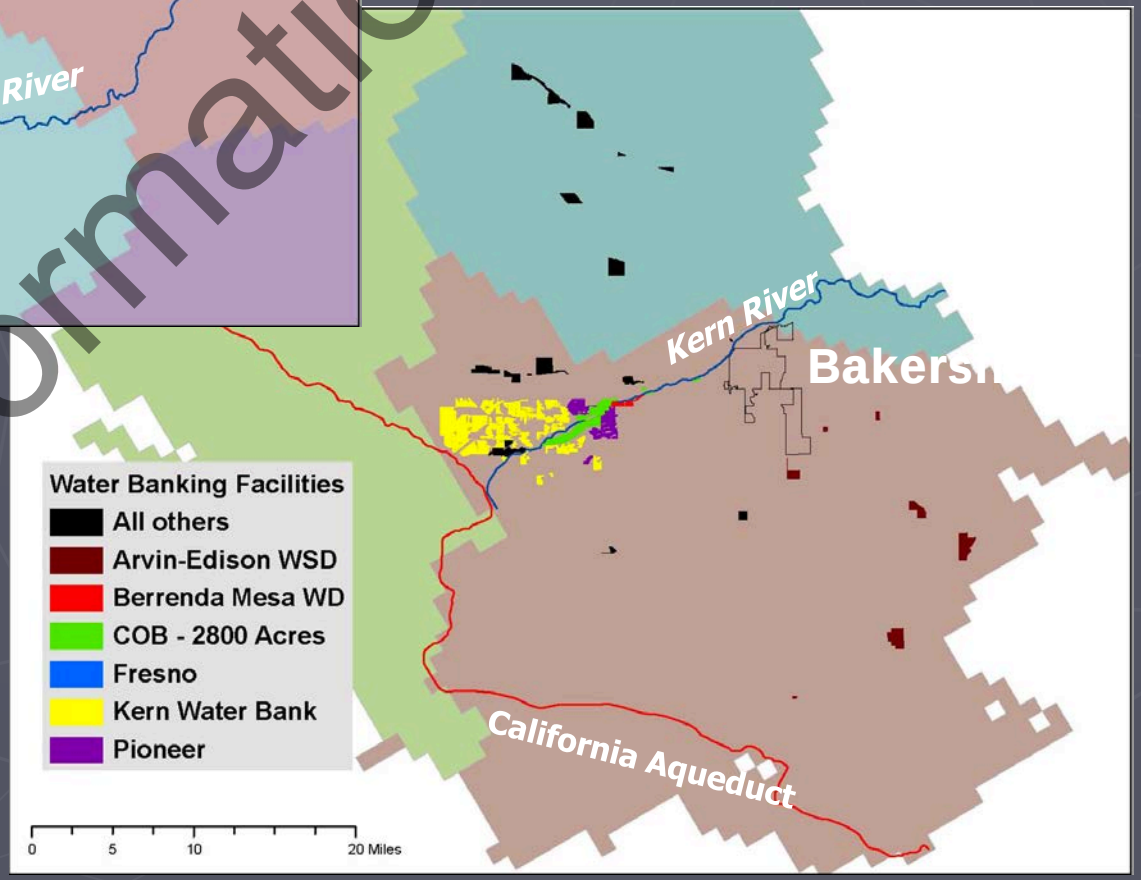


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# Today's Agenda:

**Part 4 - Model Observations and Ways to Move Forward**

**1:00-1:30 Observation Data (Claudia Faunt)**

**1:30-2:00 Data Input Networks (Randy Hanson)**

**2:00-2:15 Break**

**2:15-4:00 Discussion (possible topics and leads to discussion)**

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# Initial Conditions and calibration strategy:

- No steady-state initial condition
- Calibration with Parameter Estimation (PEST/UCODE)
  - Sensitivity Analysis
  - Water level and water level change observations
  - Stream flow observations
  - Subsidence
  - Comparisons to previous model

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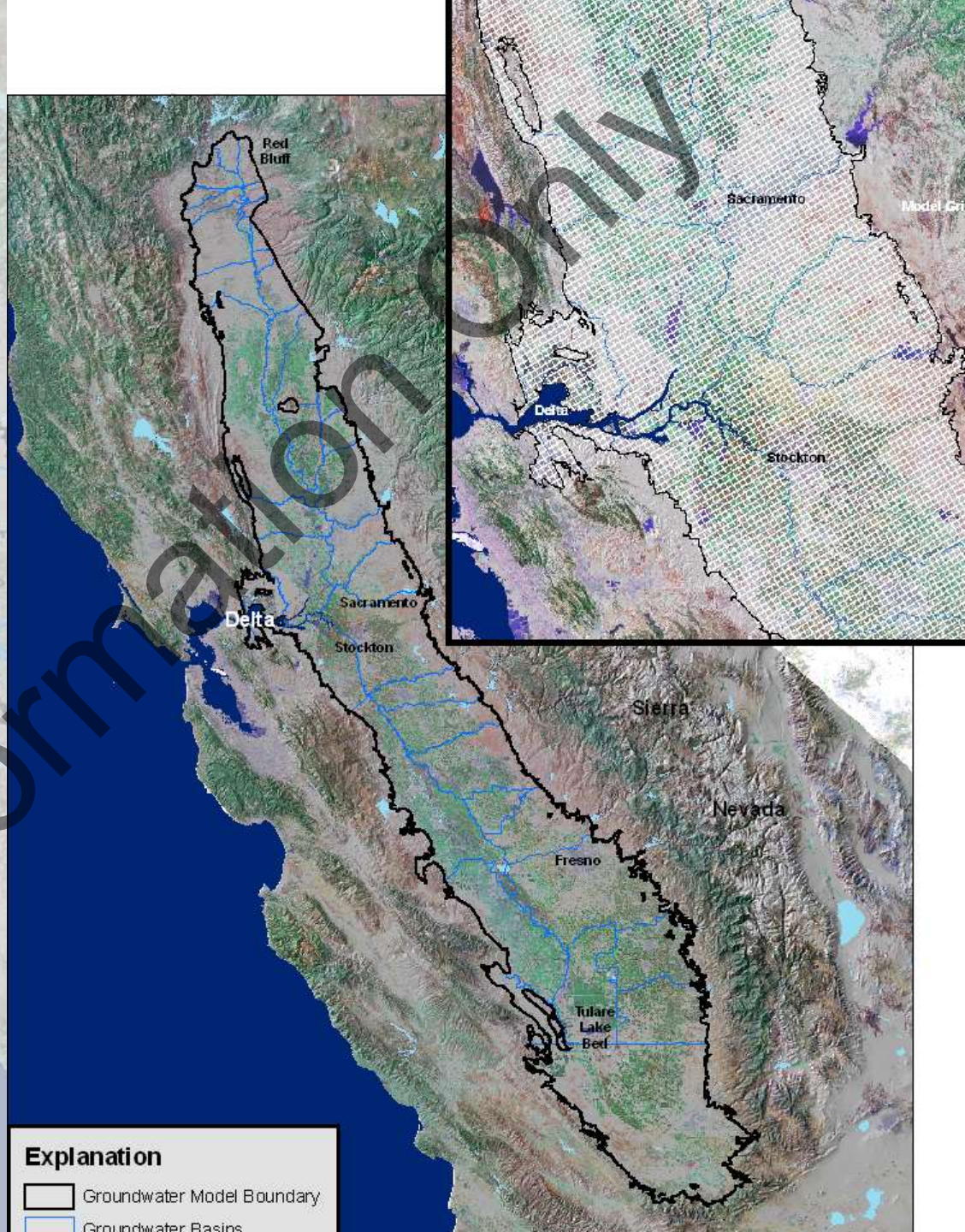
# Parameters

- K coarse grained deposits
- K fine grained deposits
- K Corcoran Clay (vertical and horizontal)
- Streambed conductance zones
- Specific yield multiplier
- K multipliers
  - Depth
  - Zone
- Farm process parameters
  - Efficiencies
  - % runoff
  - Crop coefficients
  - Fraction of evaporation/transpiration
  - Many others
- Estimation (PEST/UCODE)

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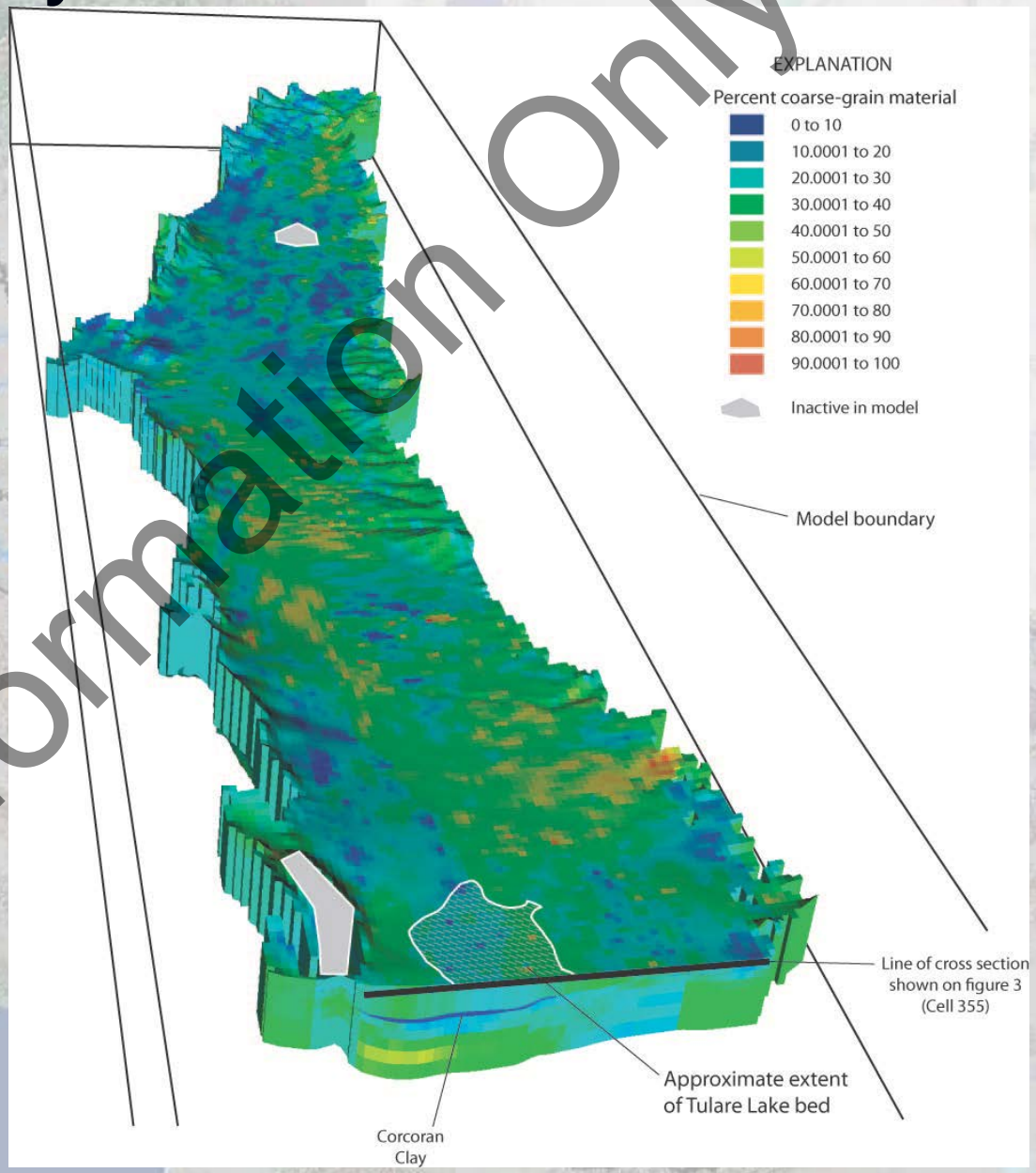
# Hydraulic Conductivity

- **Geologic/Stratigraphic units**
  - Corcoran Clay (zones/layers)
  - San Joaquin Formation (zones)
- **Generally based on texture model (percent coarse)**
- Hydraulic conductivity
  - Power mean
    - Horizontal (approx. K of %coarse)
    - Vertical (approx. K of %fine)
  - Storage and subsidence (uses % fine)
    - Elastic
    - Inelastic
    - Compressibility of water

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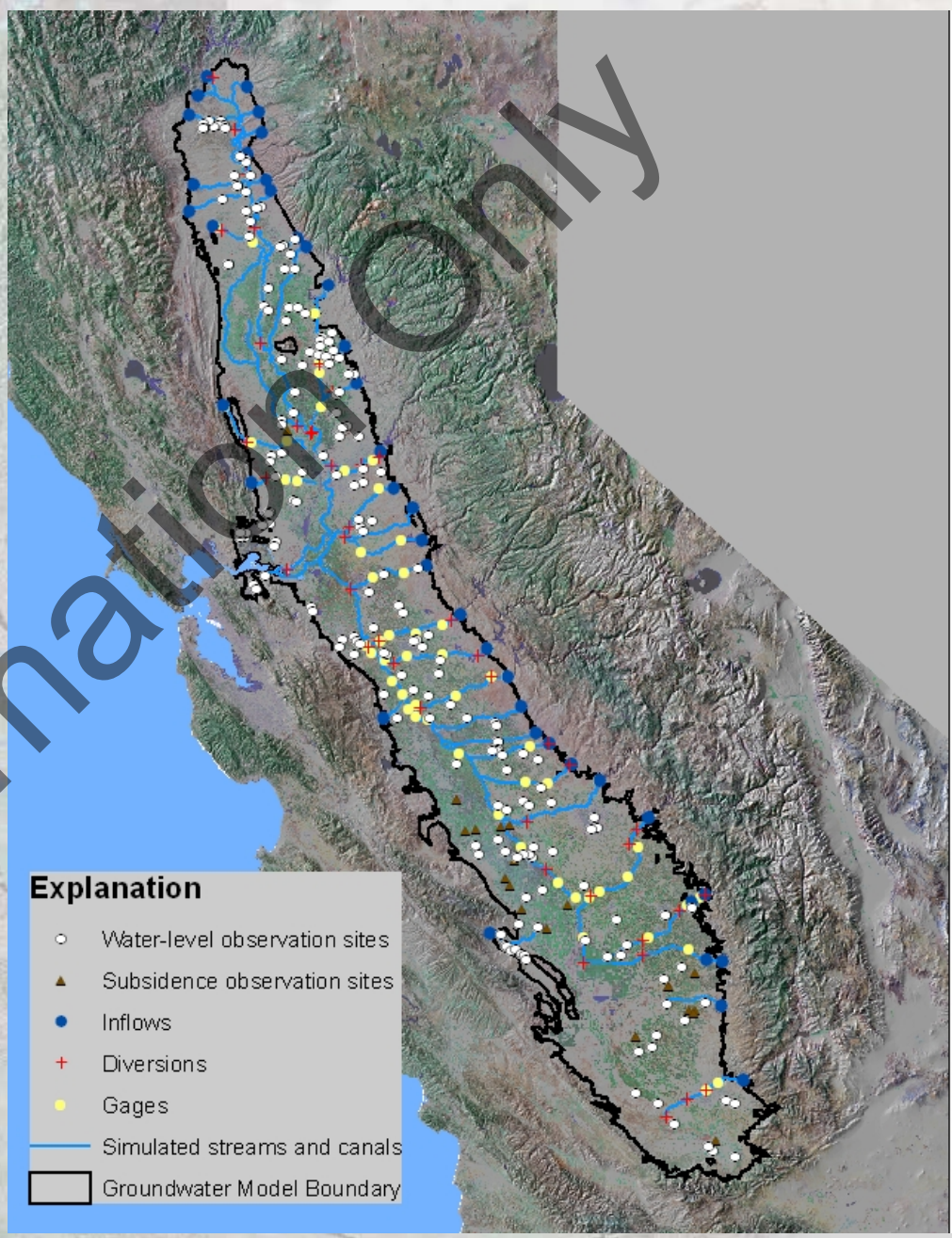
# Calibration points

- **Heads**
  - **206 wells – 19,725 obs.**
    - **continuous record through time frame**
    - **specific time (wet/dry) and spatial distribution**
- **Head gradients**
  - **Spatial (upper to lower system in wells that penetrate both)**
  - **Temporal (200 wells > 10 years)**
- **Subsidence**
  - **24 locations**
- **Streamflow**
  - **43 inflows**
  - **66 diversions**
  - **multiple paired gages**
  - **Gains/Losses (CV-RASA)**
- **Power records (pumpage)**

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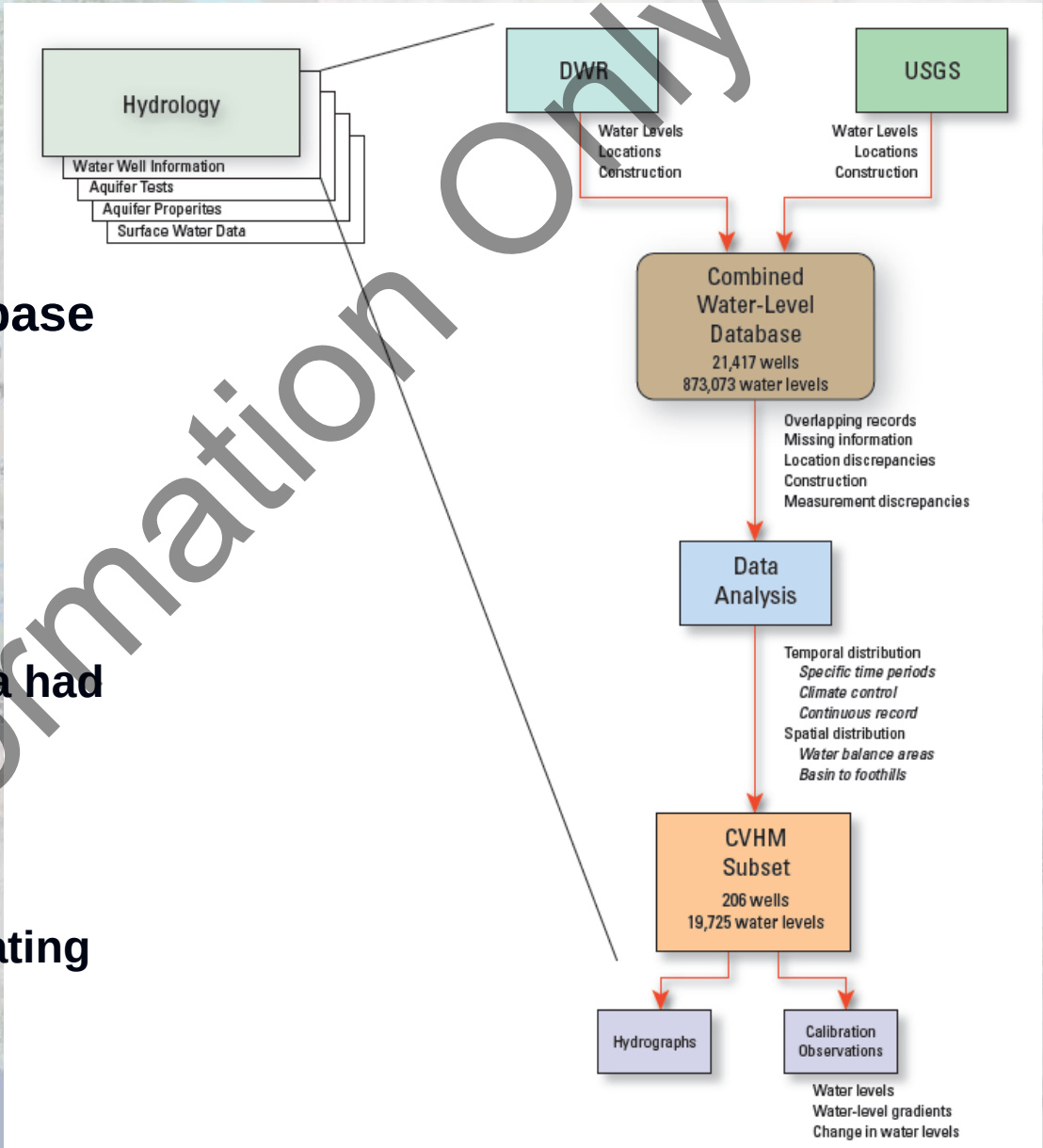
# WATER-LEVEL ANALYSIS

- Data from multiple agencies
  - USGS
  - CA-DWR
- Combine data into one database
  - Identify common wells
  - Remove duplicate data
  - QA/QC
- Construction information
  - Example:

    60 wells with construction data had water level data ranges <mid-1960s to >mid-1990s
  - Use adjacent wells to cover time-frame
  - Creative methods for estimating construction information

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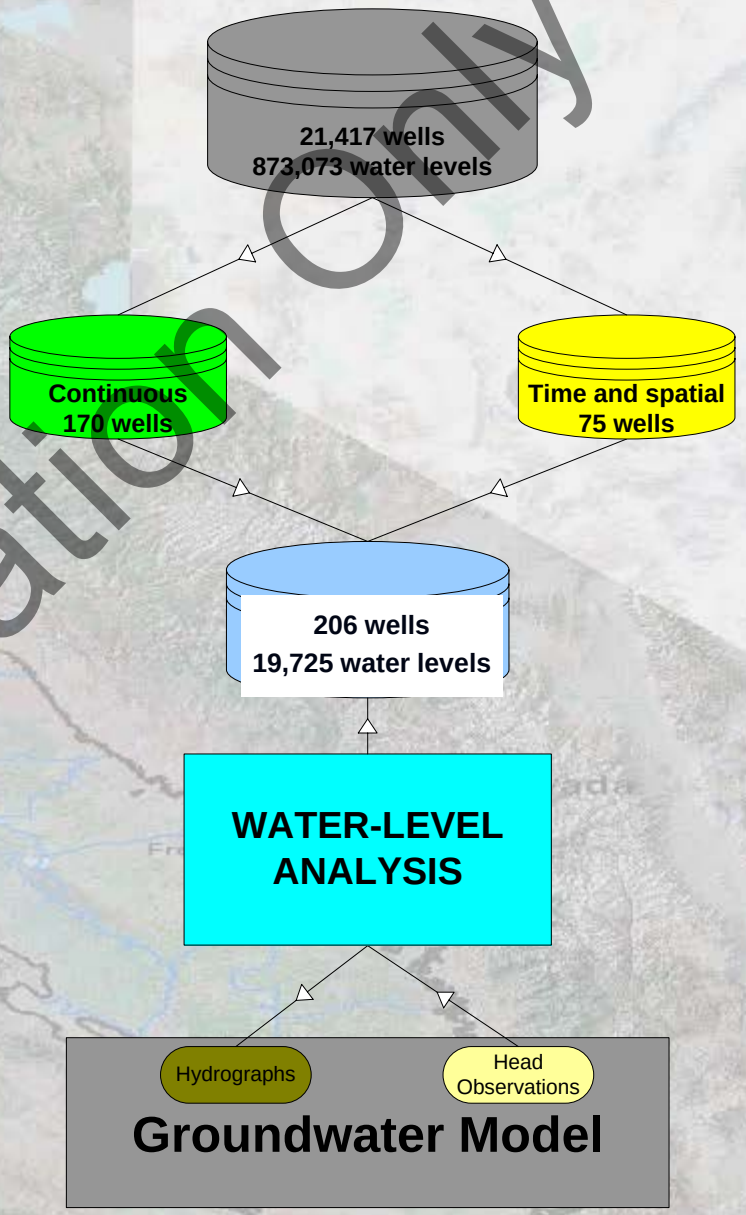


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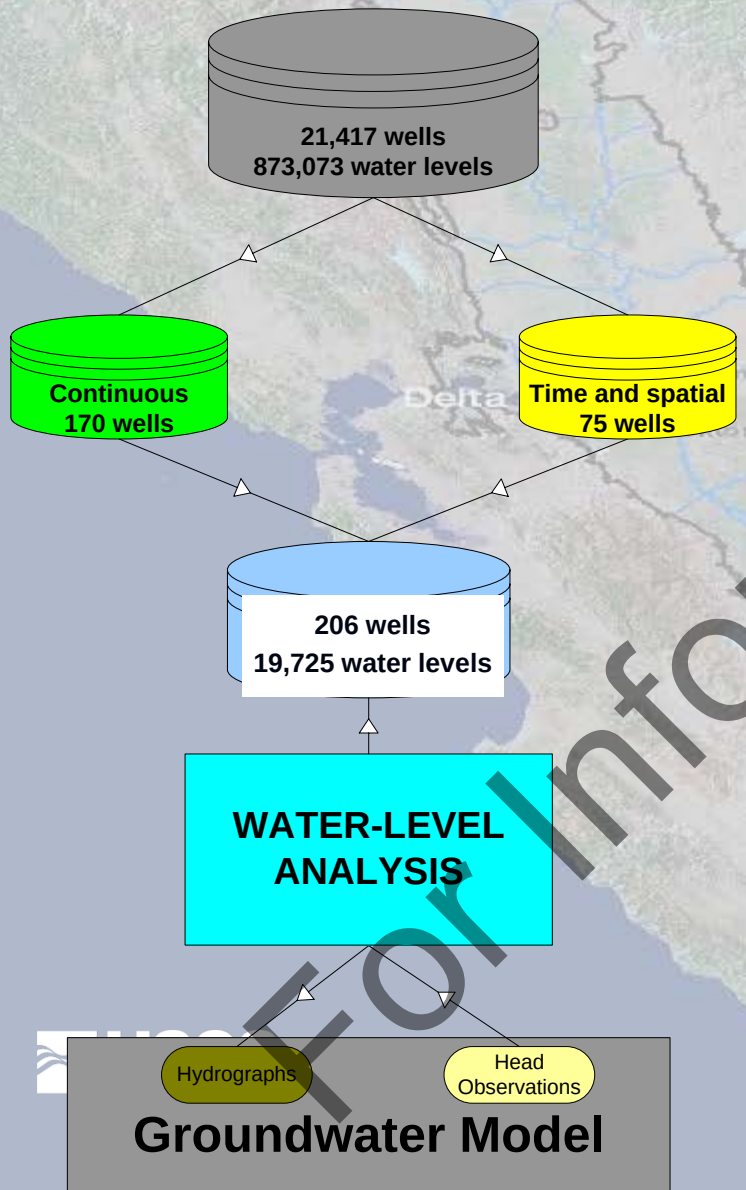


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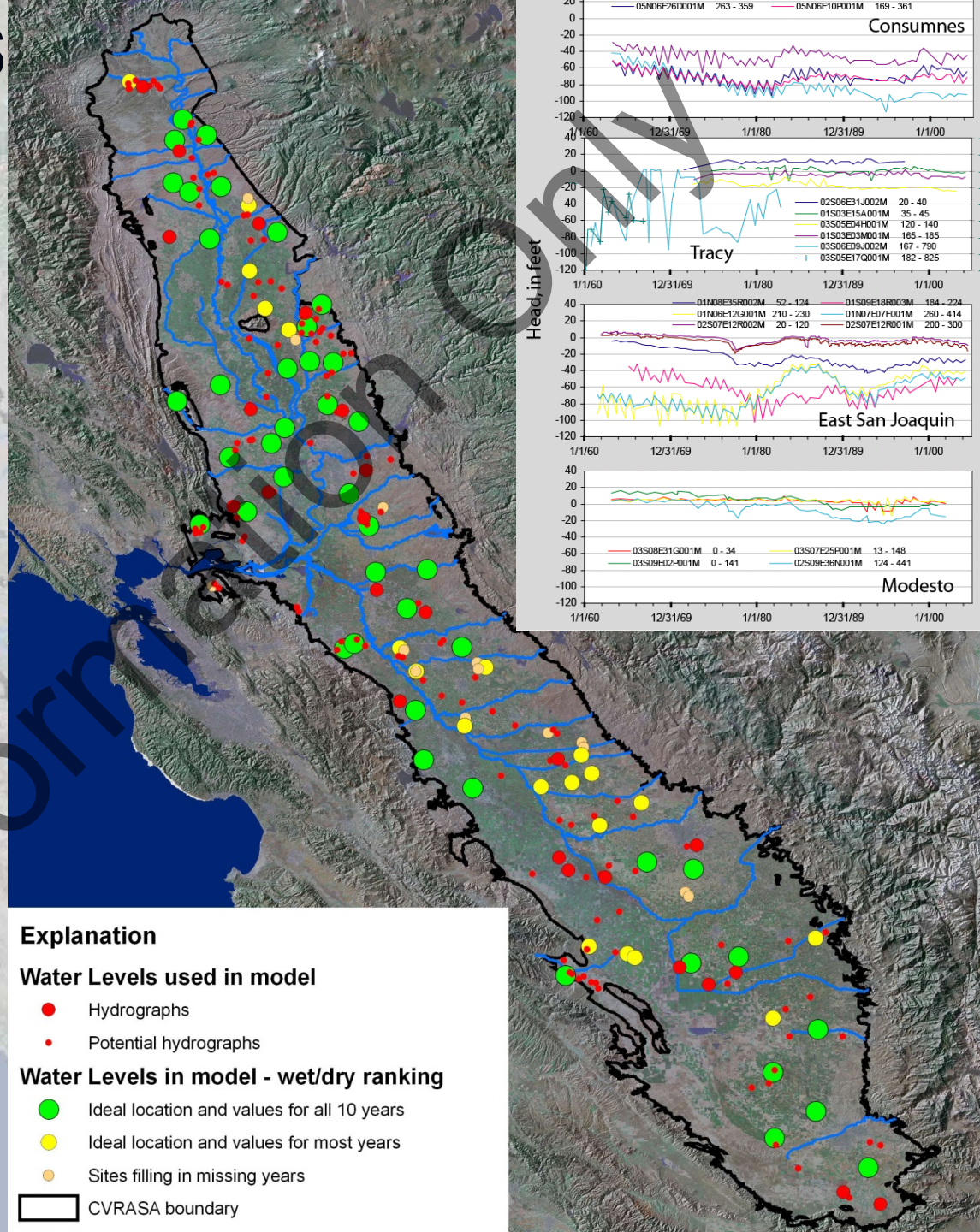
# Selection of wells

- 1) continuous record through time frame
  - 170 wells selected representative of
    - 1960 – 2003
    - Subareas
- 2) specific time and spatial distribution
  - Time intervals
    - drought
    - wet periods
  - Spatial
    - subareas
    - trough and margins
  - Additional 36 wells at selected times
- Approximately 206 wells chronologically and spatially distributed for hydrograph analysis and spot comparisons

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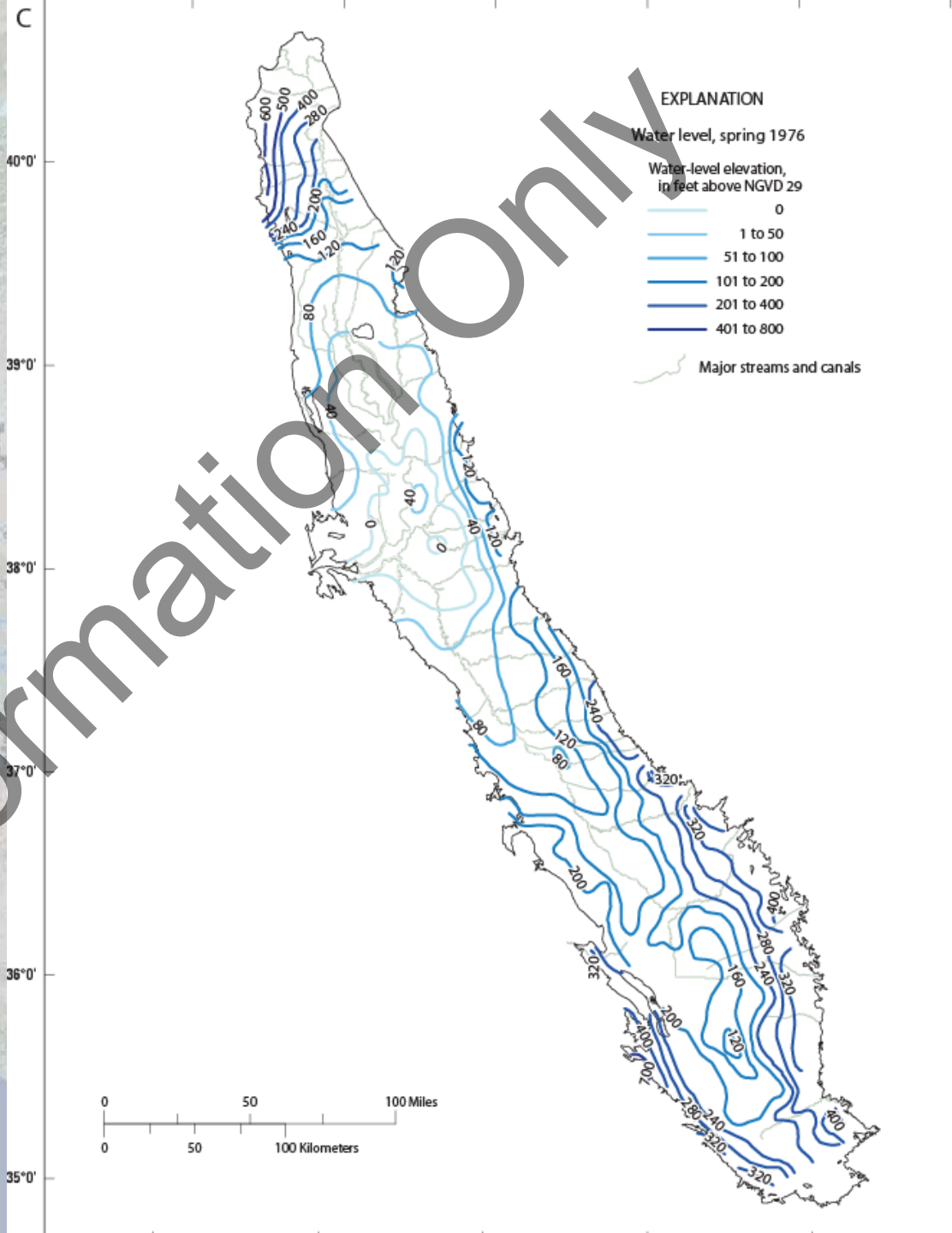
# Water-level maps:

- Water Table and Potentiometric surface
- Original CV-RASA maps used for 1961 and 1977
- Large seasonal fluctuations – spring
- New maps developed for 2000 using co-kriging
  - existing 2000 data segregated by open intervals
  - 1976 maps
- Large vertical gradients, especially in southwest

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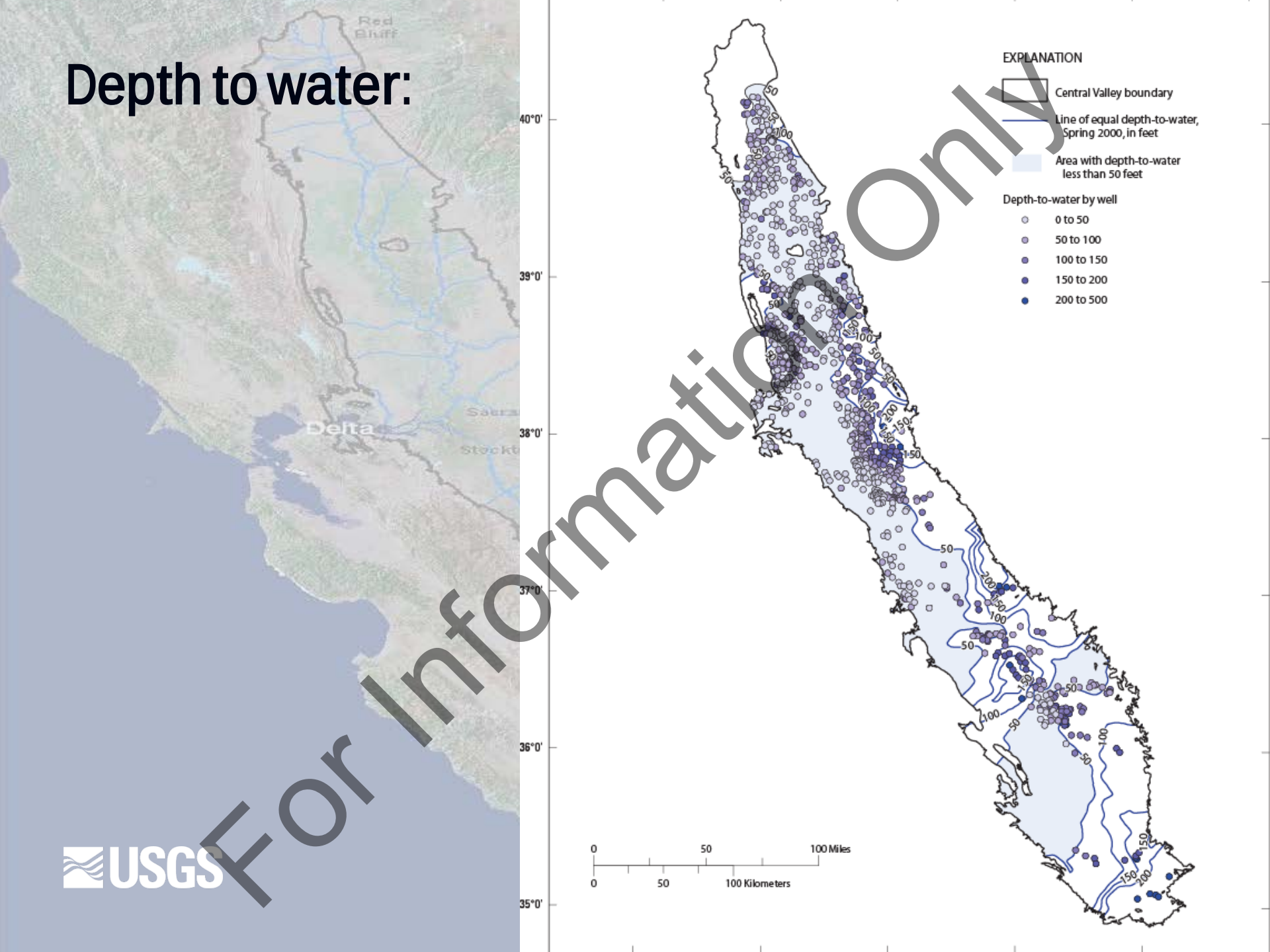
# Depth to water:

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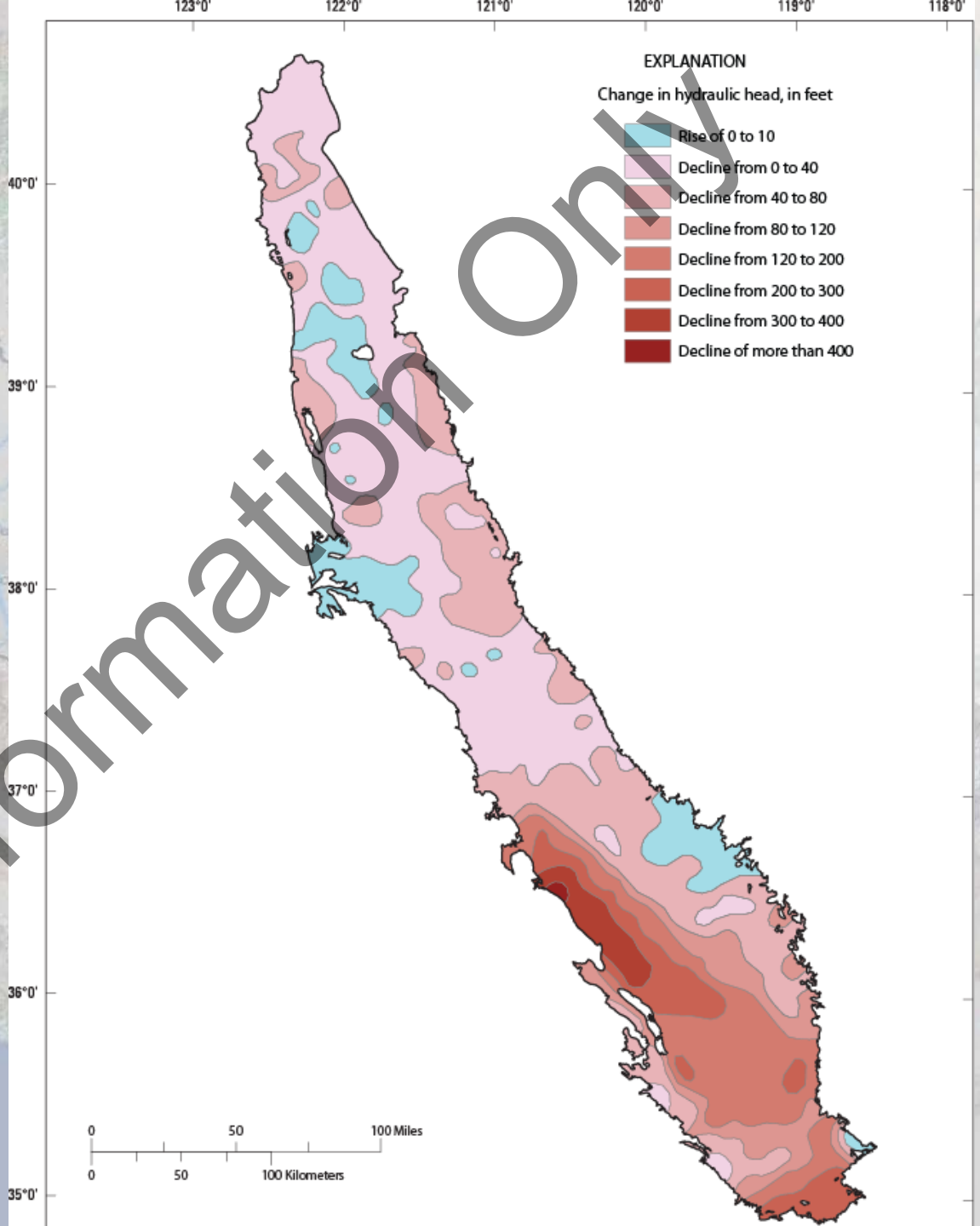
# Change in hydraulic head:

- Potentiometric surface
- Pre-development to 1961
- 1961 to 2003 (based on modeling results)

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  - **24 locations**
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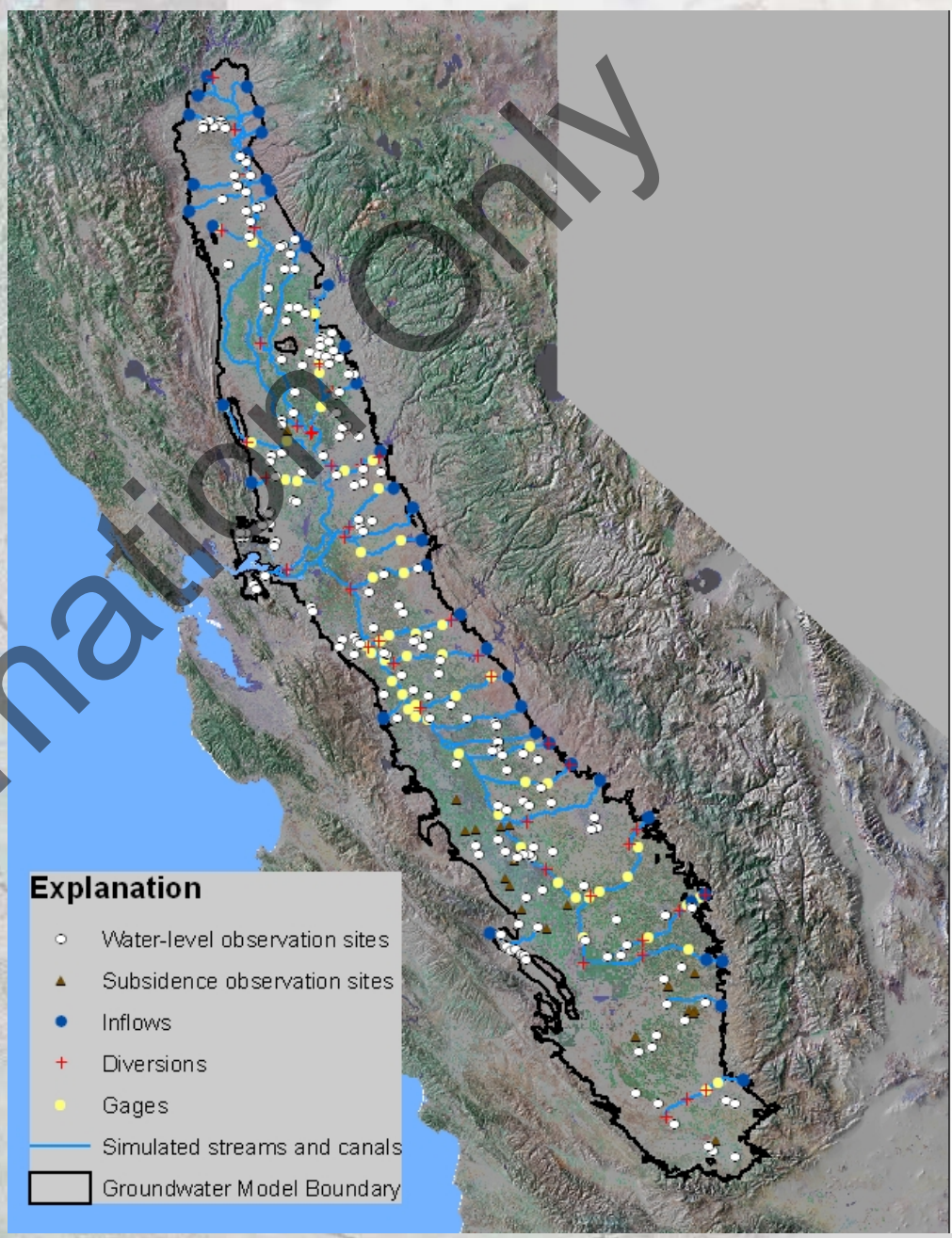


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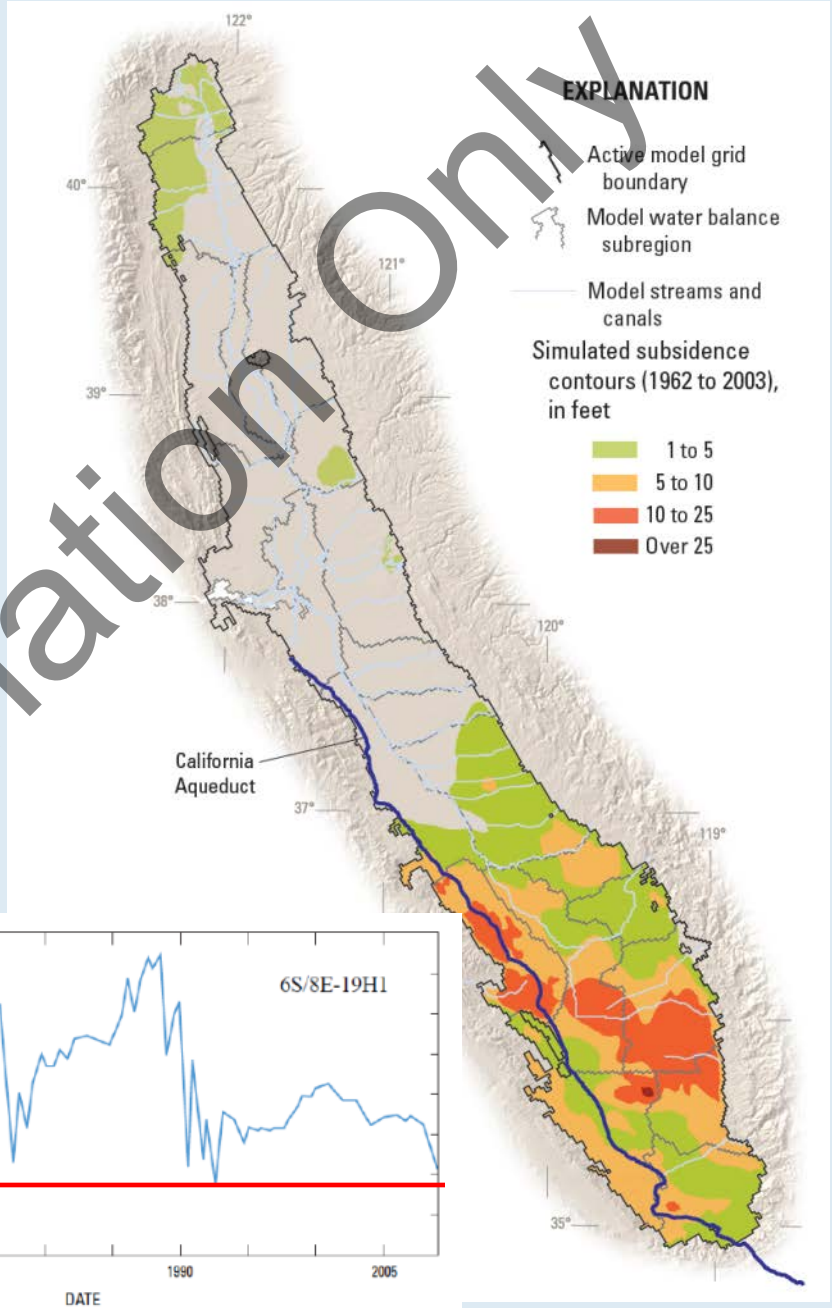
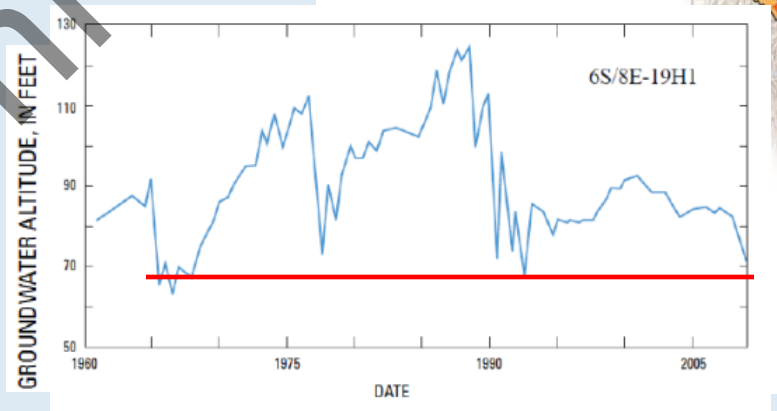
# Subsidence:

- 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
- Recently water levels were again reaching their historic lows and subsidence renewed
- Management constraint

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# Subsidence Damages Natural Resources and Infrastructure

- Natural resources
  - Reduces aquifer-system storage capacity
  - Impacts to wetland, riparian, and aquatic ecosystems
  - Restricted land uses
- Infrastructure
  - Damage to water conveyance systems and other infrastructure
    - Lost freeboard, panel damage, water surface and liner misalignment, reduced conveyance capacity
    - Roads, rails, bridges, pipelines, wells, etc.

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# Impact on Infrastructure

- The deck had to be raised and gates extended

- Constructed with 2 ft of freeboard; side walls on the bridge were later added to keep the road dry

Pictures courtesy of Chris White, Central California Irrigation District

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# What is the Economic Impact?

- Vastly underestimated and under reported

Estimated Costs of Subsidence

| Site | Damages | Costs[1], M$ |
|---|---|---|
| Santa Clara V. | Levees, wells, sewers, roadways | 375 |
| San Joaquin V. | Canals; design modifications | 145 |
| Long Beach | Flood; structural | 600 |

[1]Costs in year 2007 $US

Sources: Fowler, 1981; Freeze, 2000; NRC, 1991

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Courtesy of Devin Galloway, USGS

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# Subsidence Observations: Deformation Measurement Methods

- Land Survey
  - Spirit leveling: usually along highways, railroads, and canals
    - vertical accuracy varies
  - Global Positioning System (GPS)
    - - vertical accuracy of 15 cm or less
- Extensometer
  - vertical resolution of 1 cm or less
- Interferometric Synthetic Aperture Radar (InSAR)
  - vertical resolution of 5 mm under ideal conditions; however, a resolution of 2 cm is expected in this study
- Hydrogeologic framework (water levels, geology, etc.)

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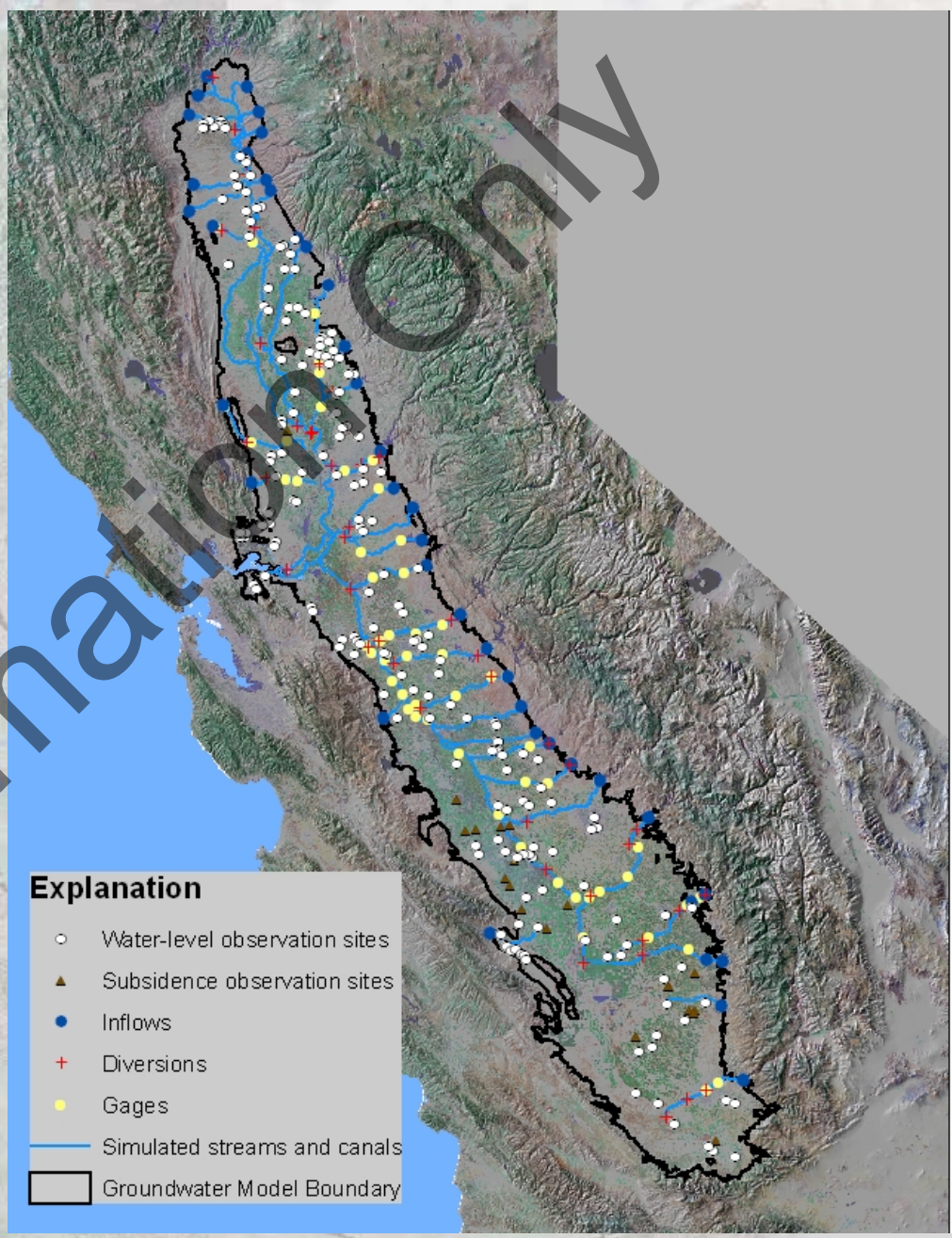


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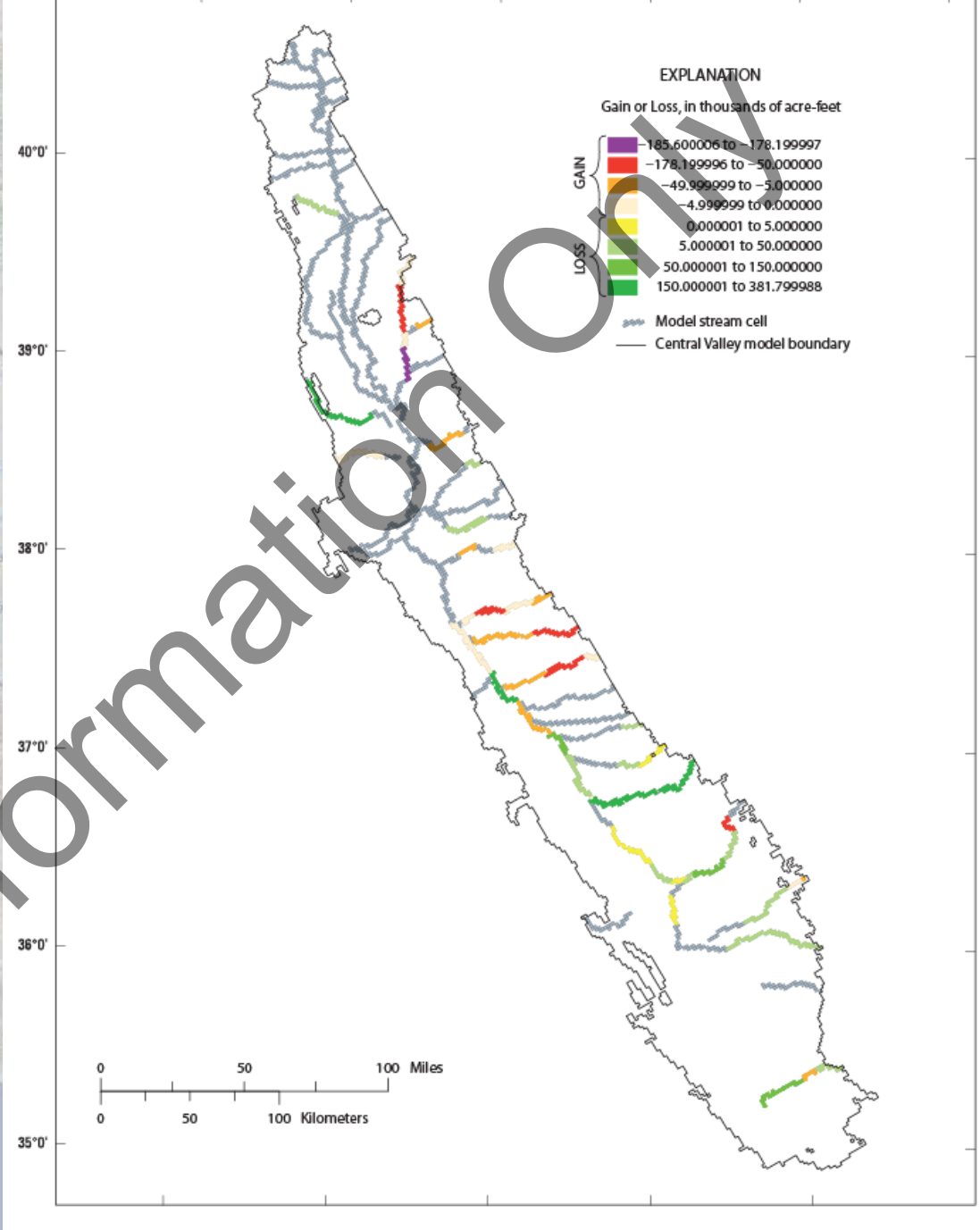
# Stream flow gains/losses:

- CV-RASA tabulated data for 1961-1977
  - Seasonal (spring/fall)
- SFR gage package
  - Script to convert model output to same time frame to compare observations
  - Pictures show average
  - Reality some years gains and some years losses on some segments

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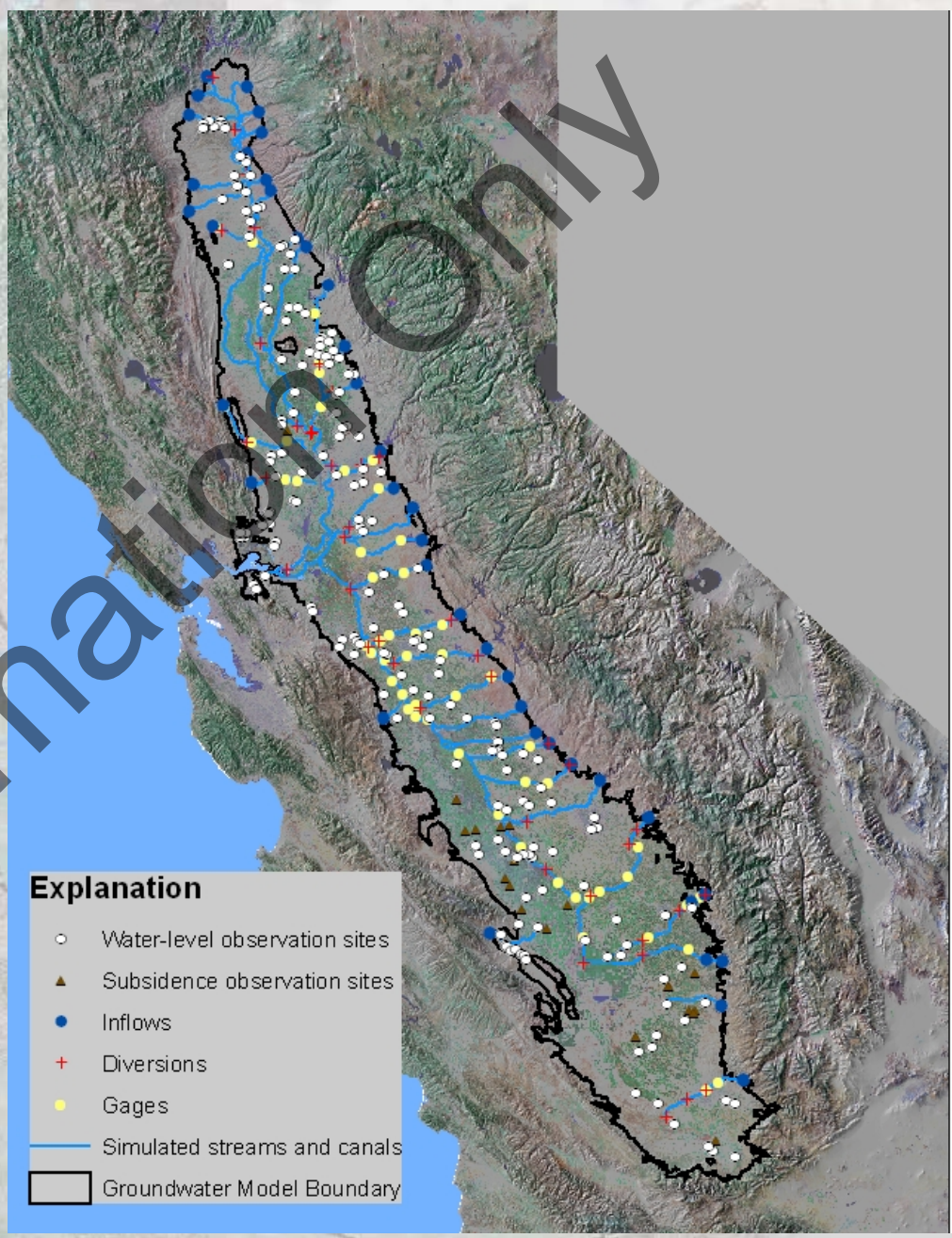
# Calibration points

- **Heads**
  - **206 wells – 19,725 obs.**
    - **continuous record through time frame**
    - **specific time (wet/dry) and spatial distribution**
- **Head gradients**
  - **Spatial (upper to lower system in wells that penetrate both)**
  - **Temporal (200 wells > 10 years)**
- **Subsidence**
  - **24 locations**
- **Streamflow**
  - **43 inflows**
  - **66 diversions**
  - **multiple paired gages**
  - **Gains/Losses (CV-RASA)**
- **Power records (pumpage)**

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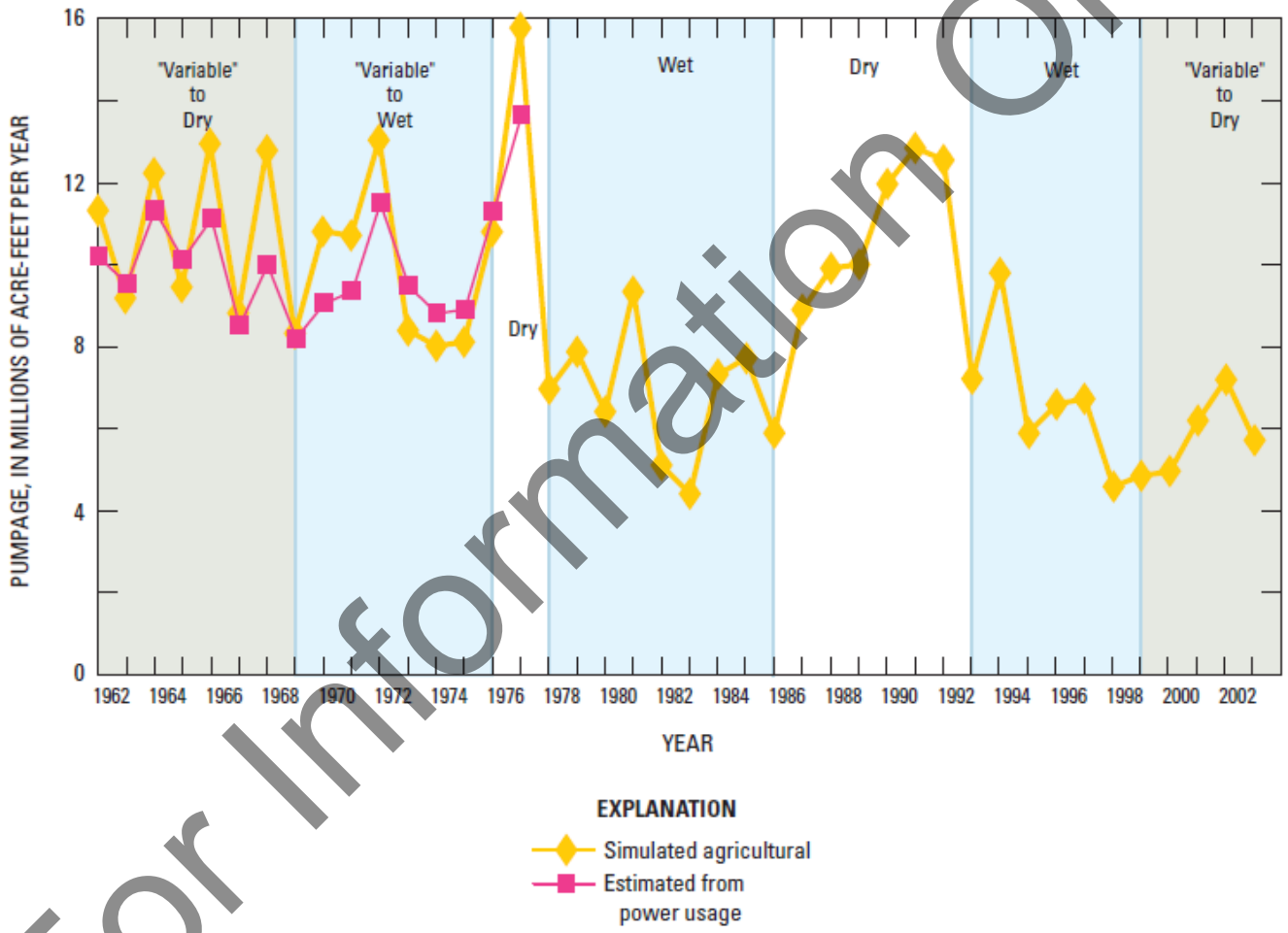
# Water Use:

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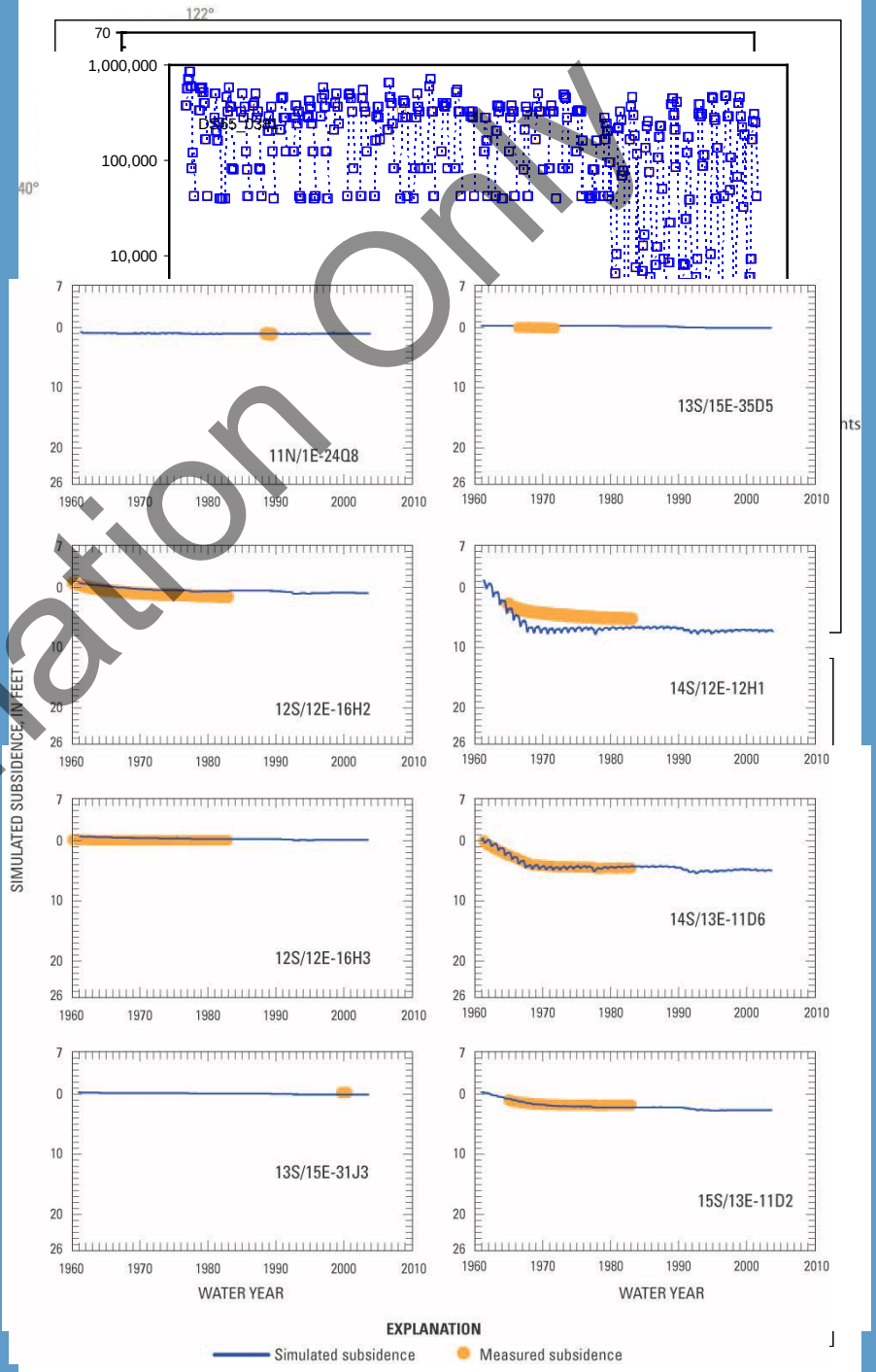
# Observations

- 23,493 total estimated
- Water levels and water level change
  - 206 wells – 19,931 obs.
- Streamflow
  - 40 segments – 782 obs.
- Subsidence
  - 24 locations – 2,780 obs.
- Other comparisons
  - Power records (pumpage)
  - 103 stream-flow gages
  - 66 diversion sites (monthly)

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# Today's Agenda:

**Part 4 - Model Observations and Ways to Move Forward**

**1:00-1:30 Observation Data (Claudia Faunt)**

**1:30-2:00 Data Input Networks (Randy Hanson)**

**2:00-2:15 Break**

**2:15-4:00 Discussion (possible topics and leads to discussion)**

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# Monitoring Networks

**State or Hydrologic Condition**

- State of System ➔ Quantity (selected Basins) and Quality (USGS/DWR - GAMA)
- Compliance ➔ Regulatory requirements (DWR - CASGEM)
- Safety/Management/Water Rights ➔ Streamflow, Reservoirs, & Diversions

**Simulation of System & Decision Support Systems**

Data Networks in support of Hydrologic Models

(➔ Self-Updating Data/SummaryFiles)

- Land-Based Data Networks
- Remotely Sensed Data

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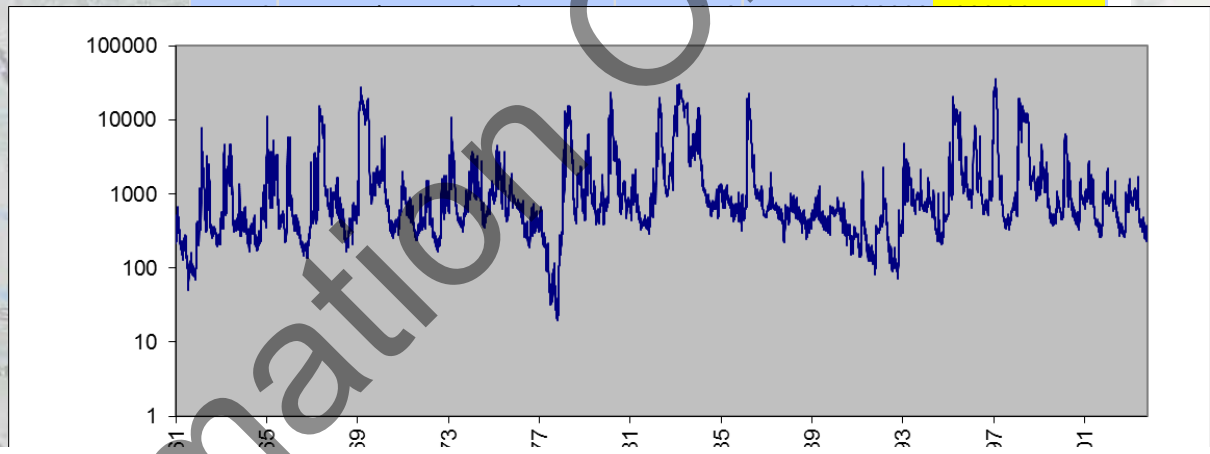
# Online data Self-updating

- Inflows (43)
- Website
  - link to source for each inflow
  - Pull data individually or as a group (graphically, tabulated
  - Hydrograph visualized for site
  - Choose
    - time frame,
    - time period groupings (monthly)
    - Selection/statistical method
  - Tabulated data downloaded

| No. | Name | Stream Node number | USGS Site Id | period of record |
|---|---|---|---|---|
| 1 | Sacramento R A Keswick | 205 | 11370500 | 1938-2009 |
| 2 | Cow C NR Millville | 211 | 11374000 | 1949-2009 |
| 3 | Battle C BL Coleman FH | 220 | 11376550 | 1961-2009 |
| 4 | Cottonwood Creek | 218 | 11376000 | 1940-2009 |
| 7 | Mill Creek | 243 | 11381500 | 1928-2009 |
| 8 | Elder Creek | 237 | 11379500 | 1948-2009 |




| DATE | SACR_205 | COWC_211 | BATT_220 | COTT_218 | PAYS_225 | ANTL_233 | MILL_243 | ELDE_237 |
|---|---|---|---|---|---|---|---|---|
| 196104 | 16162777 | 1444281 | 1283805 | 1567724 | 123443 | 534919 | 822952 | 164590 |
| 196105 | 18114235 | 947722 | 1242392 | 899938 | 39820 | 438023 | 836225 | 79641 |
| 196106 | 22882180 | 448509 | 934050 | 493771 | 0 | 246886 | 822952 | 41148 |
| 196107 | 28021515 | 67694 | 613232 | 191137 | 0 | 159281 | 358382 | 0 |
| 196108 | 27209181 | 39820 | 489789 | 163263 | 0 | 159281 | 278742 | 0 |
| 196109 | 17969156 | 61721 | 489656 | 197508 | 0 | 164590 | 246886 | 0 |
| 196110 | 14299454 | 139371 | 561466 | 203083 | 0 | 159281 | 238922 | 0 |
| 196111 | 13002641 | 720083 | 678935 | 300377 | 41148 | 329181 | 329181 | 41148 |
| 196112 | 9190515 | 3030322 | 1226464 | 1401673 | 597304 | 1075147 | 676944 | 119461 |
| 196201 | 7916267 | 1174698 | 820297 | 752603 | 159281 | 477843 | 438023 | 39820 |
| 196202 | 17599416 | 5008251 | 1811964 | 5647508 | 1234428 | 2424769 | 1631208 | 573127 |
| 196203 | 14219814 | 2918825 | 1198590 | 3516129 | 358382 | 915866 | 676944 | 438023 |
| 196204 | 11282672 | 1217969 | 1234428 | 1888675 | 82295 | 617214 | 946395 | 288033 |

| | | | |
|---|---|---|---|
| 11274000 | SAN JOAQUIN R NR NEWMAN | 37.350493 | -120.977150 |

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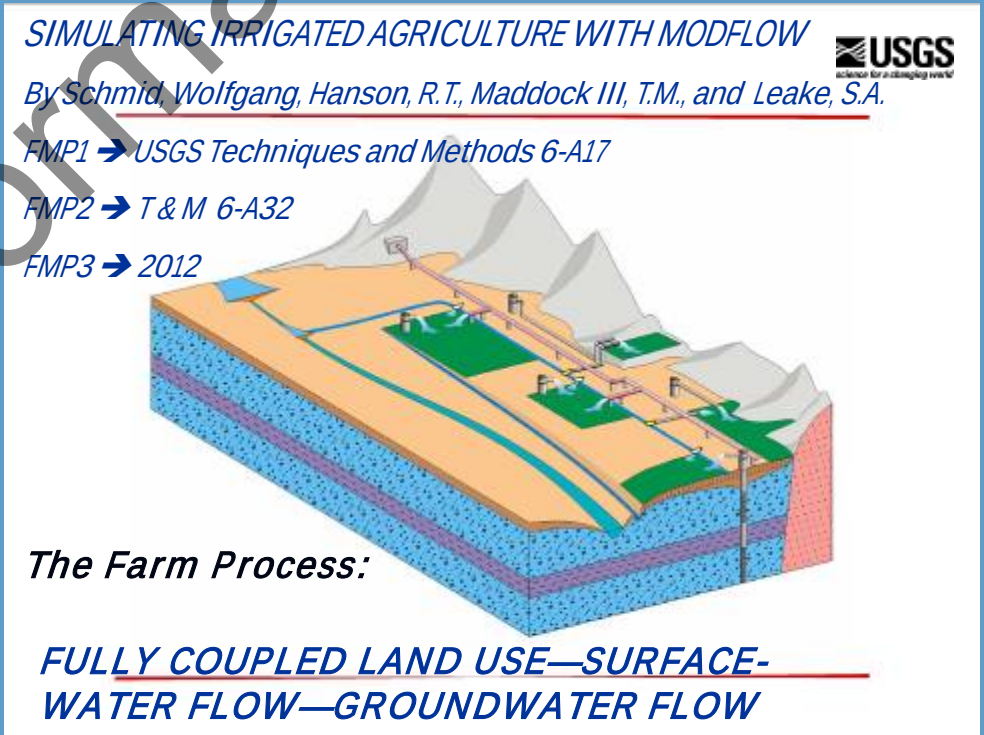
# Farm Process:

- Systematic approach for estimating water-budget components
- Based on:
  - the consumptive use of water by plants fully linked with surface and subsurface sources
  - available surface-water deliveries
  - Available groundwater pumpage

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# USGS MODLOW with the FARM PROCESS—Features and Capabilities

## Supply-and-Demand Modeling Framework Connected to Nature and Humanity

**Farm Demand for Irrigation**

**Non-Routed Deliveries as Water Transfers**

**Routed Surface-Water Delivery to Farm**

**Groundwater Pumpage by Well**

**Streamflow Conveyance and Drain Network**

**Natural and Artificial Recharge**

**Water-Use Management**

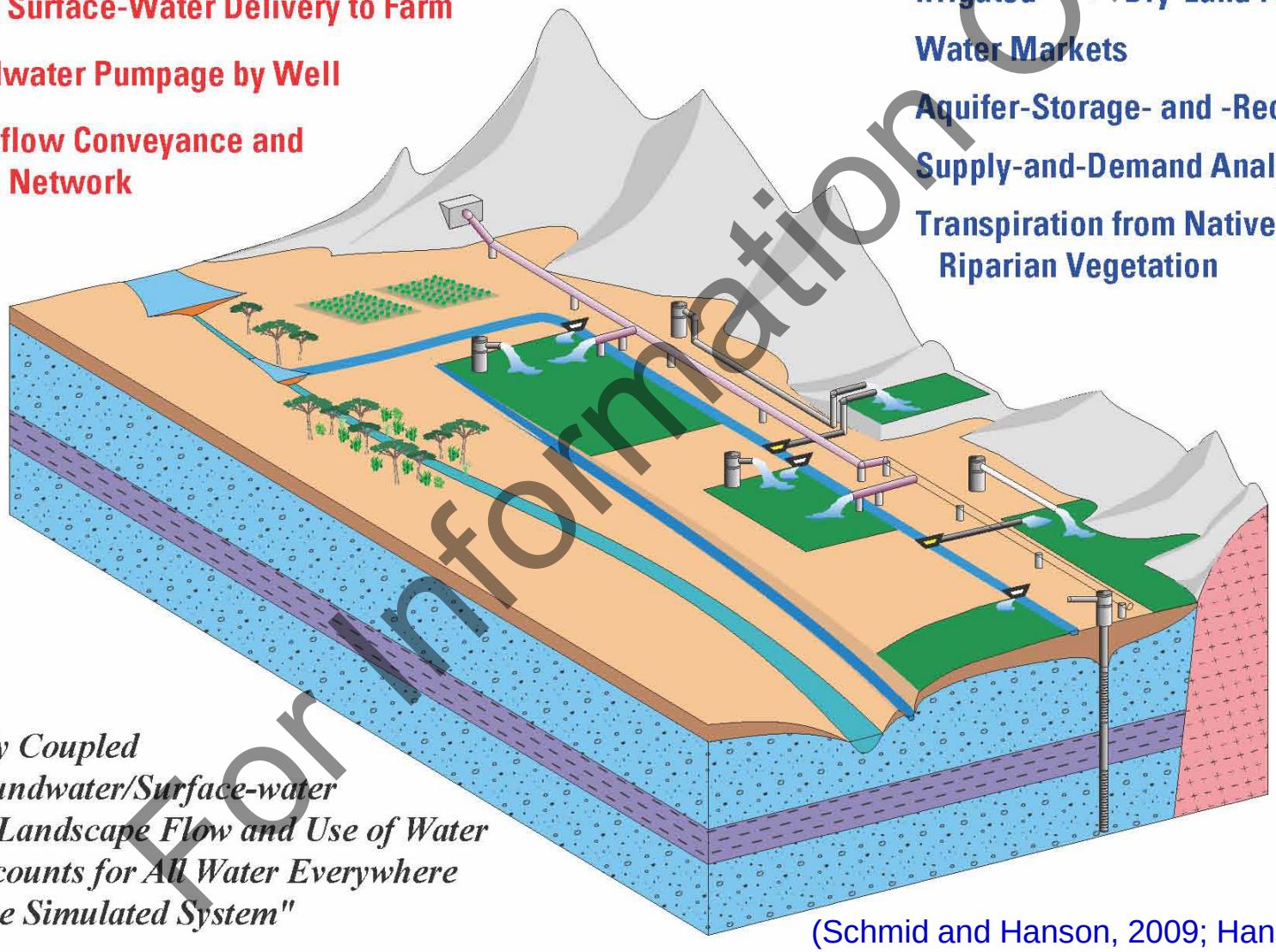
**Irrigated ⟹ Dry-Land Farming**

**Water Markets**

**Aquifer-Storage- and -Recovery Systems**

**Supply-and-Demand Analysis**

**Transpiration from Native and Riparian Vegetation**



*Fully Coupled Groundwater/Surface-water and Landscape Flow and Use of Water "Accounts for All Water Everywhere in the Simulated System"*

(Schmid and Hanson, 2009; Hanson et al., 2010)

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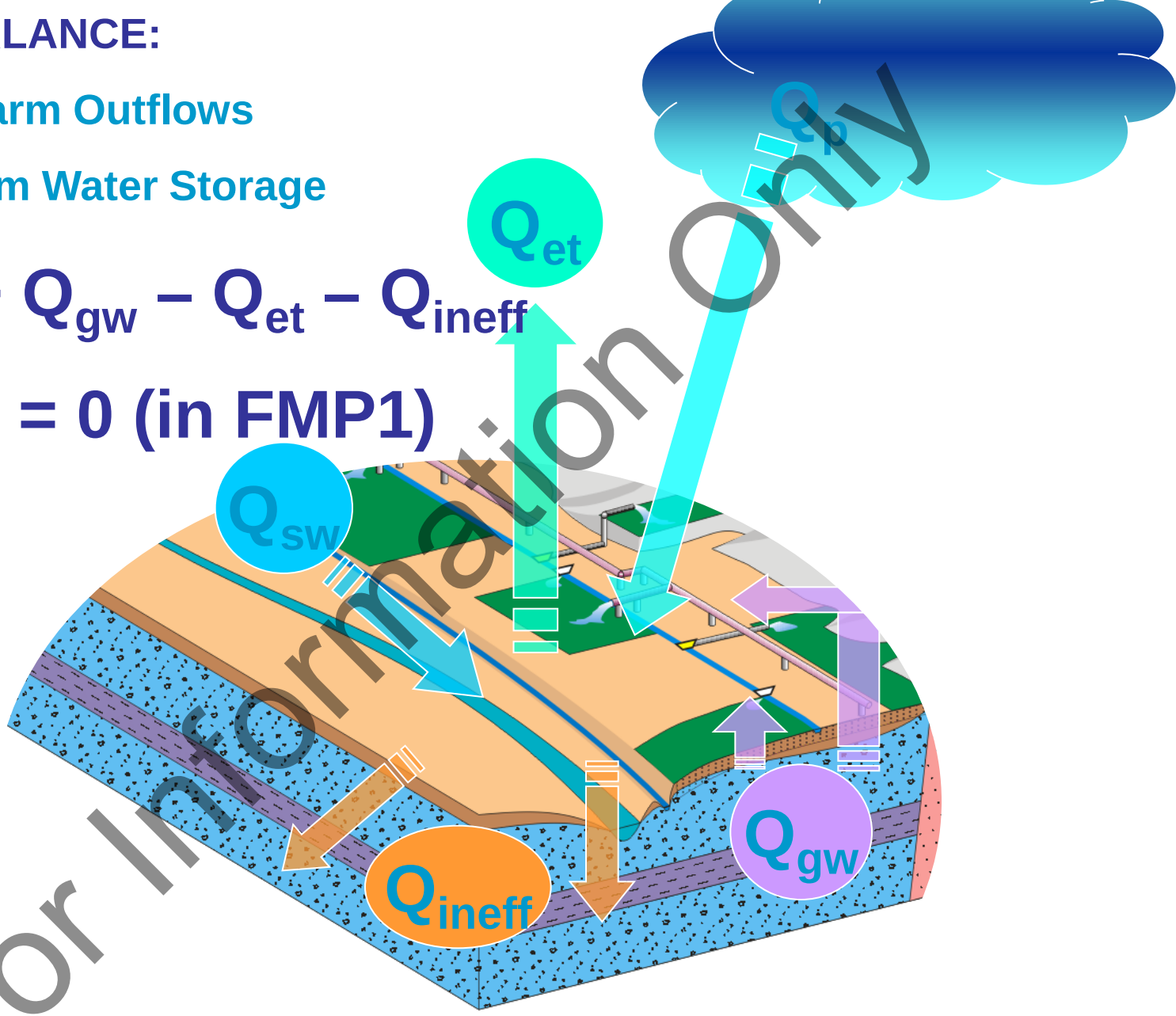
## FARM MASS BALANCE:

**Farm Inflow – Farm Outflows**

**= Change in Farm Water Storage**

$$Q_p + Q_{sw} + Q_{gw} - Q_{et} - Q_{ineff}$$

$$= dS_{farm}/dt = 0 \text{ (in FMP1)}$$

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**New MF-FMP Developments**:

(1) ASR Simulation ➔Artificial Recharge through SRD or NRD deliveries Recovery through Wellfield Option to supply one or more WBS with water from one or more ASR locations.
(2) Linkage to Land Subsidence ➔ Vertically deforming mesh affects hydraulic properties (T & S) and surface processes (Streamflow/gains-losses [SFR], Deliveries, Runoff/Returnflows, and Root Uptake [FMP], and Canal Flows/Freeboard [SWR]
(3) Embedded models ➔ More detailed simulation of localized regions [MFLGR-FMP]
(4) New Surface-water Routing Process (SWR) ➔ Full momentum equation based routing
(5) Dynamic Accounting Units ➔ Variable WBS through time to allow for changes in land use (urbanization, ASR's, more detailed deliveries, splits in ownership, etc)
(6) Groundwater Allotments ➔ Analysis of groundwater rights, sustainability analysis, BMP analysis, linkage to optimization [GWM]

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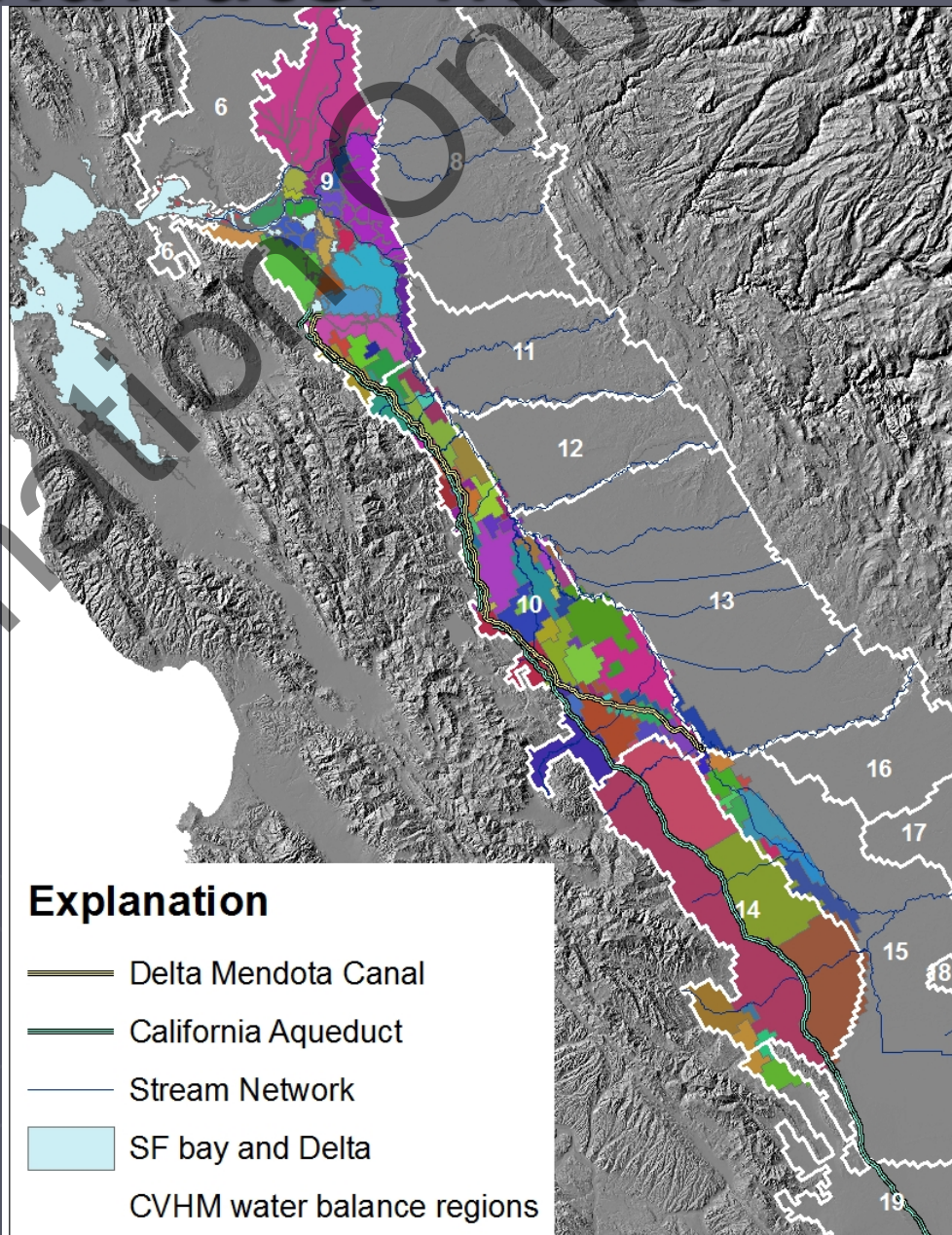
# Task 5B Groundwater model

- 2 phases of modeling
  - Update regional CVHM
  - Develop new more detailed model along DMC
  - Calibrate and build together
    - Much information identical
      - “farms”/water budgets
      - streams
      - layer numbers
    - More detailed cells
  - Possibility of expanding detail into area 15 with Thomas Harter’s group UC Davis

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# Model Code Changes :

- **MODFLOW and CVHM** updated to include:
  - (1) more accurate details in the timing of the subsidence by incorporating delay beds,
  - (2) separation of the inelastic and elastic portions of subsidence in the SUB package, and
  - (3) changes in land-surface altitudes caused by subsidence - deformable layers

| Landscape processes | Subsurface processes |
|---|---|
| Farm Process (FMP) | Layer-Property Flow Package (LPF) |
| Streamflow Routing Package (SFR) | Subsidence Package (SUB) |
| Surface-Water Routing Process (SWR) | Multi-Node Well Package (MNW) |
| | Unsaturated-Zone Flow Package (UZF) |

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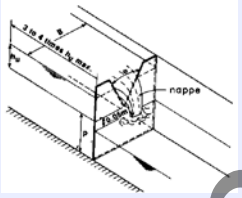
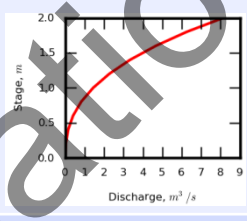
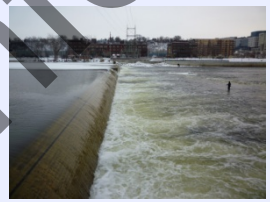
# SWR1 Structures

| Structure Type | | Operable |
|---|---|---|
| Culvert | | Fixed |
| Stage-Discharge |     | Fixed |
| Specified Discharge | | Fixed and Operable |
| Weir |  | Fixed and Operable |
| Spillway | | Fixed and Operable |

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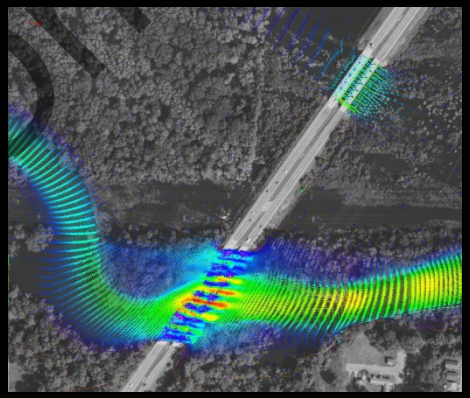
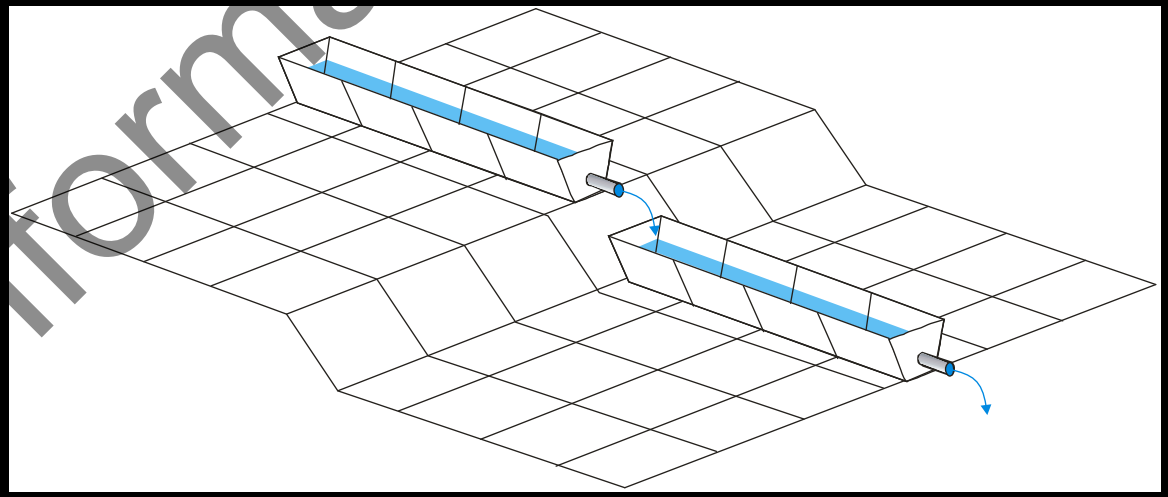
# SWR1 Routing Approximations



- Diffusive-Wave Approximation
- Level-pool
- Tilted-pool



# PUBLICATIONS (CVHM):

- **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/**

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# PUBLICATIONS (Journal Articles):

- **Texture Model:**

  Faunt, C.C., Belitz, K., and Hanson, R.T., 2009 , Texture Model of the Valley Fill Deposits of the Central Valley, California: Hydrogeology Journal, DOI 10.1007/s10040-009-0539-7, 25p.

- **Conjunctive-Use Analysis:**

  Hanson, R.T., Schmid, Wolfgang, Faunt, C.C., and Lockwood, B., 2010, Simulation and Analysis of Conjunctive Use with MODFLOW's Farm Process: Ground Water Vol. 48, No. 5, pp. 674 - 689. (DOI: 10.1111/j.1745-6584.2010.00730.x)

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# **PUBLICATIONS** (Climate Change):

- **EISOLS Subsidence:**

  Hanson, R.T., Flint, A.L., Flint, L.E., Faunt, C. C., Schmid, Wolfgang, Dettinger, M.D. Leake, S.A., and Cayan, D.R., 2010, Integrated simulation of consumptive use and land subsidence in the Central Valley, California, for the past and for a future subject to urbanization and climate change: Proceedings of the Eight International Symposium on Land Subsidence (EISOLS), Queretaro, Mexico, October, 2010, pp. 467-471

- **Future Conjunctive-Use Analysis:**

  Hanson, R.T., Flint, L.E., Flint, A.L., Dettinger, M.D., Faunt, C.C., Cayan, D., and, Schmid, Wolfgang, 2012, A method for physically based model analysis of conjunctive use in response to potential climate changes: Special Issue of Water Resources Research, Vol. 48, 25p. (DOI:10.1029/2011WR010774)

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# THE END - THANKS !

# QUESTIONS & DISCUSSION ?

## GROUND-WATER SUSTAINABILITY = CONJUNCTIVE USE ?

**Central Valley, California**

USGS Central Valley Website:
http://ca.water.usgs.gov/projects/cvhm/index.html
Integrated Hydrologic Model (MODFLOW-FMP):
http://water.usgs.gov/nrp/gwsoftware/fmp/fmp.html

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## IDEAS/TOPICS?:

How agencies can share data more easily (Nigel)
Self-updating models and decision support (Randy Hanson)
Diversions – planning vs. operation and timing
Data streams and different agencies responsible for different data streams
Linkages to water-allocation models and reservoir operations CALSIM/CALVIN
?

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