Community Advisory Group

Berkeley Lab Research in Groundwater Management

Peter S. Nico

Earth & Environmental Sciences Area
Berkeley National Laboratory

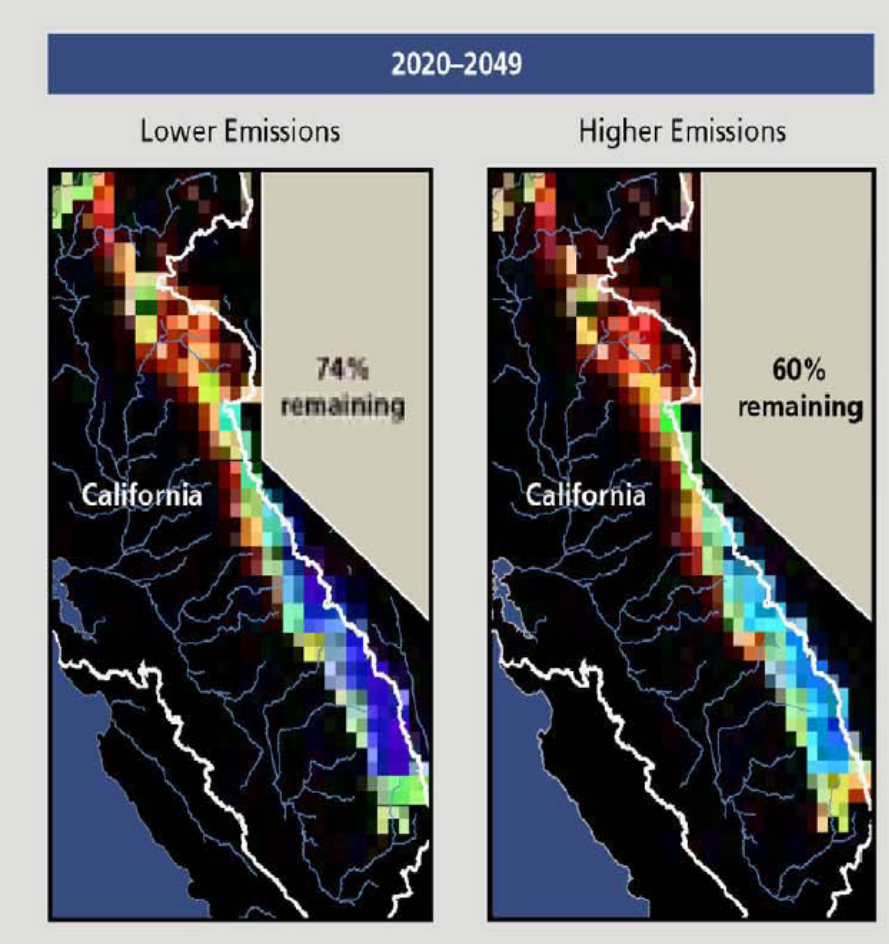
EARTH & ENVIRONMENTAL SCIENCES

BERKELEY LAB

CA Challenges are urgent and complex

- CA climate-driven changes will constrain water and energy production
- CA ‘s economy- the 7th largest in the world- depends on intensive energy/water urban and agriculture systems
- CAs energy and water demands are increasing
- CA GHG targets pose additional severe challenges for optimized water-energy management

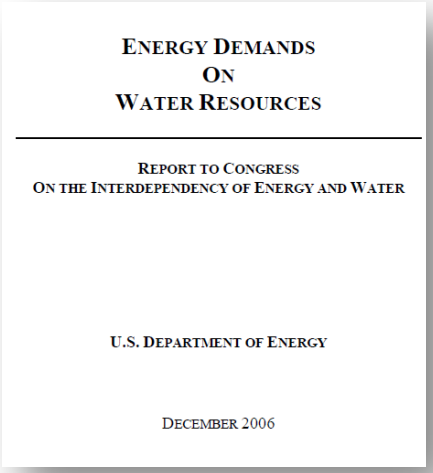
Science based approaches to guide optimized California investments in water-energy infrastructure



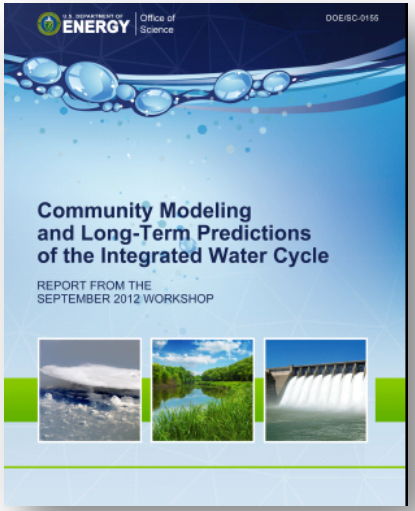
Hayhoe et al., 2004

Importance to DOE Mission

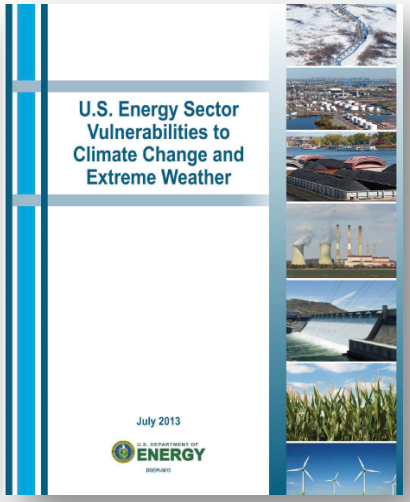
Many recent DOE reports have documented water-energy-climate challenges and relevance to DOE mission



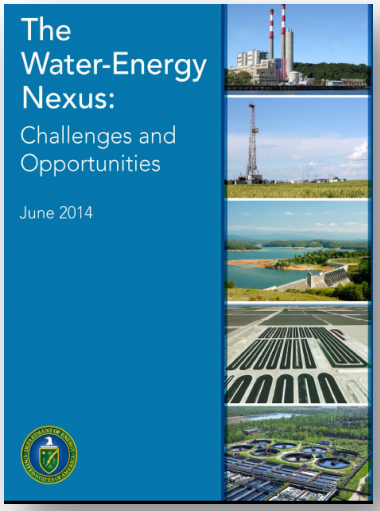
Energy demands on water resources, DOE 2006



Long term prediction of the integrated water cycle, DOE 2012



Energy vulnerabilities to climate change and extreme weather, DOE 2013

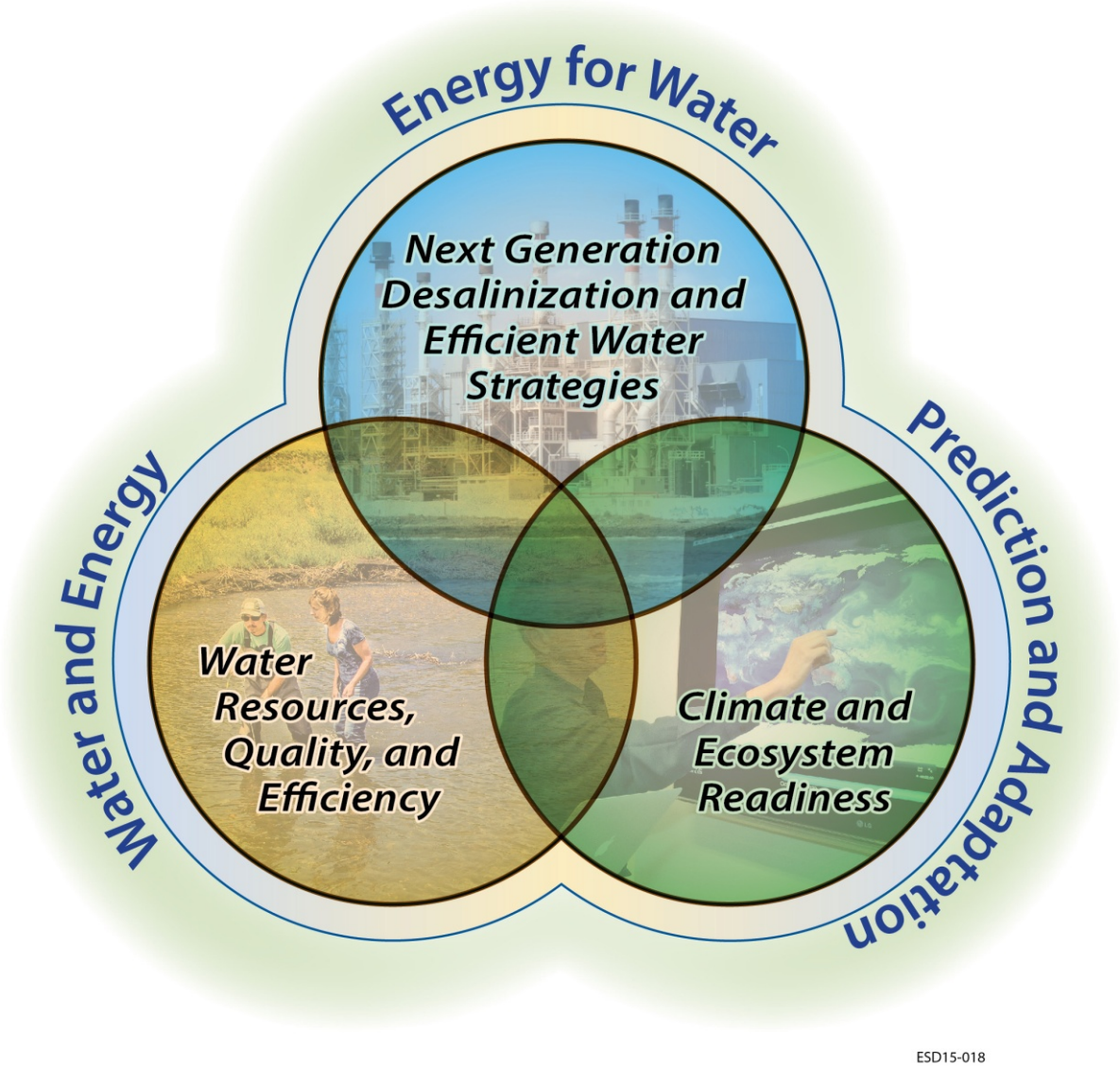


The water-energy Nexus, DOE 2014

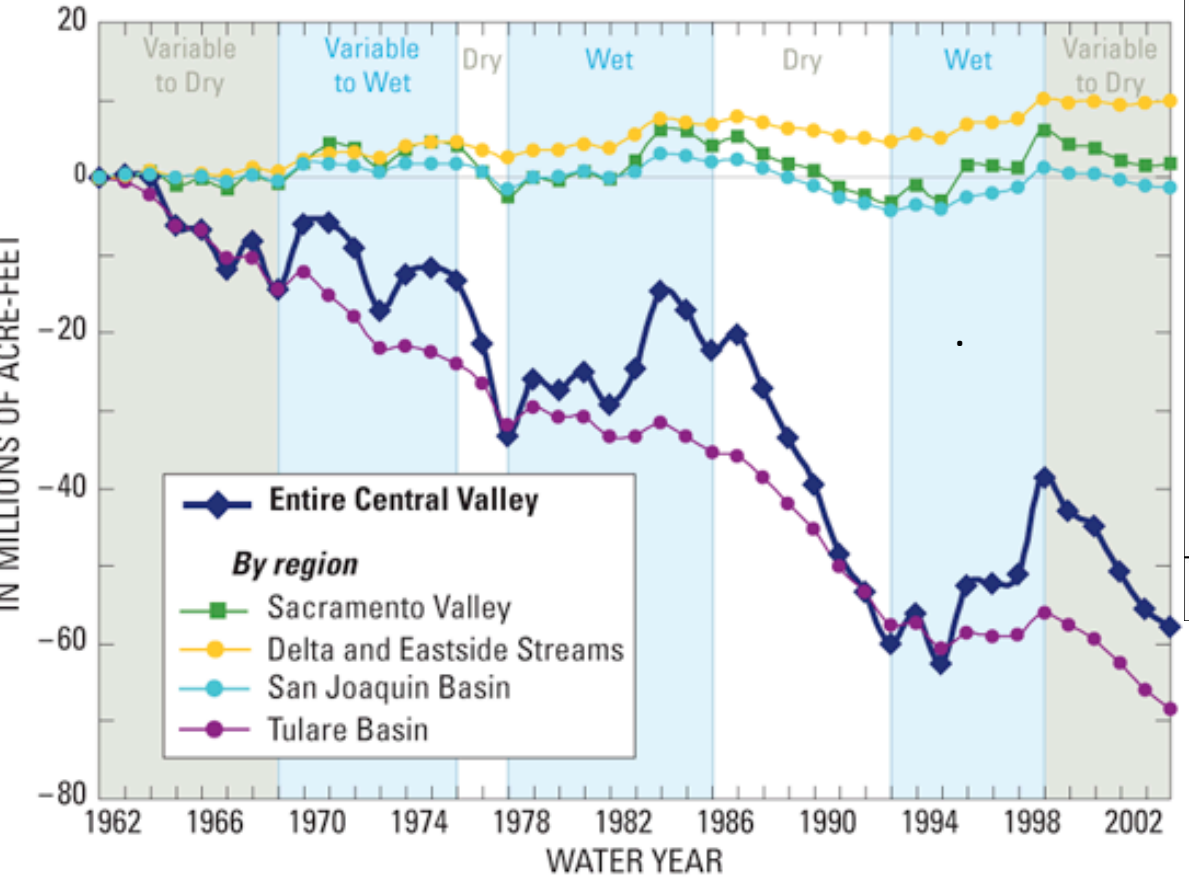
CA Climate-Water Systems @ Scale

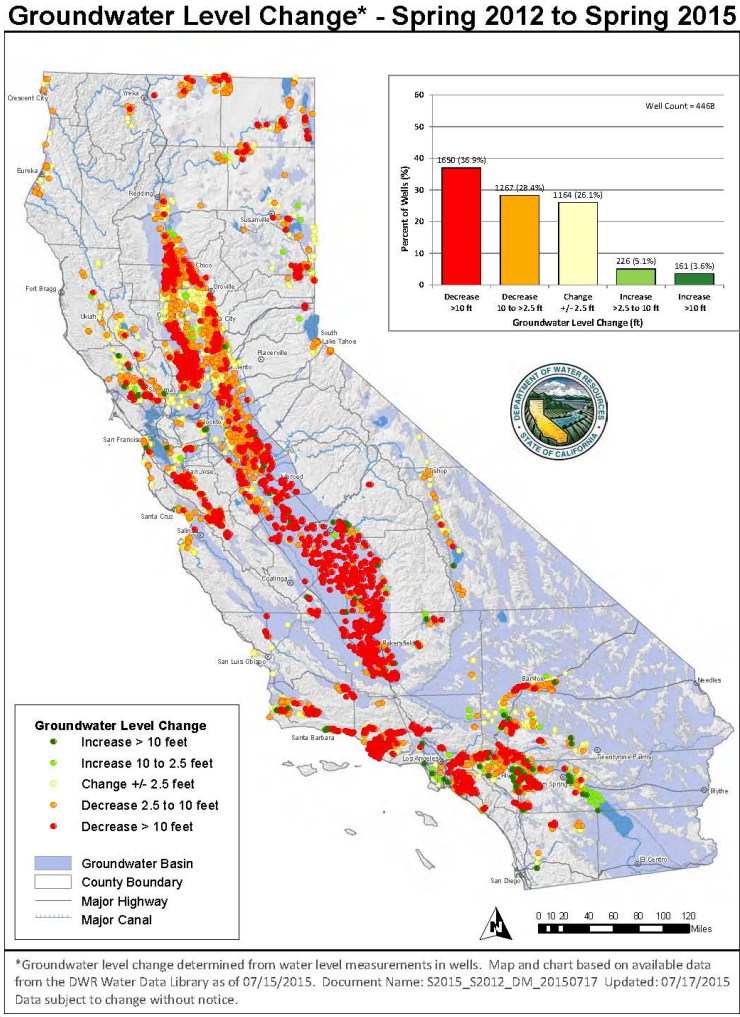
Knowledge and approaches to guide optimized California investments in water-energy systems and infrastructure

One Berkeley Lab Initiative with interconnected critical themes, **leads** and working groups



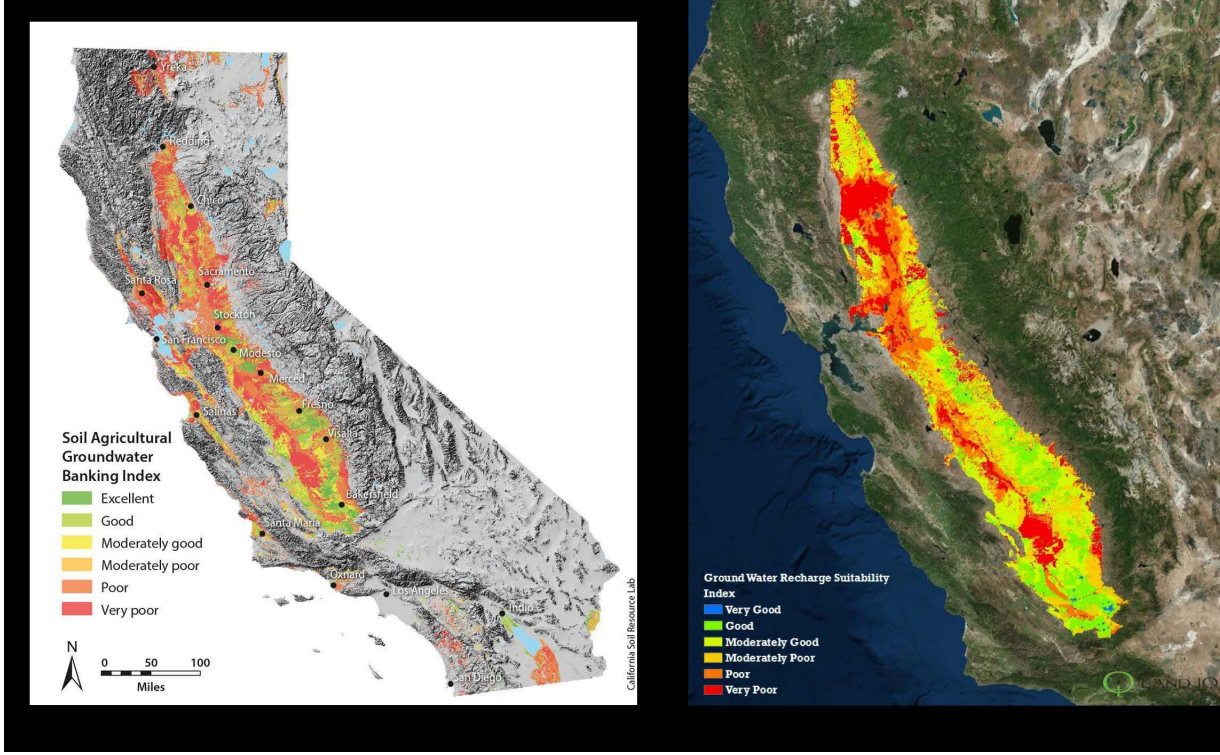
Groundwater Overdraft





Faunt, C.C. ed., 2009, Groundwater Availability of the Central Valley Aquifer: U.S. Geological Survey Professional Paper 1766, 225 p

Groundwater Banking: Use Existing Infrastructure and Agriculture Lands to Restore Groundwater?



O'Geen, U.C. Davis, Soil Resources Lab

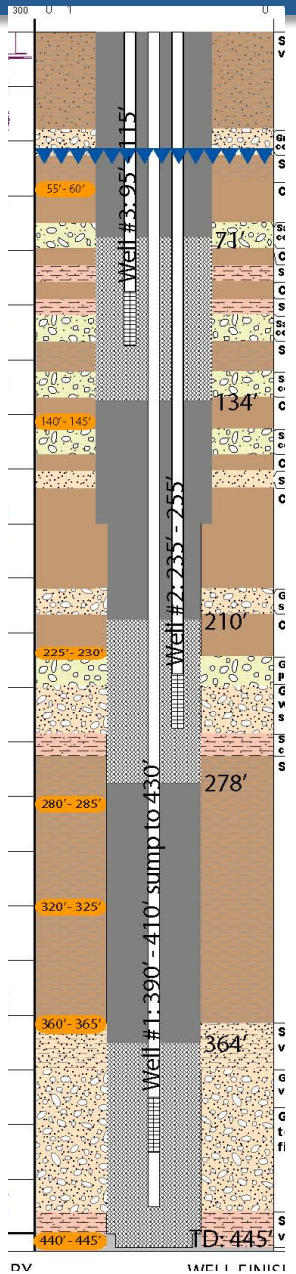
Groundwater = Wet Sand

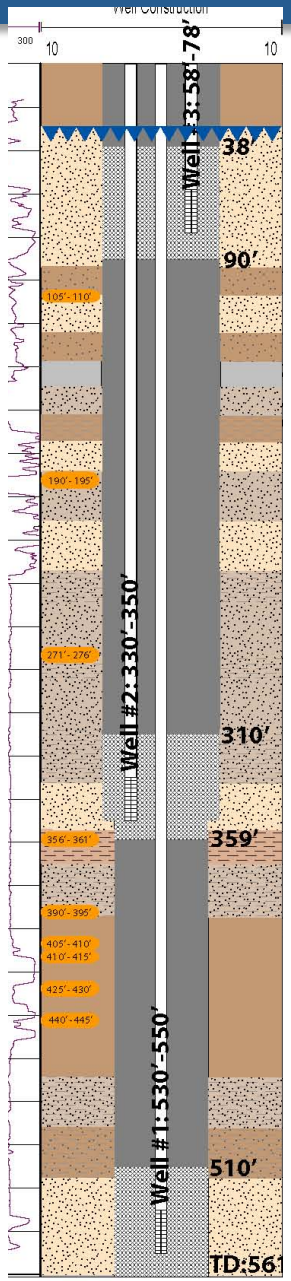
P259-3C (227.8-228.3 ft bgs):
muddy gravel w/some sand

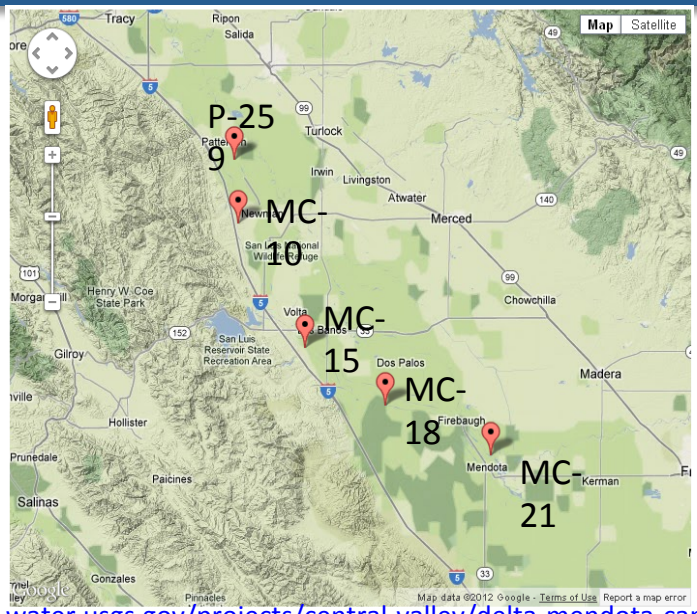
P259-5C (320.7-321.2 ft bgs):
pure clay

Different permeability, different chemistry,

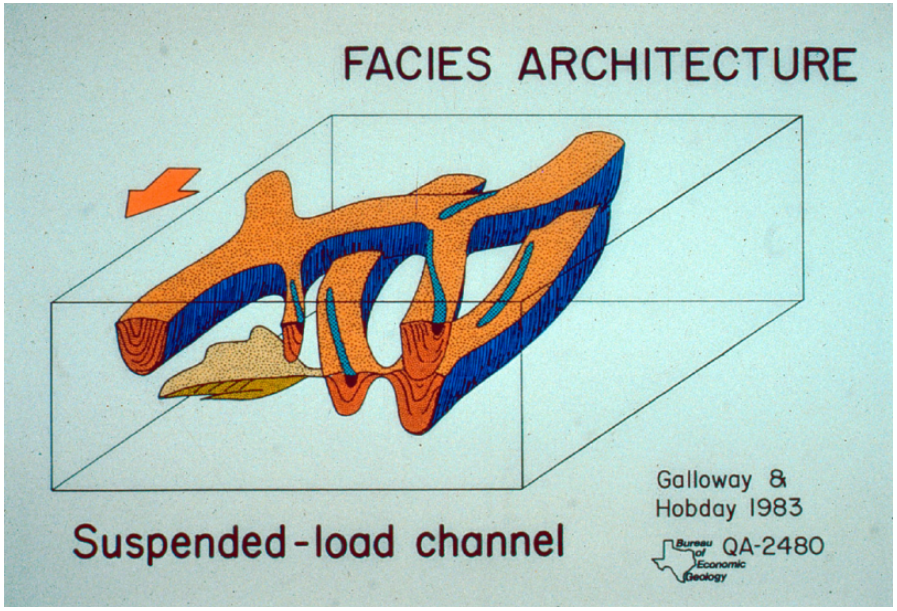
Subsurface Heterogeneity







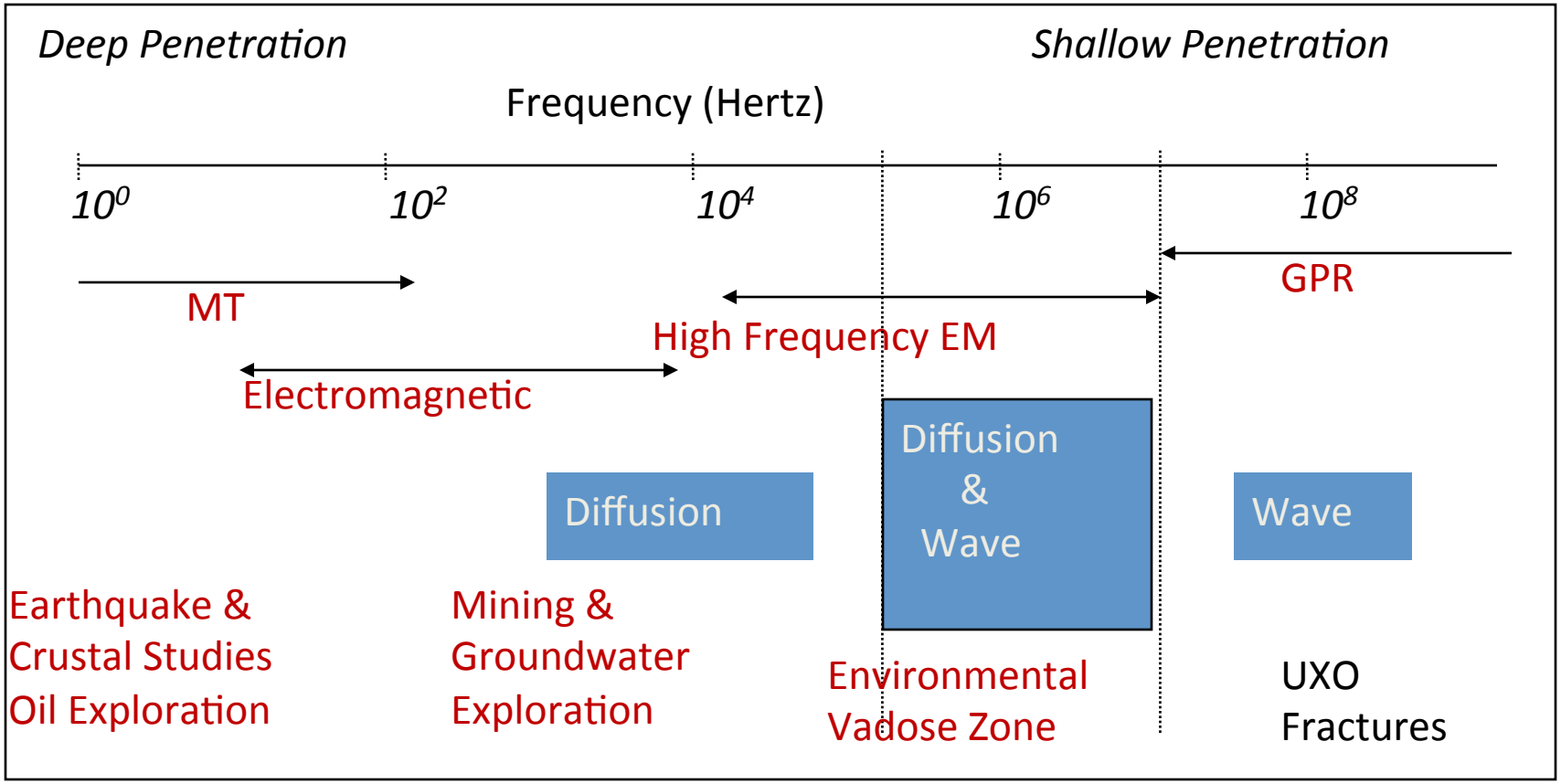
http://ca.water.usgs.gov/projects/central-valley/delta-mendota-canal-well-sites.html



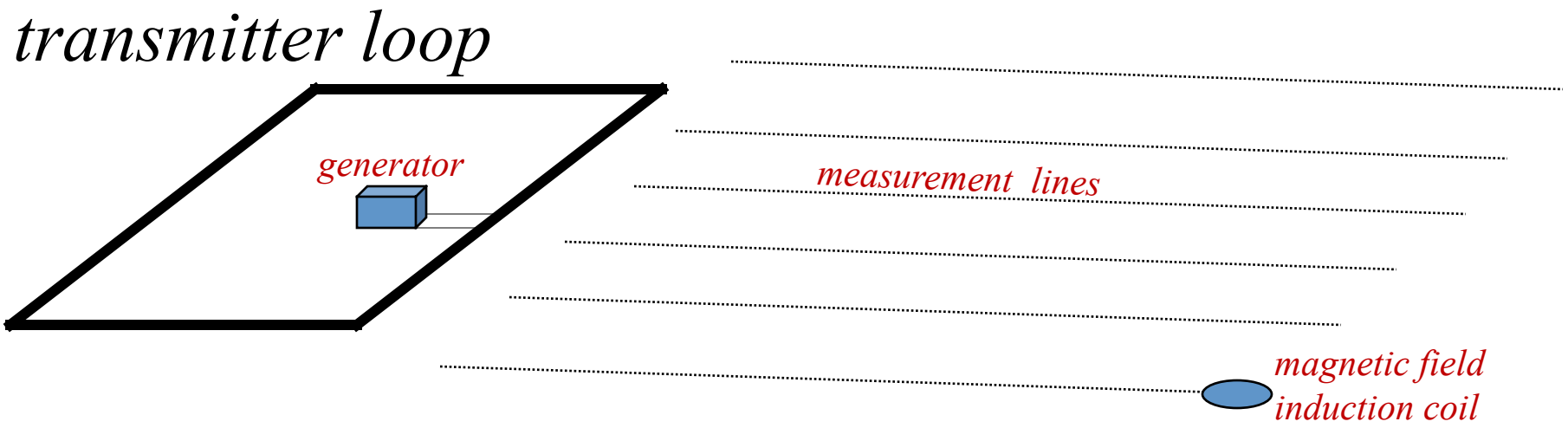
Berkeley Lab Experience/Capabilities

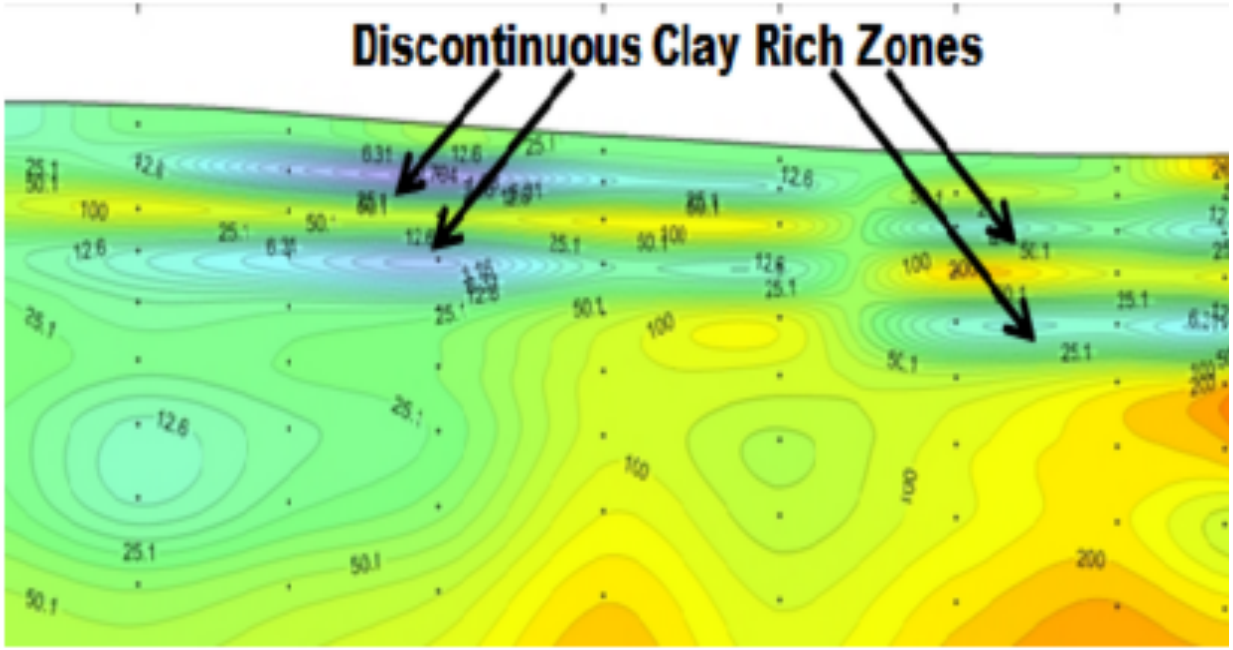
- Geophysics: **Subsurface characterization**
- Isotopes: **Water tracking**
- Physical-Geochemical Modeling**: Predictions and scenarios**

Electro-Mag. Geophysical Spectrum



Transient Electromagnetic Methods





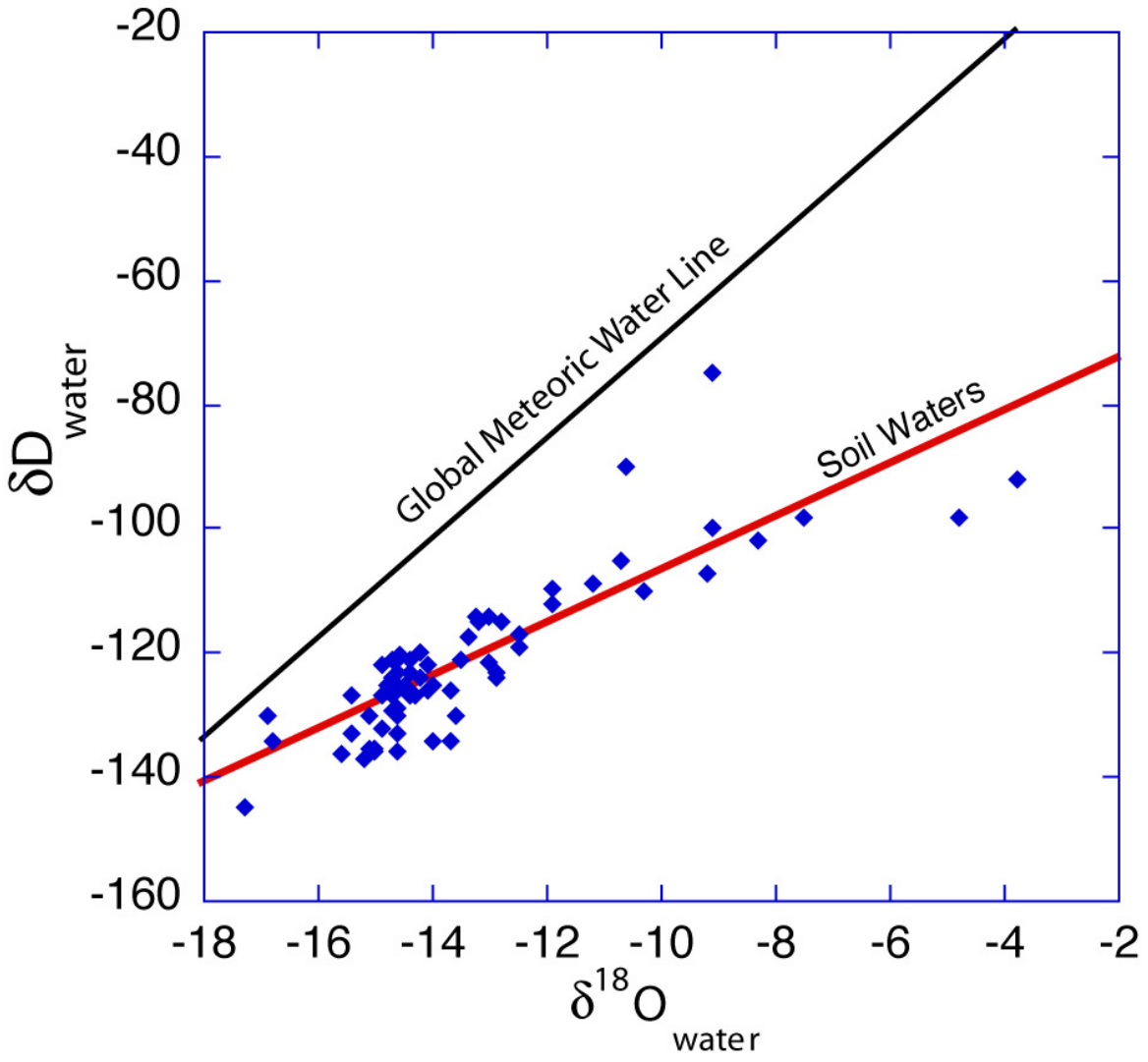
electrical conductivity map

Natural Occurring Isotopes can Track Water Movement

Hydrogen (δD) and Oxygen ($\delta^{18}O$) Isotopes of Pore Water

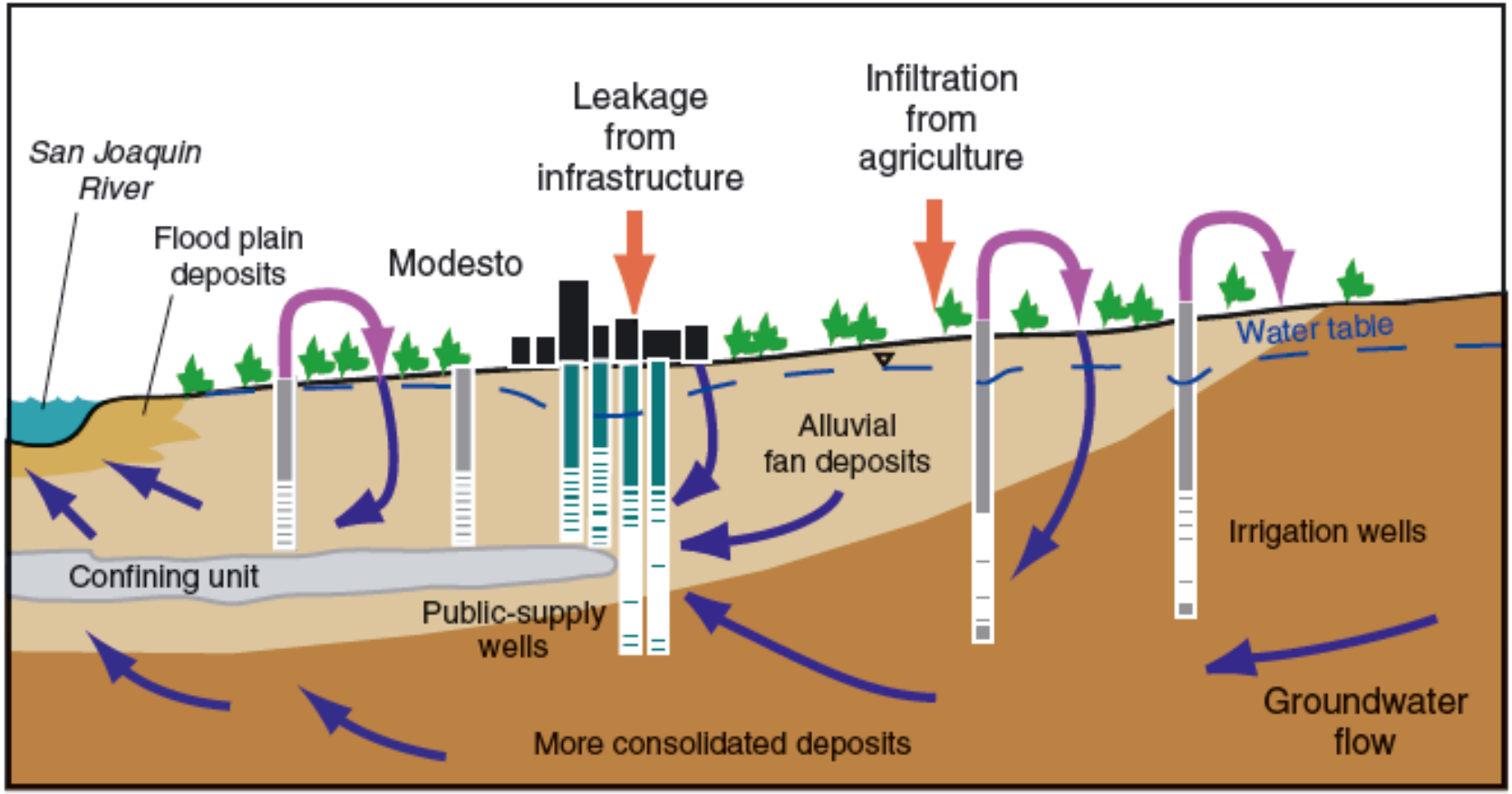
- Stable (non-radioactive) isotopes
- Direct label for infiltrating fluids
- Evaporation produces a distinctive shift in isotope ratios

Isotope Compositions of Unsaturated Zone Pore Waters



Simulations and Predictions of Water Movement and Chemistry (TOUGHREACT)

- Reaction with soil/sediments both above and below the water table
- Discharge and elemental transport
- Developed by DOE, applicable to California water issues



R.M. Yager and C.E. Heywood Groundwater 52, Focus Issue: 40–52

The Unknowns and How We Can Address Them

UNKNOWNS

- **How much** precipitation **& when**?
- **How** to infiltrate precipitation as groundwater?
- **Where** will the groundwater go?
- **Can** banked water **be recovered**?
- **What** will be the water **quality**?

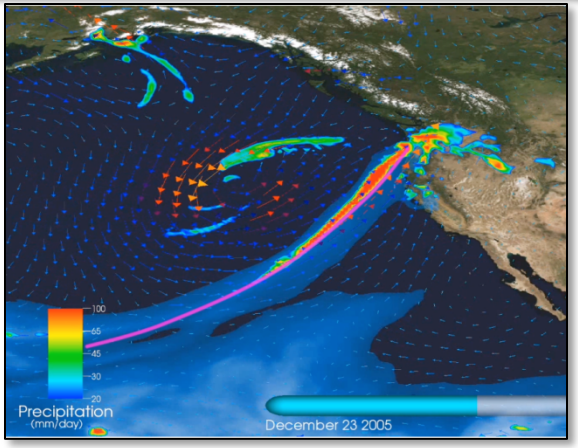
SCIENTIFIC ACTIVITIES

- Regional climate modeling
- Geophysical Characterization of Sub-surface
- Soil and vadose zone hydrology & biogeochemistry
- GW hydrologic modeling & study
- GW biogeochemistry modeling & study

- Extra Slides

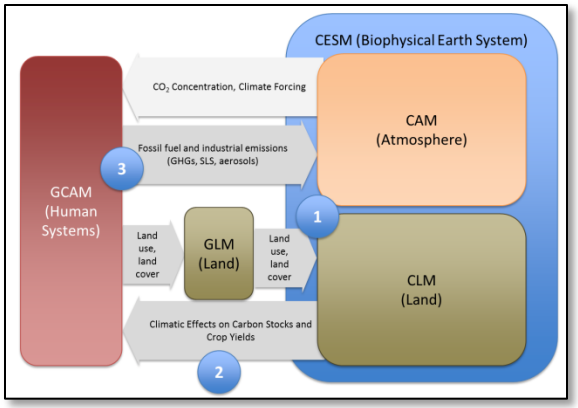
Actionable Hydroclimate Predictions for California

Goal: Provide hydroclimate predictions at scales to guide actionable CA energy-water strategies



Capabilities:

1. **Ultra-high-resolution models** to resolve California's changing precipitation and river flow.
2. **Integrated Earth-system models** for future environmental health and energy, food, and water resources.
3. The **Climate Readiness Institute** to connect to key state and local agencies and resource managers.



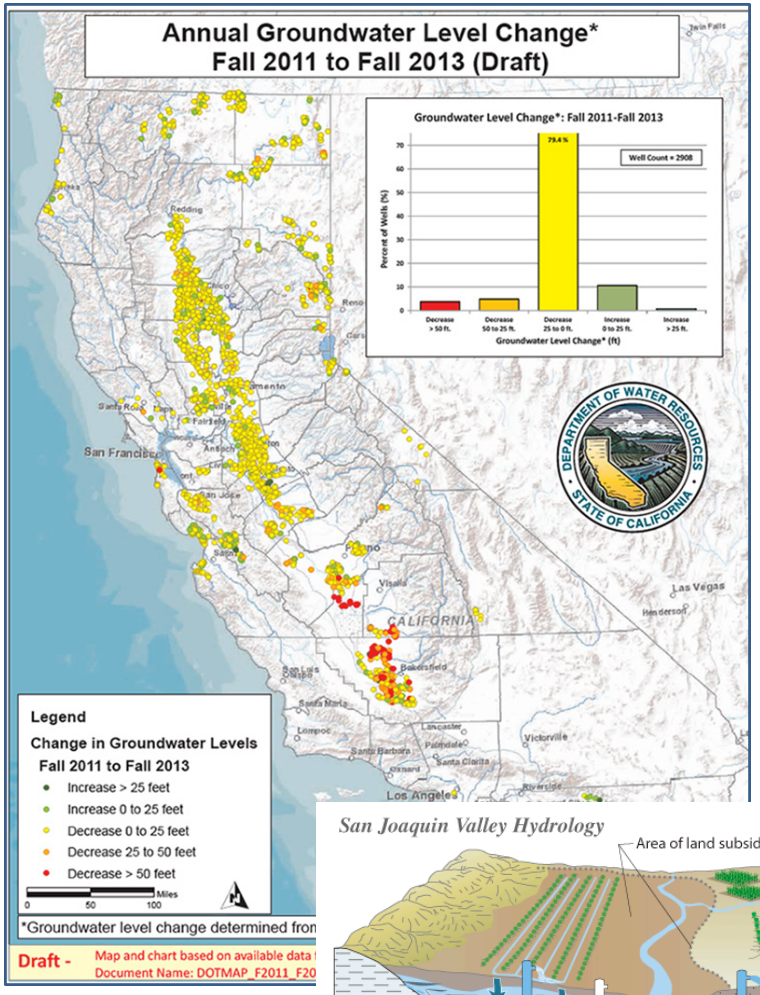
cri
CLIMATE READINESS INSTITUTE

BERKELEY LAB
Lawrence Berkeley National Laboratory

Groundwater Banking & Management at Scale

CHALLENGE

- Loss of snowpack, largest water reservoir
- Surface reservoirs high environmental impact
- Overdraft of groundwater

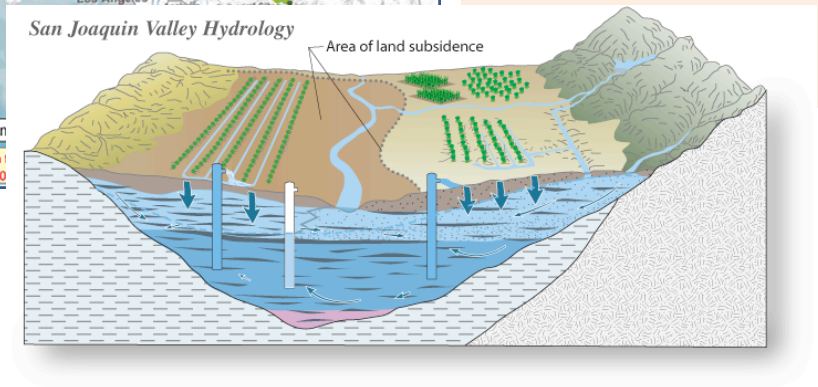


OPPORTUNITY

Groundwater banking as alternative to surface reservoirs

IF WE ADDRESS

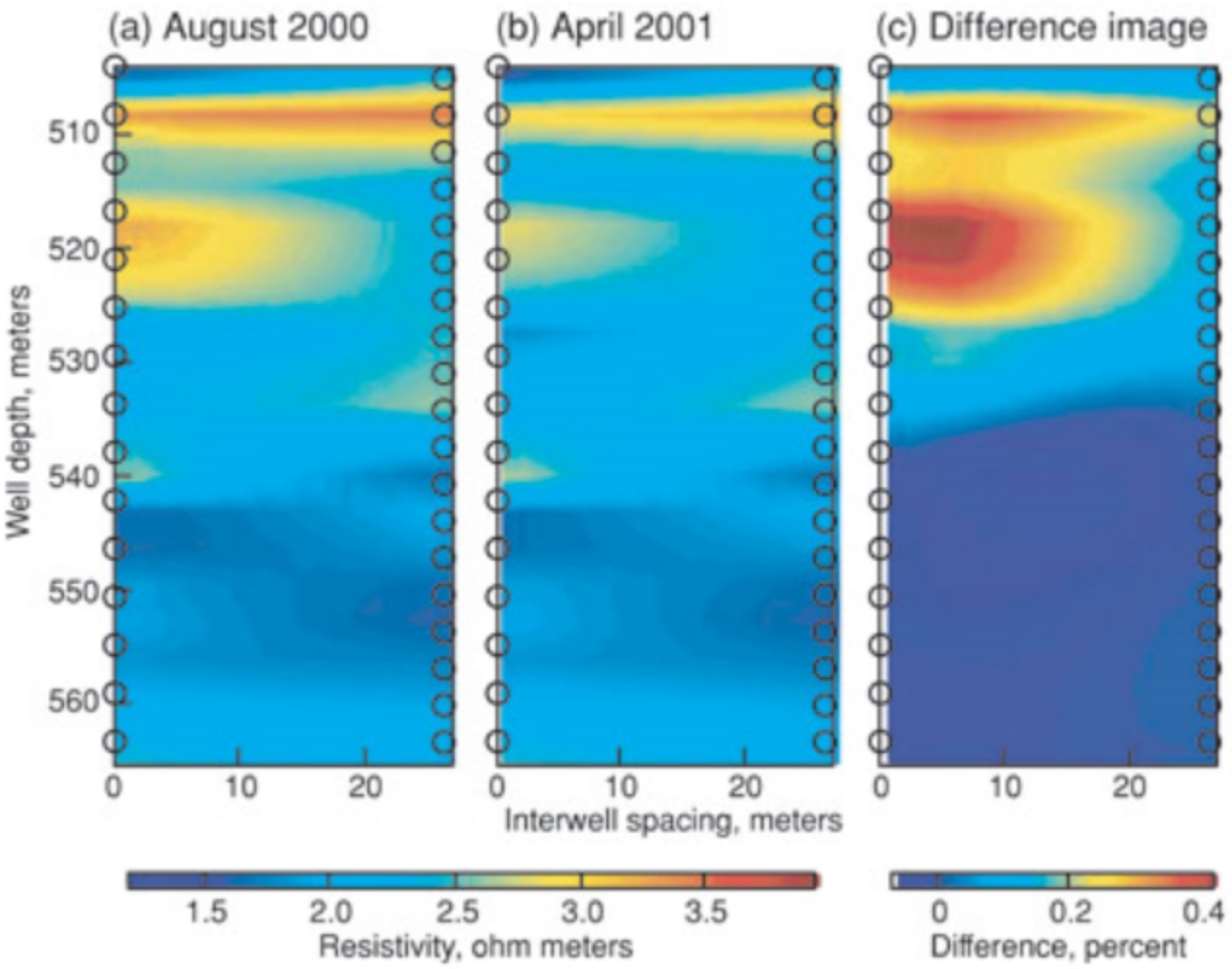
- Missing science
- Missing scale



Outline

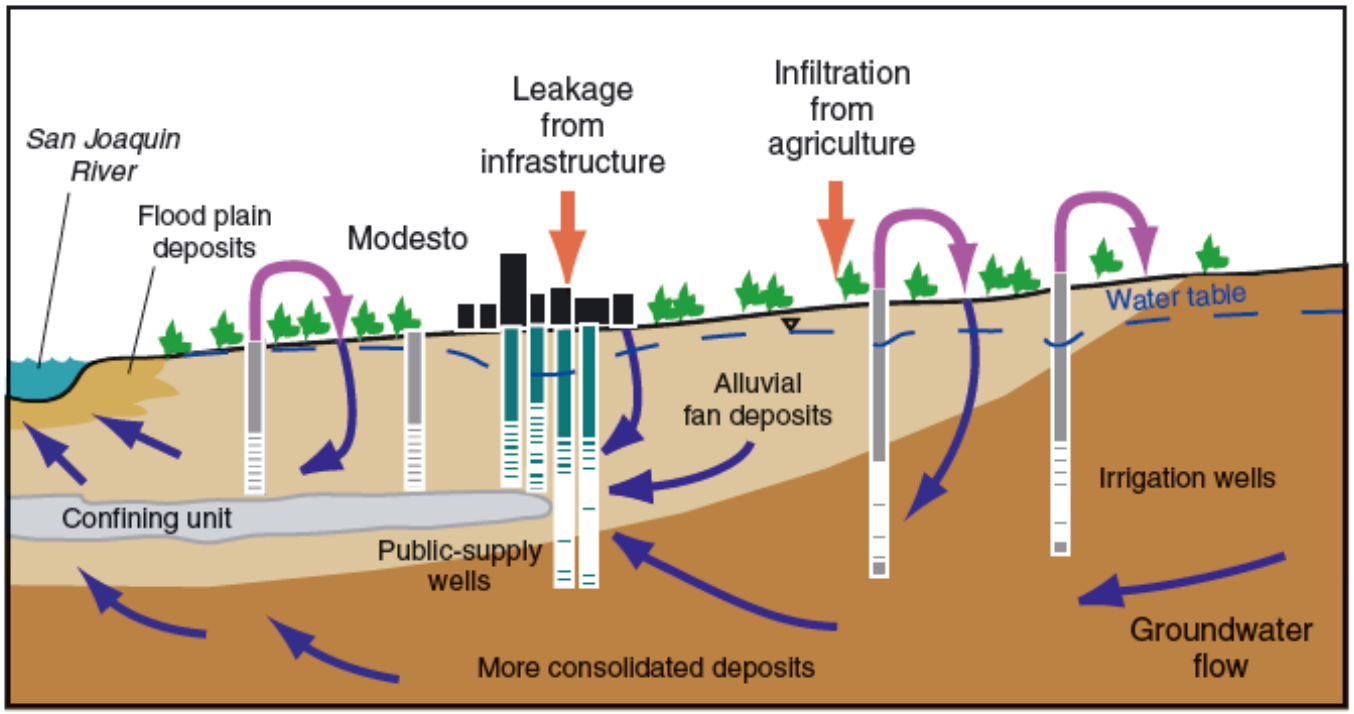
- **Introduction to Berkeley Lab**
  - Water-Energy Nexus, CA Water-Energy Systems
- **Groundwater banking and management**
- **Berkeley Lab Experience/Capabilities**
  - Geophysics: **Subsurface characterization**
  - Isotopes: **Water tracking**
  - Physical-Geochemical Modeling**:** **Predictions and scenarios**

Crosswell Electromagnetics Time-Lapse



Predicting and Preserving Groundwater Quality

CHALLENGE: Land-use activities (agriculture, urban, energy extraction, CO_2 storage) and water management impact future water quality but the connection is complicated and research is needed to understand it



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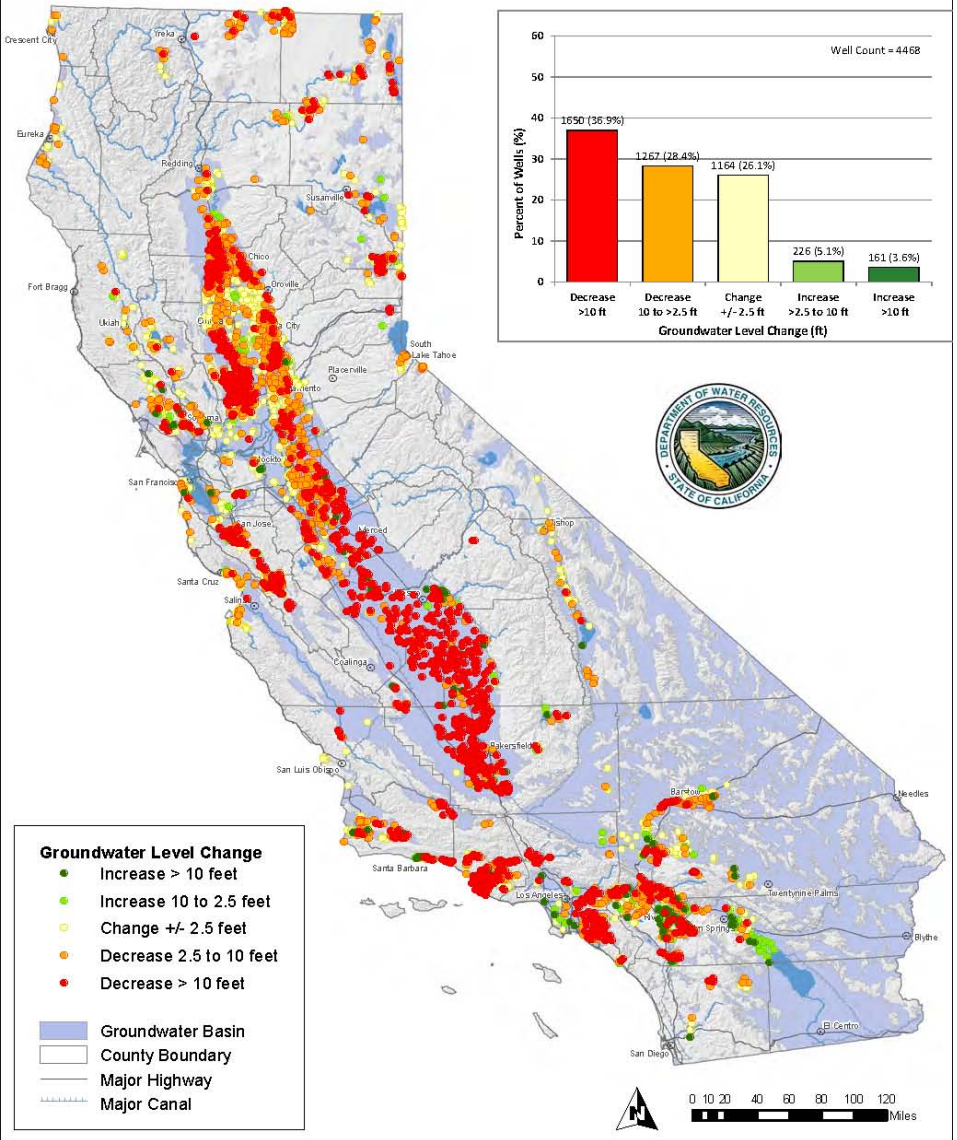
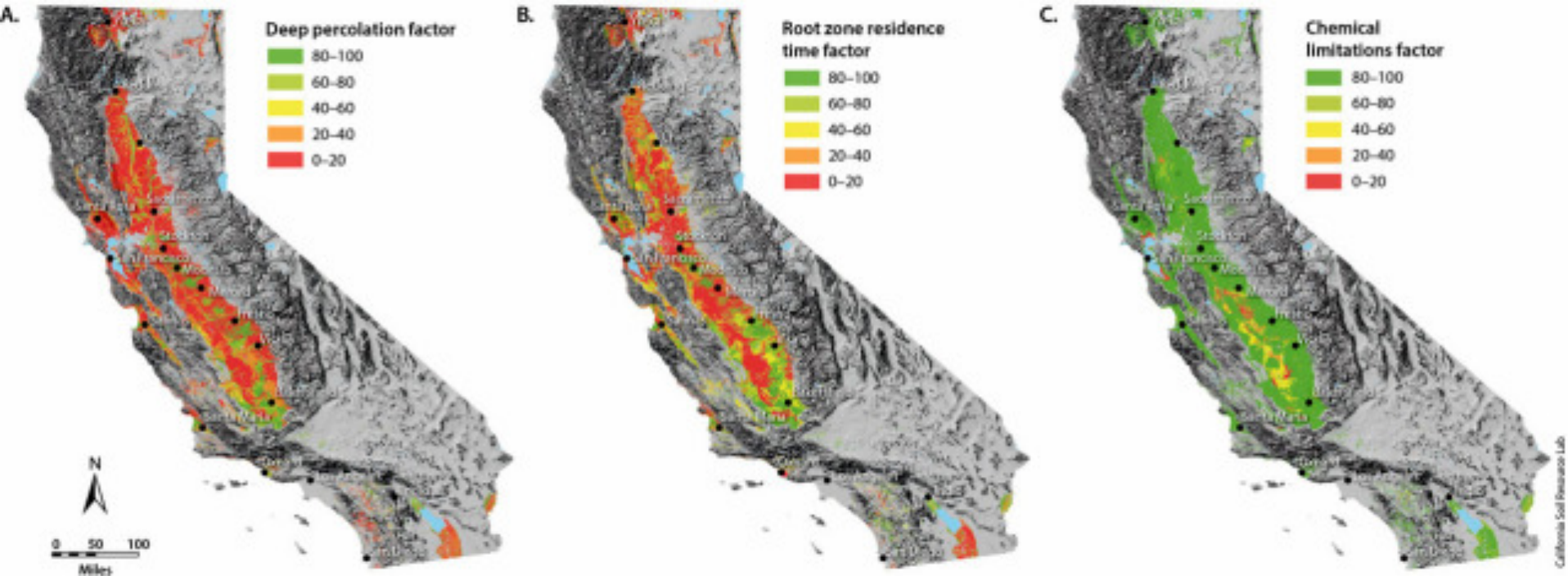
OPPORTUNITY:

To **understand and predict** the coupled chemical, physical, hydrological impacts of land use and water management decisions

Groundwater Level Change* - Spring 2012 to Spring 2015



*Groundwater level change determined from water level measurements in wells. Map and chart based on available data from the DWR Water Data Library as of 07/15/2015. Document Name: S2015_S2012_DM_20150717 Updated: 07/17/2015
Data subject to change without notice.

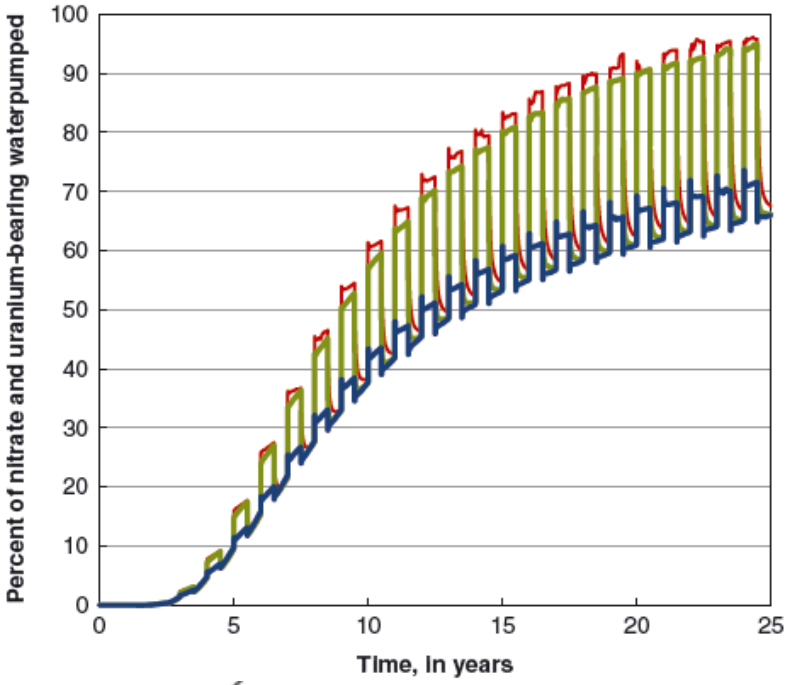

A.
Deep percolation factor
80–100
60–80
40–60
20–40
0–20
N
0 50 100
Miles
B.
Root zone residence time factor
80–100
60–80
40–60
20–40
0–20
C.
Chemical limitations factor
80–100
60–80
40–60
20–40
0–20

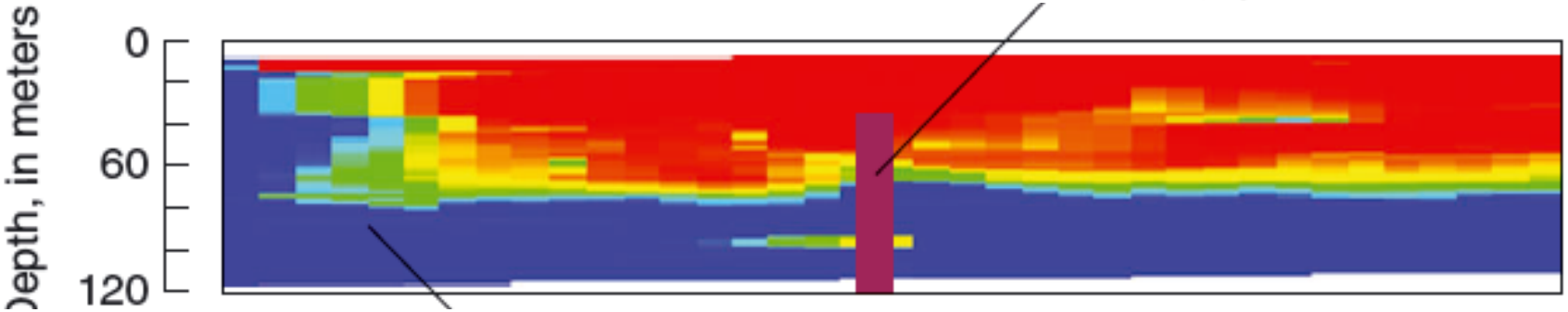
Example: Controlling withdrawals from a partially contaminated aquifer

SITUATION

Upper aquifer impacted by agricultural actives and contaminated with U and nitrate

Over time and dependent on pumping rates more or less contaminated groundwater is pumped





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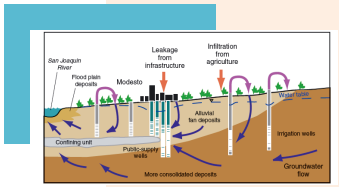
Efficient and Sustainable Groundwater Systems

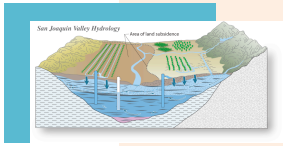
MAJOR IMPACT AREAS

GROUNDWATER QUALITY



Building the predictive link between land use (agriculture, urban, energy extraction, CO_2 storage) and ground water quality outcomes

GROUNDWATER BANKING & MANAGEMENT



Evaluating and **enabling** subsurface water storage **at scale**

RESEARCH INFRASTUCTURE

INTEGRATED SENSOR NETWORKS

Integrated sensor networks linked to advanced data interpretation for optimized water resource management

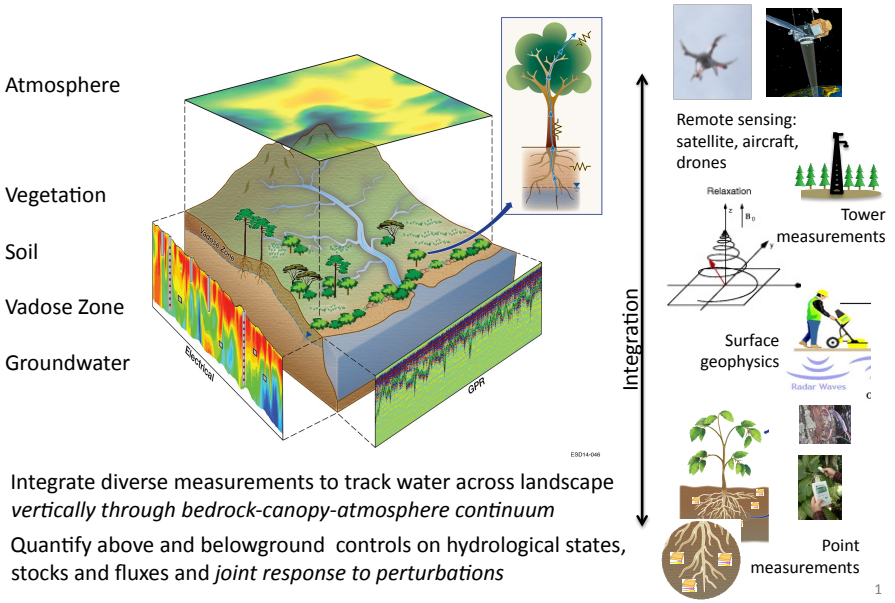
INTEGRATED WATER-ENERGY FIELD OBSERVATORY

A field observatory to develop impact areas and integrate new desalinization technologies, energy efficiency technologies, and climate predictions

Integrated Sensor, Data and Model Networks

CHALLENGES

- Novel autonomous, economical, robust sensors and measurement technologies
- Collection, curation, integration and visualization of large diverse data sets
- Tight coupling to predictive, models for decision support and system optimization



- Integrate diverse measurements to track water across landscape *vertically through bedrock-canopy-atmosphere continuum*
- Quantify above and belowground controls on hydrological states, stocks and fluxes and *joint response to perturbations*