Recharge and Reservoir Management: Keys to Water Security

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American Geosciences Institute Webinar

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Key Points

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- Climate change is already making surface storage (reservoirs) less reliable, resulting in even greater importance for subsurface storage in California.
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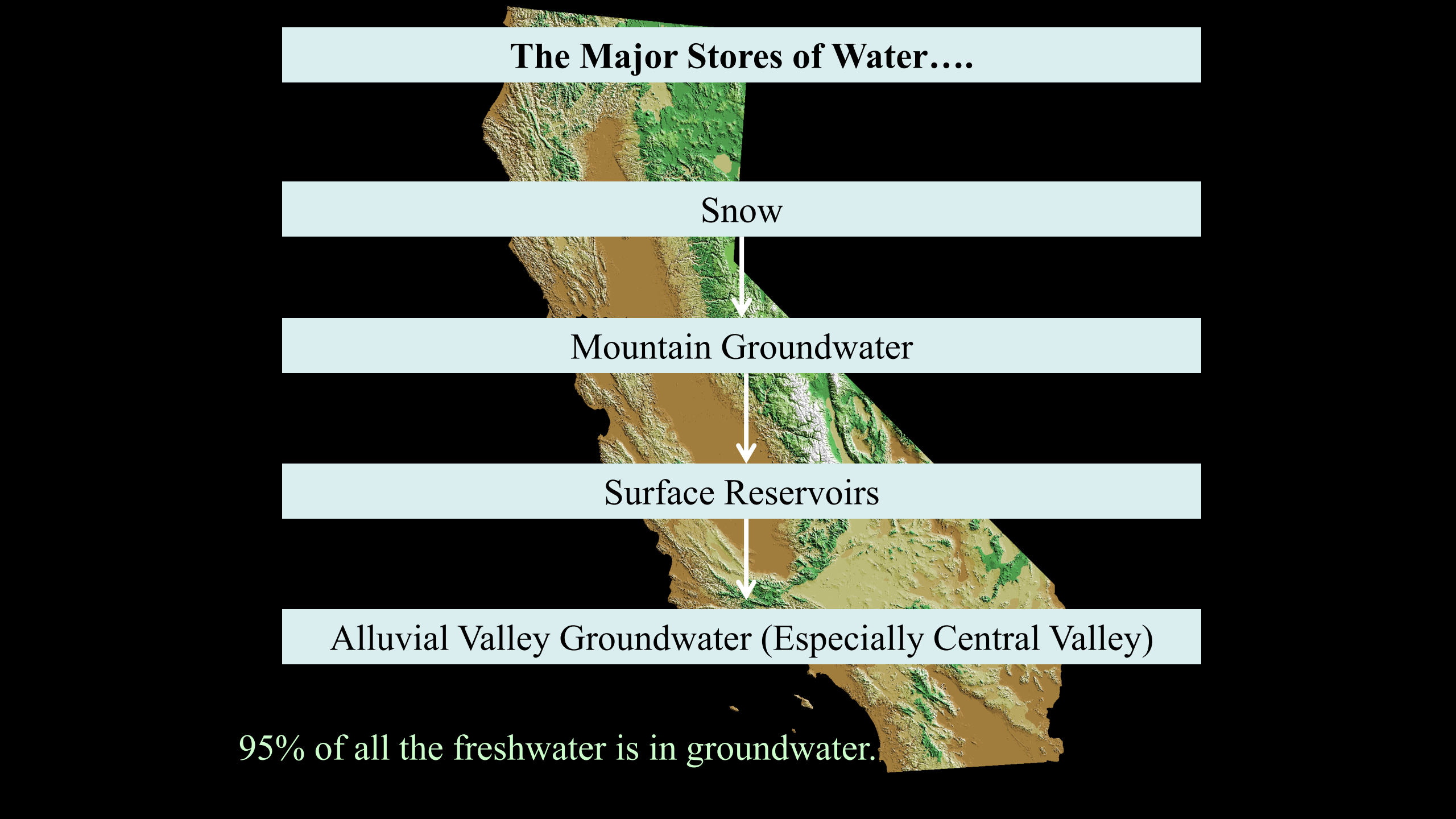
The Major Stores of Water….
Snow
Mountain Groundwater
Surface Reservoirs
Alluvial Valley Groundwater (Especially Central Valley)
95% of all the freshwater is in groundwater.

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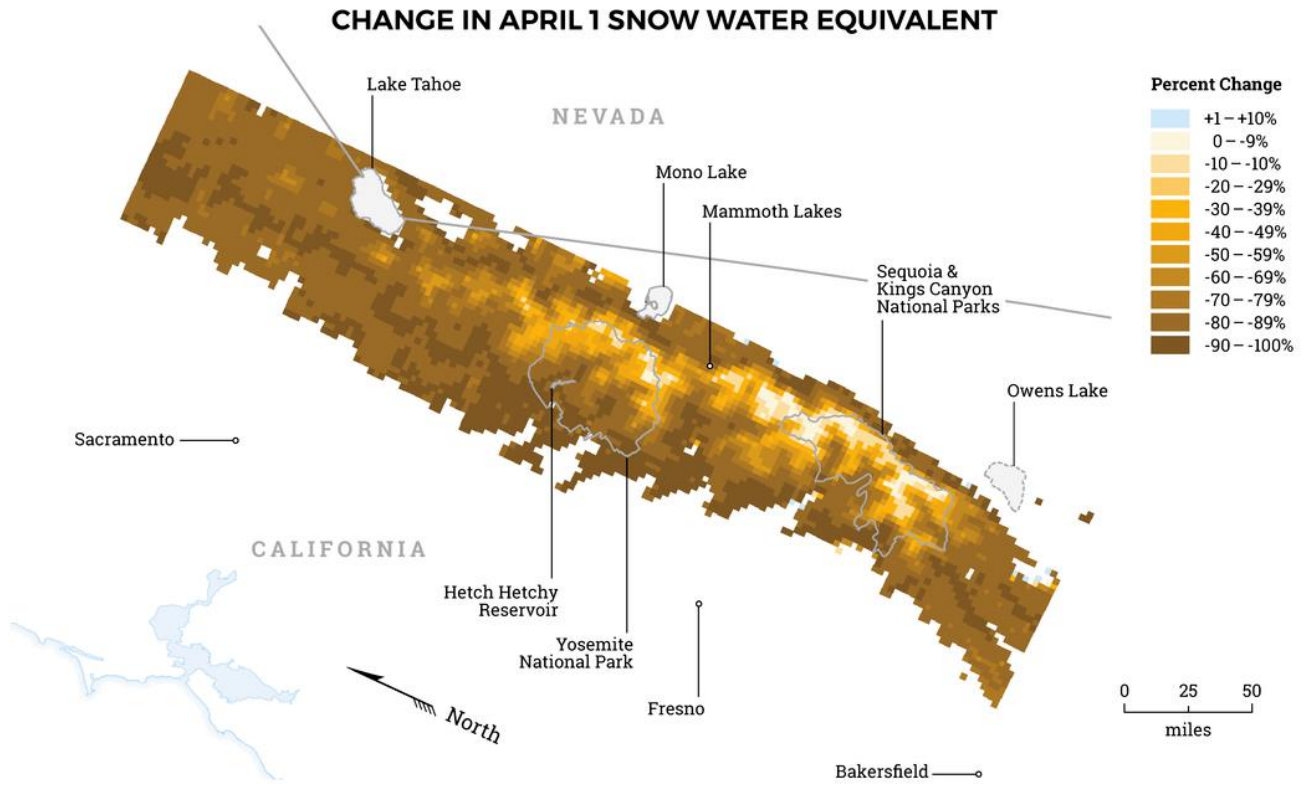
Climate Warming Is Reducing the Role of Snowpack in Water Storage

Business-as-Usual Snowpack, 2081–2100

This map depicts the percentage of average April 1 snow water equivalent projected to be lost over the Sierra Nevada by 2081–2100 under the Business as Usual scenario, compared with the historical period (1981–2000).

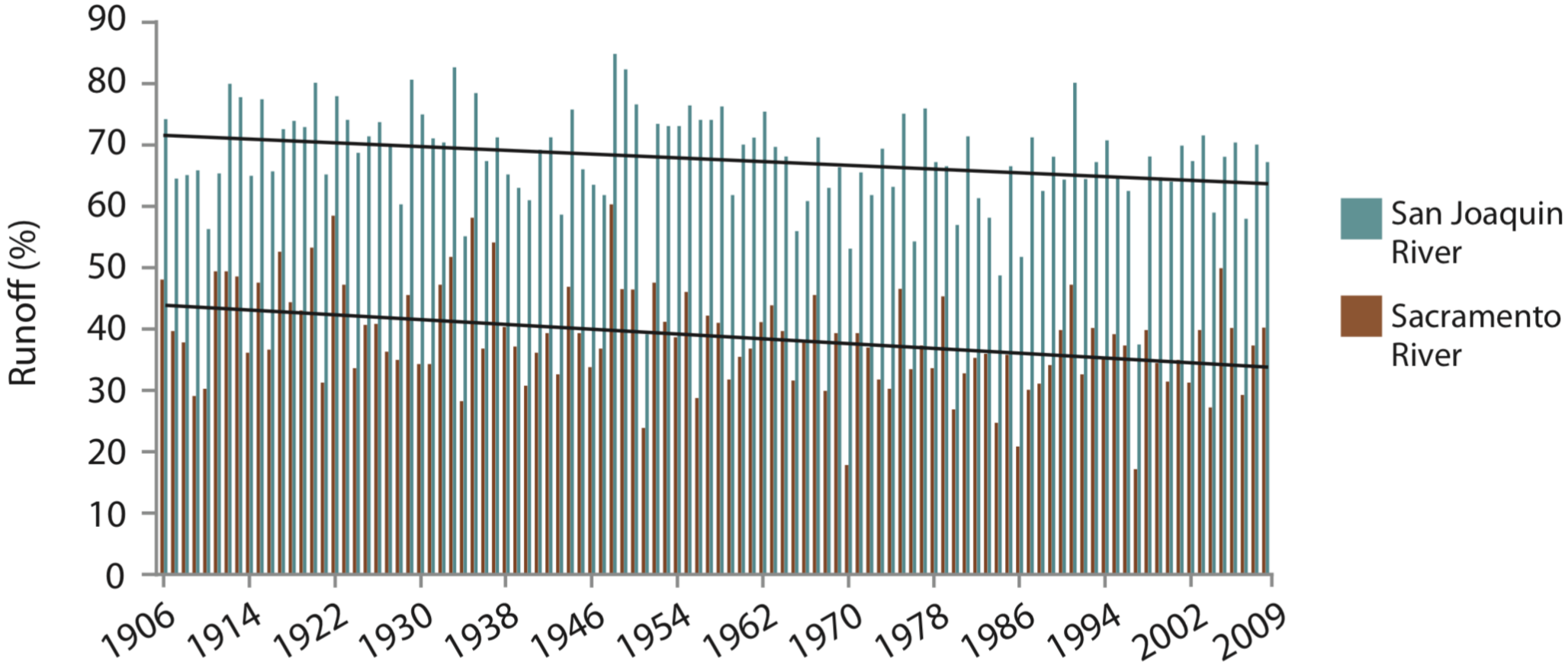


www.ioes.ucla.edu/project/climate-change-sierra-nevada

UCLA IoES

UCLA Center for Climate Science

Snowmelt Runoff (April-Sept.) Decreasing Due to Warming



From Hanak et al. (2011). Public Policy Institute of California

SOURCE: Authors' calculations using data from the California Department of Water Resources.

NOTES: The figure shows unimpaired spring and summer runoff (April 1–September 30) as a share of total annual runoff (October 1–September 30). The lines show trends over the period 1906–2009. Runoff shift from spring to winter has been 1 percent per decade ($R^2 = 0.12$) for the Sacramento River and 0.7 percent per decade ($R^2 = 0.07$) for the San Joaquin River.

Lake Shasta

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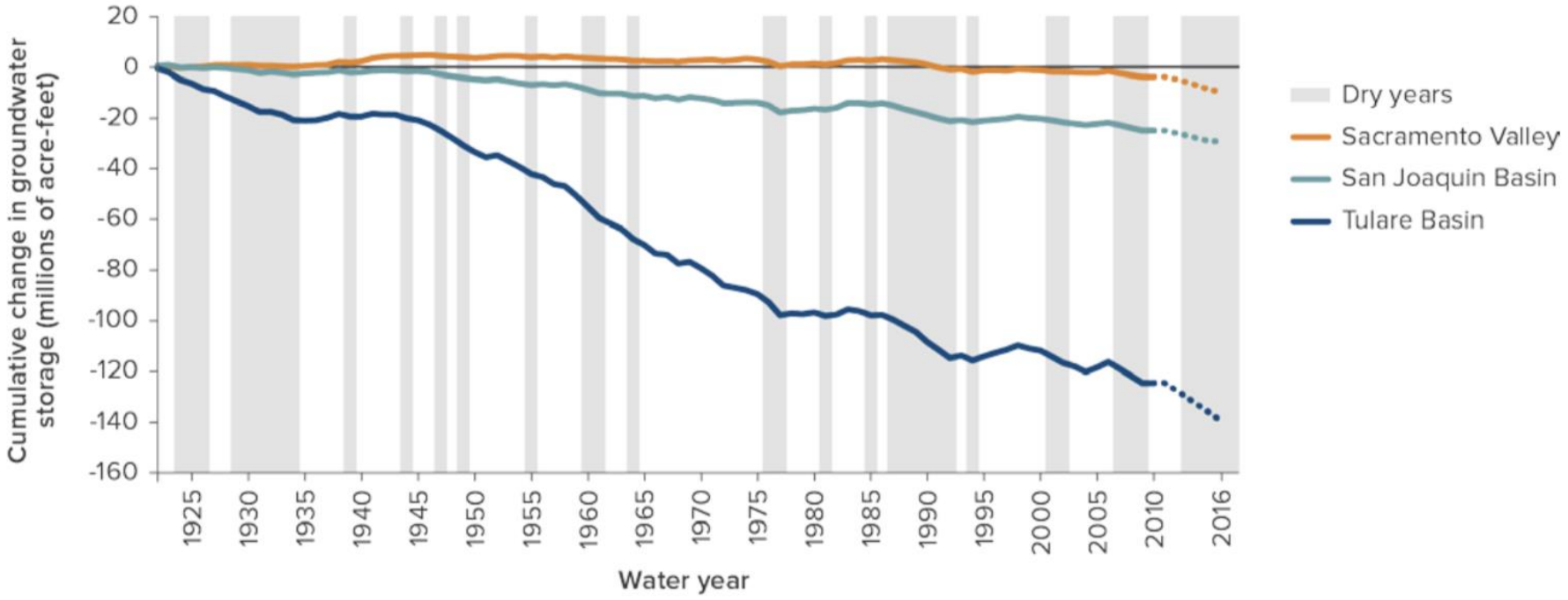
Groundwater Overdraft Trends, Central Valley *(CA avg. annual overdraft ~ 2 MAF)*

From Chapelle, Hanak & Harter 2017; http://www.ppic.org/content/pubs/jtf/JTF_GroundwaterJTF.pdf



Source: Updated from Ellen Hanak et al., *What If California's Drought Continues?* (PPIC, 2015), Figure 3, using data through 2009 from the California Department of Water Resources and author estimates thereafter.

Notes: Lines show cumulative change in groundwater storage based on water years (October–September). Projections since 2009 may underestimate depletions since the onset of the latest drought in 2012. Dry years are those classified as critical or dry in the Sacramento Valley based on the California Cooperative Snow Survey.

Available Central Valley Storage Volume

- 140 reservoirs can store **42 MAF**
- In Central Valley subsurface, room for another **140 MAF!**

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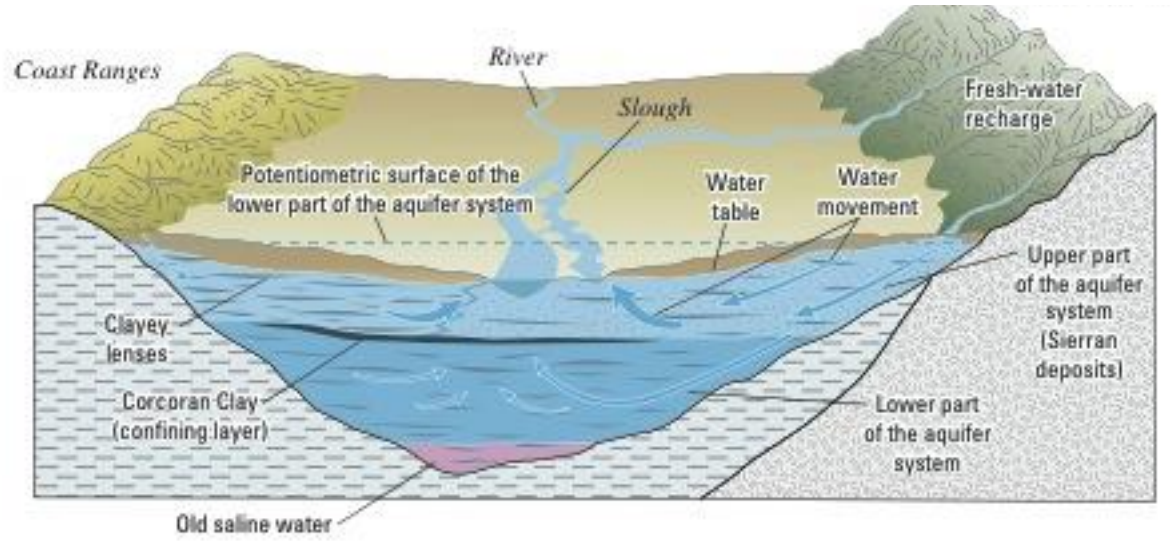
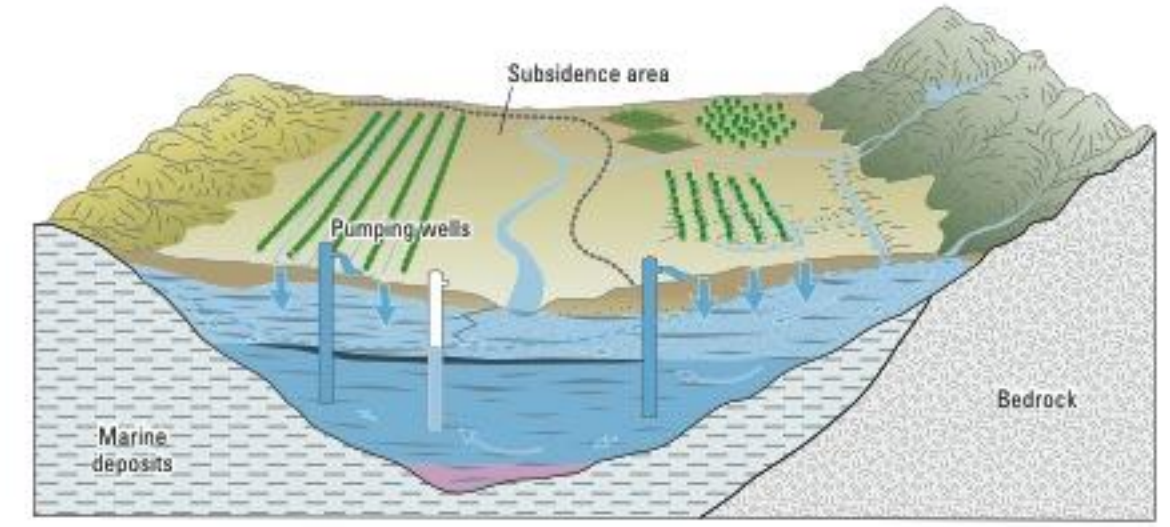
San Joaquin Valley Groundwater (from Faunt, 2009)



Pre-Development



Post-Development

Figure A9. Continued.

Irrigation Increased Recharge by Factor of 2-3

- Pre-development CV recharge ~2.6 MAF*
- Post-development CV recharge ~5.6 MAF*
- Pre-development CV floor river recharge ~-1.2 MAF*
- Post-development CV floor river recharge ~1.0 MAF (a gain of 2.2 MAF)*

Suggested further reading: Scanlon et al. (2016) Environmental Res. Letters.

*from C2VSIM (Brush, C. F., Dogrul, E. C., & Kadir, T. N. 2013. Development and Calibration of the California Central Valley Groundwater- Surface Water Simulation Model (C2VSim), Version 3.02-CG. California Department of Water Resources Technical Memorandum, 193.

Recharge on Farms and Floodplains

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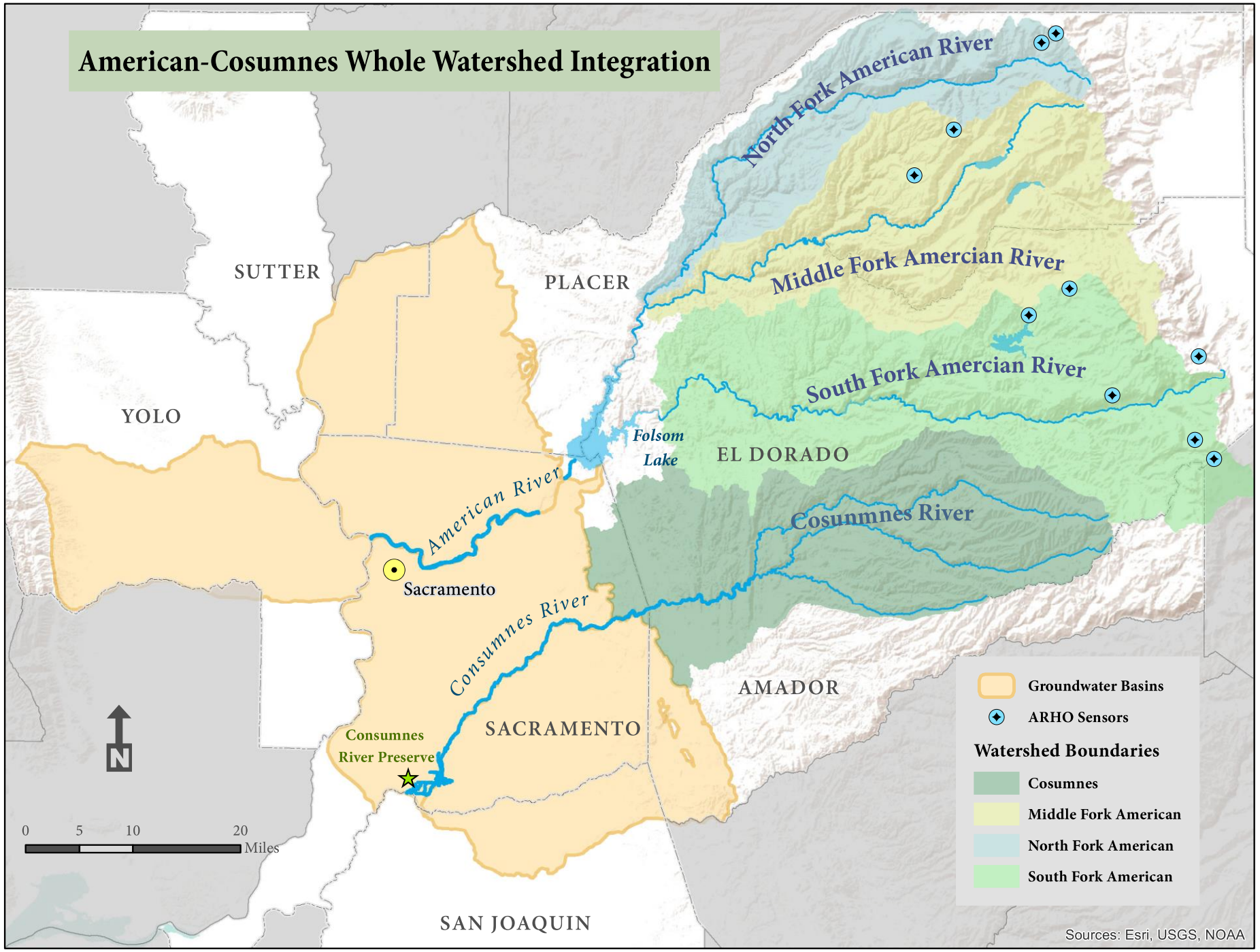
Reoperation of Folsom Reservoir & Downstream Aquifer System to Maximize Total Water Storage

Erfan Goharian, Robert Gailey, Stephen Maples, Sam Sandoval, Graham Fogg

UC Water: Univ. of California Water Security and Sustainability Research Initiative (http://ucwater.org/)

http://ucwater.org/sites/default/files/UCWater_Integrated_American_Cosumnes.pdf


Major Rivers of California
About 800 mi (1290 km) across)
River
Dry streambed
Lake/reservoir
Dry lake
Pacific Ocean
Smith
Klamath
Scott
Shasta
Salmon
Upper Klamath Lake
Lost
Goose Lake
Tule Lake
Clear Lake Res.
Pit
McCloud
Trinity
New
Trinity Lake
Redwood Cr.
S.F. Trinity
Shasta Lake
Whiskeytown Lake
Mad
Eel
Mattole
S.F. Eel
M.F. Eel
Cottonwood Cr.
Mill Cr.
Eagle Lake
Susan
Lake Almanor
Honey Lake (dry)
Pyramid Lake
N.F. Feather
M.F. Feather
Butte Cr.
Black Butte Lake
Stony Cr.
Sacramento
Feather
Lake Oroville
N. Yuba
Bullards Bar Res.
Yuba
Truckee
Lake Tahoe
Carson
Walker
Walker Lake
Noyo
Navarro
Russian
Clear Lake
Cache Cr.
Putah Cr.
Napa
Lake Berryessa
American
S.F. American
Folsom Lake
Cosumnes
Mokelumne
Calaveras
Stanislaus
New Melones L.
E. Walker
Tuolumne
Mono Lake
Lake Don Pedro
Lake Crowley
L. McClure
Alameda
San Joaquin
Merced
Chowchilla
Fresno
Millerton Lake
Owens
Pajaro
San Luis Res.
San Lorenzo
San Benito
Kings
Pine Flat Lake
Fresno Slough
Kaweah
L. Kaweah
Owens Lake (dry)
Amargosa
Lake Mead
Salinas
Tule
Lake Success
Tulare Lakebed
S.F. Kern
San Antonio
Nacimiento
Lake Nacimiento
Estrella
Kern
Lake Isabella
Lake Mohave
Buena Vista Lake (dry)
Twitchell Res.
Cuyama
Mojave
Santa Maria
Sisquoc
Santa Ynez
Lake Cachuma
Lake Havasu
Santa Clara
San Gabriel
Santa Ana
Whitewater
San Jacinto
Lake Elsinore
Los Angeles
Salton Sea
Colorado
Santa Margarita
San Luis Rey
San Diego
New
Alamo
Tijuana


American-Cosumnes Whole Watershed Integration
SUTTER
PLACER
YOLO
EL DORADO
AMADOR
SACRAMENTO
SAN JOAQUIN
North Fork American River
Middle Fork Amercian River
South Fork Amercian River
Cosumnes River
Folsom Lake
American River
Sacramento
Consumnes River
Consumnes River Preserve
N
0 5 10 20
Miles
Groundwater Basins
ARHO Sensors
Watershed Boundaries
Cosumnes
Middle Fork American
North Fork American
South Fork American
Sources: Esri, USGS, NOAA

Folsom Reservoir Reoperation

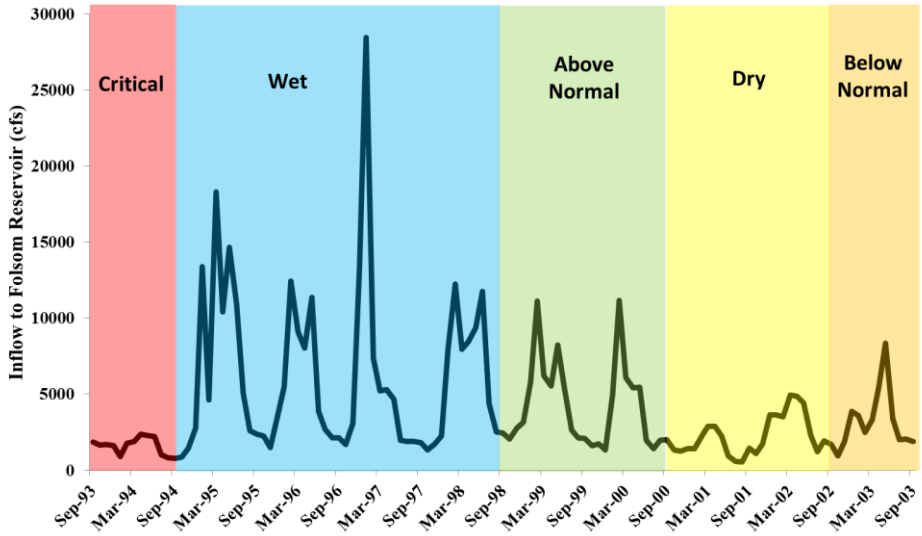
Multi-Objective Optimization:

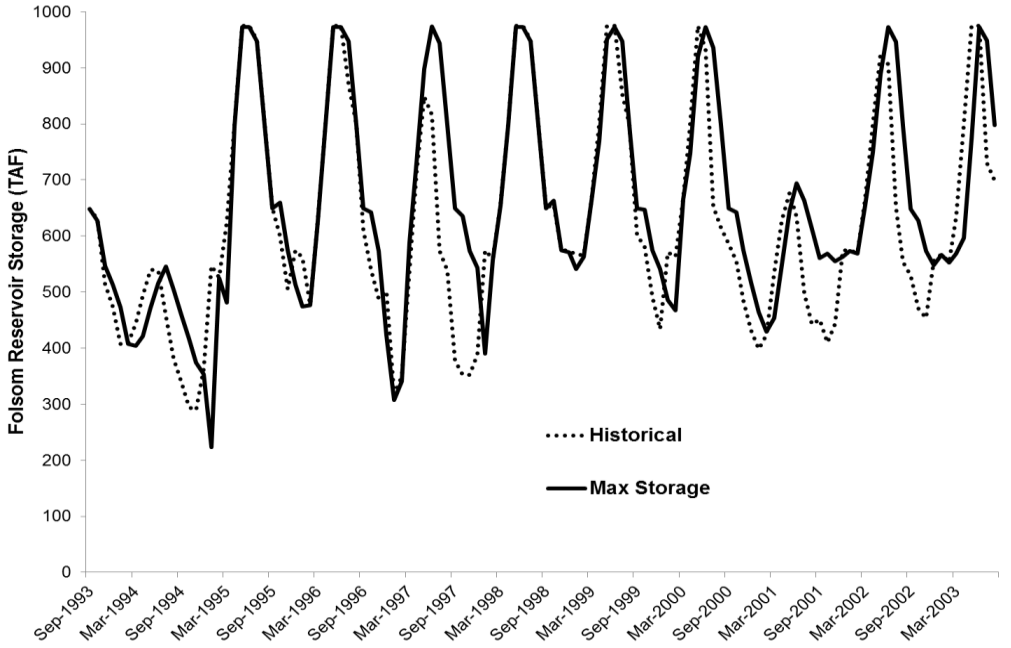
OF #1: Maximizing total water storage

OF #2: Maximizing Hydropower

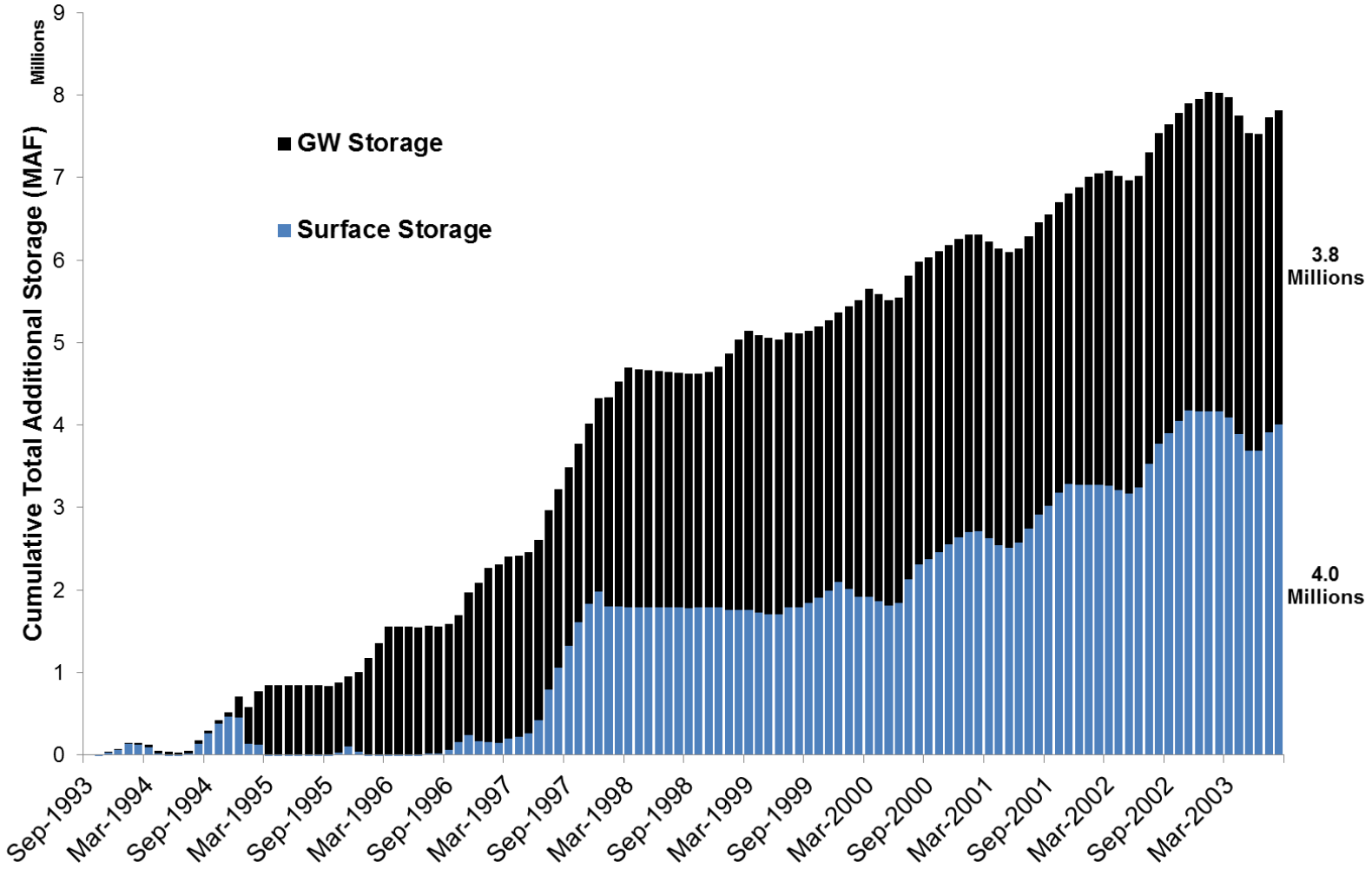
Constraints: Inflow, Minimum flow requirement, local demand, etc.

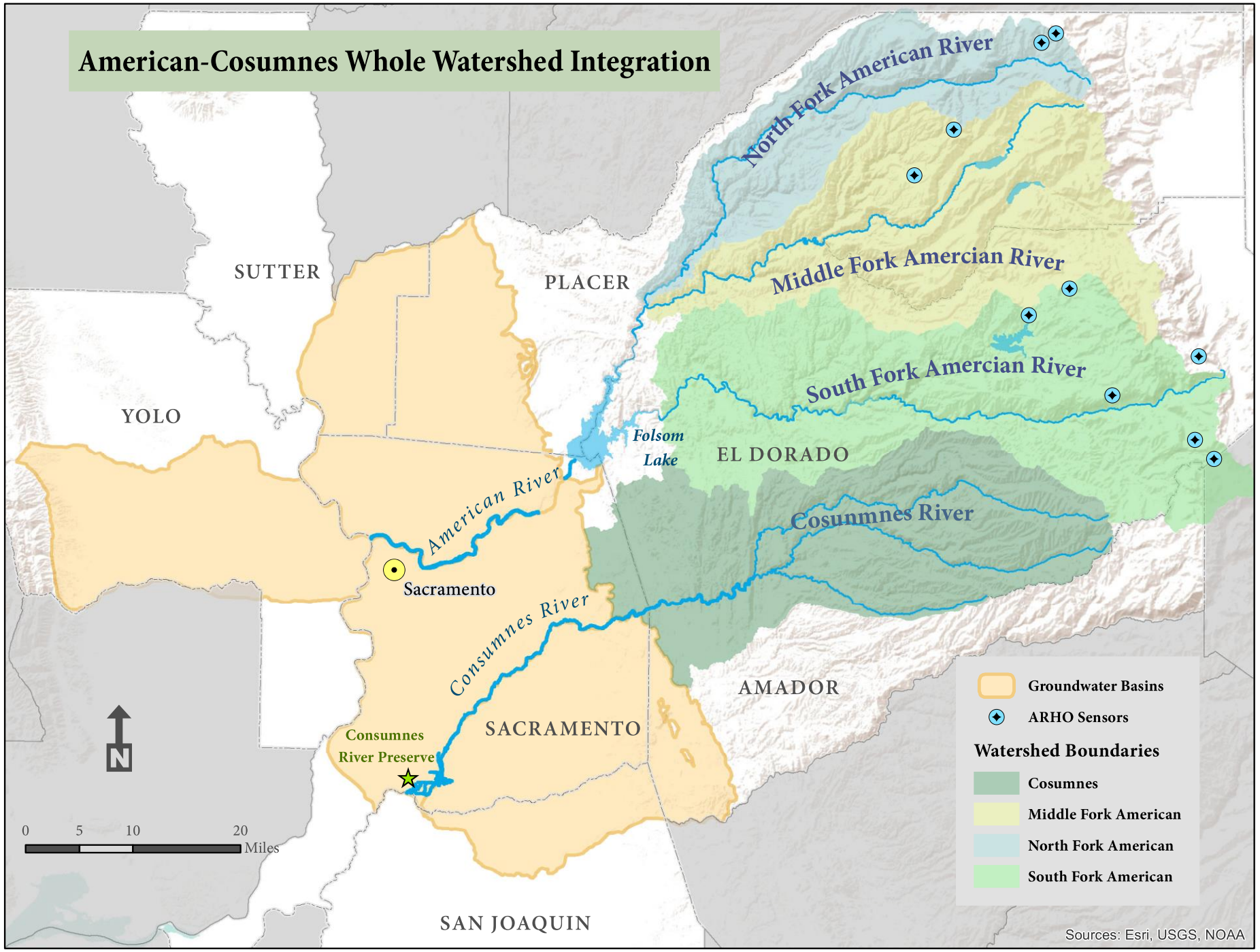
- **Extended winter recharge (Nov-Mar) for Water Year 1994-2003**
- **Using current available conveyance system (Folsom South Canal) to distribute water for recharge regionally.**





Potential Increase in Total System Storage With Reservoir Reoperation and Recharge of All Divertable High-Magnitude Flows

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Cosumnes
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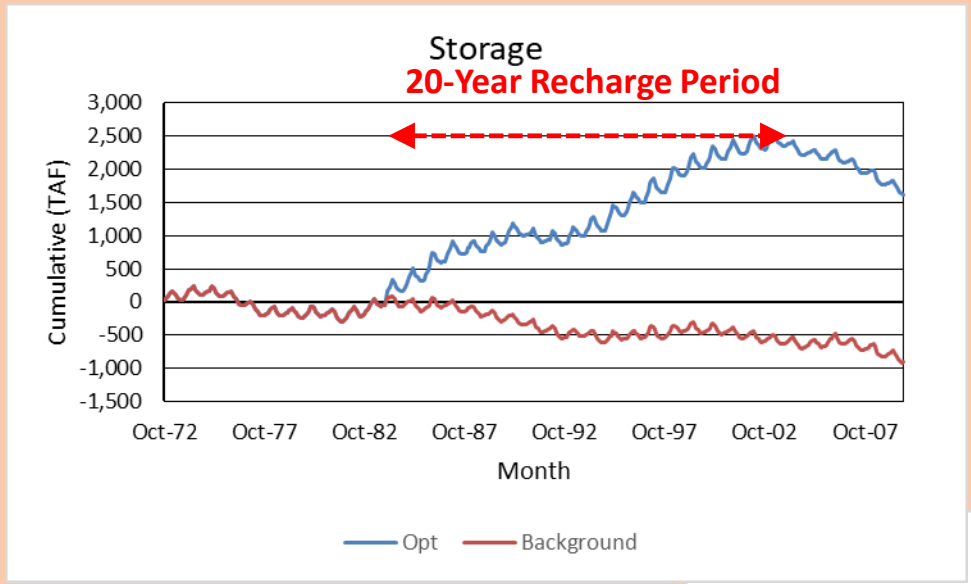
South Fork American
Sources: Esri, USGS, NOAA

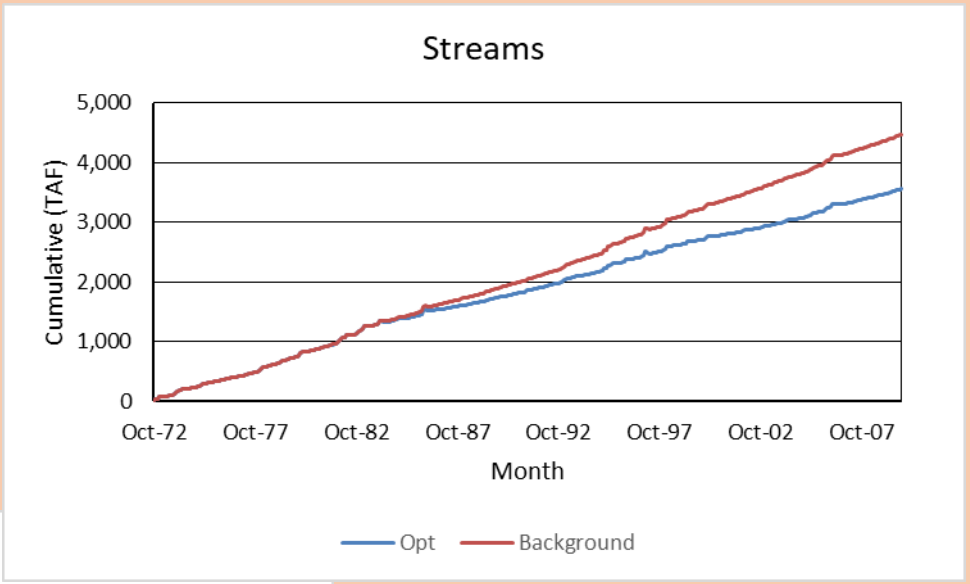
GROUNDWATER SYSTEM REOPERATION:

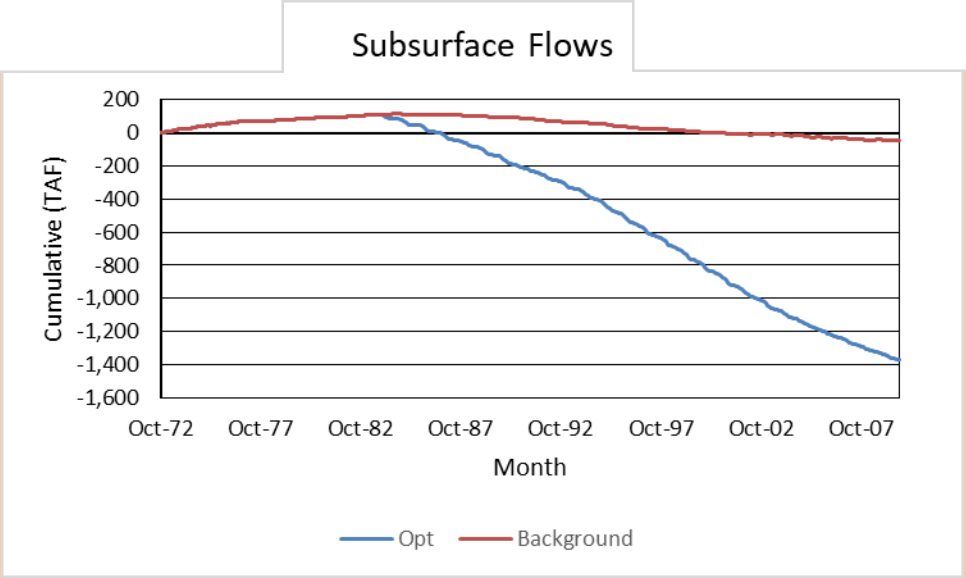
Modeling of Groundwater Flow and On-Farm Recharge Including Economic Optimization, American-Cosumnes Basin

Gailey (2018)
Ph.D. Dissertation, UC Davis

INITIAL RESULTS
WINTER EXTENDED AND ONLY CROP LAND







44% WAR used

Recharged: 4,765 TAF

Stored: 2,992 (63%)

Streams: 704 (15%)

Other Basins: 1,068 (22%)

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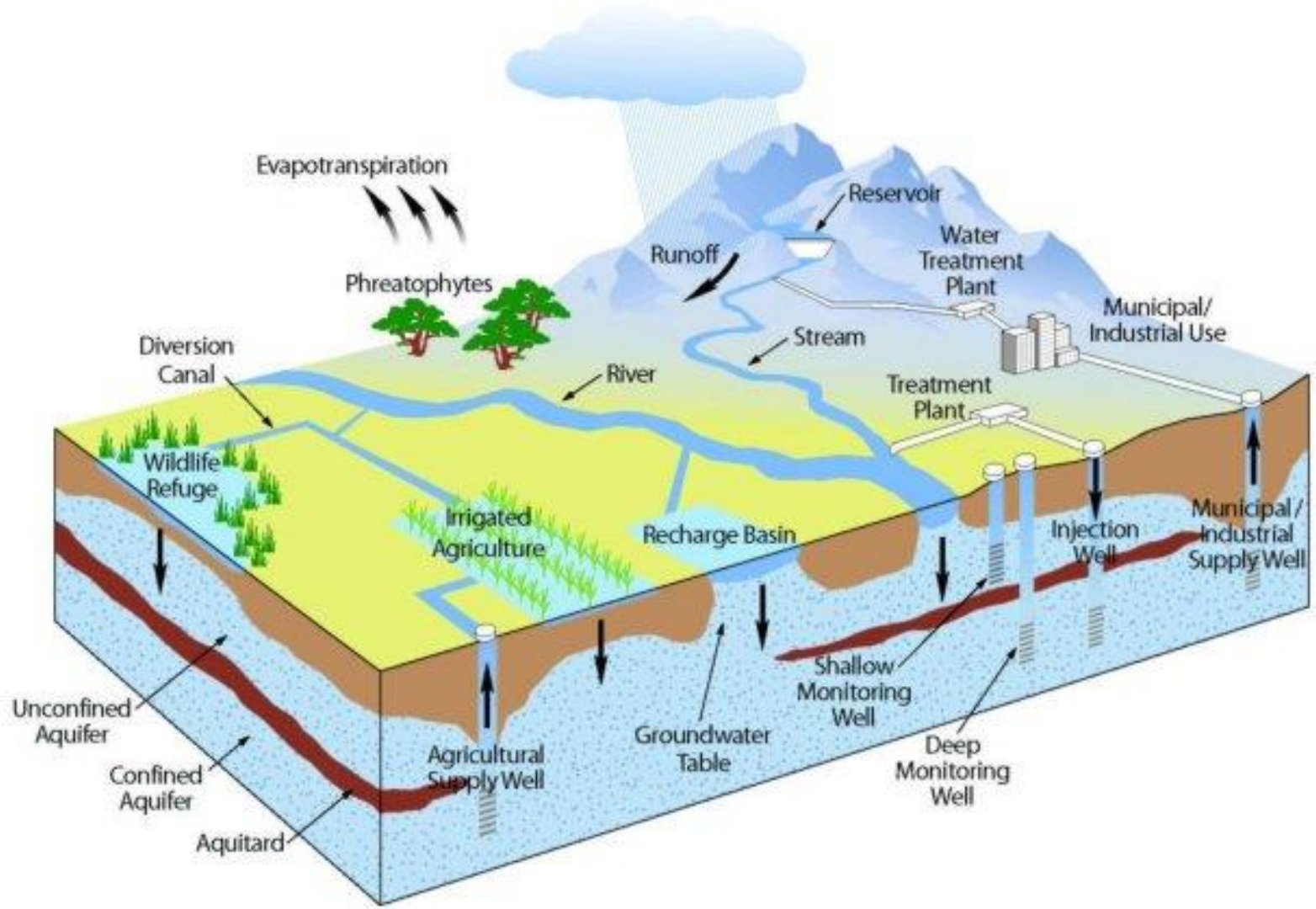
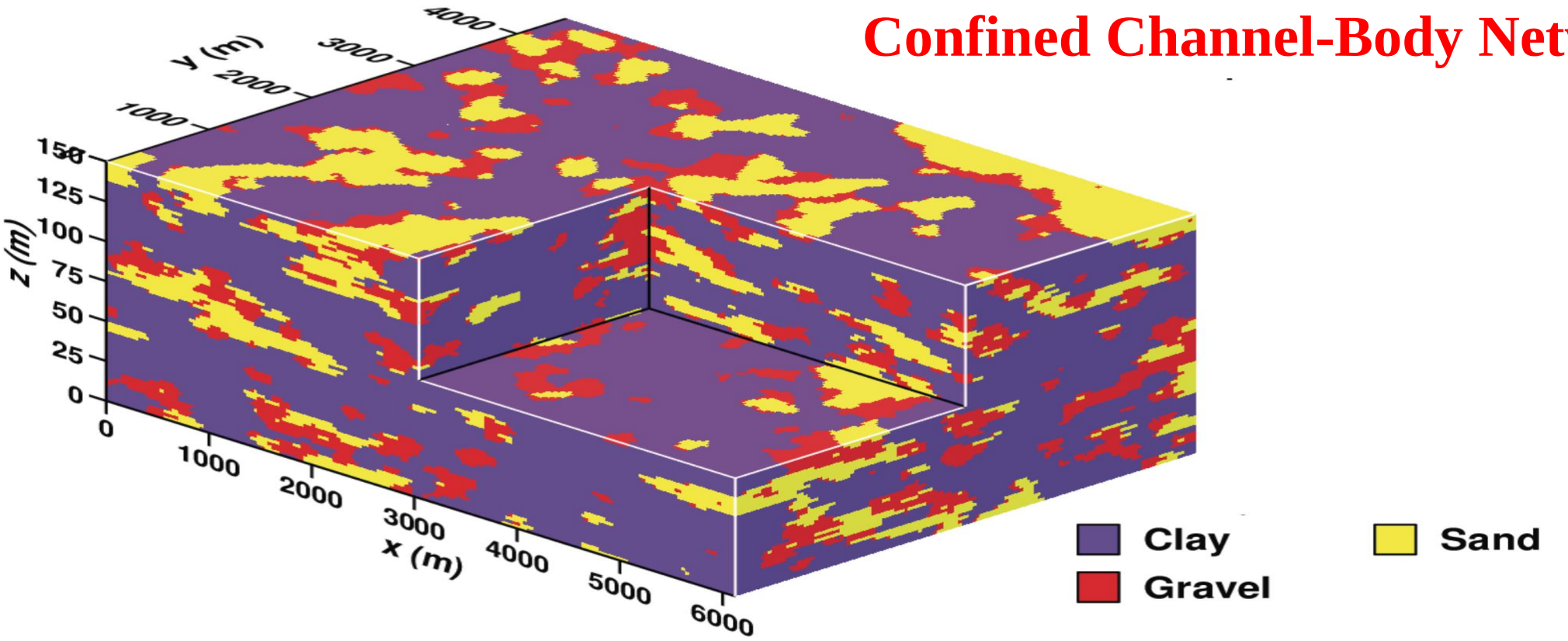
Recharging Confined Aquifers in the Central Valley

Typical Concept of Aquifer Recharge

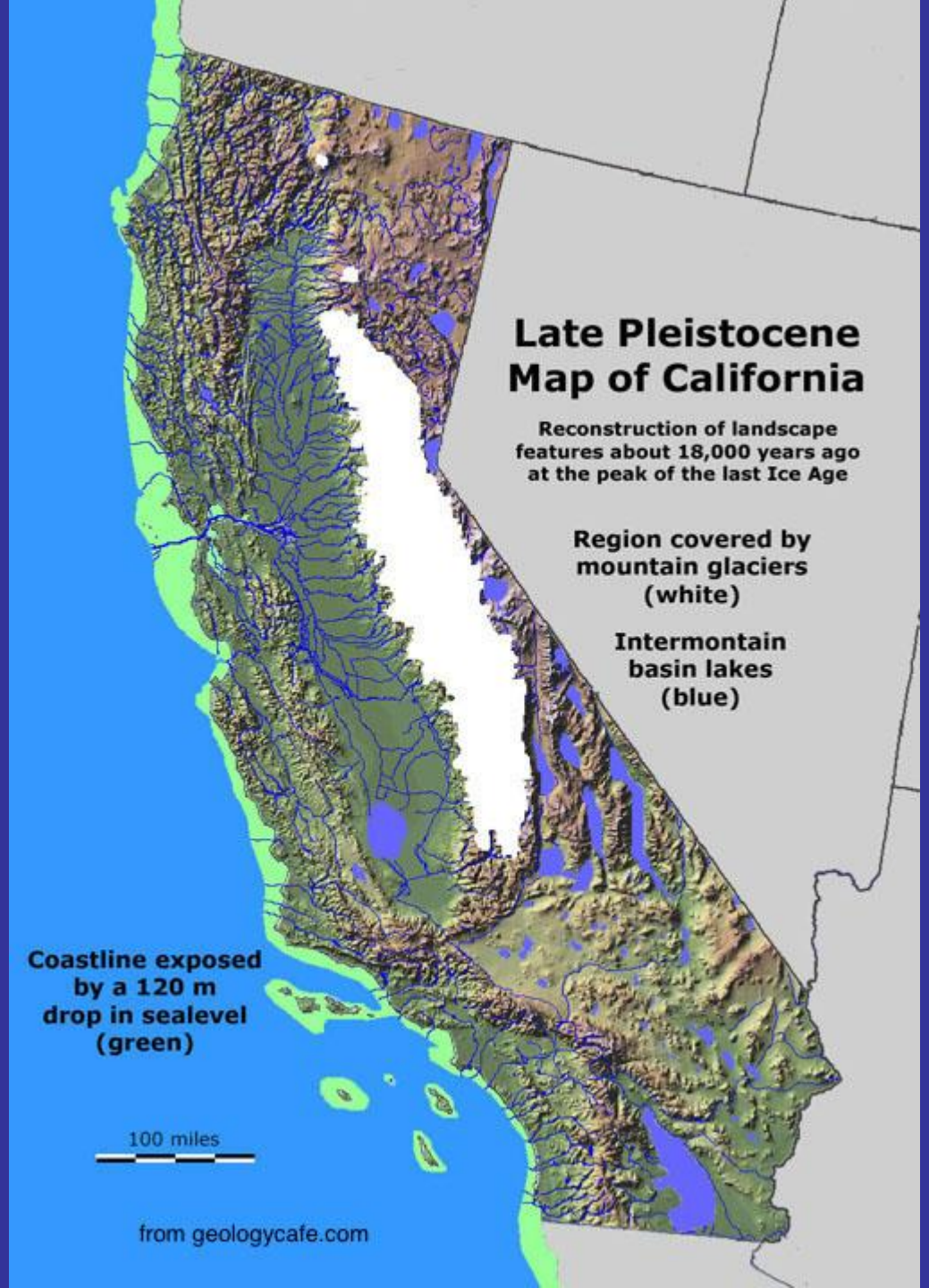


Typical Central Valley Aquifer System

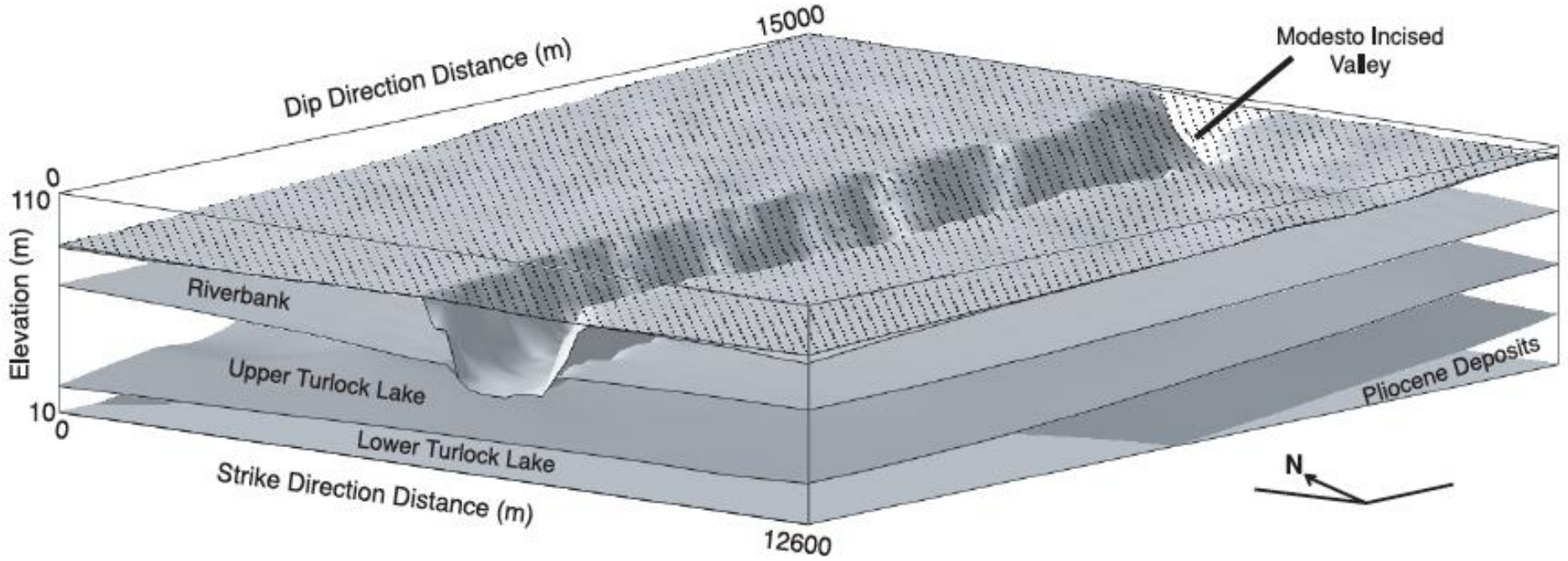
Woodland, CA (S. Maples)



Alpine Glaciation in CA

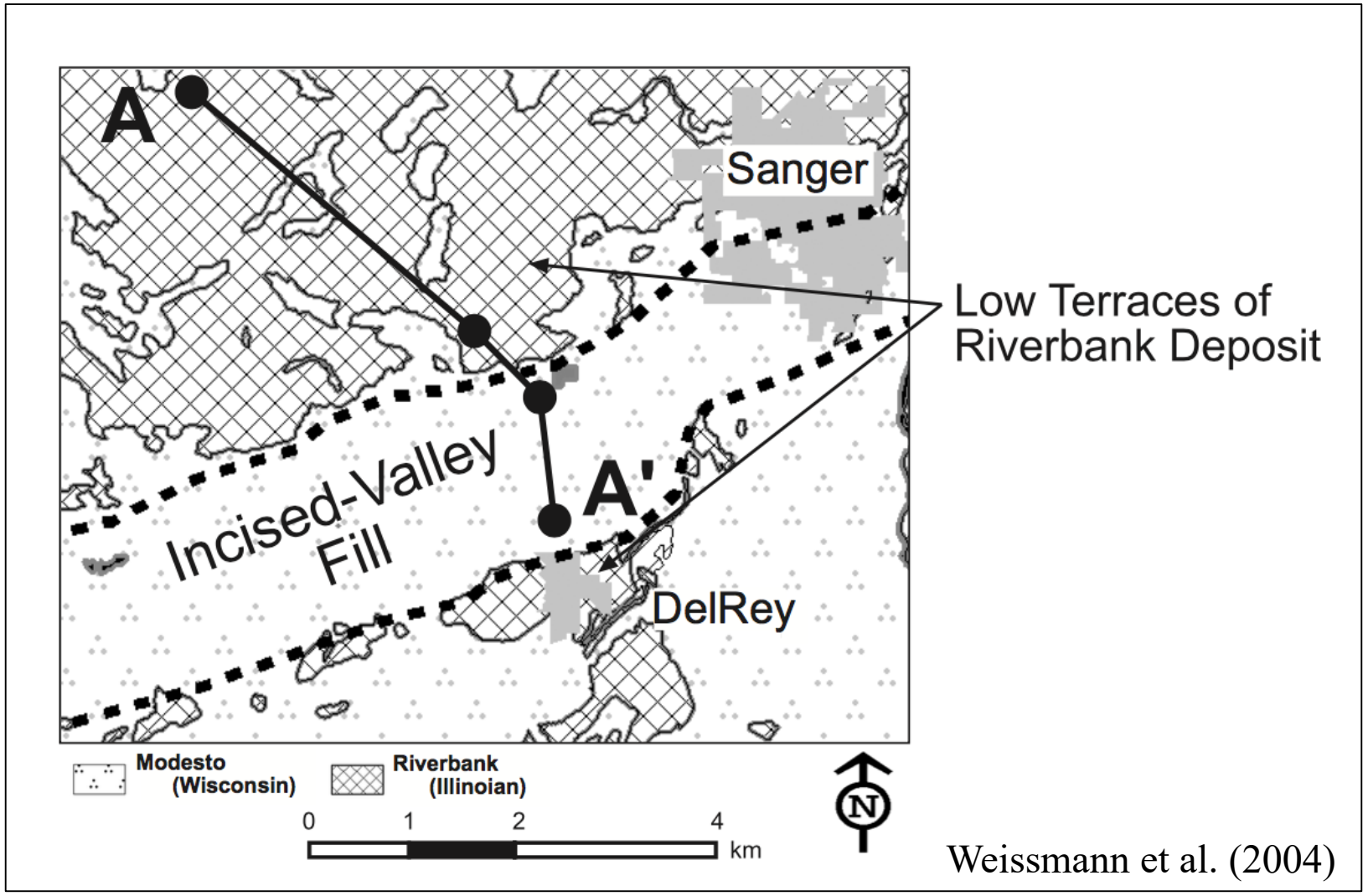


Incised Valley Fill Deposit After Most Recent Pleistocene Glaciation (Kings River System)



Weissmann et al. (2004)

Kings River Fan Incised Valley-Fill



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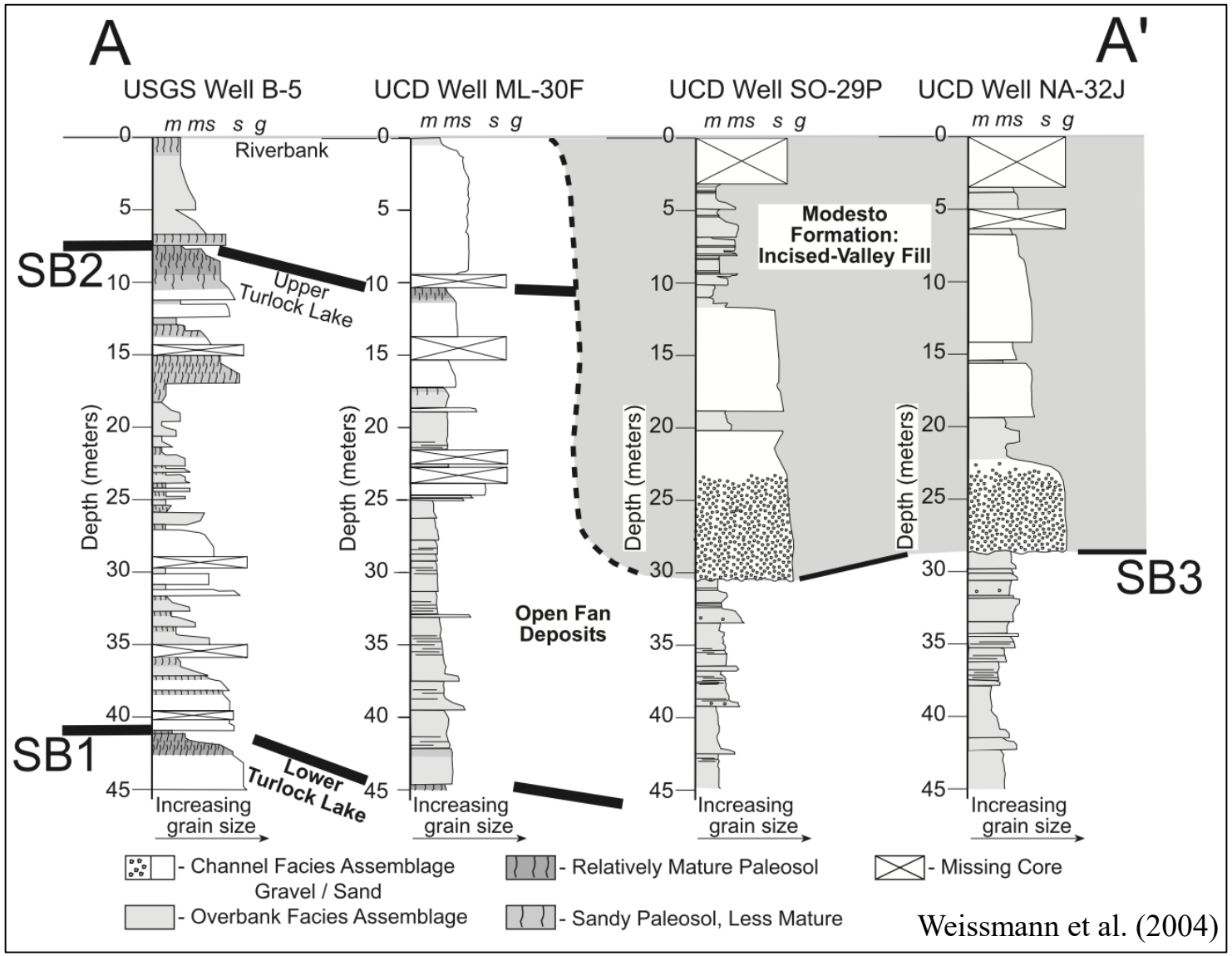
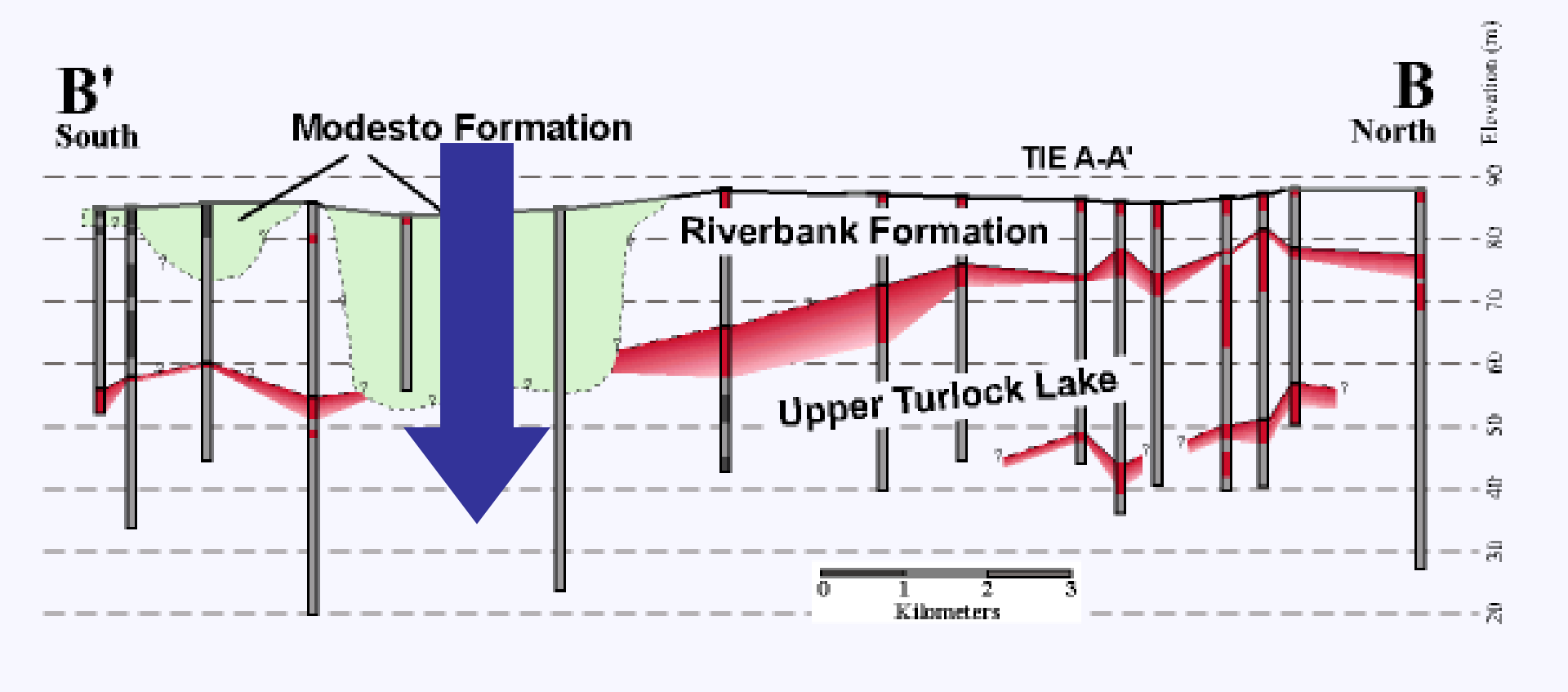


Weissmann et al. (2004)

Enhanced Recharge in Incised Valley-Fill Deposits



Graham E. Fogg, University of California, Davis

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