Flood-MAR Perspective: American-Cosumnes Basin Experience

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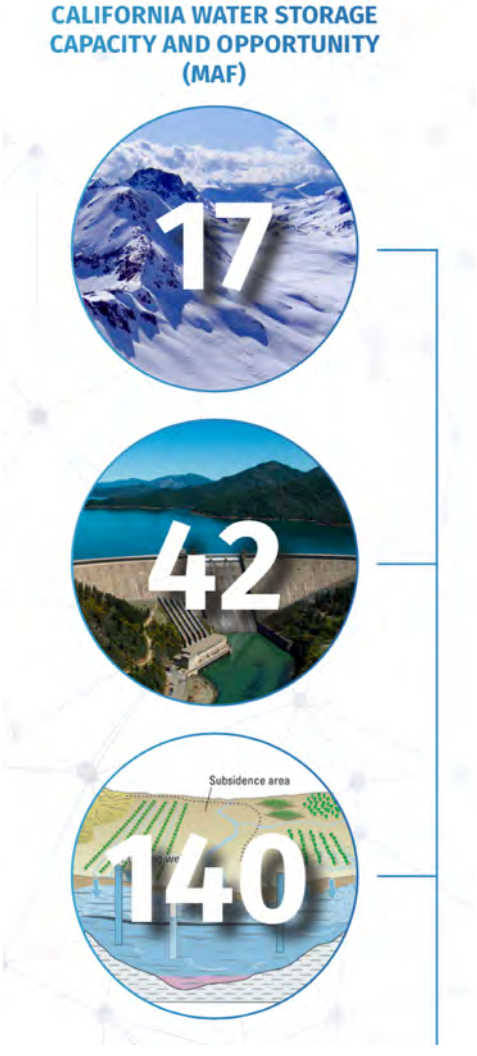
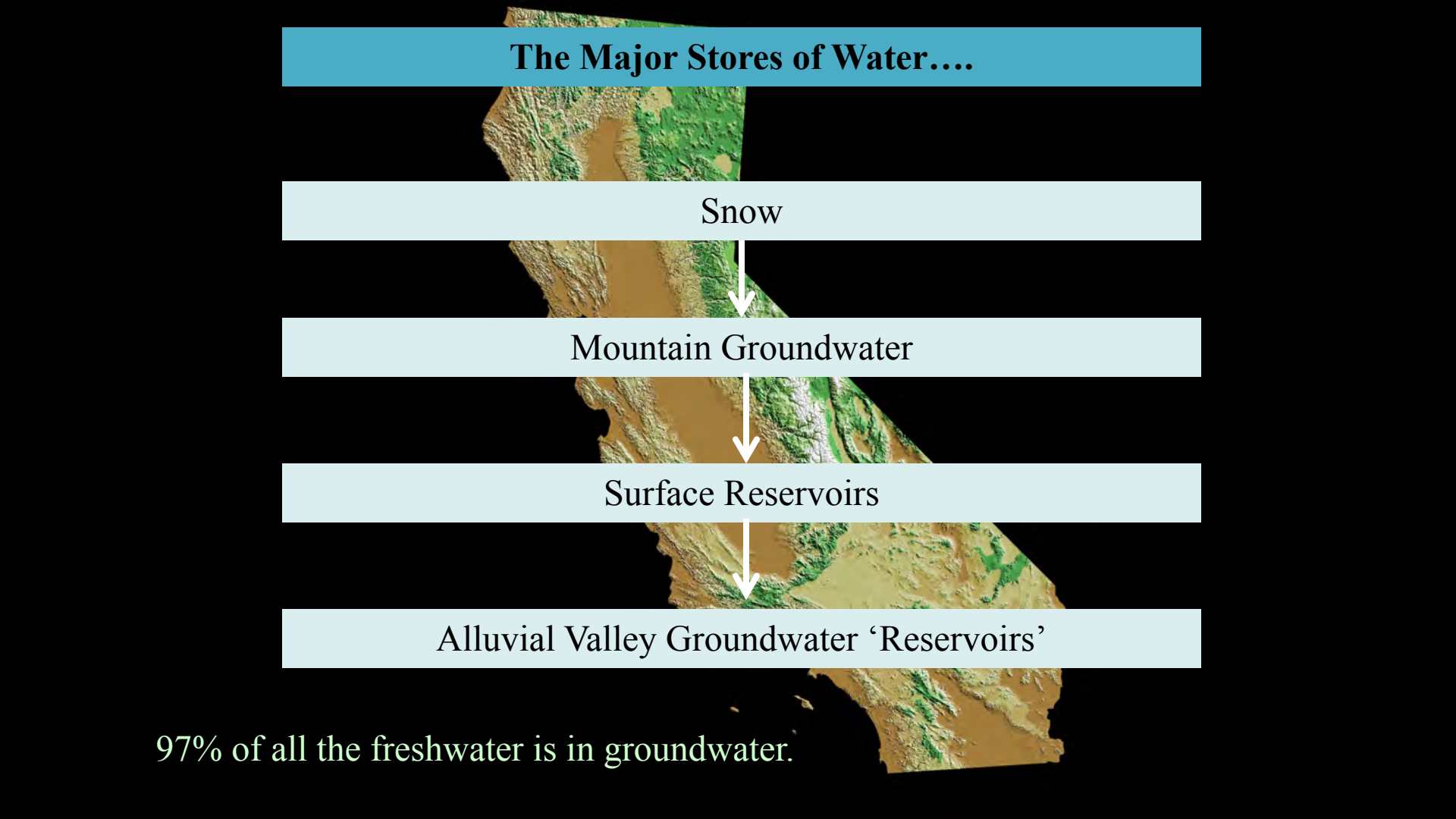
Photo by Graham Fogg, Yolo Bypass, Sacramento in background, Jan. 11, 2017



Key Storage Numbers, Central Valley

- Historical snowpack: ~17 MAF
- Reservoirs can store 42 MAF
- In Central Valley subsurface, room for another 140 MAF

From: Recharge Roundtable Call To Action: Key Steps for Replenishing California's Groundwater, 2018.



The Major Stores of Water….

Snow

Mountain Groundwater

Surface Reservoirs

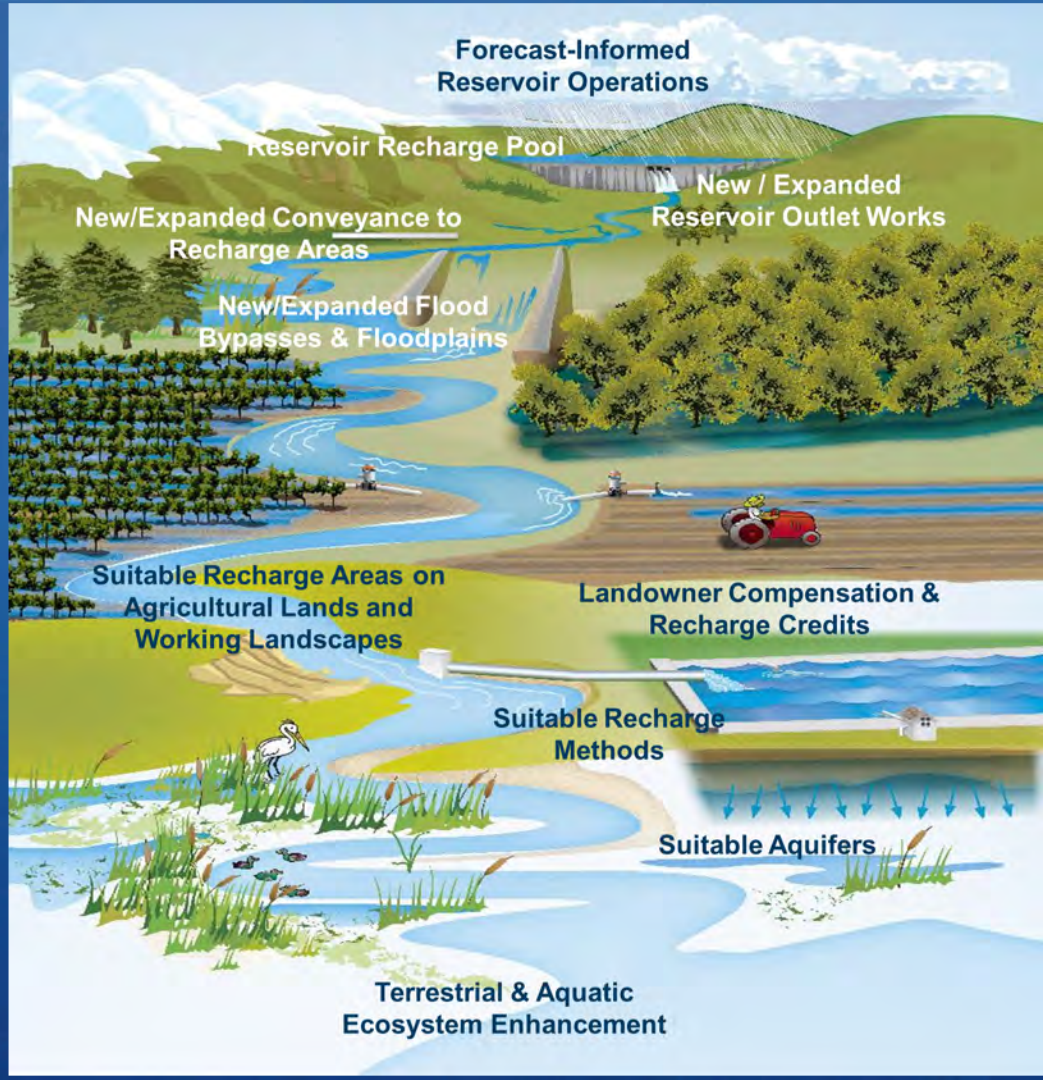
Alluvial Valley Groundwater ‘Reservoirs’

97% of all the freshwater is in groundwater.

Flood-MAR is…

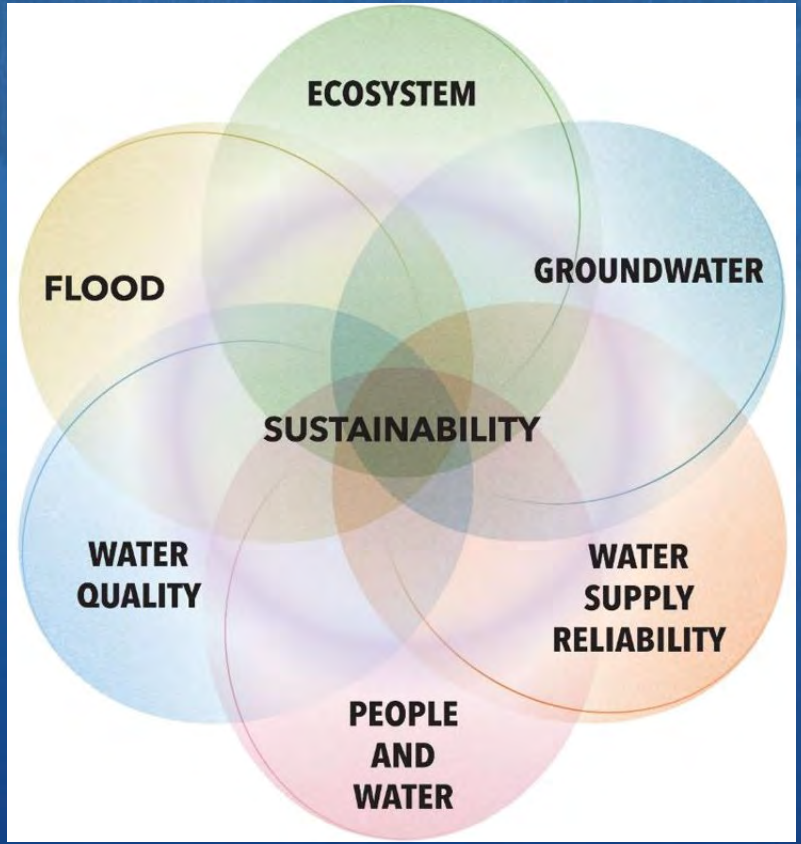
…a water resource management strategy using high flows from (or in anticipation of) rainfall or snowmelt for managed aquifer recharge on agricultural lands, working landscapes, and natural managed lands

(From J. Marr, DWR)



Flood-MAR is also…

- Voluntary
- Multi-sector
- Scalable
- Multi-faceted



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Contributors:

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[4]Ministry of Public Works, Chile

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– UC Agriculture and Natural Resources

Key Points & Background

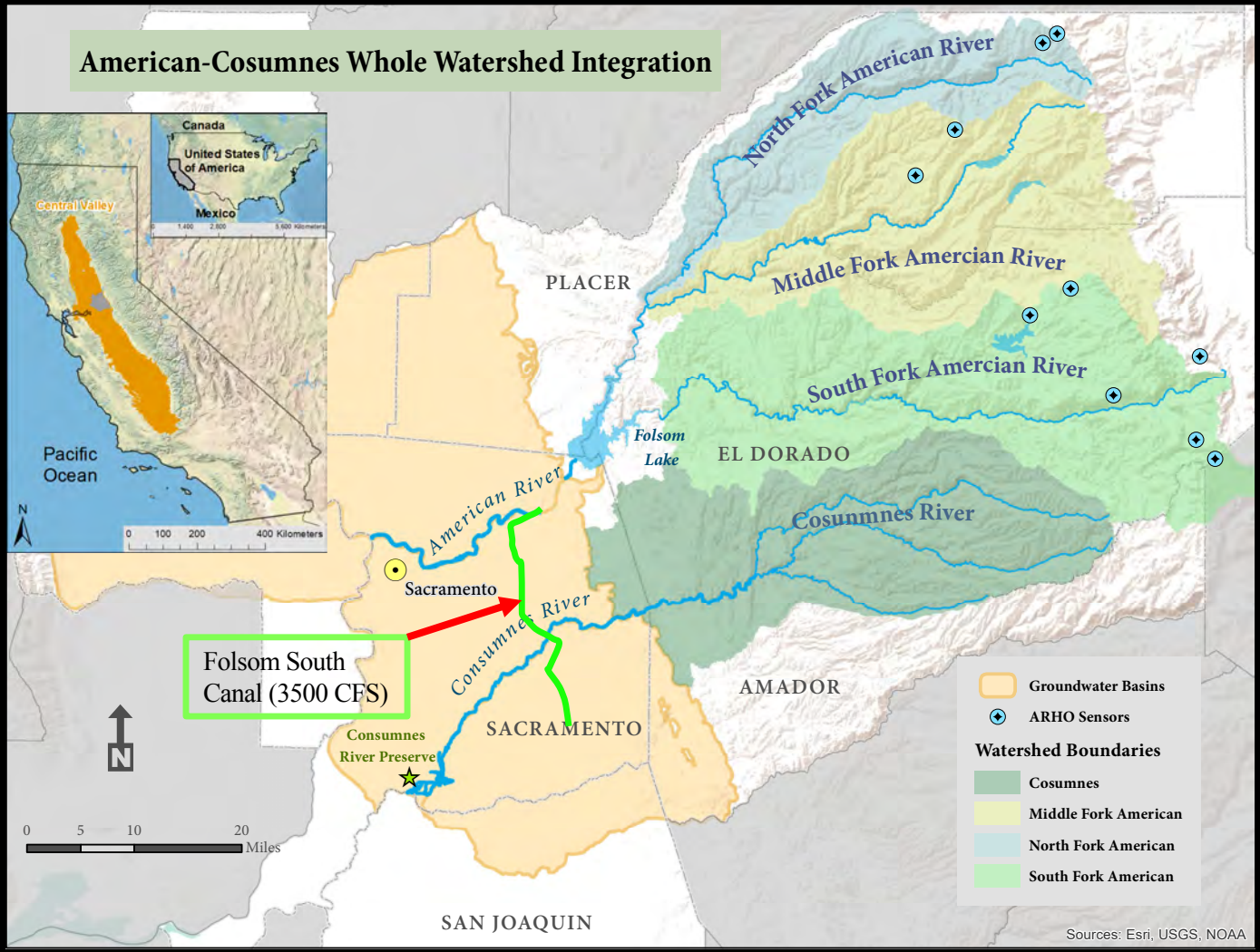
- Flood-MAR potential is very high
- Main mechanisms
  - Fallow irrigation on ag lands (Ag-MAR)
  - Recharge ponds at hydrogeologically strategic locations
    - Soils
    - Sub-soil geologic structure
    - Depth to water table
  - Floodplain inundation

Key Points & Background continued

- Ingredients for success (see http://ucwater.org/rechargeroundtable)
  - Knowledge of amount of water hydrologically and legally available for recharge in the various basins
  - Knowledge of the best sites for recharge; access to sites
  - Adequate conveyance
  - Incentivization of recharge projects
  - Operating the groundwater ‘reservoirs’ in concert with surface reservoirs
  - Making the groundwater ‘reservoirs’ sufficiently transparent to enable effective management of both water quantity and quality

Flood-MAR Case Study

American-Cosumnes Basin


American-Cosumnes Whole Watershed Integration
Canada
United States of America
Mexico
Central Valley
Pacific Ocean
0 100 200 400 Kilometers
N
North Fork American River
Middle Fork Amercian River
South Fork Amercian River
Cosumnes River
American River
Consumnes River
Folsom Lake
PLACER
EL DORADO
AMADOR
SACRAMENTO
SAN JOAQUIN
Sacramento
Folsom South Canal (3500 CFS)
Consumnes River Preserve
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

(Erfan Goharian)

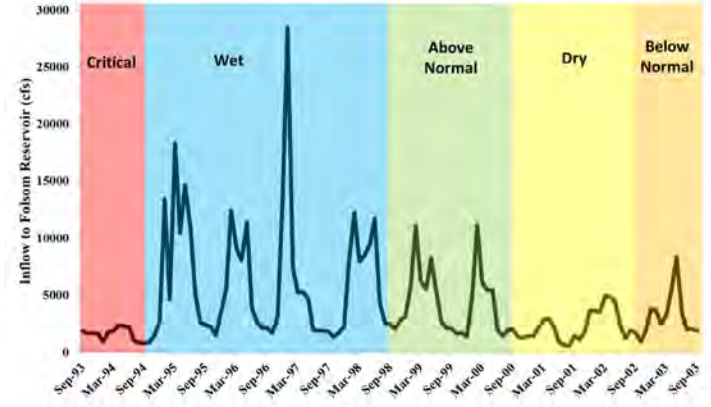
Multi-Objective Optimization:

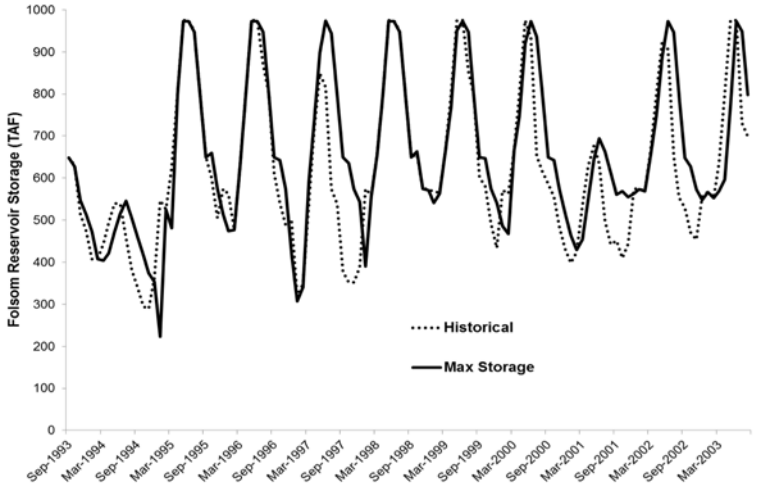
OF #1: Maximizing total water storage

OF #2: Maximizing Hydropower

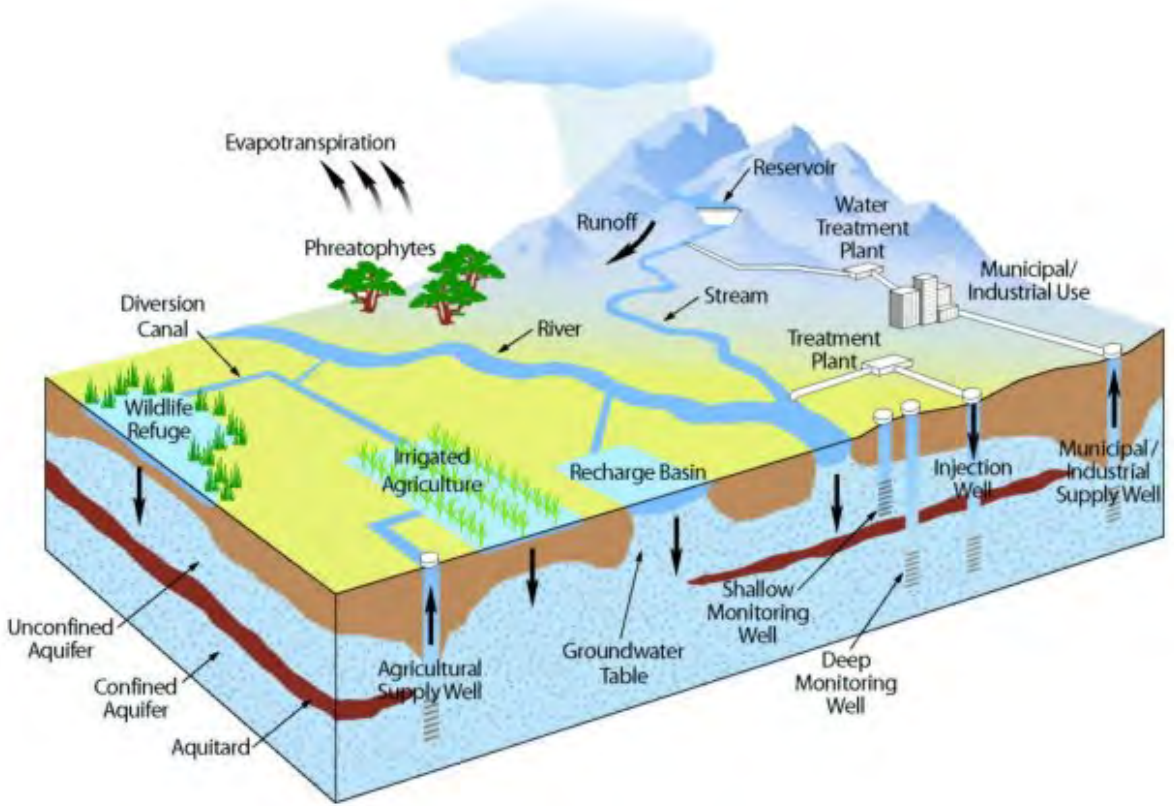
Constraints: Inflow, Minimum flow requirement, local demand, etc.

- **Extended winter recharge (Nov-Mar) for Water Year 1994-2003**
- **Using current available conveyance system (Folsom South Canal) to distribute water for recharge regionally.**
- **Produces ~0.52 MAF/yr water available for recharge (WAR)**

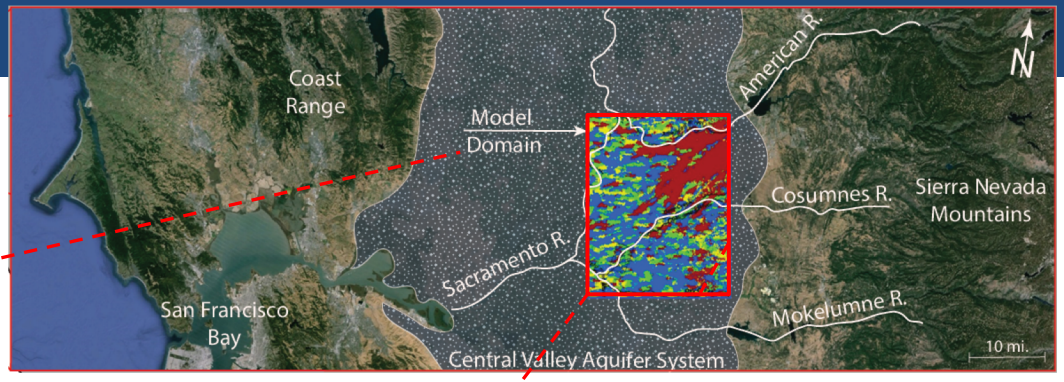


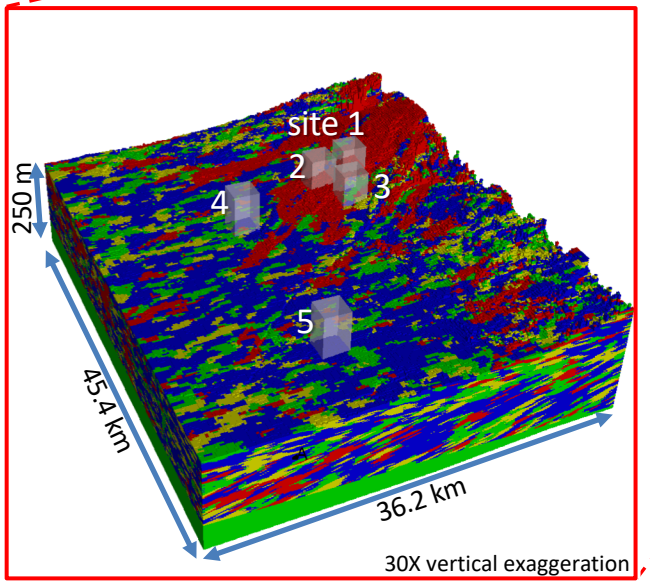


Typical Concept of Aquifer Recharge



Detailed Groundwater Model
American-Cosumnes Basin





Highly-Detailed Representation of Geologic Heterogeneity (Meirovitz, 2010)

- Stochastic geostatistical model (TPROGS) w/ ~1200 well logs
- Aquifer portions: Gravel, Sand
- Non-aquifer portions: Muddy Sand, Mud (silt and clay)

Managed Aquifer Recharge Simulations (Liu, 2014)

- 3D, variably-saturated flow model, Parflow
- 5 recharge sites
- 180-day simulations
- 10-cm ponded water over 1420 acres

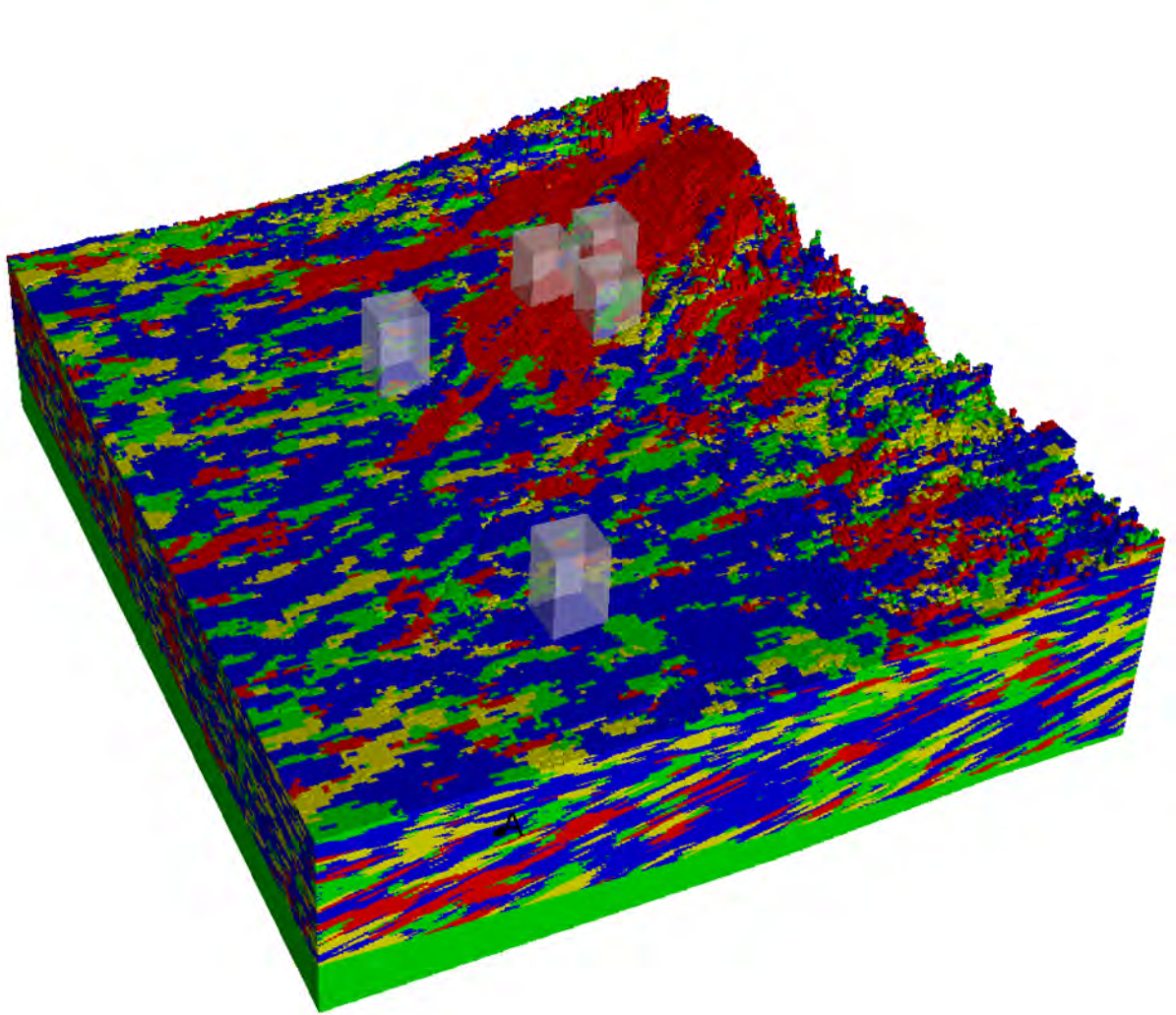
Goal:

- Sophisticated representation of physics & geology (1) simulates realistic recharge rates & (2) identifies potential for accelerated recharge.

Typical Aquifer System

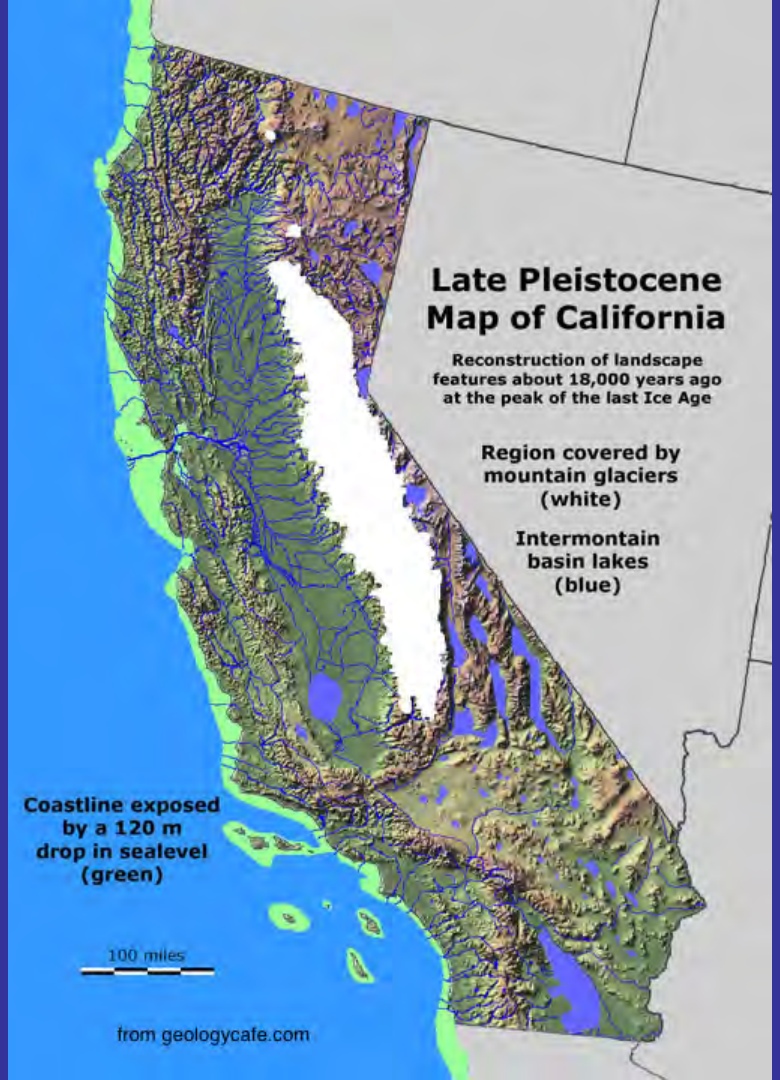
Aquifer portions:
Gravel, Sand

Non-aquifer portions:
Muddy Sand, Mud
(silt and clay)



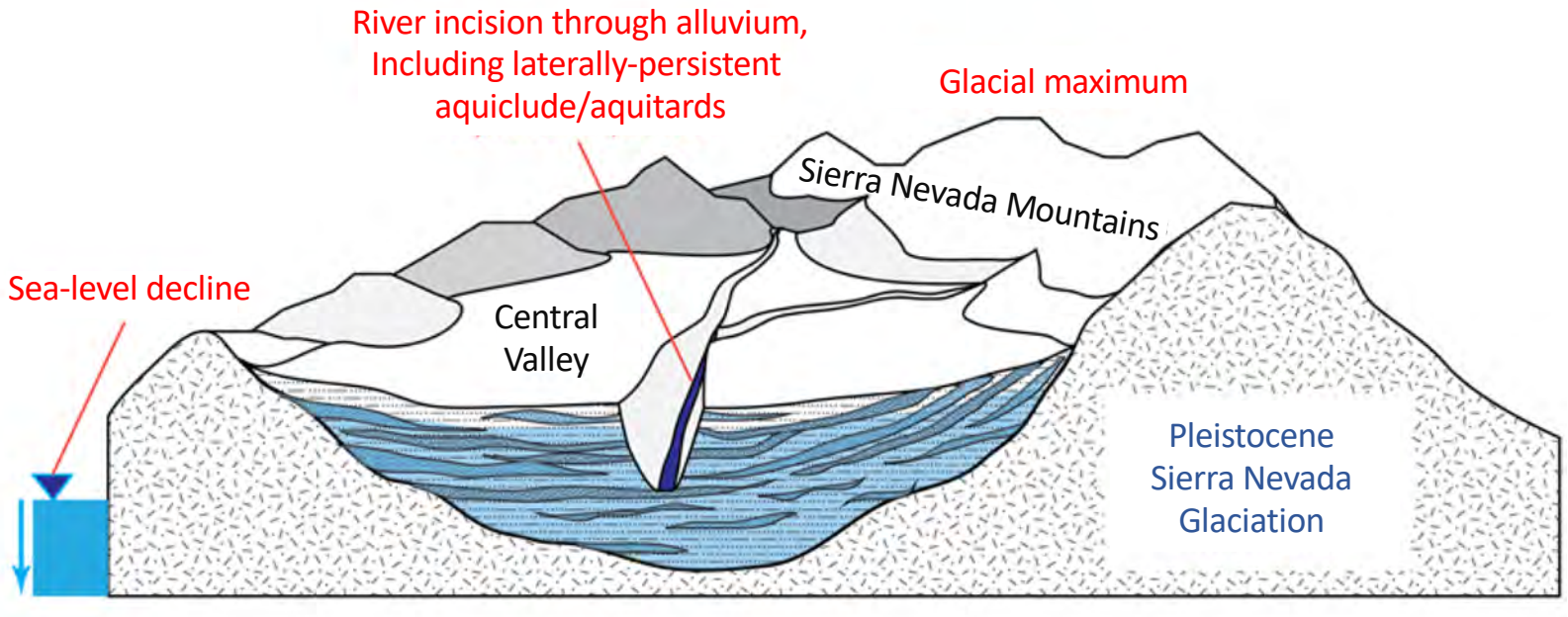
Exploitation of Geologic Features for Maximizing Recharge Rates and Volumes

Alpine Glaciation in CA



Glacial history of Sierra Nevada controls locations of the best recharge sites, Central Valley.

~1.8 mya – 10 kya
Glacial Maximum … River Channel Incision through Laterally-Extensive Aquitards



Weissmann & Fogg (1999); Weissmann et al., (2002); Meirovitz (2010)

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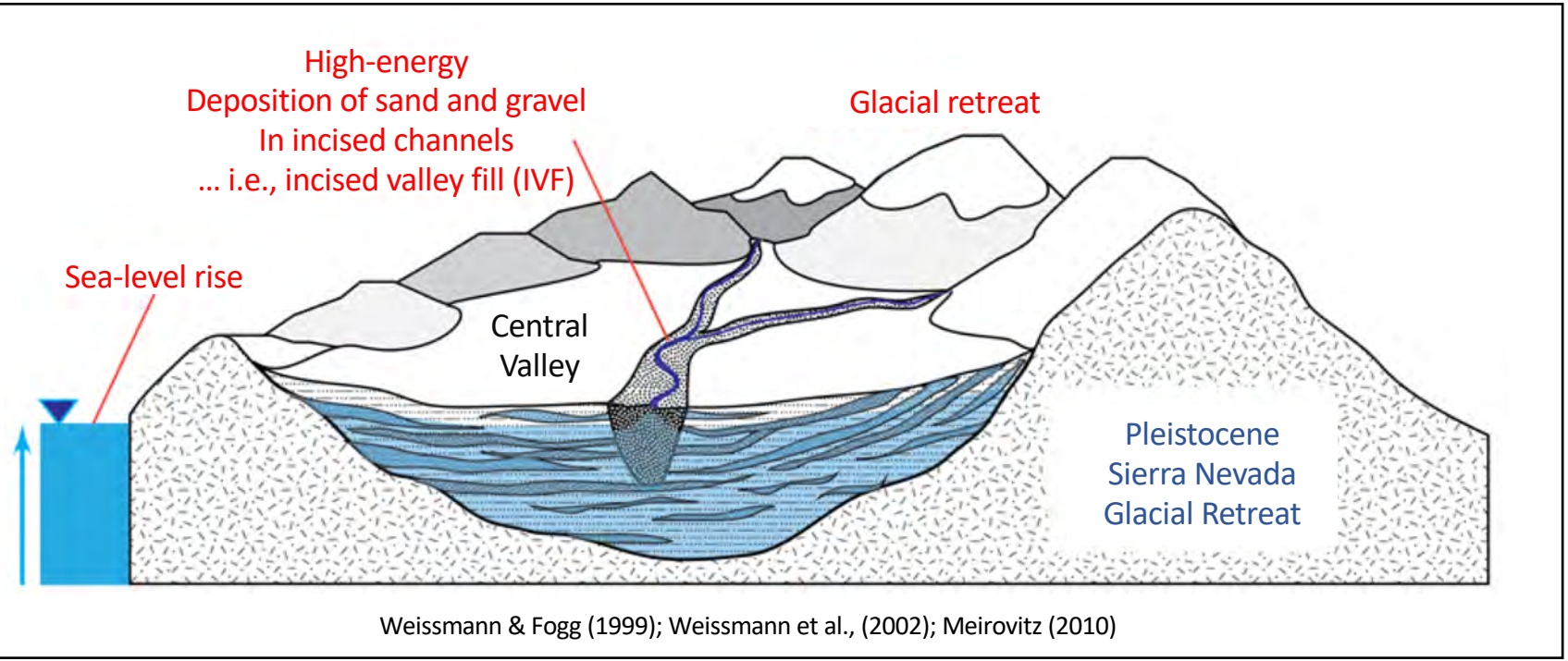
Glacial Retreat … Deposition of Coarse Sand & Gravel



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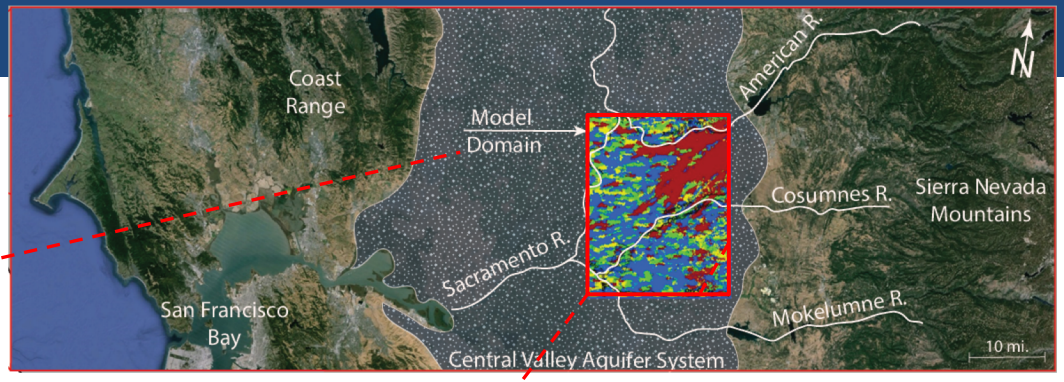
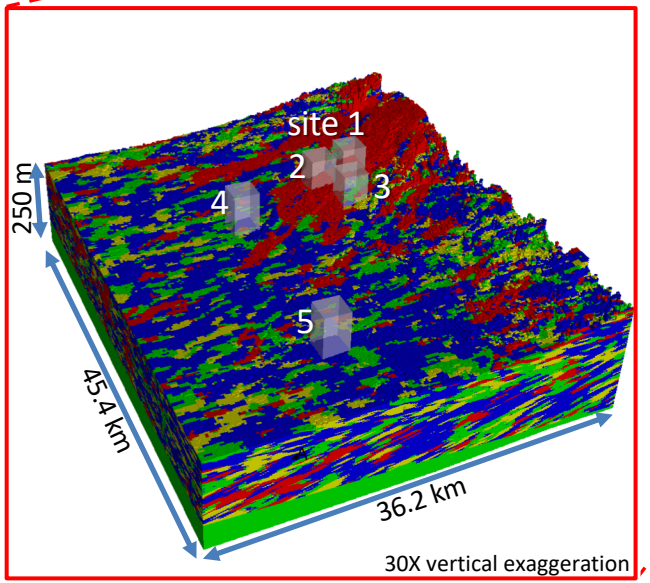
Detailed Groundwater Model
American-Cosumnes Basin

(Stephen Maples)





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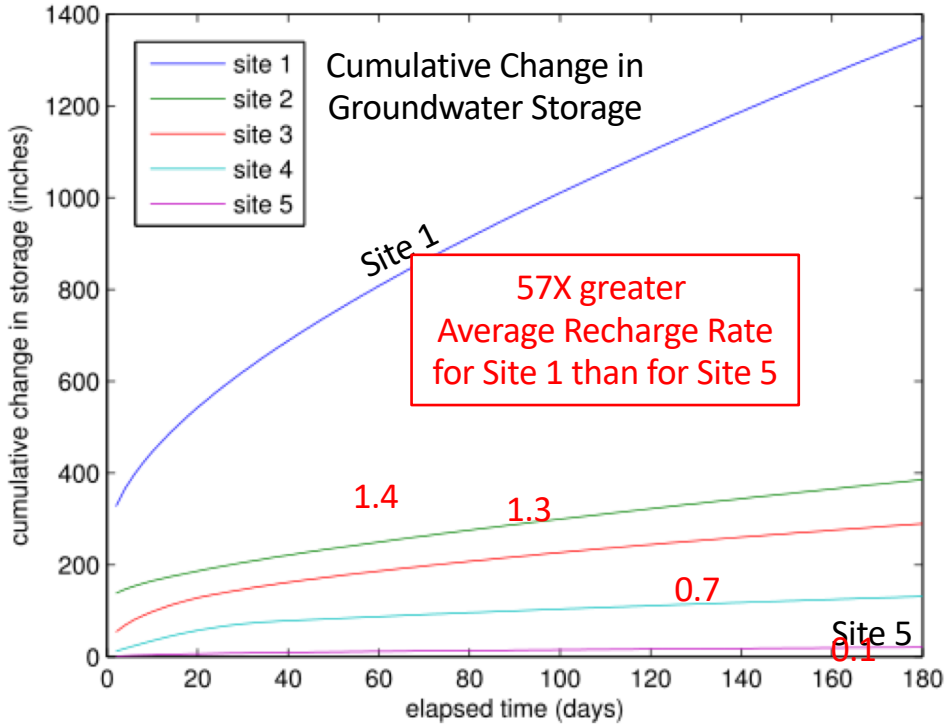
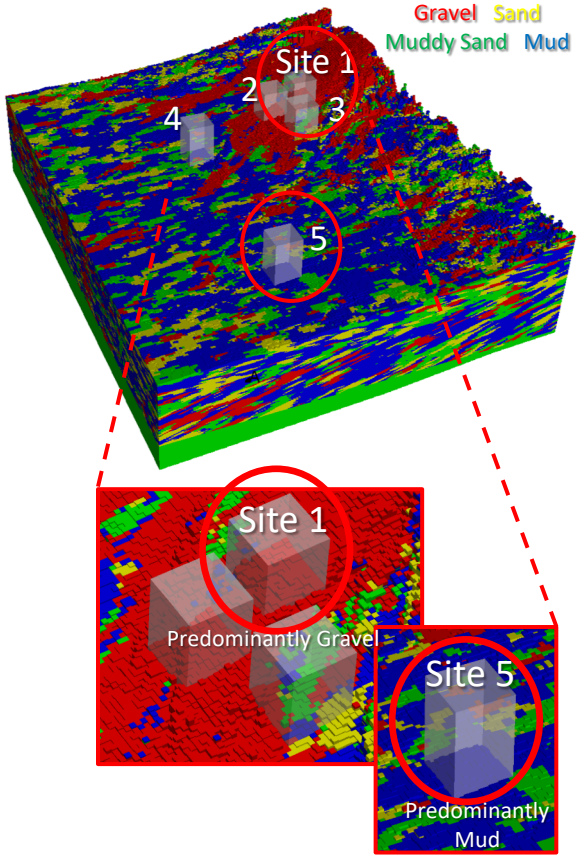
Model Results

Domain-Wide Change-in-Storage Response for Each MAR Simulation

Large Range of Responses Across Sites as a Function of Geology

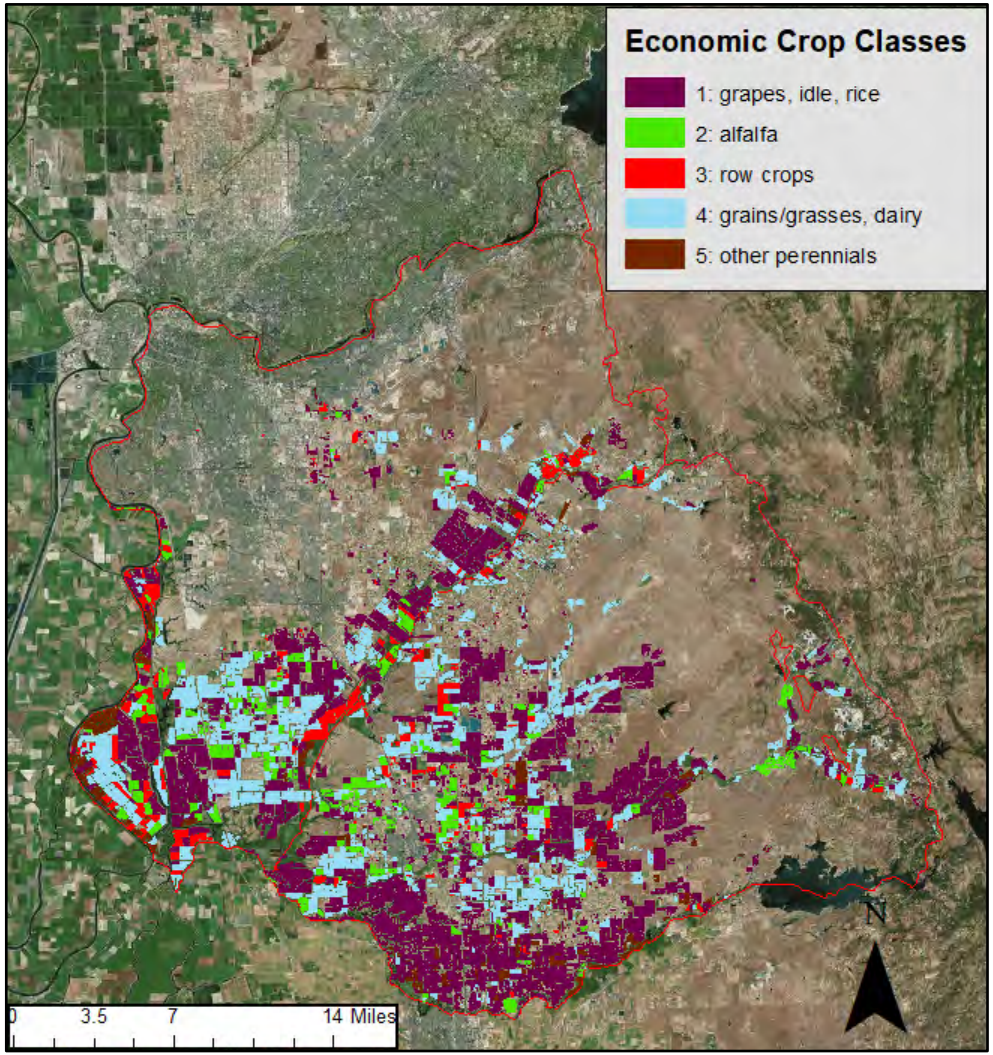




GROUNDWATER SYSTEM REOPERATION: Groundwater Hydroeconomic Model

(Rob Gailey)

Modeling of Groundwater System (w/C2VSIM) and Economic Optimization Based on Crop Value



Peer-Reviewed Papers on Flood-MAR, American-Cosumnes Basin

Reservoir reoperation

- Goharian, E., M. Azizipour, S. Sandoval-Solis, and G. E. Fogg. "Surface Reservoir Reoperation for Managed Aquifer Recharge: Folsom Reservoir System." Journal of Water Resources Planning and Management 146 (12): 04020095. https://doi.org/10.1061/(ASCE)WR.1943-5452.0001305. 2020.

Exploitation of the subsurface geology

- Maples, S. R., G. E. Fogg, and R. M. Maxwell. "Modeling Managed Aquifer Recharge Processes in a Highly Heterogeneous, Semi-Confined Aquifer System." Hydrogeology Journal 27 (8): 2869–88. https://doi.org/10.1007/s10040-019-02033-9. 2019.
- Maples, S. R., L. Foglia, G. E. Fogg, and R. M. Maxwell. "Sensitivity of Hydrologic and Geologic Parameters on Recharge Processes in a Highly Heterogeneous, Semi-Confined Aquifer System." Hydrology and Earth System Sciences 24 (5): 2437–56. https://doi.org/10.5194/hess-24-2437-2020. 2020.

Hydroeconomic system model calculations of increased recharge via Ag-MAR and exploitation of the geology

- Gailey, R.M., G.E. Fogg, J.R. Lund, J. Medellín-Azuara, Maximizing on-farm groundwater recharge with surface reservoir releases: a planning approach and case study in California, USA. Hydrogeology Journal, https://doi.org/10.1007/s10040-019-01936-x, 2019.

Summary of UC Water Work on Flood-MAR, American-Cosumnes Basin

- Avg. water available for recharge (WAR) through reservoir reoperation and hi-magnitude flow diversions < Delta outflow requirements:
  - **0.52 MAF/yr**
- Hydroeconomic model predictions for 1984-2003, winter farm spreading only:
  - **36% of WAR used**
  - **Recharged: 3.9 MAF**
  - **Stored: 2.4 MAF (62%)**
  - **Streamflow increases: 0.7 MAF (18%)**
  - **Flow to other basins: 0.76 MAF (20%)**
- Hydroeconomic Model predictions for 1984-2003, winter farm spreading & exploitation of the geology:
  - **50% WAR used**
  - **Recharged: 5.4 MAF**
  - **Stored: 3.7 MAF (68%)**
  - **Streamflow increases: 0.87 MAF (16%)**
  - **Flow to other basins: 0.89 MAF (16%)**

Key Points & Background continued

- Ingredients for success (see http://ucwater.org/rechargeroundtable)
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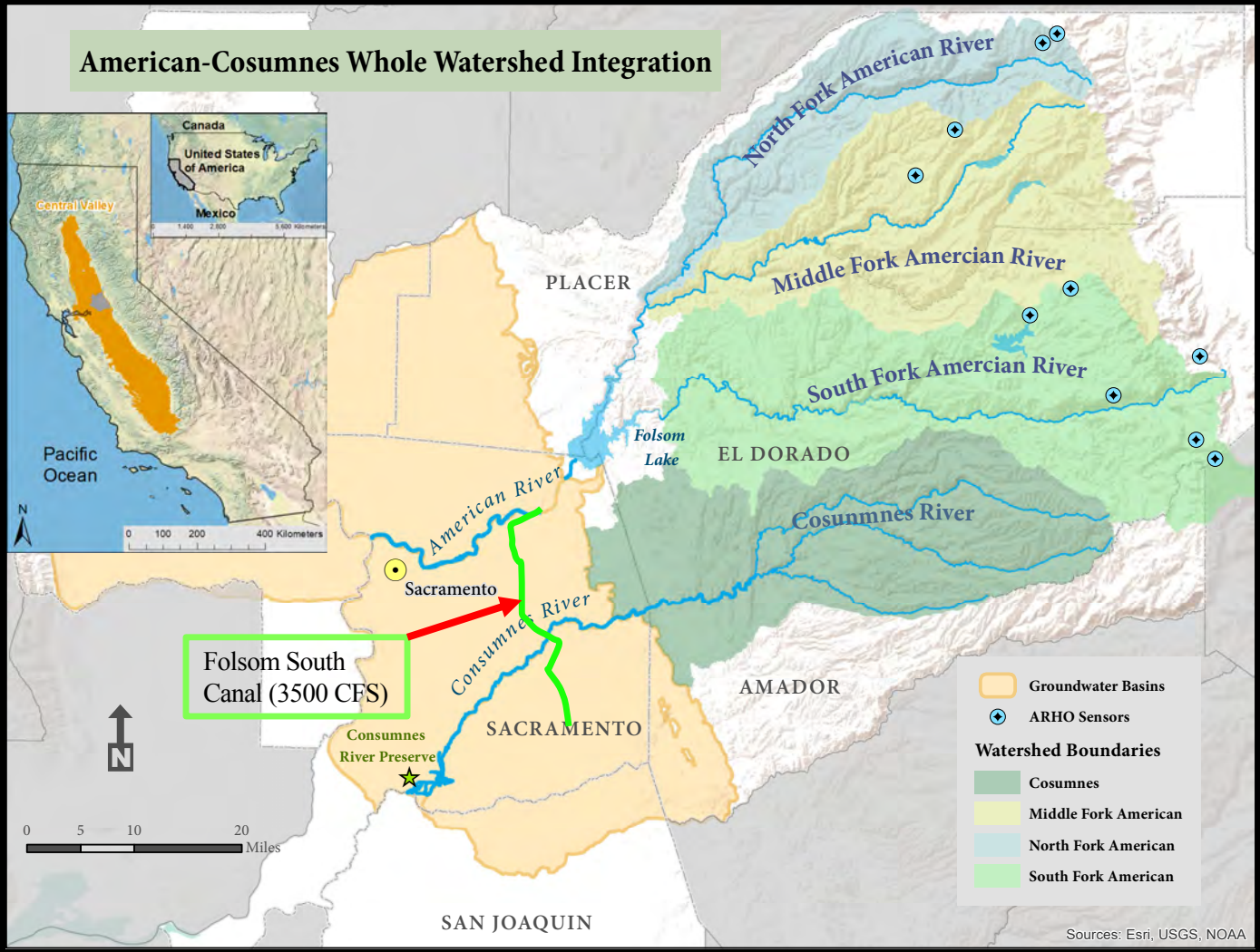
The ‘Ingredients for success…’

http://ucwater.org/rechargeroundtable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North Fork American River
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Watershed Boundaries
Cosumnes
Middle Fork American
North Fork American
South Fork American
Sources: Esri, USGS, NOAA

Problems Addressed by Increasing Groundwater Storage

- Greater total water stored in watershed; greater water security; less overdraft
- Mitigation of effects of overdraft on disadvantaged communities (shallow wells)
- Mitigation of effects of overdraft on groundwater dependent ecosystems
- Potential stabilization of declining groundwater quality from non-point sources
- Stabilization of declining groundwater quality due to intra-basin salt concentration and redistribution from rocks to the water

Summary

- Flood-MAR has tremendous, unrealized potential
  - Up to 270,000 ac-ft/yr in American-Cosumnes groundwater ‘reservoir’
  - Significantly less potential in southern Central Valley without moving water south of Delta and conveyance improvement