

Water Security, Drought and Climate Change: A California Perspective (...and a Flood-MAR Example [Flood Managed Aquifer Recharge])

Graham Fogg¹, Erfan Goharian^{1,2}, Robert Gailey^{1,3}, Stephen Maples¹, Sam Sandoval¹

¹University of California, Davis; ²Univ. of South Carolina; ³R.M. Gailey Consulting Hydrogeologist
gefogg@ucdavis.edu, goharian@cec.sc.edu, rob@rmgailey.com, srmapp@ucdavis.edu, samsandoval@ucdavis.edu

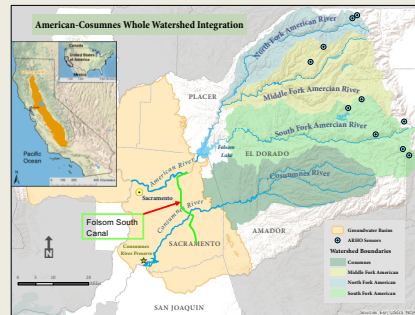
The Challenge

- Estimated California water overdraft = 1.1 to 2.4 MAF (1.4 – 3 km³) due to groundwater exploitation
- Mediterranean climate: nearly all precipitation occurs during Nov-March
- Hence water storage is paramount
- Key historical storage mechanisms:
 - Snowpack (~15 MAF [18.5 km³] in Sierra Nevada)
 - Surface reservoirs (~42 MAF [51.8 km³])
- During multi-year drought the surface storage provides only 2-3 yrs of water security
- Historically, bulk of the snowmelt runoff occurred during April-July, satisfying peak demand for cities, ecosystems and irrigated agriculture, which produces nearly half of the U.S.'s fruits, nuts & vegetables
- With climate warming more precipitation is falling as rain rather than snow, and the snow is melting sooner, greatly reducing stores of water in surface reservoirs
- Due to climate change, the increased likelihood of extreme drought and extreme flood events further exacerbate reliability of surface storage
- CA in 2014 passed the Sustainable Groundwater Management Act, requiring the elimination of groundwater overdraft

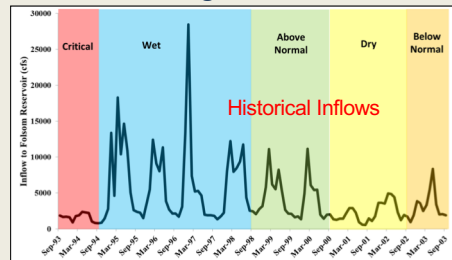
The Flood-MAR Opportunity

- Massive space for storage of *additional* water in the Central Valley aquifer system: ~142 MAF (175 km³)
- Under climate change, possibly little change in mean annual precipitation, despite increasing extremes
- Under climate change, rivers flowing from the Sierra and traversing the Central Valley floor (above the aquifer system) will have more high-magnitude flows in winter
- In areas with the most space for increased groundwater storage, the rivers are losing
- Millions of acres of inactive (in winter) farmland with irrigation infrastructure for spreading water for recharge.

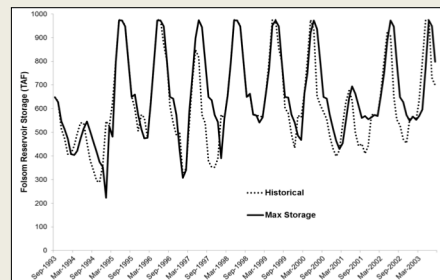
American-Cosumnes Basin Case Study



1. Strategy: Apply Flood-MAR Methods During 1993-2003...



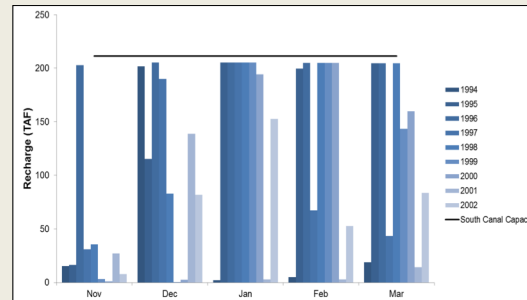
2. ... Including Reoperation of Reservoir to Optimize for Hydropower, Res. Storage & Groundwater Recharge...



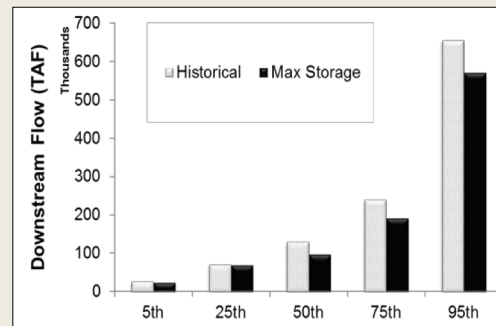
REFERENCES keyed to numbered modules above

- ¹⁻⁴ Goharian, E., R. Gailey, G.E. Fogg, S. Sandoval, M. Conklin, and M. Safeeq. Integrated watershed management and whole- system reoperation to maximize total water storage in American-Cosumnes River Basin http://ucwater.org/sites/default/files/UCWater_Integrated_American_Cosumnes.pdf. Accessed February 25, 2018.

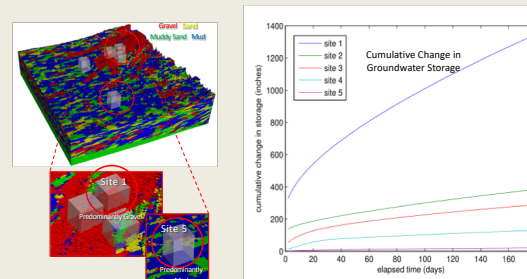
3. ... Produces ~0.52 MAF/yr (0.64 km³)
Water Available For Recharge (WAR) ...



4. ... While Maintaining Essential Env. Downstream Flows

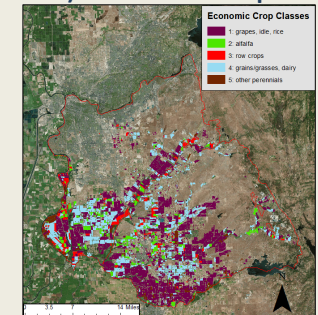


5. Hi-Resolution Aquifer Characterization Identifies Optimal Geologic Locations...

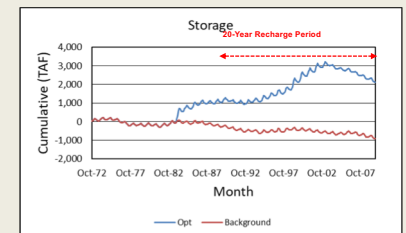


- 5 Maples, S., G. Fogg, R. Maxwell. Strategic Siting of Managed Aquifer Recharge: Maximizing Recharge Potential by Leveraging Geologic Heterogeneity in Sedimentary Groundwater Basins. In prep. 2019.

6. ... Modeling of Groundwater System (w/ C2VSIM) and Economic Optimization...



7. ... Predicts Water Recharged and Stored...



8. ... Predicts Water Recharged and Stored Via Winter Farm Spreading...

36% WAR used
Recharged: 3.9 MAF (4.8 km³)
Stored: 2.4 MAF (62%)
Streams: 0.7 MAF (18%)
Other Basins: 0.76 MAF (20%)

9. ... and Via Both Farm Spreading And Exploitation of the Geology...

50% WAR used
Recharged: 5.4 MAF (6.7 km³)
Stored: 3.7 MAF (68%)
Streams: 0.87 MAF (16%)
Other Basins: 0.89 MAF (16%)

- 6-9 Gailey, R.M., Approaches for Groundwater Management in Times of Depletion and Regulatory Change. Univ. of CA, Davis Ph.D. Dissertation. 276 p., 2018.
- 6-9 Gailey, R.M., G. Fogg, J. Lund, J. Medellin- Azuara. Maximizing on-farm groundwater recharge with surface reservoir releases: a planning approach and case example. *Hydrogeology Journal*, in press. 2018.