Water Security, Drought and Climate Change: A California Perspective

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Abstract

Water security hinges on water storage. Although the public and water resources planners habitually look to surface reservoirs for storage solutions, by far the largest 'space' to store water is underground. The very nature of freshwater distribution on Earth foreshadows future water storage solutions, as 97% of all circulating freshwater globally is in groundwater. Similarly, although 140 surface reservoirs in California can store 52 km3(42 MAF), in the Central Valley aquifer system there is room for another ˜170 km3(˜140 MAF) owing to past depletion. Despite the state's Mediterranean climate in which nearly all of the precipitation occurs between November and March when demand is lowest, historically massive snow storage and spring-summer snow melt synchronized well with surface reservoir replenishment during April-July. This system built around snow storage as a means of mitigating winter flood threats and delaying runoff until the beginning of the peak demand season is clearly demonstrating significant vulnerabilities to climate change and drought. Climate warming has already produced decades of declining snowmelt runoff, making surface reservoir storage more difficult. Moreover, as demonstrated during the 2012-16 drought, in the face of droughts longer than a few years, the surface storage offers inadequate long-term water security. This fact, the fact that California during pre-development times of the last millennium experienced far longer droughts, and ongoing climate change clearly indicate the need for a different strategy that more fully leverages both surface and subsurface storage. Kocis and Dahlke (2017) show that increasing winter runoff during wet and normal years provide enough high-magnitude flows to support a strategy of diverting flood flows for groundwater storage. This "flood-MAR" (managed aquifer recharge) approach will require a massive change in winter water and land management that exploits recharge opportunities on irrigated farm lands and in areas with suitable soils and subsurface geology. A case study in the American-Cosumnes Rivers portion of the Central Valley shows how total system water storage can be increased dramatically through diversion of high-magnitude flows and reoperation of both the surface and subsurface reservoirs including economic incentives.

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(…and a Flood-MAR Example [Flood Managed Aquifer Recharge])

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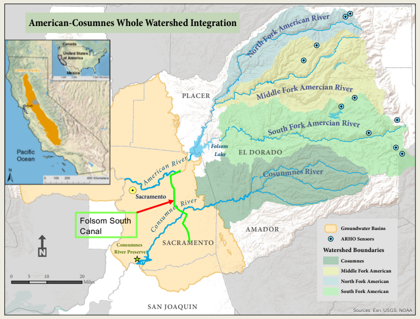
The Challenge

- Estimated California water overdraft = 1.1 to 2.4 MAF (1.4 – 3 km^3) 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 km^3] in Sierra Nevada)
  - Surface reservoirs (~42 MAF [51.8 km^3])
- 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

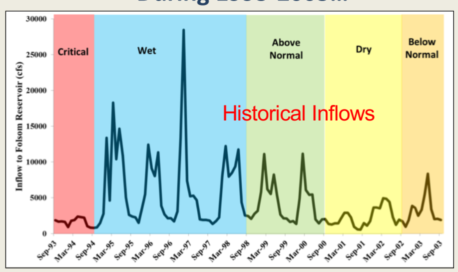
The Flood-MAR Opportunity

- Massive space for storage of *additional* water in the Central Valley aquifer system: ~142 MAF (175 km^3)
- 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.

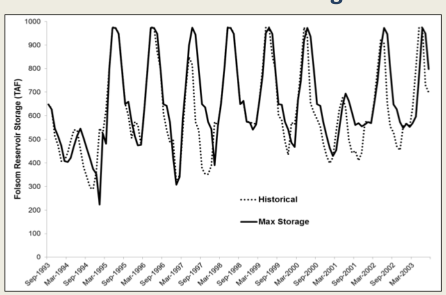
American-Cosumnes Basin Case Study



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



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



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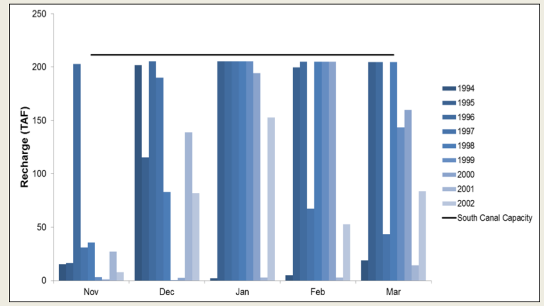
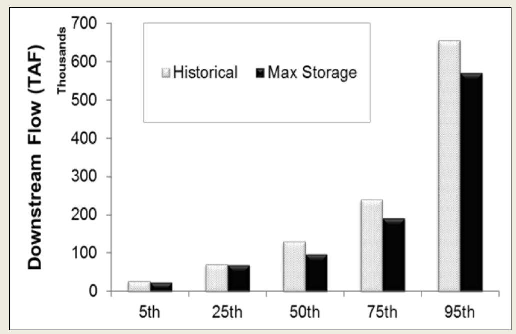
1-4 Goharian, E., R. Gailey, G.E. Fogg, S. Sandoval, M. Conklin, and M. Safeeq. Integrated watershed management and whole- system reoperation to maximize total water storage in American-Cosumnes River Basin http://ucwater.org/sites/default/files/UCWater_Integrated_American_Cosumnes.pdf, Accessed February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

1-4 Goharian, E., S. Sandoval, G. Fogg,. Estimating Available Flood Water for Managed Aquifer Recharge in American River Basin, California. In prep. 2019.

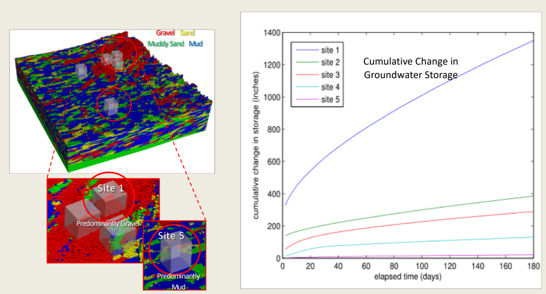
3. … Produces ~0.52 MAF/yr (0.64 km^3) *Water Available For Recharge (WAR)* …



4. … While Maintaining Essential Env. Downstream Flows

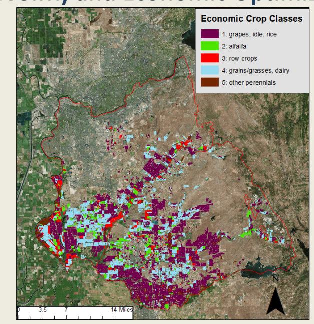


5. Hi-Resolution Aquifer Characterization Identifies Optimal Geologic Locations…

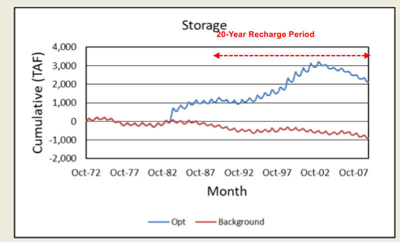


5 Maples, S., G. Fogg, R. Maxwell. Strategic Siting of Managed Aquifer Recharge: Maximizing Recharge Potential by Leveraging Geologic Heterogeneity in Sedimentary Groundwater Basins. In prep. 2019.

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 km^3)

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 km^3)

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.