INFORMATION ITEM

Lead Scientist Report

Summary

Managed aquifer recharge (MAR) has been proposed as a priority solution for reversing groundwater depletion in the Central Valley and enhancing statewide storage. Policy decisions about MAR will implicate the Delta because they will likely entail reduced inflows and/or increased exports during high-flow periods. Planning MAR projects is complicated, involving complex calculations of cost, recharge locations, diversion locations, and threshold flows that trigger operations. In this article, the research team developed a tool that can find optimum solutions that maximize storage while minimizing cost, equipping stakeholders with ways to explore economic and water storage outcomes that are possible with different choices of policy, investment level, and engineering design. While solutions that extract water from the Delta are among the most cost-efficient for the levels of groundwater storage possible, the absolute cost starts at a higher level because of the larger infrastructure, pumping, and land acquisition costs required, though attainable storage is also much higher.

Optimizing Managed Aquifer Recharge Locations in California's Central Valley Using an Evolutionary Multi-Objective Genetic Algorithm Coupled With a Hydrological Simulation Model

Kourakos, G., Brunetti, G., Bigelow, D. P., Wallander, S., & Dahlke, H. E. (2023). Optimizing managed aquifer recharge locations in California's Central Valley using an evolutionary multi-objective genetic algorithm coupled with a hydrological simulation model. Water Resources Research*, 59, e2022WR034129. https://doi. org/10.1029/2022WR034129*

During the past several years of drought, Central Valley water users have compensated for reduced exports from the Delta by extracting groundwater. Groundwater extraction has cumulatively exceeded replenishment, with consequences of land subsidence, reduced water quality, and increased costs of pumping water up from greater depths, or loss of use of wells altogether. Managed aquifer recharge (MAR), in which surface water is either directly pumped underground or allowed to percolate downward to groundwater from an inundated portion of the land surface (see visual summary), has been proposed as a solution for the dual challenges associated with groundwater depletion and the need for increasing water storage statewide, as identified in the Newsom Administration's "California's Water Supply Strategy: Adapting to a Hotter, Drier Future." Implementation, however, has many challenges. For one, to avoid infringing on water rights allocations or ecosystem water needs, diversion of water for MAR can only be done during infrequent, high-flow periods, such as the ones experienced this year. Secondly, MAR may require land acquisition and development of new infrastructure to transport excess water from rivers and aqueducts to the point of recharge. If the recharge point is at a higher elevation than the point of diversion, pumping will be required. Last, not all points of recharge are equal; at some locations, much of the water recharged into aquifers may end up "leaking" back into waterways, resulting in low storage efficiency.

Given the many possible points of diversion of water for MAR within the Central Valley, combined with many potential points of recharge, each of which is associated with different costs and efficiencies, sophisticated models are needed to determine strategies that maximize groundwater storage while minimizing costs. The research team, federally funded through the US Department of Agriculture and National Science Foundation, used a combination of a groundwater model and what is known as a "genetic algorithm"—a technique designed to efficiently search for optimal solutions in a manner inspired by evolution. In evolution, random mutations and mating create genetic variation, and "survival of the fittest" determines which genes are selected to persist in future generations. In the genetic algorithm used here, random choices of diversion points or recharge areas are the "genes," and the fitness of each individual solution is assessed based on overall cost and groundwater storage. The fittest individual solutions are selected for further random mutation (i.e., slight changes to the selected diversion points and/or recharge areas) and mating (i.e., combination with elements of other "fit" solutions), and the new "generation" of solutions is evaluated with the groundwater model to assess whether new optimum combinations of cost and storage evolved.

The team of investigators completed this procedure for finding optimum combinations of cost and storage for 12 different scenarios that represented different capacity restrictions for the infrastructure (i.e., two different caps for maximum conveyance at 100,000 and 200,000 acre-ft per month, where an acre-foot refers to water that covers one acre at a depth of one foot—the annual residential water supply of slightly under 10 Californians), different permitted flow levels that would trigger recharge (i.e., flows that are exceeded 10% of the time, versus flows that are exceeded only 5% of the time), and different source waters (i.e., ten tributaries of the San Joaquin River; ten tributaries plus the Central Valley

Project's Friant-Kern Canal; or ten tributaries plus the Friant-Kern Canal and the Delta, via the State Water Project). These scenarios represent different policy decisions that would involve consideration of environmental tradeoffs associated with reduced high flows in each of the source waters, as well as engineering tradeoffs associated with building and maintaining capacity of the infrastructure used for MAR.

Across the 12 different scenarios, optimum solutions exhibited an increase in cost as groundwater storage increased, as new gains in storage requires placing recharge areas in increasingly unfavorable locations, far from diversion points and possibly more uphill. Consistent locations for recharge emerged as most favorable across all scenarios, including areas south of the Kings and Kern Rivers and close to the San Joaquin River, northwest Kern County, and north of the Stanislaus River. Because of the possibility of operating twice as often, scenarios in which MAR could be activated for the top 10% flow levels (as opposed to the top 5%) had considerably lower costs associated with them per unit of storage gained. On the other hand, while higher diversion capacities (200,000 acre-ft/month vs. 100,000 acre-ft/month) could produce higher stored amounts of water, the cost per unit of storage was considerably higher. In general, the cost per unit of storage gained was lowest for the least restrictive diversions (i.e., diversions allowable from the Delta, Friant-Kern Canal, and 10 San Joaquin tributaries, and for the top 10% flow levels), but with accelerating costs as total storage increased. Overall, optimal solutions resulted in maximum storage capacities that ranged from 4.9 million acre-ft (at a cost of $330 million; top 5% flows, ten San Joaquin Tributaries 100,000 acre-ft/month cap) to 25.9 million acre-ft (at a cost of $1.1 billion; top 10% flows, all source waters, 200,000 acre-ft/month cap). (For comparison, Shasta Lake has a capacity of 4.5 million acre-feet, and the proposed Sites Reservoir would gain 1.3-1.8 million acre-ft of storage with a price tag of $4.4 billion). While the higher-storage end of these MAR solutions could be satisfied by just a single scenario, associated with high overall cost, the lower-storage end could be satisfied by multiple scenarios, with a range of costs (e.g., down to $150 million for 4.9 million acre-ft; top 10% flows, ten San Joaquin tributaries, 100,000 acre-ft/month cap). To help stakeholders explore the different combinations of scenarios, locations for diversion and recharge, storage capacities, and costs, the team of investigators developed a web tool that can be accessed at https://dahlke.ucdavis.edu/mar-opt.

Should statewide policy on MAR move forward, the expected impacts on the Delta would lie in reduced inflows from the San Joaquin River during wet periods, and potentially increased exports during those periods, if MAR water is sourced directly from the Delta. Reduced flushing flows may do less to reduce salinization of soils within the San Joaquin River system relative to the current system. Depending on when the reductions to peak flows occur, they may also interfere with cueing migration of fish for spawning and reduce floodplain inundation and its beneficial effects on food webs and fish rearing. More studies would be needed to quantify these tradeoffs thoroughly.

Delta Science Program Activities

Adaptive Management Forum, Part 2

Following a successful Part 1 of the Adaptive Management Forum on May 4, the second part of the Forum took place on June 27. Part 2 built on the theme of adaptive governance explored through plenary sessions and panels in part 1. Participants worked through a visioning process to collaboratively identify aspirational goals for the Delta in the year 2050, the strategies needed to achieve those goals, and the governance components to ensure that strategies could be implemented and maintained. As with part 1 of the Forum, equity and inclusiveness were common threads throughout the conversations. A few examples of goals that the different groups identified were to: 1) create more inclusive governance systems in which all perspectives have a seat at the table, 2) establish an equitable water rights system that is reflective of changing water availability and historical injustices, and 3) develop an equitable, evidence based, and risk-informed governance system where information easily flows. Approximately 15 external participants attended the workshop in person and participated in the breakout sessions, with another five online.

2023 Integrated Modeling Workshop

The Delta Science Program has released a summary report for the 2023 Integrated Modeling Framework Workshop. The workshop, held in February and March 2023, featured presentations, panels, and breakout group discussions about the challenges and opportunities of developing an integrated modeling framework and collaborative modeling center for the Delta.

The comprehensive summary report captures the full set of topics covered during the two-day workshop and provides a short summary of every workshop session. In addition to providing detailed information about the workshop contents, the summary report is also intended to serve as a foundation for development of a white paper highlighting key recommendations and near-term actions critical to advancing the vision of collaborative and integrative modeling for the Delta. The workshop summary will be available on the Council's website here: https://deltacouncil.ca.gov/delta-science-program/integrated-modeling-steering-committee.

State of Bay Delta Science Summary

The Delta Science Program has now released an Executive Summary of the 2022 edition of the State of Bay-Delta Science (SBDS), which focuses on the ecosystem services (e.g., beneficial aspects) and disservices (e.g., negative impacts) of plants and algae in the upper San Francisco Estuary. The 2022 SBDS Executive Summary includes non-technical summaries of all seven chapters and highlights the key points and recommendations provided by each chapter for future Bay-Delta management and science initiatives. The Executive Summary is available on the Council's SBDS website: https://sbds.deltacouncil.ca.gov.

National Center for Ecological Analysis and Synthesis Working Group

As part of its core function of providing science synthesis (i.e., answering large-scale questions through analyses that combine multiple datasets and studies), the Delta Science Program has again partnered with the National Center for Ecological Analysis and Synthesis (NCEAS) (https://www.nceas.ucsb.edu/) to lead a collaborative working group in summer and fall 2023. NCEAS regularly facilitates working groups to address important science questions through synthesis approaches while providing training to early-career scientists and the broader science community. The 2023 partnership with NCEAS was designed to address gaps in understanding the human dimensions of the Delta, identified in the Delta Social Science Community of Practice's Advancing Interdisciplinary Research Training and Workshop (https://deltacouncil.ca.gov/pdf/science-program/2023-02-01-air-event-summary.pdf), which took place in October 2022.

On June 26-30, 16 early career scientists from state agencies (Delta Conservancy, San Francisco Estuary Partnership, Department of Water Resources, State Water Resources Control Board, CalEPA's Office of Environmental Health and Hazards Assessment, and California Department of Fish and Wildlife) and academia (UC Davis and UC Merced) met for the first week of training. Specifically, the 2023 working group's theme involves multi-benefit approaches to managing the Delta as a social-ecological system and integrating human dimension data into research and management decision making. The group will work together through the summer to build shared skills and exchange understanding of best practices on data management and open-source coding. Throughout the fall, they will work collaboratively on applied data synthesis projects related to key questions in the Delta that focus on the human dimensions of natural resource management.

The Delta Science Program previously partnered with NCEAS in 2021 for a synthesis working group investigating drivers of the estuarine food supply, and results from that effort were presented to the Council in January 2023. Additional information about these synthesis working groups, including access to training materials, can be found on the Council's website: https://deltacouncil.ca.gov/delta-science-program/science-synthesis-working-group.

On Your Radar

New nutria detections in the Delta and Suisun Marsh

Nutria (*Myocastor coypus*) are large, semi-aquatic rodents native to South America. Outside of their native habitat, nutria can be damaging to wetlands, agriculture, and water or flood infrastructure. For example, they feed on plant material and crops and burrow up to 50 meters into banks and levees. They can also halt wetland accretion, making wetlands vulnerable to inundation and irreversible loss. Their discovery in California in 2017 caused alarm for protecting California's vulnerable ecosystems and water infrastructure. Since then, just over 3,500 nutria have been removed by the California Department of Fish and Wildlife (CDFW) – the state agency leading the effort to eradicate nutria from California – from Merced, Stanislaus, Fresno, San Joaquin, Sacramento, Mariposa, Solano, and Madera counties.

Despite efforts to keep nutria out of the Sacramento-San Joaquin Delta (Delta), considering their potential significant impacts to the area, the first reproducing population of nutria was discovered within the legal Delta boundary south of Lathrop in September 2018. Over 100 nutria have been removed from that specific location in Walthall Slough since, with the last nutria taken in March 2021. The only other Delta detections occurred in May 2019 and February 2021, when nutria were detected near Rough and Ready Island and French Camp Slough. In October 2022, a group of nutria was detected on lower Sherman Island.

In April 2023, the CDFW Nutria Eradication Program (NEP) made a temporary operational shift, increasing staff presence and expanding north, further into the Delta. This significant shift of nearly all NEP field staff is an early detection-rapid response effort to address any nutria that were potentially washed into the Delta from flooding and high flow events in the San Joaquin River system, where nutria were actively being trapped (i.e., in Stanislaus County).

In May 2023, the NEP conducted the first nutria detector dog field trials throughout the project area. During the field trial, the dogs located an additional area of nutria presence, and scat was identified on Sherman Island. Following that detection, a total of eight additional nutria were trapped and removed from the area, with the last taken on June 1st. The detector dogs surveyed multiple currently and previously infested sites within the project area, including Walthall Slough and near Rough and Ready Island. While the dogs consistently detected nutria in sites known or suspected to be infested, they did not detect any nutria present at the Delta sites with previous detections or infestations. The nutria detector dogs program, funded by a Delta Conservancy Prop 1 grant, will be an increasingly valuable tool as nutria densities decrease and the remaining animals become increasingly difficult to detect.

With the expanded operations of the NEP into the Delta, one nutria was captured on camera on May 22, 2023, on Hammond Island, to the west of Sherman Island. Trapping operations and intensified survey efforts commenced immediately to detect the extent of the nutria presence and rapidly remove the infestation. Since June 1, the department has captured eight nutria on Hammond Island and southern Grizzly Island, including 3 pregnant females. To date, nearly all captures and detections have been adult and subadult animals, with no juveniles or kits yet detected.

Despite the concerns associated with the recent nutria detections in the western Delta, the NEP continues to see steady declines in the annual number of sites with nutria taken, number of nutria taken, and density taken by site. The NEP continues to expand both its Delta-centered staffing levels and its toolbox (e.g., detector dogs, Judas nutria) to continue the early-detection/ rapid-response effort to locate and remove the nutria from the Delta as quickly as possible.

Year	Total (unique) cells with nutria taken	Total # nutria taken	Average # nutria taken per cell
2017	7	20	2.9
2018	57	348	6.1
2019	73	492	6.7
2020	157	1239	7.9
2021	145	703	4.9
2022	112	579	5.2
2023	48	159	3.3
Total Across Years	**440**	**3540**	**8.0**

To learn more about nutria and CDFW's eradication efforts, visit https://wildlife.ca.gov/Conservation/Invasives/Species/Nutria/Infestation.

By the Numbers

Science Program staff will summarize current numbers related to Delta water and environmental management. The summary (Attachment 1) will inform the Council of recent counts, measurements, and monitoring figures driving water and environmental management issues.

List of Attachments

Attachment 1: By the Numbers

Attachment 2: Visual Summary of Managed Aquifer Recharge Article

Contact

Dr. Laurel Larsen

Delta Lead Scientist

Phone: (916) 275-6888