Celebrating Five Years of Flood-MAR: Reflecting on a Creative Climate Adaptation Strategy

December 2023

Flood-MAR is a creative climate adaptation strategy that has come a long way in a short period of time

For the past five years, a group of Californians who work for the State, local public agencies, universities, nonprofits, federal agencies, businesses, and who manage private and public land have worked together to make Flood-MAR a prominent water resources management strategy, particularly in the Central Valley. Using floodwaters for managed aquifer recharge, "Flood-MAR," is a climate adaptation that uses one challenge, flood events, to solve another challenge, groundwater overdraft.

The story of how Flood-MAR moved from being a concept held and practiced by a few to being the organizing principle of the California Governor's Executive Order (EO) N-4-23 is told in the next few pages. This story is about managing complexity together, and how working together is the best way to overcome interconnected physical, social, and policy challenges.

The pace at which the practice of Flood-MAR has advanced in California is testament to the power of collaborative action, and how innovation and opportunity can drive rapid transformation. It is also a quintessential example of the broad-spectrum climate adaptation that is needed here in California and elsewhere.

The increasing capacity to practice Flood-MAR and groundwater recharge in the Central Valley of California set the stage for Governor Newsom to expedite regulatory pathways for recharge under multiple drought emergency measures, culminating in Executive Order N-4-23, issued March 10, 2023, that temporarily suspended certain regulations in recognition of

the increased flood risks posed by the historic winter precipitation. These executive actions and the significant preparations made in the past five years allowed Flood-MAR to mobilize on a scale not yet seen in the state.

The EO was the result of a historic rainfall year, following years of drought and decades of dwindling groundwater resources. Thirteen moderate and strong atmospheric rivers brought record-breaking levels of precipitation to the state. This quantity of rain and snow simultaneously activated emergency flood protection measures in many areas while also providing an opportunity for groundwater managers to use the flood waters to recharge depleted aquifers. EO-4-23 alleviated pressures on flood management and broadened accessibility for floodwaters to be used for groundwater recharge.

Figure 1. A drone view shows Discovery Park near downtown Sacramento, California, flooded by high water from the American and Sacramento rivers. Photo taken January 9, 2023. Photo credit Kenneth James, California Department of Water Resources.

California's relationship to water is a "Tale of Two Extremes"

The past five years have been exactly what climate projections have long held about how California is being impacted by climate change — more and deeper dry years, and fewer but more intense wet years. We can expect the extremes of too much or too little water at any given time to become more pronounced as the future unfolds.

In addition to surface water reservoirs, much of the state's water supplies rely on the natural bounty that the Sierra Nevada and deep aquifers provide. Each year, winter snow stored on the mountains melts in the spring and summer months and drains into the Central Valley through rivers and underground percolation. For millennia, that snowmelt filled streams, fed massive wetland complexes, and recharged groundwater basins.

Recently, however, rising temperatures driven by climate change are converting precipitation that would have fallen as snow in the mountains into rain. Reductions to the snowpack limit the landscape's natural ability to re-water itself in the drier months. Managing the increased amount of winter rain is also a challenge for the flood management and water resources systems, as reservoir operations adapt to massive fluxes in storage.

The effects of California's climate extremes will make flood protection and drought resiliency for communities and ecosystems more difficult to achieve in the years to come. That said, Flood-MAR sees these two challenges as potentially able to solve one another.

California has come to increasingly rely on dwindling groundwater resources. SGMA is the result.

Starting in the 19th century and throughout the 20th, water managers and farmers transformed the wetlands and floodplains of the San Joaquin and Sacramento valleys for a variety of purposes, including the expansion of irrigated agricultural lands. Eventually surface water supplies became less reliable or inadequate, either as a result of competing water demands (environmental laws were concurrently going into place to protect river flows for fish and

other aquatic species) or reduced summer supplies in dry years. To make up for the shortfall, farmers turned to then-plentiful groundwater aquifers for their irrigation supply. Nowadays, groundwater makes up 40 percent of California's water supply in most years. In dry years, that figure jumps to 60 percent.

By the mid to late 20th century, irrigated agricultural water demand had expanded to a degree that groundwater reserves were dwindling, causing an array of unintended consequences not limited to declining groundwater levels, degraded water quality, and land subsidence. Unlike surface water, there were no regulatory or policy limits to how much water people could pump from the ground under their properties.

By the 2000s, it was clear that dry year groundwater pumping would continue to outstrip wet year groundwater recharge. The Sustainable Groundwater Management Act of 2014 (SGMA) was the result, placing a regulatory mandate behind the idea that how we use groundwater today cannot jeopardize how our future selves can use groundwater tomorrow. SGMA requires that local groundwater basins reckon with the needs of all beneficial uses and users of groundwater to establish balance and reach sustainability.

Recharging California's depleted groundwater aquifers has become a focal point

Generally, water managers and users can support groundwater sustainability by reducing demands on groundwater pumping, increasing water supplies, or doing both. Many have looked to increasing groundwater recharge to better store the water that falls on hills and mountains in wet years for use in future dry years (in a sense, conveying that water through time rather than across space). This mimics the natural systems that once filled the groundwater basins that are now depleted.

When water inundates a land area, gravity works to move it below the surface, into the spaces between soil particles. As water above the ground's surface can be stored in constructed reservoirs, so too can water under the ground be stored in naturally occurring aquifers. Moreover, California's underground aquifers are ten times as large as California's surface water reservoirs. The underground

capacity for storing additional water in the Central Valley groundwater system is about 140 million acre-feet. Parts of the landscape, like large flat areas, can be used to intentionally encourage water to sink down into the ground. This process is called managed aquifer recharge, or "MAR."

Because surface water supplies are already stretched thin, initiatives such as Flood-MAR are finding creative sources of water for managed aquifer recharge. In the case of Flood-MAR, that source is high flows caused by precipitation or snowmelt or releases from reservoirs to create flood management control space. In this way, Flood-MAR presents the opportunity to solve both drought and flood challenges at once, and at the same time create additional opportunities to enhance ecosystems, improve water supply reliability, preserve working landscapes, and achieve other benefits.

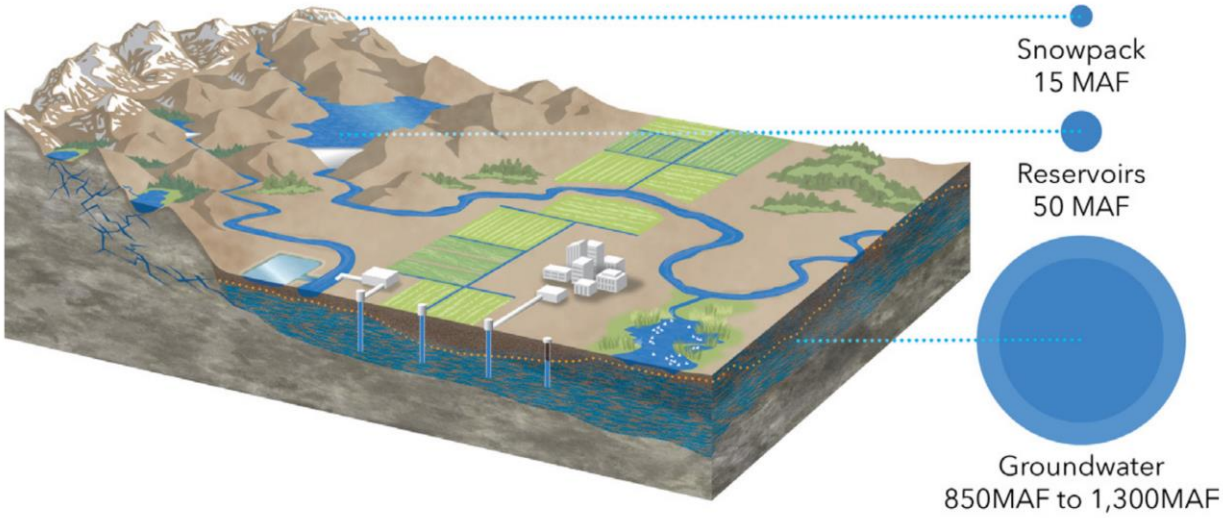

Figure 2. Diagram of California's water system depicting the relative storage volumes of water in snowpack (15 million acre-feet), reservoirs (50 million acre-feet), and groundwater aquifers (850 to 1,300 million acre-feet). Adapted from a 2023 paper published by DWR.

Early days: exploring possibilities

Preparing Groundwater Sustainability Plans under SGMA highlighted the need for healthier aquifers at the same time that Californians were recognizing the urgency of investing in flood protection and drought resilience for communities and ecosystems. By 2017, several areas in the state had started the

work of investigating ways to recharge water on the landscape.

Some of the early State efforts included public workshops held by the California State Board of Food and Agriculture (CDFA) and California Department of Water Resources (DWR) in 2017 and 2018. A DWR white paper documented the need for greater use of Flood-MAR in the state and laid out a framework for what that might entail. That paper included a suite of next steps, many of which required research and the collection of data to inform new policies, practices, permitting processes, projects, and funding pathways.

Into this need, a multi-disciplinary group of subject matter experts were sponsored to identify the research, data, guidance, and tools necessary to support more widespread implementation of Flood-MAR. State staffers were paired with external professionals (academics, practitioners, nongovernmental organizations, consultants, Tribes, government agencies, and professional associations) to co-Chair subcommittees and prepare recommendations across thirteen categories considered essential for Flood-MAR implementation in California.

This Research Advisory Committee (RAC) met three times between November 2018 and July 2019 to review the subcommittees' work, select three priority actions for each topic area, and memorialize their work in the Research and Data Development Plan. Significantly, the members of the Committee recognized how vital the interdisciplinary discussions had been to expanding familiarity across disciplines, seeing interdependencies between issues, steps to be sequenced, and priorities to be sorted out.

At a forum held in October 2019, participants grew to appreciate that practicing Flood-MAR required many overlapping and interdependent actions to take place. To achieve that level of coordination, an unprecedented level of interdisciplinary partnership would be needed. A key outcome of the forum was a broad consensus in the RAC's recommendation to initiate and sustain a Flood-MAR Network.

Figure 3. Attendees collaborate in small groups during the 2019 Flood-MAR public forum, held at California State University of Sacramento in Sacramento, California on October 28, 2019. Photo Credit: Jonathan Wong, California Department of Water Resources.

The work of the Flood-MAR Network

Answering the call of the forum and the RAC, DWR empowered a facilitation and coordination team to help the Flood-MAR Network organize itself. Through a series of workshops, individuals and organizations identified what they had to gain and what they had to give to each other in pursuit of their common goal.

Because Flood-MAR requires broad cooperation and collaboration to implement, members of the new Network knew they wanted to leverage their combined expertise to learn and act. The Network cemented information-sharing and cultivating connections with potential collaborators as their organizing principles and set a shared agenda for themselves to accomplish those goals.

On this work agenda are relatively informal monthly lunch-time webinars to share presentations with the broader audience (the series is playfully referred to as "Lunch-MAR"); learning circles on specialized topics (for example, there is a learning circle on Forecast-Informed Reservoir Operations); action teams to

mobilize shared work (for example, an action team successfully worked to launch a Flood-MAR Hub website); workshops for members of the Network to review, reflect, and adjust their shared agenda and launch new endeavors together; and biannual forums which provide a larger platform for sharing information and gathering input from the broader universe of Flood-MAR interested parties. At the time of this publication, there have been 26 Lunch-MAR webinars, 11 learning circle meetings, six action teams, nine Network workshops, and four forums, most recently in November 2023.

Figure 4. Attendees listen to presenters during the 2023 Flood-MAR public forum, held at California State University of Sacramento in Sacramento, California on November 7, 2023. Photo Credit: Marisa Perez-Reyes, Stantec.

Since May of 2022, the Network has grown to depend on support from a Coordinating Team comprised of dedicated members who support the Network's momentum and shared work through monthly organizing meetings. A diagram of these collaborators is depicted below. For more information on the Network's formation, see Addressing Complex Problems Together: A Network Story.

As the urgency of California's drought and flood challenges has grown in recent years, so too has the energy to expand Flood-MAR. Since the Network first began its work in 2020, enormous strides have been made in putting Flood-MAR theory into practice.

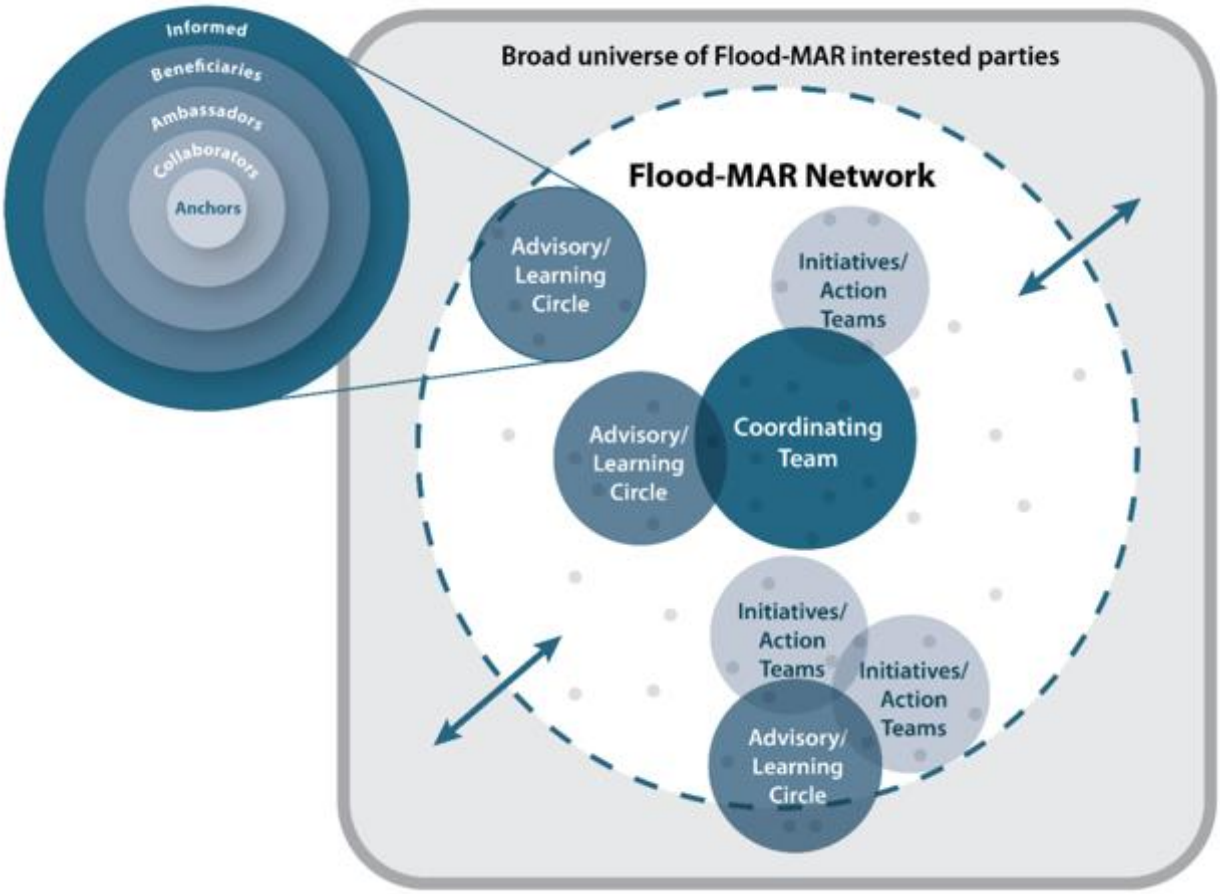

Figure 5. The Flood-MAR Network Structure adapted from Ehrlichman, 2021.

Putting Flood-MAR into action

Credit for the expansion of Flood-MAR practices in California is shared among many: local, regional, State, federal, and Tribal governments and agencies; leaders in the agricultural industry; nonprofits and community-based organizations; universities and research institutes; private landowners; and other stakeholders, have all contributed to changing policies and practices, piloting recharge projects, collecting and analyzing data, building models, constructing infrastructure, coordinating with neighbors, and building knowledge.

Figure 6. Don Cameron, general manager of Terranova Ranch, left, poses for this photograph with Matt Hurley, general manager, McMullin Area Groundwater Sustainability Agency. Recharge water flows through the pipe behind them into a planted field at Terranova Ranch as part of a groundwater recharge system designed to divert floodwater from the Kings River in Fresno County. Photo taken March 13, 2023. Photo credit Andrew Innerarity, California Department of Water Resources.

Pilot recharge studies have laid the groundwork for local water managers and landowners to ready themselves to receive flood water for recharge. One goal of the pilot studies was to identify ways to incentivize participation in Flood-MAR, since the practice has been voluntary. Incentives generally include "crediting" recharged water for later extraction.

Under SGMA, groundwater subbasins set "sustainable yields" that represent the maximum amount of groundwater that can be safely extracted without causing harm. Many places have set groundwater pumping allocations to guarantee the subbasins won't surpass their sustainable yields. Recharge, then, represents a potential opportunity for groundwater pumpers to offset their use by getting credit for the water they "bank" in the subbasin via recharge.

It's worth noting that water districts have been recharging groundwater in dedicated basins and canals for many years, and in urban Southern California, some agencies can claim over 100 years of managed aquifer recharge experience. What has changed is the addition of farmland to the mix. For example, Madera Irrigation District's recharge basins historically topped out at 8,000 acre-feet. In 2019, they were able to more than double that by partnering with growers to recharge an additional 10,700 acre-feet on farms. Tulare Irrigation District was another early adopter of on-farm managed aquifer recharge practices.

For the State's part, DWR has sponsored pilot recharge studies with the San Joaquin River Conservancy, Pajaro Regional Flood Management Agency, Merced Irrigation District, and many other local partners. The Natural Resources Conservation Service also piloted a recharge cost-share program with a few irrigation districts in the Madera, Chowchilla, and Tulare subbasins, with participation from about 20 farmers. Industry leaders like the Almond Board of California and nonprofits like Sustainable Conservation have played key roles in supporting the connections between agencies and landowners. These and other efforts have helped cultivate strong relationships, develop robust incentive programs, and demonstrate how Flood-MAR can be successfully implemented.

Most of the advancements of Flood-MAR occurred in drought and dry conditions. Finding the shared

courage to invest during dry years in preparation for wet years has now proved vital and worth celebrating. A record-breaking 414,000 acre-feet of surface waters were diverted into the Tulare Irrigation District in 2023. Of that volume, a significant amount went toward newly implemented winter irrigation applications that netted groundwater recharge at the field level. Meanwhile, Turlock Irrigation District used the 2023 storms to provide water to three pilot farms, and Madera Irrigation District successfully mobilized an incentive-based recharge program. Efforts are still underway to quantify the total amount of new recharge that occurred in 2023.

Building and sharing knowledge

As the practice of Flood-MAR has matured in the past five years, so too has the associated community of knowledge. Academic institutions, local and State agencies, elected officials, and others have worked together to generate resources and guidance documents, host workshops, and make sense of changing policies.

In partnership with the Merced Irrigation District, DWR has completed a Merced River Watershed Flood-MAR Reconnaissance Study as a proof of concept to explore the effectiveness of Flood-MAR to concurrently reduce flood risk, improve water supply, and enhance ecosystems in the Merced River watershed. Several models and innovative tools were developed and linked for a headwaters-to-groundwater assessment of climate vulnerability and Flood-MAR opportunities at the watershed scale. Both the climate change vulnerability assessments and the performance of Flood-MAR strategies are compelling, demonstrating that Flood-MAR can play an important role in adapting water management and illustrating the value of planning and implementing at the watershed scale. Next steps include expanding analysis to more watersheds and supporting on-the-ground pilot projects. DWR is currently progressing four additional San Joaquin watershed studies with local and regional partners and refining the Merced Study so that results are comparable and integrated.

Accurate data on geologic and hydrologic conditions is essential for narrowing down which land is best suited for recharging groundwater. At local scales,

survey equipment can be towed through orchards or fields to measure soil resistivity (these are called towed transient electromagnetic surveys, towed TEM, or tTEM). On a bigger scale, DWR recently conducted airborne electromagnetic (AEM) surveys, which involved flying helicopters with low-hanging magnetic hoops across much of the state. The soil resistivity data that is collected during the towed and airborne surveys is subsurface data analyzed in combination with other datasets to characterize individual groundwater subbasins. Technical studies and surveys like this are often carried out with support from universities and consultants, local landowners, water districts, and others.

Data viewers and other online tools play an important role in helping to visualize groundwater conditions that would otherwise be hidden below the surface. For example, the groundwater accounting platform developed by the Environmental Defense Fund and managed in partnership with the California Water Data Consortium demonstrates the gap between groundwater pumping and recharge. While this and other platforms currently show pumping, there is a growing demand to layer in recharge data as it becomes available. Those interested in finding how much additional recharge occurred under the EO can check the State Water Resources Control Board webpage on flood diversions to see what's been reported so far this year.

In August 2023, Sustainable Conservation, in partnership with DWR, released two Flood-MAR documents (Recharge Methods Manual and Case Studies and District Program Guidance) for growers and water districts. The documents summarize Flood-MAR for those new to the discussion and convey the successes and best-practices for Flood-MAR achieved to date.

Where we are now

Flood-MAR was practiced across the State this last winter. Policies, projects, and practices exist today when merely five years ago they did not. The Flood-MAR Network has 430 participating members now, fresh from convening an in-person forum this fall for the first time since 2019. A broad universe of people and organizations are now committed to solving drought and flood challenges through recharge, and the State's policies reflect that. Senate Bill 122

changed Public Resources Code Section 71154 to recognize groundwater aquifers as natural infrastructure and make certain elements of EO N-4-23 permanent. Much of what the 2018 paper laid out has started coming true; the operational, policy, regulatory, and collaborative space within which Flood-MAR efforts take place is vastly different than just five years ago.

There is a long way to go to sort out all the details needed to handle our new extremes. But the progress of Flood-MAR and the work of the Flood-MAR Network is representative of a very hopeful truth: California is adapting and will achieve and maintain sustainability through collaborative action.

Figure 7. At this groundwater recharge site, pumped water is discharged from this outlet to inundate an agricultural field in the Dunnigan area of Yolo County. This area saw a dramatic amount of rainfall and rising water in January 2023. Photo taken January 18, 2023. Photo credit Andrew Innerarity, California Department of Water Resources.