During concrete placement at the new auxiliary dam in Folsom, workers use repurposed water and mats to keep the concrete moist—to prevent premature cracking—while it slowly cures for one week. (Photo: Army Corps of Engineering/Facebook)

THE YEAR IN PREVIEW

Hacking the Drought

With climate models predicting precipitation extremes in some of the world's most ecologically and politically sensitive areas, scientists and engineers are coming up with creative solutions.

TAKE ACTION

DEC 14, 2015

Erica Gies' work has appeared in *The New York Times*, *The Guardian*, *Scientific American*, *The Economist*, and other outlets.

Bio

It's hard to imagine a flood on this 96-degree mid-October day northeast of Sacramento, but the laborers, covered up in jeans, long sleeves, steel-toed boots, and hard hats, are working steadily under the Central Valley sun to prevent one. Along a 3,000-foot-long channel cut into the ground, surrounded by industrial rebar girding that holds back the surrounding earth, they train high-pressure hoses into cracks, washing out mud from lumpy granite bedrock. Others trundle Shop Vacs behind them, sucking up the dirt.

The construction workers are busily cleaning rocks so the concrete that will soon cover them sets properly. Lining this channel with concrete is just one of the giant steps necessary to complete a 10-year, $900 million joint project of the Army Corps of Engineers and the U.S. Bureau of Reclamation that should ease adaptation to the extreme weather that climate models predict for this part of California—the Folsom Dam Auxiliary Spillway.

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With drought expanding through most of the American west this year and extending to an unprecedented fourth year (and ninth out of 10) in California, 2015 raised the bar for policy makers, water managers, and engineers to figure out how to do more with less; 2016 will be the proving ground for many of these proposals and solutions. Climate models predict big swings from drought to drenching, particularly in regions of the globe where mountains run hard up against deserts, as in much of California. Some of these happen to be in politically sensitive places where water shortages and flooding could lead to instability. The spillway is one hack among many that California and other similar regions of the world are deploying to upgrade water infrastructure that was built for a climate that no longer exists.

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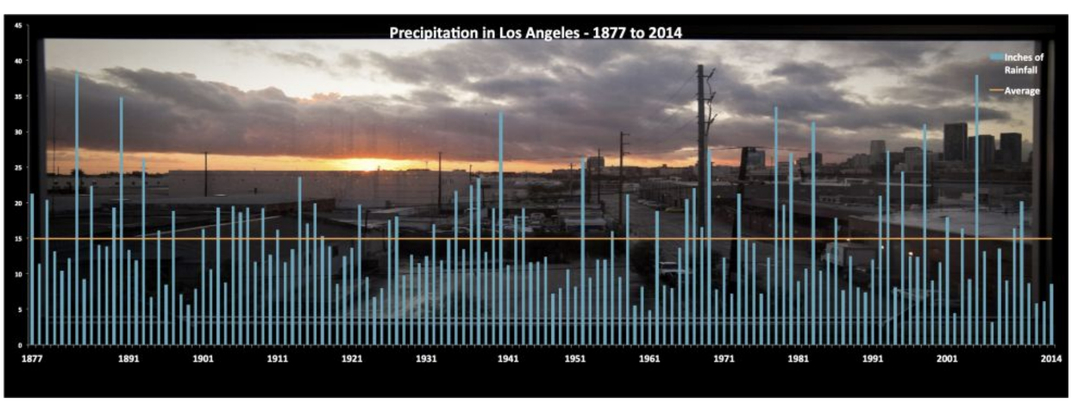
As for California, it has always been a land of extremes: The "normal" rainfall is an average of what are mostly very dry and very wet years, and the average to which we've become accustomed is itself far from typical when looked at on a longer time scale. Research into sediment beneath San Francisco Bay and carbon-dated tree stumps near Mono Lake indicates two megadroughts lasting more than 100 years during the medieval period and megafloods every century or two. The most recent came in the winter of 1861–2, when it rained for 43 days straight, turning most of the Central Valley into a massive inland lake. The new governor, Leland Stanford, traveled to his inauguration in Sacramento by boat and returned to the governor's mansion through a second-story window.



(Graphic: Sean Eckhardt; photo: Creative Commons)

Even without climate change, California is overdue for such drama. But the warming world is expected to bring even more variability in precipitation patterns, meaning that water managers can't rely on the past 100 years of experience to guide the next 100. Floods like the one in 1986, when heavy storms bigger than Folsom Dam had been built to withstand dumped enough water to nearly destroy it—and in 1997 and 2006 (and 1983 and 1978…), also heavy years—could increase in intensity as wet periods become more extreme, dropping more water at once. When such deluges follow on the heels of drought, they further ramp up flood risk because water runs off hardened soil rather than absorbing into the ground. It's time for a new set of tools, and the spillway should help manage through both extremes.

7/21 Folsom Dam auxiliary spillway construction t...

Today Folsom Lake is at just 17 percent capacity; from the top of the new dam, it looks like a drying puddle. As if in an establishing shot from a Road Runner cartoon, turkey vultures soar above the old dam, hunting desperate fish. Because of

California's drought, operators won't be able to test the spillway until there's enough water in the reservoir. That could be years.

At the top of the channel is the "control structure," essentially a second dam built askew from the original Folsom Dam. The new dam's six gates, each more than four stories high, sit 50 feet lower than the eight gates of the main dam. That will allow reservoir operators to release water from Folsom Lake before it rises to dangerous levels. Overtopping the main dam would be catastrophic. It's not like water spilling over the rim of a bathtub; the pressure could scour out the earth holding the dam, undermining its buttresses and blowing out the 69-year-old structure, sending the entire lake behind it downstream, blasting everyone between it and Sacramento, 25 miles away. Lower gates enable an earlier release.

Flood control is the raison d'être of the spillway, but—critically in semiarid Central California—it provides water storage for drought years like this one as well. The spillway makes Folsom Dam more nimble and responsive to the threat of both flood and drought by giving water managers added flexibility in storing water for agricultural and urban use.

> Billions of people in the Himalayas, the Andes, and the Middle East face challenges as mountain ice and snow are melting. Snowpack storage is decreasing because snowlines are moving uphill.
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Depending on the season, dam operators in California don't keep as much water as a reservoir can hold; they need to leave some space in the lake in case of strong winter rains or heavy spring snowmelt. Though it may seem wasteful, in autumn, as a safety measure, they often release water just to make sure there's enough room for whatever is to come during the rainy season.

But here's the thing: Sometimes the rainy season isn't rainy. When winters are dry, as they have been these past four years, it turns out that the water dumped could have been saved for the following summer, when it would be needed all the more. Because the spillway allows operators to release water before it risks a dam breech (and more steadily), it also allows them to hold on to water until a flood actually threatens, rather than having to let it go just in case. "We won't have to hold space empty waiting for a storm that doesn't come," said Shane Hunt, public affairs officer for the Bureau of Reclamation's Mid-Pacific Region. "We can hold the water longer and release on a schedule" that serves other needs, including agriculture, urban use, hydropower, and environmental benefits. Such a level of control can have many knock-on benefits as well, including directing floodwaters away from urban areas and toward wildlife refuges in historical floodplains, a strategy that also recharges aquifers.

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Perhaps the most complicating change in the water supply is that, because winters are warming, more precipitation is expected to fall as rain rather than snow. California's Mediterranean climate means that most precipitation falls during a few months in winter. Historically, it landed as snow in the Sierra Nevada, which provided handy water storage for several months, then trickled it downslope into rivers and streams over the dry summer.

That's already changing. On April 1, the snowpack held just 5 percent of its average water content, according to the California Department of Water Resources, marking the third year in a row of abnormally low readings. The average minimum temperature in the mountains last winter was 32 degrees Fahrenheit, according to California Climate Tracker, the first time it was above the snow point in 120 years of record keeping. The spillway is just one of several existing and proposed related projects that could help make up for some of that loss of snowpack; some of these include new reservoirs, raising dams, and NASA's Airborne Snow Observatory, which measures snowpack from the sky, providing more accurate data to fuel better management.

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(Photo: Erica Gies)

California is just one of many places where people have historically relied on mountain snow and ice for water. The Himalayas, the Andes, and the Middle East are also facing challenges as mountain ice and snow are melting. "Snowpack storage is decreasing because of snow lines moving uphill," said Roger Bales, a professor of engineering at the University of California, Merced, who researches water and climate.

Compared with the Himalayas and the Andes, California has a greater level of water security, said Bales. "We have good infrastructure, and we're wealthy enough to provide accurate information for decision making," he explained. "And we have imperfect but strong institutions."

These "three I's"—infrastructure, information, and institutions—are critical to water security. Places without the attributes are likely to suffer as water supplies grow more uncertain. "If you don't have storage, you can't weather a multiyear drought," Bales said. "If you don't know how much water you have in the mountains and how much will run off, you have trouble making decisions about agriculture or hydropower. And if you don’t have institutional flexibility to move water from water-rich areas to water-short areas, even if it doesn’t make economic sense, you can have real losers.”

The Folsom spillway and the ASO are syntheses of the three I’s, but big-engineering or high-tech solutions to water management aren’t as feasible in places that lack them. A lower-tech approach gaining momentum in California and elsewhere, in part because it is relatively cheap and can be deployed at any scale, is groundwater recharge.

Cities from Philadelphia to Melbourne, Australia, are reducing the amount of urban asphalt, which just sends rainfall into storm drains and out to sea; converting industrial sites along rivers to parks; installing permeable pavement, bioswales, rain gardens, sidewalk bumpouts, and wetlands; and pioneering groundwater banking schemes that pipe water into dedicated basins.

Lima, Peru, is planning to refurbish a 1,500-year-old flood control and water-storage system to allow floodwaters to seep through the Andes to feed springs; researchers with the NGO Forest Trends contend the city can make up as much as 40 percent of the water it needs during the dry season by using the ancient technique.

Elsewhere, cities from Philadelphia to Melbourne, Australia, are working to replenish underground supplies by reducing the amount of urban asphalt, which just sends rainfall into storm drains and out to sea, so more water can soak into aquifers. They and other places are converting industrial sites along rivers to parks and installing permeable pavement, bioswales, rain gardens, sidewalk bump-outs, and wetlands. When it comes to bigger projects, Kern County, California, and the state of Arizona are pioneers in groundwater banking schemes that pipe water into dedicated basins, where it soaks into the ground.

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Now, researchers at the University of California, Davis, are studying how California might expand groundwater recharge to agricultural lands. “We want to give policy makers and farmers an idea of how safe this practice would be for them,” said Toby O’Geen, a soil resource specialist with the university’s Department of Land, Air and Water Resources. O’Geen is the lead researcher on a new interactive map, the Soil Agricultural Groundwater Banking Index, that rates millions of acres of California farmland on their suitability for groundwater recharge based on soil drainage, underlying rock, type of crop, and the planting and fertilization cycle.

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Because farmers have been pumping so much groundwater recently to cope with the drought, it would be a sort of poetic justice for them to be actively contributing to groundwater recharge. One method of traditional irrigation, flooding fields, is a waste of surface water, but it helped to recharge groundwater. However, as many farmers have moved to water-saving drip systems, that hidden benefit has been disappearing. The newer, data-driven approach that O'Geen is proposing would recharge groundwater with less pollution than flood irrigation did; water dispersed on fields at the wrong time or on permanent crops like almonds might damage yields or introduce pesticides or fertilizers into aquifers.

Winter flooding of Central Valley farms would also mark a partial return to the hydrology cycle that prevailed prior to the vast march of dams, levees, and canals that have retooled the plumbing of the region over the last 100 years—and to the environmental benefits it provided. Seasonal wetlands once expanded greatly in winter, serving as habitat for creatures from salmon underwater to sandhill cranes overhead.

Given the extreme water stress brought by four years of drought, water experts and managers across the state are hoping to move fast on this use of fallow fields and capture some of the rain El Niño is predicted to bring this winter. Longer term, the state will need to build pipes or canals to move water from wet areas with low water demand to good banking sites, bridging the "disconnect between where we have water and where we use water," said Thomas Harter, a groundwater hydrologist at UC Davis.

For the practice to take off, farmers would need to be compensated for their water-storage services, receiving credits or cash payments from municipalities or irrigation districts. Another source of support could be hunting advocacy groups like Ducks Unlimited, which wants to increase wetland habitat for waterfowl. The group's lobbying and other efforts have "already expanded the wetland area by an astronomical amount," said O'Geen. "Why can't they pay a farmer to bank water?"

One area partially funded by Ducks Unlimited (with the California Department of Water Resources) is Stone Lakes National Wildlife Refuge, 17 miles south of Sacramento. As dusk fell there on another warm October day, frogs chirped from the depths of the tules while redwing blackbirds swung from their tips. Black-tailed jackrabbits hopped under brush, and geese in V formation honked overhead. Allowing water to sit on the refuge gives life to animals while serving as a release valve for heavy rains, to avert flooding of human habitat and simultaneously replenishing our supply.

Leveraging infrastructure like the Folsom Spillway and new canals to expand the flooding of uncultivated fields will give the state more options for how to use its water—which, even if supply remains roughly the same over the long term under global warming (as most models predict) will help it manage through periods of extreme storms and prolonged droughts.

Techniques like O'Geen's, and the strategies Lima and other cities are employing, are a hybrid of the natural rhythms of ancient times and the human audacity of the more recent past. Support for this vision comes from unexpected places, including the longtime proponent of hardscape, the Bureau of Reclamation, which will manage the Folsom Spillway.

"Floods are a natural part of the ecosystem," said the bureau's Hunt. "Flooding the floodplain isn't a bad thing." When the rains finally come, if policies evolve to spread floodwater around, we may get a chance to understand once again how right he is.

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