

As water utilities contemplate the potential effects of climate change, they must determine how to use available information to evaluate water system performance and vulnerabilities so they can plan more cost-effective, long-term solutions.

BY RICHARD G. SYKES, CLIFFORD C. CHAN, REY C. ENCARNACION, AND KEVIN T. RICHARDS

HOW SHOULD WATER UTILITIES PREPARE FOR CLIMATE CHANGE?

SCIENTISTS AND RESEARCHERS generally agree that temperatures around the globe will increase during the next century. The western United States will likely experience a 3°C warming, with serious effect on the region's water supply systems. Without substantially reducing greenhouse gas emissions, temperatures may rise even higher. Models also predict greater runoff variability.

The scientific community is still debating certain aspects of global warming—e.g., whether

storms will increase in intensity and frequency or the US West will experience an accelerated hydrologic cycle between drought and wet years. However, there's no doubt that climate change in the western states can affect water supply availability, flood protection, water quality, and water demand. The question for most water utilities is how to use current climate change research for water resource and operational planning. East Bay Municipal Utility District, Oakland, Calif., has found some answers.

Climate change can affect water utilities in many ways, including (clockwise from top left) rising sea levels; reduced snowpack; increased water temperatures in raw water supplies, promoting algae growth; and increased flood-control challenges.



Water Resources

WATER SYSTEMS

Research by the Lawrence Livermore National Laboratory indicates the Central Sierra Nevada region will experience significant changes to hydrological conditions, including a higher-elevation snowline, earlier and increased peak runoff, and less late spring runoff. In the last 50 yr, the western states have experienced a decrease in snowpack depth, and the percentage of runoff occurring between April and July has decreased by about 10 percent over the last century. A 3°C warming could potentially shift 28 percent of the April–July runoff to the November–March period in California’s Mokelumne River Watershed. These and similar trends could affect water utilities in several ways.

Water Supply Availability. Most water utilities in the western states enjoy the benefits of a snow-fed system, which provides “storage” that can be used in late spring and early summer when precipitation is low. With smaller snowpack and a decrease in April–July runoff, water utilities may not have enough reservoir capacity to store earlier runoffs. Compounding this problem, when water utilities evacuate reservoirs in late fall for flood control, they rely on spring runoff to refill the system. Current operational schemes may

result in releasing water that should have been stored.

Flood Control and Storage. Earlier runoff could result in increased flood-control releases for dual-purpose systems that operate for water supply and flood control. These reservoirs typically have well-defined flood-control space requirements. Under a climate change scenario, there would be less spring runoff to refill the reservoirs, and summertime water deliveries, power generation, and carryover storage could be affected. Water supply managers face a delicate balance between water supply needs and flood-control needs. If too much water is released too early, there may not be enough water to supply customers. Conversely, if too little water is released, the risk of downstream flooding increases.

Operational Reliability. Another potential consequence of climate change is a rise in sea level. Researchers conservatively estimate that during the next century sea levels may rise as much as 3 ft, or even as much as 20 ft under more extreme circumstances. Higher sea levels will inundate coastal areas around the globe. They will also seriously affect California’s Sacramento/San Joaquin River Delta, which provides drinking water to more than 20 million people. For EBMUD,

failure of levees adjacent to aqueducts that cross the delta could result in catastrophic damage and interrupt raw water deliveries to the service area.

Rising sea levels in the California Delta will significantly affect water supplies and levee integrity. The aging levee system is already vulnerable to floods and earthquakes; rising sea levels will exacerbate the situation. Levee failure will cause damage to low-lying infrastructure and lead to massive intrusion of poor-quality water into water supply intakes serving much of Southern California.

Water Quality. Climate change can also affect water quality. Increased severity of storms will likely increase turbidity levels in raw water supplies and consequently affect the treatability of those supplies. In addition, increased water temperatures during spring and summer could promote algae growth, increasing algal by-products such as taste and odor compounds. Water temperature increases could also affect water systems with fishery maintenance responsibilities, particularly those already experiencing temperature-related management problems.

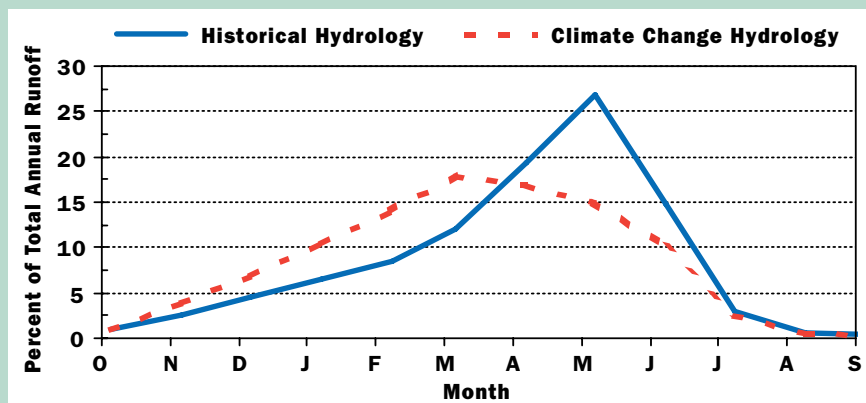
VULNERABILITY ANALYSES

EBMUD conducted various studies to evaluate the effects of climate change on water supply reliability and flood control and has used climate change studies to analyze how its system may be required to operate in the future. In general, the studies indicate only modest change to the utility’s water supply reliability. However, study results indicate a more dramatic impairment of EBMUD’s ability to contain floods in a warmer climate.

Water Supply Reliability. EBMUD created a water supply model to simulate an 80-yr historical hydrologic record under a changed climate. The simulations assumed no change in total annual precipitation but altered the runoff hydrograph, shifting runoff patterns to earlier in the year to match expected effects of a warmer climate (Figure 1). The study

Figure 1. Unimpaired Runoff Under Historical and Climate Change Conditions

EBMUD’s 80-yr water supply model reflects a shift in runoff patterns in a warmer climate.



Water utility managers have an obligation to consider potential effects of climate change and to assess mitigations for them as a part of ongoing planning efforts.



In the aftermath of Hurricane Katrina, water utility crews faced ubiquitous main breaks and service line leaks at ruined home sites throughout New Orleans. As climate change intensifies, many scientists expect to see more unusually strong hurricanes like Katrina.

indicated that an earlier runoff would have little effect on EBMUD's water deliveries because of the large percentage of spring runoff in the Mokelumne Basin, the timing and amount of demands, and the reservoir storage-to-runoff ratio.

In most recent years, the Mokelumne River Watershed's April–July snowmelt runoff has been greater than can be stored. During years of below-normal and normal runoff, the spring runoff has exceeded storage capacities 80 percent of the time, requiring flood-control releases. Under an altered climate with decreased spring runoff, fewer flood-control releases would be required and carryover storage wouldn't be significantly altered. In addition, the demand on the Mokelumne River is less than the average annual runoff, which allows EBMUD to refill its water

supply system with average runoff. The combined storage of EBMUD's Camanche and Pardee reservoirs and Pacific Gas & Electric's reservoirs, which are upstream of EBMUD's reservoirs, exceeds 800,000 ac-ft. This storage volume is greater than the average annual runoff of 750,000 ac-ft, which means there's sufficient capacity to capture large volumes of early runoff. The ability to capture this runoff is a big benefit in dry and critically dry years when the only significant runoff may be early in the season.

These scenarios were based on a 2020 level of development. Although there were changes in EBMUD's carryover storage—the amount of water in storage that was available to carry forward into the new water year starting each October 1—they weren't substantial. The analyses showed

that carryover storage was affected in 10 percent of the 80-yr simulation, with the maximum carryover storage reduction of 49,000 ac-ft. EBMUD's carryover storage capacity is about 600,000 ac-ft. Water deliveries remain unaffected unless carryover storage is less than 500,000 ac-ft at the beginning of the water year. The simulation revealed no effects on water deliveries as a result of shifting runoff earlier in the year. By 2100, EBMUD's water demands may be greater and carryover storage requirements larger. Moreover, if total annual precipitation changes, or if a more significant change in the timing of runoff occurs—such as a near complete loss of spring snowpack—greater consequences may be expected.

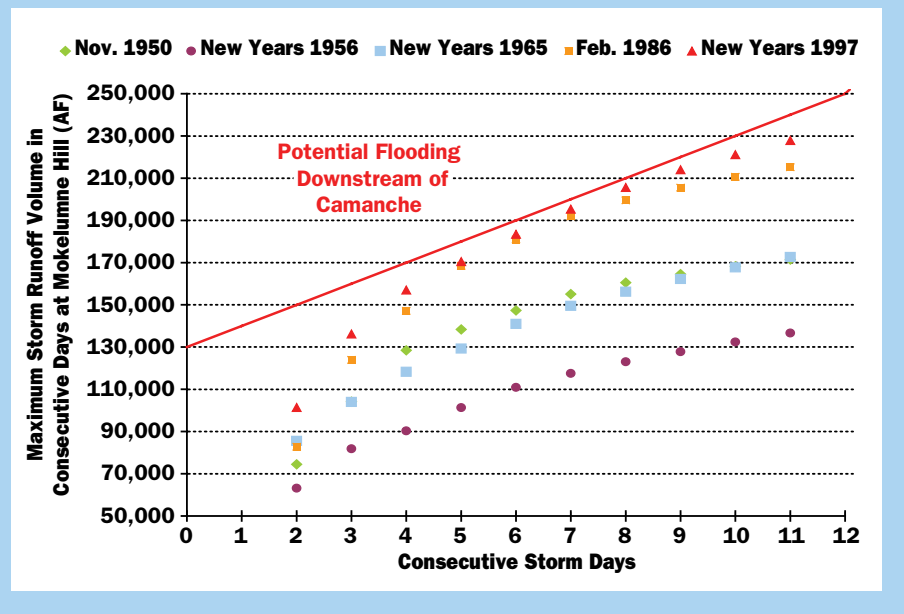
Flood Control. Increased runoff during winter months resulting from a shift

in the runoff patterns over the next century could present a challenge for flood-control managers. Although flood-control requirements are well-designed and have served their purpose in the past, the channel capacity downstream of Camanche Reservoir is limited to 5,000 ft³/sec, which restricts the utility's ability to respond to extreme flood events, such as the 1997 El Niño floods in California.

Studies simulating the 1997 El Niño storms assessed flood-control implications for a warmer-than-historical flood. The simulation assumed temperatures were 3°C warmer. The study revealed that, at its peak, the total release from Camanche Reservoir would be about 15,500 ft³/sec, well above the 5,000-ft³/sec capacity of the Mokelumne River downstream of Camanche Reservoir. Under this scenario, significant flooding would occur in the lower Mokelumne River area.

Figure 2 shows the onset of flooding potential for the five worst floods on record. The red line indicates critical storm-runoff volumes over time as defined by EBMUD's flood-control requirements. Storm-runoff volumes in excess of the red line would lead to uncontrolled spill from Camanche Reservoir and the potential for downstream flooding. Note that the system has adequately handled every storm since the construction of Camanche Dam without exceeding the 5,000 ft³/sec capacity of the downstream channel. However, the two worst storms on record occurred within the last 20 yr. Assuming a 5,000 ft³/sec release rate is initiated at the beginning of an impending storm, 10,000 ac-ft/day of water can be safely evacuated from the upstream reservoirs. Although the frequency and intensity of future storms under climate change is unknown, this graph illustrates the importance of more accurate forecasting. For example, for each day of lead time, 10,000 ac-ft of additional flood-control space can be gained. The figure also shows that a modest increase in intensity, volume, or duration

Figure 2. Storm-Runoff Development and Flooding Potential
EBMUD assessed the flooding potential for the five worst floods on record to help determine the impact of future storms.



of the 1986 or 1997 storms would have caused flooding downstream of Camanche Reservoir.

PREPARING FOR CLIMATE CHANGE

As utilities evaluate published information on climate change and its potential effects, the question remains: How should water utilities prepare? Utilities should consider how climate change could affect their supply sources. If a utility's primary source of raw water is runoff from melted snowpack, the utility should consider the effects on storage and late-season water availability. Utilities should evaluate supplemental supplies that may not be as affected by climate change. By diversifying its water supply portfolio, a utility can improve its ability to manage climate change consequences. For example, EBMUD is adding supplemental water supplies, including sources from the Sacramento River and a watershed several hundred miles north of the Mokelumne River Watershed, to ensure greater water availability if climate change

results in greater geographical variation in precipitation. In addition, EBMUD is investigating groundwater banking projects and desalination and has active recycled water and conservation programs to help reduce future demands on increasingly limited supplies.

Coastal water agencies should consider the repercussions of rising sea levels on their water supply systems and operations and find cost-effective solutions to address them. For example, the Mokelumne Aqueducts, which convey water from EBMUD's reservoirs in the Sierra to the Bay Area, cross the California Delta. Delta levees are extremely vulnerable to sea level rise and have been breached on numerous occasions. In June 2004, a breach submerged the aqueducts and damaged their coatings. If a delta levee fails, EBMUD has planned a wet repair of the Mokelumne Aqueducts, as well as coating systems that provide corrosion protection for these steel aqueducts when they are submerged.

There are also many "no regret" actions—solutions that are worth doing

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regardless of climate change effects—that water utilities can implement to help them adapt to climate change. These actions include promoting water conservation and water reclamation.

Water utilities can also strive to keep their operations climate neutral by reducing greenhouse gas emissions. EBMUD has changed its car fleet to hybrid vehicles and has installed lower-emission microturbine electrical generators on its administration buildings. It also offers transit subsidies to employees and plans to build a 0.4-megawatt solar power project at one of its water treatment plants. In addition, water utilities can support policies and legislation that encourage reducing greenhouse gas emissions. EBMUD supports California Assembly Bill 1058, a bill to reduce the state's greenhouse gas emissions.

Some agencies have developed their own policies on climate change. For example, the Metropolitan Water District of Southern California adopted a policy to support further research and “no-regret” solutions that immediately benefit water supply and quality and promote the district's ability to manage conditions resulting from future climate change.

Water utilities should support additional research to better plan for climate change. Watershed-specific models capable of providing streamflow conditions under an altered climate could help managers make more accurate predictions. Currently, EBMUD's studies are based on a 3°C increase in temperature, a 28 percent shift in the spring runoff, and a 3-ft rise in sea level. Under these conditions, EBMUD's water supply system will be able to operate without severe impairment, but with slightly less carryover storage, slightly greater flooding risk, and slightly increased risk of infrastructure damage. However, if the forecasts are incorrect or if regional temperature increases lead to unexpected variations in precipitation or storm frequency and intensity, the consequences may be significantly underestimated.

Table 1. Possible Impacts of Climate Change on Water Resources¹

Water utilities will need to adapt to possible impacts of climate change in the coming decades.

Phenomena and Direction of Trends	Likelihood of Future Trends ²	Major Impacts(s)
Over most land areas, warmer and fewer cold days and nights as well as warmer and more frequent hot days and nights	Virtually certain	Effects on water resources that rely on snowmelt; effects on some water supplies
Warm spells/heat waves; frequency increases over most land areas	Very likely	Increased water demand; water-quality problems (e.g., algal blooms)
Heavy precipitation events; frequency increases over most areas	Very likely	Adverse effects on quality of surface water and groundwater; contamination of water supply; water scarcity may be relieved
Area affected by drought increases	Likely	More widespread water stress
Intense tropical cyclone activity increases	Likely	Power outages causing disruption of public water supply
Increased incidence of extreme high sea level (excludes tsunamis)	Likely	Decreased freshwater availability due to saltwater intrusion

Sources: ¹Adger, N., et al. Summary for Policy Makers. In *Climate Change 2007: Impacts, Adaptation, and Vulnerability*, International Panel on Climate Change
²Projections are for the 21st century and are based on the *Special Report on Emissions Scenarios*, IPCC.

LOOKING AHEAD

The effects of climate change are already evident and are expected to continue through this century, even if greenhouse gas emissions stabilize. Current research and data show that on average the planet is getting warmer and the effect on the US West may be greater than in other areas because of the region's reliance on snowpack as late-spring and early-summer storage. The research is useful for making preliminary studies to determine what effects climate change will have on water supply systems. Fortunately, it's relatively simple to perform sensitivity analyses related to earlier runoff, rising temperatures, and rising sea levels.

Water utility managers have an obligation to consider potential effects of climate change and to assess mitigations for them as a part of ongoing planning efforts. Planning efforts can include

evaluating how future infrastructure will perform in a changed climate. Such evaluations may lead to changes for some projects. This is most evident for new or supplemental water supply projects such as storage, conveyance, inter-agency connections, and groundwater development where water availability may not be as predictable. Long-range planning may allow mitigation of future climate change effects at relatively low cost.

The climate change information available today is suitable for evaluating water system performance and vulnerabilities, and it can be useful when evaluating current and future infrastructure investments. Using this information now will help lead to more cost-effective, long-term solutions that will help utilities avoid or minimize climate change effects in the future.