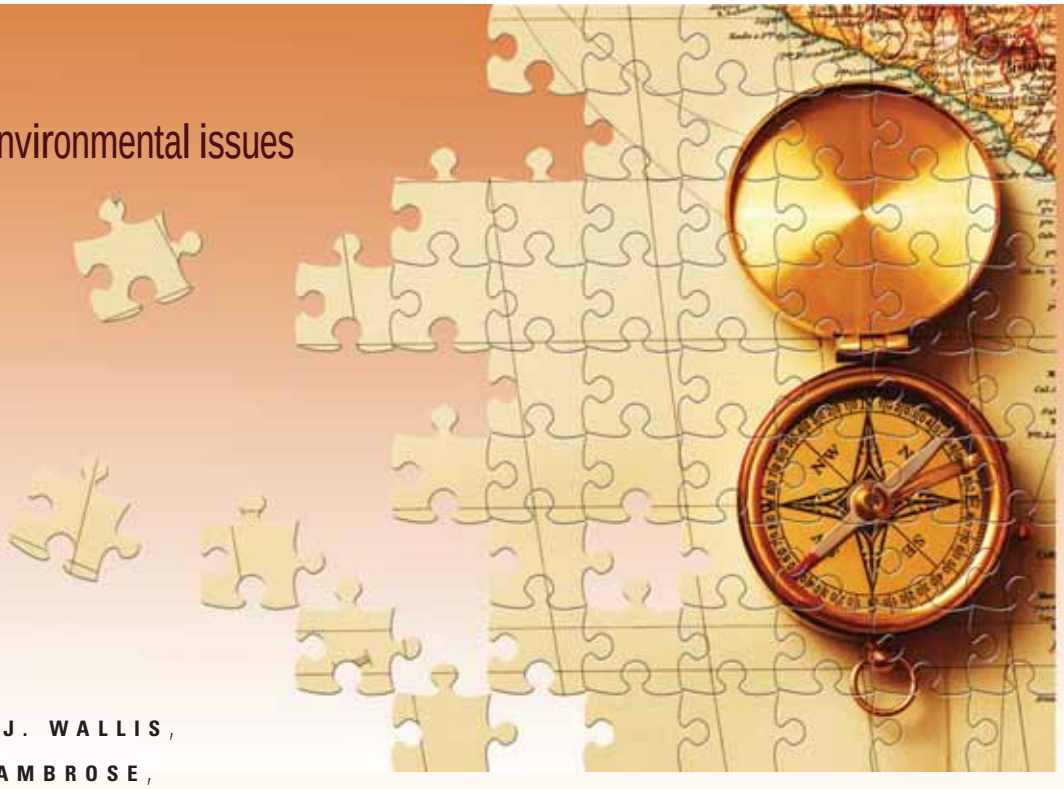


BY MICHAEL J. WALLIS,
MICHAEL R. AMBROSE,
AND CLIFFORD C. CHAN

Climate change:
Charting a water course in an uncertain future

ALTHOUGH SCIENCE HASN'T AGREED ON A MODEL TO PREDICT THE EFFECTS OF RISING TEMPERATURES, WATER UTILITIES MUST MAKE AN ATTEMPT TO DO SO AND DEVELOP MITIGATION AND ADAPTATION STRATEGIES FLEXIBLE ENOUGH TO ACCOMMODATE UNCERTAINTY.

Climate change is a growing threat to our entire planet. It threatens communities that have enjoyed plentiful water supplies for decades and that have planned their water systems on the basis of historical water supply records. Climate change science is more convincing than ever, and although the full effect of climate change has not been felt, the warning signs of change are clear. Hot spells are lengthening, sea levels are rising, less snow blankets western mountains, and rising river temperatures pose a threat to our natural resources. The path our predecessors followed to build our water supply and infrastructure, the path we learned to follow in turn, may not be the way forward. For today's western water managers—who inherited elegantly engineered systems built with confidence that winter snows bring spring runoff to fill reservoirs—difficult decisions loom about how to best provide for the needs of future generations. Water managers can no longer rely on stochastic hydrology models using historical records and must adapt to meet a different, undefined future.

Managing water resources in a warming climate demands water utilities' attention today, even though climate change forecasts and probabilities continue to evolve in the scientific community. The increasing certainty of a warmer planet creates little of the specificity water utilities need to plan for the future. It may be years before reliable predictive models of regional environmental impacts are available, but waiting for those models is impractical. Water utilities must judge their local vulnerability to climate change and develop mitigation and adaptation strategies flexible enough to accom-

East Bay Municipal Utility District uses available capacity at its wastewater treatment plant to convert trucked-in nonhazardous waste (such as food processing waste and wastewater sludge) to methane, which is used to generate renewable energy.

modate uncertain climate change predictions.

Water utilities can learn together how to plan for, prepare for, and mitigate climate change. The East Bay Municipal Utility District (EBMUD) of Oakland, Calif., has developed mitigation and adaptation strategies to deal with the changing climate and its effects on water resources.

THINK GLOBALLY ABOUT CLIMATE CHANGE

The recently released Fourth Assessment Report (AR4) by the Intergovernmental Panel on Climate Change asserts that the warming of the climate is unequivocal and assigns a better than 90% probability that the observed warming is human-caused (IPCC, 2007). Significant findings for water utilities are:

- Two greenhouse gases (GHGs), atmospheric carbon dioxide (CO_2) and methane, exist at higher levels today than in the past 650,000 years. Eleven of the past 12 years (1995–2006) are among the warmest on record, and in the past 100 years, global average temperatures increased approximately 1°C.
- For the western United States, temperatures could rise 2–7.5°C by the end of this century. Precipitation will fall less often as snow and more often as rain, and storm tracks are projected to move steadily northward, making central California drier than it is today. The snow-covered area in the mountains has decreased by approximately 5% over the past 40 years, and the spring runoff now occurs earlier in the year.
- Sea level has risen approximately 6 in. over the past century and is projected to rise another 0.6–1.9 ft by the end of the century. New data on the melting of the Antarctic and Greenland ice sheets suggest that these figures could be low.
- Heat waves, defined as at least five consecutive days with a maximum temperature higher than the average by at least 5°C, have become more frequent. Heat wave durations are projected to increase to 85 days, and the growing season to lengthen 19–28 days.

As gloomy as all that sounds, some research indicates that GHG emissions continue to outpace the worst-case scenario in AR4.

ACT LOCALLY TO UNDERSTAND CLIMATE CHANGE

EBMUD provides an average of 215 mgd of water to more than 1.3 million customers on the east side of California's San Francisco Bay. Almost all of EBMUD's water supply originates in a 577-sq-mi watershed in the Sierra Nevada. EBMUD's two primary water supply reservoirs—Pardee and Camanche—located on the Mokelumne River, provide water supply, flood protection, resource management, recreation, and hydropower. Water travels through three aqueducts that stretch 90 mi from the Sierra foothills across the Sacramento/San Joaquin River Delta) and into the San Francisco Bay Area.

EBMUD relies on snowmelt for its water supply, and predictions of dwindling snowpack and reduced precipitation challenge the water supply planning and operational

With predictions of a longer growing season, drier soils, warmer nights, and more heat waves, a warming climate is expected to increase water demand for outdoor irrigation.

assumptions. EBMUD's water transmission system crosses the earthquake- and flood-prone delta aboveground for several miles. The delta's aging levees have made national news because they are as vulnerable to failure as the levees in the New Orleans, La., area that were devastated by Hurricane Katrina. The sea level rise that is projected would exacerbate those vulnerabilities.

EBMUD's concerns about the effects of climate change are shared by its customers. In a recent customer survey, nearly 75% of respondents said climate change will be a problem for local water supplies in the next 50 years. When asked how concerned customers were about the effects of climate change on the availability of water, 46% rated it a "highest concern."

EBMUD has closely followed emerging climate science and has collected information about climate change in its region for years. EBMUD's efforts to grapple with the problem have focused on data gathering, scientific research, and peer consultations. EBMUD staff amassed a lot of information and began applying it to the water supply and operational planning. Staff members began presenting key findings to the EBMUD board of directors and to a board-led business forum that brings together key business stakeholders for discussions of emerging water issues once a year.

By mid-2007, EBMUD established a districtwide management approach to define what it needed to know to make reasonable short-, intermediate-, and long-term decisions and coordinate research efforts. EBMUD formed a climate change committee to coordinate research across departments in its 2,000-employee organization and to project climate change effects as the basis for guiding future water supply and infrastructure planning and budgeting. Today this interdisciplinary team meets regularly to guide internal work, coordinate involvement with state and federal efforts, and plan public outreach activities. The team's work is focused on

- keeping current with science and assessing potential effects of climate change,
- reviewing observed data and identifying trends that would indicate the climate in the Mokelumne watershed is changing,
- determining water supply and infrastructure vulnerabilities,
- integrating climate change in strategic planning and budgeting decisions, and
- developing adaptation and mitigation strategies as part of a water supply management plan.

DETERMINE THE VULNERABILITIES OF A WATER UTILITY TO CLIMATE CHANGE

EBMUD's research indicated that a warming climate will significantly affect the water utility. Six key areas of potential vulnerability were identified: water supply, flood management, water demand, sea level rise, power generation, and water quality. Because predictive models do not exist, EBMUD performed sensitivity analyses to understand the vulnerabilities and resiliency of existing and planned systems. Understanding the vulnerability of EBMUD's system forms the basis of planning adaptation strategies.

Water supply. Most water utilities in the western United States benefit from a snow-fed system in which snowpack provides "storage," and the gradual runoff in the late spring and early summer replenishes reservoirs and meets peak warm weather demands. In the past 50 years, the western United States has seen a decrease in the size of the snowpack, and during the past century, the percentage of runoff between April and July has decreased by approximately 10%. A California Department of Water Resources report estimated that with a 5°C rise in temperature, the April 1 snow-covered area in EBMUD's water supply watershed

The California Department of Water Resources estimates that a 5ºC rise in temperature could reduce East Bay Municipal Utility District's watershed snow pack in the Sierra Nevada, by as much as 60%.

could decrease by as much as 60% (CDWR, 2006).

EBMUD has evaluated the effects of a 28% shift in the amount of runoff, on the basis of a 3ºC rise in average temperature by 2040, occurring in early spring rather than the historical April–July period. EBMUD determined that by changing the way it operates the system, there would be little effect on water deliveries. In a warming climate scenario with decreased late spring runoff, there would be fewer years in which flood control releases would be required but no significant effect on the amount of water carried over to the next water year. Storage in EBMUD's reservoirs exceeds the average annual runoff in the basin, and re-operating the system to capture large volumes of early runoff would reduce the effect of decreased late spring runoff.

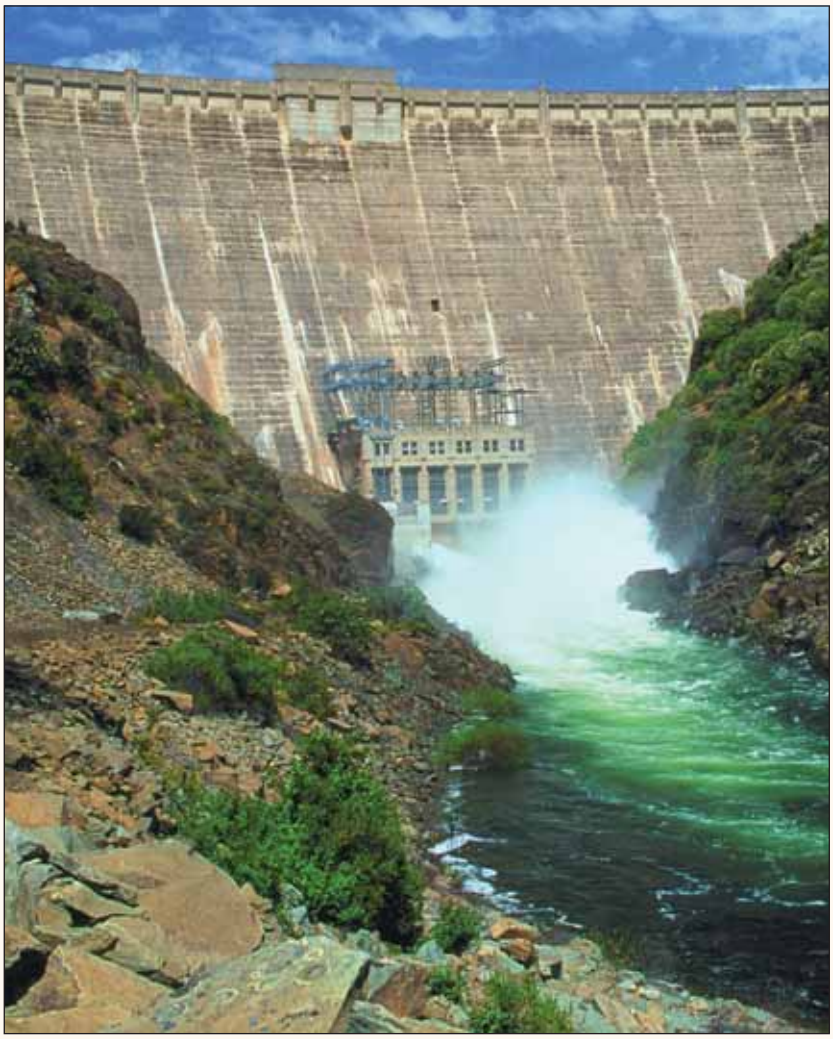
Changes in precipitation, however, will have a greater effect on water supply. Storm tracks are predicted to shift northward, which would decrease the average precipitation for central California even though the average precipitation for the entire western United States could remain the same or increase slightly.

Flood management. Water supply vulnerabilities to climate change are closely related to the effects of climate change on flood management. Most of the infrastructure and operating rules for reservoirs in the western United States were designed on the basis of historical annual snowpack data. Reservoirs that fill from snowmelt typically have well-defined and -regulated flood-control requirements. Water utilities reduce reservoir storage in late fall for flood control, relying on spring runoff to refill the reservoirs. In a changing climate, the balance between flood control and water supply will be more difficult to manage. If too much water is released in the fall and reservoirs do not refill, there may not be enough water to supply customers. However, if too little water is released, there is an increased risk of flooding in downstream communities. Dealing with these conflicting priorities will require changing the operation of the reservoirs.

With predictions of more extreme weather events, EBMUD performed studies looking at flood control effects on the basis of a 3ºC rise in temperature. Using data from 1997—the wettest year in recent history as a result of El Niño—the studies showed that the peak water release from Camanche Reservoir would have been approximately 15,500 cfs, far exceeding the actual 5,000 cfs release that occurred. Under this scenario, significant flooding would have occurred in the urbanized areas downstream of the two reservoirs.

Water demands. A third area of vulnerability is the growth of water demands, despite an aggressive conservation program and strong cus-

Water managers can no longer rely on stochastic hydrology models using historical records and must adapt to meet a different, undefined future.



East Bay Municipal Utility District relies on hydropower revenues, such as those generated by the Pardee Dam, to help offset the need for customer rate increases. Changes to water supplies could reduce the district's ability to rely on this revenue source.

tomer support for water conservation. With a warming climate, the growing season is expected to lengthen, soil moisture content will decrease, evapotranspiration rates will increase, nights will be warmer, and more heat waves will occur. All of these effects are expected to increase customer use of water for outdoor irrigation and increase water consumption. As part of a routine update, EBMUD projected its water demands for 2040. It estimated that the warming climate will increase service area water demands by an average of 4% (10 mgd).

Sea level rise. Rising sea levels are a significant risk for water utilities located in coastal areas (such as EBMUD)—and the anticipated effects in California reach far inland. The frequency of flooding is expected to increase dramatically, even with only a 1-ft rise in sea level. A recent report showed that a 1-ft rise changes a "1 in 100" storm surge flood event into a "1 in 10" storm surge flood event. In addition to the obvious vulnerabilities that would result from greater frequency of flooding in the San Francisco Bay communities served, EBMUD also identified vulnerabilities to its water transmission infrastructure. The Sacramento/San Joaquin River Delta, which provides drinking water to more than 20 million people, is at risk. Failure of the delta's complex and aging levee system will not only damage low-lying infrastructure, but will lead to a massive intrusion of poor-quality water into the water supply that serves much of California.

Although EBMUD does not divert its water supply from the delta, its three water supply aqueducts cross the delta on elevated supports. Failure of the delta levees could result in catastrophic damage, interrupting water deliveries to its service area for months.

Power generation. Energy use and hydropower generation will also be affected by climate change. Energy is a key cost driver, and if rising demand escalates prices, there could be serious effects on EBMUD. Hydropower provides revenues that help offset the need for customer rate increases, and changes to water supplies could reduce the ability to rely on this revenue source. The California Climate Change Center reported in 2006 that a warmer climate would not only increase the demand for energy but also increase the demand for peak energy use 4.1–19.3% by the end of the century (Cayan et al, 2006). In addition, if precipitation decreases or runoff patterns change significantly, hydropower generation may decrease between 10 and 30%. For EBMUD, this would result in a reduction of 18–54 GW·h in energy production out of a current annual average of 180 GW·h.

Climate change could add new challenges to water treatment. More severe storms could increase turbidity levels in raw water supplies. Higher water temperatures could result in more algal by-products such as taste-and-odor compounds.

Water quality. Climate change is expected to increase the severity of storms, and that, in turn, could increase turbidity levels in raw water supplies. This is an area of climate change vulnerability for EBMUD because its protected water source resulted in treatment systems designed for low-turbidity source water. Experience has shown EBMUD that severe storms can dramatically slow its ability to produce treated water while simultaneously increasing the costs of water production. In addition, increasing water temperature may affect water quality by promoting algae growth and result in increased algal by-products such as taste-and-odor compounds. Increases in water temperature may also affect the water system because of its fishery responsibilities, which include maintaining a "cold-water" pool in reservoirs to manage downstream river temperatures. EBMUD works in cooperation with the State of California Department of Fish and Game to manage a fish hatchery on the Mokelumne River. Temperature management is a vital part of the reservoir operation plans so that EBMUD can provide cold water during fish migration periods.

Integrating climate change into long-range planning. Climate change cannot be stopped. Projections show that the climate will continue to warm even if emissions of human-caused GHGs were completely suspended today. As the climate warms, water utilities will need to develop adaptation strategies to cope with these changes. Some of these strategies will take decades to develop. However, waiting to adapt until the climate has warmed is akin to waiting to build lifeboats after a ship has started to sink.

After defining vulnerabilities, the next significant challenge was to integrate this knowledge into long-range planning and ongoing budget decisions. EBMUD continuously works on an array of infrastructure and water supply planning efforts designed to ensure effective operations and stewardship of natural resources. In turn, these studies inform the strategic plan and five-year capital plan, which are key tools in establishing a biennial budget.

Water supply planning. EBMUD is currently updating its integrated resource water supply management program (WSMP). The WSMP is a comprehensive evaluation of EBMUD's water supply needs through the year 2040. As part of the WSMP, EBMUD is evaluating numerous water supply portfolios, with components including conservation, water recycling, groundwater banking, interbasin transfers, desalination, and surface water storage. Among other criteria, each portfolio is being evaluated for its carbon footprint. The portfolios being evaluated

Rising sea levels threaten levees in the Sacramento/ San Joaquin River Delta, home to East Bay Municipal Utility District's three primary aqueducts and much of California's water supply. A singular levee breach in 2004, shown here, submerged the district's aqueducts for more than four months.

include one with a low carbon footprint and another that is diversified in order to adapt to future changes, including climate change.

As climate and hydrology change, using past hydrologic data to make projections of future conditions may be invalid. To address this concern, sensitivity analyses are used to understand how various factors will affect water supply deliveries and the frequency and magnitude of water shortages. These factors, in turn, help assess needs to modify plans for future investments in infrastructure and equipment.

For example, because climate change projections show that weather systems will move northward to higher latitudes, EBMUD performed a sensitivity analysis to determine how a decrease in precipitation would affect water supplies. The analysis looked at how a 10–20% reduction in precipitation would affect the water system. The results showed that water deliveries decreased 4–12% during a three-year drought scenario and that by the end of the drought, reservoir storage could drop by as much as 80%.

In addition, a decrease in precipitation would increase the frequency of dry years. On the basis of current hydrology, EBMUD projects dry years in three out of 10 years. With a 10% reduction in precipitation, this would increase to four out of 10 years, and with a 20% reduction, it would increase to five out of 10 years.

Results from research and sensitivity analyses drive the development of adaptation strategies and water supply planning. They help focus attention on research and studies most relevant to the identified climate change–related vulnerabilities of the water system. To guide this effort, EBMUD has integrated climate change into its approach to planning for future programs and expenditures. It has also enhanced emphasis on diversifying its water supply.

Water supply diversification is a key element of adaptation for an agency like EBMUD, which is so reliant on the precipitation that falls in a small geographic area. EBMUD has been pursuing conservation, water recycling, and seeking supplemental water supplies for decades—to ensure a reliable water supply for its customers in the future. Recently, EBMUD partnered with Sacramento County Water Agency to build a regional water supply project that will provide water for EBMUD customers in dry years and the Sacramento region in all years. The project will have the ability to divert up to 185 mgd of water from the Sacramento River, delivering up to 100 mgd to EBMUD customers by accessing water from a separate, larger watershed.

Water utilities must judge their local vulnerability to climate change and develop mitigation and adaptation strategies flexible enough to accommodate uncertain climate change predictions.

Strategic planning and budgeting. In 2008, EBMUD incorporated a climate change strategy as part of its strategic plan. The climate change strategy publicly commits EBMUD to developing and implementing a

Because water utilities are large consumers of energy, one of the key ways to mitigate greenhouse gas emissions is through responsible energy management. East Bay Municipal Utility District has an aggressive program to minimize energy use, including use of renewable resources.

climate change monitoring and response plan to inform future water supply, water quality, and infrastructure planning. In addition, the strategy mitigates GHG emissions and supports "no regrets" capital investment decisions—those investments that are cost-effective under a variety of climate change scenarios.

With the formation of EBMUD's climate change committee, preparation of a climate change monitoring and response plan and an update to its WSMP, EBMUD is moving forward in developing sound adaptation strategies for climate change and other potential future effects.

MITIGATING THE CLIMATE CHANGE EFFECTS OF A WATER UTILITY

Being "green" and "sustainable" are currently hot topics. Some utilities have been ahead of the current emphasis on sustainability and have worked toward mitigation of their environmental effects for many years. For those without a current internal focus on sustainability, external circumstances may soon force more attention. Customers who are being bombarded with information about corporate sustainability efforts may also want to know how their local water service provider measures up.

In addition, federal and state governments are beginning to require climate change mitigation efforts. California's 2006 Global Warming Solutions Act (AB32) takes steps to manage GHG emissions. AB32 requires California to reduce its greenhouse gas emissions to 1990 levels by 2020 through a combination of regulations and market mechanisms. In the next few years, the federal government will likely pass some form of legislation to slow emissions growth.

States are also entering into regional partnerships to address climate change. One regional agreement, the Western Climate Initiative, was launched in 2007 and established a regional GHG-reduction target shared by seven states. The agreement calls for an economywide regional cap-and-trade program. The latest US regional agreement to be negotiated—the Midwestern Regional GHG Reduction Accord—commits another six states to near- and long-term GHG reduction goals under a multisector cap-and-trade system.

Although the particulars for each cap-and-trade system are different, programs are generally designed to reduce a specific type of pollution (in this case GHGs) in a defined geographic region. Under such programs, each polluting entity is issued an emissions permit for every ton of GHG it produces. This is termed its cap. Based on the assumption that it will be cheaper and easier for some to reduce their emissions below their cap, the idea is that these entities will sell off their excess permits to other emitters that cannot easily reduce their emissions. This is termed the trade. Over time the caps become increasingly strict until an overall pollution reduction goal is met.

Whether a water utility chooses to mitigate GHG emissions because of leadership from its board, staff, or the community, or in response to regulatory requirements, it makes sense to prepare by quantifying and understanding current emissions and ways to mitigate them.

Creating an inventory of utility-produced GHGs. Developing an inventory of current emissions using accepted protocols enables utilities to determine what operations cause emissions. A good inventory is the first step in establishing a strategy for mitigating GHG emissions, which often can save money in operating costs for a utility. Water and wastewater utilities are an indirect source of GHG emissions because of their use of energy to transport,

treat, and distribute water. The US Environmental Protection Agency estimates 3% of national energy consumption is used for drinking water and wastewater services and that these services emit approximately 45 million tons of GHGs into the atmosphere each year. The California Energy Commission says water-related energy use, including customer uses, consumes 19% of the state's electricity, 30% of its natural gas, and 88 bil gal of diesel fuel every year. Water and wastewater utilities also directly contribute to GHG emissions from their fleets of vehicles for operations and maintenance, and transportation of chemicals and other supplies to support their operations. Wastewater treatment is also a direct source of methane and nitrous oxide.

East Bay Municipal Utility District's efforts to grapple with the problem have focused on data gathering, scientific research, and peer consultations.

The AR4 report is optimistic that climate change can be mitigated through a 60–80% reduction in GHG emissions from current levels by 2050. This is a challenging task given expected population growth and demand for resources. According to the AR4 report, emissions of the GHGs covered by the Kyoto Protocol increased about 70% from 1970 to 2004, with CO_2 (the largest source) having risen 80%. The largest growth in CO_2 emissions was from power generation and transportation.

Some actions that may be required to adapt to climate change could result in more energy-intensive processes than in the past. As discussed earlier, climate change could reduce water quality and therefore require more treatment. Supply reductions could require groundwater storage and pumping or pumping water from more distant watersheds. Water utilities must consider the objective of reducing GHG emissions while exploring ways to meet water supply, storage, and treatment needs in ways that best balance cost, reliability, and environmental consequences.

Mitigation opportunities for utilities. Because water utilities are large consumers of energy, so one of the key ways to mitigate GHG emissions is through energy management programs. Additionally, many utilities have resources (land, water, biogas) that can be used for mitigation. Land can be reforested for carbon sequestration or used to construct renewable energy projects (wind and solar power). Water sources can be used for hydropower generation. Conservation can be used to reduce the demand on potable water sources.

Water utilities use a significant amount of energy to move and treat water. Mechanical equipment such as pumps and valves are used in these processes. Equipment should be right-sized for the application to minimize wasted energy. It should also be properly monitored and maintained to ensure peak efficiency over its useful life. The best technique to save energy and mitigate emissions is to turn off unneeded equipment or processes to avoid using energy.

Water conservation programs can also be considered energy-saving when the energy cost of water is considered. Water conservation can be especially helpful in mitigating emissions in areas in which water is conveyed long distances.

Wastewater agencies' GHG emission mitigation programs can consider both energy conservation and using biogas as an energy source. Anaerobic digestion produces biogas (methane and CO_2) and biosolids. The biogas can be used for process heating, onsite electrical generation, and other uses. Electrical energy produced from biogas is considered renewable because the emissions from this combustion are part of the natural carbon cycle, unlike those from fossil fuels.

EBMUD'S GREENHOUSE GAS MITIGATION EFFORTS

EBMUD's focus on greenhouse gas mitigation is driven by a long-standing emphasis on environmental responsibility. Its board of directors believes strongly in environmental leadership.

GHG inventory. EBMUD conducted its first GHG inventory for 2005. EBMUD caused 53,700 metric tons of GHG emissions that year—a 10% reduction from estimated year 2000 emissions. Most of its 2005 emissions (41,459 metric tons) were from indirect sources because of electrical energy use. EBMUD's total direct GHG emissions in 2005 were 12,242 metric tons. Mobile combustion sources (vehicles, portable equipment) produced 63% of EBMUD's direct GHG emissions. Natural gas–powered equipment produced the remaining 37% of direct GHG emissions. De minimis sources (< 5% of total) include propane forklifts (20 metric tons), stationary diesel generators (347 metric tons), and stationary propane generators (3 metric tons).

It's always helpful to be able to put numbers into context by looking at operations in comparison with other agencies. One of the early steps EBMUD took to help plan how to manage its effect on climate change was to join the California Climate Action Registry. The registry is a private, nonprofit organization that serves as a voluntary clearinghouse. It develops and promotes credible, accurate, and consistent GHG reporting standards and tools for organizations to measure and monitor their GHG

emissions consistently across industry sectors and geographical borders.

EBMUD is also joining the Chicago Climate Exchange (CCX), the world's first and North America's only active voluntary, legally binding trading system to reduce emissions of all six major GHGs. The CCX is a cap-and-trade system whose members make a legally binding emission reduction commitment. Members are allocated annual emission allowances in accordance with their emissions baseline and reduction schedule. Members who reduce beyond their targets have surplus allowances to sell or bank; those who do not meet the targets comply by purchasing CCX carbon financial instrument® contracts. EBMUD has committed to minimum 2010 emission reductions of 6% (1.5% per year starting in 2007) below 2000 levels.

Energy reduction projects. EBMUD has an aggressive program to minimize energy use through careful management of facilities, off-peak pumping schedules, and use of renewable resources. The district adopted a policy to encourage installation of renewable energy by establishing criteria for investments that are cost-neutral over the life of the project. To date, two photovoltaic systems have been installed, one at a maintenance facility and the other at a water treatment plant. The systems offset about 10% of the facility load, equivalent to the electrical demand of more than 60 homes for one full year.

Energy generation projects. EBMUD's resource-recovery program uses available capacity at its wastewater treatment plant to convert trucked-in nonhazardous waste (such as food-processing waste and wastewater sludge) to methane, which is used to generate renewable energy. The trucked waste program provides an environmentally responsible and economical disposal alternative for a variety of liquids and food-processing solids.

Renewable energy production has more than doubled from 2 to 4.5 megawatts over six years. This facility generates enough energy to power the equivalent of 2,500 homes at one time and supplies nearly all power required by the plant. Designs in progress will add two 4.5-megawatt turbines to generate additional power that can be sold on the electric grid. This power is considered green, which allows EBMUD to sell renewable energy credits or carbon credits.

As noted earlier, EBMUD's 40-megawatt hydropower facilities produce an average of 180 GW·h per year of renewable energy from water supply operations in the Sierra. This exceeds EBMUD's annual energy use of 145 GW·h. Hydropower is a green energy source that results in renewable energy credits and generates revenue.

Reductions in use of fossil fuels. In 2001, EBMUD started a pilot program to test daily use of gas–electric hybrids in its vehicle fleet. By 2004, 90% of EBMUD's vehicle fleet was converted to hybrids. Today, all of EBMUD's 59 sedans are hybrids. This saves 12,000 gal of gasoline and reduces CO_2 emissions by 103 metric tons each year. EBMUD also has an award-winning employee transportation program that offers incentives to encourage employees to carpool, take mass transit, or bike or walk to work. This program enables EBMUD to further reduce fossil fuel consumption.

CONCLUSION

EBMUD's work on assessing its vulnerabilities to climate change, integrating climate change considerations into the organizational structure and into long-range water supply planning and budget development programs, and developing greenhouse gas mitigation strategies illustrates how water utilities can be proactive in their efforts. Although the utility learned a lot about the science and feels confident that it has established a solid management approach, its strategy, by necessity, will continue to evolve. EBMUD is pursuing several projects to further reduce GHG emissions, including in-conduit hydroelectric power and additional photovoltaic-energy-generation projects.

Climate change is one of the greatest challenges facing the planet today. That challenge will require new approaches to planning and managing water systems and water supplies. As professionals who inherited the responsibility to deliver reliable water supplies, protect public health, and preserve natural resources, EBMUD must chart a new course for the industry. EBMUD's response to climate change will profoundly influence the public's trust in water supply management and infrastructure planning.

ABOUT THE AUTHORS

Michael J. Wallis (to whom correspondence should be addressed) is the director of operations and maintenance at the East Bay Municipal Utility District (EBMUD), 375 11th St., Oakland, CA 94607; e-mail: wallis@ebmud.com. He has 33 years of experience in the water and wastewater industry and has BS and MS degrees in civil engineering from North Carolina State University in Raleigh. Michael R. Ambrose and Clifford C. Chan are managers of regulatory compliance and water treatment and distribution, respectively, at EBMUD.

REFERENCES

Cayan, D.; Lynd Luers, A.; Hanemann, M.; Franco, G.; & Croes, B., 2006. Climate Change in California: An Overview. California Climate Change Center, University of California, Berkeley.

CDWR (California Department of Water Resources), 2006. Progress on Incorporating Climate Change Into Management of California's Water Resources: Technical Memorandum Report. CDWR, Sacramento, Calif.

IPCC (Intergovernmental Panel on Climate Change), 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (R.K. Pachauri & A. Reisinger, editors). IPCC, Geneva.