

CHARTING THE RAPIDS AHEAD:

WESTERN WATER, CLIMATE CHANGE & PUBLIC HEALTH

Snapshot of an emerging field

**An overview brief for
policy makers, public health advocates,
water managers and other key stakeholders**

A joint venture

Carpe Diem West

and

**The Public Health Institute's
Center for Public Health & Climate Change**

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WHY THIS OVERVIEW BRIEF?

Changes in the earth's climate will have profound impacts on water, and water has profound impacts on public health. From outbreaks of infectious disease to malnutrition, and from injuries and accidents to post-traumatic stress, the effects of climate change on water supply, security and sources are expected to raise significant public health issues in the coming decades.

Yet little discussion is taking place in regard to how the changing climate's impacts on water will affect public health. This lack of discussion is of particular concern in the American West, where climate scientists broadly agree that climate change is profoundly altering every aspect of water—its quality, quantity, timing, phase (rain or snow), and temperature. And in the American West, as in the rest of the nation, longstanding divisions between water users, water managers and health officials have frustrated most attempts at collaboration even before the considerations of climate change.

Together, our two organizations, Carpe Diem West and the Public Health Institute's Center for Public Health & Climate Change, talked with some of the nation's leading experts working in the fields of public health, water, and climate about what they see as some of the most significant areas of potential concern, with a focus on the American West. This paper highlights some of the common themes and issues that emerged from our discussions with these experts, and describes some questions for decision makers to consider as they address the potential impacts of climate change on water and health.

Importantly, this overview brief is not intended to be a piece of academic research or a comprehensive review of the available scientific literature. Rather, it is a snapshot of an emerging field—one intended to raise provocative questions and to instigate a broader conversation among researchers, public health officials, water decision makers, funders and policy makers.

Thanks to the time and insights of these leading experts, we now have an excellent starting point from which to further examine this challenging triangle—water, climate change and public health.



Alexandra Destler, EdM
Founder & Strategic Advisor
Center for Public Health & Climate Change
Public Health Institute



Kimery Wiltshire
President & Chief Executive Officer
Carpe Diem West

I. THE EFFECTS OF CLIMATE CHANGE ON WESTERN WATER

“ *These issues—climate, water, and health—may connect more prominently in the West than in the East because of existing water scarcity and fragile landscapes in many areas. For example, we have observed impacts on water quality in the Rocky Mountains because of the combined impacts of prolonged drought exacerbating bark beetle infestations, forest fires and denuding of forests, making them more prone to mudslides, destabilization of soil when heavy rains return.*

**Dr. John Balbus, Senior Advisor for Public Health
National Institutes of Health**

Current, broadly accepted research indicates that in the American West climate-driven changes to the water cycle are expected to be both imminent and profound. Climate change will have far-reaching impacts on water in the American West—affecting where, when, and how much water is available for humans and ecosystems—and these impacts are expected to intensify in the coming decades. The indicators suggest:

- Significant changes in the timing, amounts and forms of precipitation (with different experiences in different regions), leading to shifts in timing, amounts and variability of runoff, and resulting water supplies.
- More frequent extreme weather events, increasing the frequency and severity of flooding.
- Overall reductions in precipitation and runoff in certain parts of the West, especially the Southwest.
- Increased chances of severe droughts, exacerbated by rising demand for water from current and future populations.
- Earlier snowpack runoff, affecting seasonal storage of water and stream flows.
- A shifting demand to groundwater resources, which are prone to contamination problems that are often difficult to monitor, regulate and rectify.
- Serious threats to the ecological health and resiliency of the forested watersheds that supply some 65% of the American West's drinking water, including more frequent catastrophic wildfire and the spread of invasive species.

Although the pace and magnitude of these changes are uncertain, the forces that lead to these effects are relatively well understood, and there is some indication that many of these trends are already occurring.¹

“ *I want to emphasize the importance of not relying on just one water source and how this will only be more important with climate change.*

**Dr. Sharon Megdal, Director,
Water Resources Research Center University of Arizona**

II. THE EFFECTS OF CLIMATE CHANGE ON WATER-RELATED PUBLIC HEALTH ISSUES

“ While the primary climate-water impacts focus to date has been on water scarcity, public health professionals are equally concerned about climate change’s impact on water quality issues—from increased sediment and nutrient loads following heavy precipitation events to changes in the microbial characteristics of source waters associated with complex interactions driven in part by increases in ambient temperatures.

Dr. Joan Brunkard, Epidemiologist
Centers for Disease Control and Prevention

Current and predicted climate-related impacts to water in the American West are associated with a range of health outcomes. For example, water can be a pathway for the spread of infectious disease, particularly during flood events that compromise the effectiveness of treatment systems. In addition, standing water provides breeding habitat for disease-bearing insects, wildfires can affect watersheds that house drinking water for millions, and extreme weather events, such as flooding or prolonged drought, can lead to stress and injuries.

The following sections discuss these and other water-related public health issues in the context of predicted climate impacts.

Floods and Storms

“ Flooding and drought can have serious public health impacts, depending on their magnitude and the vulnerability of the communities they affect. Better understanding is needed of the extent and depth of the health impacts of extreme weather events.

Dr. Kristie L. Ebi, Lecturer
Department of Medicine, Stanford University

Climate change is projected to increase the frequency and severity of extreme weather events and natural disasters globally. Floods, the most frequent natural weather disaster,² can contribute to infectious diseases, toxic contamination, mental health impacts, injuries and drowning. Increased incidences of diarrheal diseases, including

cholera, cryptosporidiosis and typhoid fever, have been documented after floods in both high and low income regions of the world.³ Post-flooding contamination from spills of oil, pesticides, metals, and toxic waste has been documented in the United States.⁴

Coastal populations are most at risk of extreme weather and storm surges, with more than half of the world’s population living within 100 miles of a coastline, including some 40 million people in the American West. Many of the experts interviewed believe that program interventions in this arena should prioritize social vulnerability, adaptation and resilience planning.⁵

“ The first calls to funders following Hurricane Katrina were for help in independent monitoring of contaminants in floodwaters, drinking water, and neighborhoods as they dried out. Water, a necessity of living, also was an agent of devastation and vector of exposure.

Kathy Sessions, Executive Director
Health and Environmental Funders Network

• Increased Waterborne Disease During Flood Events

The most common concern raised by the experts interviewed for this report was the potential for an increase in outbreaks of waterborne disease during flood events, both due to the overloading of wastewater treatment plants by stormwater, and the direct exposure of affected populations to flood waters containing pathogens and other contaminants.

“ Every time there’s a flood, public health goes back to the 19th century. There are issues with sanitation, communicable diseases, and unsafe drinking water.

**Miriam Rotkin-Ellman, MPH, Scientist
Natural Resources Defense Council**

As one expert summed up, severe weather and periodic flooding will be the big elements of change, and the impacts will be increased links to waterborne diseases, gastrointestinal illness from water contamination, and huge costs to urban infrastructure as it works to manage these changes.

The capacity of the nation’s wastewater treatment plants to handle floods has been a major public health concern, even in the absence of extreme weather events possibly driven by changes in climate. Many cities in the American West do not have separate stormwater and wastewater treatment systems, meaning their wastewater treatment plants receive large surges of storm water during floods.

Such surges overwhelm the design capacity of many plants, resulting in untreated or partially treated sewage discharged directly into rivers, lakes, or oceans.

The increased frequency and severity of flooding that are anticipated to occur in the American West, combined with other human-caused factors such as large-scale expansion of impermeable surfaces (concrete and asphalt), loss of floodplain area, and increased construction of dwellings in floodplains, are changing the recurrence interval of floods in some locations. What used to be considered a 100-year flood can now be expected to occur much more frequently.

“ Floods pose a number of human health threats, including direct loss of life from flood waters and potential contamination of water systems resulting from the mobilization of contaminated sediments and discharge of untreated sewage into waterways.

**Heather Cooley, Co-Director
Pacific Institute**

• Floods and Vector-borne Diseases

“ Whether flooding events lead to changes in the incidence of vector-borne disease depends on the magnitude and extent of flooding, how precipitation interacts with mosquito breeding cycles, and the vulnerability of the affected community. Some locations because of physical, socioeconomic or other factors can experience greater (or fewer) impacts during similar flooding events.

Dr. Kristie L. Ebi

Floods can also increase human exposure to infectious agents through contact with contaminated water or mud. For example, leptospirosis, the most common zoonotic disease worldwide, infects humans who come into contact with the urine of infected dogs, pigs, cattle, and rodents. While largely tropical, the disease can occur in milder climates and may be a concern in the West as floods carry waters to new areas and communities.

Increased Risk of Contamination of Source Watersheds

“Many waterborne pathogens—viruses, bacteria and parasites are sensitive to even small shifts in temperature or precipitation patterns. More observational data are needed to better understand the potential health implications associated with observed and projected changes in climate.

Dr. Joan Brunkard

Several experts interviewed discussed the potential for climate change to increase the risk of contamination of watersheds—the sources of drinking water for much of the American West—primarily by sediment, organic matter and the related pathogens that come with them. This risk results from several interrelated factors, all of which are driven to some degree by climate.

For example, spikes in precipitation and runoff have been found to increase levels of pathogens in drinking water. These spikes can carry sediment and debris into reservoirs and other drinking water infrastructure, along with organic matter that can overwhelm treatment systems. Over a nearly 50-year period in the U.S., more than half of outbreaks of waterborne disease were correlated with heavy precipitation.⁶ In the Great Lakes region, scientists predict that more than 2.5 inches of rain in a single day could contribute to 50-100% more waterborne disease outbreaks in the following year, due to compromises in the piped water supply.⁷ Similar impacts could be expected in the American West.

Worldwide, waterborne diseases are caused by a range of pathogens, including bacteria (cholera, legionellosis), viruses (Hepatitis A), protozoa (cryptosporidiosis), parasites (schistosomiasis), and algae (neurotoxins). The most common diseases associated with waterborne pathogens are gastrointestinal, particularly diarrheal diseases. Studies have shown a higher incidence of intestinal infections and diarrhea during periods of higher rainfall, due to contaminated drinking water supplies, compromised sewage, and treatment systems.

Mental Health Consequences

Although experts have only recently begun to document the psychological effects of climate change, there is ample evidence associating extreme weather and other climate-related events with a variety of mental health impacts. Extreme weather events have been associated with negative mental health consequences, from acute stress and anxiety to post traumatic stress disorder, depression, poor concentration, sleep disruption and drug or alcohol abuse.⁸ With floods in particular, mental health problems and stress-related disorders may arise from displacement, loss of property, illness, and death or injury of loved ones. Floods and other extreme weather events can also increase long-term anxiety and stress over the future, with more severe effects for already disadvantaged communities.⁹

Water Scarcity: Drought and its Consequences

Climate change experts suggest that warmer temperatures and shifting global water cycles will contribute to severe weather events in the form of drought as well as floods. Records indicate “the percentage of Earth’s land area affected by serious drought more than doubled from the 1970’s to the early 2000’s, and can be extrapolated to predict similar impacts going forward.”¹⁰ In the American West, a stark illustration of this trend is the recent series of extreme dry years in the Colorado River Basin. From food shortages and wildfires to forced migration of human populations and other species, the impacts of water scarcity can create significant concerns for water and health officials.

Water Contamination by Wildfire

An important factor in source watershed contamination is the increase in catastrophic wildfires, which are expected to continue to become more frequent as drought conditions become more prevalent across much of the American West. Loss of vegetation and erosion following large-scale forest fires can send massive amounts of sediment, ash and organic matter downstream. This results in an overloading of treatment systems, forcing cities, such as Denver in 1996, to shut down key water supplies.¹¹

Decomposing root systems from burned trees and shrubs after the 2011 wildfires are expected to affect Arizona's water supply and security for years to come, and the region's aquifers and springs will likely see less water as runoff patterns shift with the loss of vegetation.

“ *With increased temperature, we don't get long-term winter time freezes that kill insects like the bark beetle, which increases forest susceptibility. If you add drought on top of that, the forest is primed for burning or loss of the fundamental dynamics of a healthy ecosystem and root system. This will affect runoff and groundwater. Climate change will exacerbate it.*

**Dr. Tim Brown, Director
Western Regional Climate Center**

Yet another complicating factor is the spread of bark beetles. Although a natural part of western pine forest ecosystems, in the last two decades these destructive beetles have spread across tens of millions of acres due to warmer winter temperatures. Some studies suggest that the devastation they cause to trees has substantially increased the risk of catastrophic fire in many watersheds that supply western cities and towns with drinking water.

Drinking Water Contamination through Increased Reliance on Groundwater

Another common theme discussed by the experts interviewed was the concern that as surface water supplies (i.e., lakes and rivers) become less reliable due to drought, overuse and changing runoff patterns, more communities will turn to groundwater as the primary source of drinking water. This raises several concerns. Across many agricultural areas, groundwater is contaminated with pesticides and nitrates from fertilizer. A prominent example is California's Central Valley, where many aquifers are also susceptible to depletion from excessive pumping, making them an unreliable long-term source of drinking water.

“ *There are rural areas in the Central Valley that rely on groundwater and don't have a good drinking water supply. Climate change won't help. This is partly institutional and partly raw fact of life. Water is very capital intensive and economies of scale are a huge factor.*

**Dr. Michael Hanemann,
Wrigley Professor of Sustainability,
Arizona State University &
Chancellor's Professor Emeritus, University of California**

Although state and federal laws are in effect to protect water quality and quantity, and to prevent the use of contaminated aquifers for drinking, our experts noted that these laws often do a poor job of protecting groundwater. For example, the federal Clean Water Act places no mandatory restrictions on activities like farming, which is the main source of pesticides and nitrates in many aquifers.

Likewise, most western states' water laws generally do a poor job of preventing the depletion of groundwater aquifers, which are often perceived as a limitless water source, though science and experience are proving otherwise.

Furthermore, the federal Safe Drinking Water Act, which requires monitoring and treatment for contaminants in drinking water, does not apply to water systems serving fewer than 15 connections, leaving large numbers of rural westerners who rely on individual wells unprotected.

Chemical Water Contamination

“In a changing climate, vigilance will be required when it comes to potable water quality. In particular, smaller communities utilizing well water will be vulnerable and will lack the support of infrastructure available to larger towns.

John Andrew,
Assistant Deputy Director, Climate Change
California Department of Water Resources

Water contamination from chemical pollutants, such as mercury, can be exacerbated by drought-related increases in water temperature, another predicted effect of climate change. Increased temperatures can increase the activity of bacteria which transform metallic mercury to organic mercury which then can move up the food chain.

Fresh Water Warming and Increased Nutrient Loads

Increasing surface temperatures, expected to continue occurring as the climate changes, are also associated with an increase in harmful algal blooms (HABs) in oceans and freshwater sources.¹² HABs can cause gastrointestinal, neurological, and respiratory symptoms, as well as skin irritations and liver damage when ingested, inhaled, or through direct contact with skin.¹³ HABs arise when naturally occurring blue-green algae (cyanobacteria) multiply rapidly, due to increased light and temperature. These blooms have already been reported in a number of water bodies across California, including rivers, lakes and streams that communities utilize for recreation and fishing.¹⁴

Other Vector-Borne Diseases Associated with Climate Change

“Another potential issue in this area is the amount of standing surface water retained in urban areas. Increases could change vectors like mosquitoes and the urban and rural ecology. Bugs may breed in different ways and that could increase disease.

Dr. Andrew Comrie, Professor
University of Arizona

Vector-borne diseases strike when pathogens are carried from one host to another through a vector, such as a mosquito, tick, mite or other arthropod or vertebrate. Climate and rainfall are key factors determining the distribution of vector-borne diseases. In the United States, common vector-borne diseases include Lyme disease, hantavirus

and rabies. Many other such diseases, such as malaria and dengue fever, had been virtually eliminated in the U.S., but their recent re-emergence in Florida and Texas, for example, is cause for concern.

Climate change is expected to increase the geographic range of insect vectors into regions where they have previously been eliminated and where local populations have no immunity. The population of the American West is susceptible to vector-borne diseases that are prevalent in warmer regions of the world due to travel and trade networks, as well as changes in ecosystems and biodiversity patterns that exacerbate the impacts of climate change on disease vectors.¹⁵

III. SOCIOECONOMIC IMPLICATIONS

“ When we think of natural hazards like floods or droughts, we think of them as impacting society fairly evenly. But that isn't the case. Consider Nogales, Arizona—half a city in the US and half in Mexico. If a thunderstorm dumps a bunch of rain on both sides, the impacts of that will be influenced by different social and physical factors. The better your socioeconomic status, the less vulnerable you are.

Dr. Andrew Comrie

Economic Disruption and Human Migration Patterns

Climate change is expected to affect patterns of agricultural production, in part due to changes in access to water. As a result, whole communities may be forced to relocate. If ecosystems are damaged by wildfire, if groundwater becomes tainted with pollutants, and if communities lack access to clean water, many experts foresee human migrations toward clean sources of water.

While changing agricultural patterns or access to clean water will force “voluntary” migration, reports from the United Nations indicate that natural disasters like drought and flooding displaced 36 million people globally in 2008—with more than half (20 million) estimated to be climate related. Anticipating such diverse migration patterns and preparing communities with adaptation strategies is critical for community health and infrastructure planning.

Social Justice Implications

Most of the impacts discussed in this paper will be borne disproportionately by people of lower socioeconomic status. Poorer communities do not have the ability to pay for improved water monitoring or treatment. They are more likely to live in areas of contamination, and less able to migrate to avoid impacts. Social justice considerations must therefore be taken into account as the impacts of climate change on water become even more of a reality.

“ One of the major environmental justice issues in California is the lack of safe drinking water and basic sanitation. That will get worse with water scarcity. Tribes are getting squeezed out, for example, and more than a hundred tribes are not federally recognized so they don't have access to basic resources. Some can pay for municipal resources, some can't. These communities are always first to suffer and last to recover.

Debbie Davis, Policy Director
Environmental Justice Coalition for Water

IV. TOWARDS A POLICY FRAMEWORK

“ *We’re seeing changes in the immune system, more symptoms related to allergens, susceptibility to infections, respiratory tract, skin, gastrointestinal ailments—sure it’s about living conditions and substandard housing and poverty. But is there environmental information we need to factor in? We don’t know but we should explore it.*

Dr. Fernando Guerra, Director of Public Health (retired)
San Antonio Metro Public Health

The preceding pages catalog the most prominent areas in which some leading experts in the fields of public health, climate science, and water expect to see public health impacts resulting from climate-driven changes to water in the American West. An obvious next question is what kind of policy responses are appropriate. But before policymakers can begin to address that question, it is necessary to have some sense of the relative significance of the impacts described in this report. Some of them are likely significant and merit a deep, sustained policy response. Others might require very little action, while still others probably lie somewhere in between. How can these impacts be sorted out, so policy makers can begin to formulate effective responses? The experts interviewed for this report cite two equally critical needs.

“ *Workers, communities of color, and low-income communities are disproportionately exposed to cumulative effects of the many health hazards related to climate and water, with vulnerable populations including children and the elderly most at risk. Building the capacity and resilience of affected communities is critical and will ultimately protect everyone’s health.*

Kathy Sessions

The first is for better coordination of efforts among the professional sectors and regulatory agencies that work with various aspects of water, climate, and public health. We heard repeatedly in the interviews that the “separate” issues of health, water, and climate can no longer be disaggregated and addressed in silos. One-hundred and twenty years ago, health and water

agencies were one and the same—in some places we should consider combining them again. Professionals working in all three fields need to be aware of the powerful ways in which these issues intersect, to be on the lookout for impacts, to communicate what they see to their colleagues, and to plan collaboratively for the future. Only by combining the diverse perspectives and training of the different disciplines that work with and observe the effects of climate, water, and health can we hope to get an accurate picture of their combined effects.

“ *Public health policies need to build on existing initiatives and capacities, integrating surveillance and monitoring systems, strengthening professional education, communication capacities and community participation in preparedness and response considering that different areas in the West will experience different impacts of climate change. A win-win culture related to intersectoral and interagency work will be key.*

Dr. Cristina Tirado, Director,
Center for Public Health & Climate Change
Public Health Institute

The second critical need is for much more extensive information and monitoring of the existing and emerging connections between water, climate, and health. This monitoring should be focused on answering the basic questions that diverse communities of professionals and policymakers agree are most important.

For example:

- How are precipitation, runoff, and infiltration patterns changing, and what effects are these changes having on both the landscape as well as public health?
- How are instream flow levels and air temperatures affecting water temperatures, and how are these changes altering the ecosystems that humans live in and rely upon for food and water?
- What should water treatment professionals know to foresee impacts on water quality or stresses on current water treatment infrastructure?
- What should public health officials do to effectively monitor for public health impacts such as water borne disease?

Developing a strategy to gather the information necessary to answer such questions will require a coordinated effort among the communities of professionals—regulators, academics, political leaders, and others—who are working on widespread aspects of public health, water, and climate. The first step in any such effort must be to establish a dialogue among these disparate groups.

The Center for Public Health & Climate Change and Carpe Diem West hold the space for that conversation, and welcome partners from all sectors as we develop strategies to protect and support healthy and resilient natural and human communities.

“ *Clean and accessible water is critical to public health. Current climate change indicators make it clear we must immediately start cross-sectoral dialogues, representing all potentially impacted constituencies, in order to prepare health workers and the communities they serve for every eventuality.*

**Elise Miller, Executive Director
Collaborative on Health and the Environment**

EXPERTS INTERVIEWED

The following experts in the field of water, public health and climate change provided their knowledge and insights for this document. We appreciate the time they took—many outside of their institutional affiliations—to ensure that this report included a wide range of thinking, questions and potential concerns.

John Andrew *Assistant Deputy Director, California Department of Water Resources*

Dr. John Balbus *Senior Advisor for Public Health, National Institutes of Health*

Dr. Tim Brown *Director, Western Regional Climate Center*

Dr. Joan Brunkard *Waterborne Disease Prevention Branch, National Center for Emerging & Zoonotic Infectious Diseases, Centers for Disease Control & Prevention*

Dr. Andrew Comrie *Professor, School of Geography & Development / Associate Vice President for Research / Dean of Graduate College, University of Arizona*

Heather Cooley *Co-Director, Water Program, Pacific Institute*

Debbie Davis *Policy Director, Environmental Justice Coalition for Water*

Dr. Kristie L. Ebi *Lecturer, Department of Medicine, Stanford University*

Dr. Howard Frumkin *Dean, School of Public Health, University of Washington*

Dr. Fernando Guerra, M.D. *Director of Public Health (retired), now Consultant in Public Health, San Antonio Metro Health*

Dr. Michael Hanemann *Wrigley Professor of Sustainability, Arizona State University and Chancellor's Professor Emeritus, University of California, Berkeley*

Earl Lui *Program Director, California Wellness Foundation*

Dr. Sharon Megdal *Director, Water Resources Research Center, University of Arizona*

Elise Miller *Executive Director, Collaborative on Health and the Environment*

Miriam Rotkin-Ellman, MPH *Scientist, Natural Resources Defense Council*

Kathy Sessions *Executive Director, Health and Environmental Funders Network*

Dr. Cristina Tirado *Director, Center for Public Health & Climate Change, Public Health Institute*

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The **Public Health Institute's Center for Public Health & Climate Change** contributes to building healthy and climate-resilient communities that have the right tools to mitigate and adapt to climate change. The Center draws upon the significant technical, advocacy and research capacities of the Public Health Institute (PHI) to address one of the most vital and pressing issues of the day—the impacts of climate change on human health.

Carpe Diem West leads a network of water decision makers and scientists in the American West that is developing collaborative, innovative actions and policies to create water security for our communities, the food we grow, our economy and our environment.

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