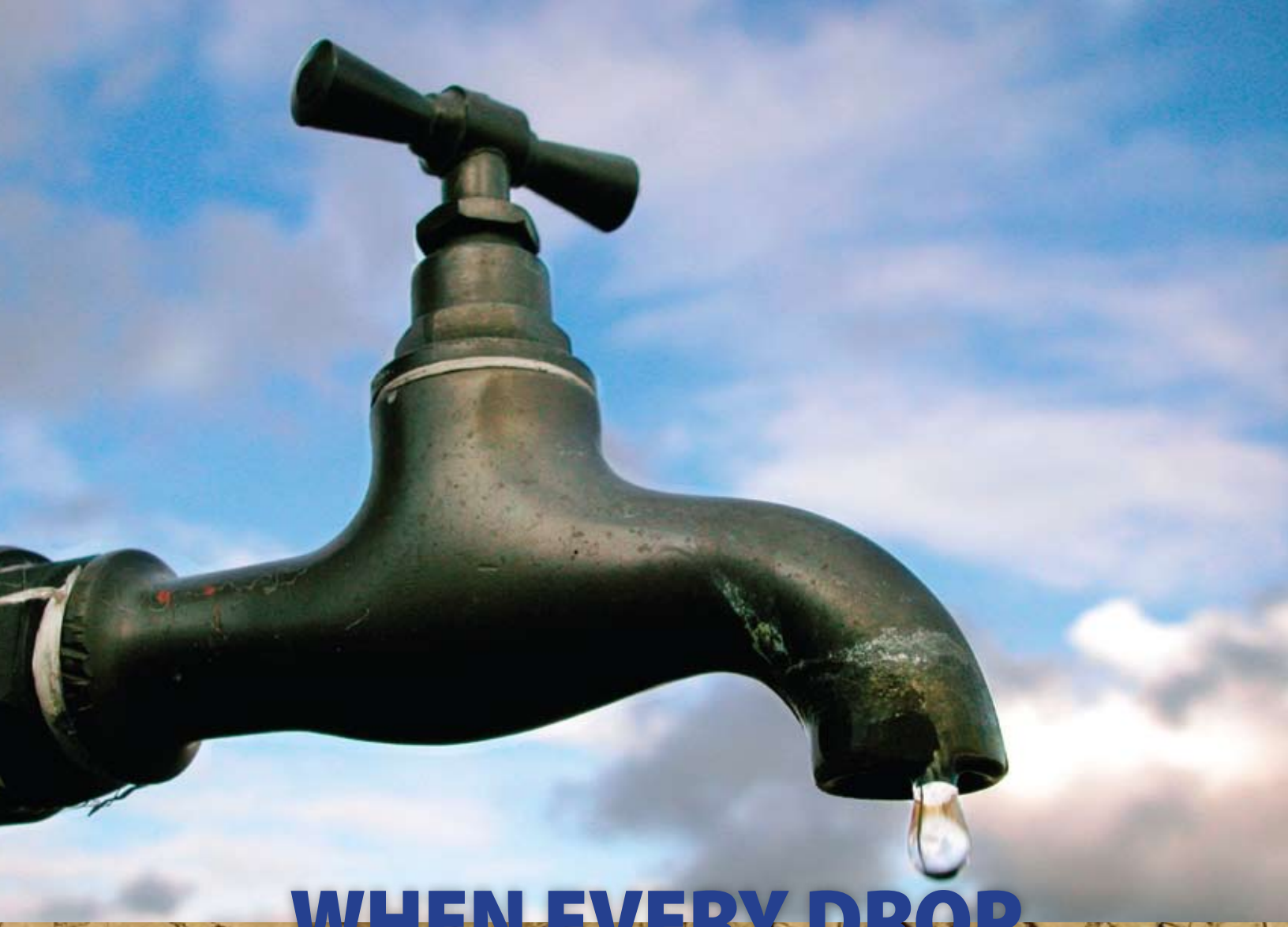

WHEN EVERY DROP COUNTS

Protecting Public Health During Drought Conditions

A GUIDE FOR PUBLIC HEALTH PROFESSIONALS

DEPARTMENT OF HEALTH & HUMAN SERVICES · USA

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

American Water Works Association

EPA

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION · U.S. DEPARTMENT OF COMMERCE

How to obtain copies

You can electronically download this document from CDC's National Center for Environmental Health (NCEH) Web site at http://www.cdc.gov/nceh/ehs/Publications/Drought.htm. To request a copy of this document or for more information, send an e-mail to drought@cdc.gov.

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American Water Works Association

Table of Contents

Acknowledgments

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Executive Summary

Although many aspects and implications of drought have been well researched in the literature, the Centers for Disease Control and Prevention (CDC) recognizes that there is much to be learned about drought as it affects the health of the U.S. public. Because no consolidated scientific evidence or guidance is currently available to help public health officials and practitioners prepare for or respond to drought at the local, state, or national level, CDC recognizes the need for a comprehensive, public-health-focused document on drought.

In April 2008, as a first step toward creating this type of document, CDC's National Center for Environmental Health (NCEH) created a working group composed of both internal subject-matter experts and external experts representing diverse fields, including all levels of public health, environmental protection, and water-related sciences. Through a series of conference calls, this group worked to determine the types of drought-related information to be included in the proposed drought document.

To consolidate existing information regarding the public health effects of drought and identify future research needs and next steps, CDC, the American Water Works Association (AWWA), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Environmental Protection Agency (EPA) collaborated to sponsor the Public Health Effects of Drought Workshop in September 2008. At this 3-day meeting, experts from diverse disciplines (including federal, state, and local public health; environmental engineering and science; coastal ecology; regulatory engineering; water-related research; risk communication; water systems management; and emergency management) used a computerized communication/facilitation tool to identify and prioritize drought-related public health issues, identify research gaps and needs in the area of public health as it relates to drought, and develop recommendations to ensure that the nation's public health system is better prepared for drought. Workshop participants also engaged in drought-related discussions and shared personal experiences with drought within their regions, including lessons learned, best practices, and challenges.

The publication resulting from these efforts, *When Every Drop Counts: Protecting Public Health During Drought Conditions—A Guide for Public Health Professionals*, reflects the experience and knowledge of the working group members who participated in numerous conference calls, the experts who attended the 2008 Public Health Effects of Drought Workshop, and on the existing literature and data that have been collected regarding the impact of drought on health. In addition to providing an overview of basic drought- and water-related information and principles (such as the definition of drought; U.S. drought and water-use trends; the relationship between drought and climate change; water distribution; water treatment and classification; and water-related policy), this document addresses numerous drought-related public health effects, which are organized into several broad categories within the document. These categories include

- compromised quality and quantity of potable water,
- compromised food and nutrition,
- diminished living conditions (as they pertain to energy, air quality, and sanitation and hygiene),
- recreational risks,
- mental and behavioral health,
- vulnerable populations, and
- increased disease incidence (for infectious, chronic, and vectorborne/zoonotic diseases).

To assist public health professionals and others concerned with human health during drought conditions, this document also contains information regarding drought preparation and response. To ensure usability, the document organizes these activities into two broad categories: those that should be conducted before and in the early stages of drought and those relevant to late-stage, severe drought conditions. Topics covered for early stages of drought include

- assessing internal capacity,
- participating in a jurisdiction-wide hazard and vulnerability assessment,
- conducting a public health vulnerability assessment,
- identifying and coordinating with key partners and stakeholders,

- communicating drought strategies and recommendations,
- educating and training key partners,
- developing mitigation strategies, and
- documenting and evaluating drought preparedness activities.

This discussion also provides readers with tables and tools designed to provide further guidance on preparedness activities, such as examples of at-risk populations and the health implications relevant for specific groups, potential partners in drought preparedness activities, and communication objectives and actions relevant to specific target audiences.

The response activities identified in this document for late-stage, severe drought conditions include

- evaluating drought-related public health impacts,
- coordinating drought-response activities with key stakeholders and partners,
- developing and communicating health-response objectives and action plans,
- assigning and using resources to achieve objectives,
- participating in incident management systems and structures,
- addressing requests for information and assistance, and
- documenting and evaluating drought response activities.

The document concludes with a discussion of much-needed drought-related research and initiatives. Identified by the experts participating in the Public Health Effects of Drought Workshop, the extensive recommendations for future needs are organized into research-related endeavors and those pertaining to initiatives and resources. Also included in the document is a list of diverse drought-related resources likely to be helpful to those committed to protecting the health of the U.S. public.

When Every Drop Counts: Protecting Public Health During Drought Conditions—A Guide for Public Health Professionals has been reviewed and vetted by CDC, AWWA, EPA, NOAA, and other stakeholder agencies and organizations. It is hoped that this publication will be used by public health officials, practitioners, and other stakeholders in their efforts to first understand and then prepare for drought within their own communities.

WHEN EVERY DROP COUNTS

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Drought is a natural phenomenon in which levels of rainfall or other types of precipitation are lower than average for an extended period of time, resulting in inadequate water supply. Understanding drought and its impact on people and the environment, however, must take into account differences in geographic regions, local demand for water, and other variables, such as a community's ability to adapt to water shortages and state/local policies that regulate water supply (National Drought Mitigation Center 2006a). For instance, what is considered a significant amount of annual rainfall in the Southwest could be considered drought in the northwestern United States.

Although many aspects and implications of drought have been well researched in the literature, the Centers for Disease Control and Prevention (CDC) recognizes that there is much to be learned about drought as it affects the health of the U.S. public. Recently, CDC's National Center for Environmental Health (NCEH) conducted an extensive search and review of existing drought-related guidance, literature, and information. NCEH found that, although some limited data on drought exist as it pertains to public health, no consolidated scientific evidence or guidance is currently available to help public health officials and practitioners prepare for or respond to drought at the local, state, or national level. As a result, public health experts working at all levels have been operating with only limited guidance about drought preparedness and response and a less than optimal understanding about how water shortages can affect the health of their communities.

This publication is intended to assist public health officials, practitioners, and other stakeholders in their efforts to first understand and then prepare for drought in their communities. It provides information about how drought affects public health, recommends steps that can be taken to help mitigate the health effects of drought when preparing for or responding to drought conditions, identifies future needs for research and other drought-related activities, and provides a list of helpful resources and tools.

In April 2008, CDC, the American Water Works Association (AWWA), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Environmental Protection Agency (EPA) committed to collaboratively creating a guide for public health and other professionals concerned with the health implications of drought. Several key processes were employed over a period of months to help inform the writing of the drought document. CDC first conducted a review of the existing drought-related public health guidance, information, and literature, and identified a need for a consolidated drought planning resource for public health. A working group was then organized composed of both internal subject-matter experts and external experts representing diverse fields, including all levels of public health, environmental protection, and water-related sciences. Over the course of several months, the working group held a series of conference calls to discuss and prioritize the type of information that should be included in the proposed drought document, along with the appropriate format and structure.

The research and consultations culminated in a 3-day workshop, which took place on September 17-19, 2008, in Atlanta, Georgia. The Public Health Effects of Drought Workshop was attended by experts from diverse disciplines, including federal, state, and local public health; environmental engineering and science; coastal ecology; regulatory engineering; water-related research; risk communication; water systems management; and emergency management (see Acknowledgments section for a list of participants and their affiliations). Participants were presented with several tasks during the 3-day meeting. They worked together through a computer-based communications/facilitation tool and engaged in discussions to identify and prioritize drought-related public health issues, identify research gaps and needs in the area of public health as it relates to drought, and develop recommendations to ensure that the nation's public health system is better prepared for drought. Workshop participants also shared personal experiences with drought within their regions, including lessons learned, best practices, and challenges.

The recommendations contained within this document are based on the experience and knowledge of the working group members who participated in numerous conference calls, the experts who attended the 2008 Public Health Effects of Drought Workshop, and the literature and data that have been collected regarding the impact of drought on health. The document has been reviewed and vetted by CDC, AWWA, EPA, NOAA, and other stakeholder agencies and organizations, including the Association of State and Territorial Health Officials (ASTHO), the National Association of Local Boards of Health (NALBOH), and the National Association of County and City Health Officials (NACCHO).

Defining Drought

Drought is a natural phenomenon during which regions or communities experience shifts in the balance between precipitation and evapotranspiration (the processes of evaporation and transpiration)—a balance that is inherent to the earth's water cycle (see the Understanding Natural Cycles in Water Distribution section). Several factors affect the impact of drought on humans and other life forms, including the timing of precipitation events, effectiveness of the rain that is falling (i.e., rainfall intensity and the number of rain events), characteristics of the built environment in the affected area, and local demand for water. Individual areas or communities can be affected differently by drought depending on several additional variables, including

- the structure and capacity of existing water systems,
- economic development,
- the at-risk populations living within the affected area,
- local governance of water use, and
- other societal factors, such as the presence of local social networks.

Because the conditions that signify drought can vary substantially by U.S. region and locality, drought should ultimately be defined based on the context and location in which the water shortage is occurring.

Although drought most commonly is defined climatologically, drought can also be exacerbated by human activities. For example, even when precipitation is occurring at average rates within a specific area, urban expansion and development without regard to existing water supply and water system capacity can trigger a human-induced drought.

Drought can occur anywhere in the world, and it is considered a transient environmental hazard except in arid geographical regions that historically receive very limited amounts of rainfall. In addition, because of the substantial amount of time that elapses between the warning signs of drought and any measurable negative consequences to human and environmental health, drought should be considered a chronic or "low rise" natural event rather than an acute emergency for public health preparedness and response purposes. Drought is unlike other natural emergencies such as hurricanes, floods, or earthquakes; drought-related conditions can take years to escalate to the point at which water supply becomes severely limited, and the length of time that drought conditions may persist and impact communities is unknown.

Past, Present, and Future Trends in Drought

Significant drought events have affected the United States throughout history. Droughts can last from a single season to multiple decades and can impact from a few hundred to millions of square kilometers. Studies of paleoclimatic indicators (e.g., sediments and tree ring patterns) reveal that cycles of drought have affected North America for the last 10,000 years (National Oceanic and Atmospheric Administration 2003). Even more is known about droughts occurring during the more recent years of the 20th century.

Perhaps the most notable and well known U.S. drought event during the last century was the Dust Bowl drought of the 1930s. During the 8 years of severe drought associated with the Dust Bowl, states located in the Great Plains experienced conditions characterized by substantial clouds of dust and sand that often blocked out the sun for days at a time. In an average year over the past century, approximately 14% of the United States has been affected by severe or extreme climatological drought, although it was as high as 65% during the Dust Bowl, and recently has been about 35% for some regions (Wilhite and Pulwarty 2005). The paleo-climate record shows that droughts have lasted decades, many more severe than was experienced over the past century.

The conditions associated with the Dust Bowl economically and socially devastated farming communities that relied on rainfall for their livelihood. These conditions also were associated with adverse health effects. During the drought of the 1930s, people exposed to clouds of dust were at increased risk for acquiring "dust pneumonia," a type of pneumonia caused when dust fills the lungs and inflames alveoli (Cook et al. 2007; Egan 2005). Often fatal, this type of pneumonia causes high fever, coughing, chest pain, and difficulty breathing. Data

regarding the exact number of persons affected by dust pneumonia during the 1930s are extremely limited; however, this drought-related illness was recognized as a significant health problem by persons involved in protecting the health of the public, as evidenced by efforts to distribute thousands of dust masks to persons living in affected areas. It is likely that the Dust Bowl was associated with other health problems, including chronic diseases (e.g., asthma) and mental and behavioral health disorders (e.g., depression).

Did you know…

An article read before the Public Health Engineering Section of the American Public Health Association at the Sixtieth Annual Meeting on September 15, 1931, in Montreal, Canada, highlighted a number of adverse health effects and conditions attributed either directly or indirectly to drought. These included increases in malnutrition, rickets, pellagra, intestinal disorders (e.g., dysentery, diarrhea, enteritis), and typhoid fever (Ravenel 1931).

The cause of the dust clouds that came to characterize the drought of the 1930s was attributed not only to lack of rainfall and dry topsoil but to poor land management practices, which underscores the key role that human activity plays in drought-related outcomes. In the 1930s, farmers had begun to increase the production of crops in response to the financial crisis that Americans faced during the Great Depression; little thought was given to the effect that increased land clearing and farming would have on the environment. It is now understood that the effects of drought can be better weathered by the implementation of more sustainable cultivation methods to help control soil erosion in dry-land ecosystems.

Did you know…

Scientists at the National Aeronautical and Space Administration (NASA) have an explanation for the Dust Bowl drought of the 1930s. Siegfried Schubert of NASA's Goddard Space Flight Center in Greenbelt, Maryland, and his colleagues used a computer model developed with modern-era satellite data to look at the climate over the past 100 years. The study found cooler than normal tropical temperatures in the Pacific Ocean combined with warmer tropical temperatures in the Atlantic Ocean to create conditions in the atmosphere leading to drought. These changes in sea surface temperatures created shifts in the large-scale weather patterns and low level winds that reduced the normal supply of moisture from the Gulf of Mexico and inhibited rainfall throughout the Great Plains. By discovering the causes behind droughts within the United States, especially severe episodes like the Dust Bowl era, scientists may recognize and possibly foresee future patterns that could create similar conditions (Schubert et al. 2004).

Since the Dust Bowl of the 1930s, droughts have continued to affect specific regions of the United States. In the 1950s, many states, particularly those located in the southern Great Plains, experienced a 5-year drought that resulted in substantial social and economic devastation. This drought was characterized not only by extremely limited rainfall, but by excessively high temperatures, causing grasslands to become scorched and unusable to ranchers who relied on livestock for their livelihood. Texas was particularly hard hit by the drought, and almost all of its counties were eventually declared federal drought disaster areas.

The United States was substantially affected by drought again in the late 1980s, when a 3-year drought impacted more than one third of the country. Areas hardest hit included the Northwest and the northern Great Plains, although many states in the eastern United States also were affected. The drought was complicated by both excessively high temperatures and wildfires. As with previous drought events, the drought of 1987-1989 was associated

with significant negative economic and societal consequences; substantial agricultural losses occurred, particularly among areas in which soybeans and corn were grown. In retrospect, researchers now understand that beyond high temperatures, fires, and rainfall deficits, other factors contributed to drought-related outcomes, including the farming of marginally cultivatable lands and the pumping of groundwater to the point of depletion.

The National Drought Mitigation Center (NDMC), which was established in 1995 and is run by the University of Nebraska-Lincoln's School of Natural Resources, provides current estimates of drought conditions by U.S. state and region. In addition, NDMC hosts the U.S. Drought Monitor, which uses a synthesis of indices and impacts to track drought conditions in the United States. According to NDMC, many areas of the United States have experienced or are currently experiencing drought conditions. Most notably affected within recent years are states in the southeastern part of the country (Alabama, Georgia, Tennessee, North Carolina, and South Carolina), certain western states (California and Nevada), Texas, and a few states in the High Plains region (Figure 1).

The National Integrated Drought Information System (NIDIS) Act of 2006 was signed into law by the President in December 2006 (Public Law 109-430). NIDIS (www.drought.gov) was developed to consolidate physical/hydrological and socioeconomic impacts data on an ongoing basis, develop a suite of usable drought decision support and simulation tools focused on critical management indicators and triggers, and engage and enable proactive planning by those affected by drought across temporal and spatial scales.

The prediction of future trends in rainfall for different parts of the United States must be extrapolated from historical data regarding climate trends over time and from other models used to predict climate, such as computer-driven general circulation models (GCMs). Drought models now take into consideration the potential effect that climate change is expected to have on future rainfall patterns within the United States (see the Drought and Climate Change section). Researchers from federal agencies, including the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA), have used rainfall patterns, climate models, historical records, and other indicators to make predictions about the amount and distribution of precipitation in the United States into the 21st century. These researchers concur that severe drought is likely to occur within the next century, particularly in midlatitude areas like the United States. It is anticipated that the southwestern United States will be most negatively impacted by these trends.

Drought and Climate Change

Data from many sources, including the Intergovernmental Panel on Climate Change, indicate that changes in the Earth's temperature patterns will likely increase both the severity of future droughts and the likelihood of intense precipitation events into the 21st century (Bates et al. 2008). Even in nondrought conditions, increases in air temperature can lead to unusual and excessive drying of soil and vegetation, which can create numerous problems for humans and animals ranging from inadequate supplies of surface water to poor soil quality and crop yields. When coupled with dry, compacted soil conditions, extreme rain events often lead to significant runoff, which increases the likelihood that critical groundwater resources remain inadequately replenished during a drought despite substantial rainfall amounts.

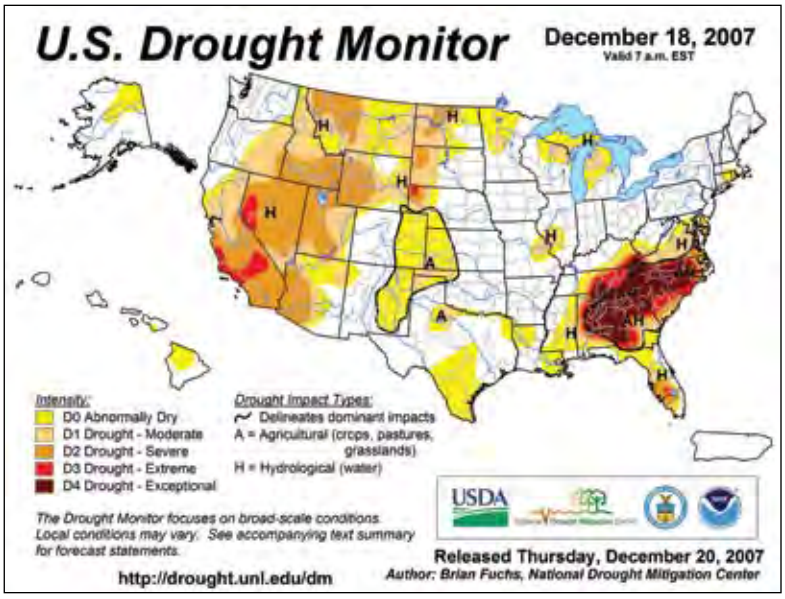

Figure 1. U.S. Drought Monitor

Source: National Drought Mitigation Center. undated. Drought monitor. Lincoln, NE: National Drought Mitigation Center. Available at http://www.drought.unl.edu/dm/ [accessed 2010 June 17].

Understanding Natural Cycles in Water Distribution

To characterize drought, it is important to understand the hydrologic cycle. The hydrologic, or water, cycle has no beginning and no end; it can be broken down into five basic processes: condensation, infiltration, runoff, evaporation, and precipitation (Figure 2). Factors such as temperature, global winds, and ground permeability are associated with each process, all of which affect water distribution around the world. According to the U.S. Geological Survey (USGS), water distribution naturally changes over time. Most of the water on earth is either not drinkable or is in unusable forms; 97% of earth's water is salt water within oceans, and of the approximately 3% of the earth's freshwater, most is found in the form of ice or glaciers (Figure 3). Although variations occur in water distribution, the amount of water that exists on Earth remains constant and should be considered a finite resource that cannot be replenished.

Water Resources

The water resources that contribute most to human quality of life and to ecosystem balance are groundwater and surface water. The term "surface water" refers to water that can be accessed at the earth's surface, which includes water from ponds, lakes, streams, and oceans. In contrast, groundwater is water that is found beneath the earth's surface in geologic formations. Groundwater can be replenished through precipitation, and it can naturally reemerge at the earth's surface through springs, geysers, and seepage or can be mechanically pumped from below through the use of wells.

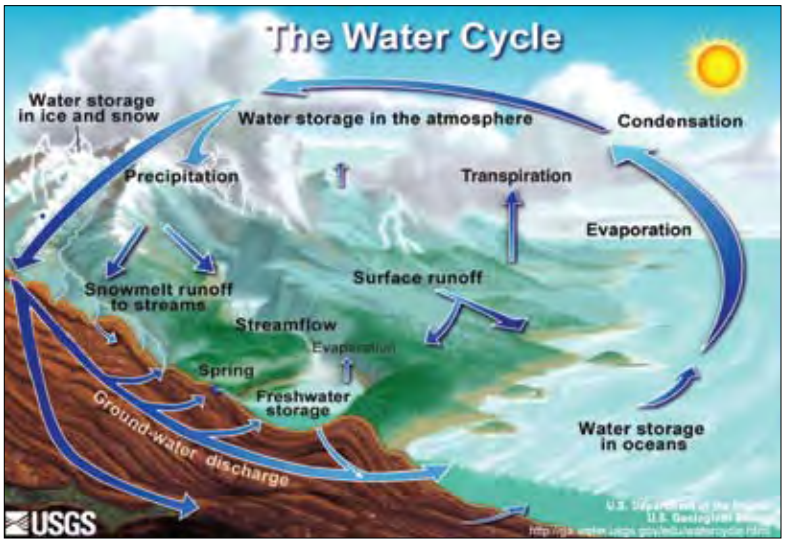

Figure 2. The Hydrologic Cycle

Source: U.S. Geological Survey. undated a. National Atlas of the United States: water use in the United States. Reston, VA: U.S. Department of the Interior. Available at http://www.nationalatlas.org/articles/water/a_water-use.html#one [accessed 2010 March 30].

The Need for Water

Water is essential to life. It is used for drinking and sanitation, irrigating crops, maintaining livestock and aquaculture, sustaining many types of industry, producing thermoelectric and hydropower, and recreational activity. Data collected during 2000 indicate that 408 billion gallons of freshwater and saline water are withdrawn each day for various municipal, agricultural and industrial uses within the United States, an increase of 3% from 1985-2000 (U.S. Geological Survey undated b). During this same period, the use of fresh groundwater increased 14%, whereas the use of fresh surface water increased by less than 2%. This demonstrates the ever-increasing need for water in a variety of uses (Hutson et al. 2004).

As mentioned previously, many different sectors utilize the country's water resources. According to USGS data from 2000, the processes used to create

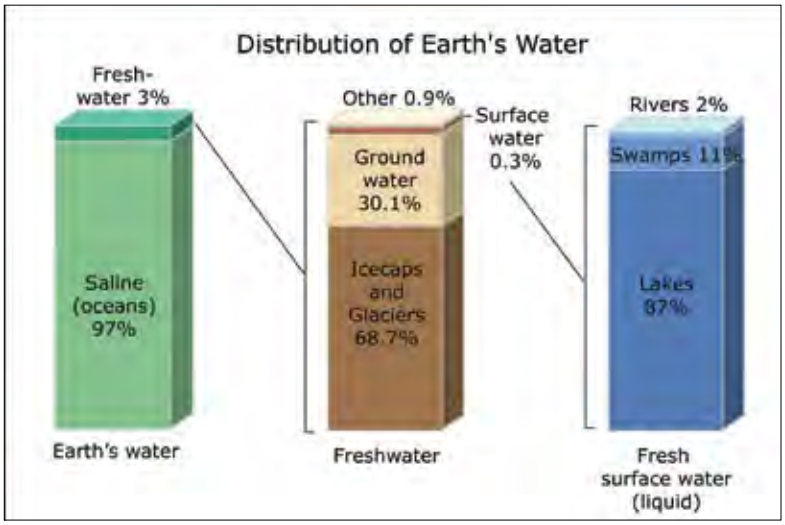

Figure 3. Distribution of Earth's Water

Source: Gleick PH. 1996. Water resources. In: Schneider SH. Encyclopedia of climate and weather. New York: Oxford University Press. Vol. 2;817-23. Used by permission of Oxford University Press. Available at http://www.drought.unl.edu/dm/ [accessed 2010 June 17].

thermoelectric power (i.e., thermal cooling) accounted for more than half (52%) of all fresh surface water withdrawals in the United States (U.S. Geological Survey undated b). A substantial amount of water also is used to support the country's agricultural industry, and this same data set indicates that 42% of the freshwater withdrawals in the United States can be attributed to irrigation activities. The demand for water varies substantially from state to state depending on urban density, land use (e.g., agriculture), and industry (e.g., thermoelectric power plants). For example, in 2005 six states (California, Texas, Nebraska, Arkansas, Idaho, and Florida) used more than half of all groundwater used in the United States; this water was primarily used to sustain the agricultural practices conducted in these states (Kenny et al. 2009).

In 2000, the USGS estimated that 43 billion gallons of water per day were withdrawn for public water supplies, during which time about 85% of Americans obtained drinking water from public suppliers. Fresh surface water accounted for 63% of the water withdrawals for public supply (Hutson et al. 2004). Since 1950, the amount of water withdrawn for public supply has more than tripled. Population changes affecting water use during 1950-2000 include an overall growth of 90%, a shift in the population of the United States from rural areas to urban areas, and a continuing shift of the mean geographic center of population west and south (Hobbs and Stoops 2002; Hutson et al. 2004).

Processes That Make Ground and Surface Water Drinkable

Because source water can have biological, chemical, and radiological contaminants, it is commonly treated before use. In the United States, 63% of the water used by public water systems is surface water (Hutson et al. 2004). Surface water must be treated to satisfy federal drinking water standards before it can be safely consumed (see the Water-related Policy section). Water treatment is aimed at controlling pathogenic organisms, harmful chemical and radiological contaminants, and constituents that affect the aesthetic quality of the water. Treatment of surface water can include technologically advanced processes, like nanofiltration, and other advanced membrane technologies. Traditional methods for treating water include

- particulate removal (through the use of flocculation, sedimentation, and filtration),
- disinfection (through the use of chlorine and ultraviolet technology), and
- alteration of the chemical properties of water to protect public health (e.g., fluoride addition, arsenic removal).

Groundwater can become contaminated because of human activities, such as failing septic systems, agricultural runoff, industrial spills, or leaking underground storage tanks, or through connectivity to surface waters. It is often disinfected to maintain quality throughout the distribution system before human consumption or use. The quality of groundwater also can be affected by drought and by increased local demand for this type of water, both of which can lower the water table and affect the quality and quantity of water pumped from individual wells. When wells are over-pumped, or used to remove water faster than it can be replaced, the catchment area from which groundwater is drawn increases, which leads to higher risk for drawing water contaminated by pathogens, nitrates, fertilizers, or other chemicals. In coastal areas, intensive removal of groundwater can result in saltwater intrusion (i.e., when the quantity of groundwater pumped from coastal aquifers exceeds normal recharge levels, resulting in pressure changes that cause an inflow of saltwater).

Water Classification

Household and industrial water applications are categorized by origin and the type of treatment. For instance, potable water refers to groundwater or surface water that either meets health-related standards set by EPA and individual states or has undergone treatment processes to ensure that it is safe for consumption. Potable water typically is obtained from surface or groundwater supplies, distributed to households via public water systems and found at the tap, or bottled and sold by manufacturers. In addition, potable water is used at industrial and manufacturing facilities in processes such as food and beverage production, power plant cooling towers, and petroleum refining.

Other types of water are not intended for human consumption, including gray water, black water, and recycled water; all of these types of water originate from human processes rather than natural sources. The term "gray water" typically refers to wastewater that is generated from domestic processes, including laundering, dish

washing, and bathing, whereas black water includes human waste. Recycled water is public wastewater generated from any type of industrial or household processes, including water contaminated by sewage that has been treated to a standard specified by an individual state and redistributed for nonpotable applications such as irrigation of golf courses.

Water Recycling and Reuse

Because freshwater is only a minimal percentage of the total global water supply and water treatment and distribution are costly, water should be considered a scarce and valuable resource. Many groups are advocating new approaches to water use and distribution. For example, the U.S. Green Building Council has proposed that traditional water distribution systems could be modified to limit the distribution of potable water and that parallel systems be developed to enable the collection and redistribution of gray water. Some municipalities have installed distribution systems that encourage households and commercial operations to use recycled water in lieu of treated freshwater for specific applications (e.g., irrigation), thus conserving the freshwater that is available within their watersheds. However, this is an expensive option because it requires the establishment of separate piping systems for the recycled water. Alternative methods for using rainwater also are being developed. For example, buildings are increasingly being engineered with the capability to collect and use rainwater for nonpotable applications (such as for flushing toilets and landscape irrigation).

In the United States, drinking water quality is regulated at the federal level by the EPA's Safe Drinking Water Act (SDWA). The SDWA, which was originally passed by Congress in 1974, gives EPA the authority to protect public health by regulating the nation's public drinking water supply. The SDWA is administered by most states through an agreement with EPA.

The EPA's Clean Water Act (CWA), also known as the Water Pollution Control Act, regulates a different aspect of water protection. CWA focuses less on water as it is used by humans, but rather on regulating and monitoring the human activities that contribute to water pollution and contamination. According to the EPA, the objective of the CWA is to restore and maintain the chemical, physical, and biological integrity of the nation's waters by preventing point and nonpoint pollution sources, providing assistance to publicly owned treatment works for the improvement of wastewater treatment, and maintaining the integrity of wetlands.

At the nonfederal level, drought-related decisions are handled differently by each state and jurisdiction according to local water-related legislation and policy. For instance, in some communities, decisions to declare a specific stage of drought and to institute or reinstate water restrictions are made by a public water supplier through an elected official, whereas in other areas, these determinations are made by the state environmental protection agency, department of health, or department of natural resources. In some areas, decision-making regarding drought preparedness and response has not been well defined or planned, leading to overlap in authority that can have both adverse and beneficial outcomes.

At times, the policies of one agency or official can be at odds with drought-related policies that have been established by other groups. For instance, agricultural and energy-related policies—like those that offer farmers economic incentives to plant a specific crop, such as corn for ethanol—and land-use or development policies often are developed without regard to water-related or public health policies. These types of policies, although beneficial in many ways, can result in conflicting interests in the prioritization of water supplies during a drought.

In other cases, rather than having adverse consequences, the policies and political agendas of non-public health agencies can be leveraged to foster drought-related public health action. For example, water conservation messages developed by local environmental agencies in the interest of protecting the environment can be used by public health professionals to help communicate the importance of conservation in ensuring the health of the community.

Existing state and federal legislation aimed at protecting certain ecosystems, animals, and other aspects of the environment also must be considered when preparing for or responding to drought at the public health level. These policies, particularly those that dictate the distribution of water during shortages, may conflict with public health policies developed to ensure adequate water quality and supply for human populations.

Because water sources may cross state boundaries, comparable agencies in different states can create conflicting plans for water prioritization and use. Each state agency develops water policies based on the unique needs of their populations and on the economic, environmental, and land-use scenarios existing within their borders. Public health agencies should anticipate these types of conflicts when making water-related decisions for their communities and have plans in place to minimize the potential for related adverse health impact.

In some aspects of preparing for and responding to drought, lack of legislation and standards, rather than conflicting policy, creates problems for public health agencies facing water shortages in their communities. Many drought-related issues have remained unregulated and therefore continue to potentially threaten public health. For example, although farmers and other professionals who rely on water for their livelihood are increasingly substituting recycled water for cleaner water sources during drought conditions, no federal standards currently exist. Many states have implemented their own policies associated with water reuse (e.g., household rainwater collection), but these regulations remain inconsistent and lack extensive data on the public health effects of these practices.

Did you know…

For over two decades, the states of Georgia, Florida, and Alabama have been engaged in an ongoing interstate conflict over water allocation in the Apalachicola-Chattahoochee-Flint (ACF) river system. Drought conditions in recent years have brought congressional attention to this dispute. The drawdown of Lake Sidney Lanier, the uppermost federal reservoir in the ACF basin, in Georgia in fall 2007 to support minimum flows in the lower basin's Apalachicola River escalated the conflict. Although the Atlanta metropolitan area's municipal and industrial water users were concerned about drawdown of their principal (and, in some cases, their only) water supply, lower basin stakeholders in other parts of Georgia, Florida, and Alabama were concerned about sustaining river flows to meet their municipal, electricity, and ecosystem needs and questioned the sufficiency of Georgia's municipal, industrial, and agricultural water conservation efforts. The U.S. Army Corps of Engineers struggled to manage ACF federal reservoirs to equitably meet upper and lower basin multipurpose water needs, especially during drought. Their challenge was to meet these needs while maintaining compliance with federal law (e.g., the Endangered Species Act); minimizing harm to the ACF river and Apalachicola Bay species, ecosystems, and oyster industry; and providing flows for hydropower and thermoelectric cooling, while also providing municipal and industrial water supply security. The Corps' operational challenge increased as water demands in the basin increased (e.g., water supply to support the growing Atlanta metro area, agriculture's increased reliance on irrigation, ecosystem and species needs), creating conflicts between maintaining water in storage and maintaining flows for in-stream purposes (Carter et al. 2008).

Despite these policy-related challenges, public health departments should be aware of the policies and legislation in place within their jurisdictions, which can vary substantially. Having a solid understanding of local decision-making processes can help ensure prompt, effective public health action by minimizing conflict, facilitating the prioritization and allocation of drought-related resources, and streamlining drought preparedness and response measures.

For humans, the health implications of drought are numerous and far reaching. Some drought-related health effects are experienced in the short-term and can be directly observed and measured. However, the slow rise or chronic nature of drought can result in longer term, indirect health implications that are not always easy to anticipate or monitor. The following sections define many facets of life that can be impacted by drought, such as nutrition and socioeconomic conditions, and identifies potential health effects. Because data regarding the health effects of drought in the United States are somewhat limited, the information contained in these sections also relies on the expertise, best practices, and lessons learned of professionals in related fields, including public health, environmental engineering and science, coastal ecology, regulatory engineering, water-related research, risk communication, water systems management, and emergency management (see the Background section).

Compromised Quantity and Quality of Potable Water

Surface Water

Drought is the result of long periods between rainfalls and higher than normal air temperatures, which together dry out soils and vegetation. Observations have shown that over the past several decades, extended dry periods have become more frequent in parts of the United States, especially the Southwest and the eastern United States. The number of dry days between precipitation events is projected to increase, especially in the more arid areas such as the Southwest.

Surface water supplies in the Southwest have been dramatically impacted by drought conditions. Lake Mead, which traverses Nevada and Arizona, and Lake Powell, which straddles the border between Utah and Arizona, has lost half of its storage since 1999 after suffering the worst drought in 100 years. Although there have been no substantial effects on water quality for the public, the reduction of water supply from these sources has caused increased scrutiny of water usage from the Colorado River systems.

Drought can impact surface water quality in many ways. Reduced stream and river flows can increase the concentration of pollutants in water and cause stagnation. Higher water temperatures in lakes and reservoirs lead to reduced oxygen levels, which can affect aquatic life and water quality. Runoff from drought-related wildfires can carry extra sediment, ash, charcoal, and woody debris to surface waters, killing fish and other aquatic life by decreasing oxygen levels in the water. The effect of wildfires on drinking water was graphically demonstrated during the 1996 Buffalo Creek fire in Colorado, which was followed by heavy rains. This event forced municipal water supplies to shut off, caused one of Denver's water treatment plants to close, required extensive cleaning of a water-supply reservoir, and forced a local beverage manufacturer to begin hauling in water for use during production activities.

The filtration components in surface water treatment facilities are designed based on historical water quality data and are effective at removing microbiological contaminants from untreated source waters. If source waters have unusually high sediment loads, such as those caused by wildfires, they can easily clog these filters. Ash particles, which are often much smaller than the microbes the surface water filters are designed to remove, can also flow through the filters and adversely impact the aesthetic quality of the water delivered to customers. In extreme circumstances, mudslides could render a surface water facility inoperable for some time, which may prevent water from being supplied for domestic, as well as fire control purposes (Idaho Department of Environmental Quality 2007).

Groundwater

Many parts of the United States are dependent on groundwater as a primary source of water. Reduced precipitation and increased evaporation of surface water can impact the recharge of groundwater supplies over time. Of all groundwater systems, shallow groundwater aquifers that exchange water with surface waters are likely to be the most affected by drought. Several areas throughout the Southeast and Southwest have reported decreased levels of water in wells in the face of drought, with many shallow wells becoming dry. Drought in coastal areas can increase saltwater intrusion into fresh groundwater supplies. The lack of rain and drying of surface water prevents the replenishment of fresh water in aquifers, which allows saltwater to enter.

Compromised Food and Nutrition

The quality and quantity of the nation's food supply can be affected by drought conditions, which can potentially lead to several types of adverse health effects. Inadequate rainfall and precipitation can substantially impact crop yields by decreasing or limiting the growing season and by creating conditions that are conducive to insect and disease infestation among certain types of crops. Low crop yields can result in elevated food prices and shortages, potentially leading to malnutrition (primarily stemming from protein and micronutrient deficiencies) among people who are economically burdened by the higher prices and those who rely on fishing and gardening for survival. Because substantial amounts of water are needed to produce and prepare food at the industrial and individual level, water shortages can also affect the availability and price of many other types of food. Beyond nutrition-related effects, the economic hardship associated with increased food costs and decreased availability can also have negative mental and behavioral health implications, including anxiety and depression.

Drought affects the quantity as well as the quality of America's crops and produce. As water supplies dwindle, the quality of water being used for agricultural purposes typically decreases. In the face of extreme drought, farmers may opt to use reclaimed or recycled water (i.e., treated municipal sewage) to irrigate their fields and process the crops they grow. If not closely monitored, this agricultural practice could pose a threat to the safety of the food supply by increasing the likelihood of public exposure to pathogens, like *Salmonella* and toxin-producing *E. coli*, and other potentially toxic substances. The use of recycled water for agricultural processes is legal in the United States given that certain criteria are met. This practice is closely monitored in the United States, but recycled water use in other countries that do not have robust systems in place for monitoring may adversely impact the quality of food being imported into the United States.

Agriculture is only one aspect of the nation's food supply for which drought can result in adverse health outcomes. Other foods are compromised as a result of drought, including shellfish and freshwater fish. Lower-than-normal levels of water create conditions that affect water quality, which can in turn affect the health of the fish and other animals that live in or depend on these water bodies; therefore, people who depend on fishing for subsistence can be more vulnerable in drought conditions. For instance, when low water levels result in an increase in the concentration of toxic chemicals in a particular river, these toxins accumulate in local fish at higher than normal levels. In turn, humans and other animals eating those fish become exposed to these concentrated toxins, which can cause illness. Low surface water levels also result in less availability of fish and other aquatic animals used as food products, because reductions in living space can increase competition for food, thereby limiting growth and reproduction. Higher water temperatures usually accompanying drought and resultant low flow conditions can affect the susceptibility and spread of disease (bacterial, fungal, parasitic) in fish and shellfish.

Drought can also affect the health of livestock raised for food. During drought, livestock can become malnourished, diseased, and die. For instance, in Oklahoma, aflatoxin-associated outbreaks of disease have occurred when cattle were given contaminated feeds that had been grown, processed, and stored in the excessively dry

Did you know…

Not all animal species are equally susceptible to cyanobacterial intoxication. Many species are susceptible, but tolerance to the toxins is variable between species. Domestic animals known to have succumbed to cyanobacterial toxins include cattle, sheep, pigs, dogs, horses, guinea pigs, geese, turkeys, ducks, and chickens. Among wild animals, poisonings have been recorded in fish, snakes, amphibians, bats, waterfowl, rodents, zebras, rhinoceros, tortoises, and bees. Species such as cattle, pigs, and dogs succumb to the toxins after ingestion of relatively small amounts of hepatotoxic cyanobacterial cells, whereas rodents are relatively resistant to ingestion of toxic cells. Different species of birds are also affected differently by cyanobacterial neurotoxins. Ring-necked pheasants were two to four times more resistant to anatoxin-a than were ducks (Ressom et al. 1994).

conditions that are conducive to the growth of toxin-producing fungi. Sick and malnourished livestock can lead to reduced herds, resulting in shortages in both the availability and quality of meat products and substantial price increases for these products.

Did you know…

The dairy industry is highly dependent on water through irrigation systems or rainfall to produce high-quality fodder, provide drinking water for stock, and operate a dairy milking shed. For example, dairy farms in Australia use 23% of surface water allocated for agriculture. This reliance on water makes the industry highly vulnerable to drought and climate variability in general. Recent water shortages caused by drought have adversely impacted the dairy industry in Australia in many ways. These include significant reductions in farm income and production, significant increases in feed costs and farm operational costs, reductions in milk quality and subsequent price penalties, severe fodder deficiencies and loss of pastures, and forced sale of cattle and herd management difficulties. Other indirect impacts include potential loss of markets due to an inability to supply, liquidity difficulties, debt and equity management issues, and long working hours and reduced family time for farmers (Australian Dairy Industry Council, Inc. 2008).

Diminished Living Conditions

Energy

Water is a key resource in the production of energy around the world. In the United States, more than 100 million gallons of water are used each day to help generate electricity to power homes, businesses, and other facilities. Hydropower production is sensitive to total runoff, to its timing, and to reservoir levels. During the 1990s, for example, Great Lakes levels fell as a result of a lengthy drought, and in 1999 hydropower production was down significantly both at Niagara in New York and Sault St. Marie in Michigan.

Lack of water, along with the changes in water temperature that often accompany drought, can compromise production capacity within power plants (U.S. Department of Energy 2009). Lower production capacity causes shortages in available electricity, which can negatively impact health and well-being. Certain populations, including persons living in nursing homes, hospitalized patients, and other persons who must rely on electrical equipment for survival, are most vulnerable.

Drought can impact other energy-related aspects of health. For instance, because the mechanical processes associated with cooling and heating homes and buildings involve the use of water, water shortages can lead to the malfunctioning of residential and industrial heating, ventilation, and air conditioning (HVAC) systems. Extreme heat or cold resulting from such a malfunction can adversely affect health, particularly among persons in susceptible populations (see Vulnerable Populations section). The health impact of drought can become

Did you know…

The Joint Commission, an independent, nonprofit organization that accredits and certifies more than 17,000 health care organizations and programs in the United States, requires hospitals and other health care facilities to determine whether they have the capability to sustain themselves (independently or by the local community) in six critical areas for 96 hours during an emergency situation. One of these six critical areas is utility management, which includes the means to provide potable and nonpotable water for drinking, sanitation, patient care, process equipment, heating, ventilating, and air-conditioning systems, and other purposes. If it is determined that—after all measures of conservation, curtailment, and support from outside of the community are exhausted—the capability is only 80 hours, then evacuation would be an appropriate response (The Joint Commission 2008).

compounded when HVAC failure is coupled with the inadequate ventilation capability that can accompany poor building design, such as the inability to open windows to increase airflow.

Hospitals, clinics, and other health care facilities oftentimes rely heavily on water to ensure the well-being of their patients. Water is used for drinking, sanitation, patient care, equipment sterilization, HVAC systems, and other essential functions throughout these facilities. During drought conditions, limited water may be available to protect patients' and workers' health.

Did you know…

New York City has a law that during a stage III and above (out of four stages) drought, water-cooled heating, ventilating, and air-conditioning systems are not permitted to fall below 79°F except in health care facilities, mainframe computer rooms, and other limited circumstances (City of New York Department of Environmental Protection 1998).

Also, according to Article V of the Sanitary Code in Rockland County, New York, the use of water for nonrecycled water-cooled air-conditioning units and heat pumps is prohibited (with limited exceptions) when the Commissioner of Health declares a Stage IV and above water emergency (Rockland County Department of Health 2002).

Air Quality

The dusty, dry conditions and wildfires that often accompany drought can compromise health, particularly among persons who have chronic health conditions. Fire and dry soil and vegetation increase the number of particulates that are suspended in the air, such as pollen, smoke, and fluorocarbons. These substances can irritate the bronchial passages and lungs, thereby exacerbating chronic respiratory illnesses (e.g., asthma) and increasing the risk for acute respiratory infection (e.g., bronchitis and bacterial pneumonia, including dust pneumonia) (see the Past, Present, and Future Trends in Drought section). Potentially, smoke inhalation and injury associated with wildfires could increase during drought conditions in particular. Shortages in the surface and groundwater supplies that are used to extinguish wildfires can lead to suboptimal emergency response measures, increasing the likelihood of adverse fire-related implications on health.

Other drought-related factors affect air quality, including the presence of airborne toxins originating from freshwater blooms of cyanobacteria. These aerosolized toxins have been associated with lung irritation, which can lead to adverse health effects in certain populations (see the Increased Disease Incidence: Chronic Disease

Did you know…

Researchers from Harvard University conducted a study in which they found that the most intense global pollution from fires occurred during droughts caused by El Niño. The most intense fires took place in 1997-1998 in association with the strongest El Niño event of the 20th century. Data were used from the National Aeronautics and Space Administration's (NASA) Total Ozone Mapping Spectrometer satellite to quantify the amount of smoke pollution from biomass burning over 20 years. The researchers concluded that biomass burning around the world was unusually high during the 1997-1998 El Niño, greater than in any other period between 1979 and 2000. The amount of carbon monoxide emitted in 1997 and 1998 was about 30% higher than the amount emitted from worldwide motor vehicle and fossil fuel combustion. Smoke from fires in Mexico and Central America was blown northward in May 1998, worsening air-quality and reducing visibility over much of the eastern United States (Duncan et al. 2003).

section). The dry, dusty conditions associated with drought also can lead to infectious disease, such as coccidioidomycosis (valley fever). This fungal infection is associated with inhaling spores that become airborne when soil is disrupted. Valley fever causes a range of symptoms, including fever, chest pain, coughing, rash, and muscle aches. Some people are at increased risk for developing disseminated infection, including those who have weakened immune systems, are in their third trimester of pregnancy, or who are of African-American, Asian, Hispanic, or Filipino descent (Centers for Disease Control and Prevention undated a).

Did you know…

The World Meteorological Organization of the United Nations, in collaboration with international partners, is developing an early warning system to help minimize potential hazards from intercontinental sand and dust storms. The Sand and Dust Storm Warning, Advisory, and Assessment System (SDS-WAS) will consist of a coordinated global network of SDS forecasting centers in countries across the world. Participating countries will enhance their ability to establish and improve their SDS forecasting and warning systems and will deliver information to a wide range of users that is useful in understanding and reducing the impacts of SDS. An important application of SDA-WAS for human health is to gather information that may help to better understand the potential role of dust and dry hot air in outbreaks of different types of diseases, including meningitis in Africa, valley fever in the southwestern United States, Mexico, and Central and South America, and influenza and Severe Acute Respiratory Syndrome (SARS) in parts of Asia (http://www.wmo.int/pages/prog/arep/wwrp/new/Sand_and_Dust_Storm.html).

Sanitation and Hygiene

The availability of water for cleaning, sanitation, and hygiene is directly linked to the reduction or control of numerous diseases. Drought conditions create the need to conserve water, but these conservation efforts should not hinder proper sanitation and hygiene. People may feel the need to conserve water in ways that can increase health risks, such as reducing or eliminating hand washing. Personal hygiene, cleaning, hand washing, and washing of fruits and vegetables can be done in a way that conserves water, while at the same time continues to promote these healthy behaviors. The installation of low-flow faucet aerators in businesses and homes is one example of how to reduce water consumption while maintaining hand washing and other healthy hygienic behaviors.

Did you know…

In October 2007, during the severe drought conditions affecting the southeastern United States, the North Carolina Division of Environmental Health issued recommendations for food-service establishments within the state that would reduce water usage while maintaining safe food practices and protecting the public's health. This guidance was released with the anticipation that businesses and citizens would attempt to save water in every possible way to avoid a water crisis. Suggestions included checking all water supply systems for leaks, educating staff about water conservation methods, installing low-flow aerators on all faucets, using single-service eating and drinking utensils, serving water only upon customer request, and switching to vinyl or paper tablecloths and napkins to reduce linen use. The example set by North Carolina demonstrates that measures can be taken to conserve water while maintaining good sanitation and hygiene practices (North Carolina Division of Environmental Health 2007).

Recreational Risks

People who engage in water-related recreational activities during drought may be at increased risk for waterborne disease caused by bacteria, protozoa, and other contaminants (e.g., chemicals and heavy metals). Exposure can

Did you know…

Cyanobacteria are single-celled organisms that live in fresh, brackish, and marine water, and use sunlight to make their own food. In warm, nutrient-rich environments, microscopic cyanobacteria can grow quickly, creating blooms that spread across the water's surface and may become visible. Scientists have credited cyanobacteria with providing nitrogen fertilizer for rice and beans, but cyanobacterial blooms are not always helpful. When these blooms become harmful to the environment, animals, and humans, scientists call them cyanobacterial harmful algal blooms (CyanoHABs). Freshwater CyanoHABs can deplete the oxygen and block the sunlight that other organisms need to live. Some cyanobacteria that can form CyanoHABs produce toxins that are among the most powerful natural poisons known. These toxins have no known antidotes. CyanoHABs can make people, their pets, and other animals sick. Often, the first sign that an HAB exists is a sick dog that has been swimming in an algae-filled pond. Children are at higher risk than adults for illness from CyanoHABs because they weigh less and can get a relatively larger dose of toxin (Centers for Disease Control and Prevention undated b).

occur through accidental or intentional ingestion, direct contact with mucous membranes, or inhalation. Untreated surface water can be a health threat in drought conditions.

In untreated surface waters, some pathogens, such as *Naegleria fowleri*, can flourish at higher concentrations during drought because low water levels may create warmer water temperatures that encourage the growth of these organisms. Concentrations of chemicals and heavy metals also are higher in these bodies of water. Diminished natural stream flow can also contribute to poor water quality during drought conditions. Drought-related increases in dust deposits in aquatic ecosystems can lead to algal blooms, which have been associated with human illness among persons exposed to these blooms during recreational activity.

As the levels of surface waters used for boating, swimming, and fishing drop, the likelihood of injury increases. Low water levels in lakes often are difficult to perceive, which can lead people participating in recre ational activities to unknowingly engage in behaviors that put them at risk for life-threatening injuries, like diving into shallow waters or striking objects that may not be immediately visible while boating. Low surface water levels also can cause potentially dangerous debris once hidden at the bottom of lakes, rivers, and ponds to become exposed.

Mental and Behavioral Health

The financial implications of drought have been shown to have an adverse effect on persons who rely on rainfall and water for their economic survival, including farmers and other agriculture-related professionals, ranchers, landscapers, horticulturalists, nursery and garden supply owners and employees, and recreational facility operators. Financial-related stress and worry can cause depression, anxiety, and a host of other mental and behavioral health conditions and disorders. These factors can lead to suicide, particularly among persons living in rural areas who have fewer options for income and limited access to mental and behavioral health care. When compared with the general population, substantially elevated rates of suicide have been observed among farm workers living in rural areas of countries affected by severe and extended droughts (e.g., Australia and India).

One study conducted in Australia demonstrated an association between a 7-year drought and increased rates of suicide among persons living in rural farming areas in that country (Sartore et al. 2007). The study revealed that drought-related crop failure and herd die-offs left many rural Australians with reduced income security, higher stress, and negative self-perception, likely contributing to increased rates of suicide during the 7-year period. Another study in India revealed that severely reduced rainfall contributed to a sharp increase in the number of suicides among farmers compared with the general population—an increase likely attributable to increased indebtedness (South Asian Women's Forum 2006). Similar trends have been observed in the upper Midwestern part of the United States. During the 1980s, male farmers and ranchers in the states of Wisconsin, Minnesota,

Did you know…

The National Farm Medicine Center conducted a study over a 9-year period that examined suicide rates in the Upper Midwest during the 1980s. The study found that more than 900 male farmers and ranchers in Wisconsin, Minnesota, North Dakota, South Dakota, and Montana committed suicide in the 1980s, and in some years the incidence of suicide was nearly double the national average for white men. Also shown was that 71 female farmers and 96 farm children killed themselves between 1980 and 1988. Using information provided by public health agencies, the study found that there were 44 suicides for every 100,000 farmers and ranchers in 1980. This rate peaked at 58 suicides for every 100,000 farmers in 1982. The decade was a particularly stressful time for farmers, with record drought, declining land values, indebtedness, and unstable prices. There were thousands of foreclosures and bankruptcies (Gunderson et al. 1993).

North Dakota, South Dakota, and Montana demonstrated rates of suicide that were twice the national rate. It is believed that drought was a major contributor to this outcome.

Vulnerable Populations

As with most natural and manmade disasters, drought impacts a variety of populations in different ways based on the unique circumstances they face. To ensure that the health needs of people in these unique populations are met during an emergency, the term "at-risk individuals" has been defined in the Pandemic and All Hazards and Preparedness Act (PAHPA). PAHPA defines at-risk individuals as children, pregnant women, senior citizens, and other individuals who have special needs in the event of a public health emergency. In addition to the populations identified under PAHPA, other groups also are at increased risk for adverse drought-related health effects, including people living in rural or remote areas who depend on water from private wells and small or poorly maintained municipal systems, the quality of which is more susceptible to environmental changes.

Increased Disease Incidence

Many types of human diseases are associated with drought, including those that are infectious, chronic, and transmitted by animals and insects (i.e., vectorborne and zoonotic). Numerous factors contribute to the increased incidence of these diseases in drought conditions, ranging from higher concentrations of human pathogens in water to changes in the behavioral patterns of wild animals. These factors are further discussed in the following paragraphs.

Infectious Disease

Increases of infectious disease through inhalation, ingestion, or other routes can be a direct consequence of drought (see the Diminished Living Conditions: Air Quality section for the valley fever example). Decreased rainfall can cause both groundwater and surface water to become polluted with a variety of contaminants, including viruses, protozoa, and bacteria, all of which cause acute infectious disease. People who obtain their drinking water from private wells may be at higher risk for drought-related infectious disease. Other groups are also at increased risk, including people who have underlying chronic conditions (see the Diminished Living Conditions: Vulnerable Populations section).

During water shortages, the risk for infectious disease increases when hygiene is not maintained. For instance, many types of infectious disease, including those that cause acute respiratory and gastrointestinal illness, are more easily spread from person to person when hand washing is compromised by a perceived or real lack of available water (Centers for Disease Control and Prevention undated c).

Food can serve as a vehicle for disease transmission during a drought because water shortages can cause farmers to use recycled water to irrigate their fields and process the food they grow (see Compromised Food and Nutrition section). When used to grow crops, improperly treated water can cause a host of infectious diseases (such as those caused by toxin-producing *E. coli* and *Salmonella*), which can be life-threatening for people in

high-risk groups. In addition, the likelihood of surface runoff, which can occur when rain fails to penetrate the dry and compacted soil that often accompanies drought, can cause the inadvertent contamination of crops.

Additional infectious disease threats are posed when drought leads to the contamination of surface waters and other types of water that are used for recreational purposes (see the Recreational Risks section), particularly because people are more likely to participate in water-related recreation when temperatures rise and rainfall declines. People exposed to contaminated recreational waters have an increased likelihood of becoming infected with pathogens that thrive in the typically shallow warm waters that exist during drought conditions.

Chronic Disease

Although not well documented, the conditions associated with drought may negatively impact people who have certain chronic health conditions such as asthma and some immune disorders. The changes in air quality that potentially accompany drought, including increased concentrations of air particulates and airborne toxins resulting from freshwater algal blooms, can irritate the eyes, lungs, and respiratory systems of people with chronic respiratory conditions (see Diminished Living Conditions: Air Quality section). Likewise, changes in water quality, including increased concentrations of contaminants, can pose a threat to persons who have compromised immune systems.

Vectorborne and Zoonotic Disease

Some diseases that are transmitted by insects and animals are associated with drought. For instance, outbreaks of West Nile virus, which is transmitted to humans via mosquitoes, have occurred when drought diminishes the size of water bodies and causes them to become stagnant, providing additional breeding grounds for certain types of mosquitoes (e.g., *Culex pipiens*). Drought can also result in increased mosquito populations in residential areas. The increased use of household rainwater collection vessels that often accompanies inadequate water supply can lead to collections of stagnant water, which ultimately become manmade mosquito breeding areas. Drought-related changes in the behavior of mosquitoes can contribute to the incidence of additional types of vectorborne diseases, including St. Louis encephalitis, Eastern equine encephalitis, and West Nile virus, by creating an atypical convergence of mosquito vectors and avian hosts.

The incidence of Lyme disease (transmitted to humans through ticks that become infected by wild animals), hantavirus (transmitted by human exposure to infected rodents and their excrement), and other zoonotic diseases (e.g., murine typhus) also would be expected to increase during a drought. In periods of limited rainfall, human and animal behavior can change in ways that increase the likelihood of certain vectorborne diseases. For instance, during dry periods, wild animals such as deer, raccoons, and rodents are more likely to seek water in areas where humans live (e.g., from dripping hoses and containers of standing rainwater). These behaviors increase the likelihood of human contact with wildlife, the insects they host, and the diseases they carry.

Drought is a slow-rise event that can affect any area of the country at any time. Unlike some natural disasters that occur unexpectedly and necessitate intense public health response activities (like earthquakes and tornadoes), drought is a condition that can be anticipated well before it becomes a threat to the health of a community. Both preparing for and responding to drought require federal, state, local, and tribal public health professionals to work collaboratively with other stakeholders and to communicate effectively with the communities they serve.

Although public health is a key component in drought preparedness and response, the roles and responsibilities of public health departments vary by jurisdiction. For instance, in some jurisdictions, health departments play a primary role in the regulation of water systems. In other jurisdictions these departments assume a more supportive role by ensuring that accurate drought-related health information is communicated to the lead agency in a timely manner.

Public health departments can play important roles in minimizing the effects of drought. Involvement in community planning can help ensure that public health concerns are identified and addressed both prior to and during drought conditions. Assisting with the development of measures for water conservation, promoting sustainable practices for water use, protecting aquifers through wastewater management, participating on local or regional water boards or water district management teams, and strengthening programs and infrastructures for sufficient water capacity will help better prepare communities for drought.

The following sections provide general guidance for public health professionals and others involved in promoting health within communities. This guidance reflects existing recommendations for drought preparedness and response developed by state and national organizations, including CDC, EPA, AWWA, and the opinions of experts who participated in the Public Health Effects of Drought Workshop. Because drought is often defined by stages of severity that warrant different types of public health activities (i.e., those that prepare jurisdictions for drought-related outcomes and those that help communities respond to them) and because states and localities define drought stages differently, the guidance within this chapter is organized by broad timeframes (i.e., early and late stage).

For public health jurisdictions that already have drought preparedness measures and plans in place, this document can be used to update and supplement existing plans, procedures, and guidance. Throughout the sections, examples of best practices are highlighted. Although these practices worked well in the communities where they were implemented, it is important to note that the effectiveness of prevention, preparedness, and response activities can vary according to a variety of factors, including the setting in which they take place and the circumstances surrounding a particular drought event.

Preparedness: Public Health Activities for Pre- and Early-stage Drought Conditions

Drought is a "chronic" natural occurrence that can be defined differently across jurisdictions and sectors. Therefore, public health agencies across the country should be prepared to address the public health impacts of drought within their communities at all times. The drought preparedness activities outlined in the following paragraphs should be undertaken only within the political context and in accordance with the established policies, plans, procedures, and guidance that exist within individual jurisdictions, which can vary widely (see the Water-related Policy section). Many of these recommendations are also applicable in an all-hazards context for public health emergency preparedness and response to natural and manmade disasters.

Conduct an Internal Capacity Assessment

An essential part of drought mitigation is ensuring that resources are in place to prevent and minimize adverse health effects to the community should they occur. To facilitate efficient and effective response, public health departments should conduct internal capacity assessments either before drought occurs or at the early onset of drought conditions. The goal of the capacity assessment should be to identify where needed resources can be obtained for specific drought-related public health action. As part of the assessment, health agencies should investigate the resources that may be available to them through mutual aid agreements with other agencies or jurisdictions.

Participate in a Jurisdiction-wide Hazard and Vulnerability Assessment

Many key stakeholders participate in hazard or vulnerability assessments as they identify the emergency preparedness strengths and weaknesses of their communities. Public health representatives can play a supportive role in hazard and vulnerability assessment at this broad level by helping to provide other stakeholders with insights regarding the needs of local public health entities and at-risk populations during drought conditions. Likewise, working closely with professionals from other agencies and sectors creates opportunities for public health representatives to explore the perspectives of their response partners.

State, local, and tribal public health departments should consult available vulnerability assessment models and tools, such as the Regional Vulnerability Assessment program (U.S. Environmental Protection Agency 2009), Public Water Supplier Drought Vulnerability Assessment report (Kansas Water Office 2007), and Impact Assessment tool (National Drought Mitigation Center 2006b). These tools can be adapted to fit individual communities' needs. Guidance on the use of such data and decision support tools for risk assessment and for embedding information into preparedness plans is offered through NIDIS (www.drought.gov). Health departments should also request additional technical assistance from local experts as needed. For instance, public health department staff could invite local utilities and water resource managers to participate in drought-related meetings, workshops, and exercises.

Conduct a Public Health Vulnerability Assessment

One of the first drought preparedness steps that should be undertaken by any health department is to conduct a public health vulnerability assessment. This type of vulnerability assessment can be used to determine both the populations most likely to be disproportionately affected by drought-related adverse health effects and the types of drought-related problems most likely to be encountered within a community. These populations and implications can vary widely between jurisdictions. For instance, because people who live in rural areas are more likely to obtain drinking water from private water sources rather than through municipal water systems, health departments serving rural communities would need to identify households relying on water from shallow wells as being more vulnerable to the negative health affects associated with drought. Identifying these types of vulnerabilities is a key step toward ensuring drought readiness.

Public health professionals should use the preceding section of this document (see The Impact of Drought on Health section) and Table 1 (page 33) to become more knowledgeable about the types of health issues likely to affect their communities in the face of drought and the populations most at risk. Once identified, public health departments can review the vulnerabilities that may affect their own jurisdictions to determine when they should be addressed chronologically over the course of a drought to ensure efficient and effective public health action.

In addition, data should be used, if available, to determine how water is used in the community and which sectors (e.g., industry, commercial, agriculture, residential) are primary users of water resources. This can vary widely between jurisdictions. For example, significant amounts of water may be used for agricultural purposes in some rural areas, but residential, commercial, or industrial use may be more prevalent in some urban and suburban areas. Knowing this information both before and during drought can assist in planning and making decisions during drought preparedness and response.

Identify and Coordinate with Key Partners and Stakeholders in Drought Efforts

To ensure optimal public health preparedness during the early stages of drought, public health professionals working in federal, state, and local agencies must identify and continually collaborate with partners and stakeholders in other sectors and disciplines who are working to reach similar objectives. Numerous entities are involved in drought preparedness and include representatives from governmental agencies, various associations and organizations, and private industry. The interagency NIDIS program is a mechanism that can be used to engage collaboration between the public health community and the drought monitoring, research and impact assessment communities. The following nonexhaustive list provides a few examples of potential partners for public health to consider when preparing for drought.

- American Water Resources Association (AWRA);
- American Water Works Association;
- boards of health;
- Centers for Disease Control and Prevention;
- Cooperative Extension Service offices;
- departments of agriculture;
- departments of education, school boards, and universities;
- departments of natural resources;
- dialysis centers and associations;
- elected and appointed officials and legislators;
- emergency management and public safety;
- emergency medical services;
- energy companies and other public utilities;
- farmer associations;
- Federal Emergency Management Agency;
- fire departments;
- home health care agencies and hospice
- hospitals and hospital associations;
- internal health department offices (e.g., environmental health, laboratories, epidemiology);
- Local Emergency Planning Committees;
- local zoning commissions;
- long-term care facilities (e.g., nursing homes and assisted living facilities);
- mental and behavioral health agencies and organizations;
- National Oceanic and Atmospheric Administration;
- National Park Service;
- physicians and other health care providers;
- recreational water coordinators and managers;
- regional water authorities;
- small business owners and chambers of commerce;
- State Emergency Response Commissions;
- the media;
- the U.S. Army Corps of Engineers;
- the U.S. Department of Agriculture;
- U.S. Environmental Protection Agency and state drinking water regulators;
- U.S. Geological Survey;
- wastewater treatment facilities;
- Water Environmental Federation;
- water boards;
- water resource managers;
- water systems managers;
- water wholesalers and retailers; and
- other appropriate partners.

Ideally, public health agencies should identify and then engage these types of partners within their communities either before drought conditions occur or before drought reaches the severe levels that necessitate emergency response and management. Many of these key partners and stakeholders have collaborative tools and

mechanisms in place that can be leveraged by public health departments to ensure a more coordinated drought preparedness effort.

Drought-related Implication	Examples of Potential At-risk Populations
Quantity and quality of potable water	Persons relying on private wells for their drinking water, children, the elderly, athletes, persons with compromised immune systems, and persons on dialysis
Food and nutrition	Persons consuming raw produce grown using recycled water, economically disadvantaged persons, persons with compromised immune systems, children, and the elderly
Energy	Persons susceptible to extreme temperatures (e.g., the elderly), persons who live in institutional settings (e.g., nursing homes), and persons who rely on electronic equipment for survival or well-being (e.g., ventilators)
Air quality	Persons with allergies, asthma, or other chronic respiratory conditions that make them more susceptible to particulate matter in the air
Recreation	Persons who engage in water-related recreational activities and persons with compromised immune systems
Mental and behavioral health	Persons who rely on water for their economic livelihood (e.g., farmers, ranchers, landscapers, horticulturalists, recreational facility operators) and persons who have anxiety or depressive disorders
Infectious disease	Persons who rely on private wells to obtain their drinking water, persons who have both a septic tank and a groundwater well, and persons with underlying health conditions, including those with compromised immune systems
Chronic disease	Persons with certain chronic health conditions, such as asthma, allergies, other respiratory conditions, and immune disorders

Table 1. Drought-related Implications and Examples of At-risk Populations

Communicate Drought Strategies and Recommendations

Communication is an essential component of drought-related public health efforts. An effective communication plan includes establishing a communication objective, identifying audiences, and developing messages aimed at achieving the desired response. The following steps can be taken to ensure effective communication and public health action.

Define the Communication Objective

Before starting any communication activity, desired outcomes should be defined. Defining a communication objective sets the stage for audience selection, message development, the channels through which messages are delivered, and evaluation of communication-related activities.

Identify and Understand the Audience

To ensure the effectiveness of communication efforts during all stages of drought, public health professionals must identify and understand the target audience. Additionally, these professionals should distinguish primary audiences (those that must be reached to achieve desired outcomes) from secondary audiences (those that are helpful but not essential in reaching outcomes). Ideally, public health agencies should identify and engage primary and secondary audiences either before drought conditions occur or before drought reaches the severe levels that necessitate emergency response and management. Public health agencies should identify public information officers (PIOs), collaborative tools, and mechanisms to disseminate messages and educational materials to their constituencies.

Communicate Appropriate Drought Messages to Target Audience

Communication with audiences should be culturally and linguistically appropriate and must take into consideration literacy and educational levels. It should also be transparent, conveying updates and recommendations throughout all stages of drought. Because drought conditions may necessitate the application of risk communication, risk communication strategies should be developed well before drought conditions occur. Such planning greatly increases the likelihood that communication will further health and safety interests and contribute positively to emergency response efforts. Communications professionals, like PIOs, can provide invaluable guidance in this endeavor.

Did you know…

To facilitate timely communication of health-related issues, public health agencies in California are tied into the California Health Alert Network—an alerting system that notifies media about public health concerns in real-time. Efforts currently are under way to tie California water systems into this network, which would improve drought-related communication and response activities associated with emerging water quality or supply issues (Crisologo 2008).

To minimize social disruption and maximize impact, messages for the public should be consistent, accurate, straightforward, and timely. In addition, they should be delivered through as many outlets as possible, including radio, television (e.g., through public service announcements), and other forms of popular media, which may include social media. They should be targeted to the populations that will most benefit from the information. For instance, messages about the potential effects of drought on local air quality should be targeted to those populations that have preexisting, chronic respiratory conditions that place them at greater risk for adverse health effects.

Public health professionals need to provide target audiences with information about the health implications of drought and issue clear recommendations of actions that can be taken to minimize negative health-related consequences. These key messages should be accompanied with supporting statements addressing target audience needs and values.

Communication messages are best understood and adopted when they are to the point, concise, credible, and easy to remember. Communication materials must also be consistent, conveying the same key messages regardless of how and where the messages are delivered. For example, if a key message is "drought affects everyone," the message should be communicated via flyers, press releases, brochures, interviews, and other forms of communication.

During the early stages of drought, public health professionals should inform the public about a wide range of drought-related issues, such as water conservation practices and the hazards posed by recreational water. Many states and localities have already developed risk communication plans and materials intended to help inform the public about a variety of health-related topics concerning water and drought. When available, these materials should be used by public health professionals to ensure a prompt communication response. For public health jurisdictions that have not created risk communication templates, drought-related messages should be developed well before drought conditions become severe. In some instances, these messages may already exist and can be modified according to current conditions. Communication professionals (such as PIOs and health educators) should be identified and engaged in the development of these messages.

Because drought is a slow-rise event, challenges may arise with competing priorities in the community to keep audiences engaged in the drought communication process. Consistent messaging from credible sources about the potential public health impacts of drought delivered via a variety of media and processes can help overcome these challenges. Engaging community partners with similar interests, such as boards of health, emergency management, and water authorities, in the development and delivery of messages can also be helpful.

The Appendix provides examples of potential target audiences and audience-specific communication tips to facilitate the communication process and enhance message delivery.

Educate and Train Key Partners

Education and training are crucial parts of the overall effort to ensure effective and consistent communication with key partners in drought preparedness and response. In coordination with other agencies and organizations that have roles and responsibilities in disaster response and water-related issues (such as those in the water supply, treatment, and distribution sectors; companies responsible for water sanitation; and health care organizations), public health departments should engage in educational and training activities to ensure that key partners understand the public health implications of drought and the ways to mitigate adverse drought-related public health outcomes. Likewise, these professionals should be encouraged to attend educational and training sessions sponsored by water-sector partners within their communities. During these sessions, communication plans should be discussed and developed (see Appendix) and previously written drought-related guidance should be consulted. These types of initiatives can help ensure a more consolidated effort to prepare for and respond to the public health implications associated with water shortages.

Develop Targeted Mitigation Strategies

Once vulnerabilities and resources are identified, public health departments can begin to develop strategies for preventing or alleviating anticipated drought-related adverse public health effects. These strategies should be designed to target the specific sectors and populations that are most likely to be involved in or affected by a particular outcome (i.e., at-risk populations) and should align with existing strategies developed by key stakeholders and partners. For instance, working within the framework of existing community emergency response plans, procedures, and guidance, public health agencies could develop a targeted strategy to reduce the likelihood of adverse health events associated with contamination of groundwater. In this case, strategies could involve the following:

- working closely with private well owners, well drillers, and other companies involved in the maintenance of wells to coordinate the testing of groundwater at individual wells;
- providing the public with adequate and consistent messages regarding the need to have their wells tested;
- monitoring water quality data;
- issuing drinking water advisories when needed;
- communicating the importance of implementing additional water treatment measures to well owners;
- providing people who obtain drinking water from wells with options for obtaining clean water;

- communicating the importance of hand hygiene and offering alternatives to hand washing when water quantity and quality are severely limited;
- educating local health care providers about the diseases and conditions most likely to be associated with a particular contaminant;
- developing plans for deciding when drinking water advisories can be lifted and for communicating these plans to the public; and
- collaborating with community partners to develop guidance for water utilities and wastewater plants for water reuse, rationing, and watershed protection.

For persons who obtain water through municipal water systems, health departments can develop similar strategies that stress the importance of creating effective and efficient lines of communication involving local utilities and other water-sector agencies.

Another example of a targeted mitigation strategy is initiating activities to help mitigate the effects of poor air quality among at-risk populations as a result of limited rainfall. Again, within the framework of existing community emergency response plans, procedures, and guidance (including existing air quality warnings and outreach programs), strategies could involve

- monitoring air particulates on a regular basis;
- issuing and communicating air quality advisories when needed;
- educating local health care providers about the effects of poor air quality on at-risk populations (e.g., persons with chronic respiratory conditions); and
- developing criteria and plans for lifting air quality advisories.

As part of a targeted strategy to improve health, public health departments should consider implementing surveillance mechanisms that enable the collection of information, such as water quality data, to demonstrate relationships between drought and public health. These data can be collected through active, passive, and sentinel surveillance efforts. In many cases, existing surveillance systems can be leveraged and modified to allow for the collection of drought-related health data. In some instances, measuring the direct impact of drought on public health can be difficult, as with chronic diseases.

Did you know…

California's Water Security Initiative was developed to provide early detection and warning mechanisms through real-time water distribution system monitoring. Although created to protect California residents from water-system-related acts of terrorism, this initiative would also facilitate the timely collection of water quality data during drought conditions (Crisologo 2008).

Although efforts to obtain health-related drought data have been minimal to date, recent advances in public health surveillance and informatics are enabling the development of more sensitive and specific data collection systems. Ideally, improved surveillance capability at all public health levels will facilitate the identification of additional, currently unrecognized relationships between drought and human health and help provide data to support existing linkages.

Document and Evaluate Drought Preparedness Activities

Public health departments should document and evaluate the effectiveness of their drought-related preparedness activities, identify critical entry points for the input of drought and climate-related information into plans at different drought stages (predrought, onset intensification, and/or demise), communicate their findings to key partners and stakeholders, and discuss methods for improvement. Successes should also be highlighted during the

evaluation process. Barriers to information flow should be assessed so that proactive measures can be implemented for future events or as a present drought intensifies.

Response: Public Health Activities for Late-stage, Severe Drought Conditions

Ideally, public health departments should engage in preparedness activities before drought severely affects their communities. Also important to ensuring the health of a community, however, is effective public health response. Although determining when to initiate response activities can be difficult in the case of drought, many areas have defined drought stages by level of severity that can be used to anticipate health impacts. In general, public health professionals should be prepared to initiate response activities before water shortages within their jurisdictions lead to conditions that threaten the health and wellbeing of any local population. Examples of threatening conditions include times when a community has no water for drinking or sanitation, when local water supplies have become contaminated and linked to adverse health outcomes, and when drought results in socioeconomic collapse or social disruption.

Ideally, public health agencies should respond to drought in accordance with existing emergency response plans, procedures, and guidance within their communities. Jurisdictions that have not included drought-related information in their emergency response plans, procedures, and guidance should consider doing so. The following drought response activities, although tailored to address drought-related specifics for the purpose of this document, can be applied to almost any disaster response effort.

Evaluate Drought-related Impacts on Public Health

One of the first steps in responding to drought-related public health threats is to conduct an evaluation of the way drought-related conditions are currently impacting or will impact the population's health. This effort also includes anticipating any future health effects. When conditions suggest that a drought may be imminent, public health professionals should identify the populations that are most affected by a particular adverse condition. For instance, immunocompromised persons drinking contaminated well water could be at increased risk for adverse health outcomes, firefighters may experience increases in wildfires in the face of a diminished supply of surface water, and people swimming and boating in lakes and rivers containing dangerously low water levels would have an increased likelihood for injury.

Once the affected populations have been identified, public health departments can actively collect and analyze quantitative and qualitative data to help determine the extent of the public health threat and whether this threat is likely to persist, be alleviated, or become exacerbated as drought conditions progress. To make informed projections about future health threats, public health professionals must not only remain knowledgeable about the drought-related health consequences in their jurisdictions, but also be aware of local drought stages and rainfall projections for their geographical areas. Best and worst case scenarios should be considered.

Coordinate Drought Response Activities with Key Stakeholders and Partners

Once the drought-related public health impacts are determined, public health professionals should contact the key stakeholders and partners identified as part of their drought preparedness activities. These professionals should be informed about the public health threats affecting their communities and should serve as collaborators in efforts to mitigate adverse public health implications. Many of these stakeholders and partners have gained public trust and have established methods for reaching certain segments of the population that can be leveraged to facilitate public health action. Partnering with them ensures a more effective and efficient response to any public health treat.

Develop Health Response Objectives and an Action Plan, and Communicate These to Involved Partners

Addressing any public health threat requires the development of health response objectives that are achievable, measurable, and specific. These objectives also should be assigned certain timeframes. Once these objectives have been defined and prioritized, action plans should be developed within the scope of a health department's available resources and assets. If sufficient resources and assets are not available to address identified public health threats during drought, mechanisms for surge capacity must be considered, such as mutual aid agreements (see the Conduct an Internal Capacity Assessment section). Because drought affects so many facets of life and varying populations, it is important to communicate any drought-related response objectives and action plans to key stakeholders and partners to minimize conflicts of interest, streamline efforts, and maximize

outcomes. It is also crucial to effectively communicate with internal public health staff because these professionals likely will be involved in relaying reliable drought-related health messages to the public and other sectors within the community (see Appendix).

Assign and Use Resources to Achieve Drought Response Objectives

After response objectives are identified, available resources should be allocated depending on the priority that has been assigned to each response activity. Resources can include both internal assets, such as monetary funds, health department personnel, surveillance tools, and communication tools, and those that are acquired outside of the health department, like support through existing mutual aid agreements, health care facility capacity, additional nonmunicipal water supplies, and water-safety-related equipment and tools. Because many defined drought response objectives cannot be achieved within the immediate response period, effective resource allocation is needed to ensure that public health response activities remain in place as long as they are needed.

Ensure Public Health Participation in Incident Management Systems and Structures

Typically, drought does not necessitate the use of incident management systems and structures normally used for emergency response, such as incident command posts and emergency operations centers (EOCs). Other situations that are directly caused or contributed to by drought, however, may require their use. For example, severe drought is often a major contributor to widespread wildfires, which require the use of the National Incident Management System, Incident Command System, EOCs, and Joint Information Centers during response. If these and other systems and structures are used, public health should be actively engaged in them to ensure the most efficient and effective response effort possible. In the wildfire scenario, for instance, a public health department representative should be assigned to initiating and coordinating communications with their jurisdiction's EOC and should be prepared to physically relocate to the EOC, if necessary. Many communities already have provisions in place to ensure that public health is actively engaged in emergency response. Become familiar with these during drought preparedness efforts.

Address Requests for Assistance and Information

Drought affects many aspects of society. During drought conditions, many agencies and organizations will be responsible for providing different sectors with accurate information associated with the diverse implications of drought (e.g., water conservation messages). Health departments should anticipate the need to provide diverse groups with appropriate drought-related health information and to respond to various requests for assistance. Public health personnel who serve as an interface between the health department and external groups and agencies should be provided with adequate drought-related information to ensure prompt and accurate communication. The use of prescripted drought-related public health messages is advantageous because it ensures a prompt, thorough, and consistent communications approach. Public health personnel who are responsible for addressing requests for assistance and information also should be kept apprised of the department's available capacity and resources, which helps ensure the delivery of accurate, transparent public health messages (see Appendix).

Document and Evaluate All Drought Response Activities

As with drought preparedness efforts, the final step of the drought response process should be the documentation and evaluation of a jurisdiction's response activities. After drought conditions have been alleviated, health departments should review their efforts to coordinate and communicate with key stakeholders; develop response objectives and action plans; assign and use resources; and participate in larger community efforts to respond to emergencies (e.g., EOCs). The evaluation of drought response activities should encompass not only programmatic effectiveness, but cost effectiveness for particular public health actions.

Future Needs: Drought-related Research and Initiatives

Although many aspects of drought have been well researched, there is still much to be learned about its public health implications. Quantitative public health data are extremely limited regarding the short and long-term impacts of drought on health, as well as the direct and indirect health effects that water shortages have on different segments of the population. To ensure optimal public health preparedness for and response to drought at local, state, federal, and tribal levels, epidemiologic and other types of studies must be conducted to provide stakeholders with basic drought-related health data. In addition to research, other types of drought preparedness activities and resources must be developed for the groups of professionals who are engaged in drought preparedness and response.

The following section provides a list of recommended drought-associated research gaps that should be addressed to facilitate optimal public health preparedness and response. Additional future resources and initiatives that could be used by public health professionals to strengthen their existing drought efforts also are outlined. Each of these research gaps, resources, and initiatives are listed as they were identified during the Public Health Effects of Drought Workshop (see the Background section) by a diverse group of experts (see Acknowledgments section).

Research

- Identify both the changes in drinking water quality and the health effects associated with drought over time.
- Investigate the health effects associated with water reuse and regularly summarize the current "state of knowledge" as a resource for public health officials.
- Determine the perceptions of public health officials regarding the importance of drought.
- Analyze existing surveillance data (e.g., hospital admissions, drought-sensitive diseases) to determine which chronic diseases are reported more frequently during a drought.
- Better understand the way that water-use policy has affected water supply and public health.
- Conduct focus groups to determine community perceptions of drought so that communication planning and strategies will be most effective with various target audiences.
- Obtain behavioral and other types of qualitative research on ways to effectively deliver risk communication messages, particularly for nonacute events like drought.
- Assess barriers and impediments to the flow of information.
- Determine the economic impact of drought on human health.
- Better understand the mental and behavioral health implications of drought.
- Obtain data on the relationship between drought and disease.
- Investigate the practice of water usage in the hospital setting and the way that these practices affect emerging disease outbreaks.
- Elucidate ways to improve drought surveillance and monitoring, especially for drought onset, intensification, and demise.
- Gather information regarding common public health perceptions about the importance of drought.
- Investigate the composition of wastewater effluent to determine how it changes during drought events.
- Study the violations in air quality standards that occur during droughts to determine the relationship with photochemical smog, disease, and drought.
- Investigate environmentally friendly and cost-effective ways to disinfect water.
- Investigate environmentally friendly ways to conserve desalinated water.
- Use existing surveillance networks and identify rare pathogens that can be used as drought indicators.
- Conduct postevent analyses of drought impacts on health and communication systems employed.

Initiatives and Resources

- Analyze 10-year after actions and case studies undertaken by jurisdictions across the United States during drought.
- Improve drought forecasting techniques.

- Create a list of best practices regarding the interface between urban planning and climate change.
- Create a public health lessons learned from drought response document.
- Develop and maintain a centralized electronic repository for public health best practices and lessons learned during drought.
- Develop methods or proxies for evaluating the impact of drought on public health.
- Communicate the findings of the American Water Works Association Research Foundation study that examined the public health risks associated with contaminated drinking water.
- Engage in long-term planning for future population growth and prepare to alter community expectations regarding water use.
- Explore the utility of creating a drought-associated public health database that can be built into the existing National Environmental Health Tracking Program.
- Determine the legal implications of specific public health actions that are taken during drought conditions.
- Compile a list of best practices regarding how state laboratories expand their capacity to test the water quality of private wells.
- Identify ways to involve research institutes and entrepreneurs in efforts to develop inexpensive methods for detecting contaminants in water.

Drought Resources for Public Health Professionals

Many drought-related resources are available to public health professionals who are preparing for and responding to drought conditions within their jurisdictions. These materials have been developed by federal, state, and local governments; private industry; water-associated organizations; and other countries and international groups that have engaged in preparedness and response efforts in the face of drought. The following list was offered by participants of the Public Health Effects of Drought Workshop (see Acknowledgments section). It provides readers with examples of existing resources that may be useful in efforts to mitigate the public health implications of drought. It is not intended to be comprehensive. Many individual states have additional drought-related Web pages and resources. Additional resources and sources of information can also be found in the References section of this document.

- Arizona Department of Water Resources: Provides Arizona's drought preparedness and water conservation plans.
  http://www.azwater.gov/dwr/drought.

- California Rural Water Association: Provides information on drought preparedness in California, including outreach, groundwater, conservation, planning, and water shortages.
  http://www.cadroughtprep.net

- City of Tucson, Arizona: Provides information about the city's drought preparedness and response plan.
  http://www.ci.tucson.az.us/water/drought-intro.htm.

- Florida Division of Emergency Management: Provides links and information regarding Florida's drought-related activities.
  http://www.floridadisaster.org/bpr/EMTOOLS/florida_drought_center.htm.

- Maryland Department of the Environment: Provides conservation tips for homes, businesses, and utilities.
  http://www.mde.state.md.us/Programs/WaterPrograms/Water_Conservation/index.asp.

- Minnesota Department of Natural Resources: Provides information regarding Minnesota's approach to managing water use during drought periods.
  http://www.dnr.state.mn.us/climate/drought/index.html.

- National Drought Mitigation Center (NDMC): Provides information to help individuals and organizations reduce their vulnerability to drought.
  http://www.drought.unl.edu

- National Integrated Drought Information System (NIDIS): Includes useful federal resources containing extensive drought-related data and resources.
  http://www.drought.gov

- National Oceanic and Atmospheric Administration (NOAA) Drought Information Center: Contains archived drought-related data and resources.
  http://www.drought.noaa.gov

- North Carolina Drought Management Advisory Council: Provides drought-related data and resources for the state of North Carolina.
  http://www.ncdrought.org

- Pima County, Arizona, Oversight Committee-Joint City/County Water and Wastewater Study: Provides a primer on drought and drought preparedness.
  http://www.pima.gov/drought/PDFs/DROUGHT_primer.pdf

- State of Connecticut: Provides water status updates and other drought-related guidance.
  http://www.ct.gov/waterstatus/site/default.asp.

- State of Georgia: Lists Georgia's drought plan document.
  http://www.georgiaplanning.com/watertoolkit/Documents/WaterConservationDroughtManagement/Drought-MgtPlanFinal03.pdf.

- State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management: Provides Hawaii's drought plan.
  http://hawaii.gov/dlnr/drought/preparedness/HDP2b.pdf

- State of Montana: Provides drought-related data and resources for the state of Montana.
  http://drought.mt.gov

- U.S. Environmental Protection Agency (EPA): Provides information and resources during severe drought.
  http://www.epa.gov/naturalevents/drought.html

- United Nations Children's Fund (UNICEF): Provides information on the effects of drought in countries severely affected by drought.
  http://www.unicef.org/drought/

- Washington State Department of Health, Division of Environmental Health: Provides the water plans developed by Washington State.
  http://www4.doh.wa.gov/dw/publications/publications.cfm?action=pubsearch&keywords=drought.

- World Health Organization: Drought technical hazard sheets that provide information about the health effects of drought.
  http://who.int/hac/techguidance/ems/drought/en.

- World Health Organization's Water, Sanitation, and Health home page: Provides information on water, sanitation, and health.
  http://www.who.int/water_sanitation_health/publications/facts2004/en

- World Meteorological Organization, Sand and Dust Storm Warning, Advisory, and Assessment System (SDS-WAS) home page: Provides information on SDS-WAS.
  http://www.wmo.int/pages/prog/arep/wwrp/new/Sand_and_Dust_Storm.html

- Wyoming Drought Task Force: Provides Wyoming's drought plan.
  http://www.wrds.uwyo.edu/sco/drought/droughtplan.pdf

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Target Audiences, Communication Objectives, and Communication Actions

Target Audience: Communities Affected by Drought

Objective: To inform and educate affected communities about the public health implications of drought, and provide recommendations to mitigate adverse public health impacts.

Audience Segments	Communication Considerations
Persons in hospitals and those residing in long-term-care facilities The elderly Persons who live in isolated or rural areas Persons with chronic health conditions Racial and ethnic minority populations Persons for whom English is a second language Persons who rely on water for their livelihood (e.g., farmers and landscapers) Other appropriate community members and at-risk populations	➤ Procure and amend (as needed) existing communication materials developed by federal, state, and local health agencies and deliver messages to intended target audiences. ➤ Use a variety of media outlets to disseminate messages, including television, print, radio, social media, and other sources. ➤ Consider issuing public service announcements (PSAs). ➤ Messages and materials should be prepared prior to or during the early stages of drought. ➤ Messages and materials should be culturally and linguistically appropriate for audience segments.

Target Audience: Federal Agencies and Organizations

Objective: To establish and enhance partnerships with federal agencies and organizations in communicating the public health implications of drought.

Audience Segments	Communication Considerations
Centers for Disease Control and Prevention (CDC) Federal Emergency Management Agency (FEMA) National Oceanic and Atmospheric Administration (NOAA) National Park Service (NPS) National Science Foundation (NSF) U.S. Army Corps of Engineers (USACE) U.S. Department of Agriculture (USDA) U.S. Department of Energy (DOE) U.S. Environmental Protection Agency (EPA) U.S. Geological Survey (USGS) Other appropriate federal agencies and organizations	➤ Inform and educate federal agencies and organizations about the public health implications of drought. ➤ Collaborate with federal agencies and organizations to address public health threats and issues during drought. ➤ Encourage lateral communication between agencies and organizations to facilitate collaboration and positive working relationships with state and local agencies and organizations. ➤ Communicate public health drought preparedness actions and response plans to ensure a more unified approach to drought mitigation. ➤ Stay informed about local and regional drought conditions. ➤ Develop and deliver public health drought-related communication materials for dissemination to appropriate target audiences.

Target Audiences, Communication Objectives, and Communication Actions

Target Audience: Local Businesses and Other Organizations

Objective: To inform and educate local businesses and other organizations about the public health implications of drought, and provide recommendations specifically addressing their interests and concerns.

Audience Segments	Communication Considerations
Business owners (e.g., farmers, landscapers, heavy water users in community, etc.) Chambers of commerce Civic organizations (e.g., Rotary, Kiwanis, Lions) The media Water wholesalers and retailers Other appropriate businesses and organizations	➤ Inform and educate all audience segments about the public health implications of drought. ➤ Inform business owners about public health risks associated with water systems during drought conditions and encourage regular water quality testing. ➤ Involve chambers of commerce and civic organizations to serve as portals of communication for public health messages to effectively deliver public health and conservation messages to business sectors most affected by drought. ➤ Engage the media in disseminating public health messages during drought. ➤ Prepare messages and materials prior to or during the early stages of drought. ➤ Distribute messages through traditional (newspaper) and nontraditional (social media) means to ensure it reaches appropriate target audiences. ➤ Use press conferences as a tool to facilitate prompt communication. ➤ Engage PIOs to create messages and serve as the health department's voice to the media. ➤ Partner with media to share information about what their audiences are asking in order to improve the accuracy of messages.

Target Audiences, Communication Objectives, and Communication Actions

Target Audience: State and Local Government Programs and Services

Objective: To inform and educate state and local government programs and services about the public health implications of drought, and collaborate with them to mitigate adverse public health impacts.

Audience Segments	Communication Considerations
Departments of agriculture Departments of education, school boards, and institutions of higher learning Departments of natural resources Emergency management and public safety Emergency medical services (EMS) Fire departments Energy companies and other public utilities Local Emergency Planning Committees (LEPCs) Local zoning commissions State Emergency Response Commissions (SERCs) Other appropriate state and local government programs and services	➤ Communicate the public health implications of drought to all audience segments. ➤ Establish collaborations and working relationships with all audience segments. ➤ Collaborate with appropriate partners to identify populations most at-risk for the public health implications of drought. ➤ Enhance communication with schools, colleges, universities, and other institutions of higher learning by using their mailings, student papers, university radio stations, and Web sites. ➤ Communicate public health drought recommendations and action plans by engaging students and teachers with self-efficacy messages. ➤ Increase awareness among energy companies and other public utilities of the public health implications associated with loss of electrical power and other critical infrastructure, particularly for certain at-risk populations. ➤ Work with partners to explore additional ways to disseminate public health drought-related messages to appropriate target audiences (e.g., energy companies and other public utilities can include messages in billing inserts or on their Web sites).

Target Audiences, Communication Objectives, and Communication Actions

Target Audience: State and Local Public Health Programs and Disciplines

Objective: To prepare state and local public health professionals and programs in communicating with affected communities and partner agencies about drought.

Audience Segments	Communication Considerations
Boards of health Environmental health Epidemiologists Health educators Injury prevention and control professionals Laboratorians Mental and behavioral health providers Public health nurses Other appropriate state and local public health programs and disciplines	➤ Prepare to answer questions from partners, stakeholders, the general public, and the media regarding the public health implications of drought. ➤ Inform all public health department staff about drought messages—every employee can become a communicator. ➤ Communicate public health drought messages to appropriate target audiences.

Target Audience: State and Local Water-related Programs and Organizations

Objective: To inform and educate state and local water-related programs about the public health implications of drought through the dissemination of messages and recommendations.

Audience Segments	Communication Considerations
American Water Resources Association (AWRA) American Water Works Association (AWWA) Recreational water coordinators and managers Regional water authorities State water regulators Wastewater treatment facilities Water boards Water Environmental Federation (WEF) Water resource managers Water systems managers Other state and local water-related programs and organizations	➤ Stay informed of drought updates and potential changes in source waters. ➤ Engage in and facilitate partnerships with regional water authorities and professional water associations, such as AWWA, WEF, and AWRA. ➤ Stay informed about the potential for changes in water treatment processes in response to poor water quality; educate appropriate target audiences as necessary. ➤ Develop and communicate messages regarding water treatment options to help improve the quality of water during drought. ➤ Increase awareness of the potential for concentrated contaminants in wastewater streams.

Target Audiences, Communication Objectives, and Communication Actions

Target Audience: Medical/Individual Care Providers

Objective: To inform and educate medical/individual care providers about the public health implications of drought and provide recommendations on how to mitigate adverse public health impacts on affected communities.

Audience Segments	Communication Considerations
Dialysis centers and associations Home health care agencies and hospice Hospitals, clinics, and other health care facilities and their associations Long-term care facilities (e.g., nursing homes and assisted living facilities) Mental and behavioral health providers Physicians and other health care providers Other medical/individual care providers	➤ Educate providers about the possible health-related effects of drought on their patients (e.g., waterborne infectious diseases, aggravated chronic respiratory conditions). ➤ Communicate recommendations for mitigating the adverse health impacts of drought to providers; encourage providers to share these recommendations with their patients, including the need to stay hydrated and maintain basic hygiene during drought. ➤ Educate providers about the possible effects of drought on mental and behavioral health, and provide guidance and resources to address the needs of their patients. ➤ Communicate the need for the development of water-related emergency plans within dialysis centers, hospitals, clinics, long-term care facilities, and other health care facilities (refer to Joint Commission guidelines if necessary); help facilitate the development of these plans by encouraging them to engage community partners in the planning process. ➤ Inform appropriate audience segments about the health-related effects of drought on at-risk populations and the need for increased epidemiological surveillance during drought.

Target Audiences, Communication Objectives, and Communication Actions

Target Audience: Political Leaders and Organizations/Elected and Appointed Officials

Objective: To inform and educate political leaders and organizations, and elected and appointed officials, about the public health implications of drought and engage them in drought preparedness.

Audience Segments	Communication Considerations
Boards of health County commissioners and managers City/county elected and appointed officials (e.g., mayor, city managers, city council) Federal, state, and local legislators Other political organizations Other appropriate political leaders	➤ Inform and educate all audience segments through clear, concise messages about the public health implications of drought, particularly on certain at-risk populations. ➤ Encourage all audience segments to become involved in drought preparedness efforts. ➤ Encourage all audience segments to address drought-related issues through legislative, regulatory, civic, and other official actions. ➤ Provide all audience segments with data regarding the public health-related costs to the community resulting from drought, if possible.