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DEATH BY DEGREES

THE HEALTH THREATS OF CLIMATE CHANGE IN ARIZONA

ARIZONA REPORT

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September 2001

This report was prepared by Physicians for Social Responsibility to alert Arizona residents to the potential health effects of climate change and to encourage them to reverse global warming's deadly course by reducing reliance on fossil fuels.

This report was made possible by the generous support of the following:
John D. and Catherine T. MacArthur Foundation
W. Alton Jones Foundation
Beldon Fund
The Turner Foundation

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The Health Threats of Climate Change in Arizona

Physicians for Social Responsibility

Death by Degrees

Climate change and human disease are intricately related. It is a phenomenon we will see more of as we continue to experience global warming.

— JOHN TAYLOR, PH.D., UNIVERSITY OF CALIFORNIA AT BERKELEY, COLLEGE OF NATURAL RESOURCES (*1*).

Executive Summary: Arizona—A State At Risk

Climate change could affect the public health of Arizonans by threatening the water supply, worsening air pollution, and increasing the number of heat-related deaths. Senior citizens, those with existing medical problems, the poor, and children are at especially high risk. Although climate change is a global problem and the effects will be felt around the world, the U.S., and Arizona in particular, will likely experience significant consequences.

Arizona is a state of contrasts: Driving from south to north, within a span of about eight hours, one passes through desert, at an elevation below 1,000 feet and rainfall less than five inches a year; farmland; valleys; mountains rising well above 12,000 feet and receiving more than 20 inches of rain a year; and eventually one ends up on the high desert plateaus where four states meet in what is commonly termed the Four Corners area(*2*). Temperatures from one part of the state to the other vary greatly, and even temperatures in the same location can vary by 50˚F or more in a single 24-hour period (*3*). Arizonans are already accustomed to living with climate variability, but the changes projected during the next 100 years could provide the greatest challenge yet.

Climate fluctuations have occurred during previous centuries, but in the early 1970s, a period of rapid warming took hold that now

shows no signs of stopping. During the past 100 years, average global surface temperatures have increased by approximately 1˚F (*4*). The last 13 years, from 1987 to 2000, have been among some of the 15 warmest years on record (*5*). Scientists at the National Oceanic and Atmospheric Administration (NOAA) announced that the winter of 2000 was the warmest winter on record since the U.S. government began keeping weather statistics 105 years ago (*6*).

The Intergovernmental Panel on Climate Change, a United Nations-sponsored group of more than 2,500 experts from all aspects of the field of climate change, recently distributed a report to government officials worldwide stating that by 2100 average global surface temperatures will increase 2.5˚ to 10.4˚F (1.4˚ to 5.8˚ C). Temperatures over landmasses likely will be even higher (*4*). The National Academy of Sciences, in a special study recently commissioned by President Bush, examined all the existing data available on climate change and concluded, "Greenhouse gases are

How Global Warming Could Threaten Health in Arizona

According to physicians who have studied global warming and its effects, the most severe health risks in Arizona could include the following:

Changes in the quality and supply of water:

- Warmer temperatures leading to enhanced evaporation combined with changes in precipitation could require more crop irrigation—further jeopardizing water resources.
- Changes in precipitation amounts and patterns could lead to more flooding in some areas and droughts in others.
- Both droughts and floods can impair water quality.

Increased accidents and injuries:

- An increase in heavy precipitation events would result in more flooding.
- There would be a potential increase in the number and severity of flash floods.
- An increase in airborne dust and sand storms could affect highway and airport safety.

More heat-related illness:

- Number of heat-related deaths could increase significantly.
- Senior citizens, the very young, and the poor are at greatest risk of death from heat stress.

Decreased air quality, causing more frequent and severe attacks of asthma and worsening of other respiratory and cardiac problems, could result from:

- Increased ozone (smog) levels.
- Greater emissions of carbon dioxide, nitrogen oxide, sulfur dioxide, particulate matter, and other toxic pollutants.
- Increased pollen levels.
- Smoke from forest fires sparked by drought.
- Increased dust and particulates.

Greater risk of infectious diseases:

- Water used for drinking and recreation can become contaminated by animal and human wastes. This is more apt to occur after heavy rainfall and can lead to bacterial, parasitic, and viral infections.
- Food-borne disease risks from *Cyclospora* associated with fruits and vegetables.
- Increased risk of rodent-carried diseases like hantavirus and plague.
- Increased risk of mosquito-carried diseases.
- Increased risk of certain fungal disease such as valley fever.

Threatened food supply:

- Decreased yields of wheat and cotton.
- Decreased ranching yields.

accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise" (*7*).

Although uncertainties exist about how high temperatures will rise and what all the effects to the global climate will be, an overwhelming consensus among scientists has emerged during the last decade on several key points:

- An increase in temperature is real.
- Human activities—in particular our burning of fossil fuels—are affecting the climate system (*8*).
- Warmer conditions on Earth will directly affect our lives, health, and well-being (*9*).

This report describes how the changing global climate could affect human health. Our focus is on Arizona, a state that many consider to be at unusually high risk for increased illness, injury, and mortality due to changes in temperature and other weather phenomena.

Perhaps the most critical resource for the Southwest could also be the most climate-sensitive: Water. Without a reliable and adequate supply of water, agriculture, ranching, mining, energy production, development, commerce, and the day-to-day necessities of life could not continue and thrive. Yet even with today's highly technical system of water storage and delivery, an adequate supply of rainfall, occurring at the right time of the year and in the right place is absolutely necessary. Climate change could substantially change the total amount of precipitation the state receives. In addition, the pattern of precipitation combined with other factors, such as warmer temperatures causing earlier snow melt and enhanced evaporation, could all work together to cause water shortages in Arizona. If current century climate scenarios for the region are proved correct, winter precipitation will increase, leaving a different set of solutions required for dealing with global warming (*2*).

Projections of global temperature increases and climate change are generated by complex computer programs that consider many processes that interact to create the global climate such as temperature, precipitation, storms, wind, and circulation. These global models use grids that divide up Earth's surface into areas that are several hundred square miles and therefore are limited in how well they represent what might happen at a smaller scale, such as for the state of Arizona. A regional model for the Southwest developed by researchers at the National Center for Atmospheric Research projects temperatures that generally agree with the larger-scale models. The regional model projects an increase of about 7˚F in the winter and 9˚F in the summer by the year 2060 (*10*).

The distribution of precipitation also is projected to change. The current models used to project trends in climate do not yet adequately account for the complex aspects of precipitation patterns in the Southwest, such as the monsoon. Experts agree precipitation patterns will change, but the specific changes are still not completely predictable (*3*). Many experts expect winter precipitation will increase and are concerned that summer precipitation may decrease. With warmer temperatures, there will likely be more of the winter precipitation falling in the form of rain, and earlier snowmelt could result in worsening spring floods and loss of stored water in the form of snow for later

use. Despite the possible overall increase in projected precipitation, warmer temperatures and more runoff could lead to greater water shortages (*3*). The regional model developed by the National Center for Atmospheric Research projects decreases in winter precipitation of about one inch per month and decreases in summer precipitation of about one-half inch per month (*10*). In addition, higher temperatures and greater evaporation, as well as greater climate variability with more of the precipitation falling during heavy precipitation events, could leave longer periods of drought in between rainfall events (*3*). Droughts and enhanced soil evaporation from higher temperatures may require more water to be used for crop irrigation. If more of Arizona's precipitation comes in the form of heavy rainfall events, there will be an increase in runoff. Depending on the timing and circumstance, groundwater recharge rates could increase or decrease (*2*).

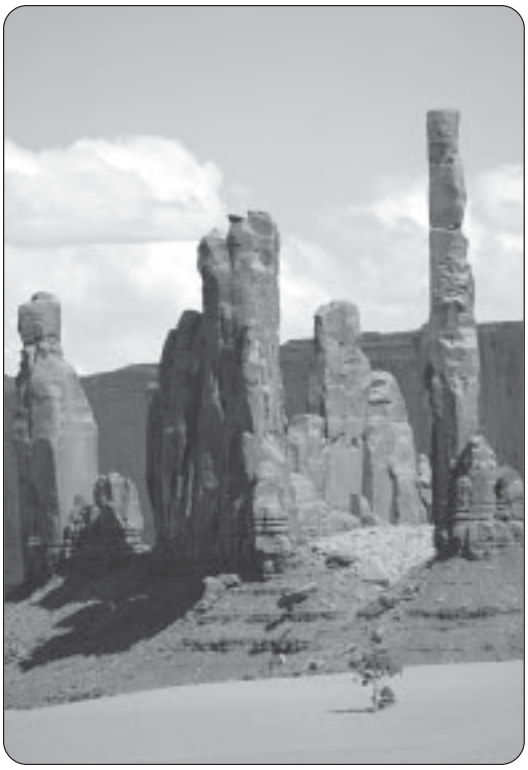
All of this uncertainty makes it difficult for Arizonans to make plans for specific outcomes. Instead, strategies to plan for the coming changes should be flexible and nimble. Sometimes these strategies are called "no regrets" plans because they encompass activities that improve the current situation regardless of how much precipitation actually falls in Arizona. Water conservation efforts, for example, reduce energy required to transport water to where it is needed, reduce the amounts of chemicals needed to treat the water, and allow Arizonans to prepare for the possibility of droughts in the future.

Both floods and droughts can result in water contaminated with microorganisms causing water-borne diseases. If contaminated water is used to irrigate or process crops, the food supply also could become contaminated (*11*). *Cyclospora* is one kind of organism that is apt to be more of a problem with warmer temperatures. *Cyclospora* causes infection associated with fresh produce (*12*). *Cryptosporidium* is another germ that has caused diarrhea by contaminating the fresh water supply. These occasions tended to follow flooding (*12*). Severe flooding also can cause direct injuries and accidents (*4*).

While projections look to the future, global and regional warming appears to be influencing the environment and society now. Numbers of very hot days and nights have increased throughout the state during the past 50 years (*13*). Arizona is one of two states with the highest annual age-adjusted rates for heat-related deaths (*14*). More heat brings more cases of heat cramps, heat exhaustion, and heat stroke. In addition, heat can cause death and tends to exacerbate the death rate from other medical conditions. The elderly, chronically ill, and the poor will likely suffer the most (*15*). Because Arizona is so attractive to retirees, already 13% of the state's population is over the age of 65 and this percentage is growing. By the year 2025, more than one-fifth of the population will be over the age of 65 (*2*).

Climate change also is expected to affect people's exposure to air pollutants. Airborne dust in Arizona, for example, may increase with either drought or flooding and dust in this region is known to be a source of valley fever and a cause of respiratory illness. As climate change affects local and regional weather, air pollutants may be concentrated in a particular area or be blown away from an area. Actual amounts of air pollutants, such as sulfur oxides, nitrogen oxides, volatile organic compounds, and particulate matter, are expected to rise with increased fossil-fuel energy consumption needed to

power air conditioners, as people try to adapt to warmer temperatures. More growth and development leading to increased burning of fossil fuels to power vehicles, industry, businesses, and homes also will lead to increased amounts of pollutants in the air. Higher temperatures cause more volatile organic compounds to escape into the air when people fuel and run their vehicles. With warmer temperatures and sunlight, ground-level ozone, which is the major component of smog, is formed from nitrogen oxides and volatile organic compounds (*16*). Ozone makes chronic respiratory diseases like asthma and chronic obstructive pulmonary disease much worse. Even healthy Arizona residents who breathe ground-level ozone, or smog, can experience coughing, lung and eye irritation, shortness of breath, and problems with short-term lung function (*16*).



Carbon monoxide, sulfur oxides, and nitrogen oxides all have negative health effects, including toxicity, lung irritation, reduced lung function, and aggravation of existing cardiovascular diseases. In addition, sulfur oxides and nitrogen oxides can combine with other pollutants in the air to form particulate matter (*16*). People who are exposed to particulate matter, including mineral dust from natural sources, can experience exacerbation of chronic respiratory or cardiovascular diseases, damage to lung tissue, and changes in the body's ability to fight off diseases that can lead to premature death and possibly contribute to cancer (*16*). The elderly, infants and children, and anyone with underlying heart or lung disease is especially vulnerable (*16*).

Climate change, moreover, could increase the risk of insect or vector-borne diseases that occur in the state. Warmer temperatures can make it easier for some insects to transmit a disease to humans (*17*). Fortunately, other factors such as higher living standards, window and door screens, and a vigilant public-health infrastructure should keep these diseases from becoming an unmanageable problem in Arizona (*18*). However, if disease surveillance systems are not strengthened and maintained, vector-borne diseases such as dengue fever could become a problem.

Climate change could further affect the production of Arizona's primary crops, such as cotton, wheat, hay, and oranges. Wheat yields are projected to suffer the most, but cotton yields are also expected to significantly decrease. Ranching is an important way of life for many Arizonans. Rangeland is dependent on adequate rainfall occurring at the right time for the growth of forage. If summer temperatures rise significantly and drier summer conditions prevail, livestock may be adversely affected (*3*).

Finally, Arizona's magnificent forests could be partially replaced by grassland as a result of warmer temperatures and drier conditions. Forest fires may become an even greater problem with the effects of climate change further reducing forested areas (*3*).

Given all of these potentially harmful effects of climate change in Arizona, people in the farming, ranching, mining, and tourism industries could face far-reaching socioeconomic impacts. One problem may be their ability to afford health insurance. Already, state uninsured rates are of concern. Currently almost one-quarter of the population of Arizona has no health insurance (*10*). The additional economic burden on existing coverage, especially Medicare and Medicaid, could be substantial. Lack of health insurance and loss of income could significantly reduce access to health care.

Arizonans need to be very concerned about the potential health effects of global warming on their population. Precautions taken now can help to lessen or avert potential health problems in the future. The following sections describe the specific health effects that could result from global warming during the next 50 to 100 years. In some cases, there is a high level of certainty about the projections. In others, the evidence is less definitive. The U.S. has some ability to adapt to and prepare for these changes because of its health care infrastructure and strong economy. However, the only viable action now, in an attempt to stabilize the climate before damage to the planet is beyond repair, is to decrease greenhouse gas emissions.

The Complex Origins of Climate Change

Since the end of the last Ice Age 10,000 years ago, average temperatures worldwide have risen only 9°F, mainly due to natural changes in the geographical distribution of the sun's energy and in the amounts of dust, carbon dioxide, and other gases in the atmosphere. In recent years, the rate of increase in temperatures has accelerated. Some greenhouse gases, such as carbon dioxide, methane, nitrous oxide, and water vapor occur naturally, residing in the atmosphere and insulating Earth. These gases retain heat from the sun's rays and keep Earth's surface about 60°F warmer than it otherwise would be (*19*). However, since the beginning of the industrial revolution, atmospheric concentrations of these greenhouse gases have greatly increased. Carbon dioxide concentrations have increased by 31% and are responsible for more than 60% of the "enhanced" greenhouse effect. Methane is released from garbage dumps, farm animals, coal mining, and natural gas producers and contributes up to 20% of the climate change impacts caused by greenhouse gases. Methane concentrations have more than doubled. Nitrogen oxides result from burning fossil fuels and have a lifespan of about 120 years, meaning that combustion byproducts of fuels burned now will remain in the atmosphere and potentially contribute to climate change until the year 2120. Nitrogen oxide concentrations have risen by about 15% (*20; 21*). These increases have caused Earth to heat up.

Human activities are among the most important factors making Earth warmer. Fuel burned to run cars and trucks, heat homes and businesses, and power factories generates approximately 80% of carbon dioxide emissions in the U.S. (*22*). Deforestation, livestock production, landfills, industrial production, and mining also can change the levels of greenhouse gases by increasing emissions or by decreasing the absorption of gases by plants.

In 1996, the U.S. was responsible for releasing about 24% of global energy-related carbon emissions into the atmosphere. In 1999, the U.S. released 13%

more greenhouse gases than in 1990 (*23*). If current trends continue, carbon dioxide concentrations could increase by 30% to 150% by the year 2100 (*19*). One certain way to reduce carbon dioxide emissions and slow the climate change trend is to drastically reduce the amount of fossil fuels burned in the U.S.

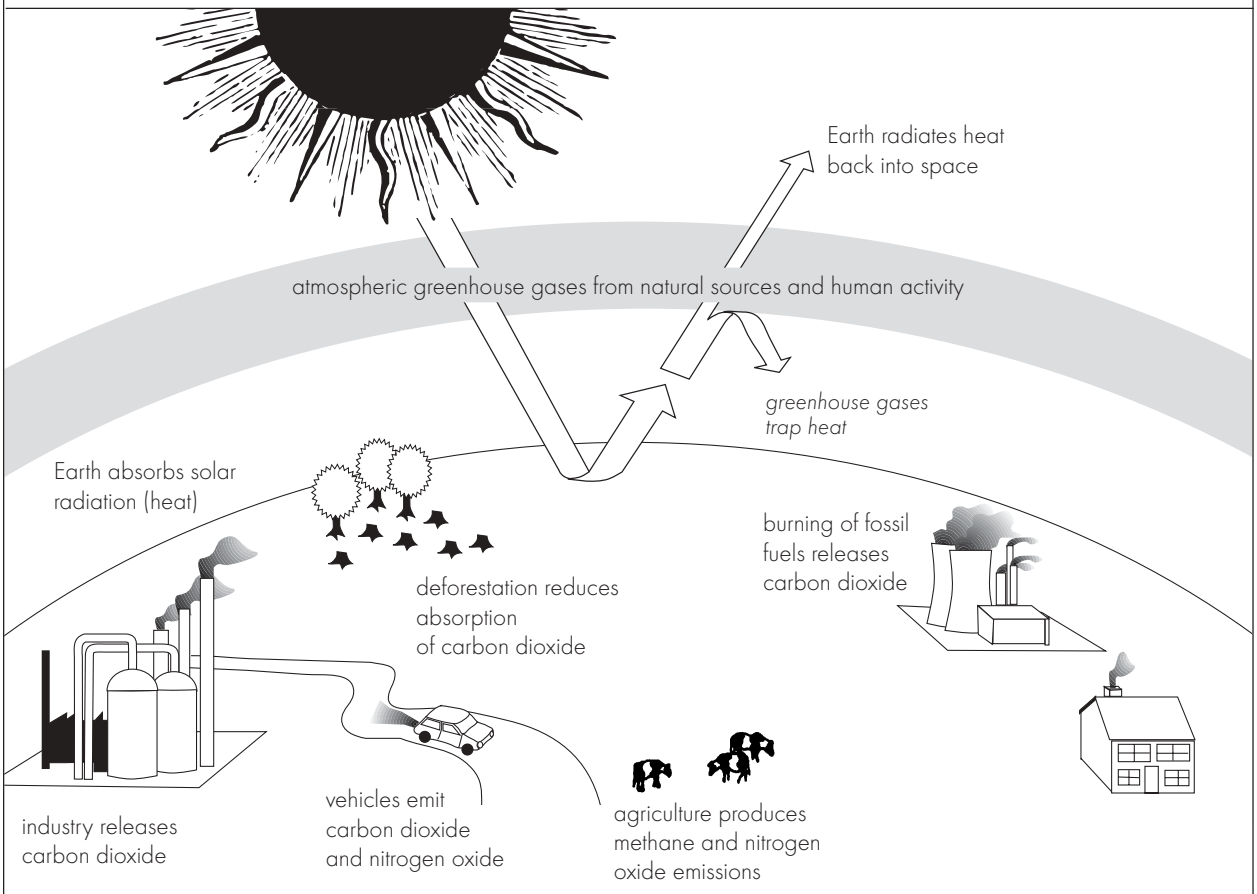
The State of the Science

There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.

—INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, 2001(*4*)

In 1995 the Intergovernmental Panel on Climate Change projected increases in global average temperatures of 1˚ to 3.5˚F (*9*). This year the Panel revised its temperature projections stating that new studies and better methods for analyzing the data have "led to a better understanding of climate change" (*4*). The new projections of 2.5˚ to 10.4˚F (1.4˚ to 5.8˚C) are for global average surface temperatures. Temperatures tend to be cooler over water,

FIGURE 1
The Greenhouse Effect



Source: Adapted from *The Impact of Climate Change*, United Nations Environment Programme, 1993; Climate Action Network.

Global Warming at a Local Level

Although the average temperature worldwide is increasing, hence the term "global warming," the story becomes more complicated at the local level. One reason is that a warmer atmosphere holds greater amounts of water, resulting in more precipitation. Another is that warmer air means changes in wind patterns. The resulting weather changes will vary from place to place. In general, we can expect more extremes—more heat waves, more storms, wetter climates in some places, drier climates in others, and even cooler temperatures in certain areas. Many scientists, therefore, prefer the term "global climate change" to "global warming." In this report, we use the term "global climate change" or just "climate change" most frequently but still use "global warming" some of the time.

which makes up the majority of Earth's surface, therefore, temperatures over land masses are likely to be higher (*4*).

Evidence that human activities have changed the climate system has been collected from scientists studying satellite data, sea surface temperatures, coral reefs, tropical glaciers, and changes in the polar regions. Two new studies lend additional strength to the evidence: A 6 April, 2001, report in the journal *Science* (*24*) and, again in *Science*, a report published 13 April, 2001 (*25*). The first report (*24*) presented data showing a progressive warming of tropical oceans since at least 1950. The authors, from the National Center for Atmospheric Research and NOAA, say this supports other evidence for human-induced climate change (*24*). The researchers also found a correlation between the warming oceans and climate changes in Northern Hemisphere winters during the 50-year study period (*24*). The warm waters appear to heat the tropical atmosphere, which influences atmospheric pressure patterns and winds over the North Atlantic and North Pacific, shifting storm paths to the north (*24*). The second study by researchers from the Scripps Institute of Oceanography found evidence for a "human-produced warming in the upper 3,000 meters of the world's oceans" (*25*).

No longer are there questions about whether Earth is warming. That evidence is now indisputable. The questions now are how much will Earth warm, how will it affect people, and what can be done to slow the process. The ensuing section will describe potential health effects of global warming on people.

How Could Climate Change Affect the Health of Arizona Residents?

Climate change is likely to have wide-ranging and mostly adverse impacts on human health.
-INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, 2001 (*8*)

How Climate Change Could Affect Water Supplies

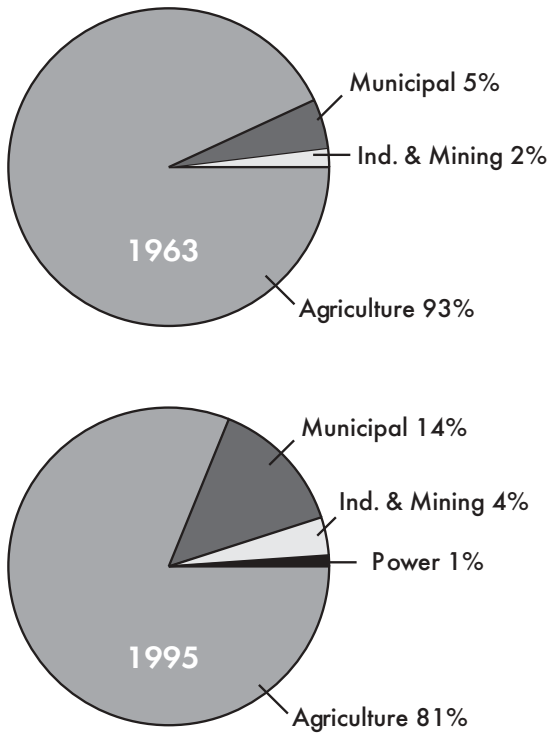
Life in the arid Southwest would not be possible without a steady, dependable source of water. Arizona's water supply currently comes from four sources: surface water, Colorado River water, groundwater, and reclaimed water (*26*). Research shows that climate change could have major effects on precipitation, stream flows, runoff, water temperatures, and evaporation, thereby affecting Arizona's water supply (*3*).

Surface water such as lakes, rivers, and streams vary dramatically in the amounts available from year to year and place to place. A variety of storage reservoirs and delivery systems help the state supply surface water when and

where it is needed (*26*). These storage and delivery systems, however, are still "severely dependent on precipitation falling at the right time, in the right place, for a sufficient amount of time, and in sufficient volume" (*2*). Relatively small changes in temperature and precipitation result in changes in soil moisture and evapotranspiration, which can result in large changes in runoff (*27*).

Climate change will also affect the regions around Arizona such as the Rocky Mountains to the North. Much of the water in the Colorado River is dependent on gradual snowmelt to provide a steady annual flow. This steady supply may be jeopardized as precipitation patterns change all over the continent. If more of the precipitation in the Rocky Mountain area comes as spring rains, there could be more problems with flooding and less of the steady water supply on which Colorado River users have come to depend (*28*).

FIGURE 2
Percentage of water use by sector in Arizona



Source: Hodge, 1964; Solley, 1998

Colorado River water is usually listed separately because Arizona, California, Nevada, New Mexico, Utah, Colorado, Wyoming, and Mexico all share the river's resources (*26*). Complicated agreements and laws dictate how much water each state and Mexico can use. The Central Arizona Project was initially built so that Arizona could use more of its share of Colorado River water and not have to use as much groundwater. According to the "Law of the River," Arizona has the right to use 2.8 million acre-feet of Colorado River water every year. One acre-foot equals 325,851 gallons. The Central Arizona Project, when fully utilized, will be able to deliver an average of 1.5 million acre-feet of this water to Maricopa, Pinal, and Pima Counties (*26*).

About 40% of Arizona's water is still pumped from underground reservoirs (aquifers) and is called "groundwater" (*26*). Water has been stored in these reservoirs for millions of years, but is now being pumped out faster than it is being replenished. When it rains, the water slowly percolates down through the soil to replenish the underground reservoir. This process is called "recharge." With very heavy rains, the soil is generally not able to absorb the water fast enough and more of the water becomes "runoff" and does not help to recharge the underground reservoir (*2*). An exception is when the first heavy rains of the season break through the hard, crusty surface of dry river beds, helping subsequent rains and runoff to percolate below. Pumping out

more water than is being replenished results in lowering of the water table, which will likely lead to water shortages in the future if the current pattern persists, and also causes land subsidence (*2*). For more information about land subsidence, see box below.

The last source of water for Arizona is reclaimed water, which is wastewater that has been treated to a quality that can be used for irrigation, watering golf courses and parks, industrial cooling, and maintenance of wildlife areas (*26*). Reusing water is a good method to conserve water supplies.

Arizona, one of the top 10 fastest-growing states in the nation, has experienced remarkable growth and development in the past decade and population is expected to increase dramatically in the coming years (*2*). Arizona's population is expected to increase between 25% and 40% by the year 2025, and much of this increase is expected to occur in urban areas (*2*). Urbanization generally means that more of the ground surfaces are paved or otherwise impervious, leading to more precipitation becoming runoff and further decreasing recharge rates. Urbanization runoff also washes significant amounts of pollutants into public waterways, which may be used recreationally and for drinking water. Arizona's water supplies are already stressed. Climate change will likely worsen the water supply problem in Arizona.

Land Subsidence Resulting from Groundwater Pumping

Land subsidence describes the settling of land that results from underground changes such as the removal of groundwater from aquifers (*29*). When water is removed from the cracks and crevices between rocks, particles pack together and thus decrease the water table (*30*). Because clay and silt compress tightly, areas that rest upon layers of these fine-grained sediments are particularly vulnerable to land subsidence, especially when the water table has decreased by over 100 feet (*30*). In the event that subsidence rates are non-uniform, fissures averaging hundreds of feet in length may result. These fissures are first observed as cracks that may be up to 50 feet deep and 10 feet wide (*30*).

Currently land subsidence affects over 3,120 square miles in Arizona, an area that includes both metropolitan areas such as Tucson and Phoenix, and agricultural regions like Pinal and Maricopa counties (*30*). In 1997, subsidence levels were 18 feet in an area west of Phoenix, representing an extreme case of the problem (*29*). Subsidence poses threats to urban communities, potentially causing damage to bridges, railroads, buildings, sewers, and other man-made structures (*27*). Farmlands and rural areas are also at risk because of changes in elevation and slope of streams, irrigation ditches, gas lines, and drains that may result from subsidence (*30*). In addition, drinking water quality may be compromised because fissures expose groundwater to contaminants such as chemicals and animal wastes. Fissures are often used as waste disposal sites, further threatening ground water quality (*30*).

The problem of land subsidence has resulted because groundwater has been pumped out of aquifers faster than it has been replenished, a condition known as overdraft (*31*). The Colorado Basin is over-pumped annually by 1.24 million acre-feet, where an acre-foot is 325,851 gallons (*27*). Roughly 80% of this over-pumping occurs in Arizona, where most groundwater is allocated to agricultural uses (*27*). The risks posed by land subsidence can be avoided if groundwater use is restricted, if areas for safe pumping are sought and used, and if groundwater is artificially replenished (*29*). Global climate change may affect both groundwater supply and demand in the Southwest, making such measures more difficult to adopt. Other factors such as new technologies, a rise in population, and economic and social conditions may further increase water demand (*27*).

How Climate Change Could Affect Water Quality

Low stream flows cause substances in water to concentrate, leading to more polluted waters. Increasing salinity levels have already been a major concern for Arizona. Drainage of irrigation water from the Wellton-Mohawk Irrigation District back into the lower Colorado River caused salinity levels so high that the U.S. was involved in a dispute with Mexico over the deterioration in the quality of the water crossing the border (*27*). To decrease the salinity, the amount of irrigable acreage in the Wellton-Mohawk Irrigation District was reduced by 10,000 acres and a desalinization plant was constructed at Yuma, Arizona (*27*).

Mercury is one of the most toxic substances known to exist, causing neurological defects, seizures, and even death. Human-made sources of this element include solid waste incineration, fossil fuel combustion, mining, and smelting. Mercury accumulates in water sources and becomes concentrated in the body tissues of fish, thus becoming a health hazard for consumers. Concentrations of total mercury in fish such as pike and swordfish can be 10,000 to 100,000 times as great as the ambient concentration in the water. Fish advisories, warning against the consumption or handling of fish from contaminated waters, have been issued for mercury in 40 states. As of 1998, Arizona had two fish advisories for mercury in effect (*32*).

Mercury is especially harmful for pregnant women because it crosses the placenta and can cause damage to the developing fetal nervous system. Women who are pregnant, or may become pregnant should check with their doctor about which fish and how much fish is safe to consume (*90*).

Pollution is not just a problem for surface waters; groundwater is also at risk. For example, Arizona Department of Environmental Quality sampled 1,089 wells in the Phoenix area. Eight percent exceeded the safe drinking water standards established by the U.S. Environmental Protection Agency (EPA) for fluoride, 1% for metals, 32% for volatile organic compounds (VOCs) and synthetic organic contaminants (SOCs), and 3% for pesticides. Nitrates, a major component of fertilizer and animal waste is especially dangerous for babies. Almost half of the 114 wells tested in the Phoenix area exceeded the safe standard for nitrates (*91*).

On the other end of the spectrum, as floodwaters wash across farmland, rangeland, industrial sites, and shallow sewage systems, pollutants such as pesticides, chemicals, and animal and human wastes enter surface and ground waters (*12*). Both flooding and droughts can cause diarrhea from a variety of bacteria (e.g. *Salmonella* and *Shigella*), viruses (e.g. rotavirus), and protozoa (e.g. *Giardia lamblia*, amoebas, *Cryptosporidium,* and *Cyclospora*) (*17*). Most healthy individuals recover, but if not treated appropriately diarrhea can become serious, resulting in dehydration and occasionally death. Children, anyone with a compromised immune system, and the elderly are particularly vulnerable to severe consequences from diarrheal disease (*12*). *Cryptosporidium parvum* is a parasite that completes its life cycle within the intestine of mammals and has caused large outbreaks of diarrhea after flooding contaminated drinking water sources (*12*).

Cyclospora, a parasite that reproduces via an egg-like structure called an oocyst passed from humans in the feces, can get into the water supply. The oocyst matures and becomes infectious in the environment. Warmer temperatures facilitate this process (*12*). When foodstuffs such as fresh

produce are irrigated or processed with contaminated water, *Cyclospora* can be ingested and can cause diarrhea.

Injuries and Accidents from Floods

More intense rainfall events accompanying global warming would be expected to increase the occurrence of floods, and warmer sea-surface temperatures could strengthen tropical cyclones.

—INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, 1998 (8)

Temperature is a major part of weather and climate, and global warming will have profound effects on the global climate. The Intergovernmental Panel on Climate Change has determined that extreme weather events likely will become more common during the 21st century. For Arizona, extreme weather events will be primarily heavy rainfall events (*4*).

Nationwide, floods are the leading cause of death from natural disasters and account for 40% of all injuries resulting from natural disasters (*33*). Drowning is the most common cause of death during a flood and, ironically, human-made structures to control floodwaters are responsible for many of these deaths. Levees, embankments, retention walls, and drainage channels all can be used effectively to control floodwaters, but when they fail they can result in injuries and deaths (*33*). The use of these structures may become more common in Arizona as greater amounts of floodwaters need to be contained.

Floods also may create areas of standing water and other conditions ideal for breeding mosquitoes. Climate-related natural disasters like floods also can increase the potential exposure to mosquitoes, since residents and recovery workers may spend more time outside removing debris, rebuilding structures, and living in storm-damaged housing. In the continental U.S., natural disasters have not yet been associated with epidemics of mosquito-carried diseases, although the potential does exist for increased risk of these diseases (*37*). Disaster response plans, especially for floods, should include heightened surveillance for mosquito-carried diseases (*38*).

Finally, several studies have documented long-term psychological and physical effects in flood victims. Both children and adults have been found to suffer severe emotional impairment after their experiences during and after floods (*39*). Other studies have found that years after the flood occurred, victims still report more perceived health problems and more hypertension, respiratory, gastrointestinal, and cardiovascular-related health problems (*39*). Thus, floods pose serious threats to public health from

accidental injury and death during the disaster, from compromised sanitation and increased risk of infectious disease immediately after the disaster, and from chronic psychological and medical problems for extended periods after the disaster (*39*). Climate change will likely cause more problems with floods in Arizona, which have significant negative health effects.

Direct Effects of Heat on Health

Heat-related disorders are caused by a reduction in, or collapse of, the body's ability to shed heat by circulatory changes and sweating. Such disorders may also develop due to a chemical (salt) imbalance caused by too much sweating (*15*). Heat may lead to severe health problems, such as heat cramps, exertional heat injury, heat exhaustion, and heat stroke, all of which could increase in Arizona as climate change causes more extreme heat days.

Heat cramps are muscle spasms that primarily affect people who exert themselves through strenuous work or exercise in a warm environment. Farmers, construction workers, ranchers, or even tourists may experience heat cramps as a first sign of heat stress. Mineral imbalances likely cause these cramps and salt and water replacement usually relieves them. A more severe condition is exertional heat injury that commonly occurs among runners who are not properly conditioned and hydrated. The body can reach 102˚ to 104˚F, with symptoms that include goose bumps, chills, nausea, vomiting, and unsteady gait (*15*).

Heat exhaustion, or heat collapse, is the most common heat-related condition. It occurs when the cardiovascular system cannot keep up with heat

The Health Risks Associated with Arroyos

Arroyos, common in the arid climates of the Southwest, can cut up to 65 feet into a valley floor and may extend for hundreds of miles (*34*). The primary factor in arroyo formation is heavy rainfall and flooding, conditions that may become more common as a result of global climate change. Other factors in their development include heavy grazing and other forms of land use that increase the rate of erosion. Arroyos are potentially hazardous land formations, threatening agriculture, flora and fauna, and human life.

As arroyo cutting begins, it drains aquifers of groundwater and thus decreases the water table in the region (*34*). This process takes away water intended for crop irrigation. Destruction to irrigation channels further increases damage to crops. In addition, water flowing through an arroyo deposits sand and gravel downstream, covering farmland with sediment. This sediment originates from subsoil layers and thus is relatively infertile (*34*).

The development of arroyos has altered the topography of the Southwest. Arroyos have drained once fertile riverbed marshes, known as cienegas, which decorated the landscape before 1865. In other areas, stream channels have been widened and deepened, changing the plant and animal life of the region (*34*).

Arroyos pose a grave risk to human life in that they increase flood severity. By changing the shape of stream channels, carving a straight path from what originally may have been a meandering one, they shorten channel length and thus reduce the containment space for floodwater. Further, sediment from arroyos can be deposited downstream, blocking a stream channel and further contributing to flooding. Arroyos also contribute to flash flooding events, carrying rapidly flowing water from distant heavy storms. A normally dry arroyo can transform to a rapidly flowing body of water in a matter of seconds (*35*). Flash floods result in the largest number of weather-related deaths in the U.S each year (*36*).

demands. An affected person feels dizzy, weak, cold, clammy, and has ashen skin and dilated pupils. The individual may require hospitalization (*15*). When moved to a cool place, victims of heat exhaustion usually recover.

Heatstroke the most severe of these conditions, can be fatal. If body temperature reaches 105°F or above, damage to the kidneys, muscles, heart, and blood cells is likely. Sweating stops altogether. Death can occur immediately or could be delayed up to several weeks due to complications, such as kidney failure (*15*).

Heat Stress, Heart Attacks, and Stroke. A 1997 study by scientists at the University of Delaware Center for Climatic Research examined mortality and weather data for a series of cities in the U.S. During oppressive heat wave events, there was a significant increase in the number of deaths per day for the general population, with the elderly being most at risk (*40*). Some of the deaths were from heatstroke, but many of the deaths were thought to be from heart attacks and stroke. When a person overheats, the heart tries to pump harder and faster to try to dissipate the heat. Heat stress may also cause the blood to form clots more easily (*15*). In general, hospital admissions and emergency room visits from all causes increase during hotter weather.

Despite Arizona's usual high summer temperatures, residents could still be susceptible to heat waves and increased temperatures. The "heat index" is one

The Precautionary Principle

Legislators, physicians, ethicists, and environmentalists often refer to a term called "the precautionary principle" when dealing with climate change issues. The term's definition states, "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context, the proponent of an activity, rather than the public, should bear the burden of proof" (*87*).

The precautionary principle has four main components.

1. Communities have a duty and a right to take anticipatory action to prevent harm.
2. The burden of proof of the harmlessness of a new technology, process, activity, or chemical is the responsibility of the proponents, not the public.
3. Communities have an obligation to discuss and to explore a full range of alternatives to the hazards posed.
4. Decisions must be open, informed, and democratic.

The precautionary principle is already used in some areas regarding health. Immunizations are given to protect someone against the relatively slim chance of developing a disease. The individual receiving the immunization does not know for certain that they would have contracted the disease if the immunization had not been given, but the possible risk of disease was significant enough to warrant taking the precautionary step of obtaining the immunization.

Global warming requires that same sense of precaution and a willingness to take action. We have strong evidence that global warming is occurring and is largely the result of burning fossil fuels and other human activities. We do not know *exactly* how much or how soon temperatures will rise; we do not know *exactly* what all the consequences will be; we do not know *exactly* how much and in what ways any individual will be affected. We do know, however, that there is significant risk of multiple, severely negative consequences of doing nothing and allowing the climate change situation to get worse. Therefore, applying the precautionary principle to the issue of climate change dictates that we take steps to slow global warming and climate change by greatly reducing our consumption of fossil fuels.

common way to compare environmental conditions that could lead to heat stress. The heat index combines the effects of temperature and humidity to better describe what the human body feels. Experts agree that the heat index for Arizona will increase during the next 100 years, but much uncertainty exists around how much of an increase to expect. Current estimates range from an increase of 8° to 25°F (*41*). That means, for example, a July day in Phoenix that currently reaches a heat index of 110°F could possibly reach a heat index of 118° to 135°F.

Residents of urban areas are at greater risk of heatstroke and other heat-related causes of mortality because buildings and roads absorb heat during the day and release the heat during the night, keeping nighttime temperatures high, so bodies do not get a chance to cool off and recuperate before the next day's high temperatures (*15*). In Tucson, Arizona, the average temperature has increased by 3.6°F during the past century (*3*). This increase is thought to be largely due to the urban heat island effect (*42*).

The elderly are particularly vulnerable to severe heat-related illnesses and death for the following reasons:

- Impaired ability to disperse heat through the body's physiological mechanisms.
- Greater risk of having underlying diseases.
- Greater risk of taking medications that may contribute to heatstroke.
- More problems with mobility.
- Difficulty with temperature perception.

These factors all combine to put Arizona's 667,000 senior citizens at greater risk of suffering a heat-related illness or death (*15*). Other groups particularly vulnerable to heat stress include babies and young children, socially isolated persons, anyone with serious cardiac or respiratory problems, anyone with mobility or other conditions limiting their ability to care for themselves and regulate their fluid intake, and the poor (*15*). Heat stress is an especially deadly problem for Mexican nationals who attempt illegal border crossings in remote deserts during the summer months.

Health Effects from Worsening Air Quality

We're likely to see an upsurge of respiratory diseases, and worsened asthma episodes.

–JONATHAN SAMET, PULMONOLOGIST,
JOHNS HOPKINS BLOOMBERG SCHOOL OF PUBLIC HEALTH (*43*)

The climate change/air quality link

The link between air quality and climate change is complex. Some of the greenhouse gases that contribute to climate change are air pollutants with known negative health effects; others, like carbon dioxide, are not especially associated with negative health effects but are major contributors to global climate change. Climate change is expected to affect air quality in at least five different ways.

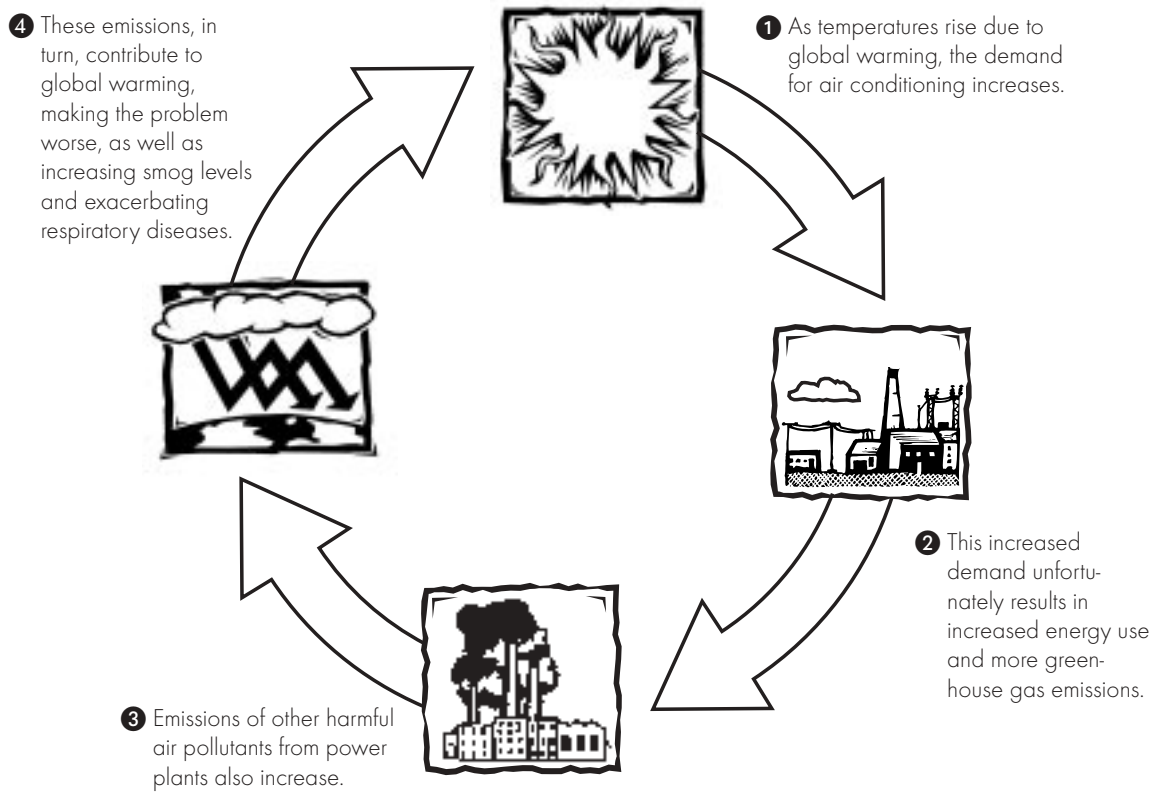
First, pollutant concentrations in the air of a specific location may be

affected by local and regional weather conditions. Still air could allow pollutants to accumulate; wind could blow pollutants to other areas. Climate change could have significant effects on local weather conditions, which then have significant effects on local air quality.

Second, concentrations of human-made pollutants could increase as a result of increased fossil-fuel use. As temperatures get warmer, air conditioners, for example, will be used more. More energy will be needed to power the air conditioners, and the production of energy from fossil fuels will release more greenhouse gases into the air contributing to further climate change and warmer temperatures (See figure 3). Air pollutants such as ground-level ozone, carbon monoxide, particulate matter, nitrogen oxides, and sulfur dioxides all have negative health effects. Climate change can increase the concentrations and compound the effects of these pollutants. Growth and development will require greater amounts of energy. If that energy comes from fossil fuels, emissions of pollutants will continue to increase.

Third, natural (nonhuman-made) sources of air pollutants also could increase. For example, higher temperatures cause forests and other sources of natural volatile organic compounds to emit greater amounts, which are not harmful by themselves, but combine with nitrogen oxides to form ground-level ozone. Desertification can expose more source regions for mineral dust.

FIGURE 3
Air Conditioning: The Vicious Cycle



Fourth, ground-level ozone is formed from nitrogen oxides and volatile organic compounds (both natural and human-made) in the presence of sunlight and heat. As temperatures increase, ground-level ozone formation increases. While ozone in the upper atmosphere, called stratospheric ozone, helps to protect us from the harmful effects of the sun's ultraviolet rays, ground-level ozone, called tropospheric ozone, is very harmful to breathe.

Lastly, airborne allergens, such as pollens, could change in concentration and distribution. Each of these pollutants is discussed in greater detail in the following section.

Health effects of air pollutants

Ozone

Ground-level ozone is the major component of what we commonly call smog, the most pervasive outdoor air pollutant in the U.S. Smog is at its worst on hot, sunny days, which are likely to become more numerous with global warming. Ozone is a toxic and irritating gas that, even in small amounts, can affect health. Ozone, or smog, is formed when nitrogen oxides and volatile organic compounds emitted from motor vehicles, power plants, refineries, factories, and even some natural sources like plants are heated by sunlight (*44*).

The health of Arizona's residents is threatened by smog, as evidenced by state air quality indexes. Maricopa County had 74 "Orange Alert" days from 1997 to 1999. An orange alert corresponds to an ozone level of 85–104 parts per billion (ppb) and means the air is unhealthy for sensitive groups (*45*). Sensitive groups include young children, citizens over 65 years of age, anyone with underlying respiratory problems and "responders." Approximately 5-10% of the general population is thought to be in the "responder" category, which is composed of anyone who is especially sensitive to the effects of ozone and is not in one of the other categories (*45*).

Exposure to elevated ozone levels can cause severe coughing, shortness of breath, pain when breathing, lung and eye irritation, and greater susceptibility to respiratory illnesses such as bronchitis and pneumonia (*46*). Even moderately exercising healthy adults can experience from 15% to more than 20% reduction in lung function from exposure to low levels of ozone over several hours (*46*). For the 40,000 children and 70,000 adults with asthma that live in Maricopa Country, ozone is of special concern (*45*). Numerous studies have shown that higher ozone levels cause more asthma attacks, increase the need for medication and medical treatment, and result in more hospital admissions and visits to emergency rooms for people with asthma (*47*). If warmer temperatures are coupled with the same or more sunny days, keeping ozone levels low may become more of a challenge.

Volatile organic Compounds (VOCs)

Another group of air pollutants consists of VOCs, which are generated by power plants, municipal waste combustors, motor vehicles, solvent use, and the chemical and food industries. VOCs include a variety of hazardous air toxins, including benzene, butanes, and toluene. VOCs in the atmosphere have two major health impacts: They are directly toxic and can combine with nitrogen

oxides to form ozone. These hazardous air pollutants are associated with cancer as well as adverse neurological, reproductive, and developmental effects (*48*). As temperatures increase, more VOCs are emitted when people fuel and operate motor vehicles (*16*). Some VOCs are emitted from natural sources like forests. Warmer temperatures lead to increased natural emissions as well. For example, natural emissions increase by two-fold with an increase of 10˚C temperature (*49*). Thus, climate change is expected to increase levels of both human-made and natural sources of VOCs, increasing ozone levels.

Nitrogen oxides

Like VOCs, nitrogen oxides have multiple roles in adversely affecting health: nitrogen dioxide can be directly toxic in the lungs and it also combines with VOCs to form ozone. In the lungs, nitrogen dioxide combines with water to form acids that damage the lung tissue (*50*). Nitrogen oxides also oxidize in the atmosphere to become nitric acid, a major component of acid rain (*16*). Higher temperatures accelerate this process, increasing the potential for acid rain with climate change (*16*). Nitrogen oxides also combine with sulfur dioxide to form particulates, discussed in more detail in the next section.

Sulfur dioxide and particulate matter

Sulfur dioxides, like nitrogen oxides, are oxidized in the atmosphere to become acid rain and can combine with nitrogen oxides to form fine particles, called particulate matter (*16*). Particulate matter can be emitted directly from the combustion of fossil fuels, industrial processes, and transportation; created by the combination of gases such as nitrogen oxides and sulfur dioxides; produced from mineral dust from roads, deserts, and washes; and formed from smoke from wildfires (*16*). Although Arizona has done a good job of reducing ozone levels, reducing levels of particulate matter has been more of a challenge. A plan to reduce particulate matter levels calls for Maricopa County to regulate excessive dust from commercial agricultural activities, construction and earthmoving projects, and unpaved roads and parking lots (*51*).

Several studies have documented that both the elderly and children had an increase in hospital admissions for respiratory and cardiac causes when concentrations of particulate matter increased (*52; 53–57*). One study conducted by a well-known group of researchers from Harvard discovered that long-term exposure to air pollution significantly increased the risk of death (*52*). Another group of Boston researchers discovered that particulate matter can trigger heart attacks in people who are obese, inactive, or have a history of heart problems. The risk for heart attack peaked two hours and again 24 hours after exposure to increased levels of fine particles, even though the levels were never above federal air quality standards (*58*).

Fine particles are especially dangerous for babies and young children. Children breathe 50% more air per pound of body weight than adults, thus

taking in more pollutants. One study found that infants living in cities with high levels of fine particles have a 26% increased risk for sudden infant death syndrome, and infants living in high pollution areas were 40% more likely to die of respiratory causes (*59*).

Pollen and natural allergens

Natural allergens such as pollens and fungal spores also contribute to air pollution and may increase with climate change. An increase in temperature and precipitation could lead to increased fungal growth, which could exacerbate asthma and other respiratory conditions (*60*). Some pollen-producing plants, such as birch trees, have been found to increase their pollen production and the allergen content of the pollen with increasing temperatures (*61*). Warmer temperatures may also lengthen the allergy season.

When we burn fossil fuels, the emissions produce health-damaging air pollution and major contributions to global climate change. By reducing the amounts of fossil fuels burned, we get immediate benefits by reducing air pollution and long-term benefits by slowing global climate change. A recent study published in *Environmental Health Perspectives* suggests that adopting

Environmental Issues on the U.S.-Mexico Border

The U.S.-Mexico border stretches for nearly 2000 miles, encompassing 10 U.S. and Mexican states including Arizona (*64*). This area has fallen victim to health problems linked to industrialization and greater border urbanization such as gastrointestinal infections, asthma, and tuberculosis (*65*). Some of the same industrial processes that contribute to global climate change also contaminate the air and water with dangerous toxins. Dwindling resources and a rise in population accentuate the threats imposed by industry. (*65*)

Political developments during the last few decades have fostered industrial growth along the border. The Border Industrial Program (1965) and more recently the North American Free Trade Agreement (NAFTA) (1992) have facilitated trade between the U.S. and Mexico, encouraging urbanization along the border. New factories, increased congestion, and a higher population density have made it more difficult for people to obtain clean water, sanitation, and other services. Currently 12% of the border population does not have access to potable water, and 30% does not receive wastewater treatment (*65*). Industrial, agricultural, and human wastes flow into rivers and present dangerous health risks. The New River of Arizona, a tributary of the Colorado River, harbors close to 30 viruses, including hepatitis A and polio (*65*). In addition, the higher volume of traffic threatens air quality, injecting toxins into the atmosphere. A study by the Arizona Department of Environmental Quality found fine particulate concentrations in Agua Prieta, a border town in Sonora, Mexico, to be the highest ever monitored, while the value for Douglas, Arizona, directly across the border, also exceeded the national average in the U.S. (*66*). These particles can cause respiratory damage and remain in the lungs for long periods of time (*66*).

The health risks that arise in this region are due in part to the difficulty in disease surveillance. The U.S. relies on a laboratory-based approach to monitoring disease. Mexico utilizes a more clinical approach, which is due in part to a lesser amount of laboratory equipment. The differing methods impede identification and treatment of cases. In addition, while Mexico and the U.S. have similar environmental regulations, these regulations are enforced much more rigorously in the U.S. (*65*). Because Mexican communities are often not capable of stricter enforcement, health hazards threaten people on both sides of the border.

Warmer temperatures and climate change may exacerbate the multitude of health risks that already exist in the border regions.

"readily available technologies to lessen fossil fuel emissions over the next two decades" in just four major cities (New York City, Santiago, Sao Paulo, and Mexico City) would prevent approximately 64,000 premature deaths, 65,000 chronic bronchitis cases, and 37 million person-days of work loss (*63*).

How Climate Change Could Affect Diseases Carried by Insects

Changing climate conditions also may affect human health through impacts on terrestrial and marine ecosystems.

—U.S. ENVIRONMENTAL PROTECTION AGENCY (*67*)

Insects, one of many "vectors," can carry a variety of diseases. These diseases are transmitted when the insect bites a human (or another animal), who is already infected with a disease. The insect itself then becomes infected with the disease, and when it bites another human, the disease may be passed from the insect to the human. Malaria and dengue fever are two good examples of vector-borne diseases. Although the mosquitoes that can carry these diseases already live in Arizona, and every year there are a few cases of imported dengue fever and malaria recorded in Arizona (*68*), the risk of these diseases becoming a big problem in Arizona is small (*62*).

Even though increasing temperatures and changes in precipitation could expand some mosquitoes' range and make some more efficient at transmitting these diseases, many other factors determine whether a disease like malaria will become a problem. For example, there were more than 50,000 confirmed cases of dengue between 1980 and 1996 recorded in three Mexican states that border the Rio Grande River. Directly on the other side of the river, however, fewer than 100 cases occurred in Texas during the same time period (*69*). Factors such as higher standards of living, less time spent outdoors in the daytime when the mosquitoes that carry dengue are more active, window and door screens, air conditioning, better mosquito control, and better public health infrastructure all combine to make large epidemics of these diseases unlikely even with rising temperatures (*18*).

St. Louis encephalitis is a mosquito-carried viral infection that can cause inflammation of the brain in a low percentage of persons infected. The type of mosquito that carries this infection in the Western U.S. breeds in stagnant pools (*70*). As climate change is likely to bring more flooding to the Southwest, this mosquito and the virus it carries may become more of a problem.

With climate change, vector-borne diseases such as malaria, dengue fever, and yellow fever could become epidemic in many other parts of the world. When this happens, the U.S., and Arizona particularly because of its proximity to Mexico, could expect an increase in imported cases (*71;72*). Continued monitoring and vigilance will be needed to ensure that these diseases, or a new disease like West Nile Virus, do not become a problem in Arizona.

Several infectious diseases are commonly found in Arizona and the Southwest. Plague, hantavirus pulmonary syndrome, and valley fever are three that are common to the Southwest and will be discussed further.

Plague is a disease cased by *Yersinia pestis*, a bacterium carried by fleas. This is a severe disease, sometimes claiming victims within days if not treated (*73*).

The disease is contracted by humans when they are exposed to the tissues of infected animals or when they are bitten by a flea that carries the bacterium (*74*). It is a difficult condition to diagnose due to the nonspecific nature of its symptoms, which include fever, diarrhea, and vomiting. Swelling of the lymph nodes sometimes also occurs, and is a more indicative symptom of bubonic plague (*75*). Once the diagnosis has been made, appropriate antibiotics can be used to cure the infection.

Most cases of plague in the U.S. have been reported in the Southwest, primarily in New Mexico, Arizona, Colorado, and California (*75*). In May of 2001, fleas in Flagstaff, Arizona, were determined to be carrying plague (*74*). Recently, the occurrence of plague has been linked to climate change. Scientists in New Mexico have found a definitive link between heavy precipitation and the plague. Rodent numbers tend to increase during periods of heavy rainfall due to increased vegetation. Larger rodent populations allow for the proliferation of fleas, increasing the likelihood that humans may be exposed to the bacteria (*73*).

The scientists found that roughly 60% of the plague cases between 1949 and 1996 occurred during years with a higher than average level of precipitation (*73*). Human factors such as crowding, behavior, sanitation, and land use practices also influence the emergence of plague (*73*). With climate change projected to increase the amount of precipitation falling on Arizona, plague may become more common.

The Problem With Pesticides

With milder winters and the possibility of greater precipitation and flooding, some residents of Arizona might be tempted to use more pesticides to reduce insect numbers. Some of the pesticides commonly in use include organophosphates (e.g., malathion and fenthion) and pyrethroids (e.g., permethrin and resmethrin) (*81*). All of these insecticides can cause harm to humans and the environment and should be used only by professionals during times of extreme need. In 1999, there were almost 60,000 pesticide-related incidents reported to poison control centers nationally; almost half of these were in children less than six years old (*82*).

Pesticides can be absorbed into a person's body by inhalation, ingestion, and skin penetration (*83*). Malathion does not last in the environment as long as other organophosphates and is therefore thought to be "safe" by some, but in 1975, malathion caused five deaths and 2,800 poisonings in Pakistan during spraying for malaria control (*83*). Symptoms can range from headache, nausea, and dizziness to loss of consciousness, convulsions, and death (*83*).

Pyrethroids are less toxic to humans and the environment than malathion and other organophosphates, but all pesticides are inherently toxic and therefore are not risk-free to humans (*83*). Signs and symptoms of mild to moderate poisoning include dizziness, headache, nausea, anorexia, and fatigue. Severe poisoning results in seizures, and evidence is mounting for an association between pesticide exposure and Parkinson's disease (*84*). Many household pesticide sprays and pet care products contain these compounds (*83*).

In addition to humans, birds, fish and other aquatic animals, and bees and other beneficial insects are at risk from pesticide poisoning. Pyrethroids are generally safer for humans and the environment, but are especially deadly for aquatic animals such as fish. In Arizona during the year 2000, a total of 2,393,305 acres were treated with over 650,000 gallons of liquid pesticides and 664,362 acres were treated with more than 1.5 million pounds of dry pesticides (*85*). Pesticides can be harmful to humans, wildlife, and natural ecosystems and should only be used as a last resort, by professionals, and only in limited quantities when public health is threatened. Ecosystems that are already stressed by pesticide poisoning and other forms of pollution may be more readily destroyed by the additional stress of climate change.

Hantavirus has affected 260 people in the U.S. since it was first identified here in 1993 (*2*). The virus causes Hantavirus Pulmonary Syndrome (HPS), a condition with symptoms similar to that of the flu, including fever, muscle aches, and respiratory distress. These symptoms last for three to five days, developing then into coughing and shortness of breath that require hospitalization and ventilation in most cases (*2*). HPS initially had a fatality rate close to 50%, all the more alarming because of the rapid progression of the condition (*2; 76*).

The first major outbreak of the virus occurred in 1993 in the Four Corners region of the Southwestern U.S. A young Navajo woman and her fiancé contracted the virus and died within days of each other (*2*). Another 80 cases of HPS were reported that year. Intense research associated HPS with a viral agent carried by deer mice. Humans contract the virus by coming into contact with infected animals' saliva or wastes, or inhaling contaminated dust from these substances when people disturb mouse habitat or infested areas (*2*).

The outbreak in 1993 is linked to the El Niño event that had occurred the previous year. El Niño is climatic phenomena that brings intense rainfall to the Southern U.S., a weakening of trade winds, and warming of the surface layers of the Pacific Ocean (*2*). It is a cyclical event, occurring at intervals ranging between two and seven years (*2*). In 1992, vegetation flourished in the Four Corners region as a result of the heavy rainfall. Consequently rodent populations swelled, reaching a population 10 to 15 times their usual level (*2*). The intense rainfall of 1992 and winter of 1993 was followed by a drought in 1993, which drove rodents such as the deer mouse to seek food from alternate sources (*77*). The result was that many rodents moved into areas occupied by people, increasing the likelihood of human exposure to the virus (*77*).

Climate change is thus intimately tied to the emergence and persistence of the hantavirus. Rainfall appears to be an important variable affecting the habitats and food sources of disease carriers, thus increasing the risk of infectious disease in humans.

Valley fever is a disease caused by a fungus. The medical name for this is coccidioidomycosis, more commonly known as "cocci." The fungus grows in the soil, across Southern Arizona and the dry areas of Southern California and New Mexico. It has been detected in and around the Phoenix and Tucson metropolitan areas (*2*). Valley fever is sensitive to temperature and moisture; therefore, changes in the climate are

How Can Insects Be Controlled?

If pesticides are not used, how can the mosquitoes and the diseases they carry be controlled? In a healthy ecosystem, one that has not been poisoned by pesticides, there are many mosquito predators that help to keep the mosquito population (and other insect pests) under control. Fish, frogs and other amphibians, beneficial insects such as dragonflies, bats, and many birds have voracious appetites for mosquitoes and other insects. One bat can eat 3,000 mosquitoes in a single night (*86*). Bat populations have declined dramatically and experts suspect this is from a combination of factors including poisoning from pesticides, habitat loss, and destruction of roosting sites (*86*).

Regular "housekeeping" measures can also greatly reduce mosquito populations. Keeping urban drains clean and emptying containers of standing water can help to eliminate mosquito breeding grounds. Backyard containers such as tires, buckets, coolers, cans, or anything that will hold even a few drops of water can be a significant source of mosquito breeding in populated areas. These can be removed or stored under cover to prevent them from collecting rain water. Naturally occurring bacteria, which kill mosquito larvae but harm no other living creatures, can be used in ponds to keep mosquito populations in check. People can also wear protective clothing and use insect repellents to protect against mosquito bites.

likely to affect the growth and dissemination of this disease. After an adequate rainfall, the moist soil provides ideal growing conditions for the fungus. After the rain stops and the soil dries out, then the fungus can be inhaled, in the form of dust, into the lungs of a person, where it causes infection (*2*).

About 60% of people who become infected with valley fever have no symptoms or only mild, flu-like symptoms. Only 1% of those infected get severe disease where the fungus spreads beyond the lungs and can infect the blood, other organs, and the brain. Those at greatest risk of developing the more severe form of the disease are persons older than 65 years of age, anyone whose immune system does not work well (such as people with AIDS and people who take medication that suppresses their immune system because of asthma or organ transplant, for example) (*2*). Seniors older than 65 years are better than five times more likely to contract the disease than a 20-year-old (*78*).

About 40% of the people who live in Maricopa, Pima, and Pinal Counties have been exposed to valley fever at some time in the past and are now immune. The greatest risk may be for senior citizens and others who travel from other areas of the country to visit Arizona. If they contract a serious case of valley fever and then return home, it may take longer for their physicians to make the correct diagnosis since valley fever is extremely rare in other parts of the country and the world (*2*).

The number of reported cases of valley fever between 1980 and 1989 remained stable at about 255 per year. Between 1990 and 1995, however, the number more than doubled to 623 cases per year (*78*). If climate change increases the occurrences of heavy rainfall and droughts in Arizona, as many experts project is likely, valley fever may become more of a problem.

Although disease surveillance programs and health care infrastructure reduce the risk of epidemics from these diseases in the U.S., the risk may increase as the climate warms and changes in precipitation and weather patterns occur (*79*). It would be prudent to continue to improve public health infrastructure, surveillance programs, and research into how climate change affects disease (*80*).

How Global Warming Could Change Arizona's Agriculture and Forests

Much of Arizona's mystique is rooted in the wide-open spaces utilized by the ranching and forestry sectors. Residents and visitors alike have a strong sense of connection with these spaces—and their health. These places provide the economic underpinnings for much of the State's general economy (it's a special place to live) and tourism in particular (it's a special place to visit). Thus, impacts in these sectors may extend well beyond those cited below causing unpredictable results statewide.

—WILSON W. ORR, DIRECTOR, NASA PROGRAM, PRESCOTT COLLEGE, ARIZONA (*28*)

How Climate Change Could Impact Agriculture

Warmer temperatures and changes in precipitation are likely to have significant effects on agriculture in Arizona. Whether yields ultimately increase or decrease will depend on many factors, including water availability,

changes in climate variability, and the ability and willingness of farmers to adapt to a changing environment. Warmer temperatures and less soil moisture from greater evaporation may increase the need for irrigation. Already the state uses 81% of its water for agriculture (*2*). As water demands increase from population growth, development, and climate change, water for irrigation may become more scarce and more expensive (*2*). Wheat yields may decrease by as much as 70% as temperatures rise beyond the tolerance levels of the crop, while cotton yields could decrease by 5% to 11% (*3*).

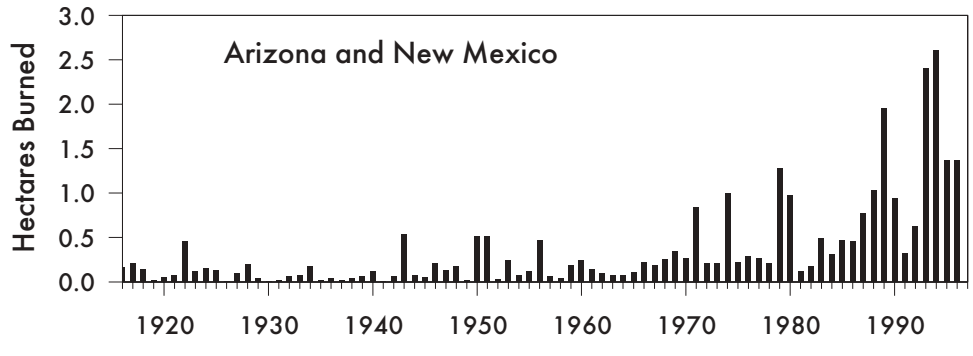
Projected Impact on Ranching

Ranching has been part of Arizona's history for more than a century, playing a central role in determining land-use patterns. Although ranching contributes less to the state's economy than it used to, more than two-thirds of all the land in Arizona is still used as rangeland (*2*). With irrigated pasture practically nonexistent, ranching is especially sensitive to variability in temperature and precipitation. Adequate rainfall is critical for the growth of vegetation for grazing as well as to fill small tanks and reservoirs that provide drinking water for the cattle. Climate change is projected to cause changes in precipitation amounts and timing, which could result in droughts as well as floods. If summer temperatures rise significantly, and if conditions become drier, the ranching industry may suffer.

Projected Impact on Forests

Global warming also could alter Arizona's forests by influencing biological diversity and forest growth (*3*). Changes in precipitation, higher temperatures, and extreme weather events could wreak havoc on the state's timber stands. With drier conditions, as much as 30% of the current forested area could be replaced by grasslands and pasture (*3*). Forested areas could also suffer more frequent and severe insect outbreaks with milder winters. Following such an outbreak, there is even greater risk of wildfire in the dead fuel left behind (*3*).

FIGURE 4
Area burned annually by wildfire



Source: Swetnam and Betancourt, 1998

Hotter, drier weather could increase the frequency and intensity of forest and brush fires. Multiple factors help determine which areas are most susceptible to wildfires including fire suppression policies, land-use patterns, and previous periods of wetter weather contributing to build-up of undergrowth (*2*).

Forest fires can affect both the health of the public and the health of the ecosystem. Fires can have a devastating effect on current timber production as well as future production by killing young trees (*88*). Important wildlife habitat can be lost and homes and businesses destroyed. From a human health standpoint, fires may cause injuries and fatalities to firefighters and nearby residents. Seventeen wildfire firefighters were killed in the line of duty between 1990 and 1998 in Arizona and New Mexico. Smoke, which can cover a wide area, may cause respiratory difficulty and exacerbate existing respiratory conditions such as asthma and chronic obstructive pulmonary disease (*89*). Arizona and New Mexico have experienced increases in the amount of area burned by wildfires since 1980 (*2*).

Conclusion

This report has reviewed the threats to human health, particularly in Arizona, that could result from climate change. The U.S. has a greater ability to adapt to, and prepare for, these changes than other countries due to our health care infrastructure and strong economy. However, the potential health effects of climate change are serious and demand attention. Increased levels of heat, extreme weather events, vector-borne and water-borne diseases, air pollution, and compromised water supplies affect all Americans. The poor, elderly, young, and anyone whose immune system does not work well will be the hardest hit.

Many of the effects of climate change will be compounded by other environmental stresses such as pollution, increasing population, over-harvesting of natural resources, and habitat loss. Thus, improving environmental practices such as decreasing discharges of pollutants into the soil, air, and water may help lessen the harmful effects of climate change on fragile ecosystems.

We must act now to slow and eventually reverse climate change by significantly reducing fossil fuel consumption and greenhouse gas emissions. In addition, we need to invest in strategies that will help us to prepare for what may come. It is essential that we formulate and implement plans to improve our public health infrastructure, including disease surveillance and emergency response capabilities. Continued research is, indeed, needed to better understand the relationships among climate change, the health of ecosystems, and the health of the public. However, we can make better use of tools and information based on what we know today about the links between climate and health toward the same aim of improved public health services.

What You Can Do

What can individual Arizonans do to stabilize the climate or reverse climate change? The number one priority is to lower the use of fossil fuels. Local, state, and federal government representatives should be strongly encouraged to support smart energy policies and the development and use of new technologies to reduce fossil fuel consumption and to reduce greenhouse gas emissions.

As an added benefit, the energy conservation techniques recommended here to combat global warming are very similar to those desperately needed to cut air pollution. Reducing greenhouse gas emissions through sound energy policies is a win-win scenario because we will not only prevent the associated health effects of global climate change but also reduce the current threats to health from air pollution. In addition, these policies can increase our standard of living while reducing economic costs. Our quality of life in the future depends upon the actions we take today.

There is a lot you can do in Arizona, starting now, to combat global climate change and bring down consumption of fossil fuels.

1 Contact your local representatives, government officials, and mayor. Find out if your city or county has a plan to reduce carbon dioxide emissions and, if not, encourage them to consider it. Demand user-friendly public transportation.

2 Contact your state representatives and governor. Information regarding your state representatives can be found in the blue pages of your phone book. Encourage them to develop and implement state carbon dioxide emission reduction plans and to create incentives for citizens and businesses to make more efficient energy choices. For example, provide tax incentives for families that purchase newer cars with better gas mileage.

3 Contact your members of Congress and President Bush. Encourage them to adopt a balanced energy policy that promotes efficiency and use of clean, renewable sources of power. Specifically ask them to:

- Fund research and implementation of new next-generation energy technologies such as solar and wind power. This will not only give the oil supply we currently have a longer life, but will also reduce the unhealthy pollution associated with both the burning of fossil fuels and the recovery of fossil fuels.
- Clean up power plants. Require that power plants that were grandfathered under the Clean Air Act be cleaned up or shut down now.
- Support "Four-Pollutant" bills regulating carbon dioxide, nitrogen oxides, sulfur dioxide, and mercury.
- Support an increase in Corporate Average Fuel Economy (CAFE) standards, or minimum miles per gallon standards, for cars, sport utility vehicles, and light trucks.
- Support international agreements to lower global carbon emissions, and take responsibility for our disproportionate contribution of greenhouse gas emissions to the world's climate change problem.

Contact information for your members of Congress and the President can be found in the blue pages of your phone book, or on the following websites: *www.senate.gov* and *www.house.gov*

4 Get your own house and business office in order. Use energy-efficient light bulbs such as compact fluorescents. Install a solar system to help provide your hot water (carbon dioxide reduction: 720 pounds per year). Recycle all of your waste newsprint, cardboard, office paper, glass, plastic, and metal (carbon dioxide reduction: 2,480 pounds per year). Lower your thermostat in winter and raise it in summer, or use a thermostat that shuts off when you are not home, thereby reducing the demand for electricity and the burning of fossil fuels. When purchasing or remodeling a home, request efficient insulation, and energy efficient appliances, refrigerators, and water heaters.

Be conscious of how your actions create carbon emissions. Our love for automobiles contributes 30% of U.S. greenhouse gas emissions. More than four million cars are registered in Arizona. Do your part by carpooling and leaving your car at home as much as possible. When you do have to drive, keep your car's tires properly inflated at all times. This ensures the maximum efficiency of your car. If your car's tires are under-inflated by just four pounds, it could cost up to a half-mile per gallon of gasoline. When purchasing a new car, buy the most fuel-efficient vehicle you can afford. At a web site launched by the EPA and the U.S. Department of Energy *(http://www.fueleconomy.gov),* you can do a side-by-side comparison and select the right car for your needs.

5 Urge the businesses you patronize to become energy-efficient. U.S. businesses spend about $100 billion on energy each year to operate commercial and industrial buildings. By using energy efficient products and procedures, organizations could reduce their energy use by 35%, or $35 billion nationally. There are now numerous programs in place to help businesses change their energy use strategies and save money at the same time. Put your favorite businesses in touch with the Energy Star Buildings program (1-888-STAR-YES, *http://www.epa.gov/greenlights*) and Climate Wise program (1-800-459-WISE, *http://www.epa.gov/climatewise).*

What Can Arizonans do to Reduce the Negative Effects of Climate Change on Human Health?

Urge your members of Congress and State agencies to apply available technology developed in the space program and the U. S. Global Change Research Program toward public health strategies. This would include satellite monitoring of environmental conditions conducive for hantavirus, encephalitis, dengue fever, and valley fever. It would also include alerts by the National Weather Service for climate conditions in the months ahead that are favorable for mosquito infestation, dust storms, and floods.

Encourage your elected representatives to support research that improves understanding of the links between climate variability and human health. This would include studies of the range of vectors under monthly to seasonal to interannual climate variability. It would also include studies of the effects of climate on the region for valley fever spores, the mechanisms for transport of wind-blown dust, and the potential for disease to be imported by aerosols and dust from places as distant as Asia.

6 Work with local groups and chapters of national organizations to promote awareness of global climate change and related issues in Arizona. These include:

American Fisheries Society, Arizona/ New Mexico Chapter (602-981-9400 x213)

American Lung Association of Arizona (602-258-7505)

Arizona State Parks (602-542-4174)

Arizona Wildlife Federation (480-644-1499)

Environmental Fund for Arizona (602-256-7728)

Food Products Quality Assurance (Agriculture) (602-542-0869)

Indian Health Service
Phoenix Area (602-364-5039)
Tucson Area (520-295-2405)

Keep America Beautiful, Arizona Affiliate (480-615-7200)

The Nature Conservancy of Arizona
Phoenix Center (602-712-0048)
Tucson Center (520-622-3861)
Prescott Center (928-717-2843)
Northern Arizona Center (928-774-8892)

Sierra Club, Grand Canyon Chapter (602-253-8633)

U.S. Public Interest Research Group (202-546-9707)

Where Physicians for Social Responsibility (PSR) Stands

Physicians for Social Responsibility (PSR), the active conscience of American medicine, uses its members' expertise and professional leadership, influence within the medical and other communities, and strong links to policy makers to address this century's greatest threats to human welfare and survival.

While we recognize that uncertainties exist in the measurement of global climate change—just as all scientific measurement is uncertain—we are moved to action for several compelling reasons. First, the overwhelming consensus among scientists is that Earth's temperature is increasing and weather patterns are changing in ways potentially harmful to human health. This fact is overlooked in statements funded by the energy industry that attempt to minimize the severity of global climate change. Second, just like businesses, governments, and responsible individuals, PSR feels the need to act decisively to protect the public health and welfare.

We cannot say exactly when to expect a noticeable increase in floods, or in deaths from asthma among people living in smog-congested cities. No one can. But as Surgeon General Luther Terry stated in his 1962 report on motor vehicles and air pollution, the need for further research should not stop us from taking "all practicable steps to minimize" the hazard. We are certain that fossil fuels play a role in global climate change, one step that we can control. For the sake of our own well-being, and that of future generations, we need to act now.

PSR is working to create a world free of global environmental pollution, nuclear weapons, and gun violence. PSR is an organization in official relations with the World Health Organization. In 1985, PSR shared the Nobel Peace Prize with the International Physicians for the Prevention of Nuclear War.

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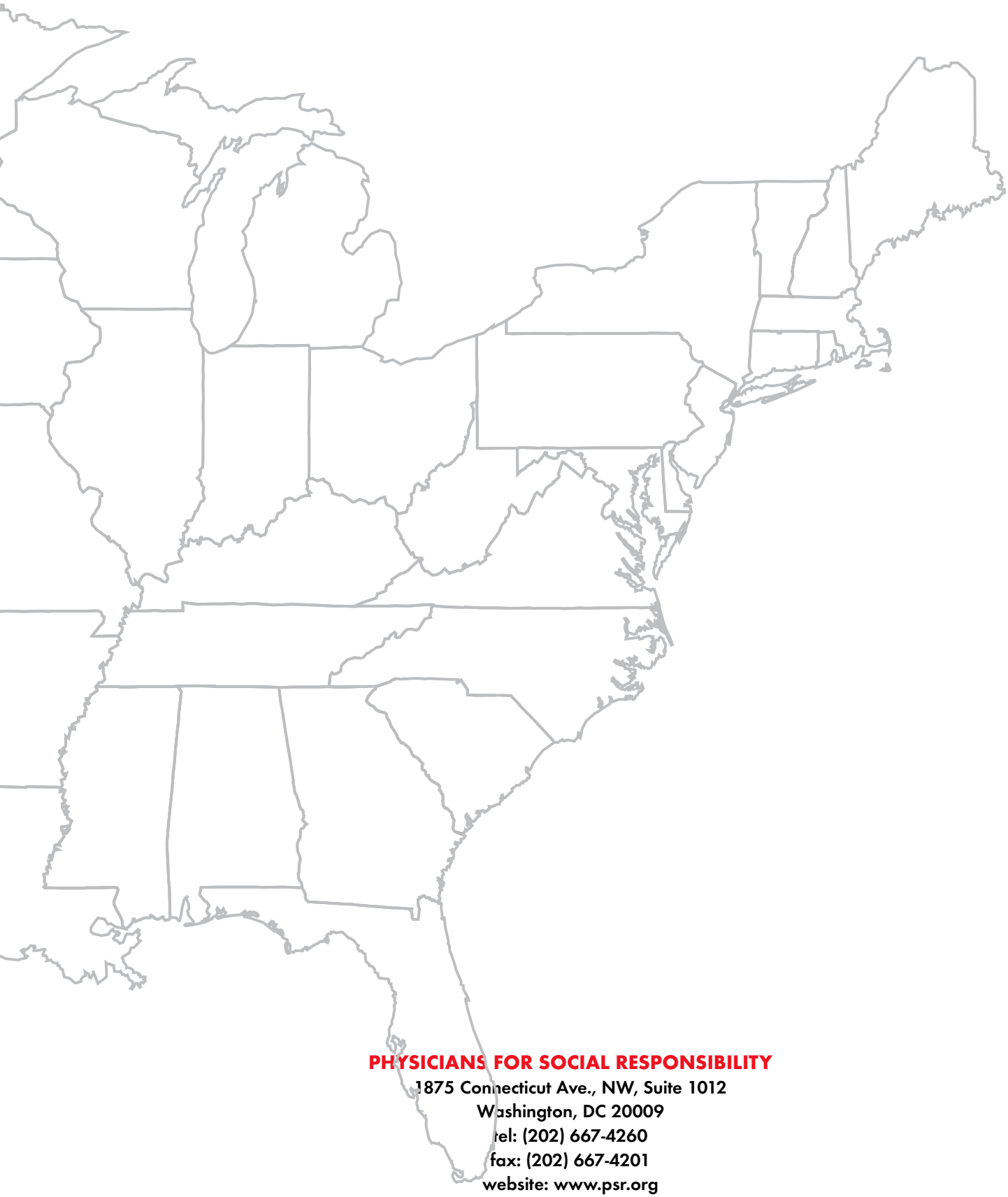

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