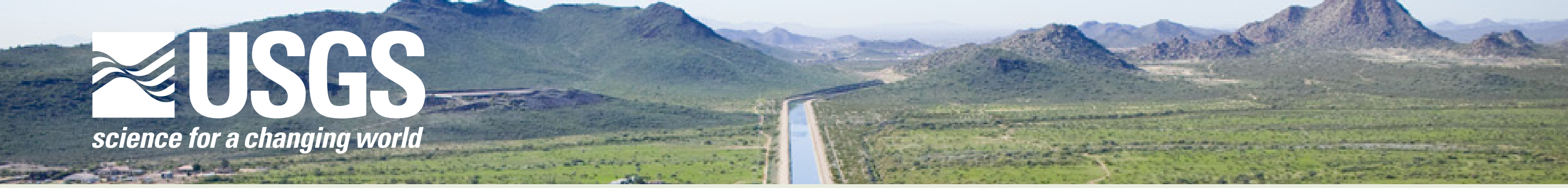

National Research Program

Water Security—National and Global Issues

"Water Security is the protection of adequate water supplies for food, fiber, industrial, and residential needs for expanding populations, which requires maximizing water-use efficiency, developing new supplies, and protecting water reserves in event of scarcity due to natural, [manmade], or technological hazards" (Tindall and Campbell, in press).

Potable or clean freshwater availability is crucial to life and economic, environmental, and social systems. The amount of freshwater is finite and makes up approximately 2.5 percent of all water on the Earth (fig. 1). Freshwater supplies are small and randomly distributed, so water resources can become points of conflict. Freshwater availability depends upon precipitation patterns, changing climate, and whether the source of consumed water comes directly from desalination, precipitation, or surface and(or) groundwater. At local to National levels, difficulties in securing potable water sources increase with growing populations and economies. Available water improves living standards and drives urbanization, which increases average water consumption per capita.

Global population tripled during the 20th century and demand for water increased ninefold (Hinrichsen and others, 1997).

Commonly, disruptions in sustainable supplies and distribution of potable water and conflicts over water resources become major security issues for Government officials. Disruptions are often influenced by land use, human population, use patterns, technological advances, environmental impacts, management processes and decisions, transnational boundaries, and so forth.

Water security is a critical factor in Government planning. However, the decisions of water-security professionals are complicated by an uneven global distribution of freshwater (fig. 1), and local to regional freshwater deficits are caused when extraction exceeds available recharge—sustainability. When water supply falls below 1,700 m^3 per person per year (about 123 gallons per person per day), which is considered minimum need (United Nations Development Programme, 2006), the source of supply is considered stressed. The demand for water grows fastest in areas of the world experiencing freshwater scarcity. Adding further stress to quality of life issues are inadequate sanitary living conditions and contaminated water, which can result in cancer, liver and kidney damage or failure, nervous system disorders, damage to the immune system, birth defects, and water-borne diseases (United Nations, 2010). Additionally, certain naturally occurring water-borne chemicals are suspect carcinogens, such as arsenic in Bangladesh and West Bengal, India, where problems associated with high arsenic levels arose due to switching from surface- to groundwater sources. Generally, areas of high-density populations stress water resources. Adding to this problem, population is increasing in areas where natural hazards—earthquakes, hurricanes, floods, and droughts—are most severe (Hinrichsen and others, 1997). Such natural hazards can disrupt potable water distribution and destabilize population centers.

Water stress affects 44 percent of the world's population. The United Nations Environment Programme (1999) projects that by 2025 , global freshwater stress owing to increasing population on water use will increase significantly, especially in northern Africa, Eurasia, the Middle East, and even the United States, and by 2050, nearly 5 billion people will be affected by freshwater scarcity.

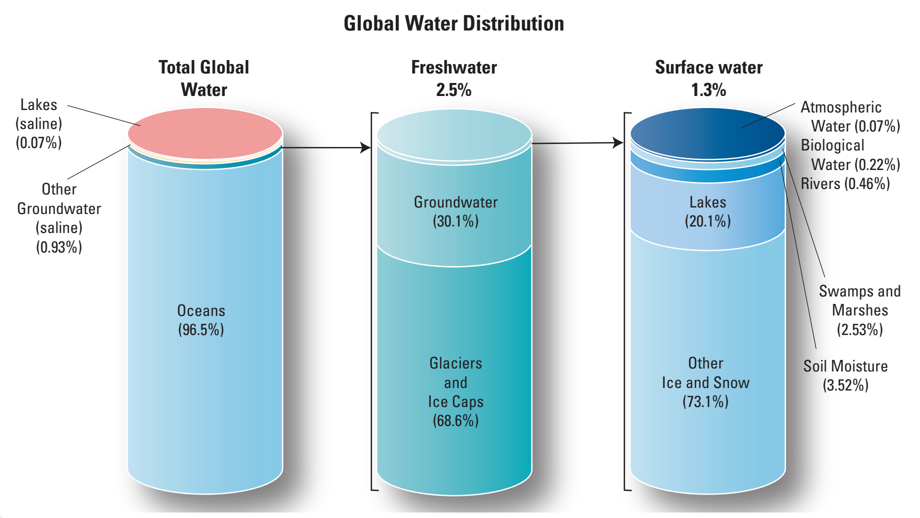

Figure 1. Data taken from United Nations Educational, Scientific, and Cultural Organization, 2006.

Global Security: The peaceful intercourse of all nations for a parallel advancement of individual to societal well being and quality of life, and the actions taken by nations to guarantee shared sustainability, safety, and continuity that challenges mutual security. Threats and hazards to Global Security evolve from Man-made (Anthropogenic), Natural, and Technological [causes] and might include such actions as disruption of natural or commodity resources; failed or failing states; pandemics (swine flu or others); climate change; mass population migrations; civil unrest; and other unsuspected or surprising disturbances to national peace (TinMore Institute, 2010).

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Effective management of "virtual water" (water used in the production of a good or service) likely will become key to water sustainability and distribution. For example, ethanol produced from corn requires nearly 2,500 liters of water to produce one kilogram (300 gal per lb) of ethanol (Brown, 2008). In the United States, corn commonly is grown in areas experiencing a 20 to 50 percent growth in population (Brown, 2008). This combination could change irrigation or crop management practices but still significantly stress water resources. Similar trends occur globally.

Urbanization in the metropolitan Denver area requires a water withdrawal of about 33.5 inches per year from the Dawson aquifer, while the natural recharge rate is only 0.5 inches per year (Moore and others, 2004): a prime example of water-resource stress and a potable-water extraction and recharge deficiency.

World

Presently, millions of people lack access to adequate potable water supplies, and Government officials are unable to appropriately manage and assess water resources owing to insufficient information and expertise. The United Nations (2003) states that approximately one billion people are deprived of potable water due to mismanagement and depletion of water resources (fig. 2). If people are deprived of water, it is likely that water needed for food production is limited, if not absent, leading to increased water-resource conflicts and negative effects on security (Tindall, 2008). Without proper prioritization of water use, production of sufficient food to meet the demands of global population growth could be more challenging. Unfortunately, unsustainable potable water supplies are becoming a global trend, especially in large urbanized areas, often leading to water-use conflicts. Water shortages and increasing conflicts between supplies, distribution, and use and management signify the need to develop and implement processes for mitigating water-security issues.

United States

Because most future population growth in the United States is projected to be in water-stressed areas, demand (fig. 3) and distribution could remain a problem. Irrigation requires about 34 percent of U.S. water supplies (table 1). Other uses include thermoelectric powerplant cooling, which returns water back to the environment (Hutson and others, 2004).

Water-security strategies depend upon appropriately developed and implemented water-management plans and practices that are best developed in concert. Also, water-management practices necessary for water security include plans for potable-water sustainability, proper wastewater- and waste-disposal methods, distribution, water-use priorities, and water-resource development.

Developing Countries

Water-management practices designed to improve water supplies can be restricted by disparate water distribution, poor infrastructure, insufficient water quantity and quality, and excessive cost issues. Nevertheless, developing appropriate practices is vital if public health and quality of life are to improve while reducing security, economic, and political concerns (Tindall and Campbell, 2009; United Nations, 2003). In this regard, local and national water-security strategies can improve foreign relations as related to transboundary water disputes and nationalist, minority, and ethnic aspirations of a State.

Development and mitigation of water-security processes follow the Water Threats and Hazards Triad (WTHT) and represent common types of hazards affecting water supply and sustainability (table 2). As an example, an occurrence of a WTHT component against critical water infrastructures could prove disastrous to water supply and sustainability from a local to regional or national level (Tindall and Campbell, 2009). From a Homeland Security perspective, an evaluation of these three primary hazards reveals risks and vulnerabilities to the population at large: a net

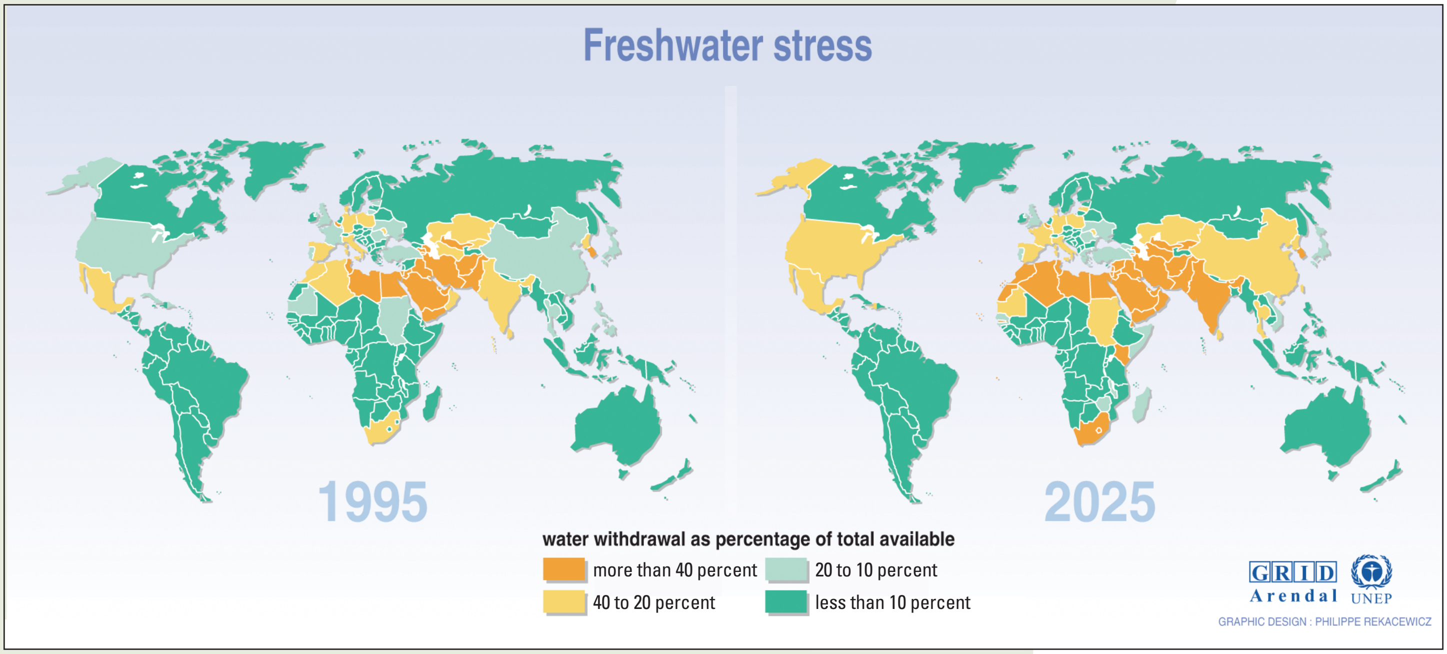

Figure 2. Global freshwater stress (Source: United Nations Environment Programme, 1999).

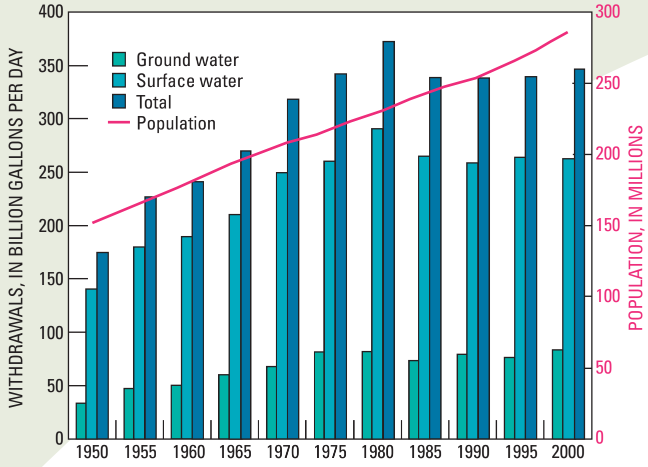

Figure 3. Total U.S. water withdrawals since 1950 (Source: Hutson and others, 2004). Since 1950, per capita water use has declined.

assessment—"all hazards" approach—in addressing water security and protecting finite potable-water resources against various threats. The WTHT components are a pressing concern for public (Government) and private (corporate) officials.

Table 1. Freshwater use in the United States (Hutson and others, 2004).

Sector	Water use (billion cubic meters/day)
Industry	291 (76.61 trillion gallons/day)
Domestic	35.8 (9.45 trillion gallons/day)
Agriculture	120.9 (34.94 trillion gallons/day)
Total	563.7* (408 billion gallons/day)

*Includes other sources not listed.

According to the FBI, prior to the 9/11 terrorist attacks Mohamed Atta scouted Hoover Dam as a potential target (Tamm, 2004).

Terrorism—A Manmade Hazard

Manmade threats currently are a major concern. Officials dedicate much time and effort to prevent attacks on exposed infrastructure. For example, an attack on Hoover Dam could affect water and power availability in the Western United States and denotes why the U.S. Intelligence Community is concerned about these types of possibilities.

Enhanced technology complications, such as operations controlled by Supervisory Control and Data Acquisition (SCADA) valves that can be operated over the Internet, make water systems more vulnerable. Similar types of controls/valves are used in the electrical power grid and nuclear plants, where nuclear power generation requires water for cooling.

Natural Threats to Water Security

Hurricanes—Hurricane Katrina (2005) caused large loss of life, ruptured levees, and led to serious water-quality consequences (Palser, 2007).

Earthquakes—Scientists predict a major earthquake will hit Los Angeles (Fialko, 2006), an event that could sever the Colorado River Aqueduct, and(or) the California Aqueduct supplying water from Lake Mead in Nevada. These two distribution systems supply potable water to 18 million residents within metropolitan Los Angeles.

Wildfires—The short- and long-term effects of wildfires are serious considerations for any water-security program. This may be particularly true in the United States after 100 years of fire suppression, where large fires have burned about 6,000,000 acres in drier years (National Interagency Fire Center, 2009). The Hayman fire in Colorado in 2002, the largest fire in Colorado's history (138,000 acres), seriously degraded the water quality of Cheeseman and Strontia Springs Reservoirs—primary water sources for metropolitan Denver—requiring $8 million over 4 years to remove debris, replace culverts, build sediment dams, and seed slopes for restoration (Robichaud and others, 2003). Further, deforestation of hillsides by fire promotes flooding and debris flow during wet periods that affect water quality.

Contaminants—Heavy rains and flooding could create particularly severe water contamination problems that can be fatal. *E-coli* infiltrated water pipes following torrential rains in Walkterton, Ontario, Canada; 7 people died and more than 2,300 became seriously ill after contracting food poisoning from the bacteria (Vicente and Christoffersen, 2006). In 1993, dozens died and an estimated 400,000 developed chronic illnesses due to the parasite *Cryptosporidium*, which contaminated the water supply of Milwaukee, Wisconsin, after heavy rainfall (Corso and others, 2003).

Climate Change—Water-security strategies need also to consider events related to extreme drought. In 1995, a severe drought extended from central, eastern, and western Texas and New Mexico into Arizona and parts of California, Nevada, Utah, Colorado, Oklahoma, and Kansas. Water restrictions increased in many cities, forcing residents to cut usage about 25 percent; winter wheat conditions in 19 States were poor; wind and insect damage significantly affected crops; a shortage of hay throughout the region reached disastrous proportions, forcing ranchers to sell cattle at the lowest prices in 10 years; and agricultural losses for cotton, wheat, feed grains, cattle, and corn and agriculturally related industries such as harvesting, trucking, and food processing in Texas alone reached $5 billion (Wilhite and Vanyarkho, 1999). Reduced supplies of irrigation water led to decreased vegetable production with related job and income losses; food prices increased as much as 22 percent in response to the lower production levels for milk, meat, produce, and other foodstuffs; and prices for gasoline, diesel, and liquefied petroleum rose 15 percent above previous levels. Fires raged throughout the region and in Colorado alone burned 262,009 hectares (647,440 acres). Total regional drought effects were estimated at $10–15 billion, although it is difficult to quantify many social and environmental impacts (Wilhite and Vanyarkho, 1999).

Table 2. The Water Threats and Hazards Triad (Tindall and Campbell, 2009): The most common hazards affecting water security, supply, and sustainability.

Manmade (Anthropogenic)	Natural	Technological
Terrorism*	Climate change	Infrastructure failure
War and civil unrest	Hurricanes	
Population growth	Earthquakes	Hazardous chemicals and biological material events
Human error and poor assessment and resource allocation	Tsunamis	
	Droughts	Malfunctions of information technology and equipment
	Floods	
	Wildfires	
	Landslides	
	Volcanoes	

*Includes foreign and domestic cyber and industrial sabotage, particularly against/including Supervisory Control and Data Acquisition (SCADA) control systems.

To strengthen water-security strategies and processes, a dual strategy is needed that will both monitor infrastructure and supplies and assess, understand, and manage water resources to avoid the threat of water-related security and conflict concerns. Also, effective monitoring of water scarcity, energy, and environmental degradation can aid water managers. In the Homeland Security arena, intelligence estimates also can factor water security into threat assessments and consider the need for creating specialized water-security data-collection platforms.

Technological Hazards

Technological hazards include, but are not limited to, biohazards and hazardous materials incidents and nuclear powerplant failures. Generally, little or no warning precedes these incidents. Victims may not know they have been affected until years later. For example, health problems caused by hidden toxic waste sites—Love Canal near Niagara Falls, New York—surfaced years after initial exposure (Heath, 1984). Perhaps the most well known example of a technological hazard is the Chernobyl nuclear reactor disaster, April 1986, in the Ukraine (International Nuclear Safety Advisory Group, 1992).

Hazards Interdependence

Understanding the complex interdependency of water with other life-support systems (critical infrastructures) is important. Certain types of energy generation are dependent on water; for example, Hoover Dam in the United States, Bhakra Nangal Dam in India, and nuclear powerplants.

International agencies such as the World Bank are well aware of the seriousness of water-security issues. Since ancient times, limiting access to water has been used as a weapon through the destruction of water resources and distribution facilities (Young, 2006). Water-use and actual or perceived ownership conflicts create social and political disorder and serious security risks to a region or a country, and international law has proven inadequate in defending the equal use of shared water supplies. Such conflicts can become zero-sum disputes involving cultural, tribal, religious, and regional and(or) transnational victims (Tindall and Campbell, 2009).

Water Security and USGS Activities

U.S. Agencies, such as the Department of Energy, Department of Defense, Federal Bureau of Investigation, Environmental Protection Agency (USEPA), and Department of Homeland Security, understand and acknowledge the importance of water security and the results of neglect to the Nation and individual States. These agencies link water security to critical infrastructure protection (CIP) and intelligence gathering capabilities (fig. 4) to develop a security strategy for water and other resources. In short, they merge the intelligence cycle (typified by the Human Intelligence [HUMINT] Cycle—upper right fig. 4) with water-resources data and information (provided by such agencies as the USGS), energy, and other fixed assets of critical infrastructure such as dams, water ways, and operations facilities (green circle, upper left). Although increasing in complexity, CIP also must consider detection, prevention, response, and mitigation as interdependent components of this process (center, fig. 4). Also considered must be the organization type in terms of structure to merge management and operations methods to the inclusive process (lower left, fig. 4). The overall process is highly complex.

A major goal of the USGS is to reduce the vulnerability of people and communities at risk from hazards by working with partners throughout all sectors of society.

As part of its mission, the USGS engages in efforts to improve the understanding and effective management of water resources around the globe to help address scientific and management concerns regarding water-resources supply, sustainability, protection, and security. The USGS investigates the complex interdependency of water with

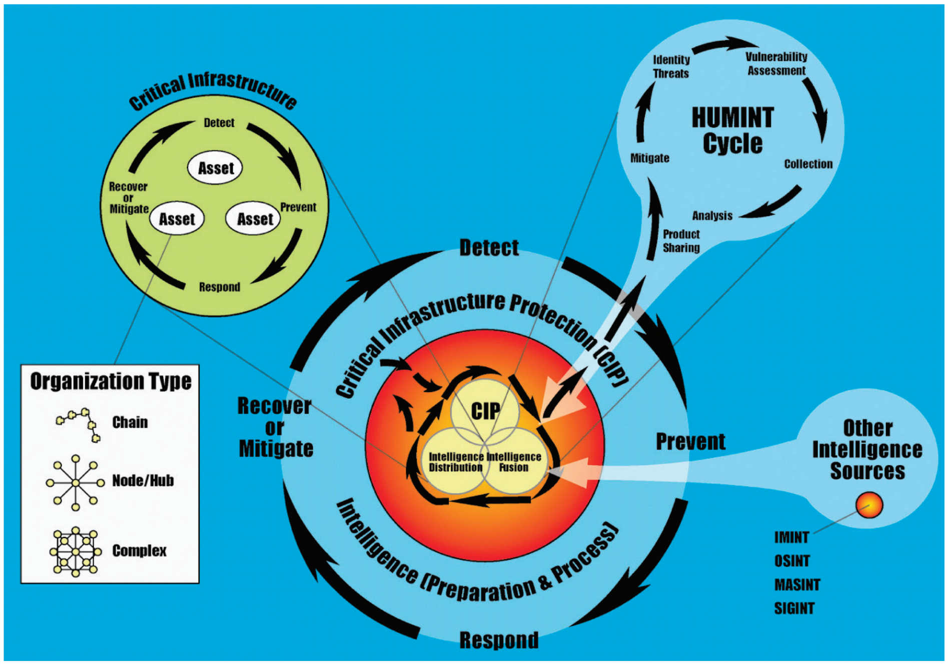

Figure 4. Critical Infrastructure Protection (CIP) within the Intelligence Process. Acronyms: IMINT (Imagery Intelligence); OSINT (Open Source Intelligence); MASINT (Measurement and Signature Intelligence); SIGINT (Signal Intelligence). Copyright James Tindall; free for public use.

An International Alert identified 46 countries with a combined population of 2.7 billion in which both climate change and water-related crises may create a high risk of violent conflict (Smith and Vivekananda, 2007); 56 countries represent an additional 1.2 billion people at high risk of political instability.

A 2004 to 2006 Somalia/Ethiopia dispute over water wells and pastoral lands left nearly 250 people killed and many more injured. A 3-year drought led to the violence, aggravated by the lack of effective government and central planning (BBC News).

In African Burkina Faso in 2007, declining rainfall led to growing clashes among animal herders and farmers with competing water needs (United Nations Office Commissioner for Human Rights, 2008). Two thousand people (including 1,400 children) fled their homes because of water disputes.

life-support systems such as power and energy, agriculture and food, and public health and how these are affected by natural disasters. These systems and(or) assets, vulnerable to the Triad threats and hazards, are essential for public health and safety, the functioning and sustainability of society, the economy, and the security of nations. In conjunction with its future science strategy (U.S. Geological Survey, 2007), the USGS continues to examine interdependencies of ecosystem functions, energy and water, and integrated information (information coupled from numerous fields of science) that can be used to help develop solutions to water-security problems. The USGS can create new products, such as mathematical models, that can aid in increasing resource security and are useful for reducing loss of life and property, as well as environmental risks. This also considers the effect on and relations to other fields of science such as climatology, hydrology, ocean sciences, seismology, volcanology, geology, biology, and so forth.

Merging the intelligence cycle, intelligence sources, critical infrastructure assets and their protection, resource data, and other information is a complex process; however, implementation is crucial for protecting billion-dollar infrastructures and favors a strategic rather than tactical approach.

Water security and sustainability problems related to climate change, desertification, growing populations, biodiversity, disparate water distribution, and distribution management and hazards, particularly wildfires, are increasing stress on global water supplies. Water conservation methods and technology such as dams, cloud seeding, desalination plants, and underground water storage may be insufficient to meet the demands of a growing global population. Because the water supply is finite, the potential for water-related conflicts are likely to increase and become more acute as demand increases (Tindall, 2008). The need for transboundary water sharing, which has been a constant source of contention since territorial times in the arid Western United States and recently in the drought-stricken Eastern United States (Dellapenna, 2005), is now a global issue.

The study and development of strategies and countermeasures to ensure water sustainability and security require a fusion of scientific and analytical skills and increased awareness by the public, resource managers, and Government entities. Programs including those promoting institutional capacity-building and networking, continuing professional education, and other activities targeting training and increasing the knowledge of citizens demonstrate the fusion of water availability and national security. The U.S. military is at the forefront of these issues and provides a high level of education and training, most notably at the U.S. Naval Postgraduate School's Center for Homeland Defense and Security. National security planners, analysts, and agencies are increasingly studying the challenge of hazards and threats to water supplies and infrastructure from hazards and transnational terrorists (Copeland, 2009; Behrens and Holt, 2005). One example is the Water Infrastructure Security Enhancements (WISE) Project supported by the USEPA, an effort to get all water utilities serving populations of more than 3,300 to voluntarily perform vulnerability and risk assessments and take preventive measures against possible attacks and other hazards.

A cooperative and concerted effort between the public, policymakers, planners, managers, science agencies, security and intelligence groups, and law enforcement will be required to develop solutions to water-security threats. Ensuring and protecting water supplies is a complex issue that is critical to national and international security interests and the health, welfare, and security of all Americans.

The U.S. Government can provide world leadership on water security and sustainability issues through science, education, and international programs. Research activities of the USGS are well suited to solve many scientific, technical, and management problems encountered in this area. Universities and research institutes could further promote and develop water security as a distinct discipline, thus expanding public education. Intelligence agencies could be further tasked to integrate water-security issues and define them within the context of national security.

Perhaps the most advantageous approach to enhance water security is a local, regional, national, and global dialogue to address pertinent questions such as:

1. ***How do we best develop flexible and adaptable transboundary water-sharing policies and planning for hydrologic, political, and socioeconomic circumstances?***
2. ***What are the interdependencies between water and energy, agriculture, ecosystems, biodiversity, conservation, and climate change?***
3. ***How should long-term planning and policy account for these issues to ensure that competing users of water, especially energy and agriculture, have adequate supplies to continue regional and national economic growth?***
4. ***Given the critical importance of water, what capacity and capabilities within the U.S. Government would be needed to address and manage national and international water-security policies, intelligence resource conflicts, and threats?***
5. ***The primary threats to water security are population growth, terrorism, climate change (sustained droughts), and industrialization. These threats can be interdependent. What are the best procedures for developing comprehensive strategies to address them?***
6. ***How can we achieve stakeholder cooperation between the Federal and private sectors for information sharing, vulnerability analysis, and risk assessment to improve sustainability?***

Few other issues affect the United States or the global community so directly as water security. All are stakeholders for ensuring the sustainability and security of water supplies.

—By James A. Tindall and Andrew A. Campbell

Water infrastructure (clockwise from top right: tap; second Los Angeles Aqueduct; Hoover Dam; world map in background). Source: Transnational Resources Development Associates (*www.transrda.com*); used by permission.

References

Behrens, Carl, and Holt, Mark, 2005, Nuclear power plants—Vulnerability to terrorist attacks: Washington, D.C., Library of Congress, Congresssional Research Service Report Number RS21131.

BBC News World, 2004, "Dozens Dead" in Somalia clashes: BBC World News Online Edition, accessed March 23, 2009, at *http:// news.bbc.co.uk/2/hi/africa/4073063.stm*.

Brown, Lester R., 2008, Plan B 3.0—Mobilizing to save civilization: New York, W.W. Norton and Company.

Copeland, Claudi, 2009, Terrorism and security issues facing the water infrastructure sector: Washington, D.C., Library of Congress, Congressional Research Science Report Number RL32189.

Corso, Phaedra S., Kramer, Michael H., Blair, Kathleen A., Addiss, David G., Davis, Jeffrey P., and Haddix, Anne C., 2003, Cost of illness in the 1993 waterborne Cryptosporidium outbreak, Milwaukee, Wisconsin: Emerging Infectious Diseases, v. 9, no. 4, p. 426–31.

Dallapenna, J.W., 2005, Interstate struggles over rivers—The southeastern states and the struggle over the "Hooch": New York University Environmental Law Journal, v. 12, no. 3, p. 828–900.

Fialko, Yuri, 2006, Interseismic strain accumulation and the earthquake potential on the southern San Andreas fault system (PDF): Nature, v. 441, no. 7096, p. 968–971.

Heath, Clark W., Jr., 1984, Uses of environmental testing in human health risk assessment in environmental sampling for hazardous wasters: American Chemical Society Symposium Series, v. 267, chap. 2, p. 7–13.

Hinrichsen, D., Robey, B., and Upadhyay, U.D., 1997, Solutions for a water-short world: Baltimore, Johns Hopkins School of Public Health, Population Information Program, Population Report, Series M, no. 14.

Hutson, S., Barber, N., Kenny, J., Linsey, K., Lumia, D., and Maupin M., 2004, Estimated use of water in the United States in 2000: U.S. Geological Survey Circular 1268, revised February 2005.

International Nuclear Safety Advisory Group, 1992, INSAG-7—The Chernobyl accident: Vienna, International Atomic Energy Agency, Safety Series 75-INSAG-7, update of INSAG-1.

Moore, J.E., Raynolds, R.G., and Barkmann, P.E., 2004, Groundwater mining of bedrock aquifers in the Denver basin—Past, present, and future: Environmental Geology, v. 47, no. 1, p. 63–68.

National Interagency Fire Center, 2009, Wildland fire statistics: National Interagency Fire Center, accessed April 3, 2009, at *http://www.nifc.gov/fire_info/fires_acres.htm*.

Palser, Barb, 2007, Hurricane Katrina—Aftermath of disaster: Minneapolis, Minn., Compass Point Books, 96 p.

Robichaud, Peter, MacDonald, Lee, Freeouf, Jeff, Neary, Dan, Martin, Deborah, and Ashmun, Louise, 2003, Postfire rehabilitation of the Hayman Fire: U.S. Department of Agriculture Forest Service General Technical Report RMRS-GTR-114.

Smith, Dan, and Vivekananda, Janani, 2007, A climate of conflict—The links between climate change, peace and war: International Alert, accessed July 10, 2008, at *http://aquadoc.typepad.com/waterwired/files/climate_conflict.pdf*.

Tamm, Quinn J., 2004, Hoover Dam, Boulder City, Nevada, mileage review: Las Vegas, Nev., Federal Bureau of Investigation Las Vegas Field Division, Memorandum for the Record MFR04016243, accessed at *http://intelfiles.egoplex.com/2004-01-06-911-FBI-Atta-Hoover-Dam.pdf*.

Tindall, James A., 2008, Expected key trends likely to influence global security: Global Security Affairs and Analysis Journal (*www.gsaaj.org*), v. 2, no. 3, September 2008, 21 p.

Tindall, James A., and Campbell, Andrew A., 2009, Water security—Nation, State, and international security implications: Disaster Advances Journal, v. 2, no. 2, April 2009, p. 16–25.

Tindall, James A., and Campbell, Andrew A., in press, Water security conflicts, threats, policies: Denver, DTP Publishing.

TinMore Institute, 2010, A definition of global security: TinMore Institute, A Think Tank, accessed at *http://tinmore.com/security-def.php*.

United Nations Development Programme, 1999, Global environment outlook 2000: London, United Nations Development Programme, Earthscan.

United Nations Development Programme, 2006, Human development report 2006. Beyond scarcity—Power, poverty, and the global water crises: New York, United Nations Development Programme, p. 14.

United Nations Educational, Scientific, and Cultural Organization, 2006, Water—A shared responsibility. The United Nations World Water Development Report 2: Paris, UNESCO Publishing/Berghahn Books.

United Nations Office Commissioner for Human Rights, 2008, Burkina Faso—Innovation and education needed to head off water war: United Nations Office for the Coordination of Humanitarian Affairs, accessed July 29, 2008, at *http://www.irinnews.org/PrintReport.aspx?ReportId=74308*.

United Nations, 2003, Water for people—Water for life. The United Nations World Water Development Report: Paris, UNESCO Publishing, 576 p.

United Nations, 2010, The millennium development goals report: United Nations Department of Economic and Social Affairs.

U.S. Geological Survey, 2007, Facing tomorrow's challenges—U.S. Geological science in the decade 2007–2017: U.S. Geological Survey Circular 1309, 67 p.

Vicente, Kim J., and Christoffersen, Klaus, 2006, The Walkerton *E. coli* outbreak—A test of Rasmussen's framework for risk management in a dynamic society: Theoretical Issues in Ergonomics Science, v. 7, no. 2, p. 93–112(20).

Young, Herbert C., 2006, Understanding water rights and conflicts, 2d ed.: Denver, BergYoung Publishing, 337 p.

Wilhite, D.A., and Vanyarkho, O., 1999, Drought—Pervasive impacts of a creeping phenomenon, *in* Wilhite, D.A., ed., Drought—A global assessment: London, Routledge Press, 304 p.

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