The Twenty-First Century Water Commission Act of 2008

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EXECUTIVE SUMMARY

Freshwater is a natural resource vital to the survival of humans and ecosystems. In the United States (US), over 408 billion gallons of freshwater are consumed daily for agricultural, industrial, thermoelectric power, and domestic uses. The US possesses a network of lakes, rivers, and aquifers that is used to supply the nation's freshwater needs. Overuse and pollution stress our freshwater supply and endanger our national welfare. As the US population and industry continue to grow, demands will overwhelm the freshwater supply, especially in regions that already face issues of freshwater scarcity or impurity. Despite the importance of freshwater to the country, no national strategy for managing the country's freshwater supplies exists.

The Twenty-first Century Water Commission Act of 2008 (the Act) is an attempt to address current and projected stresses on freshwater supplies. The Act acknowledges that as the US population and industry expand and regionally shift in coming decades, its freshwater resources will face increasing stress and pressure. A thorough assessment of all viable technological, institutional, and economical measures and strategies that freshwater managers can take to alleviate this pressure will provide solutions to meet freshwater needs across the country. The Act establishes the Twenty-first Century Water Commission (the Commission), which is charged with surveying existing freshwater systems and developing a comprehensive strategy to address future challenges. The Commission must consult with freshwater management experts at all levels of government and the private sector to determine what technological, institutional, economic, and other advances can be made to best ensure safe and plentiful freshwater supplies well into the future.

Currently, freshwater is managed at the state level of government. This delineation of freshwater rights ignores natural watershed boundaries. The Act aims to maintain localized freshwater control while increasing regional cooperation. A successful strategy is dependent on the Commission understanding the scientific aspects of water problems and their solutions. The climate, geography, and other physical systems of a region determine the supply of freshwater while the human need determines demand. No single solution exists for the freshwater problems threatening the US. The Commission must analyze existing freshwater management programs and form new studies to determine regionally appropriate solutions and assist regional managers with their implementation. A thorough understanding of the science of freshwater dynamics is crucial to forming a comprehensive strategy to ensure safe, adequate, reliable, and sustainable freshwater supplies well into the future.

Safe freshwater is defined by the Safe Water Drinking Act and Clean Water Act, which set the acceptable levels of various contaminants based on their health effects while allowing individual states to petition to set their own standards. The Commission will have to review the existing programs and determine whether there is a need for improved standards or more federal oversight. Freshwater quality is degraded by the addition of chemical pollutants, harmful microorganisms, and physical disruptions to freshwater sources. In most cases, the safety of freshwater for human consumption is ensured through purification technologies; however, at times these technologies fail. Cryptosporidium, a parasite that causes sometimes-fatal diarrheal illness, is resistant to standard treatments and small enough to move through most filters. An outbreak of Cryptosporidium in Milwaukee, Wisconsin in 1993 demonstrated the importance of using the most effective technology. The Commission will compile information on new and existing purification methods in order to make recommendations on the best available technology.

Adequate freshwater means the necessary amount is available where needed for domestic use, irrigation, industrial use, or for any other need. Freshwater supply is driven by the hydrological cycle, which replenishes both surface and groundwater sources through precipitation. In many cases withdrawal from a freshwater source exceeds replenishment, causing the depletion of the source. Freshwater availability is highly uneven across the country; ground and surface freshwater bodies are located in different regions and often cross state boundaries. The Ogallala Aquifer lies beneath eight states in the Midwest and supplies 30% of total groundwater used for irrigation in the country. This aquifer is under increasing stress from overuse and in some areas water levels have dropped over 50 feet. Because freshwater is managed at the State level, conflict often arises when multiple states are drawing freshwater from a single source, threatening the quantity of freshwater available.

Reliable infrastructure is crucial to ensure that a safe and adequate freshwater supply can be delivered to the populations that need it. The US has extensive water infrastructure, including public water systems, dams, levees and wastewater treatment facilities; this infrastructure must be monitored for deficiencies and repaired or replaced when necessary. Currently, there are many areas in need of infrastructure improvements. One example is the New York City public water supply. The Delaware Aqueduct, which supplies 50% of the city's water, is leaking at a rate of 36 million gallons per day. Deficiencies such as this demonstrate the benefit of redundancy in infrastructure systems and the potential loses from inefficiency and deterioration. In making a successful national freshwater strategy, the Commission must consider both the improvements needed for existing infrastructure and the new infrastructure that will be needed in the next 50 years as existing systems reach the end of their useful lives and demand for water systems increases.

Sustainability is the key to ensuring that the goal of a safe, adequate, and reliable freshwater supply is met in the long run. Sustainability refers to achieving a balance between the supply of and demand for freshwater. Supply is driven by the hydrological cycle and the climate of a given region, as well as patterns of use; demand stems from freshwater consumption for human purposes. In many regions, high demand is resulting in freshwater overuse and reduced quality of freshwater supply. The Colorado River Basin, which supplies water to seven states and includes the nation's two largest reservoirs, is an area in need of effective management. The snowpack which provides 96% of the system's replenishment is declining as a result of climate change; at the same time the population supplied by the Basin has been continuously increasing for decades. The reservoirs are being depleted and the current rate of use is unsustainable. The solution to this problem is effective management of freshwater resources. For the Commission to successfully plan for the future, it must examine existing water management strategies, used at the local, state and federal levels, to make recommendations on the optimal methods of reconciling human demand with natural limitations.

Although the Commission will be forming recommendations on the most basic of resources, the task of forming a comprehensive national strategy will be anything but simple. There are many controversies surrounding science and politics related to freshwater. Controversies surrounding the science of freshwater include difficulties in quantifying freshwater supply, debates over the benefits of technological versus natural solutions, and predicting the effects of climate change. There are many different predictions about what affect climate change might have on precipitation and thus freshwater availability in the US, making it hard to move forward with a specific policy. Additionally, climate predictions show different effects across the nation, with some regions becoming drier while others experience increased precipitation. These complicating factors make it even more difficult to make decisions based on scientific recommendations.

The uncertainty inherent in science makes for further controversy when science comes into conflict with politics, economics, or social values. Water policy decisions are made at the State level, but because water sources are often shared across state boundaries there are frequently conflicts between states over water sources. The contention between Georgia, Alabama, and Florida over the freshwater of Lake Lanier exemplifies the sensitivity of the issue and possibility for conflict when freshwater is shared. The importance of maintaining freshwater systems is not controversial, but action becomes stalled when faced with the cost; one Environmental Protection Agency estimate suggested that $276.8 billion dollars is needed over the next twenty years to replace public water systems; this does not even take into account all of the other important water systems in need of repair. Finally, public perception of freshwater programs is integral to their success. For instance, greywater recycling is often considered as a means of conservation; however, the public may not be comfortable with the idea of using “dirty” water.

The Commission is assigned a challenging task. A comprehensive national freshwater strategy will have to take into account the regional variability, localized control, and interconnectedness that characterize the nation’s freshwater sources in making recommendations on achieving a freshwater supply that is safe, adequate, reliable, and sustainable for the next 50 years. This task will be understandably difficult, but if the Commission is successful, it will be an achievement that helps protect the security of freshwater supply and avoid problems of scarcity and interstate conflict over freshwater resources in the future. The Commission will compile the most accurate and comprehensive information necessary to make recommendations for collaborations across all levels of government; its success will be determined by whether the US has a national strategy to sustain a safe, adequate, and reliable freshwater supply 50 years into the future and beyond.

I. The Twenty-First Century Water Commission Act of 2008

Overview

The Twenty-First Century Water Commission Act of 2008 (the Act) was introduced in the Senate by Georgia Senator John Isakson on March 6, 2008. The Act acknowledges that as the United States (US) grows in coming decades, its water resources will face increasing stress and pressure. A thorough assessment of the actions, both technological and economical, that the country can take to alleviate this pressure is crucial to ensure water needs are met across the country. S. 2728 and H.R. 135 look to establish the Twenty-First Century Water Commission (the Commission), a federal commission with the purpose of conducting an assessment of national water use and availability to craft recommendations for a comprehensive strategy to ensure the existence of uncontaminated and sustainable water supplies in the next 50 years. The Commission will study quantitative and qualitative assessments of current freshwater resources and management in the US along with estimates of future demand. With this information it will make recommendations on the technological, economic and management tools available to help meet future need. The Commission is charged with providing the President and Congress with recommendations and reports regarding the management, infrastructure, policy, financing, and conservation of national water resources over the next 50 years. The Commission will consult with public and private experts in freshwater management and hold hearings in distinct geographical regions of the country to develop its conclusions. The resulting water strategy will be of major national importance, as water availability and safety are crucial for future US environmental and economic interests.

Duties of the 21st Century Water Commission

The act establishes that the Commission must study national supply and demand for freshwater and management programs across all levels of government and the private sector to make recommendations on improving freshwater quality and resources. The Commission will consult these programs to develop the nation's water strategy. The act requires that the Commission develop recommendations that observe the following goals for a national strategy:

- Leaves the main role of water oversight to individual States;
- Defines incentives to promote an adequate US water supply for the next 50 years;
- Avoids strategies that mandate State and local government action;
- Eliminates redundancies and unnecessary bureaucracy between Federal programs;
- Considers all available technologies and methods to improve water supplies;
- Captures excess water sources for drought relief and conservation use;
- Finances both management and public works projects;
- Conserves existing water supplies addressing the issue of aging infrastructure; and
- Develops additional water management initiatives.

Membership, Director, and Meetings of the Commission

The Twenty-First Century Water Commission must be formed within 90 days of passage into law and consist of nine members. Five of these nine members will be appointed by the President, including the Chairperson, two will be appointed by the Speaker of the House, and the remaining two will be appointed by the Senate Majority Leader. Members should be distinguished in the area of water policy, represent a broad geographical cross-section of the US, and will serve without salaried compensation. The Speaker of the House and the Senate Majority Leader will appoint a Director for the Twenty-First Century Water Commission. They will consult with the both the House and Senate minority leaders to make their decision, the chairman of the House Resources, Transportation and Infrastructure Committees, and the chairman of the Senate Energy and Natural Resources, and Environment and Public Works Committees. The Commission will have its first meeting no later than 60 days after all its members have been appointed.

Proceedings and Reports of the Commission

During the lifetime of the Commission, a minimum of 10 hearings must be held and may be in conjunction with Commission meetings. At least one hearing must be held in Washington, D.C. to take testimony from federal agencies, national organizations, and Congress. Federal agencies are obligated to 1) honor requests of information from the Commission within 30 days, and 2) temporarily assign members of their staff on a reimbursable basis to assist the previously stated duties of the Commission. The other nine hearings will be held across the United States, seeking diverse testimony on water issues from all levels of government and the private sector. The Commission will produce bi-annual progress reports for The President, House Resources Committee, House Transportation and Infrastructure Committee, Senate Energy and Natural Resources Committee, and the Senate Environment and Public Works Committee. After three years, the Commission must deliver its final report with findings, conclusions, and policy recommendations. The Commission must terminate no more than 30 days after it delivers its final report. This means that the Commission would have at most three years, seven months to complete its work. Finally, the Commission is authorized $9,000,000 to carry out its tasks.

II. Safe, Adequate, Reliable, Sustainable

The bill explicitly states that the goal of the comprehensive strategy must be to "ensure safe, adequate, reliable, and sustainable water supplies" now and into the future. While this is a broad mandate, it can be understood to encompass four main areas. To ensure the safety of freshwater supply is to guarantee that it is of safe drinking quality. The adequacy of freshwater supply is ensuring there is enough water to meet human demand. Freshwater systems will be reliable if required infrastructure is well-maintained and uses the optimal technology available. Finally, freshwater use is sustainable only if demand does not outstrip supply and freshwater sources are managed effectively. Whether or not the strategy is successful will be determined by whether these four criteria are met.

1. Safe

The water strategy created by the Commission must recommend means of ensuring that the water supply remains safe for the next 50 years. Currently, safe water is defined primarily by the Environmental Protection Agency (EPA) though the Clean Water Act (CWA) and Safe Water Drinking Act (SWDA). Contamination of both surface and groundwater sources threatens freshwater quality in the US. According to the SWDA, the term contaminant means any physical, chemical, biological, or radiological substance or matter in water. The SWDA and CWA establish both the levels of safe human consumption of specific contaminants and the feasible limits of contaminant levels in water bodies. The CWA also regulates water pollution through the National Pollutant Discharge Elimination System (NPDES) program. State quality standards must at least meet national EPA standards.

In the US there are currently 170,000 public water systems regulated under the SDWA. All states in the US except for Wyoming and the District of Columbia have received authority form the USEPA to enforce and implement SDWA standards. As such, state water suppliers must conduct assessments of their water sources for vulnerability to contamination ("Understanding the Safe Drinking Water Act", 2004 and "Public Drinking Water Systems: Facts and Figures", 2006). If a public water supply fails to comply with the standards of the SDWA then the persons served must be notified ("National Primary Drinking Water Regulations: Public Notification Rule", 2004). In 2007 alone 5,461 public water systems serving 20,532,704 people had health based violations. However, this may be an underestimation due to the inaccuracies and underreporting inherent in the system. This elucidates the possibility for improvement in terms of coordination between national and state organizations and their respective information systems ("Factoids: Drinking Water and Ground Water Statistics for 2007, " 2007).

Through the National Water Quality Assessment Program (NWQAP), the USGS is charged with collecting long term local and national information on water body quality conditions ("The National Water-Quality Assessment Program," 2001). Concurrently, the EPA is charged with assuring the quality of public drinking water; logically it would proceed that these institutions should be coordinating highly on all spatial scales to provide safe drinking water to the US populations.

Despite existing regulation of water quality, there are still areas where standards are not met. Currently, 15 % of the nation's lake acreage and 5 % of the nation's river miles are under state-issued fish consumption advisories ("Management Strategy," 2008). Methyl-mercury build up in fish from human sources causes problems for the people who depend on fish as a dietary necessity. Since December 2004, there have been over 2,240 advisories for mercury across 41 states ("Mercury Update," 2001).

As part of a comprehensive water strategy, the Commission will have to consider how to maintain the safety of water sources and improve current freshwater quality into the future. The Commission must also determine whether new standards are appropriate, whether for different contaminants or different levels, given projected future supply and use conditions. To do so, the Commission must develop a thorough understanding of the different types of contaminants that threaten the freshwater supply.

Chemical Pollution

Point source contamination is defined by the EPA as any pollutant that drains directly into a water source, such as through a pipe feed ("Water Pollution," Environmental Protection Agency). Industrial effluent and sewage are two major point sources of contamination in the US. However, these are closely monitored and regulated through the EPA's (NPDES), which requires industries to apply for a permit limiting water pollution discharges into US waters (National Pollutant Discharge Elimination System, 2007). Although this policy has decreased the amount of point-source pollution, there are still many pollutants entering the water system. For instance, in 2007, the National Response Center recorded 35,274 chemical and oil spills ("National Response Center: Statistics," 2007).

Non-point source contamination is defined as any indirect source of contamination to water, and is created as water picks up contaminants while moving over a surface (What is Nonpoint source (NPS) Pollution?," 2008.). Measuring and managing non-point source contamination is very difficult because these contamination sources and points of entry are hard to identify, control and measure. A major source of non-point pollution is surface runoff, water that flows back into water sources after precipitation or irrigation (Ward, 1995). Runoff itself is not a pollutant; rather, the chemicals, metals and nutrients carried by and dissolved into the water are the sources of contamination. Urban runoff carries with it toxic chemicals and heavy metals such as lead and mercury that can make water unsafe for humans or other organisms to consume (Greenberg, 2003). Agricultural runoff is rich with nutrients such as nitrogen and phosphorous (Spiro, 2003). In water sources nitrate compounds released by agriculture and industry are the most prevalent chemical pollutants (Figure 1). Once these contaminants have entered our waterways they pose a significant hazard to human and ecological health. Excessive input of nitrates causes high growth in phytoplankton populations. Some of these populations may produce toxic compounds that bioaccumulate in fish species that are consumed by humans. Additionally, due to the high inputs of nitrogen large algal blooms will grow. By the process of eutrophication, these blooms die and are decomposed by anoxic bacteria dissolved oxygen is removed from the water, leading to hypoxia. This suffocates the remaining organisms that rely on dissolved oxygen and creates an environment that is uninhabitable for plants and fish.

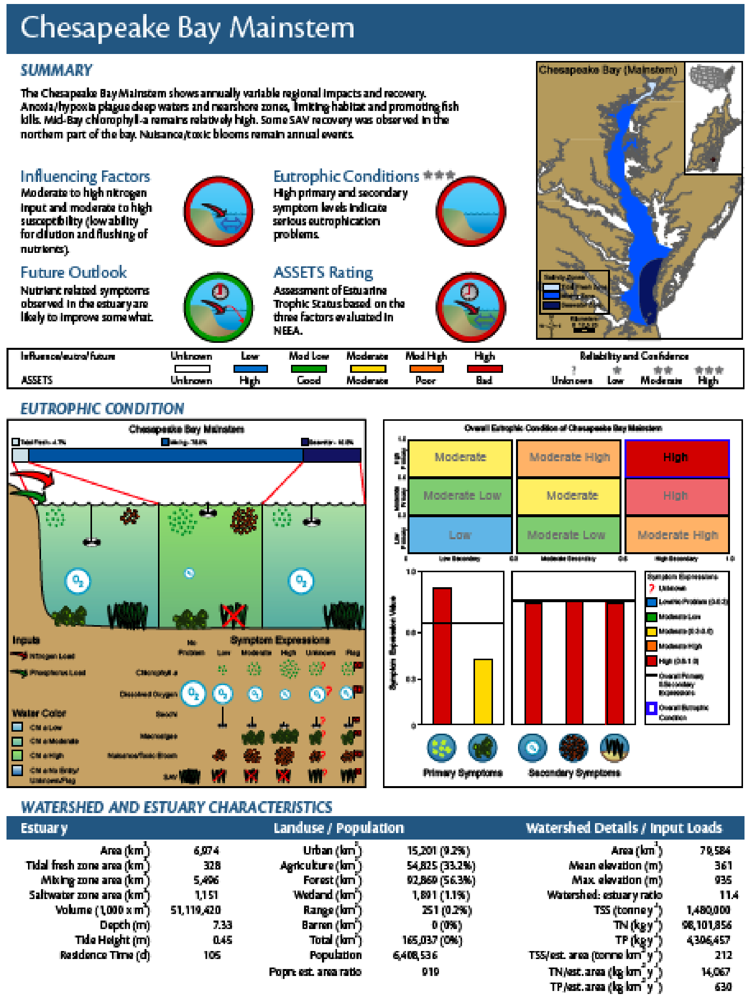
Figure 1: Point-Source Pollution

Chemical	Pounds	Metric Tons	Percent of Total
Nitrate Compounds	231,367,165	105,041	89.4
Ammonia	7,917,711	3,595	3.1
Manganese Compounds	5,398,239	2,451	2.1
Methanol	3,873,380	1,759	1.5
Barium compounds	2,182,327	991	0.8

Figure 1: The top five chemical contaminants discharged into surface freshwater bodies in the United States. Adapted from Thomas G. Spiro. Chemistry of the Environment. 2nd Edition. 2003

Case Study: Chesapeake Bay

The Chesapeake Bay is an estuary, which is an important habitat for specific aquatic life that thrive in brackish water. A study by Hagy et al. (2004) found a positive correlation with Nitrate (NO_3)loading from Sasquahhana tributary and dissolved oxygen (DO) concentrations in the Bay from 1950-2001. This process is known as eutrophication and causes decreased amounts of DO in the water column that suffocates organisms and damages the ecosystem. This problem is unique in that the major effects are felt in the Chesapeake Bay area, but the source of NO_3 comes from over 200 miles away and crosses multiple state boundaries before reaching the Bay. Since the late 1970's multiple agencies and states have been working together with the federal government on the Chesapeake Bay Program (Blankenship, 2001). Now, 30 years later nutrient loads from wastewater treatment facilities have been reduced by 80% and 50% respectively ("History of Chesapeake Bay", 2008). Fish, oyster, and crab markets have also rebounded 10% since 2006 through the combined effort and organization of the different agencies ("History of Chesapeake Bay", 2008).



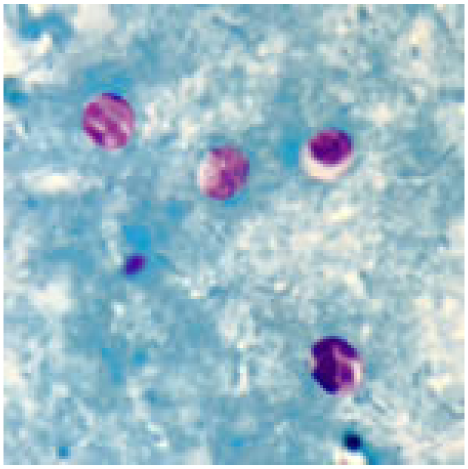
The figure is from the NOAA 2007 report on Effects of Nutrient Enrichment in the Nation's Estuaries: A Decade of Change, an assessment of the Chesapeake Bay Mainstem:

Blankenship, Karl. "'Cap' Strategies envision new approaches to nutrient control." Alliance for the Chesapeake Bay Bay Journal May 2001. 8 June 2008 <http://www.bayjournal.com/article.cfm?article=1412>

Biological Contaminants

Sewage effluents threaten water quality and feed high amounts of toxins and nutrients, increasing the growth of harmful bacterial. Each year, more than 860 billion gallons of sewage enters freshwater systems. Sources of effluent include storm water, combined sewer overflow (CSO) from wastewater treatment plants, livestock feces runoff, and leaking septic tanks ("Water Education," 2008). Sewage and wastewater can contain various bacteria, fungi and parasites. Common potentially harmful bacteria found in freshwater include *E. coli*, shigellosis, salmonella, and cholera; fungi include Aspergillus; parasites consist of Cryptosporidium and roundworm. In the US 3.5 million illnesses are reported each year from bacterial and parasitic illnesses caused by sewage in the water system ("Effects of sewage-contaminated water on human health," 2008).

Case Study: Cryptosporidium Parasite



Cryptosporidiosis is an infection caused by the parasite Cryptosporidium, which contaminates both surface and groundwater systems through cattle feces run-off. Cryptosporidiosis is commonly spread through recreational water activities, but can also infect drinking water supplies. The Cryptosporidium parasite is resistant to many purification techniques and is small enough to pass through filters. The highest reported case of Cyrptosporidium occurred in Milwaukee, WI in 1993, when over 400,000 people were diagnosed with cryptosporidiosis, which include symptoms of diarrhea, vomiting and fever. (“Crypto,” 2008)

Image: Cryptosporidium oocysts in a modified acid-fast stain.

Physical Disruptions and Quality

Water quality is also disturbed in less obvious ways. Land-cover change, such as deforestation, opens up the land to increased soil erosion. Land-use change, such as urbanization, increases the expanse of impermeable surfaces, increasing pollution through runoff. Additionally, almost half of our country’s natural filtration systems, such as wetlands, have been destroyed since the settling of the first European colonies, and up until 1954 an average of 814,000 acres were being drained each year, primarily for agriculture (Hansen, 2006). These actions not only remove a natural function that benefits humans but also destroys entire ecosystems. In 1991, the White House implemented a policy of "no net loss" of wetlands, and in recent years policy has attempted to reverse the tide by creating, improving or protecting as many as a million acres of wetlands every year (Hansen, L., 2006). There is a high level of difficulty in measuring the loss of wetlands in the US (Squires, L.E., et al., 2004). However, these actions show that the government is attempting to further take advantage of the role that wetlands play in maintaining water quality by acting as a natural filter.

Water quality can also be affected by temperature change. Many industrial processes rely on water as a coolant. Once the water has gone through the industrial process it absorbs excess heat. This water is then sent back into the environment as thermal effluent, thus altering the temperature of the water body. Aquatic plant and animal life are often very sensitive to temperature change, so heat pollution can be detrimental to the natural systems relying on the water body (Squires, L.E., et al., 2004).

Saltwater intrusion can occur when an aquifer is over pumped. Typically an aquifer located in coastal inlands consists of a freshwater layer above a denser saltwater layer. This is separated by a diffusion layer which creates a barrier from mixing the two different water areas. As the freshwater is over pumped through a well, a pressure gradient occurs forcing the diffusion layer to upwell and later diffuse, causing saltwater movement into the aquifer. This results in an overall increase in water salinity. The increase of salt levels in groundwater is a significant threat to food crops and public water quality in many coastal regions throughout the United States. In areas where saltwater is not available to take the place of freshwater that is drawn out of an aquifer, the space between the units that make up the substrate can collapse and subsidence occurs (Barlow 2003). This presents a threat to public and private property and makes impacts from natural events such as flooding harsher and more likely (Galloway D., et al., 1999).

Figure 2: Areas of the US at Risk of Saltwater Intrusion

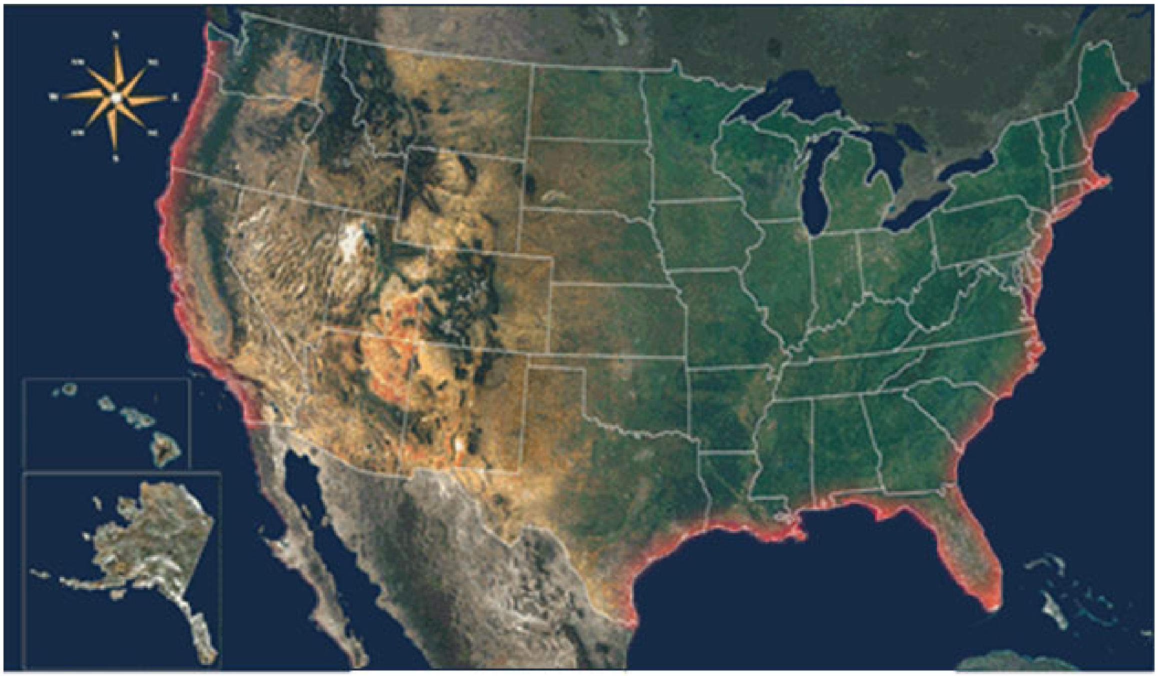
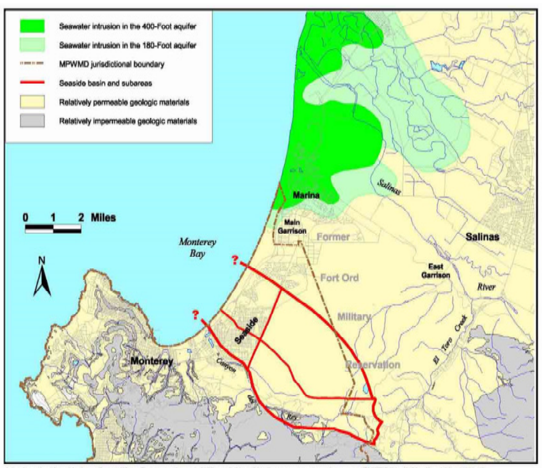


Figure 2: Over pumping groundwater in coastal regions leads to saltwater intrusion.

Case Study: Saltwater Intrusion
Salinas Valley, CA

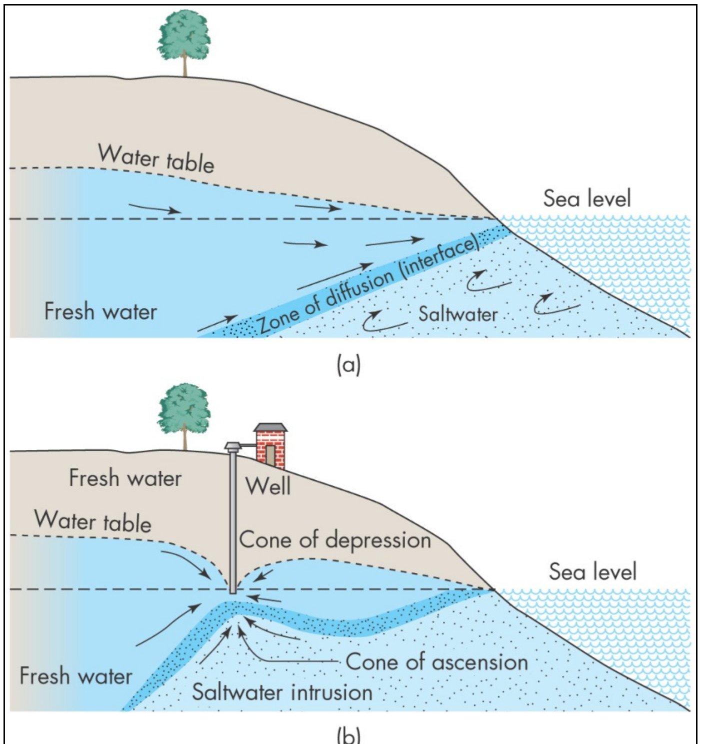
Excessive groundwater pumping has created pumping troughs (water-level depressions) in the Paso Robles and Santa Margarita aquifers in the Northern Coastal Subarea. A monitoring program had found that of the three aquifers in the study area, two aquifers, the "180-ft" and the "400-ft," had been intruded. The third aquifer, the "900-ft" aquifer, had not shown signs of sea-water intrusion (Mills et. al., 1988). Ground water has played a leading role in transforming California into the nation's top agricultural producer, most populous state, and the 7th largest economy in the world. Today, ground water supplies about 40 percent of the water California uses or about 16 million-acre feet per year (Leedshill-Herkenhoff, I., 1985)



Intrusion extent from Monterey County Water Resources Agency, 2003, available at http://www.mcwra.co.monterey.ca.us/SVWPO/01swi180.pdf and 01swi400.pdf

Figure 17. Map of Seawater Intrusion in the Salinas Valley Area

(Eugene et al., 2005)



2. Adequate

The Commission must make recommendations on ensuring that the national water supply is adequate over the next 50 years. Timing water recharge with water consumption is the fundamental challenge in ensuring that there is enough water available to strike a balance between freshwater supply and demand. Freshwater supply is defined by both quantity and quality of ground and surface water sources, and represents the water available for human use. In the scope of the Act, freshwater demand encompasses the many facets of human consumption. In forming a freshwater strategy, the Commission will have to examine the current national patterns of freshwater supply and demand as well as the projected patterns for the next 50 years.

The national demand of freshwater is broken down into categories: electricity production (48% of total demand), irrigation (68%), personal well-being (11%), and industry (6%) (USGS[1], 2008). National statistics describe a general overview of the country's water use; however, at the regional and local levels demand varies considerably based the dominant use in a region, be it agriculture, industry, public consumption or combination of influences. Our freshwater supplies in natural systems and human-made reservoirs are showing signs of depletion because current rates of withdrawal exceed those of natural replenishment. Population growth, suburban sprawl and urbanization have placed great demands on our nation's freshwater supply and could be having a significant impact on our ability to maintain adequate water reserves.

Appendix A: Freshwater Consumption in the US.

Supply

Freshwater supply is determined by the hydrologic cycle. The major driving force of this cycle is the sun, which provides the energy to transform water from a liquid to a gas, driving the hydrological cycle. These special physical and chemical properties allow water to be transient and pass through the earth's systems in various forms. In the atmosphere, evaporation, condensation, and precipitation dominate hydrologic movement. The interaction between the atmosphere, biosphere, and hydrosphere form the precipitation which recharges freshwater supply, and is necessary for human, plant and animal survival (USGS, 2004).

The rates of evaporation and precipitation determine the amount of water available in ground and surface water sources. The amount of water available for natural recharge to the ground-water system and as surface runoff to streams is represented by the amount of precipitation minus the amount of evapotranspiration. The average evapotranspiration rate in the US is 67% in arid areas, meaning that only 33% of precipitation that falls is used for recharging water sources; the majority is evaporated or absorbed by plants (Reilly, T.E., et al., 2008). Due to increasing temperatures in these arid regions, the evapotranspiration rate is increasing and is usually higher than the precipitation rates in the long term. This indicates high potential for future water scarcity in these areas (Reilly, T.E., et al., 2008).

Figure 3: Precipitation minus Evaporation

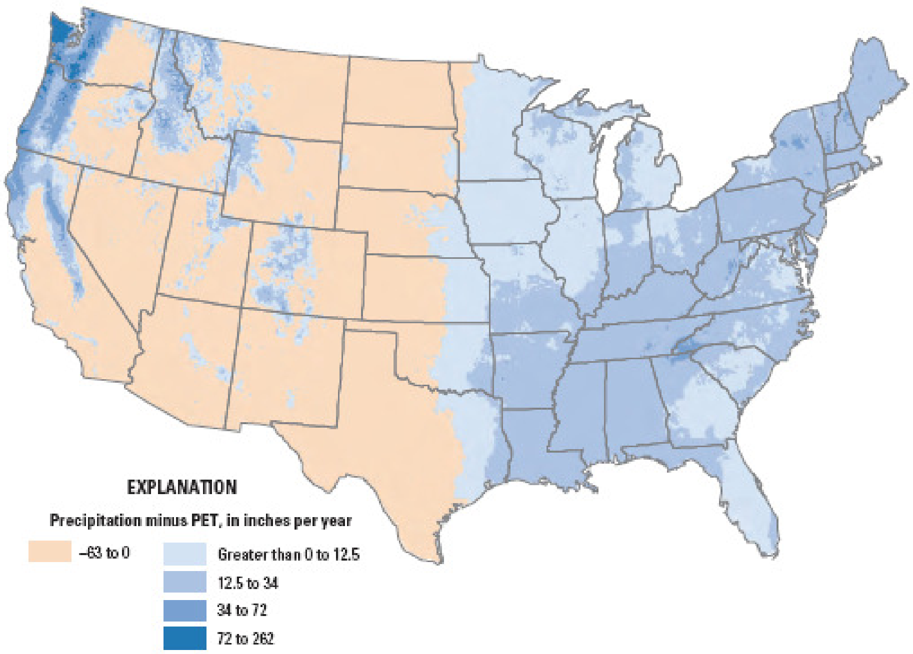


Figure 3: Difference between annual precipitation and potential Evaporation (PET) Rates for the United States (adapted from Healy and others, 2007)

Water measurement methods of annual precipitation and evaporation for the entire country are relatively accurate. However, a comprehensive national water strategy must take into account the vast regional differences in precipitation and evapotranspiration across the country. At a regional level the hydrological cycle, and therefore the water supply, is highly dependent on local features such as the topography, climate, limnology of water sources and biotic components of dependent ecosystems. For instance, the position of a lake determines how much groundwater and surface water runoff are added while the size of a lake determines, along with climatic factors, the amount of water lost through evaporation (Kump, 1999). Topography influences the extent surface runoff; the amount of runoff from precipitation is greater at steeper slopes than at more gradual ones. This influences where unsaturated precipitation flows: into surface water, into rivers or streams, or onto flat land causing floods ("The Water Cycle: Surface Runoff", 2007). Even biota, most notably flora, can be considered reservoirs within the hydrological cycle. These living reservoirs increase local atmospheric moisture through transpiration as well as retain water within their bodies (Molles, 2005). The hydrological cycle is a complex system incorporating many variables; these variables differ across the country.

Figure 4: The Hydrological Cycle

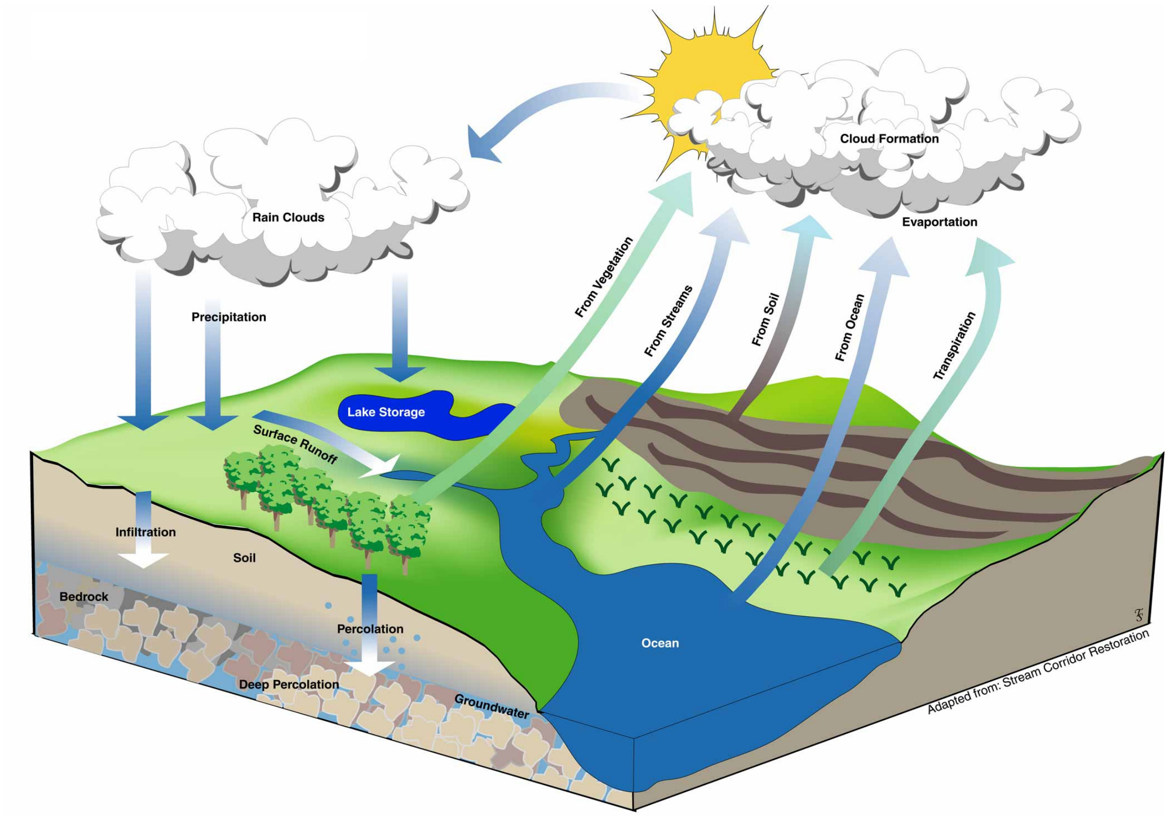


Figure 4: Representation of the Hydrologic cycle (Iowa State, 2008)

Demand: Surface Water

Precipitation is the major source of replenishment of water into fresh surface water bodies. After a rainfall, water drains from the earth's surface toward the nearest fresh water body, either surface or groundwater. This process determines watershed regions. In a perfect world, the amount of precipitation would represent the amount of water replenishing surface and groundwater bodies. However, surface water availability is influenced by various factors including infiltration into groundwater bodies, evaporation, transpiration, human use and groundwater discharge. This accumulation of variables on fresh surface water availability creates difficulty in assessing the true supply value of this water source.

Approximately 80% of human freshwater used comes from surface water sources (USGS[2], 2008). Surface water is defined by the EPA as all water that is naturally open to the atmosphere, such as lakes, rivers, seas and reservoirs (USEPA, 2008). Currently, the USGS estimates that the amount of surface water available is only 0.3% of the total water on the planet. The exact amount of fresh surface water available is unknown for the US due to difficulty in measuring ever-fluctuating quantities. Since human industry and survival is dependent on this water source, it is important to understand the science issues affecting its availability.

The categories of fresh surface water use include public consumption, domestic use, irrigation, livestock, industrial, mining and thermoelectric power. The largest consumers of surface fresh water are thermoelectric power using 100% of its water needs from surface water at a rate of 195,000 Mgal/day, followed by irrigation which uses surface water for 58% of its water needs at rate of 137,000 Mgal/day (USGS, 2004).

With the increase in temperatures due to climate change, evaporation rates are increasing, allowing less of the falling precipitation to recharge our freshwater supply (Ohta, 1995). At the same time, the demographic of the population of the United States is changing, and consequently populations are moving and expanding to different areas of the country. This large scale movement is largely attributed to the economic benefits, such as jobs and cheaper expenses that are becoming more prevalent in historically warm dry areas that have room for expansion. Also, the first wave of the baby boomer generation is retiring and moving to areas of ample sun, warmth and leisure (US Census Bureau, 2000). Unfortunately, many of these warm areas are already suffering from water scarcity. Arid states, such as Nevada and Arizona in the west, and Georgia and Florida in the east, have seen substantial, if not remarkable growth in the previous decade (Figure 5).

Figure 5: Percent Change in Resident Population for the United States, 1990-2000

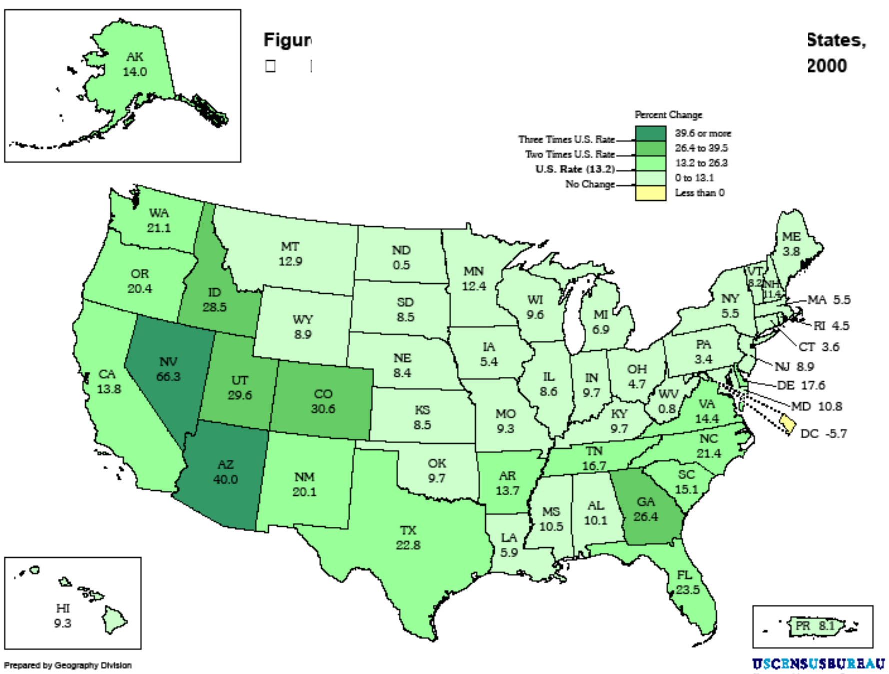


Figure 5: percent change of population for each state in the US over the period of 1990-2000. (U.S. Census Bureau, 2008)

Case Study: Climate Change Impacts on Lake Mead, Nevada

Increasing air temperatures and declining precipitation in the U.S. have led to decreased snowpack and rainfall and increased evaporation.

Created by the impoundment of Hoover Dam on the Colorado River, Lake Mead provides freshwater to southern California and Nevada. Increasing water demand from growing cities like Las Vegas and decreasing snowpack and precipitation due to climate change, make providing an adequate water supply a serious challenge for the coming decades. The water level in Lake Mead has been steadily declining over the last few years and is expected to continue to decline with decreasing snowpack and increasing withdrawal.

http://www.hprcc.unl.edu/nebraska/Lake-Mead-2007.html; image: University of Nebraska-Lincoln

Demand: Groundwater

Groundwater is water that sits below the surface; one common source is aquifers which generally consist of loosely spaced sediment or rocks that fill with water over a period of time (Barlow, 2003). Through percolation and infiltration, water enters groundwater storage, composing approximately 30.1% of total freshwater sources (USGS[2], 2008). It is important to understand the replenishment process to address the problems associated with groundwater quantity. Groundwater replenishment is a long and complex process. The formation of aquifers is not a recent event, most formed during the last glacial ice period. Precipitation percolating into the ground replenishes aquifers; however, replenishment is much slower than the rate of human extraction. A groundwater system can be made up of many aquifers and confining beds. The top boundary of the saturated groundwater system is the water table. The presence of a water table usually signifies an unconfined aquifer, which allows for more rapid water recharge from nearby surface water sources. Confined aquifers, also known as artesian aquifers, have higher rates of drawdown because they have less recharge ability due to an impermeable layer made up of clay or rock (USGS GW report). Many of these slow recharge aquifers were originally inudated with water thousands of years ago and thus contain paleowater, water deposited during the last ice age (Rosenberg, 1999). The effects of overusing groundwater include drying up of wells and aquifers, ground subsidence and salt-water intrusion. Due to the inaccessibility of groundwater, hydrologists cannot easily measure quantity levels. They can only roughly estimate the amount available. This is problematic because it leads to uncertainty to the level supply, which increases difficulty in managing an appropriate water extraction.

Human extraction rate is a major concern for many regions throughout the US, which rely on groundwater as their major source of freshwater. The highest users of groundwater include domestic, livestock and mining. Most of the major aquifers are located in areas with low precipitation, including Texas and the Southwest (Figure 6). Population distribution in the US indicates that human industry and populations are located in areas where groundwater availability is a concern, and must be monitored.

Figure 6: Location of Principal Regional Aquifers

http://water.usgs.gov/nawqa/studies/praq/images/PAmap.gif

Case Study: Ogallala Aquifer

1. Background: The Ogallala Aquifer underlies about 45,000 km^2 of the U.S., encompassing the states of: South Dakota, Wyoming, Colorado, Nebraska, Kansas, Oklahoma, Texas and New Mexico. The majority of the water in the aquifer can be dated back to the last ice age. It provides water for approximately 20% of the irrigated land in the U.S. About 20 km^3 are withdrawn every year while the rate of recharge is only 0.5-1 inch per year. (Rosenberg et al., 1999). One prediction states that the aquifer will be depleted as soon as 25 years (Bannerman, 2004).

   Figure: Major water depletion in the Ogallala Aquifer since predevelopment.

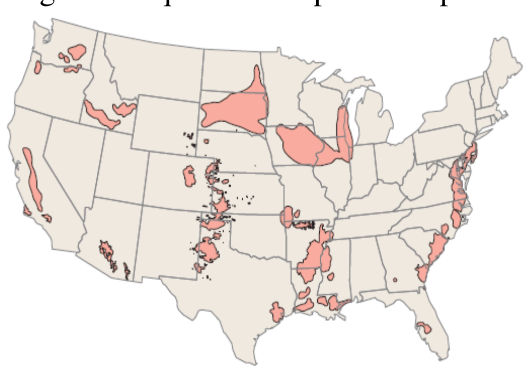
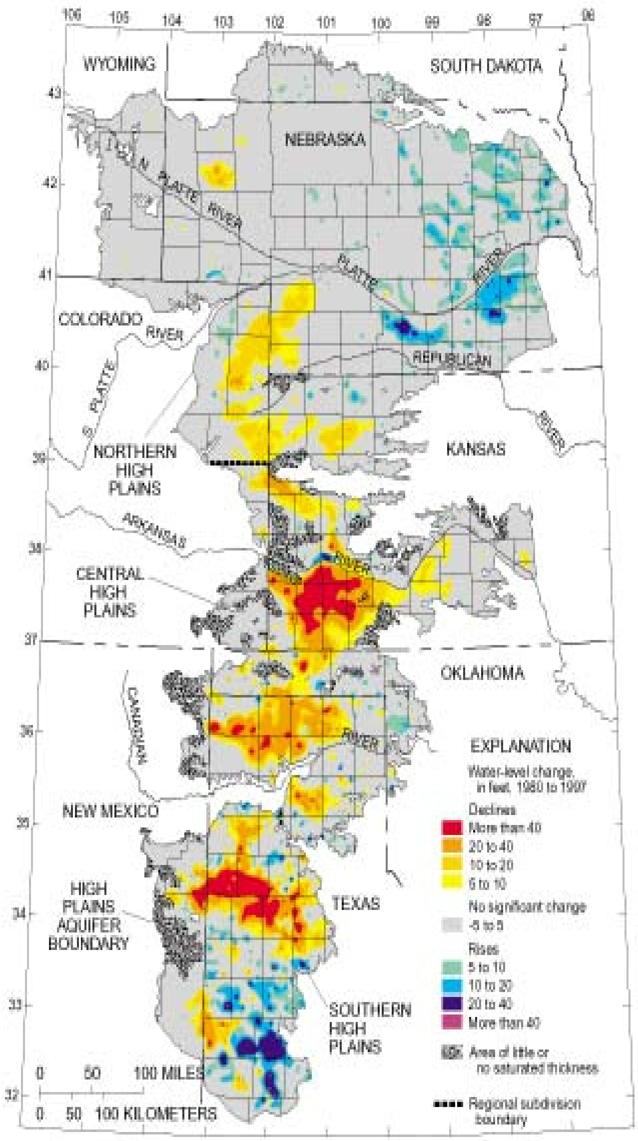


Figure 10. Areas of water-level decline in excess of 40 feet in at least one confined aquifer since predevelopment, and areas of water-table decline in excess of 25 feet in the water-table aquifer since predevelopment.



Source: McGuire et. al., 1999

Unfortunately for policy makers, areas of high population growth such as the southeast and southwest are also areas where water challenges are greatest. These internal migratory patterns are redistributing the population from areas of ample water to areas of water scarcity. Because water is still a cheap commodity, water scarcity is not reflected in home prices and people's decisions to relocate do not usually take water availability into account. USGS drought maps from November 6th, 2008, and June 24th, 2008 provide a snapshot of water scarcity conditions across the nation (Figure 7).This figure shows that major regions of the United States face persistent water crises.

Figure 7: Drought Conditions Across the US

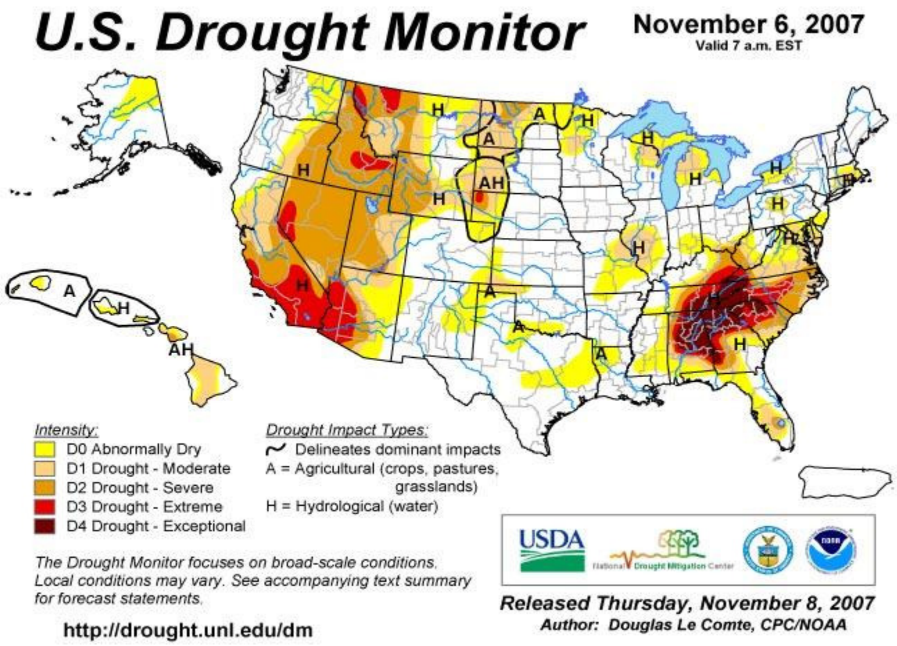


Figure 7.1: Broad-scale Drought Conditions Accross the US, November 6th, 2007

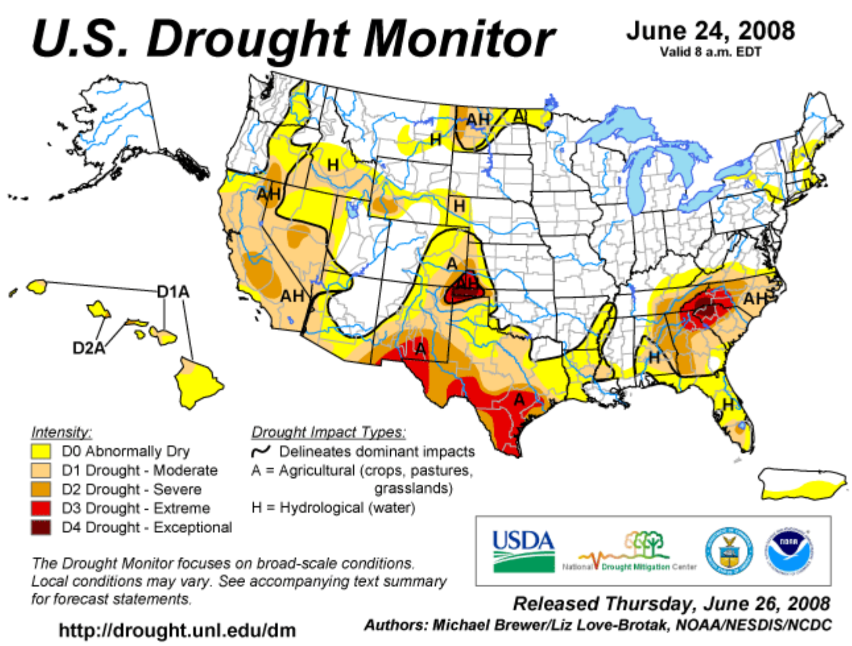


Figure 7.2: Broad-scale Drought Conditions Across the US, June 24th, 2008

Ground subsidence occurs when ground levels sink because a significant amount of water has been withdrawn from the groundwater below. This occurs naturally in unconsolidated aquifers and confining beds that compact due to lack of water moisture. Human withdrawal of groundwater can exacerbate the problem. The USGS reported that approximately 17,000 square miles in 45 states have directly been affected by subsidence due to human groundwater withdrawal (Cunningham and Bartolino, 2003).

Case Study: Subsidence
Joaquin Valley, TX

San Joaquin Valley, CA is one of the largest human alterations of the Earth's surface topography. It resulted in excessive groundwater withdrawal to sustain its agriculture industry. The area is prone to subsidence because of the presence of fine-grained compressible confining beds in the aquifer from the Sacramento-San Joaquin Delta to basins through central and southern California (Galloway et al., 2000).

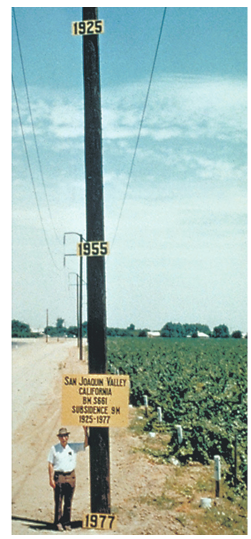


Figure ##. Approximate location of maximum subsidence in United States identified by research efforts of Joseph Poland (pictured). Signs on pole show approximate altitude of land surface in 1925, 1955, and 1977. (Galloway and Riley, 1999).

3. Reliable

The Commission is charged with forming a plan that ensures the safety and adequacy of the water supply in the next 50 years. However, even if there is an ample supply of quality water, there must also be dependable means of delivering this supply to the populations who need it. Reliability means that the water infrastructure must be functional and efficient, and appropriate to the needs of specific locations. As the Commission reviews existing water systems it will make recommendations on the technological, natural and other methods available to ensure a reliable water supply. The Act specifies that the Commission must form recommendations on repairing aging infrastructure, adopting new infrastructure, conserving existing infrastructure, capturing excess water and overall effective management of water systems. In this case, effective management refers to the care and monitoring of water infrastructure. Water infrastructure must be carefully designed, managed, repaired, and updated to ensure that there will be no breaks in water provision and quality.

Conservation

The Act suggests that the Commission focus on conservation methods as one way of increasing and maintaining the water supply. Conservation is a seemly simple method for increasing reliability of the water supply because it should increase availability. However, it will be difficult for officials at the federal level to create water policy that encourages conservation nation-wide, as the regional differences in water availability mean that very different conservation methods are appropriate across the country. There are many conservation methods and technologies in use and being developed. One method is less household use through more efficient fixtures or reduced used on lawns and landscaping. The EPA estimates that over three trillion gallons of water would be saved per year if all homes in the US installed water efficient appliances. Another important area where more conservation methods can be adopted is agriculture, where over 192 billion gallons of water are used each day ("Benefits of Water Efficiency" 2008). Irrigation is a major area of water use. In the year 2000, 137,000 million gallons per day were withdrawn for irrigation. Using more efficient agricultural irrigation practices such as drip irrigation and remote satellite irrigation can help reduce this amount, but currently adoption is not widespread; out of 61,900 thousand irrigated acres, only about 4,180 thousand use microirrigation systems (Perlman, 2005). It will be up to states to determine what conservation measures are appropriate given the watersheds under their control.

Figure 8: Microirrigation water use in the United States

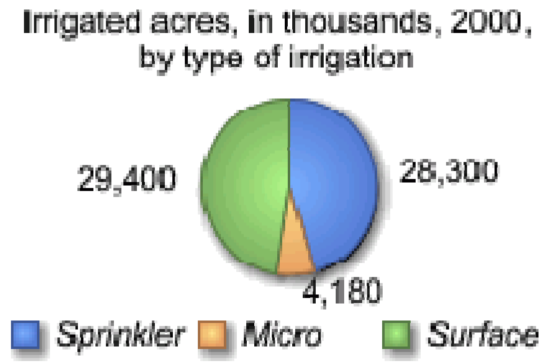


Figure 8: Irrigated acres by type of irrigation,2000.
http://ga.water.usgs.gov/edu/graphics/irrigationtypes2000.gif

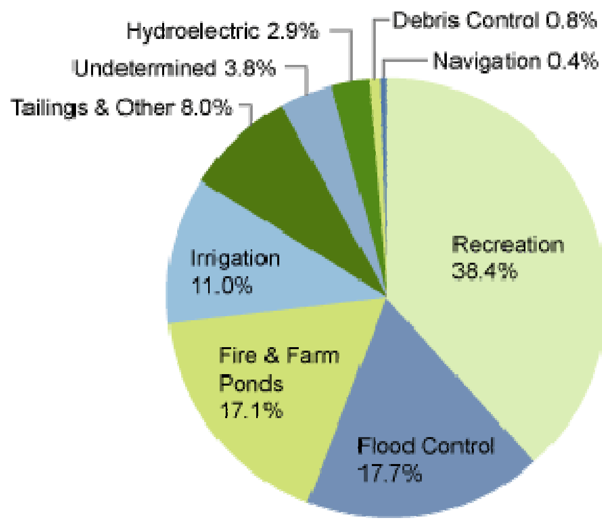
Infrastructure Repairs

The United States already has extensive water infrastructure to meets demands, but this must be maintained and updated. The benefits of keeping infrastructure at optimal capacity include increasing the efficiency of the systems and minimizing water lost through leaks or disruptions. Most importantly, maintaining water infrastructure is necessary in order to ensure the safety and adequacy of the water supply. Ideally all infrastructure systems should be kept in top condition, but in reality large infrastructure repair projects are extremely expensive. As a result, sometimes repairs are delayed or inferior materials or designs chosen to minimize cost. All around the nation, States and municipalities face the problem of what to do with infrastructure once it reaches the end of its useful life. The original infrastructure created in our nation's attempt to harness nature has become outdated and is in a state of decline. Much of the country's current infrastructure, such as the extensive national dam system and public water pipe systems, was built to handle previously anticipated climate patterns and now faces more extreme and variable conditions due to global warming. A brief look at the country's infrastructure situation shows a great need for repair. In order to ensure that the water supply is reliable in coming decades, these areas of improvement and oftentimes replacement are going to have to be prioritized. Current infrastructure needs include:

- **Dams:** provide a wide range of social and economic benefits. They also create reservoirs that supply water for a variety of uses, including industrial, municipal, and agricultural. Ten percent of American cropland is irrigated using water stored in reservoirs. In addition to helping farmers, dams help prevent the loss of life and property caused by flooding. Flood-control dams impound floodwaters and then release them at slower flow rates to the river below the dam by storing or diverting the excess floodwaters. They provide enhanced environmental protection, such as the retention of hazardous materials and detrimental sediments. Throughout the US retaining dams allow for mine tailings from 1,300 mining operations to be with held from entering the environment. The US relies heavily on hydropower. Dams produce over 103,800 megawatts of clean renewable electricity to our nation. The reservoirs and locks created by dams provide for an intricate system of inland river transportation creating shipping routes hundreds of miles inland. Also, dams create recreational facilities: boating, skiing, camping, picnic areas and boat launch facilities are all supported by dams ("Benefits of Dams", 2006).

According to the 2005 update to the National Inventory of Dams there are 79,500 dams in the US. However, like any man made infrastructure dams have a life expectancy. In 2003, 30% of all dams in the National Inventory are at least 50 years old. Approximately 3,243 had deficiencies that left them more susceptible to failure. Approximately one third of the dams in the US pose a "high" or "significant" risk if they fail (Power, 2008). Breaching weakens the structure of the dam and can cause failure within moments or over long periods of time. The potential dam failure is increasing as infrastructures age and storm intensity is increasing with climate change. The Commission will be faced with the daunting task of devising strategies to deal with the issue of aging dams ("National Inventory of Dams").

Figure 9: Dam Use by Category



http://www.fema.gov/hazard/damfailure/benefits.shtm

- **Leaky pipes**: 20-40% of our daily drinking water is lost to leaky pipes. Of these leaks 50% are attributed to post-war piping of lower quality (Hodge, 2008). The Delaware Aqueduct, which provides 50% of New York City's water supply, is currently leaking 36 million gallons of water per day. It can not be shut down for repairs, however, until a third pipe is constructed to supply the water needs of the city. Public water supply infrastructure is in need of repair nationwide, but action is restricted by cost; the EPS estimates it would cost $276.8 billion over 20 years to repair all of the systems in the country ("Drinking Water Infrastructure Needs Survey and Assessment", 2005).
- **Levees**: there is no national oversight of levee systems; the majority of building, repair, safety and control of levees is done on the local level. However, most rivers run though many localities and cross state borders. The nature of levees is such that the condition and construction of a levee system upstream affects towns downstream. This relationship demonstrates the need for some degree of federal oversight of levee construction and repair. A federal overseer would ensure that levee infrastructure can work most

effectively as a single system. The weakness of the system was exposed during the summer of 2008 when severe flooding overloaded the levees along the Mississippi River. The levee infrastructure was insufficient to protect against the high flood levels. The levees were built to a 100-year flood standard, but given the increasing prevalence of severe weather events due to global warming, this standard is not sufficient to protect populations in the floodplains ("Workshop identifies research needs to protect levees," 2007).

- **Wastewater infrastructure**: just as it is crucial that the US have reliable infrastructure to deliver safe water, it must also maintain the infrastructure to remove and treat wastewater. There are approximately 16,000 wastewater treatment systems in the country, and many are in poor condition as a due to lack of investment in repairs and updates. Blocked or broken pipes result in sanitary sewer overflow (SSOs), releasing in as much as 10 billion gallons of raw sewage into water bodies each year. Older systems in need of repair are unable to handle major storms or snowmelt, resulting in combined sewer overflows (CSOs) the discharge of untreated wastewater directly into water sources, an estimated 850 billion gallons per year ("Impacts and Control of CSOs and SSOs", 2004). The EPA estimates that the cost to replace existing wastewater systems and build new ones to meet demand will be as much as $390 billion over 20 years ("Budget", 2005)

New Technologies

In its assessments of water systems the Commission will have to consider new technologies becoming available for water infrastructure. New technologies may have high potential to help alleviate stress on the water system, but many new technologies are extremely expensive and have not yet been proven to the level of confidence required to be adopted on large scales. The Commission is assigned to explore all available technological methods for alleviating the nation's water problems. By finding the most appropriate technological solutions for providing safe and ample water, water managers can also insure that the sources are reliable. No single solution, technological or otherwise will solve all of the country's problems. Different solutions will be appropriate for different problems in different locations. In many situations combinations of technologies and management strategies will be optimal to address regional-specific problems. The Commission will need to have a thorough understanding of the many options available in order to successfully make recommendations to water managers on maximizing the reliability of the water supply.

Appendix B: Technologies for improving safety adequacy and reliability of water supply.

4. Sustainable

The focus of the Act is to ensure that water supplies are safe, adequate and reliable, not only in the present but also into the next 50 years. For this goal to be achievable, water use must be sustainable: more water cannot be used than is available. In this sense, sustainability is a management issue; water resources must be carefully managed to ensure that demand does not outstrip supply. Additionally, avoiding contamination will be paramount to ensuring that freshwater systems are not damaged or depleted beyond repair. The Act is explicit in insisting that the Commission study existing management strategies and consult experts and managers representing Federal, State, Interstate, and local agencies as well as those from the private sector. The study will have to integrate complex management strategies with scientific observation and data analysis in order to regionalize sustainability strategies. In terms of applicability, this is especially important given the variation in the water supply and demand across the nation. The means to achieve sustainability are dependent on the regional context.

Sustainability is an end. At the community level, sustainability is going to be achieved by effective management. In this case, that means creating and enforcing a trend toward a sustainable freshwater use. However, due to climate change, achieving sustainability will be like shooting at a moving target. As the climate changes, dry areas are predicted to become drier, creating more variability in available water supply (IPCC, 2007). This means that in order to compensate for the predicable change in environmental conditions, a sustainable water management plan will have to include adaptive management strategies with considerable contingency components. In terms of management, within each local area sustainability should be centered on individual behavior. All regional and national sustainability programs and initiatives will fail if the individual is not given the proper reasoning and incentives to conserve water sources.

Defining Sustainability

Local

For local municipalities, the entire idea of water management will have to be restructured to focus on ensuring water availability for the community. In order to asses how to accomplish this goal, ongoing collection and use of hydrologic data will be necessary. To implement the national strategy, the report will likely recommend successful building code practices, such as installing low flow technologies in the home, reducing watering of lawns, reducing evaporation of reservoirs, aqueducts, and fixing leaky infrastructure. For examples, in the case of cities in arid climates, residents could be prohibited from having large, grassy lawns or swimming pools. As maximizing use of available water becomes more important there will be a greater emphasis placed on keeping chemicals and contaminants out of the hydrologic cycle. In terms of sustainability, more clean water means more water available. This is an important concept for localities to address. In the report the Commission will share the best management practices that lead to the highest conservational measures and prevent the most pollutants from entering freshwater sources.

Regional

- **Infrastructure**

  State and regional authorities must improve infrastructure design and reliability in order to implement new technologies, which will help achieve water supply sustainability. Efficient and effective drinking water treatment plants, sewer lines, drinking water distribution lines, and storage facilities will ensure protection of human health, access to clean water, and enable ecological sustainability as well ("Sustainable Infrastructure for Water and Wastewater", 2008). Providing clean water efficiently not only benefits humans, but ecosystems as well. Maintaining sustainable management practices in terms of infrastructure can free up more water for ecosystems, which in turn have the ability to provide services, such as microclimate regulation and natural filtering. Using natural processes to take care of some water filtering processes may reduce the capital outlays required to provide clean drinkable water for the public supply.

- **Management Cooperation**

  The other critical component of reaching sustainability is achieving regional cooperation regarding shared water sources. Common pooled resources are often overused if left unregulated. Assessing and monitoring the condition of these common resources through integrated data monitoring networks will help predict and respond to water resource problem areas. As scarce water resources become more stressed, setting up legal frameworks to ensure equity in water distribution will be necessary. In the high plains, state water laws and local groundwater management districts regulate groundwater withdrawal (Peterson, 2003). Currently, these states have different regional cooperation strategies on effective use of large water sources. Creating common frameworks for water management will ensure that water resources are equitably distributed to meet the needs of all stakeholders.

National

The report may recommend that the federal government create coordination between policies to improve water quality and quantity. Through this process, a focus on multi-objective-optimization would ensure sustainability water quantity and quality. For the US, this would mean allocation cooperation will become coordination of water use. This comprehensive resource planning takes into account the impacts that other policies have on water resource uses and attempts to address any conflicting incentives or resource conflicts that may be created as a result. For instance, the EPAct of 2005 encourages the use of agricultural based ethanol and biodiesel in the transportation sector by providing financial incentives to make ethanol production facilities functional by 2010 (EPAct, 2005). Currently, 93 million acres of corn are planted annually and 14.3% of that is used for ethanol production (Morrisson, 2006). Converting land to agricultural production increases the demand on water supply as well as increases the risk of non-point source pollution. Water-use incentive polices must be addressed comprehensively in order to create an effective national water plan that leads to sustainable resource use.

Over the long run, sustainability begets stability. The commission will do well to outline the policy mechanisms that create sustainability and the changes that will be necessary to make them possible. In this case, it may turn out that atypical management ideas are the most efficient for a particular watershed. This could lead to recommendations that eliminate the idea of state and regional water management in favor of watershed and aquifer based management. This would be done to achieve the most cost-efficient infrastructure and sustainability management plans. Additionally, using advanced management frameworks would help avoid large aquifer draw downs and resource conflict in a much more effective manner. However, implementation of atypical water management frameworks will be dependent on regional and local acceptance of widespread change in current water management organizational structure. Unfortunately, the policy which would likely be most scientifically valid and successful in achieving sustainable water use would politically be the most difficult to implement.

III. Issues and Controversies

Science will be key in mitigating water problems in the Twenty-First Century, however, it is also important that the Commission understand the nature of science and the controversies that arise due to scientific uncertainty or misunderstandings. Issues and controversies will arise in two ways. The first is through disagreements among the scientific community over what constitutes "good science" and the second is through the conflict between science and the arenas of politics, economics and social values. The Commission will be most successful in forming a comprehensive water strategy if it acknowledges these controversies. Additionally, the Commission will have to take care to conduct as many studies as possible to cover the range of scientific findings and communicate its recommendations to politicians, economists, and members of the general public in a clear and understandable way. To create a useful report and viable strategy, the Commission will need to continually underscore the importance of science in maintaining the water supply and in making the wisest possible decisions.

Controversy within the Scientific Community

Issue: Quantifying Water Supply

Quantifying our water supply is instrumental in developing a policy to preserve our nation's freshwater resources. However, different methods for quantifying water supply may produce differing pictures of water availability in the United States. When focusing on water supply for the US as a whole, it may appear that we have an abundance of water. The continental US receives 1,400 billion gallons per day (bgd) from rainfall, retains 280,000 bg in reservoir capacity and stores 28,000,000 bg in groundwater systems (Frederick, 1995). According to this measurement, of this available water the US uses 408 bgd and only 94 bgd of the water used is consumptively lost. These numbers equate to an adequate supply of water for the US over the next 50 years (Center for Sustainable Systems, 2008). However, these numbers are estimates and do not reflect the uncertainty in our ability to precisely measure water availability. Additionally, these figures do not take into account regional distribution of water.

Inadequate scope of water quality analysis in large estimates gives rise to controversy surrounding the issue of water availability. Regionally, water supply is not evenly distributed; some areas experience floods while others suffer from regular drought. In June 2008, floods in the Midwest claimed 13 lives and cost an estimated $8.5 billion dollars. The total cost of the flood has not yet been accounted for, but is expected to surpass the 1993 Missouri River flood damage total of $12 billion dollars (Feldman, 2008). In contrast, the Oklahoma Panhandle was granted disaster relief funds in July 2008 to cope with record drought conditions; the area has received only 18% of the average rainfall it normally receives (Littlefield, 2008).

Water availability varies temporally and spatially across the US and is reflected in long-term weather patterns. Seasonal variations generally lead to a surplus of water in the US during spring, fall, and winter seasons when rainfall is relatively high and usage is low. However, some regions, especially in the south and west of the nation, experience drought during the summer months when rainfall is low and usage is high. The Commission must face the issue of regional and seasonal variations in water availability across the country. Despite shortcomings, national statistics paint an accurate picture of current water quantity issues across the country. The uneven distribution of water gives rise to interstate controversies when drought stricken states struggle over limited regional supply. Increasing population and global climate change have already increased weather variability and according to the IPCC report on climate and water, will likely exacerbate these problems through increasing demand and intensifying extreme weather events such as drought in the future (Bates, 2008).

Issue: Difficulty Predicting Climate Change

For the past century, the US has faired well in predicting water availability patterns to know when to plant, conserve water, regulate reservoir capacity and harvest crops. However, recent decades have shown greater variability and intensity of weather events. This puts significant attention on the issue of weather forecasting. The primary contributor to climate change is global warming, which is causing increased evaporation rates of surface water and low mountain snowpack that feeds major rivers (Egan, 2001). Climate change stems from increased radiative forcing due to accumulating greenhouse gas concentrations. The increase in temperature directly impacts climate system patterns, including precipitation and evaporation rates, the determinants of surface and groundwater levels ("Climate Change: Basic Information," 2008). In order to plan ahead for changing water availability patterns, governments and industries dependent on water have turned to scientists for projections of future climate patterns.

Weather predictions come in different levels of accuracy. Currently, short-term forecasting can provide high resolution predictions up to three months in advance and long-term predictions provide broad resolution data about our future. Long-term predictions, looking ahead 50 to 100 years, continue to improve, but they are subject to controversy (Redding, 2008). Long-term predictions are based on models that extrapolate from past records and attempt to account for multiple variables to predict future climate patterns. Due to the virtually unlimited number of variables and difficulty predicting each independent variable there are an unlimited number of model predictions. However, there are still large numbers of models that show similar trends or that can be averaged together to provide an agreeable estimate for the long term future. The resolutions of these long term predictions: "are not necessarily about specific weather events, but they do give us a good idea about what kind of weather to expect over the long run in a particular part of the country," claims Noah S. Diffenbaugh, member of the Purdue Climate Change Research Center (Boutin, 2005). On June 28, 2008, climate modeling scientists met in Aspen to discuss short-term climate predictions for the next decade. The meeting was called together by concerned parties such as skiing and agricultural industries who have economic interests in these predictions. When asked, scientists say it is hard to make short-term predictions, but some skeptics say that climate scientists are unwilling to stake their reputations on predictions that will be proven or disproven within their lifetimes (Redding, 2008). The variation in competing predictions models is clear (Figure 10).

Figure 10: Climate Change Projections

9.1 9.2

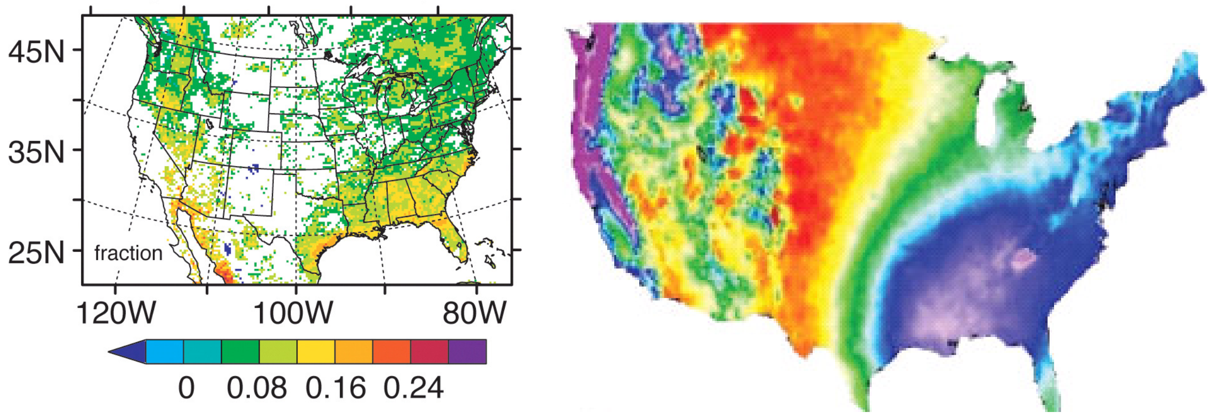


Figure 10.1 Community Climate System Model of precipitation patterns. The lighter colors indicate (red) drier conditions and darker colors (blue) indicate wetter conditions.
Figure 10.2: Diffenbaugh's precipitation model for the next century.

Issue: High-Tech versus Low-Tech Systems

Another controversy related to preserving and increasing the water supply falls within the debate between those who believe technological systems are the best remedy for meeting water demand and those who prefer low-tech or non-technical solutions. Natural systems still play a valuable role in our water supply. Most treatment plants mimic and enhance natural nutrient and toxin removal systems. Natural systems such as wetlands offer many auxiliary benefits to water systems such as absorption of excess water during storm events and erosion buffers. Increasingly, such systems have been developed as prime real estate for aesthetic or agricultural purposes over the last century. The loss of these systems has led to a decline in the function of our water system as a whole. Society has tried to counter natural system loss with its own man-made infrastructure of dams, levees, treatment centers, and pump stations. Currently, States are developing a new appreciation for the water quality services that natural systems provide and are exploring ways to preserve the remaining wetland ecosystems or discover ways to create systems that duplicate their functions (Edwards, 2003). After losing over half of these natural systems, research of the economic benefits of keeping the remaining natural systems versus replacing them with man-made infrastructure is beginning (Status and Trends, 2006). This assessment will prevent the use of valuable natural ecosystems for alternative purposes. Classifying and placing monetary value on these natural systems is a growing debate because nature provides such a wide range of functions. Florida recently spent $1.7 billion dollars in a campaign to save the Everglades (Kleinberg, 2008).

On the other side of the controversy are the technological optimists. Many believe that technological solutions are the best option given the complexity of water issues in the United States and beyond (Porcelli, 2003). However, some of the technology currently in development is still at an early phase and is not nearly ready for wide scale implementation. One plan is being tested in Utah to alter the effects of shifting precipitation patterns. The process of cloud-seeding is being studied as a viable solution to decreasing rainfall. Cloud-seeding works by injecting a super cooled compound into the atmosphere such as silver iodide. The compound cools the air which induces condensation and freezing of water vapor to form clouds and increase rain or snowfall. Cloud-seeding has shown increased rainfall in certain regions by artificially creating rain clouds (Griffith, 1991). China has been using this technology for decades over its dry northern and western plains to increase rainfall, and is now planning on using the technology to control weather and clean the air during the 2008 summer Olympics (Associated Press, 2007). However, using cloud-seeding to increase the amount of clean water available is still questionable. It is difficult to distinguish increased rainfall results from natural variability. The Commission will have to discern which options are fully developed and applicable, what technologies in development will be feasible for use in the US and what the costs of these technologies are. In order for the Commission to be successful it must develop a strategy that incorporates new technology but takes into account the costs and difficulties of adopting unproven technologies. No state can be expected to easily make a large investment in technology that is not yet proven.

Economic, Social and Political Issues

Issue: Public Perception

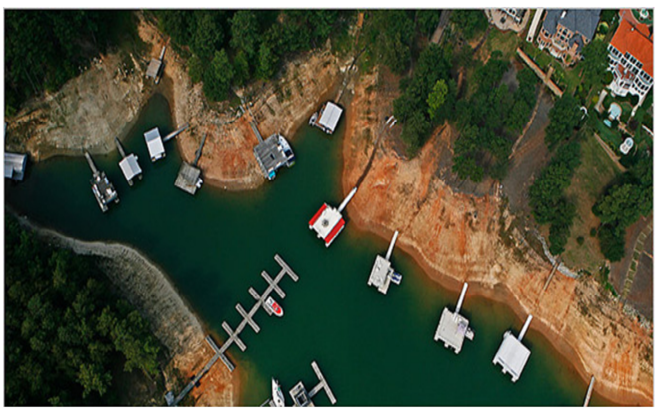
Another potential issue arising in the national water strategy is the public perception of new technologies employed in maintaining the water supply. Wastewater recycling is a new method used for treatment in which water is treated on different levels; primary, secondary, tertiary, osmosis and UV treatment. This treatment is energy and labor intensive, but yields an extremely clean, consumable product. The current operational cost of these new facilities is approximately $550 per acre-foot (Weikel, 2008). This is slightly higher than the upper limit in a wide range of historic treatment costs which reach as high as $500 per acre-foot (Lightfoot, 2008). However, the recycled water process yields a product cleaner than most cities' drinking water. The EPA estimates the average cost to treat and deliver drinking water using traditional systems at about $680 per acre-foot. This cost is considerably more than the new treatment technology but is somewhat misleading; only 15% of the $680 is used for treatment and the rest goes to transport ("Cost accounting and budgeting for improved wastewater treatment", 1998). The current process uses significant amounts of energy for pumping drinkable water far away into an aquifer because public opinion deems it unacceptable to drink recycled water directly from the treatment facility (Cavanaugh, 2008). The recycled water is already within the municipality and it requires far less money to deliver it to nearby users than removing it to a distant reservoir. By using recycled water within the city, the cost of transport is cut down as well as the treatment price. Ultimately, this leads to a cheaper, more efficient water system (Weikel, 2008). The Commission will have to take public perception into account when promoting water management strategies, and will have to carefully convey messages to constituents about the safety and benefits of treated and recycled water.

Issue: Science versus Politics

A key responsibility of the Commission is establishing a water resource management system that spans State borders. Issues that the Commission should keep in mind during this process are that different states have different definitions of clean water for each of its different uses. Additionally, increased usage coupled with global warming is stressing the existing water supply (Hutson, S.S., et al., 2004). This amplified usage creates more situations where one community's wastewater is entering another's water source ("Water Data Program," 1995). Wastewater from industries and municipalities is used and filtered in many different ways and discharged into different systems. Currently, wastewater from various areas is required to meet minimum levels based upon EPA determined standards, which vary dependant on the sources of the wastewater. States also apply their own standards, which must meet or be more stringent than EPA standards, which are established by the Clean Water Act. Many of these limits are based on the current level of technology and the cost associated with bringing water to a certain level of purity. In many cases standards are not met because technology is outdated (Willis, J., 2000). Improving technology and creating a unified quality of drinking water standard could lead to the development of more appropriate nation wide standards.

Case Study: Water Stress and Conflict between States

Decreasing water supplies from intensifying droughts, coupled with urban growth, can lead to disputes over shared water resources.



The Atlanta Journal-Constitution

Over the past few years, drought has been intensifying in the Southeast region of the U.S. Recently, serious conflicts among Georgia, Alabama, South Carolina, and Florida have emerged over water rights, which had to be resolved in the Supreme Court. With increasing demand from growing urban areas and decreasing precipitation due to climate change, conflicts like these are likely to continue to happen into the future.

(Goodman, 2008)

Issue: Science versus Economics

Costs of replacing old infrastructure and adopting new infrastructure

All around the nation, States and municipalities face the controversy of what to do with aging infrastructure. The original infrastructure created in our nation's attempt to harness nature has become outdated and is in a state of decay. Uncoordinated development has led to a patchwork system rather than a coherent one. Much of the country's current infrastructure, such as the extensive national dam system and public water pipe systems, was built to handle previously anticipated climate patterns and now faces more extreme and variable conditions due to global warming. In the past, our nation has mistakenly sacrificed planning and reliability for cost. We now face the challenge of replacing these systems. One of the primary reasons for delaying the replacement of inefficient infrastructure is cost. The estimated cost for the US to replace its plumbing system is $277-480 billion dollars (Long, 2008). As demand for water grows, so will its cost; eventually, it will be more efficient to replace the leaky municipal water pipes and shift to more efficient technologies.

Other technological advances can help preserve the water supply. As we use more land for infrastructure, we tend to reduce ecosystem functions. Paved surfaces and buildings cannot absorb runoff as well as natural surfaces. As a result, man-made surfaces tend to increase flash flooding and combined sewer overflow incidents (Fiegel, 2008). There are multiple methods for coping with increasing water problems in the case of combined sewer overflow. Some municipalities have turned to permeable pavement, green roofs, catchment basins, or a combination of methods to control excess influx of polluted water to sewers during heavy rainfall events. Permeable pavement, such as found in Chicago, allow rain water to enter the groundwater system as it would naturally, reducing flooding, increasing groundwater recharge and naturally filtering water (Fiegel, 2008). Catchment basins, like the ones found in New York, offer alleviation of flooding but do not activate any natural process (Plumb, 2008). The Commission should be aware of the pros and cons of the options available and where options will be most practical.

Issue: Science versus Society

Water supplies are threatened in areas where water recharge is low but demand is high. Areas where recharge is low are attractive for agriculture because of the soil quality and amount of sun; however, many of these regions are also among some of the driest. Some of these areas are also undergoing the highest population growths. According to the Negative Population Growth (NPG) database, Nevada, Arizona, Georgia, and Colorado have seen the largest growth over the past decade; at the same time these States are facing severe water shortages. Additionally, climate change may only amplify the already desperate conditions in many regions, making dry areas drier and wet areas wetter.

According to current predictions by the Intergovernmental Panel on Climate Change (IPCC) water systems will be under increasing pressure spurred by global warming and population trends. Climate change will not affect all regions equally; some will experience increased precipitation while others will suffer increased drought (Bates, 2008). Diversion from wet regions to dry regions may be a solution, but political entrenchment, proper planning, and economic problems will be the primary issues in implementation. Large water systems spanning interstate borders, such as the Missouri River, have been harder to manage given changing climate patterns and different water flows in different regions (Prato, 2003). Alleviating this pressure by discouraging further settlement of arid regions and building in historical flood plains and encouraging more conservative water practices are social changes that would be controversial and hard to implement without mass public support. Technology and understanding of water supply and demand combined with projections of future water availability suggest that water intensive development in arid regions is not a sustainable practice; however, the general public will most likely be adverse to restrictions on where they can or can not live.

IV. Conclusion: Measuring Success

With respect to the legislation, the success if the Twenty-First Century Water Commission Act of 2008 is defined as meeting the goals of a safe, adequate, reliable and sustainable water supply. The Commission must address these goals through a four part strategy comprised of effective management, repairing current infrastructure, utilizing new technology, and conservation. At the broadest level, the goal of the Commission is to address the freshwater needs of the country in terms of quantity and quality of water. Therefore, measuring the success of the national water strategy will be done through indicators of quality and quantity and the reliability of freshwater infrastructure in providing access to these supplies. If these goals are met in 50 years, it will in itself be the indication that the nation has achieved sustainability in its freshwater use.

The Commission must consider not only current water quality and quantity but also future projections. As a result existing indicators may not be adequate in evaluating success. Therefore, measuring program success will also depend upon using existing water quantity and quality indicators and developing new ones based on models of future water supply and demand. A major challenge the Commission will face when determining indicators of success will be reconciling differences between national and federal standards. Federal water guidelines are issued through the EPA under authority of the Clean Water Act and the Safe Drinking Water Act. While the guidelines are issued by the federal government, water management and implementation is done at the local and regional levels. The current arrangement has led to the development of a varied set of standards for measuring water quality and quantity that differs between regions as a result of differences in climate, geography, needs, priorities and funding (Keller, 2008).

The delisting and listing process under the CWA is one example of standard variations among states despite national federal guidelines. In the case of Alabama and Colorado, the difference in listing was the result of variations in methodology and sampling. Alabama listed a creek in 1992 for exceeding the fecal coliform based on a single incidence of excessive levels in the water while in Colorado, a listing was based on data collected 229 times over a six year period (Keller, 2008). In addition to standard variation between states, there is also the problem of decentralized data collection that poses a difficulty when forming a national strategy. These variations should be addressed to measure success of the program accurately.

Challenges

A major challenge in determining the success of providing a sufficient quantity of water is the lack of centralized withdrawal data available. According to a US Geological Society Report to Congress, data for withdrawal rates are available but scattered throughout State and Federal agencies including the Department of Agriculture, Bureau of Economic Analysis and Bureau of the Census. In addition many local agencies and non-profits collect withdrawal information. Without a central database of information it will be difficult for the Commission to assess national freshwater trends and form a strategy for sustainability. In addition, much of the available information is outdated. For instance, the last major groundwater assessment was the USGS Regional Aquifer System Analysis between 1978 and 1995. ("Report to Congress", 2002). The tasks assigned to the Commission include compiling as much information as possible and conducting new studies for use in recommending water management strategies.

Quantity Indicators

Currently, the USGS monitors indicators that determine quantity on a daily basis at its 8,682 sites in 21 different water resource regions ("Surface Water", 2008). Current indicators that are monitored are stream levels, streamflow discharge, rainfall and runoff rates. Much of this information is affected by climate patterns and geographical variation, making it important to compile regionally-specific data (Backlund et al, 2008).

Another measure of the amount of water available is the amount that is withdrawn for use. The average U.S. household uses 50 to 85 gallons per day to meet domestic needs. If other needs dependent on water are factored in, such as the water used to grow food crops, 1,200 gallons are needed to sustain each American ("Water Supply", 2005). Sustained demand at current levels will not be possible if adequate water supplies are to be maintained for future generations. The Commission will have to compare data on the specific quantity of water available and hydrological data with data on human consumption to truly measure adequacy and the sustainable use of freshwater sources. Sustainability requires that the removal rate of freshwater does not exceed the replenishment rate. This lends particular importance to monitoring groundwater levels, as the absolute amount of usable water in aquifers is not well known and they are typically replenished must more slowly than surface water bodies. This is even more important because the US has been increasingly relying much more heavily on groundwater. In 2000, there was a 14% increase in groundwater withdrawal compared to 1985 (Hutson et al, 2004).

Consumption can also be monitored as a proxy for the effectiveness of conservation efforts. In 1998 Las Vegas passed a law that provides $1.50 per square foot of lawn removed from residential or commercial properties. Measuring success in this case would involve monitoring the effectiveness of such incentives in reducing water consumption in the residential sector (Southern Nevada Water Authority, 2008).

Quality Indicators

Human activities degrade water quality through intensive agricultural and industry activities. As a result of anthropogenic activities, many of natural water systems have been damaged. In the National Coastal Condition Report, estuaries and the Great Lakes were examined for overall national condition and all six of the major regions were either in poor or the low range of fair conditions ("Overall Condition of Estuaries and Great Lakes 2000", 2001). Indicators used included water clarity, dissolved oxygen, levels of pollutants (organics and inorganic) and eutrophic conditions. The Commission can use these indicators to track progress in water quality improvements in surface and groundwater bodies. However, improvements can only be made if the causes of quality degradation are monitored as well.

In 2006 US farmers used more than 21 million tons of nitrogen, phosphorus and other fertilizers that made their way into the Mississippi river and eventually into the Gulf of Mexico (Walsh, 2008). In addition, urban runoff and sewage is ejected into many of the nation's surface water bodies. New York is one of many cities that has old infrastructure with a combined sewer overflow (CSO) system. When there are major storm events, excess stormwater that cannot be treated is directly ejected into the Hudson and East Rivers as CSO. The reduction of pollutants, both point and non-point source, entering freshwater sources is an important indicator of success for the national water strategy. The Commission will have to decide whether current acceptable contaminant levels are adequate or if new standards should be formed.

The indicators that the Commission will use to determine the success of its freshwater management strategy are primarily monitoring mechanisms; it will become important to not only monitor but respond appropriately to the outcome of the solutions. Adaptive management of the strategy will become essential. Through program success indicators for water quality and quantity, we will be able to monitor how the Commission's goals are being met across the country and determine how to best address these issues on a regional basis to provide a plentiful and clean freshwater supply to Americans for the next 50 years.

Conclusion

The Twenty First Century Water Commission will be assigned a challenging task. A comprehensive national freshwater strategy will have to take into account regional variability, localized control, and the interconnectedness that characterizes the nation's freshwater sources in making recommendations on achieving a safe, adequate, reliable, and sustainable freshwater supply for the next 50 years. This task will be understandably difficult, but if the Commission is successful, it will be an achievement that helps secure the nation's freshwater supply and avoid future problems of scarcity and interstate conflict over freshwater resources. The success of the Commission can be determined by whether it is capable of compiling the most accurate and comprehensive information to make recommendations that will assist freshwater managers in critical decision-making processes that will secure the nation's freshwater supply. The success of the Twenty-First Century Water Commission will ultimately be measured by the availability of clean, plentiful water for the entire United States over the next 50 years.

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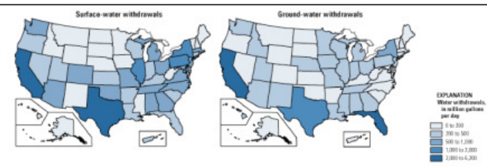
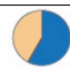
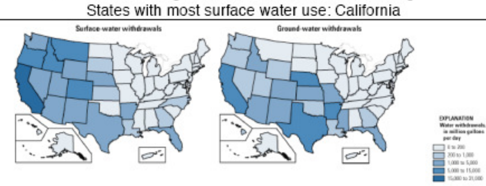
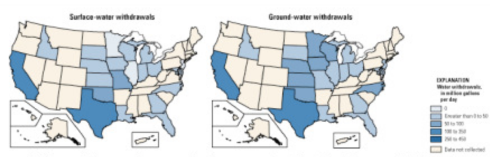
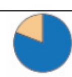
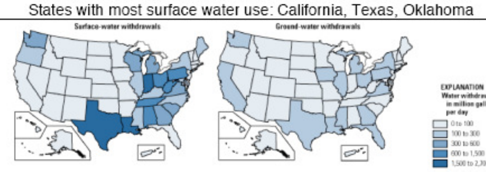
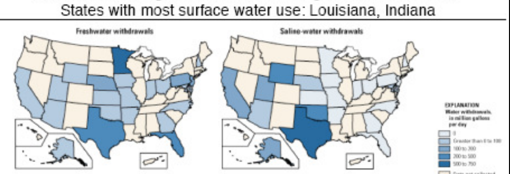
Appendix A: Overview of Freshwater Consumption in the US by State

Category	Description	Examples of Use	Amount consumed (Mgal/day)	Water withdrawals in the U.S., 2000 (Surface water withdrawals, in percent) Surface water / Ground water	Distribution of water usage
Public Consumption	water withdrawn by public and private water suppliers that furnish water to at least 25 people or have a minimum of 15 connections.	Drinking fountains, public pools	43,300	 63%	 States with most groundwater use: California, Florida States with most surface water use: California, Texas
Domestic	water used for indoor and outdoor household purposes	Drinking, bathing, toilets	3,590	 2%	 States with most groundwater use: California, Michigan States with most surface water use: California
Irrigation	water use includes water that is applied by an irrigation system to sustain plant growth in all agricultural and horticultural practices.	Field prep, harvesting, golf courses, landscaping	137,000	 58%	 States with most groundwater use: California, Texas, Nebraska States with most surface water use: California
Livestock	water associated with livestock watering, feedlots, dairy operations, and other on-farm needs.	Dairy, beef and poultry	1,760	 43%	 States with most groundwater use: California, Texas, Oklahoma States with most surface water use: California, Texas, Oklahoma
Industrial	water used for such purposes as fabricating, processing, washing, diluting, cooling, or transporting a product; incorporating water into a product	Food, paper, chemicals, metals	19,700	 81%	 States with most groundwater use: Georgia, Louisiana, Texas States with most surface water use: Louisiana, Indiana
Mining	water for the extraction of minerals that may be in the form of such solids as coal, iron, sand, and gravel	Quarrying, milling, oil recovery	3,490	 62%	 States with most groundwater use: California, Alabama, Oklahoma, Texas, Wyoming States with most surface water use: California, Texas
Thermo Electric Power	water used in generating electricity with steam-driven turbine generators.	Cooling system in dams	195,000	 100%	 States with most groundwater use: Illinois, Texas, Tennessee States with most surface water use: California, Florda

http://pubs.usgs.gov/circ/2004/circ1268/index.html

Appendix B: Overview of Technological Options

Technology	Product	Description	Where Applicable	Pros/cons
Desalination	Clean water, hypersaline brine water, high energy consumption	Saltwater is forced through a microscopic membrane, only water and not its dissolved ions pass through	Near the ocean, cost increases with the distance sea water must be pumped and the lack of space to put brine water	Clean water from salt water/high energy consumption, brine
Injection	Water into aquifer is filtered by natural processes	Water is pumped back into an aquifer that public water is drawn from, it is filtered by natural processes similar to granular filters	Anywhere there are ground water shortages or high groundwater extraction rates combined with water scarcity	Clean water by natural filtration recharge depleted water table has ecological benefits and water security benefits/water must be highly treated before injection
Granular filter	Particulate free water	Granular filtering medium removes contaminants as the water passes through	Anywhere the incoming water needs to have suspended contaminants removed	Effectively removes suspended contaminants /does not effectively address other forms of contamination
Fiber filter	Particulate free water	Fiber filtering medium removes contaminants as the water passes through	Anywhere the incoming water needs to have suspended contaminants removed	Effectively removes suspended contaminants /does not effectively address other forms of contamination
UV disinfection	Sterile water	UV light is used to destroy bacteria, and sometimes chlorine species	Anywhere bacterial contamination is a problem	effectively removes suspended contaminants /does not effectively address other forms of contamination
Distillation	Pure Water	distillation removes many if not all contaminants from the water	Anywhere chemical and bacterial and viral contamination exist and a single solution Is needed	effective purification/high energy requirements to distill water
Fog catching	Pure Water	nets condense fog water into drinkable water	Supplies where new water that was not previously available for extraction	Creates new water supplies/not very much water created, requires fog (regionally limited)
Rain catchment	Landscape and grey water uses	Catchment systems collect rainwater and stores it for later use	In rainy areas. Offsets use of potable water effectively reducing consumption	Creates new water supplies/limited by the amount of annual precipitation
Cloud seeding	Potentially increased precipitation	Sulfur nitrate causes clouds to precipitate	Areas with low precipitation	Creates new water supplies/ not proven/ unpredictable
Ozone	Sterile water	Ozone destroys bacteria	At point source bacterial decontamination	Removes bacteria/other contaminants remain
Wetlands	Cleaner water, Ecosystem services	Natural processes filter and purify water	Many places where natural wetlands exist/ existed	Provides ecosystem services regenerates ground water/ not purified to drinkable

Technology	Product	Description	Where Applicable	Pros/cons
Catchment ponds	Water infiltrates and is purified by natural processes	Natural processes filter and purify water	Urban areas to catch runoff and filter	Filters contaminated runoff, centralized around storm events
Erosion controls	lower sediment concentrations and lowered sediment entry into water bodies improved water quality, lower silting	coconut bales, sediment traps, and hydro seeding prevent soil contaminants from entering water body	Ranches, construction sites, changing land use zones	prevents water contamination/ complicated to implement in everywhere that sediment pollution exists or to find the right place to implement
Infiltration basins	more water available for ecosystems or groundwater table	Natural processes filter and purify water	Urban areas to catch runoff and filter	increases water available for ecosystem use and in the groundwater table/ take up valuable urban real estate
Bioswales, green spaces	More water available for plants or groundwater table	Natural processes filter and purify water	Urban areas to catch runoff and filter	Filters contaminated runoff, feeds water to ecosystem / not as effective at creating water availability or increasing quality as other methods
Water Reclamation	30% pure water if primary treated, 70-80% pure water if secondary treated, drinkable water if tertiary treated	Mechanical, biological and chemical filtration methods are used to remove human and industrial contaminants from water	Anywhere significant waste water amounts are generated by humans or industry	Clean water, variable levels of treatment depending on investment/ expensive, require extensive infrastructure and monitoring, and power hungry

Adapted from United States Geological Survey: www.usgs.gov

Appendix C: Glossary

Adequacy: In the context of freshwater, adequacy refers to the supply of satisfactory quantities of freshwater for the nation's various needs.

Aquifer: An underground layer of permeable rock that contains, receives, and discharges freshwater.

Conservation: The practice of reducing water consumption through more efficient technology or improved methods and behaviors.

Effective Management: In the context of the bill, it refers to the collaborative nature in which water needs to be managed in order to avoid transboundary conflicts and achieve equitable gains.

Erosion: The movement of surface solids due to the force of moving water. In particular, this relates to the loss of topsoil that is useful for agriculture and the movement of nutrients and contaminants into freshwater systems via displacement from the ground.

Eutrophication: An increase in an aquatic or coastal ecosystem's primary productivity as a direct result of increased nutrient loading into that ecosystem.

Groundwater: Freshwater located beneath the ground surface in soil pore spaces and rock formations.

Hydrological Cycle: The closed system on earth of water movement in various phases due to evaporation, precipitation, runoff, and flow.

Infrastructure: In the context of water, it refers to man-made structures designed to store, transport, purify, or treat water.

Irrigation: The artificial application of freshwater to soils.

Pollution: The introduction of harmful contaminants into the environment.

Recharge Rate: The rate at which a freshwater system, such as an aquifer, receives water annually from upland flow or percolation.

Reliability: In the context of freshwater, it refers to the ability of infrastructure to constantly supply adequate quantities of freshwater to society's end-users.

Redundancy: The duplication of critical components of a system to increase reliability in case of future failures.

Safety: In the context of freshwater, it refers to the provision of freshwater with appropriate quality for drinking or other purposes.

Saltwater Intrusion: The mixing of freshwater with saltwater due to a drop in freshwater levels inland or an increase in sea level, increasing saline content in water.

Stormwater Runoff: Freshwater from precipitation that flows into local waterways or sewer systems, carrying soluble and insoluble materials with it.

Subsidence: The sinking of land surface due to decreased water pressure and loss of moisture content in soils resulting from heavy withdrawals.

Surface Water: Any freshwater at the Earth's land surface, such as rivers, streams, and lakes.

Sustainability: In the context of the bill, it refers to the ability to balance supply and demand in society for an unforeseeable period of time.

Thermal Discharge: The disposal into surface water of warm freshwater that was initially taken in as cold freshwater.

Watershed: The total area that drains into a water basin, such as the Chesapeake or Mississippi watersheds.

Withdrawal: The removal of freshwater from a system for societal purposes.