Mother Nature's Machine

By imitating natural processes, we can meet the water needs of current and future generations.

BY RONALD B. LINSKY

All too often we read bold headlines claiming that the world is running out of water. Like so much of the information found in the media, such statements tend to exaggerate. So far, our planet is the only truly water-rich planet known in the universe. In retrospect, we might more accurately call the planet Water, not Earth.

The hydrologic cycle is a fundamental system of our planet. Massive amounts of water fall from the atmosphere onto the land as liquid rain. There it freezes into a solid state or runs off into the seas, where it evaporates back into a gaseous state and returns to the atmosphere.

After billions of years of modification and refinement, this gigantic machine continues to serve as our planet's life insurance policy, and the process requires no technological intervention from humans to maintain its integrity.

As human populations expanded, however, they had profound effects on the water supply. Since time immemorial, people have faced water shortages resulting from droughts, floods, and contaminated supplies. The larger the population, the more severe the impacts.

In past millennia, when Earth was less crowded, people simply moved to a new location when water supplies were contaminated by natural or human means or evaporated in extended periods of drought. For today's modern urban societies, however, relocation is not a viable option.

Imitating Nature

The cycle of finite resources used over and over has been fine-tuned over billions of years of evolutionary development on Earth. As the world's population grew, the need for resources grew accordingly and eventually became critical for the viability of human life. Fortunately, evolving ingenuity led to new discoveries that solved many of the problems associated with water distribution, treatment, waste management, and contamination. Today, most Americans have access to safe and reliable water supplies 24 hours a day, thanks to an array of remarkable technologies developed over the past 200 years.

From the early 1800s until midway through the 20th century, the federal government encouraged the westward movement of the population by promoting agriculture and ensuring reliable water supplies. During that period, the federal government and private entrepreneurs built dams and crafted water-diversion schemes at an unprecedented pace. Though the heyday of such innovation and investment in infrastructure is over, these technologies continue to provide utility customers with the highest quality of water in the world. Unfortunately, technology can't reduce the demand for water, so water providers will need to turn again to human ingenuity to usher in a new era of innovations.

California Dreaming

Human populations have always settled along the shorelines of oceans, rivers, and lakes to take advantage of Mother Nature's remarkably efficient machine. People who settled near the oceans may have enjoyed plentiful seafood and pleasant climate but were faced with very limited potable water supplies. In the United States today, over 50 percent of the population lives near shorelines of one type or another, and 20 percent of the population now lives in the Sunbelt, which stretches from Florida to California across Georgia, Alabama, Mississippi, Louisiana, Texas, New Mexico, and Arizona. These demographic shifts have placed increasing pressure on existing water supplies.

The water needs of the Sunbelt, with a population of over 50 million, are enormous. Southern California alone has 17 million residents, and its water utility managers face a daily challenge to meet these residents' need for water. The current residents of southern California alone consume 1.7 billion gallons of water a day. On an annual basis, that's 620 billion gallons, or over 2 million acre-feet per year.

If the current population stabilized at its current level, utility managers would probably not worry about water supply shortages in the near term. However, the California Department of Finance has projected that the state's population will grow at a rate of 600,000 people per year for the next 20 years. That's 12 million new residents by 2020. Of those new residents, 60 percent, or over 7 million people, will reside in southern California. Southern California water utility managers will therefore have to find, or make available, 36 million gallons a day of new water, or 13.1 billion gallons each year for the next 20 years to satisfy new customer demands. Is this a daunting challenge? Yes, but it is not impossible.

To meet the challenge, decision makers will have to consider the full array of policy alternatives and technological strategies. A variety of technologies that have evolved over the last several decades can contribute substantially to fulfilling the anticipated demands for additional supplies. But decision makers must remember that all the available naturally occurring water resources in the United States are known, and new water will come only from existing water.

We must now ask, what alternatives will be available for future generations?

The answer may lie in discoveries emerging from university research centers and industry laboratories, which are refining and making available technologies to produce water supplies of higher quality than Mother Nature's machine.

Trumping Mother Nature

Throughout the world, water-supply projects have used a variety of technologies to filter agricultural irrigation waters, municipal wastewater, brackish coastal and ocean waters, and salt-laden ground and surface waters.

Consider the 22 countries that make up the Middle East and North Africa. This region contains the world's largest thermal desalination operations, which account for 50 percent of the world's annual desalinated water production, or over 4 billion gallons a year of drinking-quality water.

Several processes are used to create potable water by extracting salts from sea water. The two most common methods of desalination are thermal and membrane processes. The systems capable of the largest output of desalinated water are thermal systems, found primarily in countries with abundant supplies of oil, for example Saudi Arabia, Kuwait, United Arab Emirates, and Bahrain. Thermal processes require substantial quantities of energy to heat seawater or brackish waters, convert them to water vapor leaving the salts behind, and condense and capture the vapor as fresh water. As their names imply, both multi-stage flash distillation and multi-effects distillation involve several stages and depend upon heating salt water in a boiler and lowering atmospheric pressure, which causes water to "flash," or evaporate rapidly, within the pressure vessels. The more stages in the process, the more desalinated water can be extracted from the system.

Vapor compression distillation systems are generally used in conjunction with these thermal processes. In the vapor compression distillation system, the heat for evaporating water comes from the compression of the vapor instead of the direct exchange of heat from a boiler. These technologies, which are used exclusively for desalting ocean waters, are energy intensive and therefore most useful in oil-rich countries.

Two other desalination techniques that require less energy in the process are the membrane technologies: reverse osmosis and electrodialysis. Both processes mimic nature and work by separating salts and water molecules as the water passes through micropores within the structures of thin membranes that prevent the salts from passing through.

Reverse osmosis systems operate in a closed environment under pressure that literally pushes water molecules through the membrane and leaves the salts behind as reject material. This technology is used today to desalt seawater, wastewater, and agricultural irrigation waters very effectively. New plants currently in the works in Israel will provide substantial supplies for Israelis, Palestinians, and Jordanians. Finding solutions to the water problems in the Middle East is the key for reducing, if not eliminating, the tensions within the region.

Electrodialysis technology, on the other hand, operates under the principle that opposite charges—positive and negative—attract. Electrodes within the system cause the negative salt ions to travel toward the positive electrode, and the positive salt ions tend to move toward the negative electrode. The salt ions moving toward the electrodes pass through a membrane and leave behind the water molecules. However, membranes will allow only one type of ion—positive anions or negative cations—to pass through its pores, and electrodialysis systems must use both types of ion. These are arranged in alternate fashion within the system with space in between to allow the desalted waters to flow out. This technology is used very effectively with brackish water desalting operations common in coastal regions, inland seas, and areas with salt-laden water.

Global Thirst

Because of increasing demands for reliable sources of water, desalination plants are increasingly coming on line in Europe, the United States, Japan, China, Africa, Pacific Islands, and the Caribbean areas. Significant improvements in technologies, moreover, are making the process more cost competitive. This advantage has made desalination affordable for a number of regions that have always suffered from inadequate water resources. The island of Malta, for example, depends upon desalination of ocean water to provide over 60 percent of its fresh water needs at a cost of $4.28 per thousand gallons. In Cyprus, desalinating the same amount costs $4.20, and in the Virgin Islands, it costs $7.81.

Tampa Bay Water, Florida's largest wholesaler, provides water to over two million people in the greater Tampa Bay area, which includes the cities of Tampa and St. Petersburg. On average, Tampa Bay Water provides 247 million gallons of drinking water every day to its customers. In the last several decades, however, rapid growth and economic development have taxed the groundwater supply. Under a master plan approved in 1995, Tampa Bay Water began a program to analyze and compare various options that were economically and technically feasible and environmentally sound.

In April 2000, Tampa Bay Water selected seawater desalination as a drought-proof, cost-effective means to diversify the water supply. The project undertook the development of a partnership between private and public entities, with the private sector incurring much of the financial risk. The partnership members include Tampa Bay Water, Tampa Electric, and Southwest Florida Water Management District (SWFWMD).

As a result, final cost to Tampa Bay Water will be $1.60 per thousand gallons of desalinated water. When compared with other desalination costs in the world, the Tampa Bay price is the lowest achieved to date and compares favorably with traditional supplies from nondesalinated sources, which can range from $0.40 to $1.40 per thousand gallons, depending on location. The Tampa Bay Plant will initially produce 25 million gallons a day of high-quality drinking water with the potential at a later date to increase its capacity to 35 million gallons a day. This price has attracted significant international attention.

Another reverse osmosis plant is currently under construction at Point Lisas on the island of Trinidad, in the southeast Caribbean. This plant is designed to deliver 29 million gallons per day of high-quality drinking water at a projected price of $2.00 per thousand gallons. This price is competitive with the price of treated fresh water from domestic supplies of various countries: Australia, $6.76 per thousand gallons; Germany, $5.60 per thousand gallons; United Kingdom, $3.72 per thousand gallons.[1]

Reuse, Recycle

Using water more than once through reuse or recycling is a strategy gaining wider acceptance and rapidly expanding throughout the world. Since 1964, Japan has promoted the concept of water reuse to avoid drought and today has expanded its use to include toilet flushing, landscape, urban waterscapes, agricultural irrigation, and cooling waters. But reclaimed water is not cheap. Current prices average $11.32 per thousand gallon compared with the price of drinking water, $14.12 per thousand gallons, in the city of Fukuoka on northern Kyushu Island.[2]

California has also long promoted water reuse. In the 1970s, the state set regulations for reclaimed waters for beneficial uses. Commonly known as Title 22, this regulation sets out criteria for the quality of water for reuse applications. The beneficial uses include toilet flushing, industry, agriculture, recreation, and groundwater recharge. Reuse of water is beneficial to the environment as it reduces the amount of water that has to be mined or transported far distances. The term *reuse,* however, has caused difficulty in the past because of the public's perception of used water.

Unfortunately, the public doesn't perceive that recycling, or reusing, water mimics the elegance of Mother Nature's machine. All the waters of the world are cycled over and over again, day after day, year after year, century after century, millennium after millennium. Every living creature on Earth drinks recycled water every day. Today's water reuse technologies simply enhance nature's machine by speeding up the process to meet the increased needs of the expanding population. Every drop of water available should be used a minimum of 12 times before it is given back to Mother Nature's machine.

Pure, Clean Water

Orange County, California, is planning a groundbreaking project that may help promote acceptance of reused water across the nation. The planned water treatment plant will use new technologies to provide 100,000 acre-feet per year of high-quality water to more than 2 million residents. The recycled water will be potable, and it will help conserve the limited groundwater supplies of the region.

The Groundwater Replenishment System is a joint venture of the Orange County Water District and the Orange County Sanitation District. A cost-effective solution to anticipated water needs, this project will use advanced water-treatment techniques to take treated wastewater from the sewage treatment plant and purify it to levels that far exceed current EPA drinking water standards.

The system uses microfiltration membranes to remove suspended particles. Microfiltration is the same type of technology used in the beverage industry and in computer-chip manufacturing. It is also used to sterilize medicine that cannot be heated.

Microfiltration will be followed by reverse osmosis filtration, which acts like a strainer to allow only water molecules to pass through while filtering out all the minerals and contaminants, including salts, bacteria, viruses, and pesticides. Then the water will pass through ultraviolet disinfection that acts as concentrated sunlight and serves as another barrier of protection. Ultraviolet disinfection provides extra assurances that unwanted contaminants will not pass through the system and that the water will be of the highest quality possible.

By 2020, over 32 billion gallons of water will be reclaimed or recycled from used waters that are now being discharged to the ocean at a daily rate of over 200 million gallons. The projected costs of the new water from the project will be in the range of $1.80 to $2.50 per thousand gallons or $600 to $800 per acre-foot.

The groundwater replenishment system will provide a new drought-proof water source and will reduce the need to purchase imported water. In addition, the system will improve the quality of the groundwater basin by lowering the mineral content when it is injected and stored in the groundwater basin.

After centuries of extraction, we are now faced with the challenge of finding adequate sources of water from dwindling natural resources. The problem is not a lack of appropriate technology, but rather of diminishing resources. People are fast becoming the abundant resource, while natural resources are fast becoming scarce.

Water is an asset that provides services of real value. To ensure the maintenance of these valued services for future generations, we must invest in the asset. The hydrologic cycle is the planet's life insurance policy. That's why water reuse, recycling, or reclamation are absolute necessities if generations to come are to enjoy an economically and environmentally secure future.■

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NOTES

1. Paul Simon, *Tapped Out: The Coming World Crisis in Water and What We Can Do about It* (New York, NY: Welcome Rain, 1998).

2. M. Ogoshi, Y. Suzuki, and T. Asano, "Non-Potable Urban Water Reuse–A Case of Japanese Water Recycling," *Water* 21 (June 2000), pp. 27-30.