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WATER PRODUCTIVITY AND WATER CAPITAL – ADDRESSING FRESH WATER AVAILABILITY CHALLENGES

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BACKGROUND

Access to fresh water is an increasingly critical national and international issue, especially since demand for fresh water in many regions of the world has already outstripped fresh water supplies. Based on data from the United Nation's "World Water Development Report," more than 50 percent of the nations in the world will face water stress or water shortages by 2025, and by 2050, as much as 75 percent of the world's population could face water scarcity (United Nations, 2003). Recently, the United Nations Secretary General Ban Ki-moon urged business and political leaders at the World Economic Forum in Switzerland that the looming crisis over water shortages should be at the top of the global agenda in an effort to prevent conflicts over the growing scarcity of fresh water supplies.

Like so much of the world, access to fresh water is an increasingly critical issue in the United States. This was highlighted in a recent Government Accountability Office (GAO) report in 2003 on fresh water supply availability (GAO, 2003). In that report, the GAO presented results of a national survey of state water managers on expected water shortages. As presented in Figure 1, the responses show most regions of the country expect local to regional water shortages over the next decade under average climate conditions. Water shortages are not just a Southwestern or Western U.S. issue anymore! The reason for these concerns is a combination of high population growth in the Southeast and the West, and the continuing limitation on fresh surface water supplies and continued unsustainable use of fresh groundwater in many of the major aquifer systems across the U.S.

WATER PRODUCTIVITY AND WATER CAPITAL

The growing limitation of fresh water resources is forcing a rethinking about how water is valued, used, and managed. Water is a natural resource heavily used by all sectors including agriculture, energy production and electric power generation, industrial processing and cooling, and for domestic supplies. This makes water availability and water use a significant driver for future economic output and growth. This is highlighted in Figure 2, where growth in the U.S. Gross Domestic Product (GDP) since 1940 is compared to two economic growth indicators, water and energy supply availability. As shown, our GDP tracks more closely with the growth in water resource development over the past 60 years than with energy development and production.

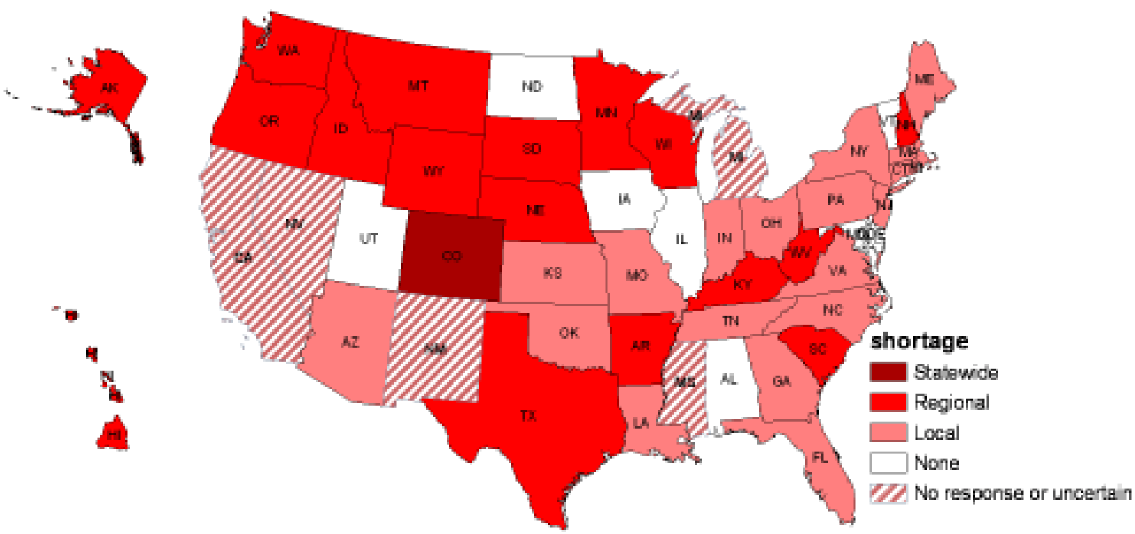
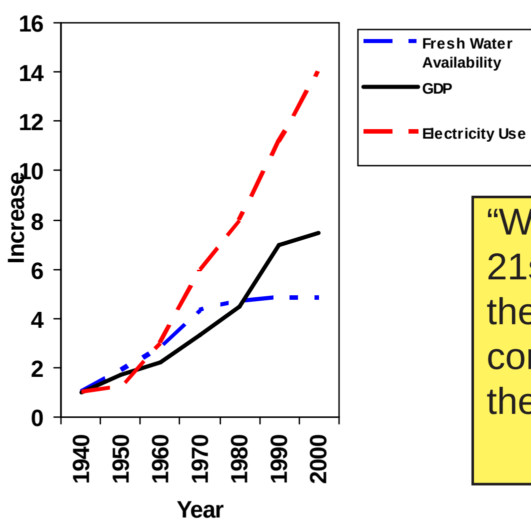


Figure 1. State Water Managers Expecting Water Shortages over the Next Decade



"Water promises to be to the 21st century what oil was to the 20th century: the precious commodity that determines the wealth of nations."
Fortune Magazine, May 15, 2000

Figure 2. Growth in U.S. GDP Relative to Energy and Water Resource Growth

Water is increasingly seen as the major critical resource driving future economic growth, and as noted in the quote above from Fortune magazine, water could become one of the most precious commodities of the 21st century. No wonder there is growing international concern over potential national or regional conflicts over water. It is also no wonder that water is now being discussed in economic terms such as "water capital" and "water productivity."

The term "water capital" is used loosely and is not well defined. In the context of economic considerations, "water capital" defines the intrinsic value of a water resource or water supply. Fresh water often has the highest economic capital in that it has the highest value, able to be used directly for almost any use at minimal treatment or cost. Therefore, using fresh water resources for applications where lower quality water could be used is not valuing the intrinsic value of fresh water, and thus wasting "water capital." In the economic analogy, the misuse of fresh water for other than high value needs is wasting capital and makes poor economic sense.

On the other hand, "water productivity" is more commonly used and denotes increasing the efficiency of use of water resources. In terms of water use, it would include efficiency concepts such as "more crop per drop" in agriculture and "more watt per drop" for electric power generation. While increasing efficiency or productivity is applicable to all water resources, when applied to fresh water, "water productivity" includes using nontraditional waters where they can be cost-effectively substituted for fresh water. This increases nontraditional water use, increases fresh water productivity, and at the same time preserves fresh water capital.

Traditionally, water management in the U.S. has relied on water allocation approaches primarily based on water quantity use or delivery metrics. Therefore, water management approaches often do not value water quality or the intrinsic value of fresh water in water allocations of water utilization. As concerns over water become more heated and fresh water supplies become increasingly strained, water management approaches that incorporate both "water capital" and "water productivity" considerations and optimization will become common.

BACK TO THE FUTURE

While this may appear to be a major shift in water management, the concepts have actually been used for millennia. For example, the Romans saw the importance of water to public health and economic development, and during the Second Samnite War in 310 B.C., chose to begin to address their inadequate and unreliable water supplies. The Roman Senate developed a water infrastructure and water management program to procure water rights from surrounding areas and develop a system of reservoirs, aqueducts, cisterns, springs, and community distribution systems to maintain a steady and reliable supply of fresh water. Many of the water systems they built are still operating as originally designed throughout Italy today, as illustrated in Figures 3 and 4.

Figure 3. Roman structure protecting a fresh water spring in Sienna, Italy

The concepts used included water infrastructure security and watershed management principles as well as approaches to optimize water capital to improve public health and to optimize water productivity. A few examples of these Roman water management principles highlighted in a Sandia National Laboratories paper (Ekman, 2001) on water security include references to Roman water management approaches from 40 BC to 95 AD. Examples include:

> "...purposely sunk their aqueducts in the ground and did not show them on their plans, so that they were not easily cut by the enemy..."
>
> "...The basins...have for the most part been connected with the different aqueducts by two pipes each, so that if an accident should put either of the two out of commission...the service may not be interrupted..."
>
> "...managed watersheds and provided treatment to insure water quality for each use..."

Figure 4. Roman fountain providing different waters for drinking and washing

> Reserved aqueducts for separate purposes
> "...separate them all and then allot their separate functions…according to their special qualities..."
> "...distributed water of three qualities, for drinking, for public baths and fountains, and for use in residences…"

The Romans understood the social and economic aspects of providing adequate water supplies to support a growing nation. As can be seen from the excerpts above, they focused on using water wisely, which drove both their water infrastructure development and water planning, which is still serving them well 2000 years later.

WATER MANAGEMENT USING WATER CAPITAL AND WATER PRODUCTIVITY CONCEPTS

To finish this discussion I would like to provide a couple of current examples of how "water capital" and "water productivity" concepts could be easily incorporated into water management strategies today. For example, Figure 5 shows the average daily direct and indirect water use per person per day. While direct domestic water use, such as showers, baths, flushing toilets, and watering lawns, is often used by planners to identify future water needs, each person uses daily a significant amount of water indirectly for irrigating the food they eat and to cool the power plants that provide the energy they need for lights, electric appliances, and air conditioning. Interestingly, the water used indirectly significantly exceeds the water needed for direct personal uses and improvements in agricultural water use efficiency and electric power water use efficiency could significantly increase overall "water productivity." Therefore, for growth planning, "water capital" and "water productivity" must be considered within a total water system needs context, which will require broader water planning involvement in sectors other than just domestic water use.

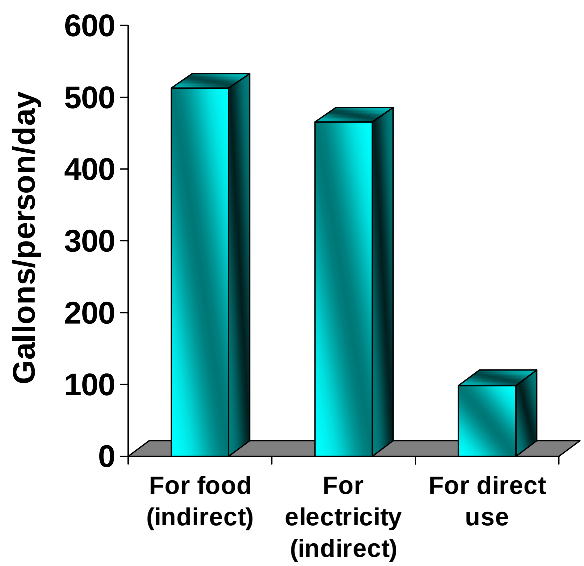


Figure 5. Average Direct and Indirect Water Use per Person per Day (Gleick, 2003)

As an example, Figure 6 below shows the water balance for a typical 500 MW, evaporative-cooled coal power plant, the bulk of the electric power plants projected to be constructed through 2030 (EIA, 2006). As shown in Figure 6, the plant uses over 5,000 gallons of water a minute. Of that amount, about 80 percent is lost to evaporation from the cooling towers, and 20 percent is discharged to on-site evaporation ponds as high salinity blowdown or wastewater. Several options exist to increase fresh "water capital" and "water productivity" by decreasing fresh water use and increasing water use efficiency in electric power generation. Examples include:

INCREASE FRESH WATER CAPITAL

This would include approaches that eliminate the use of fresh water in electric power generation, leaving as much fresh water as possible for higher uses and saving fresh "water capital." Options include:

- Use of non-fresh water, such as produced water, wastewater, seawater, or brackish groundwater, etc. for cooling and process water
- Use of cooling technologies that do not require water, such as dry cooling
- Substituting part of the plant output with renewable energy technologies that do not use fresh water, such as wind, solar, or geothermal energy

INCREASE FRESH WATER PRODUCTIVITY

In cases where fresh water resources need to be used because of energy cost and reliability issues, options are available to increase fresh "water productivity." Examples include:

- All of the previous examples that use non-fresh water or little fresh water all increase fresh water productivity
- Utilizing hybrid cooling designs that combine evaporative and dry cooling to reduce the fresh water needed
- Using technologies to condense evaporation from cooling towers and reuse the water
- Using the blowdown pond water to grow algae for use as biofuels or animal feed, minimizing fresh water needed to grow crops or produce biofuels

These examples are not applicable to all sites and can have cost and energy performance penalties. Using brackish or seawater for cooling can require the use of special materials, water treatment, or special withdrawal approaches to protect ecosystems, all of which can increase costs. Use of renewable energy systems, because they are often intermittent, can negatively impact energy reliability. The benefits of saving water compared to increased energy costs or reduced energy reliability must be evaluated within a system-level context to balance energy reliability and costs with sustainable water use economic growth.

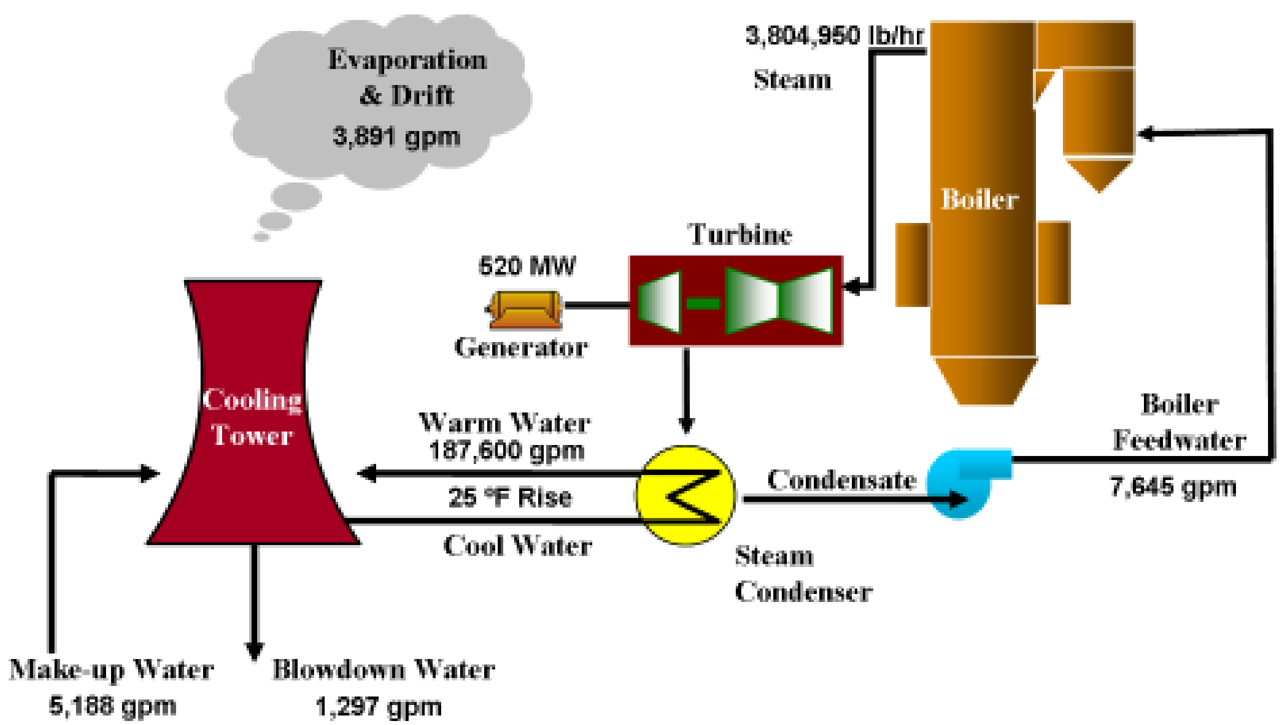


Figure 6. Water Balance for a 500 MW Coal Power Plant

The examples do highlight that terms such as water "capital" and "productivity" can provide a metric for integrating sustainable water and natural resource management within a system context.

A similar set of considerations and water use improvements can be presented for the agricultural, industrial, and domestic water use sectors. Improvements in irrigation practices and return flow reuse, domestic and industrial wastewater reuse, and improvements in water use efficiency in each sector have increased "water productivity" and preserved fresh "water capital" for future uses.

CHALLENGES AND EMERGING OPPORTUNITIES

Integrating water and natural resource policies and management approaches is unfortunately easier said than done. This is especially true in any state with different agencies managing energy resources and development, water resources and development and water rights, environmental and ecological oversight, coastal development, and economic development. In general, this is most states! In many cases state agencies have policies that discourage preserving fresh "water capital" or increasing fresh "water productivity." For example, while Texas encourages the use of coastal waters and seawater for desalination and power plant cooling, which preserve fresh water and reduce fresh water use, California's Coastal Commission has severely curtailed opportunities for siting coastal power or desalination plants, unwittingly exacerbating California's endemic and worsening fresh water demand and supply problems.

On the other hand, innovative water treatment technologies have significantly increased the ability to use non-traditional water resources such as brackish water and wastewater more cost-effectively and for a larger number of purposes, encouraging their use. Technologies like GPS have accelerated the use of drip irrigation and improved water use efficiency in agriculture as well as improved computing, and communication and control technologies have significantly improved water control, management, and use in all sectors. Innovative technology development and implementation will enhance opportunities to further improve fresh water use and conservation.

As noted above, water management concepts using metrics such as "water capital" and "water productivity," though used extensively in the past, are not current water management drivers. To meet future water demands sustainably, water supply and use associated policies such as agricultural, energy, industrial, domestic, and environmental will need to be considered within a system-level water management context. By incorporating emerging technology improvements and utilizing concepts and metrics such as preserving "fresh water capital" and encouraging "fresh water productivity," we can effectively manage our water and natural resources in a way that preserves our fresh water resources while meeting future economic development water demands.

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