Sustainability of Ground-Water Resources

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INTRODUCTION

Ground water is one of the Nation's most important natural resources. It provides about 40 percent of the Nation's public water supply. In addition, more than 40 million people, including most of the rural population, supply their own drinking water from domestic wells. As a result, ground water is an important source of drinking water in every State (Figure 1). Ground water is also the source of much of the water used for irrigation. It is the Nation's principal reserve of freshwater and represents much of the potential future water supply. Ground water is a major contributor to flow in many streams and rivers and has a strong influence on river and wetland habitats for plants and animals.

The pumpage of fresh ground water in the United States in 1995 was estimated to be approximately 77 billion gallons per day (Solley and others, 1998), which is about 8 percent of the estimated 1 trillion gallons per day of natural recharge to the Nation's ground-water systems (Nace, 1960). From an overall national perspective, the ground-water resource appears ample. Locally, however, the availability of ground water varies widely. Moreover, only a part of the ground water stored in the subsurface can be recovered by wells in an economic manner and without adverse consequences.

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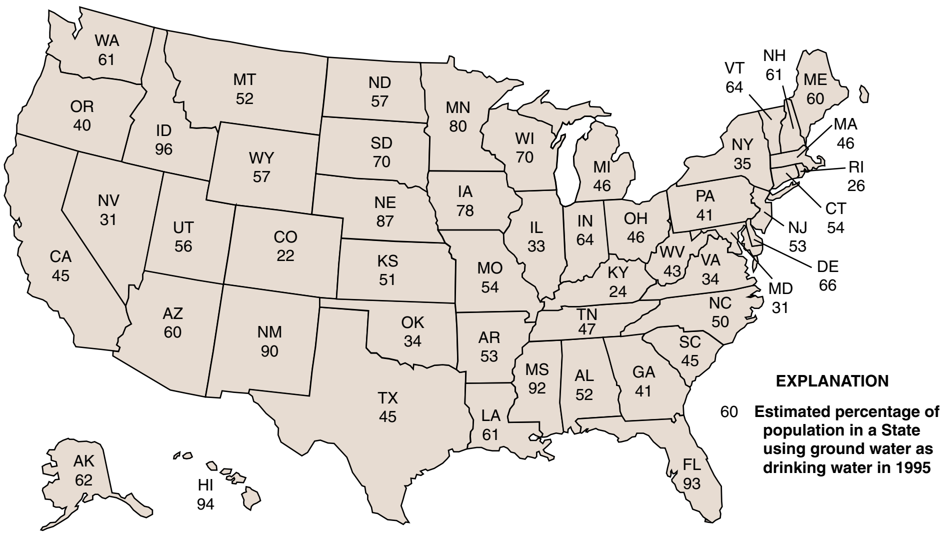

Figure 1. *Ground water is an important source of drinking water for every State. (U.S. Geological Survey, 1998.)*

The construction of surface reservoirs has slowed considerably in recent years (Figure 2). As surface-water resources become fully developed and appropriated, ground water commonly offers the only available source for new development. In many areas of the United States, however, pumping of ground water has resulted in significant depletion of ground-water storage. Furthermore, ground water and surface water are closely related and in many areas comprise a single resource (Winter and others, 1998). Ground-water pumping can result in reduced river flows, lower lake levels, and reduced discharges to wetlands and springs, causing concerns about drinking-water supplies, riparian areas, and critical aquatic habitats. Increasingly, attention is being placed on how to manage ground water (and surface water) in a sustainable manner (Downing, 1998; Sophocleous, 1998; Gelt and others, 1999).

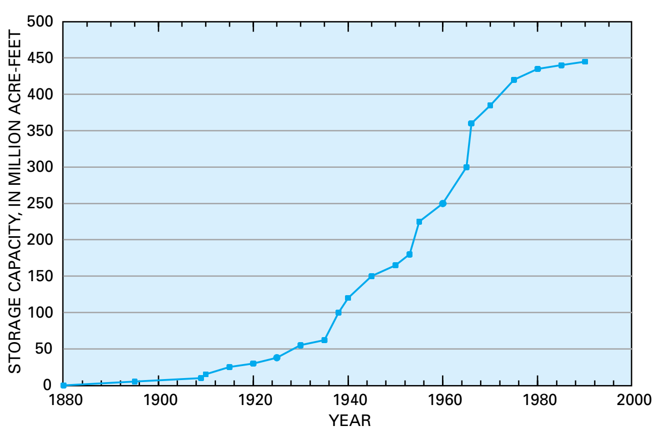

Figure 2. *Total surface-water reservoir capacity in the conterminous United States from 1880 to 1990. (Modified from Solley, 1995.)*

Resource sustainability has proved to be an elusive concept to define in a precise manner and with universal applicability. In this report, we define ground-water sustainability as development and use of ground water in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences. The definition of “unacceptable consequences” is largely subjective and may involve a large number of criteria. Furthermore, ground-water sustainability must be defined within the context of the complete hydrologic system of which ground water is a part. For example, what may be established as an acceptable rate of ground-water withdrawal with respect to changes in ground-water levels may reduce the availability of surface water to an unacceptable level. Some key goals related to ground-water sustainability in the United Kingdom are listed in Figure 3. These goals apply equally well in the United States.

THE PRIORITIES FOR GROUND-WATER MANAGEMENT

- SUSTAINABLE LONG-TERM YIELDS FROM AQUIFERS
- EFFECTIVE USE OF THE LARGE VOLUME OF WATER STORED IN AQUIFERS
- PRESERVATION OF GROUND-WATER QUALITY
- PRESERVATION OF THE AQUATIC ENVIRONMENT BY PRUDENT ABSTRACTION OF GROUND WATER
- INTEGRATION OF GROUND WATER AND SURFACE WATER INTO A COMPREHENSIVE WATER AND ENVIRONMENTAL MANAGEMENT SYSTEM

TO PROTECT A PRICELESS NATIONAL ASSET

Figure 3. *Vision statement of priorities for ground-water management in the United Kingdom. (Modified from Downing, 1998.)*

Perhaps the most important attribute of the concept of ground-water sustainability is that it fosters a long-term perspective to management of ground-water resources. Several factors reinforce the need for a long-term perspective. First, ground water is not a nonrenewable resource, such as a mineral or petroleum deposit, nor is it completely renewable in the same manner and timeframe as solar energy. Recharge of ground water from precipitation continually replenishes the ground-water resource but may do so at much smaller rates than the rates of ground-water withdrawals. Second, ground-water development may take place over many years; thus, the effects of both current and future development must be considered in any water-management strategy. Third, the effects of ground-water pumping tend to manifest themselves slowly over time. For example, the full effects of pumping on surface-water resources may not be evident for many years after pumping begins. Finally, losses from ground-water storage must be placed in the context of the period over which sustainability needs to be achieved. Ground-water withdrawals and replenishment by recharge usually are variable both seasonally and from year to year. Viewing the ground-water system through time, a long-term approach to sustainability may involve frequent temporary withdrawals from ground-water storage that are balanced by intervening additions to ground-water storage.

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Three terms that have long been associated with ground-water sustainability need special mention; namely, safe yield, ground-water mining, and overdraft. The term “safe yield” commonly is used in efforts to quantify sustainable ground-water development. The term should be used with respect to specific effects of pumping, such as water-level declines, reduced streamflow, and degradation of water quality. The consequences of pumping should be assessed for each level of development, and safe yield taken as the maximum pumpage for which the consequences are considered acceptable. The term “ground-water mining” typically refers to a prolonged and progressive decrease in the amount of water stored in a ground-water system, as may occur, for example, in heavily pumped aquifers in arid and semiarid regions. Ground-water mining is a hydrologic term without connotations about water-management practices (U.S. Water Resources Council, 1980). The term “overdraft” refers to withdrawals of ground water from an aquifer at rates considered to be excessive and therefore carries the value judgment of over-development. Thus, overdraft may refer to ground-water mining that is considered excessive as well as to other undesirable effects of ground-water withdrawals.

In some situations, the focus of attention may be on extending the useful life of an aquifer as opposed to achieving long-term sustainability. This situation—for which the term ground-water mining is perhaps most fitting—is not addressed specifically in this report; however, many of the same hydrologic principles that we discuss herein still apply.

This introductory discussion indicates that the concept of ground-water sustainability and its application to real situations is multifaceted and complex. The effects of many human activities on ground-water resources and on the broader environment need to be clearly understood.

We begin by reviewing some pertinent facts and concepts about ground water and some common misconceptions about water budgets and ground-water sustainability. Individual chapters then focus on the interactions between ground water and surface water, on ground-water storage, and on ground-water quality as each aspect relates to the sustainability of ground-water resources. We conclude by discussing the importance of ground-water data, uses of ground-water models, and strategies to meet the challenges posed in assuring sustainable use of ground-water resources.

Throughout the report, we emphasize that development of ground-water resources has consequences to hydrologic and related environmental systems. We discuss relevant concepts and field examples in the body of the text, and provide more technical discussion of special topics and additional field examples in “boxes.” An exception is the next special section, “General Facts and Concepts about Ground Water.” Many readers familiar with ground-water concepts will want to go directly to the chapter on “Ground-Water Development, Sustainability, and Water Budgets.”

“If sustainable development is to mean anything, such development must be based on an appropriate understanding of the environment—an environment where knowledge of water resources is basic to virtually all endeavors.”

Report on Water Resources Assessment, WMO/UNESCO, 1991