Lakes

Lakes, both natural and human made, are present in many different parts of the landscape and can have complex ground-water-flow systems associated with them. Lakes interact with ground water in one of three basic ways: some receive ground-water inflow throughout their entire bed; some have seepage loss to ground water throughout their entire bed; and others, perhaps most lakes, receive ground-water inflow through part of their bed and have seepage loss to ground water through other parts. Lowering of lake levels as a result of ground-water pumping can affect the ecosystems supported by the lake (Figure 16), diminish lakefront esthetics, and have negative effects on shoreline structures such as docks.

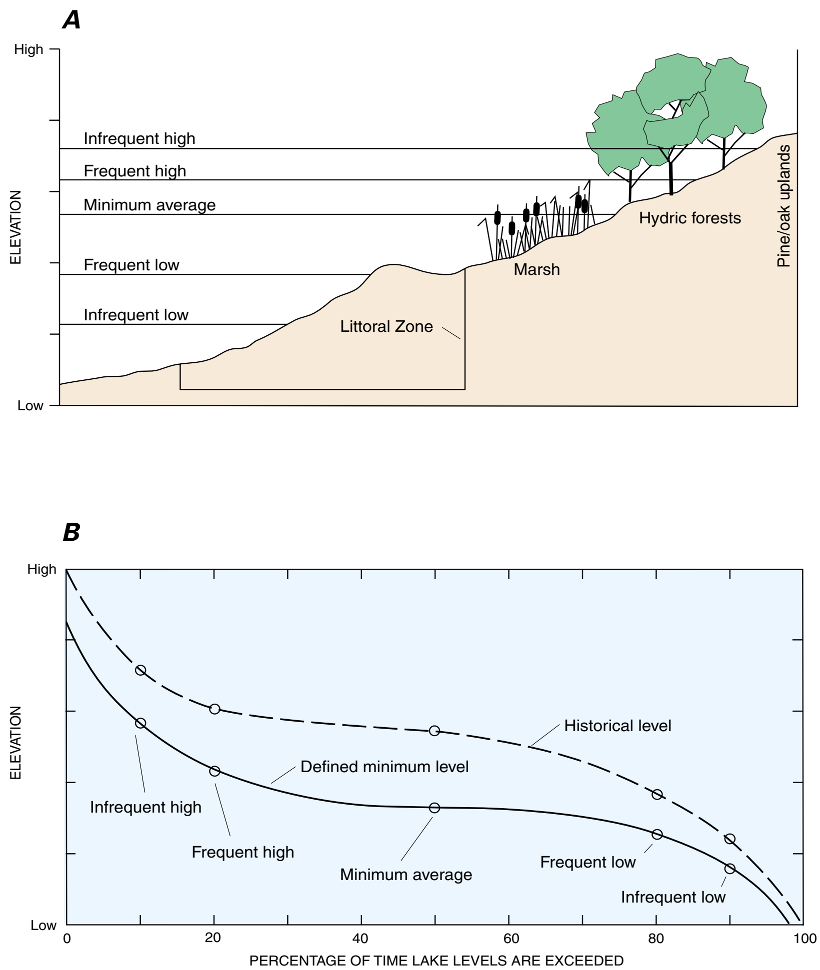

Figure 16. *Setting minimum water levels in Florida lakes. (Modified from McGrail and others, 1998.)*

As part of efforts to prevent significant undesirable environmental consequences from water-resources development, water-management agencies in Florida are defining minimum flows and water levels for priority surface waters and aquifers in the State. For lakes, the minimum flows and water levels describe a hydrologic regime that is less than the historical or optimal one but allows for prudent water use while protecting critical lake functions. As an example, five possible minimum water levels defined for a lake are shown in A. An elevation and a percentage of time the level is exceeded characterize each of these levels. The upper curve in B shows the percentage of the time that the lake is historically above each corresponding level. The goal is to ensure that water withdrawals and other water-resource management actions continue to allow the lake water levels to be at or above the minimum levels shown by the lower curve in B for the percentage of time shown.

Dock on Crooked Lake in central Florida in the 1970’s.

The same dock in 1990.

As a result of very low topographic relief, high rainfall, and a karst terrain, the Florida landscape is characterized by numerous lakes and wetland areas. The underlying Floridan aquifer is one of the most extensive and productive aquifers in the world. Over the past two decades, lake levels declined and wetlands dried out in highly developed west-central Florida as a result of both extensive pumping and low precipitation during these years. Differentiating between the effects of the drought and pumping has been difficult. (Photographs courtesy of Florida Water Resources Journal, August, 1990 issue.)

The chemistry of ground water and the direction and magnitude of exchange with surface water significantly affect the input of dissolved chemicals to lakes. In fact, ground water can be the principal source of dissolved chemicals to a lake, even in cases where ground-water discharge is a small component of a lake’s water budget. Changes in flow patterns to lakes as a result of pumping may alter the natural fluxes to lakes of key constituents such as nutrients and dissolved oxygen, in turn altering lake biota, their environment, and the interaction of both.

Wetlands

Wetlands are present wherever topography and climate favor the accumulation or retention of water on the landscape. Wetlands occur in widely diverse settings from coastal margins to flood plains to mountain valleys. Similar to streams and lakes, wetlands can receive ground-water inflow, recharge ground water, or do both. Wetlands are in many respects ground-water features.

Public and scientific views of wetlands have changed greatly over time. Only a few decades ago, wetlands generally were considered to be of little or no value. It is now recognized that wetlands have beneficial functions such as wildlife habitat, floodwater retention, protection of the land from erosion, shoreline protection in coastal areas, and water-quality improvement by filtering of contaminants.

The persistence, size, and function of wetlands are controlled by hydrologic processes (Carter, 1996). For example, the persistence of wetness for many wetlands is dependent on a relatively stable influx of ground water throughout changing seasonal and annual climatic cycles. Characterizing ground-water discharge to wetlands and its relation to environmental factors such as moisture content and chemistry in the root zone of wetland plants is a critical but difficult to characterize aspect of wetlands hydrology (Hunt and others, 1999).

Wetlands can be quite sensitive to the effects of ground-water pumping. Ground-water pumping can affect wetlands not only as a result of progressive lowering of the water table, but also by increased seasonal changes in the altitude of the water table. The amplitude and frequency of water-level fluctuations through changing seasons, commonly termed the hydroperiod, affect wetland characteristics such as the type of vegetation, nutrient cycling, and the type of invertebrates, fish, and bird species present. The effects on the wetland environment from changes to the hydroperiod may depend greatly on the time of year at which the effects occur. For example, lower than usual water levels during the nongrowing season might be expected to have less effect on the vegetation than similar water-level changes during the growing season. The effects of pumping on seasonal fluctuations in ground-water levels near wetlands add a new dimension to the usual concerns about sustainable development that typically focus on annual withdrawals (Bacchus, 1998).

Springs

Springs typically are present where the water table intersects the land surface. Springs serve as important sources of water to streams and other surface-water features, as well as being important cultural and esthetic features in themselves. The constant source of water at springs leads to the abundant growth of plants and, many times, to unique habitats. Ground-water development can lead to reductions in springflow, changes of springs from perennial to ephemeral, or elimination of springs altogether. Springs typically represent points on the landscape where ground-water-flow paths from different sources converge. Ground-water development may affect the amount of flow from these different sources to varying extents, thus affecting the resultant chemical composition of the spring water.

Comal Springs

The highly productive Edwards aquifer, the first aquifer to be designated as a sole source aquifer under the Safe Drinking Water Act, is the source of water for more than 1 million people in San Antonio, Texas, some military bases and small towns, and for south-central Texas farmers and ranchers. The aquifer also supplies water to sustain threatened and endangered species habitat associated with natural springs in the region and supplies surface water to users downstream from the major springs. These various uses are in direct competition with ground-water development and have created challenging issues of ground-water management in the region. (Photograph by Robert Morris, U.S. Geological Survey.)

Coastal Environments

Coastal areas are a highly dynamic interface between the continents and the ocean. The physical and chemical processes in these areas are quite complex and commonly are poorly understood. Historically, concern about ground water in coastal regions has focused on seawater intrusion into coastal aquifers, as discussed in a later chapter of this report. More recently, ground water has been recognized as an important contributor of nutrients and contaminants to coastal waters. Likewise, plant and wildlife communities adapted to particular environmental conditions in coastal areas can be affected by changes in the flow and quality of ground-water discharges to the marine environment.

In summary, we have seen that changes to surface-water bodies in response to ground-water pumping commonly are subtle and may occur over long periods of time. The cumulative effects of pumping can cause significant and unanticipated consequences when not properly considered in water-management plans. The types of water bodies that can be affected are highly varied, as are the potential effects.

EFFECTS OF GROUND-WATER DEVELOPMENT ON GROUND-WATER STORAGE

Previous chapters have discussed the "ground-water-flow system," including recharge and subsequent flow of ground water through the system to areas of discharge, primarily bodies of surface water. In this context, the ground-water-flow system functions as a conduit that transports water, sometimes over considerable distances (miles, tens of miles), from areas of recharge to areas of discharge. In this chapter, the focus changes from the dynamic aspect of the ground-water-flow system to another aspect—the fact that the flowing ground water in the system represents a large, sometimes huge, volume of water in storage. In this context, it is appropriate to change terminology from "ground-water-flow system" to "ground-water reservoir," which emphasizes the storage aspect of ground-water systems.

A key feature of some aquifers and ground-water systems is the large volume of ground water in storage, which allows the possibility of using aquifers for temporary storage, that is, managing inflow and outflow of ground water in storage in a manner similar to surface-water reservoirs.

Storage Changes

A change in the water level of any well (change in head) is a measure of a change in storage in the ground-water reservoir in the neighborhood of the open interval of the well. Thus, a rising water level in a well represents an increase in storage and a declining water level represents a decrease in storage in the ground-water reservoir. This situation is analogous to changes in water level in surface-water reservoirs. However, the relation between changes in water levels in wells and changes in the volume of water in storage is considerably more complex in ground-water reservoirs than in surface-water reservoirs (see Box A).

Even in aquifers and parts of aquifers that are not stressed by pumping wells, water levels in wells change continuously in response to changes in natural rates of recharge and discharge in the ground-water-flow system. Water levels in many wells exhibit an approximate annual cycle—water levels are highest during months of highest recharge, commonly the spring of the year, and lowest during months of lowest recharge, commonly the summer and early fall. In addition, large changes in recharge and discharge occur from year to year, which results in a potentially significant rise and decline in water levels during wet and dry years, respectively (Figure 17).

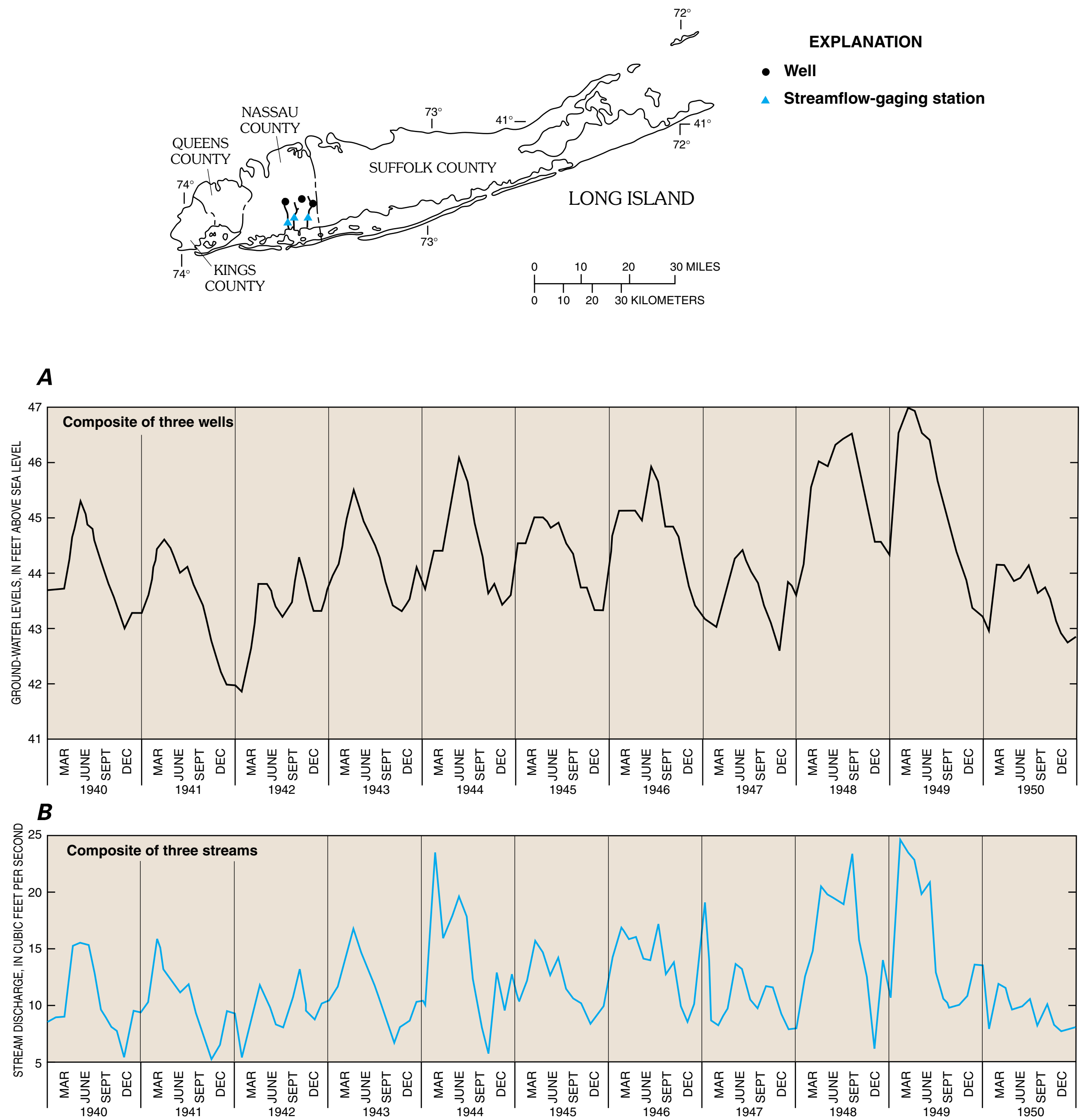

Figure 17. *Composite average monthly (A) ground-water levels in selected wells and (B) discharge of selected streams in Nassau County, Long Island, New York for the period 1940-50. (Modified from Franke and McClymonds, 1972.)*

The highly transmissive surficial deposits of sand and gravel, low relief, and humid climate of Long Island create ideal conditions for good hydraulic connection between the unconfined aquifer and numerous small streams. Before development more than 90 percent of total streamflow was derived from ground-water inflow; thus, these streams have been described as "ground-water drains." The good correspondence between ground-water levels in the unconfined aquifer and flow in nearby streams reflects the fact that in this ground-water system most of the streamflow is derived from ground water and there is good connection between the two systems.

Declines in heads and associated reductions in storage in response to pumping can be large compared to changes in unstressed ground-water systems. For example, declines in heads as a result of intense pumping can reach several hundred feet in some hydrogeologic settings. Widespread pumping that is sufficient to cause regional declines in heads can result in several unwanted effects. For example: (1) regional declines in heads may represent large decreases in aquifer storage, particularly in unconfined aquifers; (2) some wells may become dry because the lower heads are below the screened or open intervals of these wells; (3) pumping costs will increase because the vertical distance that ground water must be lifted to the land surface increases; (4) locally, the rate of movement of contaminated ground water and the likelihood that the contaminated ground water will be intercepted by a pumping well are increased; and (5) pumping of ground water may result in land subsidence or intrusion of saline ground water in some hydrogeologic settings. Because large and widespread changes in heads in aquifers are of interest to water managers and users of the ground-water resource, maps of heads (water levels) often are prepared periodically for individual, heavily pumped aquifers by water agencies. Comparisons of these synoptic-head maps permit changes in ground-water levels in wells to be documented through time for individual aquifers. Such histories of head change sometimes serve as the basis and catalyst for initiatives to manage the affected ground-water reservoir. The following examples illustrate aquifer response to pumping and associated changes in storage in different environmental settings.

High Plains aquifer—Let's first return to a previous example, the High Plains aquifer (see section on "Ground-Water Development, Sustainability, and Water Budgets"). Ground-water pumping from this unconfined aquifer has resulted in the largest decrease in storage of any major aquifer in the Nation. In parts of the central and southern High Plains, more than 50 percent of the predevelopment saturated thickness has been dewatered (see Figure 10*B*). The water table continues to decline under much of the High Plains. During the past two decades, however, monitoring of water levels in wells indicates an overall reduced rate of decline of the water table (McGuire and Sharpe, 1997). This change is attributed to improved irrigation and cultivation practices, decreases in irrigated acreage, and above normal precipitation during this period. In parts of the High Plains, water-level rises have occurred because of seepage losses from surface-water irrigation or the recovery of local cones of depression as a result of decreased pumpage.