POTENTIAL EFFECTS OF GROUNDWATER DEVELOPMENT IN EASTERN CAMDEN COUNTY, GEORGIA, ON GROUNDWATER RESOURCES OF CUMBERLAND ISLAND NATIONAL SEASHORE

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Abstract. Proposed withdrawal of groundwater from the surficial aquifer system confined zone, or the upper and lower Brunswick aquifers in eastern Camden County, Georgia, could result in drawdown extending beneath the Cumberland Sound and potentially could affect groundwater levels and natural resources at Cumberland Island National Seashore. Using a nonequilibrium formula, estimated drawdown after 5 years of pumping at a rate of 0.2 million gallons per day along the western edge of Cumberland Island's wilderness area would be about 26 feet in the surficial aquifer confined zone, 39 feet in the upper Brunswick aquifer, and 3.7 feet in the lower Brunswick aquifer. Pumping from the lower Brunswick aquifer at a rate of 2 million gallons per day for 5 years would result in 37 feet of drawdown along the western edge of the wilderness area. Water-level declines in aquifers beneath wetland areas could reduce quantities of water discharging from confined units into the unconfined parts of the surficial aquifer system, which are important for sustaining freshwater wetland ecosystems on Cumberland Island.

INTRODUCTION

Cumberland Island is the largest barrier island along the coast of Georgia. The island contains about 2,500 acres of freshwater wetlands that are influenced by surface water, groundwater, rainwater, and seawater (Frick and others, 2002). Proposed development of a 27-square-mile (mi^2) area of eastern Camden County would include 5,000 homes with a projected groundwater withdrawal of 2 million gallons per day (Mgal/d) from the surficial and/or Brunswick aquifer systems (Denesia Cheek, National Park Service, written commun., August 22, 2002). This withdrawal could result in drawdown of water levels in these aquifers, extending beneath Cumberland Sound and potentially could affect wetlands by reducing fresh groundwater discharge. The U.S. Geological Survey, in cooperation with the National Park Service, conducted a study to assess the impact of projected groundwater development on groundwater levels at Cumberland Island. This study will provide information to assist the National Park Service in managing the natural resources of Cumberland Island National Seashore. Hydraulic properties derived from aquifer tests conducted in the surficial and Brunswick aquifer systems in Glynn and Camden Counties were used to estimate drawdown during 1-, 5-, and 10-year pumping periods.

Study Area

Proposed residential developments in eastern Camden County are within 2 miles (mi) of Cumberland Island (Fig. 1). Camden County is located in the Coastal Plain physiographic province of Georgia. Coastal Plain sediments consist of layers of sand, clay, limestone, and dolomite that range in age from Late Cretaceous through Holocene.

Cumberland Island is the southernmost and largest barrier island along the coast of Georgia and is biologically and topographically diverse. Cumberland Island has 2,500 acres of freshwater wetlands, which range from permanent and semipermanent ponds to seasonal wetland areas including emergent, scrub/shrub, and forested palustrine areas, most located within the wilderness area (Fig. 1). The viability of some plant communities, wildlife, and aquatic animals are closely linked to the wetlands, which provide habitat to some threatened or endangered organisms. Unconfined portions of the surficial aquifer system are important for sustaining freshwater wetland ecosystems on the island. Recharge to this aquifer system is primarily by infiltration of rainfall, seepage from wetlands, and upward leakage in areas where the hydraulic potential in underlying confined aquifers is higher than in the surficial aquifer system (Frick and others, 2002).

Hydrogeologic Setting

Principal water-bearing units in Camden County are, in order of increasing depth, the surficial, Brunswick, and Floridan aquifer systems. Low-permeability clayey confining units separate these water-bearing units. Generally, the surficial aquifer system is divided into three water-bearing zones composed of fine to medium quartz sand interbedded with clay and silt (Clarke, 2003). The uppermost zone is unconfined, and the two lowermost zones are confined.

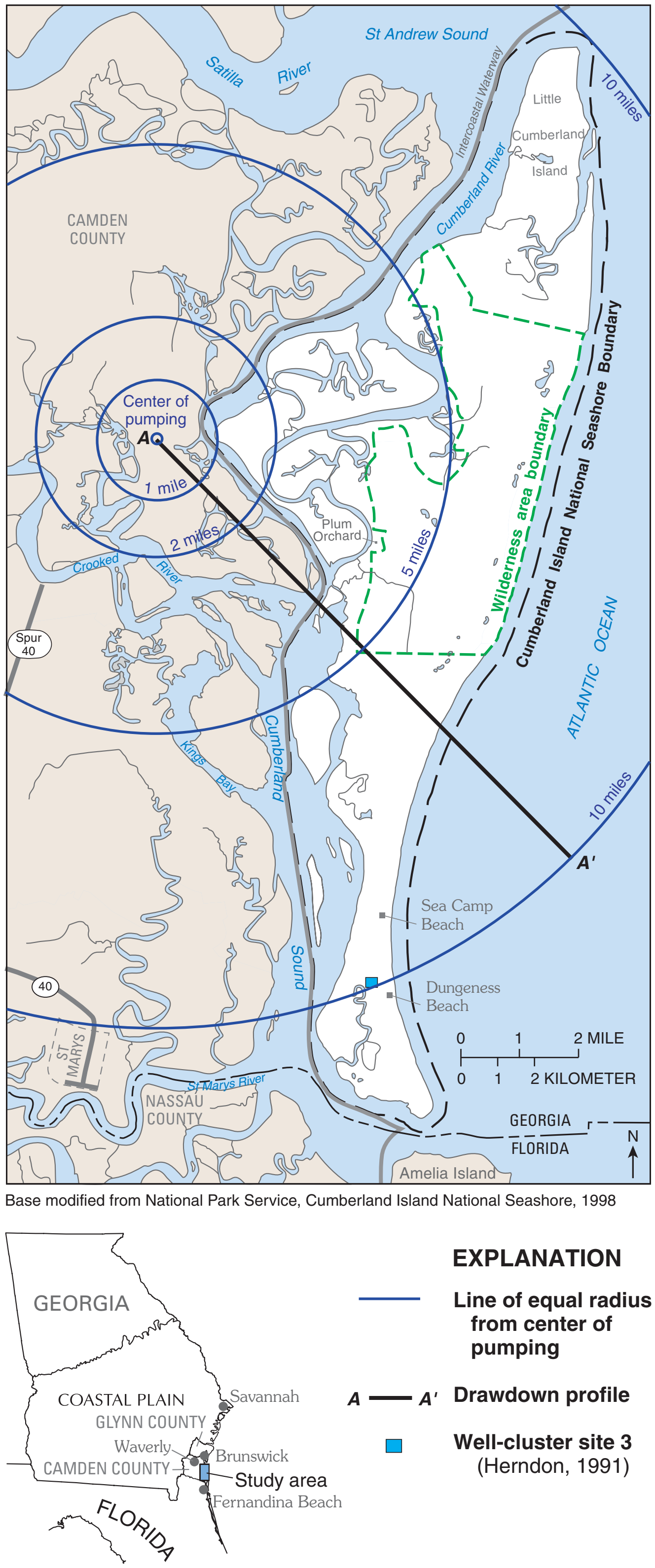

Figure 1. Location of study area, Cumberland Island National Seashore, and potential groundwater pumping center in eastern Camden County, Georgia.

The confined Brunswick aquifer system is divided into two water-bearing zones—the upper Brunswick aquifer and the lower Brunswick aquifer (Clarke, 2003). The upper Brunswick aquifer consists of fine to coarse, quartz sand and limestone; the lower Brunswick aquifer consists of poorly sorted, fine to coarse, phosphatic sand and limestone. The confined Floridan aquifer system is divided into the Upper Floridan and Lower Floridan aquifers, consisting of massive limestone and dolomite in Camden County (Clarke and others, 1990).

This paper focuses on potential water-bearing units for the residential development in eastern Camden County—the confined zones of the surficial aquifer system and the upper and lower Brunswick aquifers. Reported transmissivity for the confined zones of the surficial aquifer system in Camden County ranges from 500 feet squared per day (ft^2/d) at Waverly (Sherlyn Priest, U.S. Geological Survey, written commun., 2004) to 540 ft^2/d at St. Marys (Sharp and others, 1998). Reported transmissivity of the upper Brunswick aquifer ranges from 70 ft^2/d at Waverly (Sherlyn Priest, U.S. Geological Survey, written commun., 2004) to 250 ft^2/d at Cumberland Island (Herndon, 1991). Transmissivity data are not available for the lower Brunswick aquifer in Camden County; however, data are available at a test site in Glynn County, about 35 mi north of the proposed development site, where the reported transmissivity is 3,000 ft^2/d (Golder Associates, Inc., 2003).

Storage coefficient data for the aquifers are limited. For the confined surficial zones, Herndon (1991) reported storage coefficient values ranging from about 0.00002 to 0.00006 at Cumberland Island. Herndon (1991) reported a storage coefficient of 0.00005 for the upper Brunswick aquifer from a well at Cumberland Island. In Glynn County, reported storage coefficient for the lower Brunswick aquifer is 0.0001 (Golder Associates, Inc., 2003).

The potential for interaquifer flow between adjacent hydrogeologic units is controlled in part by the hydraulic gradient between the units. Hydraulic head data are limited for Cumberland Island. Herndon (1991) reported groundwater levels for June 1990 at three well-cluster sites located in the southern part of the island. One of the sites (site 3, Fig. 1) is located about 10 mi from the potential pumping center in eastern Camden County. At this location, the potential for interaquifer flow is downward from the water-table zone toward the confined zones of the surficial aquifer system, with a head difference of 2.42 ft. Although water-level data at this location indicate a downward potential for flow, it is possible that upward flow potential from confined zones to the water-table zone exists elsewhere on the island.

ESTIMATED DRAWDOWN

To estimate the impact of groundwater development in the vicinity of Cumberland Island, drawdown in the surficial and Brunswick aquifer systems was estimated using an analytical method and existing hydraulic-property data. Using the nonequilibrium formula of Theis (1935), drawdown was computed for 1-, 5-, and 10-year intervals from the initiation of pumping at 1-ft, and 1-, 2-, 5-, and 10-mi radii from the potential withdrawal location. The nonequilibrium formula is:

$$s = \frac{Q(W(u))}{4\pi T} \qquad u = \frac{r^2 S}{4Tt}$$

Where

s is the drawdown in feet;

Q is well discharge in cubic feet per day;

T is the transmissivity in feet squared per day;

t is the elapsed time since pumping started in days;

r is the radius from the pumping well in feet;

S is the storage coefficient (dimensionless); and

W is the well function of u (determined graphically, or from data tables such as those reported by Ferris and others, 1962, pp. 96–97).

Drawdown estimates were computed for each aquifer based on reported average transmissivity and storage coefficient. Initially, the expected pumping rate of 2 Mgal/d was used for the drawdown computations; however, low transmissivity of the surficial and upper Brunswick aquifers resulted in excessive drawdown, and the aquifers were presumed unable to sustain this high pumping rate. Thus, a pumping rate of 0.2 Mgal/d was used to compute drawdown in the three aquifers (Fig. 2). In the more productive lower Brunswick aquifer, drawdown resulting from a pumping rate of 2 Mgal/d was also computed at 1-, 5-, and 10-year intervals (Fig. 3).

Profiles for each aquifer showing estimated drawdown at a 0.2-Mgal/d pumping rate within a 10-mi radius from the proposed development site indicate that drawdown near the well was greatest in the upper Brunswick aquifer and least in the lower Brunswick aquifer (Fig. 2). At the end of 1 year of pumping at 0.2 Mgal/d, maximum drawdown at the center of pumping was 95 ft in the surficial aquifer confined zone, 280 ft in the upper Brunswick aquifer, and 17 ft in the lower Brunswick aquifer. The cone of depression during this 1-year period had propagated beyond 10 mi in all three aquifers, with drawdown at 10 mi of 6.4 ft in the surficial aquifer confined zone, 6.2 ft in the upper Brunswick aquifer, and 1.6 ft in the lower Brunswick aquifer. By the 10th year, drawdown at the center of pumping was 104 ft in the surficial aquifer confined zone, 310 ft in the upper Brunswick aquifer, and 19 ft in the lower Brunswick aquifer. Drawdown 10 mi from the center of pumping after 10 years of pumping at 0.2 Mgal/d was 15 ft in the surficial aquifer confined zone, 30 ft in the upper Brunswick aquifer, and 3 ft in the lower Brunswick aquifer.

Pumping the lower Brunswick aquifer for 1 year at a rate of 2 Mgal/d resulted in 170 ft of drawdown at the center of pumping, and 16 ft of drawdown 10 mi from the center of pumping (Fig. 3). By the 10th year of pumping at this rate, drawdown was 186 ft at the center of pumping and 32 ft at 10 mi from the center of pumping.

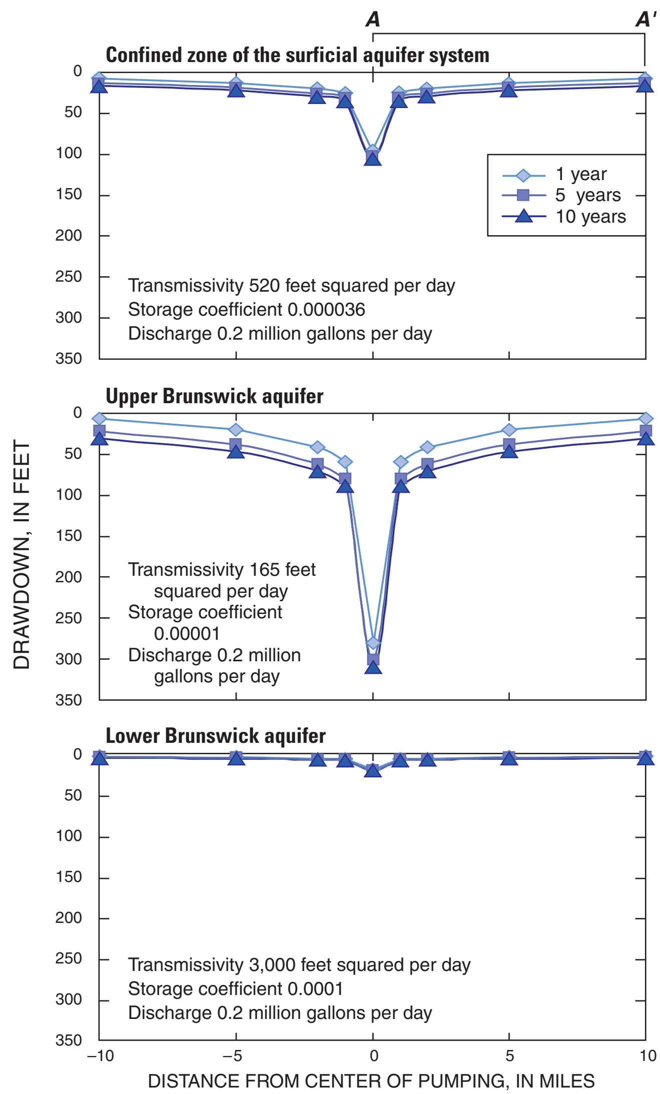

Figure 2. Estimated drawdown in the confined zone of the surficial aquifer system and in the upper and lower Brunswick aquifers at a pumping rate of 0.2 million gallons per day for 1-, 5-, and 10-year time intervals, Camden County, Georgia. See Figure 1 for line of section.

POTENTIAL EFFECTS OF DEVELOPMENT ON GROUNDWATER

Pumping for proposed residential development in eastern Camden County would result in declining water levels in the surficial and Brunswick aquifer systems that will extend to Cumberland Island and have the potential to affect the water levels in the surficial aquifer system, which is important for sustaining freshwater wetland ecosystems. Most of the wetland areas are located within the wilderness area on Cumberland Island, about 5 mi from the center of pumping (Fig. 1). Near the western edge of the wilderness area, estimated drawdown after 1 year of pumping at a rate of 0.2 Mgal/d was 16 ft in the surficial aquifer confined zone, 19 ft in the upper Brunswick aquifer, and 2.5 ft in the lower Brunswick aquifer (Fig. 2). In the same area and at the same pumping rate, drawdown after 5 years was 26 ft in the surficial aquifer confined zone, 39 ft in the upper Brunswick aquifer, and 3.7 ft in the lower Brunswick aquifer. After 10 years of pumping at a rate of 0.2 Mgal/d, drawdown in this area was 30 ft in the surficial aquifer confined zone, 47 ft in the upper Brunswick aquifer, and 4.2 ft in the lower Brunswick aquifer.

The lower Brunswick aquifer has the greatest development potential of the three aquifers because of a relatively higher transmissivity of about 3,000 ft^2/d (Golder Associates, Inc., 2003). Pumping from the aquifer at a rate of 2 Mgal/d would result in drawdown along the western wilderness area boundary of 25 ft after 1 year, 37 ft after 5 years, and 42 ft after 10 years (Fig. 3). Water-level declines in wetland areas could reduce quantities of water discharging from confined units into the unconfined parts of the surficial aquifer system, which are important for sustaining freshwater wetland ecosystems on Cumberland Island.

LIMITATIONS OF ANALYSIS

The drawdown analysis using the nonequilibrium formula of Theis (1935) is limited by several simplifying assumptions that do not account for all of the variability of aquifer sediments and their water-bearing properties. These include (Ferris and others, 1962):

- The aquifer is homogeneous, isotropic, and of infinite areal extent.
- The discharging well has an infinitesimal diameter and penetrates and receives water from the entire thickness of the aquifer.
- Transmissivity of the aquifer is constant at all times and all places.
- Water removed from storage is discharged instantaneously with decline in head.

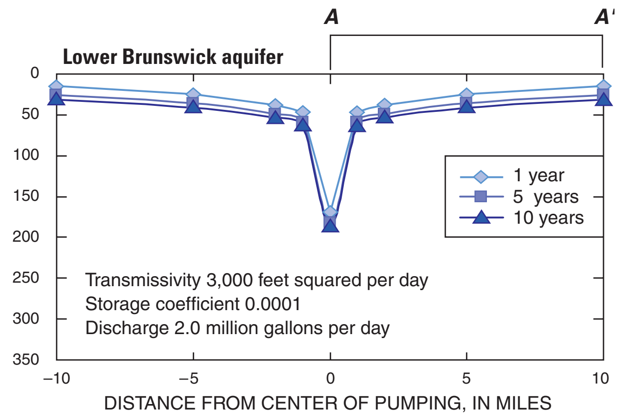

Figure 3. Estimated drawdown in the lower Brunswick aquifer at a pumping rate of 2 million gallons per day for 1-, 5-, and 10-year time intervals, Camden County, Georgia. See Figure 1 for line of section.

In addition, recharge to the aquifer through precipitation or interaquifer leakage is not accounted for by the analysis. Despite these limitations, the analysis is useful for the estimation of the magnitude and extent of drawdownresponse in an aquifer. To account for aquifer heterogeneity and interaquifer leakage, a digital groundwater flow model could be used to synthesize field information and simulate possible drawdown response.

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