

# HYDRAULIC CHARACTERIZATION OF THE UPPER FLORIDAN AQUIFER IN THE CHICKSAWHATCHEE SWAMP, SOUTHWESTERN GEORGIA

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**Abstract.** The Chickasawhatchee Swamp is an expansive palustrine wetland located primarily in western Dougherty, eastern Calhoun, and northern Baker Counties, Georgia, in the Dougherty Plain district of the Coastal Plain physiographic province. The Chickasawhatchee Swamp is underlain by a shallow carbonate aquifer that may have a pronounced effect on the hydrologic signature of the wetland. The Swamp likely functions both as a groundwater recharge area and as a groundwater discharge area for the Upper Floridan aquifer. In the wetlands, the shallow aquifer is overlain by poorly drained swamp-alluvial soils, however, in areas where erosion has removed the overburden the carbonate rocks that comprise the aquifer are exposed. Nine wells tapping the Upper Floridan aquifer were installed in a spatially distributed pattern over the western part of the Swamp. A conceptual aquifer framework was developed and single-well aquifer tests were conducted. Each well was pumped at a low, intermediate, and high pumping rate that ranged from about 5 to 60 gallons per minute to evaluate yield characteristics, well efficiency, and aquifer response. Test results indicate the transmissivity ranges from about 1,140 to 21,300 square feet per day over the study area. The calculated transmissivity did not vary significantly between the three pumping rates which indicates that aquifer response is linear and that low volume, single-well pumping tests conducted in small-diameter wells can be used to develop representative estimates of aquifer transmissivity.

## INTRODUCTION

Wetlands within karst landforms are distributed across the Coastal Plain province of the southeastern United States. The Chickasawhatchee Swamp is an expansive palustrine wetland that consists of more than 30,000 acres in western Dougherty, eastern Calhoun,

and northern Baker Counties, Georgia, in the Dougherty Plain district of the Coastal Plain physiographic province (figure 1). It is the second largest southern deepwater swamp and riparian wetland in the State, only exceeded in areal extent by the Okefenokee Swamp of southeastern Georgia. The Chickasawhatchee Swamp is underlain by the shallow, carbonate Upper Floridan aquifer that may have a pronounced effect on the hydrologic signature of the wetland. Moreover, the wetland may have a dynamic interconnection with the underlying carbonate aquifer and seasonally function as either a recharge or discharge. In the Dougherty Plain area of southwestern Georgia, the Upper Floridan aquifer is at or near land surface and receives recharge directly, or indirectly, from an average annual precipitation of about 52 inches.

Balancing the goals of protecting natural resources with the anthropogenic use of our lands requires a detailed knowledge of environmental factors that affect



**Figure 1. Location of study area.**

ecologically sensitive areas, such as the Chickasawhatchee Swamp. In the case of southern deepwater swamps and riparian wetlands, understanding the interactions among wetland water regimes and the shallow carbonate aquifer; variable inflow loads and the chemical mitigating capacity of the wetlands; and the relation between hydrology and ecosystem primary productivity is critical for effective natural resource management and protection. In order to gain a better understanding of the groundwater and surface-water interactions and geochemical processes, the rate of groundwater movement from points of recharge to points of discharge must be defined. For this to be accomplished, estimates of aquifer transmissivity (T) must be developed. Typically, this is accomplished by conducting a large-scale pumping test that requires a sizeable capital investment and is often difficult, or impossible to design where discharging groundwater from the pumping well does not confound the test results. It is hypothesized that low-volume aquifer testing will provide accurate estimates of the aquifer T using single-well tests in the hydrogeologic environment beneath the Chickasawhatchee Swamp.

To better understand the hydrologic relations in this vast wetland area, the Joseph W. Jones Ecological Research Center in cooperation with the Georgia Department of Natural Resources is conducting a long-

term hydrologic evaluation of the streams, aquifers, and wetlands. This paper describes the low-volume hydraulic testing of the Upper Floridan aquifer conducted as a part of this evaluation.

## APPROACH

A map and field reconnaissance was conducted to identify sites within the western portion of the Chickasawhatchee Swamp that could be accessed by water well drilling equipment. Sites were located on aerial photomaps to evaluate their spatial distribution. Monitoring wells were installed at nine sites distributed over an area of approximately 15,000 acres (figure 2). Each site contains one well that fully penetrates the Upper Floridan aquifer. At four of the sites, a second well was installed tapping only the water-table aquifer. The Upper Floridan wells were installed using hydraulic rotary and air-reverse drilling techniques. A 4-inch diameter steel casing was cemented into the top of the competent limestone and the lower part of the limestone formation was completed as an open hole. Each well was developed first using the air-lift method, followed by pumping at a high rate using a submersible pump until the water was clear and free of sediment. Aquifer tests were conducted using two different pumps. Each well was pumped at the low rate using a Grundfos Rediflow II submersible pump capable of

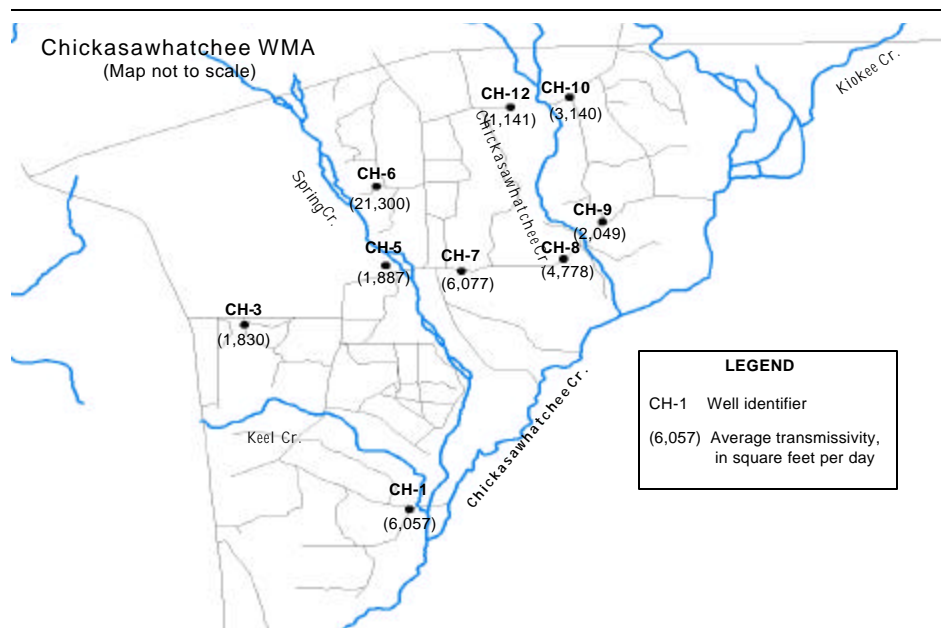


Figure 2. Locations of monitoring wells and calculated transmissivity.

withdrawing water at a maximum rate of about 6.5 gallons per minute (gals/min). Withdrawals at the intermediate and high rates were accomplished using a larger Grundfos submersible pump designed for homeowner applications capable of pumping at a maximum rate of about 70 gals/min. The intermediate rate was obtained by using an inline valve to restrict the pump outflow. Although this method successfully produced the desired rate of withdrawal, the restriction resulted in turbulence in the well as the pump surged under the load created by the artificial head and produced erratic water-level readings.

Water-level fluctuations were monitored in the pumped well using a Troll SP4000 (In-Situ, Inc.) downhole monitoring instrument that utilizes a pressure transducer to sense change in hydraulic head. Water-level data were stored in the Troll and periodically downloaded to a personal computer during pumping to visualize the progression of the test. Each test was continued until water-level decline diminished indicating theoretical steady-state conditions were achieved. Pumping duration ranged from about 30 to 90 minutes per test and was dependent on the aquifer characteristics and the pumping rate. Water-level data were downloaded in the office into a spread-sheet format for manipulation, and plotted on linear and semi-logarithmic graphs using a computer graphical software package. The data were analyzed and transmissivity estimates made using the straight-line approach developed by Cooper and Jacobs (1946).

## HYDROGEOLOGY

Most wells installed for this study terminated in the upper part of the Lisbon Formation of middle Eocene age which provides vertical confinement to the Upper Floridan aquifer. In this area the carbonate sediments of the Ocala Formation of late Eocene age form the Upper Floridan aquifer. In most areas the aquifer is confined above by a dense clay layer that has resulted from the weathering of the overlying Suwannee Formation of Oligocene age.

The Lisbon Formation consists of brownish-green argillaceous, glauconitic limestone containing thinly bedded layers of clay and fine sand. Because of the presence of the glauconite, the formation was easily identified and the monitor well drilling was terminated when drill cuttings bearing this mineral were detected. The completion depths of the Upper Floridan aquifer monitoring wells range from 54 to 114 ft below land surface. Drilling was halted in two of the monitoring wells before the Lisbon Formation was encountered due

to the loss of circulation resulting from drilling into a large cavity in each well. The lower part of the Ocala consists of recrystallized, fractured, dolomitic limestone. Voids, up to 1 ft in vertical extent, were encountered in about 25 percent of the wells which are indicators of solution developed secondary porosity. However, the lateral connectivity of the voids was not determined and they do not appear to be areally extensive aquifer features. The upper part of the Ocala typically consists of fossiliferous, recrystallized chalky limestone. Formational layers alternate between very soft weathered limestone and hard recrystallized limestone. The Ocala Limestone is overlain by a regionally extensive layer of soft, orange to white to gray, plastic clay. The clay layer ranges from 2 to 4 ft in thickness over the study area. Limestone fragments were commonly observed within the clay, thus, indicating that the clay may be residuum of a younger carbonate formation; assumed to be the Suwannee Limestone. Remnant boulders of Suwannee Limestone were encountered in the overburden at several drill sites and can be found scattered throughout the area landscape. The remainder of the overburden above the clay layer consists of a wide range of lithology including sand, silt, and clay in various proportions. The clay layers within the upper part of the overburden appear to be somewhat random, but appear to be more extensive both areally and vertically at the monitoring sites located nearest the present day stream channels. In the swampy areas of the Chickasawhatchee, the shallow aquifer is overlain by poorly drained swamp-alluvial soils, except in areas where erosion has removed the overburden and the carbonate rocks that comprise the aquifer are exposed.

## AQUIFER TEST RESULTS

In order to use the method of transmissivity estimation described by Cooper and Jacobs (1946), a number of conditions must be met. The most significant error can be attributed to an analysis based on data collected from an incomplete test; incomplete in the sense that steady-state conditions pumping duration is not adequate to allow steady-state conditions to develop. During the early stages of a pumping test the drawdown cone developed proximate to the pumping well is initially in an "unsteady shape. As the pumping test continues the cone of depression begins to assume a relatively steady shape, first near the pumping well and then gradually to greater and greater distances" (Heath 1983). When withdrawals continue for a sufficient period of time the groundwater moving along the

hydraulic gradient is equal to the rate of pumping and drawdown ceases to increase. At this time the cone of depression is said to be at steady state. The Cooper and Jacobs method of transmissivity estimation is valid only when the time of pumping has been adequate to create steady-state conditions and only then will the water-level readings from the monitored well begin to fall on a straight line when plotted on semi-logarithmic graph paper. When steady-state conditions have developed, the slope of the straight line is directly proportional to the pumping rate and the transmissivity of the aquifer (Heath 1983). The transmissivity was calculated using the equation:

$$T = \frac{2.3 Q}{4\pi (s_2 - s_1)}$$

where, T = transmissivity, in square feet per day (ft<sup>2</sup>/day)

Q = rate of pumping, in gallons per minute

(s<sub>2</sub>-s<sub>1</sub>) = change in drawdown over one log cycle, in feet

Figure 3 shows the drawdown data plots from two well sites where multiple rate pumping tests were conducted. Well CH-7 was pumped at constant rates of 5.6, 41, and 64 gals/min until steady-state conditions developed. At these pumping rates, it appears that steady-state conditions began developing less than 1 minute after pumping began. Data were collected at 3-second intervals throughout each test to ensure that a reliable assessment of the drawdown could be made during "early time" as well as later in the test. The calculated T at well CH-7 at the low, intermediate, and high rates was 6,030, 5,980, and 6,222 ft<sup>2</sup>/day, respectively. The specific capacity was about 35, 34, and 29 gals/ft, respectively.

Well CH-8 was pumped at constant rates of 5.6, 45, and 59 gals/min. At this well, it appears that steady-state conditions did not develop until pumping had continued about 3 or 4 minutes. Estimates of T at the low, intermediate, and high pumping rates was about 4,900, 4,632, and 4,802 ft<sup>2</sup>/day, respectively. The specific capacity was about 43, 28, and 33 gals/ft, respectively.

Estimates of T ranged from about 1,140 ft<sup>2</sup>/day at well CH-12 located in the north central part of the study area, to about 21,300 ft<sup>2</sup>/day at well CH-6 located in the northwestern part of the study area near Spring Creek. During drilling of well CH-6, it was noted that a

significant part of the limestone formation was highly fractured which would suggest the likelihood of enhanced aquifer transmitting potential as a result of secondary permeability. Transmissivity estimates for well CH-6 averaged 21,300 ft<sup>2</sup>/day and were an order of magnitude greater than observed in other study area wells.

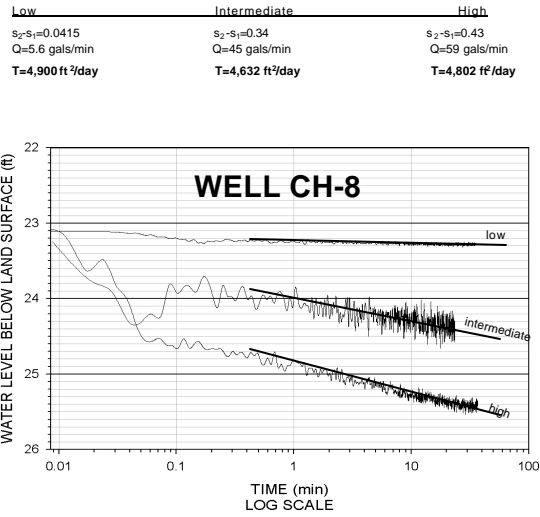
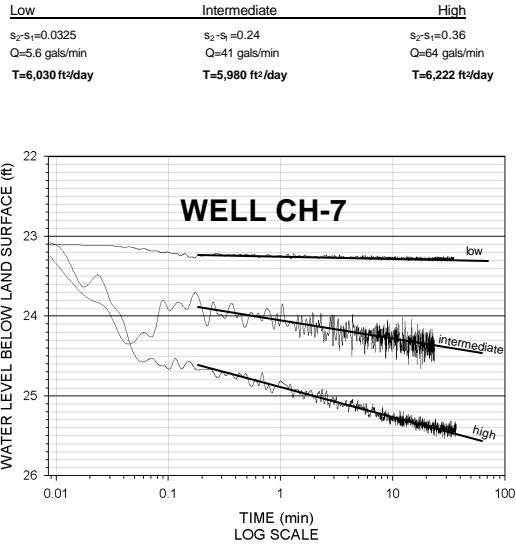
## WELL EFFICIENCY

The efficiency of the pumped well is not a factor in the determination of aquifer transmissivity from a single-well test. However, a component of the well efficiency, well loss, can result in a significant increase in drawdown at higher pumping rates. Drawdown due to well loss in the pumped well increases rapidly as the pumping rate is increased. In most wells, the drawdown in the pumping well is always greater than the drawdown in the aquifer immediately outside the well bore. The total drawdown observed in the pumping well represents the drawdown in the aquifer caused by the removal of water by the pump combined with the drawdown that occurs as water moves from the aquifer formation into the well bore. In simple terms, the well loss is the component of drawdown that is the result of water moving from the aquifer into the well.

Well loss was evaluated in each of the pumping wells by graphically plotting the specific capacity observed versus the corresponding pumping rate. This analysis proved inconclusive as some wells appeared to increase in efficiency as the pumping rate increased. However, there was no discernable well loss in any of the wells over the pumping range used in these tests.

## CONCLUSIONS

Single-well, low-volume aquifer tests were conducted in 4-inch diameter monitoring wells installed in the Upper Floridan aquifer at the Chickasawhatchee Swamp. Each well was pumped at a low, intermediate, and high rate of withdrawal until steady-state conditions were developed in the pumping well. Drawdown data were analyzed using the Cooper and Jacobs (1946) method. Transmissivity estimates ranged from 1,140 to 21,300 ft<sup>2</sup>/day. The calculated transmissivity did not vary significantly between the three pumping rates which indicates that aquifer response is linear and that low volume, single-well pumping tests can be used to develop representative estimates of aquifer transmissivity in small diameter wells.



**Figure 3. Water level response to pumping and transmissivity calculations.**

#### REFERENCES

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