DEVELOPMENT OF A CONCEPTUAL MODEL OF GROUNDWATER FLOW, CHESTERFIELD COUNTY, SOUTH CAROLINA

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Abstract. Chesterfield County is located in the north central part of South Carolina (SC) and is adjacent to the North Carolina border. The County lies along the Fall Line, the geologic boundary between the Atlantic Coastal Plain (ACP) and Piedmont physiographic provinces. Between 2000 and 2007, the population increased from 42,768 to 43,191 people (U.S. Census Bureau, 2007). Associated with this population growth is an increased demand for domestic, public, industrial, and agricultural water supplies. The ACP sediments underlying Chesterfield County contain abundant supplies of high-quality groundwater (Newcome, 2004).

The U.S. Geological Survey, in cooperation with the South Carolina Department of Natural Resources is investigating the ACP groundwater resources of Chesterfield County. The initial task of the study is to establish a hydrologic data-collection network for the ACP part of the County. A groundwater-flow model and derived water budgets for the ACP aquifer that underlies most of the County will be constructed and calibrated later in the study. Both anthropogenic and natural groundwater contaminants that have been identified in the study area will be quantified and described as part of a companion study.

Introduction

Much of Chesterfield County (fig. 1) is served by Alligator Rural Water and Sewer (ARWS), a public supply utility, whose sole source of water is the ACP aquifer. Currently (2010), ARWS withdraws approximately 2-3 million gallons per day that is served throughout much of Chesterfield County. The future holds potential for the construction and operation of new industries in Chesterfield County, which, along with population growth, will require substantial additional volumes of high-quality potable water. Impacts of these proposed increases in withdrawals on existing groundwater and surface-water resources of the area are unclear. Additionally, ARWS is planning to construct a regional waste-water treatment plant that will dispose of effluent by land application. Simulations of groundwater flow, groundwater-travel times, and potential groundwater contaminant transport near the proposed waste-water treatment plant could provide valuable information for decision makers and area stakeholders.

There are water-quality concerns for the groundwater resources in Chesterfield County. Several ARWS public supply wells (fig. 2) along with numerous private wells have had samples of raw groundwater that exceeded the U.S. Environmental Protection Agency Maximum Contaminant Limit (MCL) for ethylene dibromide (EDB), dibromochloropropane (DBCP), and radium (Paula Brown, South Carolina Department of Health and Environmental Control, written commun., 2010). The EDB and DBCP are most likely related to agricultural fumigant uses and possibly leaks from underground storage tank sources while the radium is related to natural processes.

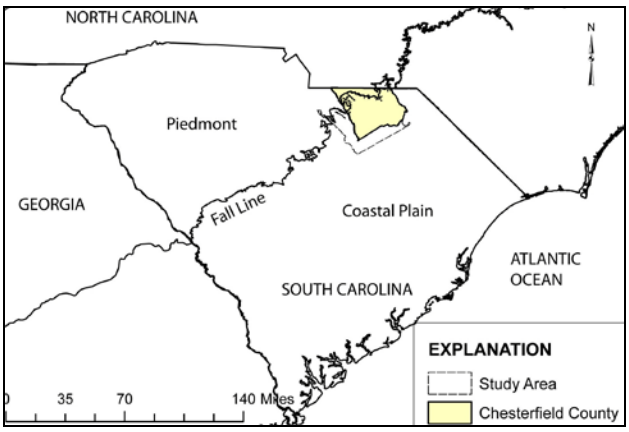

Figure 1. Location Map of Chesterfield County, South Carolina.

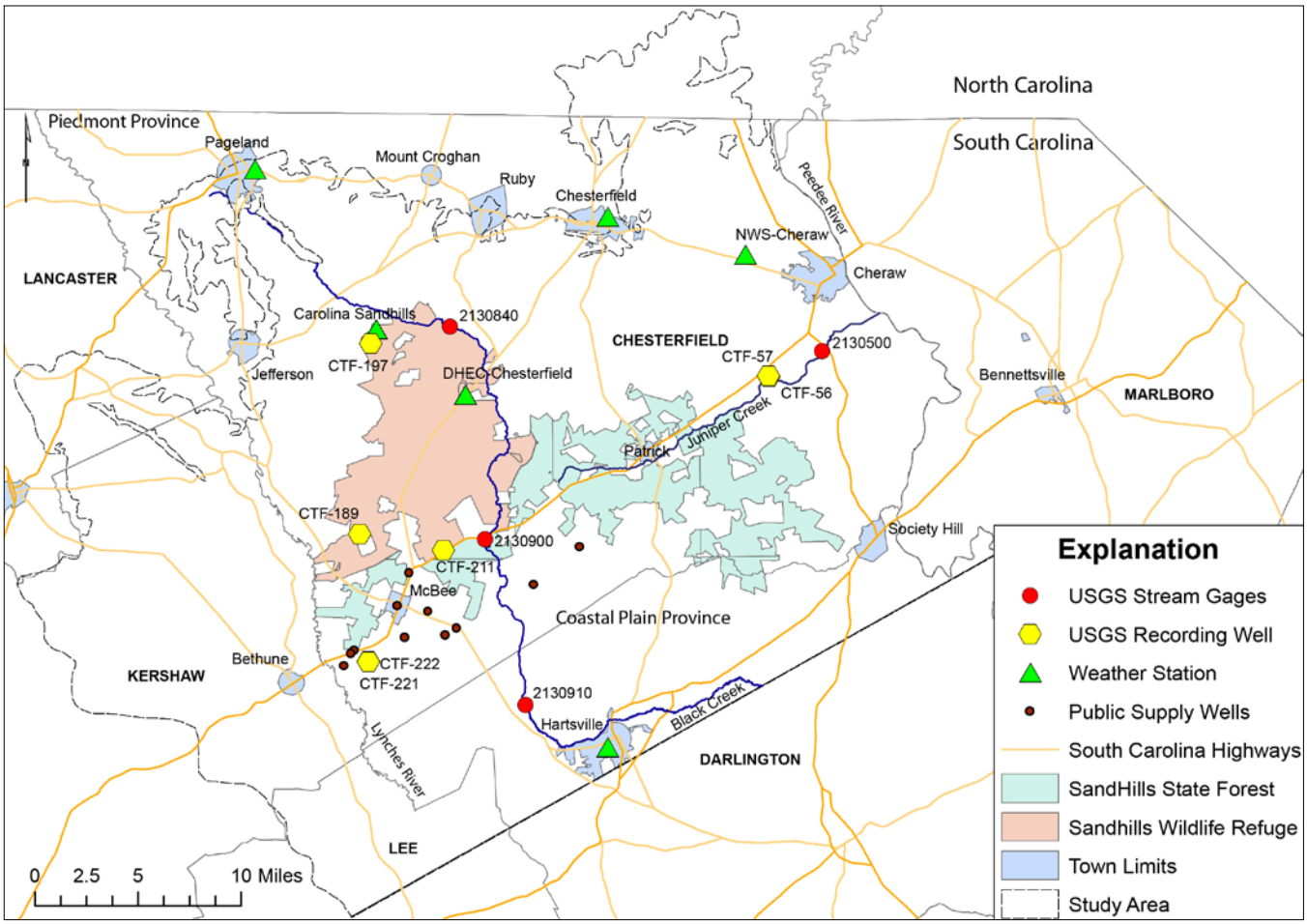

Figure 2. Location map of hydrologic monitoring stations in Chesterfield County, South Carolina.

The primary objective of the investigation is to develop and apply a groundwater flow and management model to assist in the water-resources management of the area and to better understand the groundwater contamination issues in Chesterfield County. Results of the investigation could be used to help assess sustainability of the water resources of the study area and to help minimize the potential for excessive groundwater level declines and adverse impacts on surface-water resources. In addition, a better understanding of the relation between the groundwater contaminants, their sources, and their transport will provide information for decision makers on the fate of these contaminants with respect to potable water supplies. The first step towards achieving the study objectives was the establishment of a basic hydrologic data-collection network for precipitation, groundwater levels, and streamflows.

A preliminary conceptual groundwater-flow model for the ACP aquifer of Chesterfield County has been developed. This conceptual model has most of the annual precipitation entering the ground surface. Much of this infiltrated precipitation is quickly transpired by the vegetation in the area while some infiltrated precipitation directly evaporates from the land surface. The remaining water moves into the groundwater flow system, first through the unsaturated zone of the area, which ranges from 0 to 200 feet thick. Next, the groundwater flows vertically and horizontally through the saturated zones with most of the groundwater discharging to a dense network of springs, streams, and wetlands in the study area. A small part of the groundwater flow moves downgradient into the deeper flow zones of the ACP aquifers southeast of study area.

Methods

A basic hydrological data-collection network has been established in Chesterfield County utilizing existing data-collection sites along with new ones that have been constructed for the study. Several weather stations are present in the County including one long-term station operated by the National Weather Service near Cheraw, SC (fig. 2) that has been in continuous operation since 1894. Three USGS streamflow gaging stations are currently in operation on Black Creek (a Pee Dee River tributary) in Chesterfield County with station 02130900 (Black Creek near McBee) in continuous operation since

1959 (fig. 2). Additionally, a discontinued stream gaging site is located on Juniper Creek (2130500) near Cheraw, SC, for which 12 years of streamflow data were recorded from 1940 to 1958. There are no long-term, continuous groundwater-level monitoring stations in Chesterfield County; however, five groundwater-level monitoring sites have been established as part of the current investigation (fig. 2). Of these five sites, two are well clusters with both a shallow and deeper well that are monitored for groundwater levels.

A finite-difference groundwater-flow model code (MODFLOW-2005) (Harbaugh, 2005) is being used to construct and calibrate a fully three dimensional groundwater-flow model of the ACP aquifer present in Chesterfield County.

A series of reconnaissance-level soil-gas samples are being collected to assess the presence or absence of EDB and DBCP in the aquifer and associated unsaturated zone in the study area. Groundwater samples analyzed for volatile organic compounds and naturally occurring radium along with groundwater age-date samples also will be collected as part of the investigation. Results for the water-quality investigation phase of the study will be available at a later date (Landmeyer and Campbell, 2010).

Data

Data collected to date (June 2010) provide some insights into how the groundwater system in the ACP aquifer is functioning in Chesterfield County. The streamflow data collected at station 02130900 (Black Creek near McBee, SC) clearly show the impact of the extended drought of 1998-2002 with the lowest flows of record in the summer of 2002 (fig. 3). The average annual mean flow is 147 cubic feet per second (ft^3/s) and ranges from 53 (2002) to 265 ft^3/s (1998). Baseflow recession analysis (Rutledge, 1998) of the continuous streamflow record from USGS stream gaging station 02130900 (Black Creek near McBee, SC) indicates that approximately 80 percent of the streamflow is derived from groundwater discharge. Given the sandy nature of the ACP sediments in Chesterfield County, this is probably a low estimate and most likely almost all of the gain to the streamflow downstream from the Fall Line is derived from groundwater discharge. Observations during rainfall events by personnel from the Sandhills Wildlife Refuge and the Sandhills State Forest (fig. 2) indicate that little precipitation moves across the sandy land surface as runoff and most infiltrates into the ground quickly.

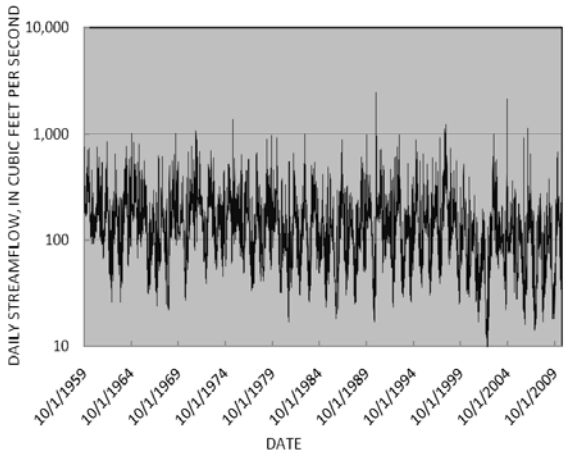

Figure 3. Daily streamflow, recorded at USGS stream gaging station 02130900, Black Creek near McBee, South Carolina, 1959-2010.

Continuous groundwater levels recorded at well CTF-222 (fig. 4) from September 2008 to June 2010 show a slightly downward trend in the water levels during 2008 and 2009 but with the heavy winter rains of 2009-2010, the water level appears to have stabilized. The water level in the well responds quickly to precipitation, even though the water level is approximately 134 feet below land surface. These quick rises in water level typically recess to the original level in a matter of hours.

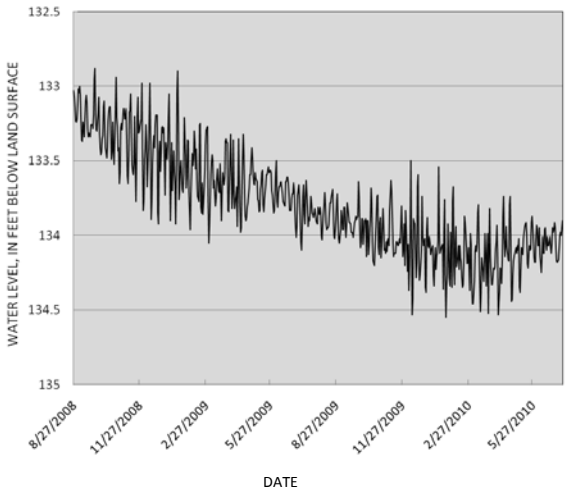

Figure 4. Groundwater levels recorded in the Atlantic Coastal Plain aquifer at well CTF-222, near McBee, South Carolina, 2008-2010.

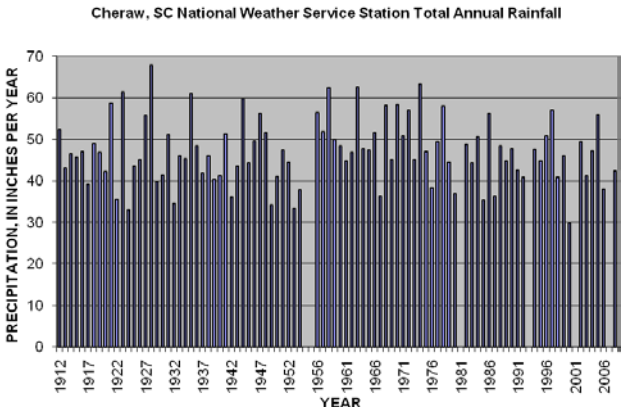

Figure 5. Annual precipitation 1911 to 2009 at Cheraw, SC National Weather Service station. Blanks indicate missing annual data.

Annual precipitation rates (fig. 5) at Cheraw, SC (fig. 2) vary between 29 inches (in 2001) and 67 inches (in 1929). The annual mean for the period of record (1894-2009) is 47 inches. The 1998 – 2002 drought can be seen in the data even though the data for the year 2002 are not presented due to incomplete records at the station. For 2002, nearby stations in Hartsville, Chesterfield, and Pageland (fig. 2) recorded total annual precipitation of 43.51, 43.58, and 39.46 inches, respectively (National Climatic Data Center, 2002).

Summary

The ACP aquifer underlying the Chesterfield County area is a valuable natural resource providing baseflows to springs, streams, and wetlands in the area along with high-quality water supplies for the county residents. Groundwater contained in the aquifer is generally of high quality except in limited areas where both natural and anthropogenic contaminants have degraded the water quality.

A hydrologic monitoring network has been established in the ACP part of the Chesterfield County area that consists of both existing stations and newly constructed ones. The network is composed of weather and precipitation stations, streamgages, and continuous groundwater level monitoring stations. Some of these stations were in operation during 1998-2002 and recorded the severe drought during this time period.

A conceptual groundwater-flow model has been developed for the study area that will be used to construct a numerical groundwater-flow model. The numerical model is expected to provide insight in managing the groundwater resources of Chesterfield County by quantifying the groundwater budget, and predicting groundwater contaminant transport and fate.

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