ASSESSMENT OF SALTWATER MIGRATION THROUGH THE UPPER FLORIDAN CONFINING UNIT IN THE SAVANNAH HARBOR AREA

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Abstract. Pumping in the Savannah vicinity has decreased the potentiometric surface of the Upper Floridan aquifer and induced a cone of depression, and saltwater is assumed to leak downward through the confining layer toward the aquifer. Marine seismic subbottom profiling, core drilling, and porewater geochemistry data collected as part of the ongoing Supplemental Studies to Determine Ground-water Impacts to the Upper Floridan Aquifer were used to better define the stratigraphy and hydraulic characteristics of the confining layer.

The current study focuses primarily on the "area of concern" from Field's Cut to approximately two miles offshore of Tybee Island, where the confining layer naturally thins and several deep buried paleochannels have cut further down into the confining layer. The results of the porewater data derived from this work are believed to demonstrate the depth to which seawater has penetrated downward through the confining layer and indicate that chloride breakthrough has occurred in some locations along the Savannah River channel.

INTRODUCTION

The U.S. Army Corps of Engineers is studying the potential effects on the Upper Floridan aquifer due to a proposed harbor expansion of the Port of Savannah. The proposed Savannah Harbor Expansion Project consists of deepening approximately 35 miles of navigation channel (Fig. 1). The objective of the current study is to determine if deepening the Savannah Harbor channel has the potential to impact water quality in the Upper Floridan aquifer, the primary source of drinking water in the coastal area. The study focuses on the Miocene age upper confining unit of the Floridan aquifer (i.e. confining layer), which in some areas of the present harbor is exposed in the bottom of the navigation channel. Special emphasis is being placed on the role of buried paleochannels that have cut into the confining layer.

The clay-rich, low permeability confining layer protects the underlying porous limestone strata. Prior to the 1880's, wells drilled into the artesian aquifer would yield a head of water up to 35 feet above mean sea level (MSL) in the Savannah-Hilton Head, South Carolina area. However, since the 1880's, due to increasing withdrawals of water from the aquifer, a resulting cone of depression in the Savannah area has lowered the water level in the aquifer to as much as 130 feet below MSL. The net effect of this lowering of water level has reversed the natural pre-development flow of ground water from the aquifer upward through the confining layer to a downward flow of water through the confining layer toward the center of the area of greatest pumping from the aquifer (Savannah). Since much of the area within the drawdown cone of depression is overlain by saltwater, chloride levels in the Upper Floridan aquifer in the Savannah area are expected to increase.

Removing additional confining layer material during the dredging process would effectively reduce the thickness of the layer; therefore, it is important to determine what effect this may have on the level of chlorides in the Upper Floridan aquifer due to any potential increase in the rate of downward leakage of saltwater.

BACKGROUND AND RELATED WORK

Various investigators have described the geology, hydrogeology and potential for saltwater encroachment in the Savannah/Hilton Head area (Siple, 1960; Counts and Donsky, 1963; Miller, 1986; McCollum and Counts, 1964; Furlow, 1969), and more recently the Georgia Geologic Survey published a comprehensive assessment of the geology and ground-water resources of coastal Georgia (Clarke and others, 1990).

The U.S. Army Corps of Engineers, Savannah District first addressed impacts to the Upper Floridan aquifer due to dredging in 1980 (USACE, 1980). The Savannah Harbor Comprehensive Study (USACE, 1982) contained detailed information as to potential ground-water effects due to saltwater intrusion in the Upper Floridan aquifer. A field investigation included drilling two deep core holes and performing a limited subbottom seismic survey. The report concluded that the aquifer strata would not be impacted given the proposed project depth at that time.

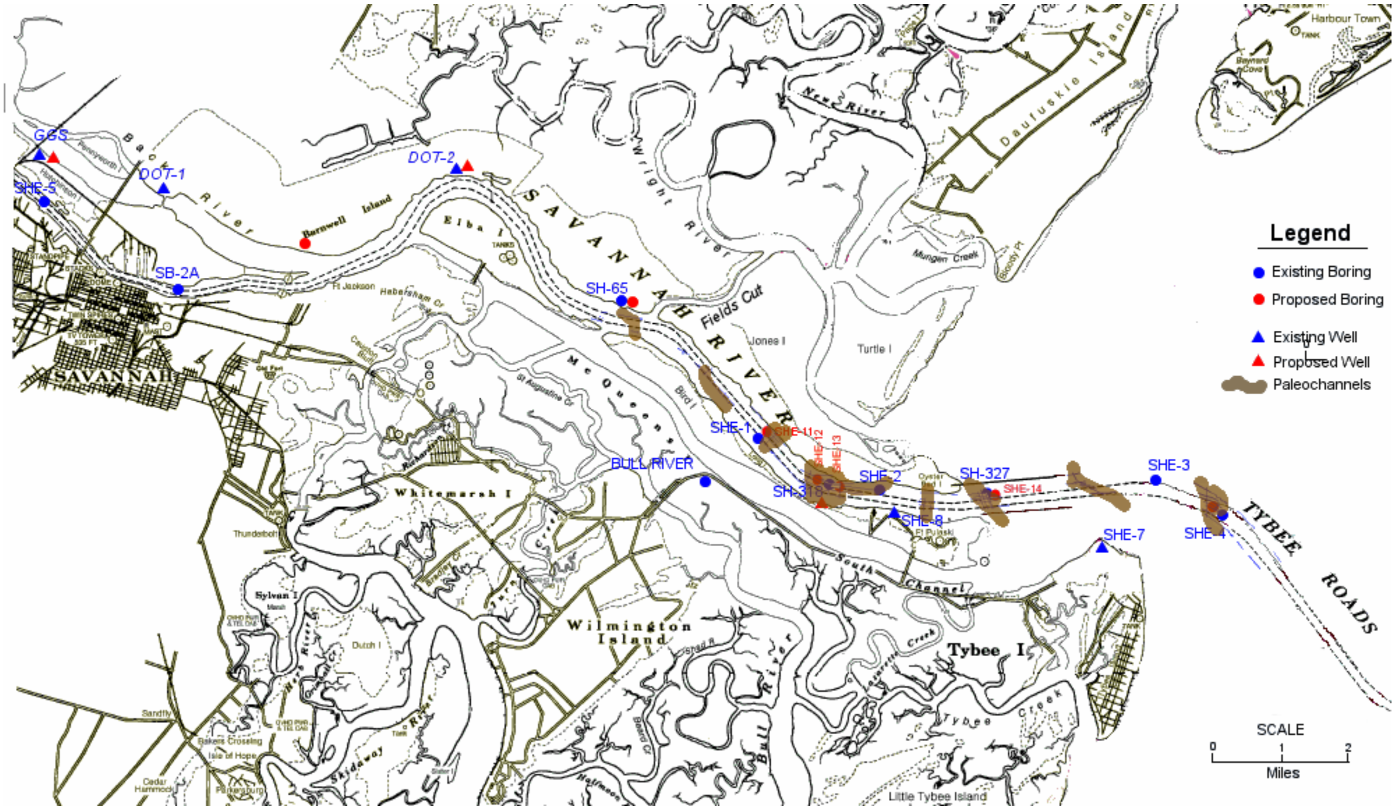

Figure 1. Proposed Savannah Harbor expansion project area map.

In 1992, the Savannah District issued a contract to further evaluate the potential for saltwater intrusion in the aquifer by compiling and examining existing seismic reflection data and boring logs along the navigation channel. The detailed investigation revealed several buried relict stream channels (i.e. paleochannels) had downcut into the Miocene confining layer and were later in-filled with younger sediments of different lithology than that of the confining layer. The report concluded that dredging associated with a proposed project depth of 46.0 feet below mean low water (MLW) would not directly penetrate or breach the confining layer, and seepage associated with paleochannels underlying the navigation channel would depend on the hydraulic conductivity of both the channel fill sediments and the confining layer. The report recommended drilling additional cores in paleochannel materials (Henry, 1992).

The findings of the 1992 report focused on paleochannels intersecting the navigation channel, and subsequent studies were conducted to evaluate their role in potential impacts to the Upper Floridan aquifer. Specifically, the studies aimed to evaluate the postulation that if the paleochannel in-fill material was more permeable than the underlying confining layer, then seawater would have a more direct path through the confining layer, thus increasing the rate of saltwater intrusion into the Floridan aquifer. In 1998, the U.S. Army Corps of Engineers, Savannah District, published the resulting efforts in a report entitled Potential Ground-Water Impacts as part of the Savannah Harbor Expansion Project Feasibility Study (USACE, 1998). The field investigation included drilling eight core borings, conducting laboratory analyses, and examining well data to determine the physical properties of sediments underlying the proposed project area. In addition an extensive, site-specific subbottom geophysical survey was conducted to better determine the physical relationship between the various stratigraphic units below the existing Savannah River navigation channel. The resulting data were used to create a comprehensive profile of the geologic and hydrogeologic units underlying the navigation channel and to calculate a vertical leakage rate of seawater through the paleochannels and Miocene confining layer to the top of the Floridan aquifer.

METHODS

The methods employed in this study to better determine the effect of thinning the confining layer were intended to build and expand on the information from previous studies, particularly the internal studies done by the Savannah District and the report by Clarke and others (1990). Primary objectives identified for the study were:

- Conduct additional subbottom seismic surveying in paleochannel areas;
- Conduct additional marine drilling and porewater analysis in selected paleochannel areas;
- Conduct additional land drilling with porewater analysis and multilevel well installations; and
- Develop a three-dimensional numeric solute transport ground-water model.

The subbottom seismic survey performed as part of this study was designed to complement and expand upon subbottom data gathered in 1997. Specifically, the survey aimed to identify and profile all significant paleochannels underlying the navigation channel from Field's Cut (Intracoastal Waterway) to approximately two miles offshore of Tybee Island, where the confining layer is thinned and the aquifer is highest in elevation. The data collected also provided a means for locating several of the marine borings completed as part of this study.

Initially, data was acquired along each edge of the navigation channel, and supplemental track lines were established in areas where prominent paleochannels passed under the navigation channel. The supplemental track lines were oriented such that the paleochannels were spatially well defined in seismic profiles (Fig. 2). In total, the survey incorporated approximately 60 miles of tracklines and greater than 50 survey lines.

Porewater samples of the confining layer and paleochannel fill material were extracted from undisturbed core samples (3-inch diameter) from both marine and land borings. The samples were then sent to the U.S. Geological Survey in Columbia, South Carolina for hydrochemical analysis via established ion chromatography methods. Samples were collected at 10-foot intervals, and the resulting chloride values were plotted versus depth to create vertical profiles of chloride

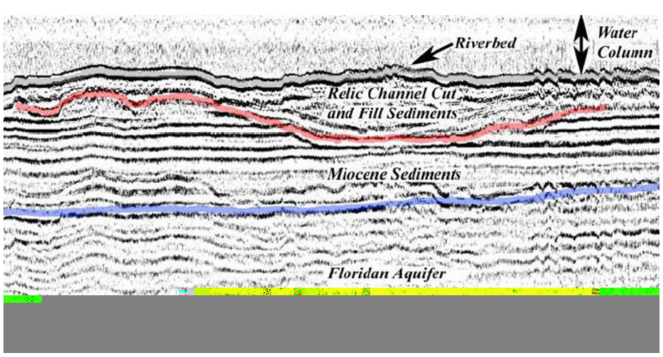

Figure 2. Paleochannel seismic record.

penetration at each boring location (Fig. 3).

The porewater profiles will be incorporated into a three-dimensional solute transport ground-water model to test various scenarios related to the hydrologic system in the immediate vicinity of the navigation channel. The model will also incorporate various other hydraulic properties, confining layer thickness, and historic, present, and future withdrawal rates to assess the full range of plausible aquifer responses to dredging.

RESULTS/DISCUSSION

The subbottom seismic survey provided a comprehensive data set of the stratigraphy underlying the navigation channel within the area of concern. The seismic profiles generated from the survey were used to better understand the three dimensional relationship of the navigation channel, paleochannels, and the confining layer. In general, subbottom data indicated that the paleochannel features identified in the entrance channel are oriented north-south and perpendicular to the present-day course of the river. In addition, seismic profiles were used to locate several boring locations within the deepest extent of paleochannel deposits.

The porewater data derived from work completed as part of the supplemental studies indicate that, as expected, seawater is moving downward through the Miocene confining layer toward the Oligocene limestone (Upper Floridan aquifer), and, in some locations, low concentrations of chlorides have migrated entirely through the confining layer and into the limestone. The pronounced profiles show that chloride concentration decreases with depth from the top to the bottom of the confining layer, and chloride values ranged from a high of 20,000 mg/L near the top of the layer to a low of 15 mg/L near the bottom of the layer. The data also suggest somewhat enhanced leakage of saltwater in areas where deep paleochannels cut across the present navigation channel (Fig. 3).

In borings drilled outside paleochannels, the corresponding porewater profiles showed decreasing chloride concentration with decreasing elevation in samples throughout the confining layer, and concentrations varied depending on the composition of overlying sediments and/or water. Profiles constructed within paleochannels showed punctuated increases in vertical migration of chloride through the paleochannel material, and the spikes in chloride concentration typically occurred at the paleochannel/confining layer contact. Otherwise, the profiles illustrated the same trend seen outside paleochannels: in the confining layer, chloride concentration decreased with decreasing elevation. The punctuated increase of concentration at the base of the

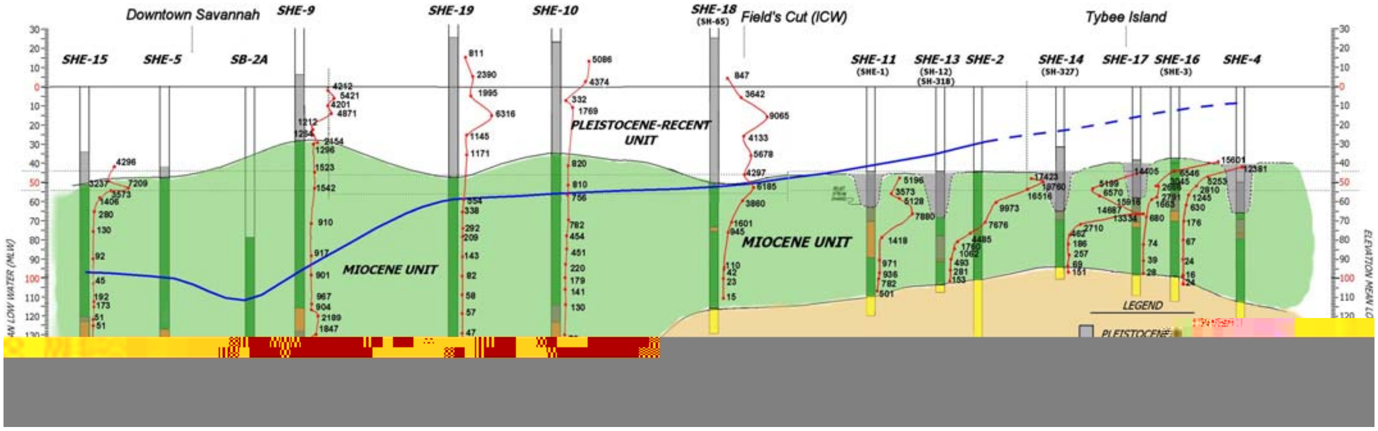

Figure 3. Porewater chloride profiles along Savannah River entrance channel.

paleochannel material and the decreased thickness of the underlying confining layer generally resulted in higher chloride concentrations near the top of the limestone.

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