

Characterization of Saltwater Intrusion into the Upper Floridan Aquifer of the Southern West-Central Florida Ground-Water Basin.

Michael H. Beach, P.E.
Southwest Florida Water Management District
Brooksville, Florida 34604-3899, USA

ABSTRACT

The Southwest Florida Water Management District manages the water resources within a 26,000 square kilometer (Km²) area of west-central Florida. The Upper Floridan aquifer is the principal source of water supply in the District and can be aerially divided into three ground-water basins. The southern west-central Florida ground-water basin (SWCFGWB) covers most of the southern half of the District. Saltwater intrusion is the principal constraint on the development of ground water in the coastal area of this basin. The purpose of this presentation is to describe the methods used by the District to characterize saltwater intrusion in the SWCFGWB.

The hydrogeology of the area consists of three recognized aquifer systems: the surficial aquifer, the intermediate aquifer system, and the Floridan aquifer system. The surficial aquifer is a sand aquifer ranging in thickness from 6 to 18 meters (20 to 80 feet) in the area. Its productivity is very poor relative to the underlying aquifers. The intermediate aquifer system consists of flow zones within the intermediate confining unit between the surficial and Upper Floridan aquifer. The flow zones of dolostone and limestone are interbedded with gravels, sand and clays. The flow zones may or may not be regionally extensive. The intermediate aquifer is moderately productive and an important source of water in the southern portion of the study area. The Floridan aquifer system is divided into the Upper and Lower Floridan aquifers. The water quality from the Lower Floridan aquifer has been reported to be unusable, so only the Upper Floridan is used. Even the Upper Floridan is of limited use in the southern-most part of the District due to poor water quality. The Upper Floridan aquifer is a thick, regionally extensive, limestone and dolostone aquifer. It is 350 to 550 meters thick and provides about 75 percent of all water supplies in the study area.

Under predevelopment conditions, the early 1900s, the Upper Floridan aquifer in the SWCFGWB discharged about 530,000 cubic meters per day (m³/day; or 140 Mgal/day) of freshwater from the Upper Floridan aquifer into the Gulf of Mexico and Tampa Bay along 145 Km (90 miles) of coastline. Ground-water levels steadily declined in the aquifer from the early 1900s to the late 1980s, at which time annual-average ground-water levels were about 10 meters (30 feet) below predevelopment levels. In May of 1989 and 1990, the ground-water level over some 2,000 Km² (800 mi²) was below sea level. In May of 2000, area below sea level would reach nearly 2,500 Km² (950 mi²).

In the late 1980s, the District undertook a comprehensive assessment of the risk that saltwater intrusion posed to the Upper Floridan aquifer water supply. The prolonged decline in ground-water levels due to development of water supplies indicated that saltwater intrusion should be occurring. However, the District had little reliable water-quality data to indicate the existence of regional saltwater intrusion into the Upper Floridan aquifer. Experience had taught well drillers and well owners the perils of completing wells along the coast into the deeper zones of the Upper Floridan aquifer, but this data was only anecdotal.

The District expanded and improved an existing hydrogeologic exploration program, constructed dedicated monitor wells, performed aquifer assessment tests, and implemented a

water-quality sampling network and data collection program. Based on data from these undertakings, the District developed conceptual models of water quality, estimated the slope of the interface, made estimates of the rate of intrusion, and developed the basis for several ground-water flow and transport models. Based on this characterization and the subsequent modeling, the District is now establishing a minimum aquifer level to address saltwater intrusion, as required by the State of Florida.

Data Collection

The District had an existing program, the Regional Observation and Monitor-Well Program (ROMP), to create a water-level monitor network. The network was to consist of Floridan aquifer wells on a grid (16 Km by 16 Km) over the District. Initially, the wells were "wells of opportunity" (i.e. available to the District for free that the owner might avoid legal abandoning requirements) with large diameters, large open intervals, and generally open to multiple aquifers: poor candidates for monitor wells.

Then, the District began to construct its own wells. At these sites, the District obtained a permanent easement for the permanent monitor wells and a surrounding, temporary construction easement for equipment and other wells. Each site was cored to the limits of the drill rig, generally about 360 to 460 meters (1,200 to 1500 feet) below land surface (bls). Monitor wells constructed at these sites generally consisted of a large, open interval, Upper Floridan aquifer well, an intermediate aquifer well and a surficial aquifer well. If water quality reached 250 mg/L of chloride, the limit for drinking-water standards, the well was completed at that depth and no further exploration was carried out. Few sites were tested for aquifer parameters.

In the current program, the principal goals are 1) exploration, testing and description of existing conditions and 2) the construction of dedicated monitor wells for future monitoring of water levels and water quality. Exploration at the site describes the hydrostratigraphy (identifying the production zones and confining units), the water quality with depth, and the aquifer characteristics. First, each site is cored to the limits of the drill rig as before. Then, a larger drill rig, drilling via the reverse air method, carries out additional exploration. Water quality samples are collected during exploration with the goal to provide as near as possible a complete description of water quality change with depth. Bailer samples, thief samples, and packer tests have all been used in this quest. Packer tests, although not as discrete as the other two methods, provide the most reliable data.

Flow zones are identified and a series of wells are constructed. These wells consist of production wells for aquifer performance tests (APTs), dedicated monitor wells, and observation wells. Often the wells are drilled for an initial purpose and then modified for an additional purpose (e.g. a large production well drilled for an APT might be back plugged and lined to become a dedicated monitor well). After identification of the flow zones, as many as five APTs may be performed at a site: one in the surficial aquifer, two in the intermediate aquifer, and two in the Upper Floridan aquifer. Besides packer testing for water quality, the method is also used to assess hydraulic conductivity of the low permeability and confining units. Dedicated monitor wells are generally 10 to 15 centimeters (4 to 6 inches) in diameter and have small open intervals, about 5 to 15 meters (15' to 50 feet), where water quality is changing with depth.

The District has added sites to the original grid in a few selected coastal locations. These sites, known as transect well sites, house only one monitor well. A transect consists of three dedicated monitor wells constructed approximately 1.6 Km (1 mile) apart. The purpose of these sites is to aid in the cross-sectional description of the saltwater interface. One site, usually the center site, is a full ROMP exploration and monitor well site. At the end sites, water quality exploration is carried out to locate the saltwater interface and a single monitor well is constructed. The District has defined the interface as the 1,000 mg/L chloride concentration surface.

Temporal water-level and water-quality data are collected from the monitor wells under two separate programs. Water levels are collected from each dedicated monitor well via various kinds of continuous recorders. The data are summarized to daily values in the database. Regional water-quality data are collected one or three times per year under the Water Quality Monitoring Program.

Characterization of Saltwater Intrusion

The data collected under the above programs have been used to better establish the hydrostratigraphy of the area; characterize water quality with depth at specific locations; estimate the slope of the interface and position of the toe; and, approximate rates of intrusion.

The water quality versus depth data is invaluable for creating water quality conceptual models and guiding the subsequent solute transport model development. The conceptual model of water quality with depth within 5 to 10 Km of the coast consists of three water quality types: a calcium-bicarbonate water overlying a calcium-magnesium-sulfate water overlying the sodium-chloride water. The calcium-magnesium-sulfate water originates in the central area of the basin near the base of the Upper Floridan aquifer. The base of the Upper Floridan aquifer is the middle confining unit and contains considerable evaporites of anhydrite and gypsum.

Water quality above the middle of the Upper Floridan aquifer is very good except on the barrier islands and immediately adjacent to the coast. The interface and transition zone are generally found in the highly transmissive (fractured dolostone), lower permeable zone of the Upper Floridan aquifer (Avon Park Formation). Vertical movement appears to be retarded by the overlying Avon Park Formation and the Ocala Limestone: low permeability dolostones and limestones. The upper permeable zone of the Upper Floridan aquifer coincides with the Suwannee Limestone. It is one-fifth to one-tenth as transmissive as the lower permeable zone and has tended to retard any lateral movement into this permeable zone.

The slope of the interface in the lower permeable zone has been estimated at 1:50. This is about one degree. The estimate is based on data collected from the northernmost transect wells. The transition or diffuse zone has been described as relatively sharp: about 15 to 30 meters (50 to 100 feet) from freshwater to seawater. The position of the interface toe was estimated and projected onto area maps based on slope estimates at two locations and the depth to the interface at several locations along the coast. The estimate of slope would be invaluable as a control on the solute transport models.

The District made estimates of the rate of movement of the interface at several locations by relating the spatial water-quality data from the exploratory work and temporal water-quality data from the completed monitor wells. The methodology is semi-graphical and very approximate. It is assumed that the transition zone has been vertically translated upward and the vertical distribution of water quality has not changed significantly since the exploration. From the vertical distribution of water quality, the gradient of the water quality (c/z) is evaluated in the vicinity of the 1,000 mg/L chloride concentration. The interface monitor wells targeted the 1,000 mg/L chloride concentration. The gradient of concentration change with time (c/t) is also evaluated as close to 1,000 mg/L of chloride concentration as possible. Dividing c/t by c/z yields an expression for the vertical rate of movement of the interface. Using the interface slopes, determined above, the horizontal rate of movement may also be determined. The District determined the slopes of these data from graphical plots.

This analysis and data gathering has proven very fruitful when developing solute transport models for the area. Future data collection will concentrate on improved location of the toe of the interface and overcoming water quality restrictions on data gathering in the south.