

# Effects of Aquifer Heterogeneity on Ground-Water Flow and Chloride Concentrations in the Upper Floridan Aquifer near and within an Active Pumping Well Field, West-Central Florida

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Chloride concentrations have been increasing over time in water from wells within and near the Eldridge-Wilde well field, near the coast in west-central Florida. Variable increases in chloride concentrations from well to well over time are the combined result of aquifer heterogeneity and ground-water pumping within the Upper Floridan aquifer. Deep mineralized water and saline water associated with the saltwater interface appear to move preferentially along flow zones of high transmissivity in response to ground-water withdrawals. The calcium-bicarbonate-type freshwater of the Upper Floridan aquifer within the study area is variably enriched with ions by mixing with introduced deep and saline ground water. The amount and variability of increases in chloride and sulfate concentrations at each well are related to well location, depth interval, and permeable intervals intercepted by the borehole.

Zones of high transmissivity characterize the multilayered carbonate rocks of the Upper Floridan aquifer. Well-developed secondary porosity within the Tampa/Suwannee Limestones and the Avon Park Formation has created producing zones within the Upper Floridan aquifer. The highly transmissive sections of the Avon Park Formation generally are several orders of magnitude more permeable than the Tampa/Suwannee Limestones, but both are associated with increased ground-water flow. The Ocala Limestone is less permeable and is dominated by primary, intergranular porosity. Acoustic televiewer logging, caliper logs, and borehole flow logs (both electromagnetic and heat pulse) indicate that the Tampa/Suwannee Limestone units are dominated by porosity owing to dissolution between 200 and 300 feet below land surface, whereas the porosity of the Avon Park Formation is dominated by fractures that occur primarily from 600 to 750 feet below land surface and range in angle from horizontal to near vertical. Although the Ocala Limestone can act as a semiconfining unit between the Avon Park Formation and the Tampa/Suwannee Limestones, seismic-reflection data and photolinear analyses indicate that fractures and discontinuities in the Ocala Limestone are present within the southwestern part of the well field. It is possible that some fracture zones extend upward from the Avon Park Formation through the Ocala, Suwannee, and Tampa Limestones to land surface. These fractures may provide a more direct hydrologic connection between transmissive zones that are vertically separated by less permeable stratigraphic units.

Ground water moves along permeable zones within the Upper Floridan aquifer in response to changes in head gradients as a result of pumping. Borehole geophysical measurements, including flow logs, specific conductance logs, and continuous monitoring of specific conductance at selected fixed depths, indicate that borehole specific conductance varies substantially with time and in response to pumping stresses. Ground-water mixing between hydrogeologic units likely occurs along highly transmissive zones and within boreholes of active production wells. Ground-water movement and water-quality changes were greatest along the most transmissive zones.

Variable mixing of three water-type end members (freshwater, deepwater, and saltwater) occurs throughout the study area. Both deepwater and saltwater are likely sources for elevated chloride and sulfate concentrations in ground water. Mass-balance calculations of mixtures of the three end members indicate that deepwater is found throughout the aquifer units. Samples from wells within the southwestern part of

the well field indicate that deepwater migrates into the shallow permeable units in the southwestern part of the well field. Deepwater contributes to elevated sulfate and chloride concentrations, which increase with depth and are elevated in wells less than 400 feet deep.

The greatest increases in chloride concentrations over time are found in water from wells closest to the saltwater interface. Ground water with a saltwater influence occurs primarily within the Avon Park producing zone nearest the saltwater interface, deeper in the aquifer system. Because chloride concentrations in saltwater are greater than those associated with deepwater, even small percentages of saltwater have a substantial effect on chloride concentrations. The highest percentages of saltwater are found in ground water from 600 to 750 feet deep within the transmissive zone of the Avon Park Formation. Specific conductance logs and long-term chloride concentration data indicate that saltwater may move preferentially inland along this transmissive zone. Chloride concentrations range from 5,000 to more than 15,000 milligrams per liter between 640-780 feet below land surface in wells less than 1 mile southwest of the well field. Elevated chloride concentrations in the well field are highest in wells where the potentiometric surface has been lowered.

Lowered ground-water levels associated with the Eldridge-Wilde well field affect the regional potentiometric surface of the Upper Floridan aquifer and may provide the potential to induce saltwater movement along transmissive zones of enhanced secondary porosity. From 1997 to 2000, water with elevated chloride concentrations migrated into the Eldridge-Wilde well field within the highly transmissive zone of the Avon Park Formation between 600-750 feet below land surface. In 2000, chloride concentrations reached 250 milligrams per liter in monitor wells tapping this production zone beneath the center of the well field. Isotopic analyses of deuterium, oxygen-18, and strontium-87/ strontium-86 indicate that saltwater mixing is a primary source of the observed chloride.