Significant Water Quality Trends Observed in the Lower Hawthorn Aquifer of Southwestern Florida, Occurrences and Solutions

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ABSTRACT
A majority of water utilities in Southwestern Florida use a brackish raw water supply treated by reverse osmosis water treatment to potable standards. The aquifer most commonly used for this brackish raw water supply is the Lower Hawthorn aquifer of the Upper Floridan aquifer system (FAS). This aquifer has typical chloride concentrations in the range of 500 mg/L to 2,000 mg/L. Anomalous high chloride concentrations have been observed in several wellfields during construction or operation of raw water production wells. These occurrences can be attributed to lateral saltwater intrusion, vertical upconing of poor quality water, or vertical conduits (fissures, cracks and fractures) which connect deeper saline water sources to the Lower Hawthorn aquifer. Manmade vertical conduits may result from old improperly abandoned agricultural or oil prospecting wells which may promote upward movement of groundwater from deeper more saline aquifers. The identification of possible sources for the degrading water quality in individual wells is needed prior to well modifications, or recommending operational changes to the wellfield to minimize salinity impacts.

INTRODUCTION
This paper describes the hydrogeologic framework and factors affecting increased chloride concentrations observed in separate wellfields throughout southwestern Florida. Water quality trends are affecting the quality and quantity of the Lower Hawthorn aquifer, a carbonate aquifer used for raw water supply for treatment to potable water to meet demands in southwestern Florida. Overall, certain wellfields have become more brackish over time as demands have increased. Also, there have been occurrences of localized saline water upconing or vertical migration. These trends are hard to predict because carbonate aquifers in general tend to have high degrees of heterogeneity due to their relatively high variability in depositional porosity, permeability and their susceptibility to diagenetic alteration, which can profoundly change the hydraulic properties of carbonate rock (Maliva et al. 2002).

Background
Historical water quality data was analyzed from several wellfields in southwest Florida. With permission, historical water quality data from two Lower Hawthorn aquifer brackish wellfields are presented here; the City of Cape Coral and City of Fort Myers Wellfields. The water quality was collected at varying times between 1988 and 2007 which is dependent on when the wellfield started operation.

HYDROGEOLOGY
Three major aquifer systems underlie the study area of Cape Coral, Florida: the Surficial Aquifer System (SAS), the Intermediate Aquifer System (IAS), and the Floridan Aquifer System (FAS), with the upper portion of the FAS being the focus of this study. These aquifer systems are composed of multiple, discrete aquifers separated by low permeability “confining” units that occur throughout this sequence. Salinity substantially increases with depth.

WELLFIELD WATER QUALITY TRENDS

Water quality trends can occur in two fashions; slow trends over time within the wellfield, and fast changes in individual wells. Certain mechanisms can be responsible for these trends or quick changes, however, many times the exact answer is not known without intense and potentially expensive investigations. There are ways to minimize the effects of water quality changes within a wellfield.

City of Cape Coral – Southwest RO Wellfield

Water quality declines were noted during the first 15 years of operation. During the 1984 wellfield expansion, chloride concentrations in the wellfield averaged approximately 550 mg/L. Changes in chloride concentration over time is presented in Figure 1, showing combined chloride levels in all wells increasing from 550 mg/L in 1988 to 850 mg/L in 2006. While average salinity levels for all wells combined have steadily increased between years 1988 and 2006, differences were observed in individual wells, as presented in Figure 5. It is evident that salinity in certain production wells exhibited dramatic TDS changes, such as evident in Well 214 that exhibited a TDS increase from 1,810 to 3,940 mg/L. The overall effect of the wellfield improvement strategies was to minimize stresses on individual wells and the wellfield alignments, and minimizing the potential for saltwater intrusion and upconing. Water quality of the raw water to the ROWTP has increased from about 1,400 mg/L TDS from 1988 to 1,900 mg/L in 2000. Water quality has remained stable since that time. The data suggest that readily implementable wellfield operational protocols can minimize water quality changes to manageable levels, thereby prolonging the life of the resource and treatment plant operational requirements.

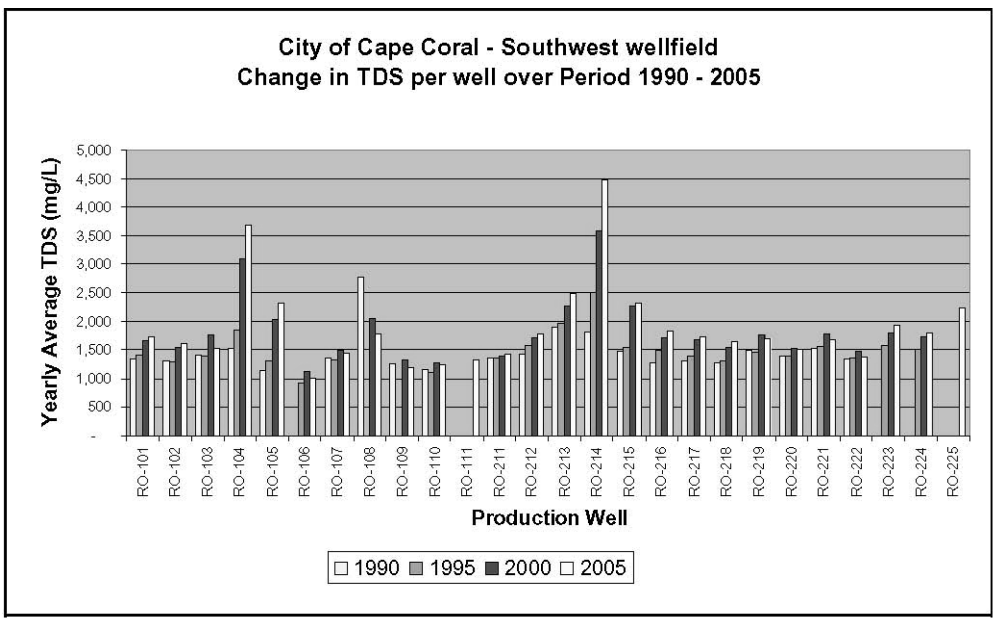

Figure 1. Total Dissolved Solids Trend in Southwest Production Wells Combined

City of Fort Myers Brackish Wellfield

The City of Fort Myers completed construction of the Phase I wellfield in 2000 (7 wells) and Phase II wellfield (5 wells) was initiated in 2003. During the development of the first production well in Phase II, the water quality quickly deteriorated from conductivity of approximately 7,000 microsiemens per centimeter (µS/cm) to 40,000 µS/cm (approximately 20,000 mg/L TDS or approximately 10,000 mg/L chloride). Because of the poor water quality and in concern for the other wells, this well was partially back plugged and converted to a monitoring well. Due to the extreme need for water, construction carefully proceeded with the other wells in the area. The testing during construction did not reveal any water quality issues with the other four wells. By mid October 2004, it was apparent that the high salinity in the first well had begun migrating to the next closest new production wells. The City considered information concerning the possibility that the high salinity could be caused by some naturally occurring feature (fractures or other geologic anomalies) within the northern section of the wellfield. To date, the lateral migration of salt water has impacted three of the five Phase II brackish production wells.

POTENTIAL SOURCES OF POOR QUALITY WATER

In Florida, vertical or lateral saltwater intrusion can affect water quality over time. Lateral saltwater intrusion occurs when seawater migrates inland from a natural reduction of freshwater heads (drought) or pumping of wells. Fractures which are also evident in carbonate aquifers of southwestern Florida may also increase lateral movement of saltwater into these coastal wellfields. Vertical saltwater intrusion occurs when saline water moves upward through fractures from underlying more brackish aquifers. Production wells are occasionally drilled into fractures that are oriented vertically or at high angles. These fractures may act as intersecting conduits for high salinity water to move upward rapidly degrading the water quality of some wells soon after they go into production, while not directly impacting others. In general, the rapid water quality changes experienced at these utilities seem to be connected to a vertical conduit (vertical fractures or old borehole) that is allowing upward movement of saline water from a deeper aquifer. The changes observed in one or two wells appear to be isolated.

Improperly Abandoned Historical Exploratory Wells

After finding uncharacteristically poor water quality following the development of the first well at the City of Fort Myers, it was suspected that an improperly abandoned exploratory oil or gas "strat" well may be responsible. It is known that Lee County (and surrounding counties) has many of these types of wells which originated back in the 1940s and 1950s with the advent of oil and gas exploration of the area. Many of these wells or exploratory holes were not publicly well documented. For very saline water to enter into an aquifer, the changing of potentiometric heads can cause open vertical conduits to actively water to be exchanged between aquifers which did not occur when potentiometric heads were undisturbed.

SOLUTIONS TO MINIMIZE MIGRATION

There are some solutions that can be imposed on wells that are experiencing impacts from poor quality water. At times, multiple solutions need to be used simultaneously to achieve the desired effect. Abandonment of a well shall always be considered the last option available. Reducing the impacts of upward or lateral migration of poor quality water shall always be considered the first option as it is prudent to try to save the high capital investment in production wells of today.

Back Plugging with Cement

It is possible that wells may be usable in the future if they are back plugged thus reducing stresses which will cause less water to be pulled from the bottom of the borehole. Typically, the deep flow zones are responsible for the connection to poor quality water. It is possible that production can be increased by acidizing a less dominant flow zone higher in the borehole.

Hydraulic Control and Water Quality Blending

Since a well may be connected or in close proximity to (not intersecting) a vertical conduit, it is quite possible that back plugging or abandonment will not be completely successful. Further operational analysis may show that the impacted well can be used at lower flow rate and the water produced can be diluted into the raw water stream to the ROWTP. This action has a higher chance of success when the additional wells exist or are planned in the immediate future. It is also possible that affected wells can continue being pumped and discharged to the ROWTP deep injection well for disposal, or used for a raw supply for a high pressure RO system. There are permitting and pipeline considerations to be made with this option, however, it can be a viable option if the current wellfield cannot be expanded to increase the blending capacity. Maintaining hydraulic control of the movement of the highly saline water may be the only option for a utility. An abandoned well provides no options for hydraulic control methods.

DISCUSSION AND CONCLUSIONS

Significant increases in salinity, which appear to be localized, may be caused by natural geologic features such as karst collapse features or localized vertical fractures, or man-made conduits of past activities, namely oil and gas exploration**.** Several existing wellfields in Lee County have exhibited significant water quality changes over time. These changes can affect single wells, multiple wells, or the entire wellfield. Efforts can be made to minimize effects of significant poor quality water migration. In some instances, sacrifices need to be made to protect the rest of the wellfield. These sacrifices can be loss of production from back plugging, reduction in production from a well with significant water quality changes, disposal the raw water from an impacted well to the concentrate deep injection well to maintain hydraulic control, endure lower ROWTP recovery efficiencies due to continued use of an affected well, endure higher ROWTP operational costs from higher feed pressures, costs for construction of a high pressure RO system, or abandonment of an affected well. The concept of hydraulic control is new in the municipal wellfield toolbox; however, it can prove to be a valuable way to protect water supplies from significant water quality changes that can impact an entire wellfield by migration.

REFERENCES

Maliva, R. G., Kennedy, G. P., Martin, K. W., Missimer, T. M., Owosina, E. S., and Dickson, J. A., 2002, *Dolomitization-Induced Aquifer Heterogeneity: Evidence From the Upper Floridan Aquifer, Southwest Florida*, GSA Bulletin, Vol 114, No. 4; p. 419-427.

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