Water Quality in the Southern Part of the Coconino Aquifer

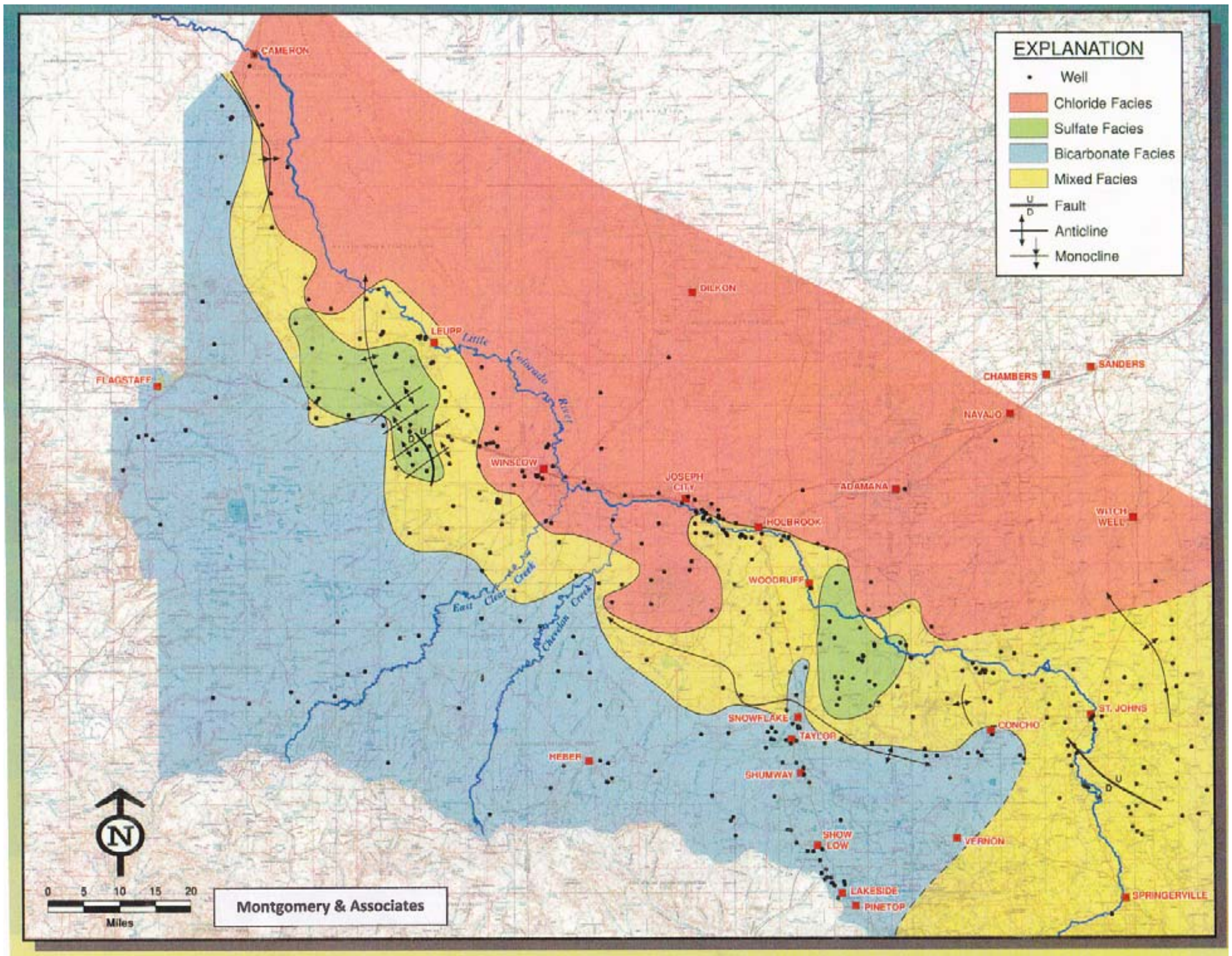

FIGURE 1. HYDROCHEMICAL FACIES AND SELECTED GEOLOGIC STRUCTURES

In Navajo and Apache counties, Arizona, as in all of the desert southwest, water is precious. Nearly as important as the water itself, though, is the quality of the water.

According to Ed McGavock, hydrologist at Montgomery and Associates, groundwater quality is a major problem in many areas. McGavock says that the groundwater doesn't meet drinking water standards in about 30 percent of off-Reservation Navajo County, and 65 percent of off-Reservation Apache County, and much of it isn't even suitable for livestock, agricultural irrigation, or industrial uses. An estimated 10 to 15 percent of the groundwater is so saline that dissolved minerals can't cost-effectively be removed by desalination processes.

To better understand the causes and extent of poor-quality water, as well as the potential for large-scale pumping to affect water quality, McGavock analyzed chemical data from about 500 wells. The wells are in an area that extends from east of St. Johns to near Flagstaff, and from Cameron through Holbrook, Heber, Snowflake, Show Low, Pinetop, and Springerville. In addition to evaluating total dissolved solids or “TDS” (the most commonly used indicator of water quality), McGavock looked at the individual chemical compounds that contribute to TDS levels.

McGavock and other researchers have long recognized that evaporites have a major impact on groundwater quality. The evaporites are minerals that remained when sea water flooded the area and then evaporated millions of years ago. There are layers of evaporites in the upper Supai Formation, underlying the Coconino Sandstone aquifer. The most common evaporite mineral is halite (sodium chloride or common table salt), followed by anhydrite and gypsum (both calcium sulfate). Potassium-bearing evaporite minerals near the Petrified Forest National Park have great economic importance, but little effect on the water quality.

In most areas, dissolved evaporite minerals are prevented from getting into the aquifer by a tight siltstone layer beneath the Coconino Sandstone. But in some locations, geological structures (including faults, fractures and folds) have created breaks in the siltstone layer. In those locations, groundwater can move upward from the evaporites, allowing the dissolved minerals to migrate into the aquifer, decreasing water quality.

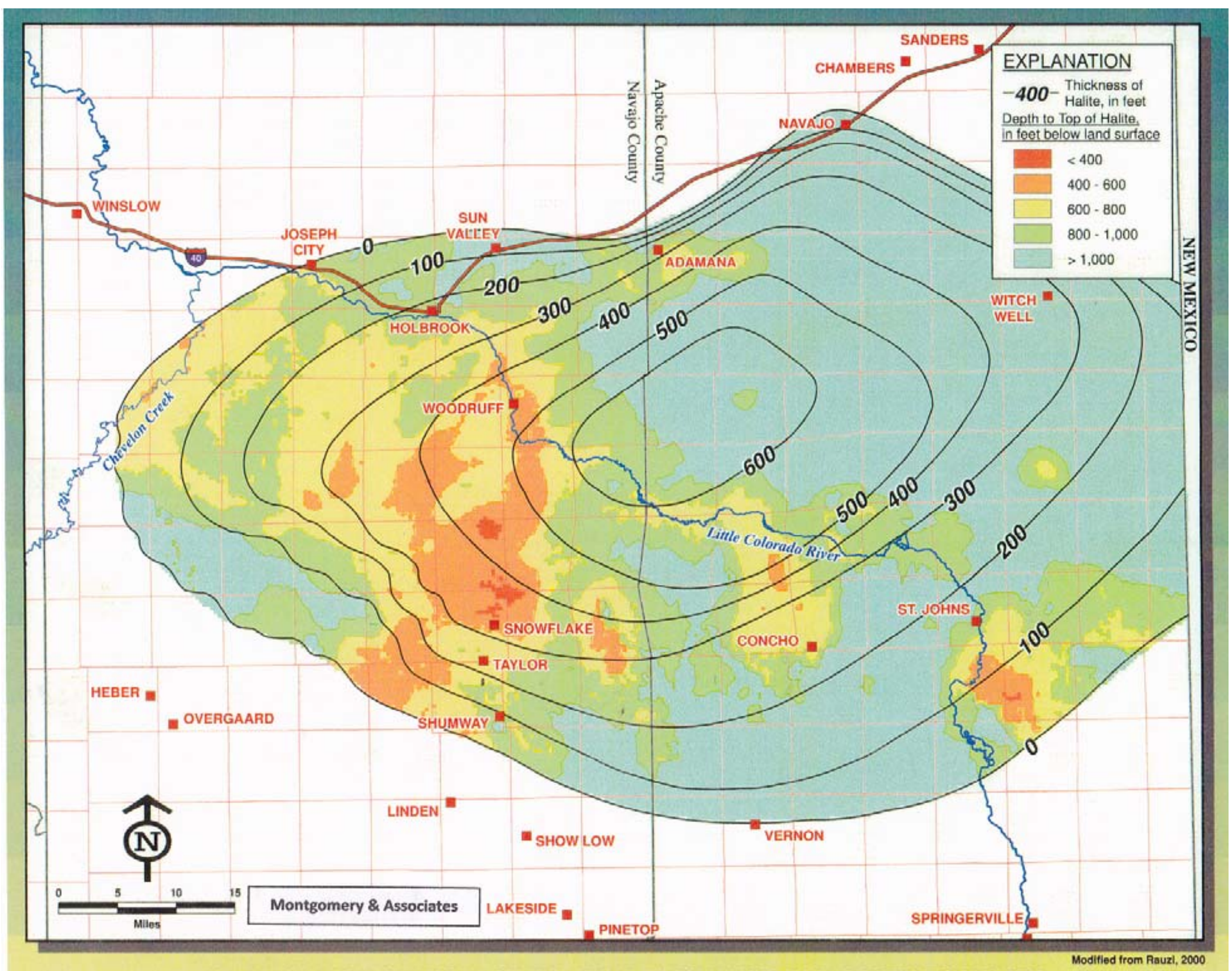

FIGURE 2. DISTRIBUTION, CUMULATIVE THICKNESS, AND DEPTH TO HALITE

While that process can explain why there are evaporite minerals in the aquifer, it is only a partial explanation for their presence in various areas. As he began his investigation, McGavock noted that there appear to be complex relationships between locations with low-quality groundwater, the boundaries of the evaporite layers, and breaks in the layers. Much of the lowest quality groundwater is in areas where there are no underlying evaporites.

To evaluate the relationships, McGavock added another variable: the direction of movement of groundwater. Most groundwater enters the aquifer as rainwater or snowmelt near the Mogollon Rim, and migrates slowly to the north and northwest toward the Little Colorado River. In addition to natural movement, there are local changes in direction of movement due to large-scale pumping, which causes lateral movement of groundwater toward the wells, and allows vertical movement of the groundwater due to decreased pressure in the aquifer.

McGavock theorized that groundwater movement over time has led to the migration of compounds, but the relationships to known geological structures are unclear, as is the extent of migration away from specific breaks in the siltstone layer, and the potential for large-scale pumping to affect migration.

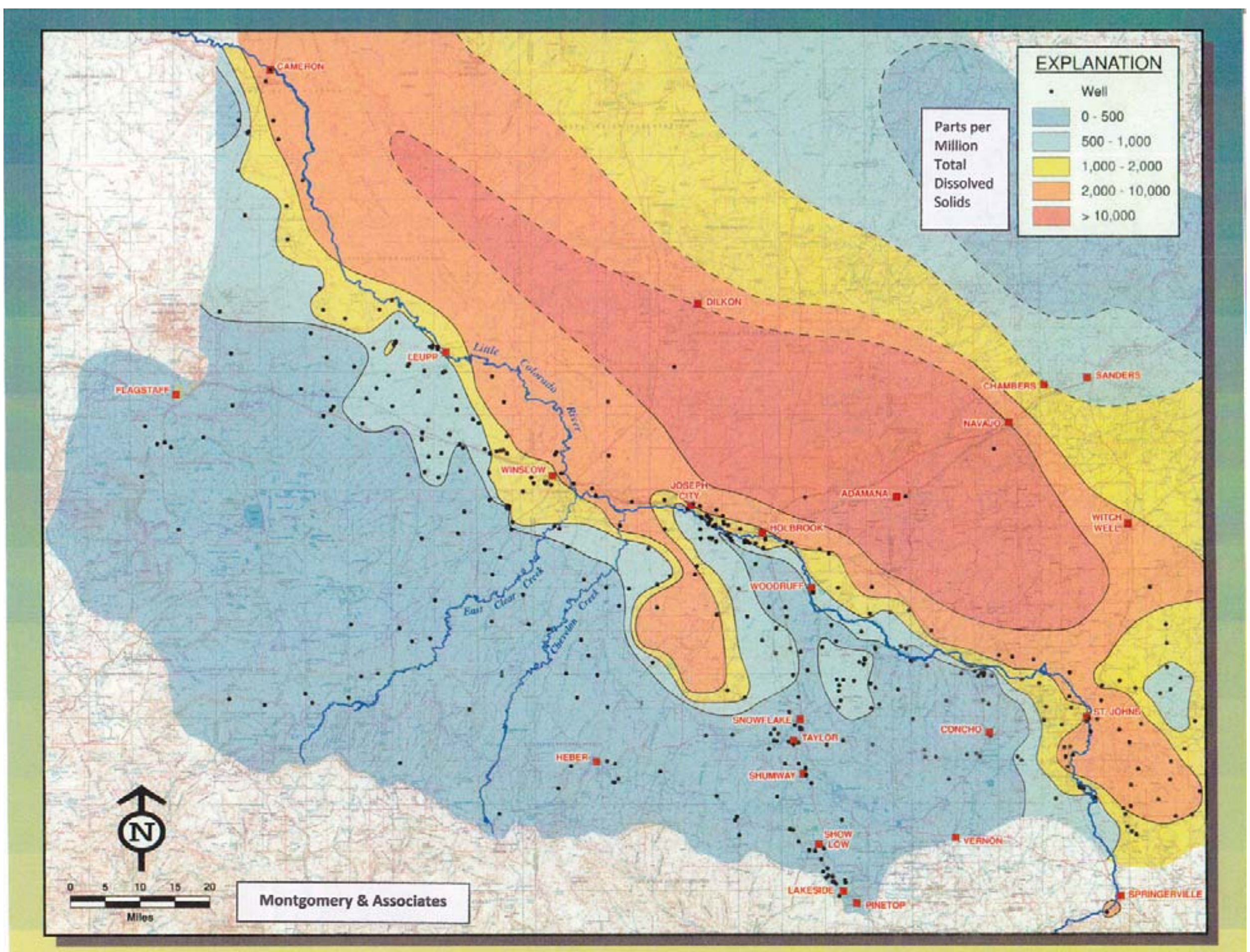

FIGURE 3. DISTRIBUTION OF TOTAL DISSOLVED SOLIDS IN THE SOUTHERN PART OF THE COCONINO AQUIFER

To better understand these relationships, McGavock produced maps of both TDS levels and the compounds that are dominant across the aquifer. He compared the locations of the different types of water to the known directions of movement of groundwater, and to the locations of breaks in the siltstone layer.

Figure 1 shows the compounds that are dominant in different areas. Technically, each body of water of a specific type is called a "hydrochemical facies," or water-chemistry type. The water type in the southern and western parts of the aquifer is labeled "bicarbonate" because calcium bicarbonate is the dominant compound. Bicarbonate water is dominant in areas near the Mogollon Rim where the water relatively recently entered the aquifer, and hasn't been affected by evaporite minerals in the Supai Formation.

A chloride water type is located generally to the north, mostly north of the Little Colorado River. Chloride also dominates a plume that begins northwest of Snowflake near Dry Lake, and extends to near Joseph City.

Between areas dominated by bicarbonate and chloride, there are areas where no single compound is dominant, rather, the water has all three in roughly equal proportions. This is labeled "mixed facies," or mixed type of water. Within the mixed facies, there are also two relatively small areas where the dominant compound is calcium sulfate, probably the result of the underlying evaporite minerals gypsum and anhydrite.

Figure 1 also shows the locations of faults, fractures, and folds. These structures are identified in the legend as faults, anticlines, and monoclines. The most well-known structure of this type is the Holbrook anticline (actually a monocline), that extends from the Dry Lake area eastward through Snowflake and beyond.

Figure 2 shows the location and boundaries of halite, the most easily dissolved evaporite mineral.

The levels of total dissolved solids are shown in Figure 3. The highest TDS-levels are in the chloride facies, always more than 1,000 parts per million (ppm). Levels above 1,000 are not considered suitable for drinking. The mixed and sulfate facies have intermediate levels, and the bicarbonate facies has the lowest levels--usually less than 500 ppm--which is good drinking water.

McGavock says these results indicate that low-quality groundwater has migrated from the faults, fractures, monoclines and anticlines, and traveled in the predominant directions of groundwater flow. Recent studies indicate that this type of leakage is still happening near parts of the Holbrook anticline. The areas of mixed water type indicate that the boundaries between facies aren't stable, suggesting the possibility for further water-quality changes in response to large-scale pumping.

Another complicating factor is the presence of poor-quality water in the Moenkopi Formation which overlies the Coconino in much of the area. Failure to seal off this upper Moenkopi layer often results in low-quality water leaking into poorly-constructed wells.

Additional ongoing analyses, including a water-quality monitoring network, are needed in order to track changes over time, and to better predict future pumping impacts on water quality.

These results reflect work in progress that McGavock presented in a poster session at the Arizona Hydrological Society 24th Annual Symposium in Flagstaff, September 18-20, 2011. Synopsis by Kathy Hemenway, PhD, February 21, 2012. Figures used with permission.