

How ground-water chemistry helps us understand the aquifer

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Although water is commonly thought of as simply H₂O, literally thousands of other substances are dissolved in water in the environment. Most of these substances occur naturally, and many are present in water in only small quantities. The term “water chemistry” (or water quality) refers to the quantities of these various substances (commonly called solutes) that are present in a particular water sample, making up its chemical composition. In the Santa Fe Group aquifer system of the Middle Rio Grande Basin, patterns in the water chemistry of ground water have helped refine important concepts about the ground-water-flow system, including sources of water, directions of flow, and travel times. The water chemistry of a ground-water sample can be thought of as a chemical signature that reflects the sum total of all physical processes and chemical reactions that affected the water from the time it began as dilute rainfall, infiltrated the soil above the water table, passed into the aquifer (ground-water recharge), and traveled, sometimes over great distances and depth, to the point of sample collection or discharge from the aquifer.

Water acquires very small quantities of some solutes from dust and gases when it falls through the atmosphere as precipitation, but water typically acquires the majority of its solutes once it reaches the land surface. Solute concentrations that were already present in the water increase in concentration because of the processes of evaporation and transpiration—processes that, for the most part, remove water while leaving the solutes behind. In some arid environments like New Mexico, plants can withdraw more than 90 percent of the precipitation that has infiltrated into the soil zone. As water infiltrates through the soil zone, it also tends to dissolve carbon dioxide (CO₂) gas that exists in the soil in large quantities (relative to the atmosphere) because of biological activity. When CO₂ dissolves in water in the soil zone, a weak acid is formed. This acid promotes the dissolution of minerals that are present in the soil and rocks, which releases solutes to the water and causes their concentrations to increase. Because of these processes, water in the soil zone can acquire the bulk of its chemistry before it reaches the water table.

In ground water, only seven solutes make up nearly 95 percent of all water solutes (Runnells, 1993; Herczeg and Edmunds, 1999). These solutes are calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chloride (Cl), sulfate (SO₄), and bicarbonate (HCO₃). Although many sources and reactions influence the concentrations of these solutes, the predominant sources of these solutes to ground water in the Middle Rio Grande Basin (Anderholm, 1988) include (1) the dissolution of limestone (calcite, CaCO₃) and dolomite (CaMg(CO₃)₂) for Ca, Mg, and HCO₃; (2) the dissolution of gypsum (CaSO₄·2H₂O) and anhydrite (CaSO₄) for Ca and SO₄; (3) the dissolution of halite (NaCl) for Na and Cl; and (4) ion exchange reactions on the surfaces of some clay minerals whereby sodium is released to the water in exchange for calcium or magnesium. Sodium also is derived from the dissolution of silicate minerals, such as plagioclase feldspars, which make up some of the sand and gravel that fill the Middle Rio Grande Basin. Potassium is derived from the dissolution of some silicate minerals in granitic rocks and from reactions with some clay minerals. Few reactions remove these seven solutes from ground water. However, some minerals, such as calcite CaCO₃, can precipitate from solution to form a solid phase.

In addition to the seven predominant solutes in water, some other solutes known as trace elements typically exist in very small quantities, as do particular isotopes of dissolved constituents (see Box I). Processes that affect the concentrations of trace elements and isotopes are not always well understood. However, combined with data on the predominant water-chemistry, trace-element and isotopic data for ground water can provide a powerful tool for tracking ground-water flow.

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In a very broad sense, the mineralogy of aquifers can be divided into two groups—those aquifers that contain relatively reactive minerals and those with mostly unreactive minerals. In aquifers composed of reactive rocks and minerals like limestone, dolomite, gypsum, halite, and organic matter, solute concentrations (and isotopic compositions) can change significantly with distance along a ground-water flow path, reflecting extensive chemical reaction. In aquifers composed of mostly unreactive material, like sand and gravel from the chemical and mechanical breakdown of silicate rocks and minerals, solute concentrations change only slightly with distance down a flow path. In these relatively unreactive aquifers, such as the Santa Fe Group aquifer system, water tends to acquire its predominant chemical composition during the process of recharge and retains that composition as it flows through the aquifer.

Much of the ground water in the Middle Rio Grande Basin has acquired its chemical (and isotopic) composition during recharge, either as infiltration of precipitation on the basin margin, as seepage from rivers and arroyos, or as ground-water underflow from adjacent aquifer systems that border the basin. Water chemistry differs depending on the source of water, the degree to which it has been evaporated, the types of rock and mineral it has encountered, and the time it has been in contact with reactive minerals.

Therefore, water in the Middle Rio Grande Basin commonly differs in the concentration of any particular solute and the concentration of that solute relative to other solutes. These distinct differences allow for the delineation of areas of the aquifer that have similar chemical “signatures.” The spatial extents and configurations of these areas can provide important information about the ground-water-flow system. For example, the chemistry of an area with a particular signature can be compared with the chemistry that might be expected from water moving through a source area with a known rock type or seeping through a river with known surface-water chemistry. The likely source of the ground water can be determined from such comparisons. Boundaries between areas of dissimilar chemical signatures can represent general boundaries between waters from the different sources. The shapes of the areas can also broadly define the directions of ground-water flow. Also, the vertical extent of ground water in the aquifer having a particular chemical signature can indicate how well water is mixing vertically through the aquifer. If this vertical extent is known, the approximate volumes of ground water with different signatures can be calculated and used to estimate the relative amounts of recharge from different sources.

Interpretations of water-chemistry data are most reliably made within a conceptual framework of the ground-water system that has been derived from several additional types of hydrologic and geologic data, such as water levels, that indicate general directions of ground-water flow (see Box *F*). In combination with the multitude of hydrologic and geologic data obtained as part of the USGS Middle Rio Grande Basin Study, water-chemistry data have improved the understanding of the aquifer through recognition of ground-water sources, delineation of flow paths, and determination of ground-water traveltimes calculated using isotopic data (see Box *I*).



Ground-water sampling at the 98th Street well. Because monitoring wells typically do not contain pumps, a portable sampling pump must be lowered into the well.