Ground Water and Energy Development in the San Juan Basin

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The San Juan Basin is classified as an arid region: most of the area receives less than 10 inches of precipitation a year. Mean annual precipitation in marginal mountainous regions may be as much as 30 inches a year, but surface water is scarce, except for the San Juan River and its tributaries in the northern part of the basin. Most water users, therefore, depend on ground-water supplies. The San Juan Basin contains a thick sequence of sedimentary rocks (more than 14,000 ft thick near the basin center). Most of these are below the water table and therefore saturated with ground water (Fig. 1). Many of these are the very same strata that contain the energy resources of the San Juan Basin: coal, oil, gas, and uranium. Water plays a key but varying role in the development of each of these energy resources. The purposes of this paper are to 1) briefly describe the ground-water resources of the San Juan Basin and 2) suggest their role in energy-resource development there. Information presented comes from various previous studies done by the New Mexico Bureau of Geology and Mineral Resources, or by New Mexico Tech graduate students funded by the bureau.

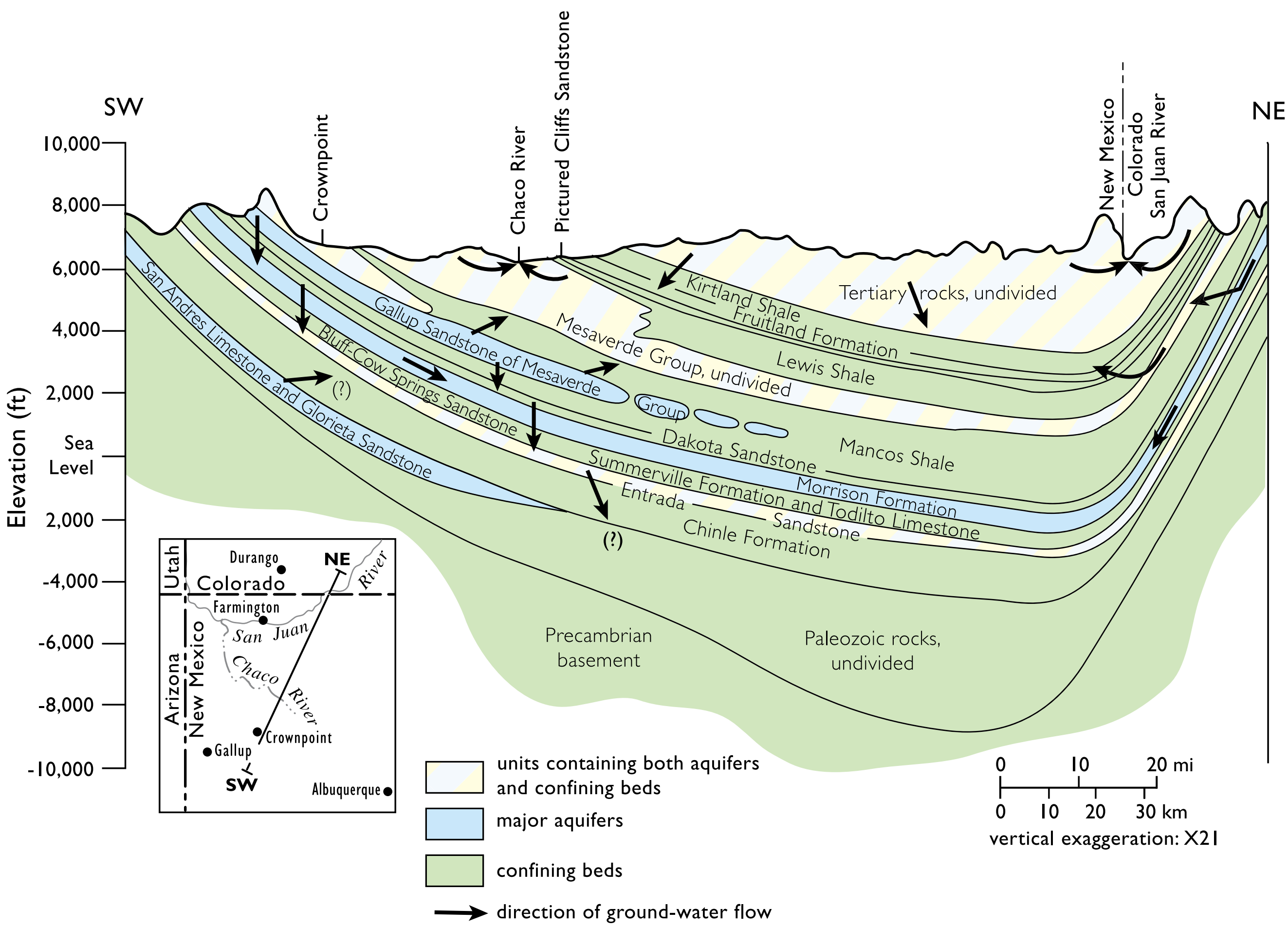

FIGURE 1 Hydrogeologic cross section of the San Juan Basin. Major aquifers are blue; confining beds are green; units containing both are crosshatched.

WHERE AND HOW DOES THE GROUND WATER OCCUR?

Ground-water occurrence may be described in three ways: the rock unit containing the ground water, the pressure condition under which the water exists, and depth to the ground water. Most of the useable ground water exists in rocks with open space between grains, rather than in fractures. The specific rock units yielding useful quantities of water to wells (aquifers) vary with location. In the northeastern part of the basin, sandstones of Tertiary age are the best targets for ground water. In the western and southern parts of the basin, the most successful wells tap Mesozoic sandstones. Only along the northern flank of the Zuni Mountains, east of Gallup, New Mexico, are productive wells completed in fractured rock (Permian limestone).

Most of the ground water in the San Juan Basin exists under confined (artesian) or semi-confined hydrologic conditions: under pressure, prevented from seeking its own level by an overlying rock unit of low permeability (aquitard). In the Mesozoic rocks of this region, the artesian sandstone aquifers are interbedded with shales that behave as low-permeability, confining aquitards. The Triassic mudrock sequence is the aquitard for the Permian limestone. By contrast, ground water in the alluvium along streams and in the shallow Tertiary sandstone aquifers is generally unconfined: the water is not under pressure, not overlain by an aquitard, and is open to the atmosphere through pores in overlying permeable rocks.

The depth to ground water varies from place to place, because of the slope of the water table and dip of the strata. The depth to water in unconfined aquifers is the depth to the top of saturation or the regional water table, which varies from less than 100 ft to several hundred feet, depending on the aquifer in question and the overlying topography. In the case of confined aquifers, there are two different depths to water: one before it is penetrated by a well, and one after penetration has occurred. Before well construction, the depth to water is the same as the depth to the top of the confined or artesian aquifer. Depths to the top of a specific confined aquifer also vary throughout the basin due to the dip of the strata. Depth to the Tertiary sandstones (for example, Ojo Alamo Sandstone) varies from less than 100 ft to as much as 4,000 ft; depth to the deepest sandstone aquifer widely used (Westwater Canyon Sandstone Member of the Morrison Formation) varies from less than 100 ft to nearly 9,000 ft.

After a confined aquifer is penetrated by a well, water rises above the top of the aquifer. The level to which it rises is called the potentiometric surface. Each artesian aquifer in the basin has its own potentiometric surface. The depth or elevation of this surface also varies across the basin, depending upon the dip of the strata and the pressure of the confined ground water.

WHICH WAY DOES THE GROUND WATER FLOW?

In the San Juan Basin, as elsewhere, ground water flows from higher elevation recharge areas (mountains), located around the basin margin, toward lower elevation discharge areas (rivers). Northwest of the continental divide, ground water flows toward the San Juan River or Little Colorado River. Southeast of the divide, it flows toward the Rio Grande.

HOW FAST DOES THE GROUND WATER MOVE?

The rate of water movement in an aquifer depends on its hydraulic properties (porosity and permeability) and the hydraulic gradient (steepness of the water table or potentiometric surface). Thus, the rate of movement varies from aquifer to aquifer. Ground-water modeling has suggested rates for total ground-water inflow and outflow in the basin. These rates are 20 cubic feet per second (ft^3/s) or approximately 9,000 gallons per minute (gpm) for the Tertiary sandstones and 40 ft^3/s or approximately 18,000 gpm for the Cretaceous and Jurassic sandstones.

HOW GOOD IS THE WATER?

Water is of good quality near basin-margin recharge areas, but deteriorates with distance along its flow path as it dissolves minerals. A general measure of water quality is salinity. This is commonly evaluated by specific conductance, a measure of a water's ability to conduct electricity. Values are reported in the strange unit of microSiemens/centimeter (uS/cm). The lower the number, the better is the water quality. Values of less than 1,000 uS/cm generally indicate potable water. Values for valley-fill alluvium are generally less than 1,000 uS/cm in headwater areas and greater than 4,000 uS/cm in downstream reaches, due to discharge of deeper water from bedrock. Specific conductance of water from sandstone aquifers ranges from less than 500 uS/cm near outcrop to almost 60,000 uS/cm at depth.

Bicarbonate content is relatively high in waters having specific conductance values of as high as 1,000 uS/cm. Sodium, sulfate, and chloride are major dissolved components in ground water having specific conductance values of as high as 4,000 uS/cm

HOW MUCH GROUND WATER IS THERE?

Ground water in most of the region is very old. Studies at the Navajo mine showed the long-term ground-water recharge rate to be very low (0.02 inches/yr). Pumping of aquifers far exceeds this recharge rate and thus results in the depletion of ground-water resources that cannot be replaced in the foreseeable future. It has been estimated that as much as 2 million acre-feet of slightly saline ground water (having less than 2,000 milligrams per liter of total dissolved solids) could be produced from the confined aquifers in the San Juan Basin with a water-level decline of 500 ft. Although that is a lot of untapped water, it is too salty for many uses and installing wells that could handle the anticipated 500-ft drop in water level would be very expensive.

WHAT ARE THE IMPLICATIONS FOR ENERGY DEVELOPMENT?

Water is an important component in the development of the basin's energy resources. Both water quantity and quality issues must be considered. Is there a sufficient supply of good-quality water for development needs? Does development impact local or regional water quantity and quality? The answers vary from resource to resource.

Coal Coal is currently being extracted by strip-mining methods. Water plays a key role in various aspects of such extraction, and water supply is therefore an issue. Large amounts of water are needed for the mine-mouth, coal-fired power plants (for steam generation) as well as for reclamation (especially revegetation). However, quality of water in the principal coal-bearing unit (Fruitland Formation) is poor (Fig. 2). Thus, water for coal-mining needs has historically come from the San Juan River, especially in the northern part of the basin. Irrigation associated with revegetation may flush salts from the unsaturated zone to the first underlying sandstone. Although the quality of ground water in that rock is so poor that it is not being used, it discharges to the San Juan River and may increase salt loads there.

Oil and Gas The main issue in petroleum extraction is the potential for contamination of fresh ground-water supplies by produced brine or hydrocarbon spills. On average, six barrels of water are produced

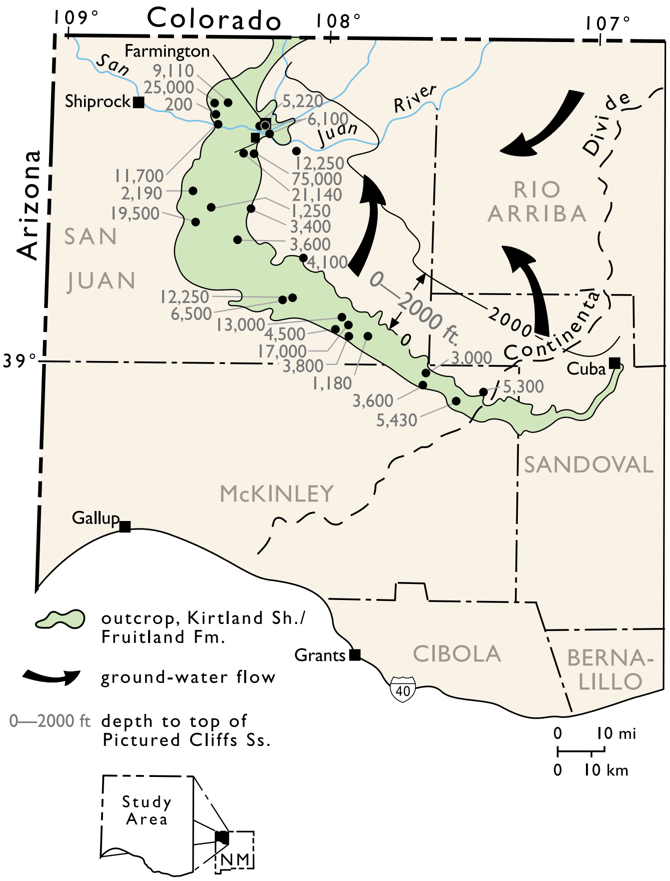

FIGURE 2 Generalized flow directions and quality of water in the Kirtland Shale/Fruitland Formation, undivided. Units shown are in µS/cm.

for every barrel of oil produced. The practice of collecting water and oil in unlined drip pits has been outlawed. However, confined brine may mix with shallower fresh water in older wells where casings and/or seals have deteriorated. The integrity of existing wells should be checked periodically, and abandoned wells should be properly decommissioned to prevent contamination.

Coalbed Methane Water is also produced in coalbed-methane development. Unlike the brine associated with petroleum extraction, this water may be fairly fresh. In an arid region like the San Juan Basin, such water should not be wasted by injecting it into a deep saline aquifer, as is often done with brine from oil wells. However, water rights must be obtained from the state engineer before it can be put to beneficial use. Work is under way to clarify this issue and develop a protocol for beneficial use of produced water. However, much more work is needed on the hydrologic system(s) involved, water treatment, technologies for reducing the quantities produced and markets for beneficial use.

Uranium Underground mining of uranium was once intense in the Grants mineral belt. Water supply was not an issue, as the large volumes withdrawn in dewatering (the process of pumping water out of the mine) from the major uranium-bearing unit (Morrison Formation) were of good quality and readily met water needs. Some of the freshest water in the basin is associated with the Morrison Formation (Fig. 3). However, both water quantity and quality were impacted in places. Ground-water modeling showed that had dewatering continued, water-level declines would have been felt all the way to the San Juan River by the year 2000. Dewatering also lowered artesian pressures such that vertical gradients were locally reversed (became downward instead of upward), permitting poor-quality water in one Cretaceous sandstone to flow downward into the underlying Jurassic sandstone aquifer containing good-quality water. Although that mining activity has ceased, sizable reserves of uranium remain in the ground. Such water-quantity impacts will recur should uranium prices warrant renewed underground mining. However, current interest centers on in situ extraction. The Navajo Nation and environmental groups are still protesting the feasibility of such mining, in view of the potential impact on ground-water quality.

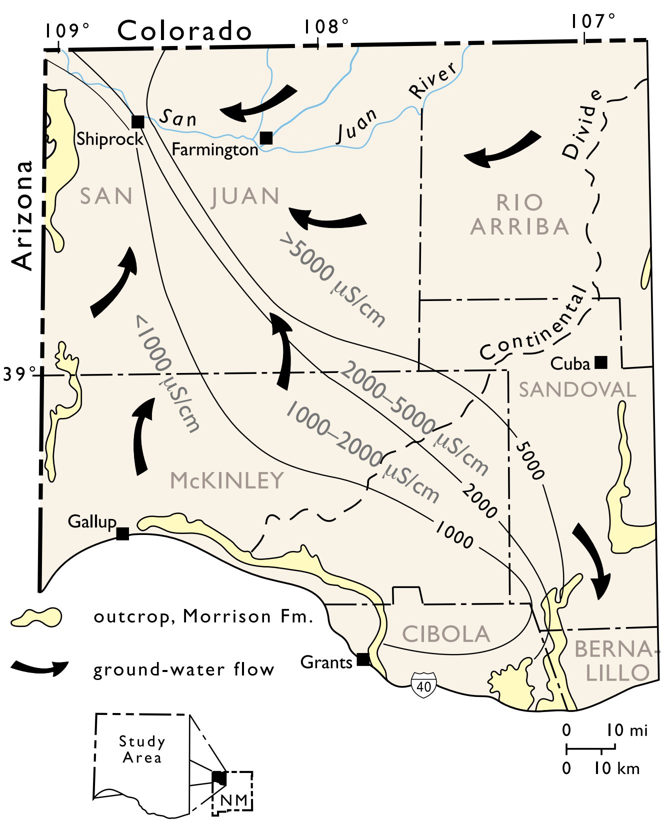

FIGURE 3 Generalized flow direction and quality of water in the Morrison Formation.

SUMMARY

Ground water and energy development are intimately related in the San Juan Basin. As a result, there is both good news and bad news.

- *The good news:*

  1 Ground water is associated with the same rocks as the energy resources, so there may be a ready supply.

  2 Studies have shown that there are large amounts of water of moderate quality in various aquifers, at various depths, in various locations.

- *The bad news:*

  1 Ground water is associated with the same rocks as the energy resources, so it is vulnerable to quantity and quality impacts.

  2 Water demands are increasing among the major non-industrial water users, including Indian reservations, municipalities, irrigators, and ranchers.

  3 As demands of these users along the San Juan River and its tributaries grow beyond their present surface-water supplies, they will have to look to ground-water sources for additional water.

  4 At that point, energy developers in the San Juan Basin will be in direct competition for ground water with other users.

Thoughtful regional planning and frequent environmental surveillance will be essential for sound management and protection of ground water in this multiple water-use area. Successful energy development will be compatible with regional water-use goals.

ADDITIONAL READING

Stone, W. J., 1999, Hydrogeology in practice—a guide to characterizing ground-water systems: Prentice Hall, Upper Saddle River, New Jersey, 248 pp.

Stone, W. J., 2001, Our water resources—an overview for New Mexicans: New Mexico Bureau of Mines and Mineral Resources, Information Series 1, 37 pp.