Monitoring the Effects of Ground-Water Withdrawals from the N Aquifer in the Black Mesa Area, Northeastern Arizona

science for a changing world

Prepared in cooperation with the
Arizona Department of Water Resources and Bureau of Indian Affairs

In 1968, Peabody Coal Company began strip-mining operations on land leased from the Navajo and Hopi Tribes on Black Mesa (fig. 1). Of the 11 to 13 million tons of coal that are extracted each year, an average of about 5 million tons are transported as slurry by a 273-mile-long pipeline from the coal-lease area west to the Mohave Generating Station near Laughlin, Nevada. Transporting the coal in slurry form consumes, on average, about 3,800 acre-ft of water annually. The slurry water is provided through a network of 8 wells that tap the confined parts of the D and N aquifers underlying Black Mesa. Most of the slurry water is pumped from the confined part of the N aquifer which also is the primary source of water for municipal users within the 5,400-square-mile Black Mesa area.

The Navajo Nation and Hopi Tribe became concerned about the long-term effects of industrial withdrawals from the N aquifer on the availability and quality of water supplies for domestic and municipal purposes. These concerns led to an ongoing investigation of the water resources of the Black Mesa area begun in 1971 by the U.S. Geological Survey (USGS) in cooperation with the Arizona Department of Water Resources (ADWR) and the Bureau of Indian Affairs (BIA).

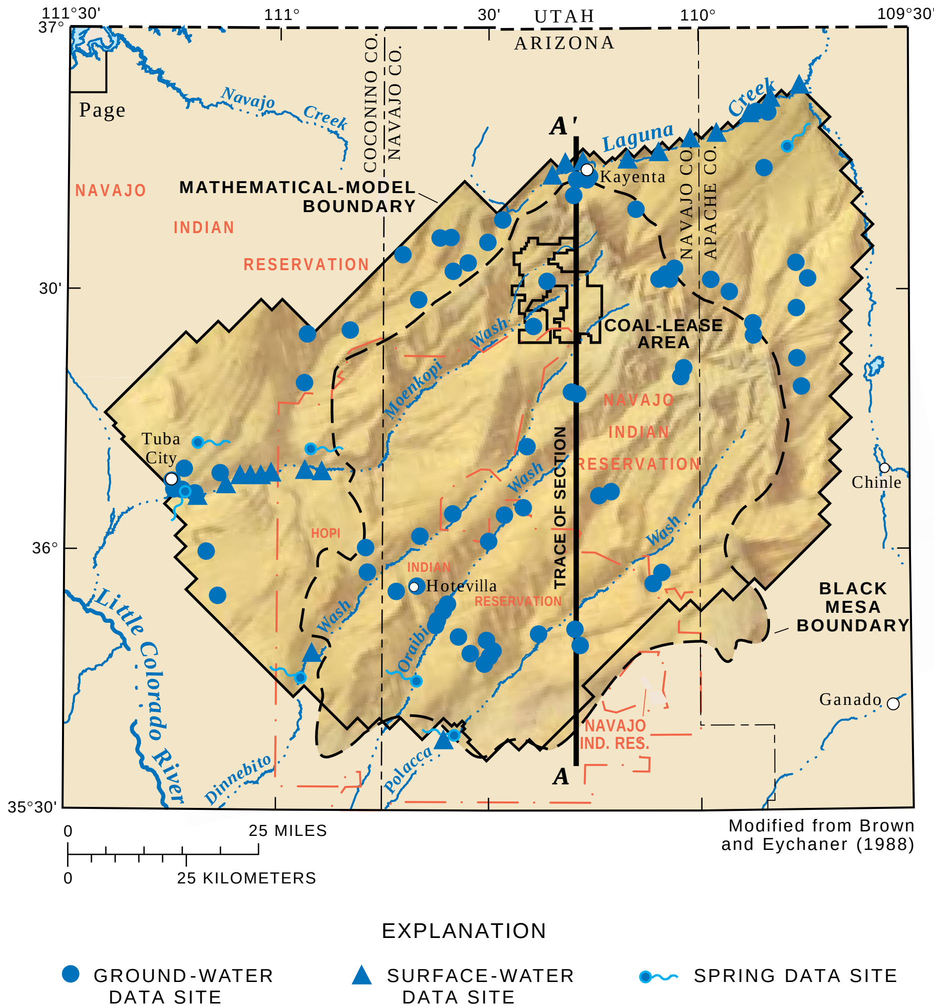

Figure 1. Study area and data-collection network.

Hydrogeology

Three rock formations that are hydraulically connected compose the N aquifer—the Navajo Sandstone, the Kayenta Formation, and the Lukachukai Member[1] of the Wingate Sandstone. The N aquifer is unconfined in parts of the study area that generally correspond to areas of ground-water recharge (fig. 2; Eychaner, 1983). In the Black Mesa area, the N aquifer is separated from the overlying D aquifer by a leaky confining rock layer that is predominantly siltstone and massive mudstone (fig. 3).

Data-Collection Activities

Data-collection activities include continuous and periodic measurements of ground water and surface water at about 100 sites in the Black Mesa area (fig. 1). Ground-water data from wells completed in the N aquifer include annual pumpage from municipal and industrial well systems, annual water levels from selected municipal and stock wells, water levels from continuous-record observation wells, and water chemistry from selected municipal and industrial well sites. Discharge and water-chemistry data are collected from selected springs that issue from the N aquifer.

Surface-water data are collected at streamflow-gaging stations and include continuous-stage data and bimonthly stage and discharge measurements. Miscellaneous discharge data also have been collected at selected sites during seepage investigations.

[1]Of former usage, formally abandoned by Dubiel (1989).

Ground-Water Withdrawal

Water is withdrawn from the unconfined part of the N aquifer for municipal use and from the confined part of the aquifer for industrial and municipal use. Eight wells at the coal-lease area are for industrial use. The BIA, Navajo Tribal Utility Authority, and Hopi Tribe operate about 70 municipal wells throughout the Black Mesa area.

The present and future effects of ground-water withdrawals on water levels are analyzed using a finite-difference ground-water flow model developed by Eychaner (1983) and recalibrated by Brown and Eychaner (1988). Measured water levels are routinely compared to simulated water levels to test the reliability of the model as a predictive tool and to estimate how much of the water-level decline is the result of industrial or municipal pumping.

Surface-Water Discharge

Outflow from the N aquifer occurs mainly as surface flow in Moenkopi Wash and Laguna Creek and as springs near the boundaries of the aquifer (Davis and others, 1963). Stage and discharge data are collected at the continuous-record gaging stations at Moenkopi, Dinnebito, and Polacca Washes, and at Laguna Creek. Continuous-record gaging stations at Dinnebito and Polacca Washes monitor outflow from two prominent seepage areas along the western and southern boundaries of the aquifer. Discharge data are collected at selected springs and miscellaneous measurement sites along Moenkopi Wash and Laguna Creek.

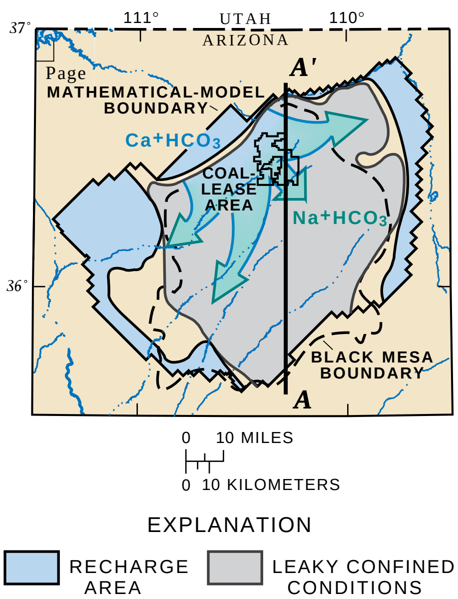

Figure 2. Ground-water chemistry—calcium bicarbonate ($Ca+HCO_3$) water changes to a sodium bicarbonate ($Na+HCO_3$) water.

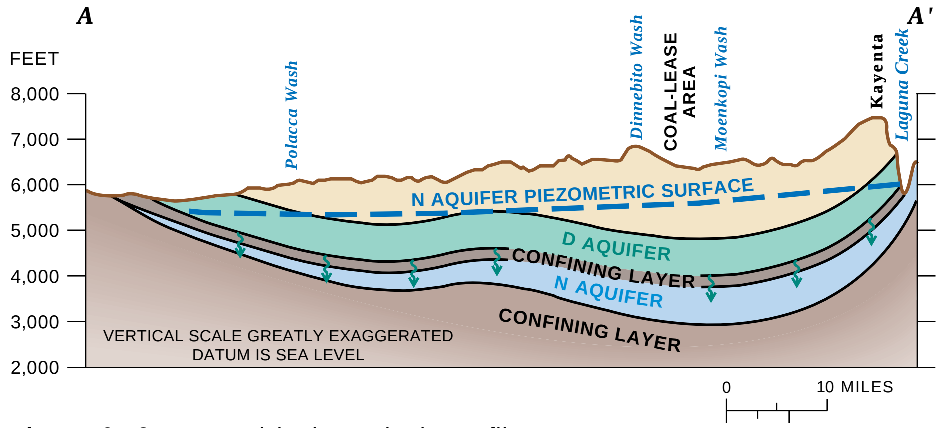

Figure 3. Conceptual hydrogeologic profile.

Water Chemistry

In general, water in the N aquifer is a calcium bicarbonate type in the upgradient or recharge part of the study area north and northwest of Black Mesa and a sodium bicarbonate type elsewhere throughout Black Mesa and surrounding areas (fig. 2). As water moves from the recharge area under Black Mesa toward discharge areas to the west, southwest, and northeast, ion exchange along the flow path generally converts calcium-bicarbonate type water to sodium-bicarbonate type water (Wickham, 1992).

Water from the N aquifer is analyzed for selected chemical constituents to determine if declining hydraulic heads are inducing vertical leakage from the overlying D aquifer (fig. 3). On the average, the concentration of dissolved solids in water from the D aquifer is about 7 times greater than that of water from the N aquifer, concentration of chloride ions is about 11 times greater, and the concentration of sulfate ions is about 30 times greater. Any increase in the leakage rate as a result of pumping from the N aquifer probably would become evident as an increase in concentrations of dissolved solids, chloride, and sulfate in the most heavily pumped wells (Eychaner, 1983).

— Gregory R. Littin

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