



Geohydrology of the Westwater Canyon Member, Morrison Formation, of the southern San Juan Basin, New Mexico

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GEOHYDROLOGY OF THE WESTWATER CANYON MEMBER, MORRISON FORMATION, OF THE SOUTHERN SAN JUAN BASIN, NEW MEXICO

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INTRODUCTION

The San Juan Basin of New Mexico has long been considered as an area having very limited ground-water potential. Farmington, the largest city in the basin, as well as the City of Aztec, have depended exclusively on surface water from the Animas River for their municipal water supplies. Shiprock is dependent upon the San Juan River. Wells at Cuba, New Mexico, tap the Ojo Alamo Sandstone, however these are low-yielding wells that produce highly-mineralized water. Elsewhere in the basin, isolated wells have been drilled at trading posts, as well as for stock and domestic purposes. However these have often been low capacity wells tapping the shallowest available aquifer.

Only Crownpoint, New Mexico, has had a dependable supply of ground water. The first four wells drilled at the community tapped Cretaceous strata, including the Gallup Sandstone and the shallower Crevasse Canyon sands. Well No. 5 was completed in the Westwater Canyon Member of the Morrison Formation in 1958 and well No. 6 was completed in the same deposit three years later. During this same period, a tremendous amount of information about the Westwater Canyon was being obtained in the Ambrosia Lake area where major uranium ore deposits were being mined from the Westwater sandstones. As exploration for uranium has spread into the deeper parts of the San Juan Basin, it has become obvious that the Westwater Canyon is the principal aquifer in the southern part of the basin.

The economic importance of the Morrison Formation has led to the publication of a great deal of information concerning the geology of the formation and its various members. However very little data is available pertaining to the hydrology of these units. Although all the members of the Morrison have local economic importance, only the Westwater Canyon Member is an aquifer of regional significance. Therefore the purpose of this paper is to summarize the available hydrologic data and provide a general review of the hydrologic conditions in the Westwater Canyon Member of the Morrison.

The author gratefully acknowledges the information that was furnished by various mining companies, individuals, federal and state agencies.

GEOLOGY

The Morrison Formation is widespread throughout the Colorado Plateau, and it is particularly well developed in the Four Corners region. The principal lithologies are cross-bedded sandstones and variegated shales of continental origin. These deposits are conformable with the underlying San Rafael Group by an angular unconformity.

The stratigraphic nomenclature generally used in the southern San Juan Basin was described by Craig and others (1955), although locally derived terminology frequently is used in the

Ambrosia Lake and Laguna areas of New Mexico (Hilpert, 1963). The Morrison Formation has been divided, on the basis of lithologic characteristics, into four members: the Salt Wash Member at the base; the overlying Recapture Member; the Westwater Canyon Member; and the uppermost Brushy Basin Member.

Not all of these units are present throughout the southern part of the basin. The Salt Wash Member has not been recognized south of the vicinity of Burnham Trading Post, and in the Gallup area the Brushy Basin Member was probably removed by pre-Dakota erosion. Consequently, near Gallup, only the two middle members are present (Saucier, 1967). The Brushy Basin thickens eastward from a feathered edge near Thoreau and comprises the bulk of the Morrison at Laguna east of Grants (Freeman and Hilpert, 1956).

Throughout most of New Mexico, the Westwater Canyon Member is identified by its lithologic characteristics. The Recapture and the Brushy Basin members are composed primarily of siltstone and shale with thin stringers of fine-grained sandstone. The Westwater Canyon Member is a cliff-forming sandstone with minor amounts of shale. At the outcrops, the Westwater is characterized by yellowish-gray to light brown quartzose sandstone with minor amounts of pink feldspar and dark heavy minerals; the cementation is quite variable, but it is usually calcareous.

Grain size distribution within the Westwater is shown in Figure 1. Craig and others (1955, p. 157) suggested that the deposit was formed as a broad, fan-shaped alluvial plain by streams flowing northeastward from a highland area in west-central New Mexico and adjacent Arizona. As would be expected, the more coarse-grained sediment was deposited closer to the source areas and these coarse elastics now predominate in the southern and western parts of the San Juan Basin.

Craig and others (1955, p. 154) described two facies within the Westwater. A conglomeratic sandstone was identified in a wide lobate area north of Gallup, New Mexico. This unit was described as containing a large number of pebbles and cobbles, whereas the second unit is called the sandstone facies and was characterized by the absence of pebbles. The conglomerate facies generally coincides with that part of the Westwater Canyon that is predominantly coarse grained (fig. 1). Coarse-grained sandstone has been found as far east as T. 10 N., R. 4 W., N.M.P.M., about 30 miles east of Grants. Medium-grained sandstone borders the coarser deposits on the north and east; fine-grained sandstone is most common in much of Sandoval County (Flesch, 1974) and adjacent areas to the north.

Numerous workers have described the tremendous variation in grain size found in the Westwater. Saucier (1967, p. 141) has shown that the average grain size near Gallup is 0.38 mm;

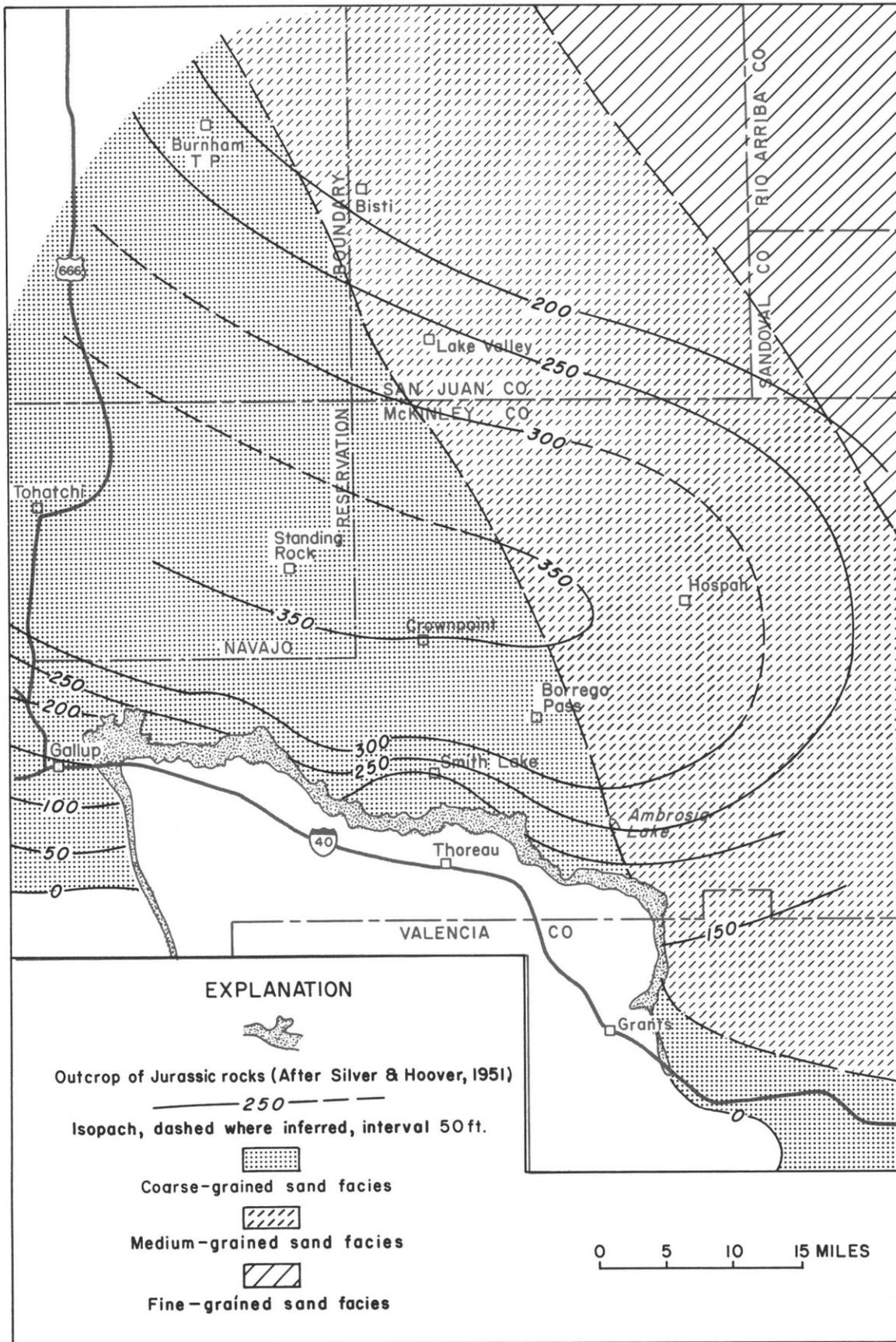


Figure 1. Lithofacies and isopach map of Westwater Canyon Member of the Morrison Formation.

GEOHYDROLOGY

Harshbarger and others (1957, p. 67) described boulders up to four feet in diameter within the Westwater west of Tohatchi. However the lithofacies shown in Figure 1 are believed to accurately represent the average grain size for the total vertical thickness of the Westwater Canyon even though it is recognized that grain-size distribution in alluvial deposits are extremely variable in very short lateral distances.

The southern edge of the Westwater is an erosional boundary caused by pre-Dakota structural tilting and erosion (Saucier, 1967, p. 141). Rather abrupt thickening occurs north of the outcrop belt between Gallup and Grants with a maximum known thickness of about 350 feet penetrated by wells at Crownpoint. Slightly less than 300 feet was measured in outcrops northwest of Gallup (Harshbarger and others, 1957, p. 55). The Westwater thins gradually toward the north and east with corresponding increase in thickness of the Recapture and Brushy Basin members.

The configuration of the Westwater Canyon generally reflects the shape of the southern San Juan Basin and its bounding structures. There is a gentle north-northeast slope away from the Zuni Mountains between Gallup and Grants (fig. 2). The western flank of the basin is marked by the Defiance uplift. In the vicinity of Ambrosia Lake, the upper surface of the Westwater has been offset by numerous faults, however the regional dip is toward the north-northeast.

HYDROLOGY

The most important hydraulic property of an aquifer is its capacity to transmit water to wells. This property commonly is expressed as the transmissivity of the aquifer. Transmissivity is frequently defined as the rate of flow of water in gallons per day through a vertical strip of the aquifer one foot wide extending the full saturated height of the aquifer under a hydraulic gradient of 100 percent. This value is commonly expressed in units of gpd/ft (gallons per day per foot) of aquifer thickness.

Although transmissivity is a measure of aquifer yield, specific capacity is a measure of well yield expressed in gpm (gallons per minute) per foot of drawdown. For example, if a well is pumped at the rate of 300 gpm with a maximum drawdown of 150 feet, the specific capacity of the well would be 2 gpm/ft of drawdown.

Transmissivity is equal to the permeability multiplied by the saturated thickness of the aquifer. Since permeability is a function of such lithologic controls as grain size, sorting and cementation, transmissivity will also be affected. It is also a function of the aquifer thickness—or the amount of the aquifer that is penetrated by the well.

In most instances it has not been necessary for a well to fully penetrate the Westwater Canyon aquifer in order to obtain an adequate supply of water. Consequently the aquifer tests that have been made in the Westwater only represent a value for partial penetration and would give lower transmissivity values than a fully penetrating well.

Although there are a number of variables that affect the transmissivity of the Westwater, a distinct pattern is shown by the transmissivity values that have been measured in the southern part of the basin (fig. 3). The 2000 gpd/ft line of equal transmissivity extends southeastward from the vicinity of Burnham Trading Post to Borrego Pass. This line is nearly identical to the boundary between the coarse-grained facies and the medium-grained facies (fig. 1). South of Borrego Pass

the transmissivity decreases; this is due to thinning of the aquifer near the outcrop.

West of the 2000 gpd/ft line of equal transmissivity, there is a progressive increase in values to more than 2300 gpd/ft. Southwest of Crownpoint transmissivity values may exceed 2500 gpd/ft. East of the 2000 gpd/ft line, transmissivity values have a very wide range which probably reflect variations in permeability, the type of water well completion, and the testing methods used. In the vicinity of Ambrosia Lake, the average transmissivity is about 1500 gpd/ft but mines to the east show a distinct increase. This probably is due to secondary permeability in the aquifer that was induced by faulting. Northeast of Hospah the transmissivity of the Westwater is less than 500 gpd/ft and is probably the result of decreasing grain size in the aquifer. Due to the paucity of data and the local variations in transmissivity, it is difficult to map these values with any degree of accuracy east of the 2000 gpd/ft line shown in Figure 3.

The Westwater Canyon is a classic example of an artesian aquifer. Recharge that falls on the outcrop area around the Zuni and Defiance uplifts moves downdip toward the deeper parts of the basin. The topographically high recharge areas produce an artesian head which results in flowing wells from the Westwater Canyon in much of northern McKinley County and most of San Juan County (fig. 3).

The western boundary of this zone of flowing wells coincides with the front of the Chuska Mountains west of US-666. Along the south edge of the basin, the outcrop belt of the Point Lookout Sandstone generally coincides with the southern limit of flowing wells from the Westwater. The eastern boundary is roughly defined by the 6,550-foot land surface elevation.

The discharge area for ground water in the Westwater Canyon Member has not been accurately identified due to the complex stratigraphy of the Jurassic deposits and the lack of accurate hydrologic data in the Four Corners area. Craig and others (1955, fig. 22) has shown that the Recapture Member becomes more sandy north of Gallup and that a sandstone and conglomerate facies can be identified which directly underlies the Westwater Canyon. Harshbarger and others (1957, p. 53) have reported that the Westwater intertongues with the massive Cow Springs Sandstone northwest of Gallup. Farther north, the Cow Springs interfingers with the sandstone of the Brushy Basin Member. Consequently precipitation which falls on Westwater Canyon outcrops along the southern edge of the San Juan Basin probably moves north and west where it crosses formation boundaries and enters the thick sandstone deposits in Arizona and Utah.

A minor amount of ground water from the aquifer probably discharges to the San Juan River where the outcrop belt is crossed by the river near the Four Corners Monument. Also there probably is some leakage upward into the Dakota Sandstone near Gallup where the Brushy Basin Member has been removed by erosion. In this area the Westwater Canyon and Dakota form a multiple-aquifer system (West, 1961, p.7). In other areas, the differences in artesian head of the two aquifers indicate that leakage from the Dakota may recharge the Westwater Canyon.

Throughout most of the southern San Juan Basin the chemical quality of the water in the Westwater Canyon is suitable for most industrial and agricultural uses. In the outcrop areas the total dissolved solids do not exceed 500 mg/l

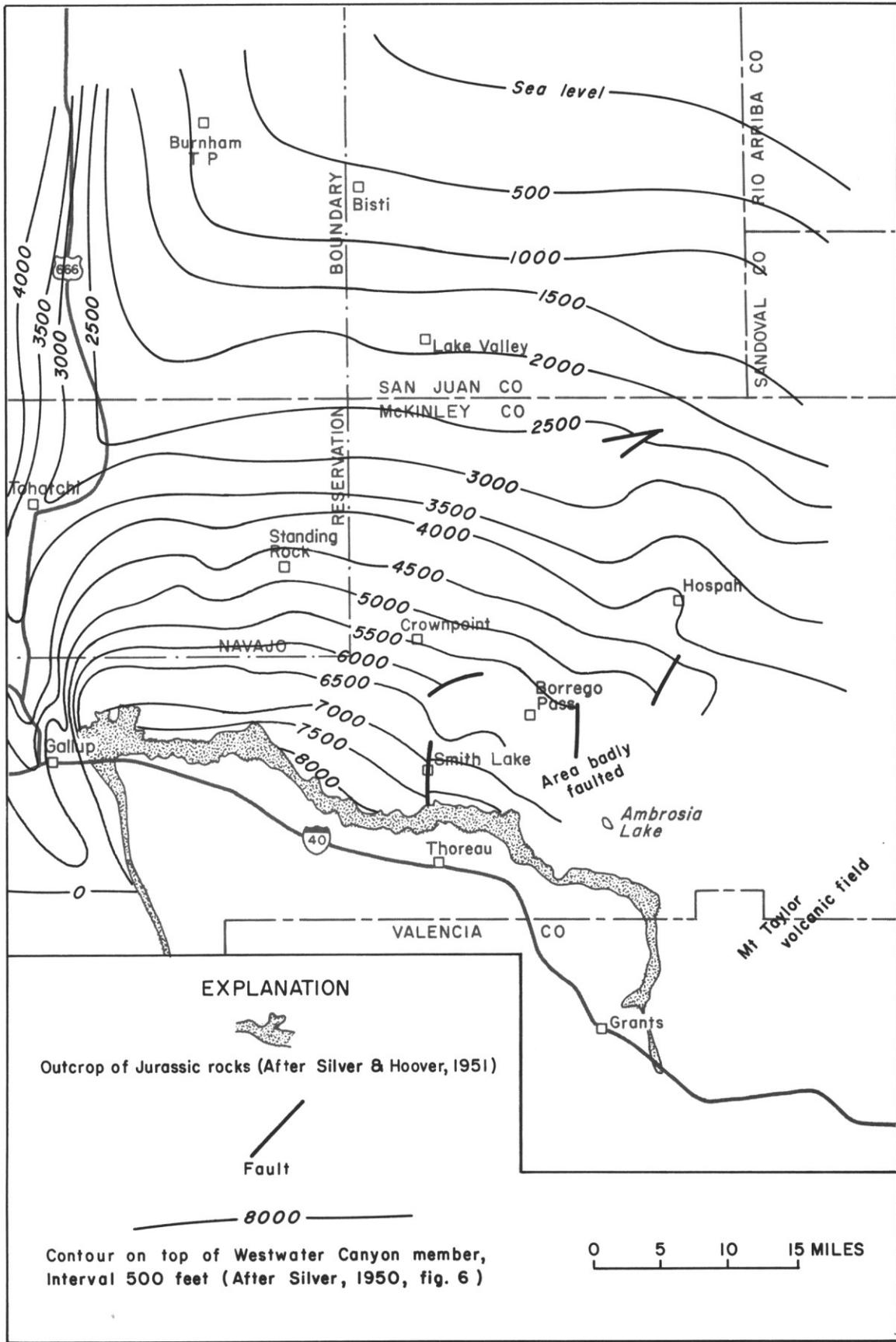


Figure 2. Structure contour map on top of Westwater Canyon Member.

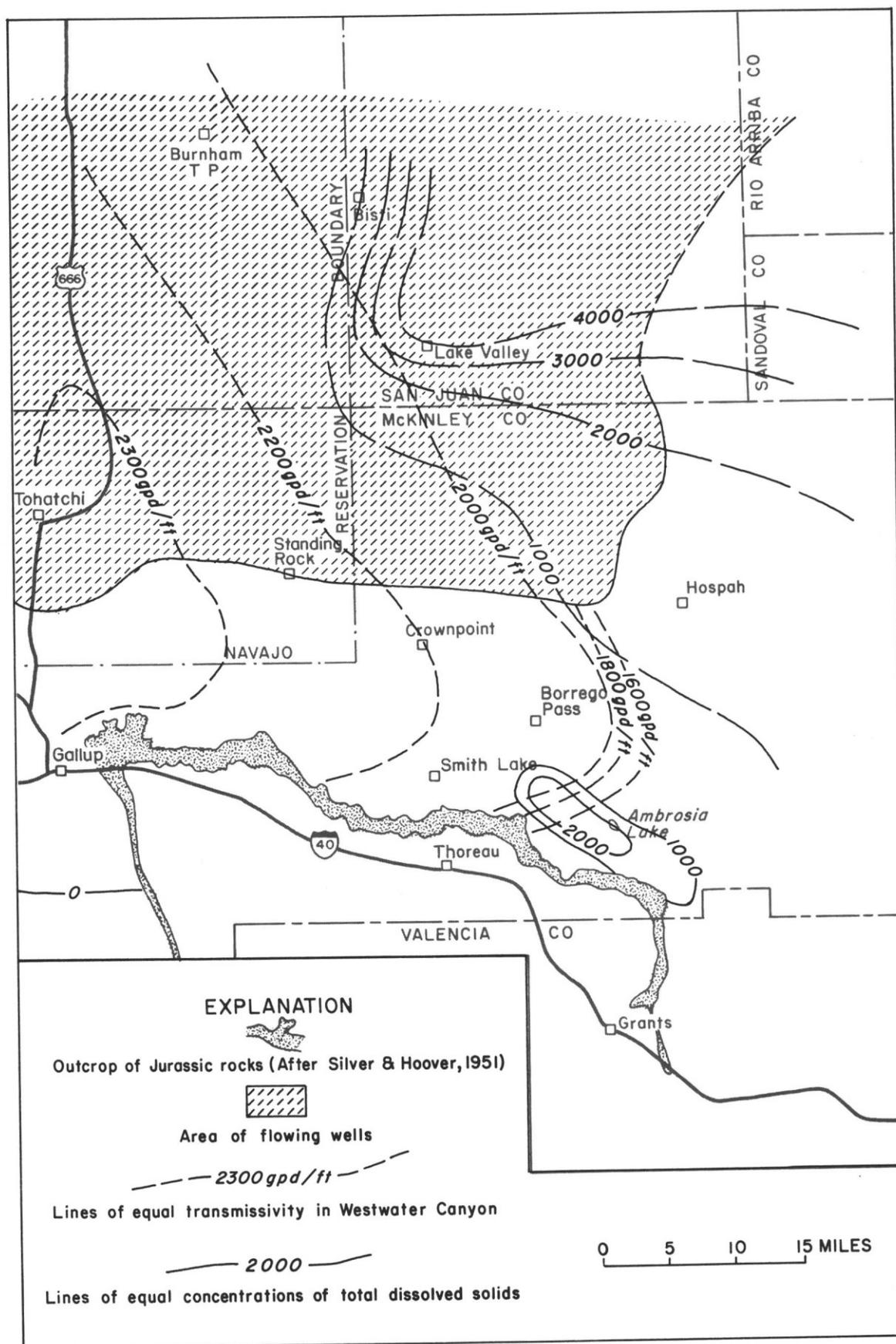


Figure 3. Transmissivities and water quality in the Westwater Canyon aquifer.

(milligrams per liter). Mineralization increases to about 800 mg/1 near Borrego Pass and Standing Rock. Northeast of this area the ground water becomes more highly mineralized (fig. 3).

Anomalous water-quality conditions exist in the vicinity of Ambrosia Lake where uranium ore bodies have been mined in the aquifer. Wells in the area that tap the Westwater usually produce water having about 600 mg/1 dissolved solids, however concentrations in excess of 2300 mg/1 have been found (Cooper and John, 1968, table 3). The high levels of mineralization may be due to natural contamination by more highly mineralized water from the overlying Dakota Sandstone. Faulting in the Ambrosia Lake area has offset both the Westwater Canyon and the Dakota, and it is quite probable that there has been interformational migration of ground water from the Dakota to the Westwater. This downward ground-water movement has also been facilitated by mining operations which reduce the ground-water head in the Westwater Canyon and induce migration from the Dakota. The average dissolved solids in the Dakota Sandstone in McKinley County is about 1400 mg/1 as compared with an average of less than 1000 mg/1 for water from the Westwater Canyon.

In recent years a considerable amount of study has been devoted to the impact of uranium mining on water quality in the Westwater Canyon (Environmental Protection Agency, 1975). Ground-water discharge from some mines contains as much as 75 times the natural concentrations of radium; uranium and selenium also increase significantly. This is due to the oxidation and leaching that occurs when ground water migrates through the mine from a reducing environment in the aquifer.

The contaminants in mine waste are extremely difficult to treat by conventional methods, and the levels of mineralization prevent the water from being used for many industrial or agricultural purposes. In most instances the mine waste is being held in evaporation ponds and the contaminants are not being reintroduced to the aquifer.

SUMMARY

The growth of uranium exploration and development in the southern San Juan Basin has provided evidence that the

Westwater Canyon Member of the Morrison Formation is an aquifer of major importance in the region. Transmissivities of the aquifer range from less than 500 gpd/ft northeast of Hospah to more than 2300 gpd/ft west of Standing Rock. The increase in transmissivities toward the west generally coincides with an increase in grain size of the Westwater; stratigraphic thickness is also a factor. Flowing wells have been completed in the aquifer throughout much of north-central McKinley County and in San Juan County. Chemical quality of water from the Westwater Canyon is suitable for most industrial and agricultural purposes. Water-quality anomalies in the Ambrosia Lake area are probably due to contamination from the Dakota Sandstone which has been induced by faulting and further complicated by mining activity.

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