Will Pumping from the Fractured Dakota Sandstone Aquifer at the Fence Lake Coal Mine Lower Water Levels at the Sacred Zuni Salt Lake, or Are Pumping Effects Limited to the Mine Site? – A Tale of Conflicting Analytical Models

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Abstract

Zuni Salt Lake (ZSL) is a saline lake contained in a maar located approximately 20 miles northwest of the town of Quemado in Catron County, New Mexico. ZSL has multiple water sources, including ground water that upwells through the maar vent from underlying artesian aquifers, with the Dakota aquifer as one important source of water for ZSL. The lake has important spiritual and cultural significance for the Zuni people and numerous other native peoples in the region. The Salt River Project (SRP) has proposed the establishment of a surface coal mine approximately eight to twelve miles northeast of Zuni Salt Lake. During operation of the mine, SRP proposes to pump ground water from one (or all) of the three major aquifers at the mine site. SRP proposes to use the fractured Dakota Sandstone aquifer (also referred to as the Dakota aquifer) as the primary water source for the mine, using a well located approximately 12 miles northeast of the lake. Overlying aquifers that can also be used for the mine's water supply include the fractured Atarque sandstone and Quaternary alluvium. The Dakota Sandstone is continuous in the subsurface between the Fence Lake Coal Mine (FLM) and Zuni Salt Lake.

Glorieta Geoscience, Inc. (GGI) was retained by the Pueblo of Zuni to evaluate potential effects of ground water diversions from SRP's proposed mine on ZSL. GGI examined outcrop analogs in the vicinity of FLM and ZSL, reviewed pumping test data, mapped geologic structures in the area, and reviewed available hydrology and geology studies. Based on this research, GGI concluded that the Dakota aquifer should be evaluated as a fault-bounded confined aquifer, and that pumping effects from the FLM could be analyzed using either a strip aquifer model or a simple Theis analytical model. GGI's application of a Theis-type model to evaluate pumping effects from the proposed FLM predicts that effects <u>will</u> extend to ZSL. After pumping the Dakota well at 85 gallons per minute for 40 years, the resulting decline in head in the Dakota Sandstone aquifer at ZSL will be between four and five feet. Because the depth of ZSL fluctuates between one and four feet, the predicted drawdown (4 to 5 feet) over the life of the mine would have devastating effects. GGI's conclusions are in stark contrast to the conclusions reached by SRP and presented in the Permit Application Package (PAP) for the mine. SRP argued that the Dakota aquifer should be treated as a leaky-confined aquifer. SRP's leaky aquifer model predicts that pumping effects will not extend beyond a radius of 3708 feet from the mine's pumping center, resulting in zero drawdown and no depletions at Zuni Salt Lake. The disparity between the conclusions reached by GGI versus those reached by SRP arise from differing interpretations of pumping test results, and a resulting difference of opinion as to what model best represents the aquifer system. This conflict illustrates how seemingly esoteric debates between hydrologists can have critical consequences in policy-making and land use decisions. If the decision is made to approve the mine, the effects on a sacred lake will be long term and, possibly, irreparable.

Introduction

Zuni Salt Lake is a saline lake contained in a maar located along the Jemez lineament in west-central New Mexico (Figure 1). Numerous tribes in the region have relied upon ZSL as a source for salt and as a ceremonial center to which they made periodic pilgrimages. ZSL is situated in a large lowland and valley floor area bordered by mesas that was treated as a neutral zone where weapons and fighting were not allowed. For Zuni Pueblo, it is the home of one of their most important deities, Salt Mother. The Salt River Project (SRP) has proposed the establishment of a surface coal mine approximately eight to ten miles northeast of Zuni Salt Lake (at the western boundary of the mine lease area (Figure 2). During operation of the mine, groundwater will be pumped from one (or all) of the three major aquifers underlying the mine site for which SRP has declared water rights. SRP proposes to use the Dakota Sandstone aquifer (also referred to as the Dakota aquifer) as a primary water source for the mine, using well (FL-36), located approximately 12 miles northeast of the lake.

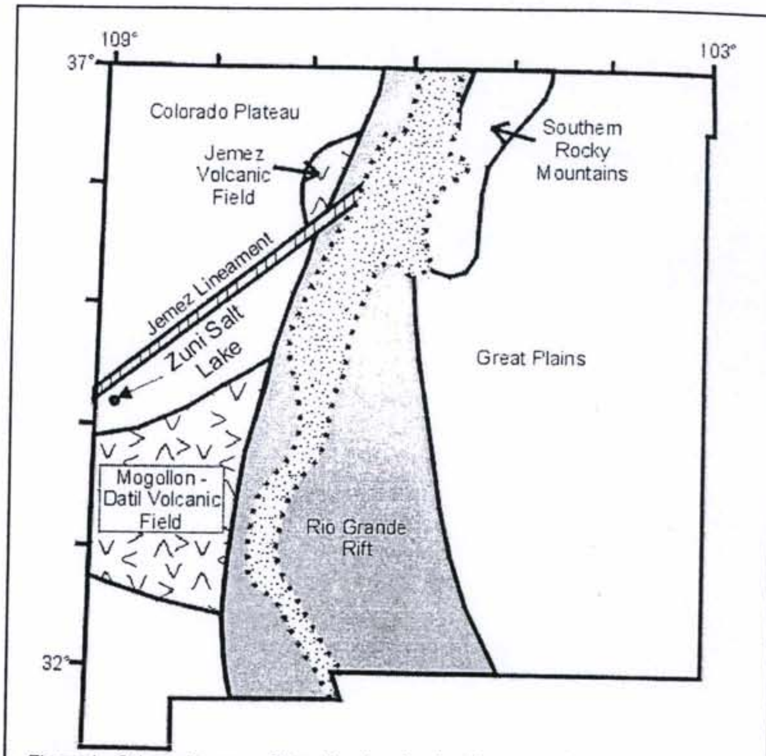
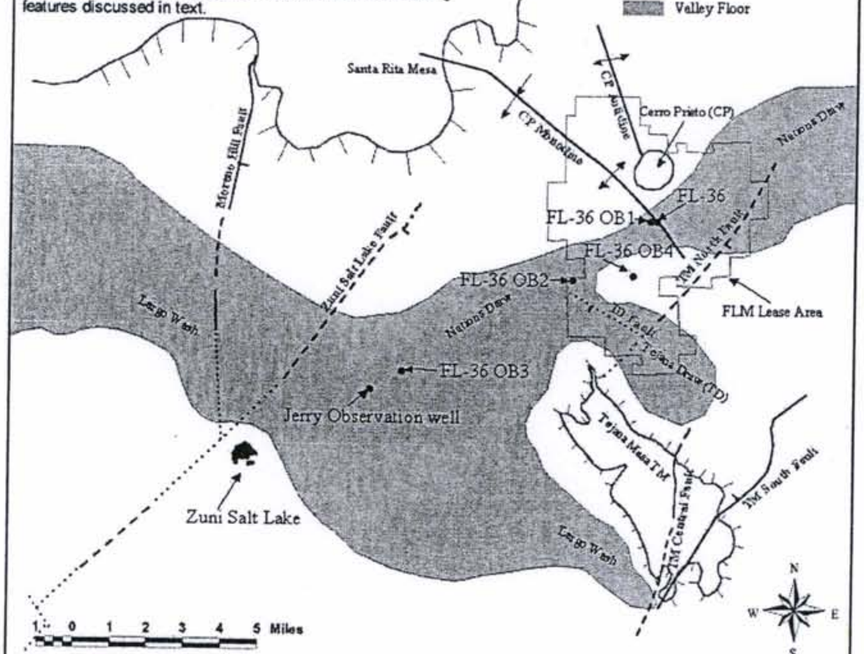


Figure 1. Schematic map of New Mexico showing the approximate location of Zun Salt Lake and the approximate limits of various physiographic provinces/features discussed in text. Modified from Sanford et al., 1995 and Keller and Cather, 1994).

Figure 2. Schematic map of the Zuni Salt Lake area showing features discussed in text.



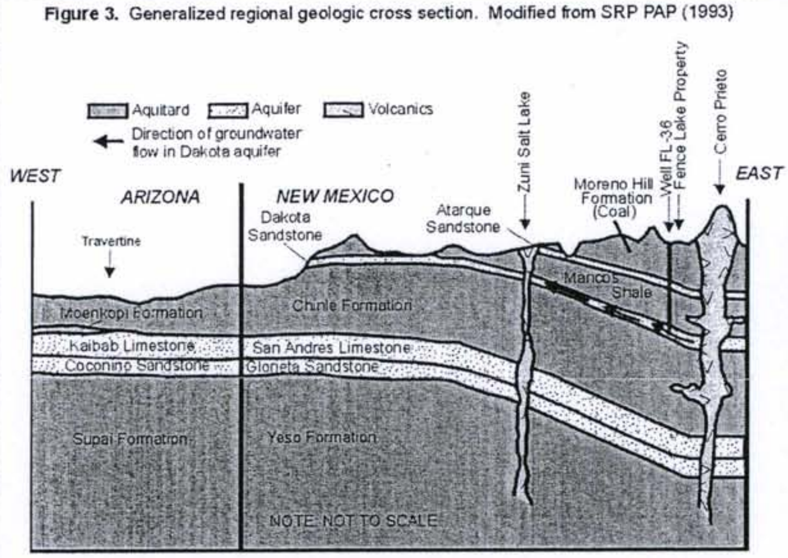
Hydrogeologic Setting

Zuni Salt Lake, Nations Draw, and the Fence Lake Coal Mine area (Figure 2) are underlain by Permian through Cretaceous sedimentary rocks that unconformably overlie Precambrian rocks. Zuni Salt Lake and Nations Draw lie along the Jemez Lineament, a southwest to northeast trending zone of structural weakness expressed by a series of volcanic centers and northeast-trending faults extending from the Springerville volcanic field in Arizona to the Taos Plateau volcanic field in New Mexico and Colorado, and including the Jemez Mountains, the Mt. Taylor/Zuni-Bandera Volcanic field, and Zuni Salt Lake (Laughlin et al., 1982).

Bedrock aquifers in the site vicinity occur as fractured sandstone beds separated by shale and mudstone aquitards. The FLM proposes to use water produced from two Cretaceous aquifers, the Dakota Sandstone and the Atarque Sandstone (Figure 3), and from the Quaternary Alluvium. The Dakota Sandstone is a productive artesian aquifer in the vicinity of the FLM that has over 1100 ft of pressure head. As the most productive aquifer underlying the mine identified thus far, SRP plans to utilize the Dakota for a some percentage or for all of the mine water supply. The Atarque Sandstone and the Alluvium would be used to supplement the Dakota water supply. Because the Dakota is continuous in the subsurface between the mine site and ZSL (Figure 3), however, questions have arisen over what effect pumping the Dakota at FLM would have on ZSL.

Hydrologic/Chemical Balance Of Zuni Salt Lake

Figure 3. Generalized regional geologic cross section. Modified from SRP PAP (1993)



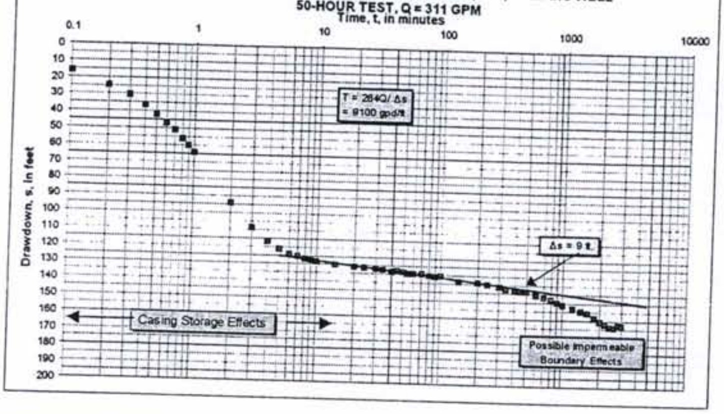
Although minor fresh water is added to ZSL through precipitation and surface runoff, and a relatively minor quantity of brackish and fresh water is provided by springs, water upwelling through the vent is a major contributor to the hydrologic balance of the lake. The groundwater that comes directly up the vent to feed ZSL is the water source that would be most directly affected by SRP's planned pumping of the main body Dakota Sandstone aquifer. The vent that was the source of the eruption of Zuni Salt Lake Maar penetrates every aquifer in the stratigraphic column (Figure 3) and is likely manifested as a vertical fracture zone which allows artesian waters from lower units to flow to the surface. ZSL is quite sensitive to changes in imput from any of the major water sources because it fluctuates in depth between one and four feet under normal conditions.

Bradbury (1971) and SRP (PAP, 1994), suggest that the saline water feeding Zuni Salt Lake is likely derived in part from dissolution of evaporite beds within the Yeso Formation. King Engineering, (2001) concluded that the source of salinity in the lake is evaporation of low salinity Dakota and Atarque aquifer waters, alluvial aquifer waters, and surface runoff. Regardless of whether the majority of brine is supplied to the lake from the Dakota or the Yeso, a decrease in head in the Dakota aquifer will result in changes not only to the water level in the lake, but will cause significant changes in the chemistry of both the lake water and in the aquifers that underly the lake.

Dakota Aquifer - Confined Or Unconfined?

It is critical to accurately characterize the nature of the Dakota aquifer prior to modeling the system. The Dakota is the highest head aquifer identified and is a major source of water for ZSL; therefore, any decrease in head in the Dakota aquifer below Zuni Salt Lake will adversely affect the lake In the early 1990's, SRP analyzed the results of pumping tests conducted in the Dakota aquifer. SRP concluded that, because the slope of the drawdown curve in the *pumping well* decreased after approximately ten minutes (Figure 4), the aquifer is leaky and the decreased slope is due to recharge from surrounding units. This interpretation was accepted by the State of New Mexico Mining and Minerals Division (MMD) and the Federal Office of Surface Mining (OSM) during the mine application process. In an independent review of the data, it was concluded that the decrease in slope is a result of casing storage effects, rather than recharge to the aquifer (Drakos and Lazarus, 1997). If anything, late time data from the pumping well indicate the presence of an impermeable boundary, although the test was not run for a sufficient length of time to definitively support this conclusion.

FIGURE 4. DRAWDOWN DATA FROM FL-36 (OB1) PUMPING WELL 50-HOUR TEST, Q = 311 GPM



Outcrop analog analyses were conducted in the Zuni Salt Lake area to evaluate surface exposures of the Dakota Sandstone, Atarque Sandstone, and surrounding units. Outcrops of the Dakota Sandstone and the Atarque Sandstone had ubiquitous penetrative fractures, while shale units above and below the Dakota Sandstone (Mancos and Chinle Fms.) were not fractured (Drakos and Lazarus, 1997; Drakos et al., 2001). In addition, bentonite aquicludes are present within the Mancos Shale. Using these outcrops as analogues to the subsurface is supported by video logs of the SRP Dakota wells, which show fractures in the Dakota in the subsurface (McGurk and Stone, 1986) and SRP's experience with open hole completions, in which shale units swelled to fill the borehole. Outcrop analog analyses support the confined aquifer pumping test analysis and is consistent with the conclusions of Myers (1992) Core (1996), and King (2001).

Because SRP concluded that the Dakota aquifer is a leaky-confined system, they used the Hantush-Jacob method of aquifer analysis to determine the effects of pumping at the mine. The result of their model was that drawdown would not extend more than 3708 feet from the pumping center after 40 years. However, this method grossly underestimates the true drawdown effects because the Dakota is a confined aquifer (Myers, 1992; Core 1996; Drakos and Lazarus, 1997; King , 2001; Drakos et al., 2001). For a confined aquifer, a Theis analytical model predicts that drawdown effects would propagate beyond Zuni Salt Lake and drawdown at the lake would be at least four feet (Drakos and Lazarus, 1997).

Current Status

As a result of on-going Zuni appeals, federal officials have not given final approval to the life of mine permit. A recent revision to the MMD permit (currently under appeal by SRP) requires extensive testing of the Dakota, and may reduce or prohibit its use for mining operations. The dispute between Zuni Pueblo and SRP remains unresolved as of this writing. Federal officials indicate that a decision is imminent.

References Cited

Bradbury, J.P., 1971, *Limnology of Zuni Salt Lake, New Mexico*: Geological Society of America Bulletin, v. 82, p. 379-398.

Core, A., 1996, *Analysis of a pumping test at the Salt River Project Agricultural Improvement and Power District proposed Fence Lake Mine, Catron County, NM*: internal memo to Tom Morrison, Chief, Hydrology Bureau, OSE.

Drakos, P., and Lazarus, J., 1997, *Hydrogeology of Nations Draw area from Zuni Salt Lake to Proposed Fence Lake Coal Mine: Review of Salt River Project (SRP) Hydrology Submittals for Fence Lake Coal Mine Permit Application Package (PAP)*: unpublished consulting report to the Pueblo of Zuni

Drakos, P., Lazarus, J., Riesterer, J., Hodgins, M.,, Chudnoff, M., 2001, *Hydrogeology of Nations Draw area: Analysis of potential impacts on Zuni Salt Lake from proposed Fence Lake Mine groundwater diversions*: unpublished consulting report to Zuni Pueblo

Hantush, M.S., and Jacob, C.E., 1955, *Non-steady radial flow in an infinite leakyaquifer*: Am. Geophys. Union Trans., vol. 36, p. 95-100.

King (King Engineering), 2001, *Potential Hydrological Impacts of Pumping at Fence Lake Coal Mine on Zuni Salt Lake*: prepared for the Bureau of Indian Affairs, Office of Trust Responsibilities.

Laughlin, A.W., Aldrich, M.J., Ander, M.E., Heiken, G.H., and Vaniman, D.T., 1982, *Tectonic setting and history of Late-Cenozoic volcanism in west-central New Mexico*, in New Mexico Geological Society Guidebook 33rd Field Conference: Albuquerque Country II, p. 279-284.

McGurk, B.E., and Stone, W.J., 1986, *Conceptual Hydrogeologic Model of the Nations Draw Area, Catron and Cibola counties, New Mexico*, Report to Salt River Project.

Myers, R.G., 1992, *Geohydrology and potential hydrologic effects of surface coal mining of the San Augustine coal area and adjacent areas, Catron and Cibola Counties, New Mexico*: U.S.G.S. WRI Report 92-4004, 52 p

Salt River Project, 1993/1994, *Fence Lake Mine Permit Application Package*