HYDROLOGIC INVESTIGATION OF THE DRY LAKE REGION IN EAST CENTRAL ARIZONA

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ABSTRACT

The Dry Lake Region is located in Navajo County, Arizona, near the southern margin of the Colorado Plateau. The region's internal drainage basin of 160 mi^2 is further augmented by 50 mi^2 of the Phoenix Park Wash drainage. The dominate surface water inflow to the playa is the 12 to 13 MGD of paper pulp mill effluent from Southwest Forest Industries near Snowflake, Arizona. As a result, the playa surface water is now covering several thousand acres. Dry Lake water quality is relatively poor by Arizona Department of Health Services (ADHS) drinking water standards. Ground water in the region is produced from the Coconino Aquifer which is comprised of the Coconino Sandstone and the Kaibab Limestone. The depth to ground water is 400 feet with a saturated zone 100-175 feet thick. Wells in the region yield from 0 to 500 gpm. The presence of the Holbrook Anticline and the Dry Lake Syncline influence both ground water flow direction and artesian conditions.

There is concern that the playa may not be suited as an evaporative disposal basin because of the potential influence that karst topography and linear surface features may have on the water balance of the region.

INTRODUCTION

This report is a combination of on-site field investigations and the review of available literature and aerial photography. The investigation was undertaken in connection with a proposed land exchange between the Arizona State Land Department and Southwest Forest Industries, Inc. (SWFI) during the late summer and fall of 1978.

PHYSIOLOGIC SETTING

The Dry Lake playa lies in the southern portion (Township 14 North, Range 18 East) of Navajo County, Arizona, approximately 126 miles east, northeast of Phoenix, Arizona and 20 miles west, northwest of Snowflake, Arizona (see Figure 1). The region is historically made up of small farming, ranching and recreational communities such as the Town of Snowflake (population 2600) which date back to the late 1800's. Several small abandoned towns dot the region, such as the Town of Zeniff (Barnes, 1960). The largest single employer within the region is Southwest Forest Industries, (SWFI), who owns and operates a pulping and paper mill located in Section 21, Township 13 North, Range 19 East west of Snowflake, Arizona (Figure 1). Liquid wastes from their operation are discharged to Dry Lake (Section 1, Township 14 North, Range 18 East) for evaporation and settling.

The project area lies in the COLORADO PLATEAUS PROVINCE (Heindle, 1960) between 5800 and 6000 feet elevation (MSL). Vegetation types trend from desert grassland to juniper-pinon woodland. The alluvial soils found in the Dry Lake region are predominantly derived from decomposed Moenkopi sandstones, silts and clays of the Moenkopi Formation as well as some igneous materials.

Precipitation in the region averages 12.28 inches per annum, and the mean annual air temperature is 52.1°F, with extremes from below freezing to 100°F (Johnson, 1962). Very windy conditions (25-45 mph) prevail throughout the year.

The authors were all members of the Water Rights Division staff of the Arizona State Land Department, Phoenix, Arizona. Their positions were respectively Technician, Hydrologist, and Hydrologist.

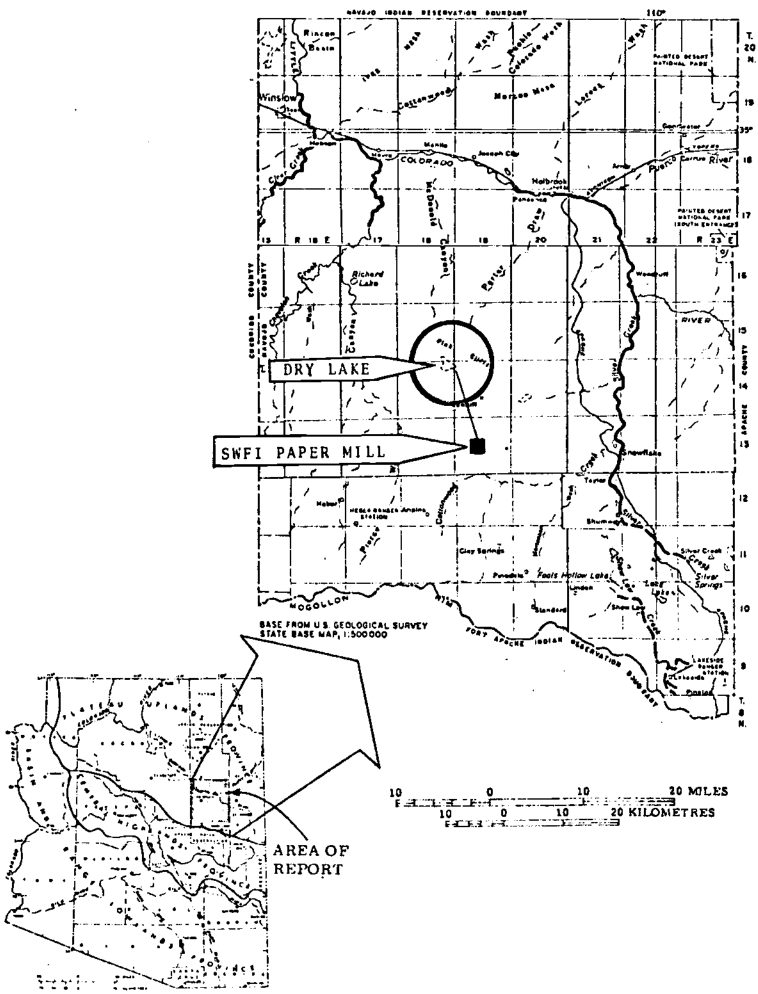

FIGURE 1

Area of Report Showing Dry Lake, SWFI Mill and Effluent Discharge Channel
(Taken from New Mexico Geological Society, 13th Field Conference, 1962)

GEOLOGIC SETTING

Dry Lake lies equidistant between the surface expression of the Holbrook Anticline to the north and the Dry Lake Syncline to the south (see Figure 2). The Lake overlies approximately 60 feet of Quaternary alluvium. Beneath the alluvium is a thin veneer of Kaibab Limestone (Arizona Bureau of Mines, 1960). The Kaibab and the underlying Coconino Sandstone are the principal aquifer in the area (Mann, 1976). The Coconino is 729 feet thick beneath Dry Lake (California Oil Co., 2 test holes). Beneath the Coconino is the Supai Formation, an interbedded sequency of shales, siltstones, and evaporites comprising some 1400 feet of thickness.

The Dry Lake drainage area comprises about 160 square miles of internal drainage and 50+ square miles of drainage from Phoenix Park Wash, which breeches the internal drainage basin along its southern edge. The origin of the Dry Lake depression appears (Bahr, 1962) to be the result of collapse from dissolution of the evaporites within the Supai. Geologic evidence indicates the collapse was pre-Quaternary (greater than one million years ago). The drainage patterns illustrated in Figure 2 are indicative of the geologic time frame. A less dramatic geomorphic feature is the karst topography east of Dry Lake (Township 13 North, Range 20 East) and northwest of Dry Lake (Township 16 North, Range 17 East). The sinkholes surrounding Dry Lake are locatable on the ground and easily identified on aerial photography. It is thought that the origin of the smaller sinkholes located in and around Dry Lake are a result of tension-induced features at the time Dry Lake depression collapsed. Figure 3 is an interpretation of U-2 aerial photography indicating many of the sinkholes located in and around Dry Lake.

Field work at Dry Lake has disclosed at least one set of sinkholes along the southern edge of the lake, enclosed by a dike to prevent movement of water into those features. The deepest portions of the sinkholes have a liquid residue purported to be the remnants from a filling of the features several years ago. There was no evidence of seepage through the dike. The elevation of the residue surface was about ten feet below the elevation of the lake surface. Reportedly, several sinkholes opened up several years ago as a result of a rapid rise in lake level. Bahr (1962) found alluvium-filled older sinks, which indicates the appearance of sinks is an on-going process. Proper monitoring of the potential for new sinkholes and subsequent diking should prevent movement of Dry Lake water into any new sinkholes.

HYDROLOGIC SETTING

GROUND WATER

The following ground water conditions are summarized from Mann (1976). The Kaibab and Coconino, combined, comprise the aquifer in the region surrounding Dry Lake. Well yields are from 0 to 500 gpm and are a function of the saturated thickness, artesian conditions, and well design. Wells are designed for the intended use, that is, any yield up to 500 gpm is generally possible. In the near vicinity of Dry Lake, depth to water is approximately 400 feet. Water is generally absent several miles to the north of the lake. The thickness of the saturated zone will vary in the region south of the lake, but rough estimates of 100-175 feet would coincide with regional trends. Volume of recoverable water is highly variable.

In general, ground water moves perpendicularly to the structural contours of the Coconino. However, near Dry Lake, regional flow is northeast. From an interpretation of Mann (1976) ground water probably moves northwest and southeast at Dry Lake as a result of the Holbrook Anticline. Recharge to the aquifer occurs along the Mogollon Rim through the more permeable materials. Some percentage of the recharge undoubtedly occurs along the northward flowing streams. For example, in Lone Pine Dam south of Show Low, seepage losses into the Kaibab are of such magnitude that almost all of the water is lost.

SURFACE WATER

Internal drainage patterns developed within the subsiding Dry Lake basin. Some older drainage channels show evidence of reversal as the gradient reversed (refer back to Figure 2). The major drainage pattern of the basin does not appear to be fault aligned; however, Phoenix Park Wash, which is a major drainage within the basin, exhibits a dendritic pattern.

There is evidence, though, that numerous minor drainages are influenced by shallow sub-surface fractures. The small sinkholes inspected on the south side of the lake exhibited a closely spaced linearity. Although not substantiated by previous geologic data, it is believed that these smaller (12-25 foot diameter) sinkholes are not

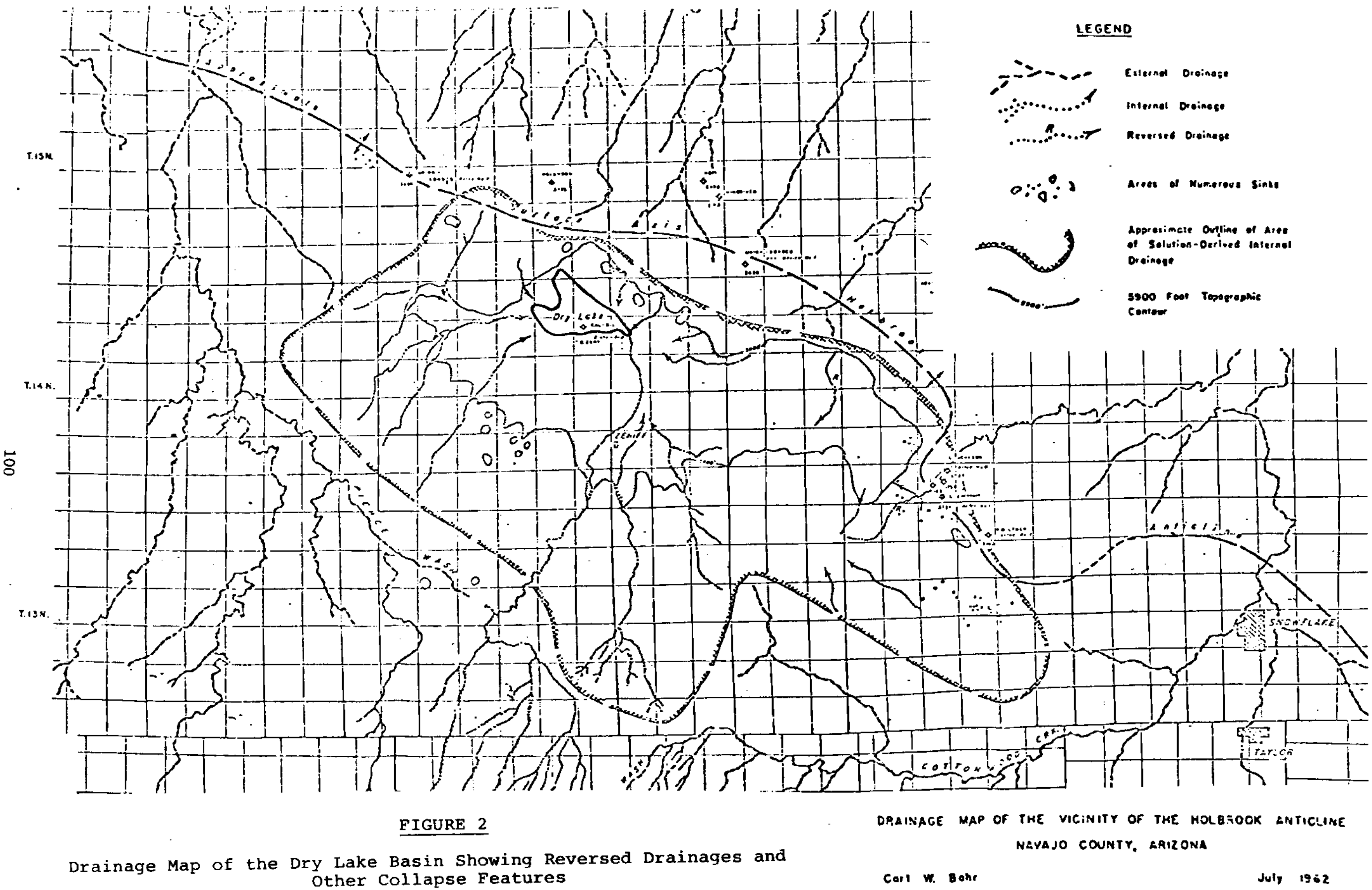

FIGURE 2

Drainage Map of the Dry Lake Basin Showing Reversed Drainages and Other Collapse Features

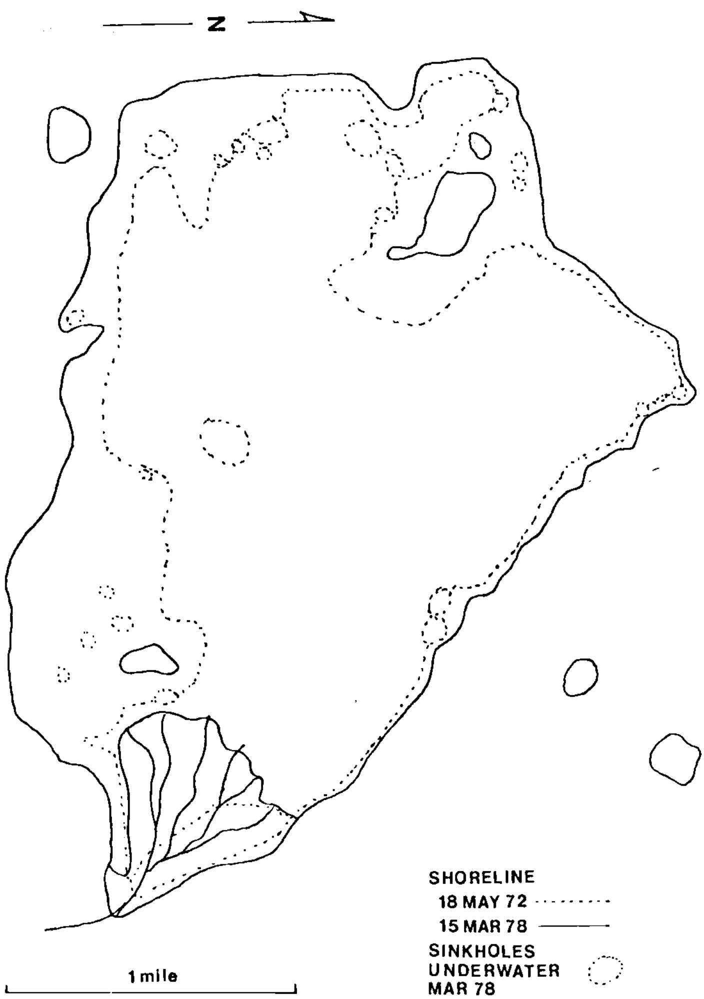

FIGURE 3

Interpretation of Aerial Photography
Showing Dry Lake, Sinkholes and Other Changing Features

associated with dissolution subsidence of the Supai Formation as previously eluded to, but are, in reality, associated with dissolution phenomena occurring within the Moenkopi Formation (or within a thin veneer of Kaibab Limestone) which underlies the alluvium in the region. The Moenkopi Formation consists of "predominantly sandstone, siltstone, claystone, mudstone, limestone, and gypsum beds" (Johnson, 1962).

As mentioned previously, fracturing of the Moenkopi Formation probably occurred as a result of compression stresses on the upper strata as the Dry Lake basin subsided. Surface drainage flowing through such fractures, and subsequent dissolution of shallow lenses of limestone and/or gypsum, could account for formation of localized karst formations, which periodically exhibit themselves through collapse of the alluvial overburden. Present day internal drainage to the basin most likely is continuing to play an active role in the formation of this localized karst formation.

The possibility of leakage from Dry Lake and/or the effluent channel to the Coconino aquifer increases significantly if active karst formation is taking place within the Moenkopi and/or Kaibab Formations.

WATER QUALITY

Other than Dry Lake playa, the quality of the surface water in the area is assumed to be similar to other regions in the Colorado Plateau. There are no known mineral or salt deposits that would add large amounts of dissolved or suspended material to the surface runoff. Phoenix Park Wash and Sheepskin Draw both carry large amounts of sediments during peak runoff events as is the nature of ephemeral streams in Northern Arizona.

The water in Dry Lake playa had a noxious taste and odor when sampled during the field investigation. The dark color of the water sample submitted to the Arizona Department of Health Services Laboratory has hampered the analysis procedure.

Ground water samples from two wells were tested by Arizona Testing Laboratories for tannin/lignin content and compared to the basin surface water. One well [A(14-18)5adb] was two (2) miles west from Dry Lake and the other well [A(14-20)30dad] was seven (7) miles to the east. The results of the chemical analysis for these wells shows the quality to be only marginal for domestic purposes at this time. The surface water was found to have 170 milligrams per litre (mg/l) tannin/lignin-like substances while the ground water contained less than 0.2 mg/l tannin/lignin.[1/]

There is an abandoned well within several thousand feet of the basin [A(14-19)7ccc] which was recommended to SWFI as a potential monitor well for the Coconino aquifer with respect to potential contamination from Dry Lake. This well was recently refurbished by SWFI and pump tests and sampling are presently under way. No chemical results are available for this well at the time of this report, however, verbal reports of the pump test results would indicate that the Coconino aquifer in this region may have a low specific capacity (0.5 gallons/minute/foot of drawdown).

CONCLUSIONS

ENVIRONMENTAL CONCERNS

The playa is currently being used as the main disposal basin of a watery pulp mill effluent (average discharge is 12-13 million gallons per day). The toxicity and longevity of the discharge substance is unknown; however, McKee and Wolf (1967) report that tannin/lignin levels of 100 mg/l will kill goldfish (carp) in nine (9) hours. The amount of chlorine needed to disinfect a public supply would greatly increase if there is lignin in the raw supply. The levels of tannin/lignin in the basin will increase over time regardless of the amount of effluent disposed into the basin due to evaporation.

The photographic interpretation of linear features and sinkholes in the Dry Lake playa leads to a conclusion that there are geologic conditions that could allow contamination of the ground water system by the surface disposal of effluent. There are

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1. The .2 mg/l would be the approximate lower limit of test accuracy performed by ATL, however, there are measurements in the range of .05 mg/l accuracy (McKee and Wolf, 1967).

no less than 25 sinkhole-like structures in the present wetted portion of the lake (Figure 3). While the ground verification or truthing of the aerial photographic interpretation cannot be done under the water in the playa, there are some areas on the southern and western margins of the basin that could be reached. The geologic conditions that are evident in the area include sinkholes of varying sizes from several feet across to several hundred feet wide. The linear features, or surface expressions of fractures, faults or cracks, show that there are subsurface geologic conditions that are influencing surface topography and possibly ground water movement.

Percolation rates may be on the order of several inches/day to several feet/year; however, little is known about the Dry Lake region's Coconino Sandstone permeability. Transmissivity coefficients of Coconino Sandstone have been developed for other areas of the Colorado Plateau, but they may not be applicable to the hydrologic situation here. The regional direction of ground water flow trends to the northeast; however, the Holbrook Anticline may channel the flow to the east and southeast at Dry Lake.

The sealing clays of the playa floor and the silts and mudstones of the Moenkopi Formation may not bridge the wider cracks and voids resulting from sinkholes and fracturing. This means that even if the majority of the playa floor is solid clay, the sinkholes and cracks could provide a direct pathway from the surface to the Coconino Sandstone. If there is a direct link of the surface and ground water systems, then the horizontal rate of ground water movement in the Dry Lake region becomes important.

RECOMMENDATIONS

1) The need for further hydrologic investigation into the exact nature of ground water movement and possible contamination in the Dry Lake basin is evident from the inconclusive data collected from the area to date. The data that was collected and analyzed indicates that, while at the present time there is no apparent contamination outside the basin proper, little is known about the site in terms of geology and hydrologic systems as they relate to water quality and environmental hazards.

2) The interpretation of the U-2 aerial photography resulted in a number of sinkholes being identified in the wetted portions of the lake. Field investigations of the area did not confirm or deny any observable downward flow of surface water. The use of currently available geophysical methods should be employed to determine the extent of the openings and the rate of downward water flow, if any, for each sinkhole and fracture site.

3) A water balance of the inflow and evaporation rate from the surface of the lake should be recomputed (Dry Lake is equipped with a stage recorder; however, this was inoperative at the time of this investigation). The rapid build-up of a 40-acre deltaic deposit at the lake head should be examined to determine the exact nature of the delta. It is conceivable that the surface runoff into the basin was underestimated by several thousand acre feet (personal communication with L. Mann, September, 1978). This additional inflow combined with a smaller surface area for evaporation could result in higher lake elevations and greater downward pressures on the basin floor. New and larger collapse features might develop beneath the water, yet remain undetected by visual inspection.

4) Although a potential exists for contamination of the ground water in the Dry Lake area by pulp-mill wastes, there is little evidence to substantiate whether influx to the Coconino Sandstone aquifer is actually occurring. Continued monitoring and sampling is recommended. Possible consideration might be given to drilling additional monitoring wells in the regions east and northwest of the lake.

5) The contamination of regional ground water by pulp mill wastes cannot be discerned at this time. Further data collection and analysis would be required to either substantiate or disprove the theory that waste materials are entering the Coconino Sandstone aquifer from Dry Lake or the waste transport channel through karst dissolution cavities.

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