OVERVIEW OF THE HYDROGEOLOGY AND ANALYSIS OF GROUND WATER WITHDRAWAL IN THE MENDENHALL-D'LO AREA, SIMPSON COUNTY, MISSISSIPPI

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INTRODUCTION

The cities of Mendenhall and D'Lo, located in Simpson County, Mississippi, rely on ground water for their public supply and industrial needs. Most of the water comes from an aquifer of Miocene age. Regionally, water levels in Simpson County have been declining at the rate of about 1 foot per year (Newcome et al. 1972). Continued population growth and the development of new industries may increase the rate of water-level decline. In 1991, the U.S. Geological Survey, in cooperation with the Pearl River Basin Development District and the Mississippi Department of Environmental Quality, Office of Land and Water Resources, began an investigation for the purpose of describing the hydrogeology, analyzing effects of ground water withdrawal by making a drawdown map, and projecting the possible effects of increased ground water withdrawals on water levels in the Miocene aquifer within the Mendenhall-D'Lo area (Strom and Oakley 1995). This paper describes the hydrogeology of the area and presents the results of the analysis of the effects of ground water withdrawals through 1994 on water levels.

General Setting of the Study Area

The study area covers about 30 square miles in Simpson County, south-central Mississippi (Figure 1). The area is located in the Southern Pine Hills of the Gulf Coastal Plain physiographic province (Fenneman 1938). The land surface is hilly, ranging in altitude from about 260 to 520 feet above sea level. The Strong River, the major surface-water drainage, flows southwestward between Mendenhall and D'Lo and drains into the Pearl River about 15 miles southwest of the study area. The Strong River has an alluvial plain that is about 1 mile wide in the study area. The normal mean annual temperature at D'Lo is about 63 degrees Fahrenheit; normal annual precipitation is about 59 inches.

HYDROGEOLOGY

The hydrogeology of the study area is described here in terms of the hydrogeologic units and their relation to each other and ground water movement. All of the formations and deposits described have potential water-bearing zones; however, a lower sand in the Catahoula Formation of Miocene age is the principal source of ground water in the study area.

Description of the Hydrogeologic Units

Geologic units that crop out in the study area range from Tertiary to Quaternary age. The sediments include alluvial and fluvial gravel, sand, and silt; deltaic sand, silt, and clay; and prodeltaic and marginal marine clays. The geologic units, from oldest to youngest, are the Catahoula and Hattiesburg Formations of Miocene age; the Citronelle Formation of Pliocene or Pleistocene age; terrace deposits probably of Pleistocene age; and alluvium of Holocene age (Figure 2). Descriptions of the geologic units are from May and Marble (1976) except where noted.

Catahoula Formation. The Catahoula Formation is fluvial to marginal-deltaic in depositional origin. The sediments probably represent a regressive, offlap sequence. The Catahoula Formation reaches a maximum thickness of about 450 feet in the study area and dips to the southwest at about 20 feet per mile. The formation mainly consists of deltaic silt and clay deposited in a low energy environment and lenses of sand deposited in a high energy environment. Induration of the materials occurs primarily at surface exposures (Gilliland and Harrelson 1981).

Many of the sand lenses in the Catahoula Formation are not continuous; however, an upper and lower sand interval exists within the formation. The upper sand consists of medium to coarse grained lenses and ranges from 35 to 45 feet in thickness. The lower sand is fairly continuous in the study area and ranges from 35 to 65 feet in thickness; greater thicknesses usually contain some clay or silt lenses. The lower sand primarily is a coarse to very coarse, poorly sorted quartz sand that is fluvial in nature. The upper and lower sands are both considered aquifers in the study area; however, most wells are screened in the lower sand.

The Catahoula Formation is unconformably underlain by the Vicksburg Group of Oligocene age. Clay from the Bucatunna Formation confines the Catahoula Formation from aquifers in the Vicksburg Group. The relation between the Catahoula Formation and other units is shown in Figure 3.

Hattiesburg Formation. May and Marble (1976) describe a "Post-Catahoula Unit" that will be referred to as the Hattiesburg Formation in this report. Reasons for adopting this nomenclature are the same as those pointed out by Gilliland and Harrelson (1981): the "Post-Catahoula Unit" is in the same stratigraphic position as the Hattiesburg Formation, and other publications, such as the geologic map of Mississippi (Bicker 1969), show the unit as the Hattiesburg Formation.

The Hattiesburg Formation is fluvial to marginal-deltaic in depositional origin. The sediments probably represent a regressive sequence, similar to the underlying Catahoula Formation. The Hattiesburg Formation has a maximum thickness of about 130 feet in the study area and dips slightly west of south at about 20 feet per mile. The formation mainly consists of an upper argillaceous silt deposited in a low energy environment and a lower medium to coarse grained, poorly sorted sand, deposited in a high energy environment. The Hattiesburg Formation is not heavily pumped in the study area.

Citronelle Formation. The Citronelle Formation is fluvial in depositional origin. The formation probably formed a continuous blanket of sediment in the past (Boswell 1979), but now exists only at the higher altitudes in the study area. The Citronelle Formation has a maximum thickness of about 150 feet in the study area and dips slightly west of south at about 10 feet per mile. The formation mainly consists of coarse sand and gravel deposited in a high energy environment. The Citronelle Formation is not heavily pumped in the study area.

Terrace Deposits. Terrace deposits are present on hills lower in altitude than the hills that are capped by the Citronelle Formation. Thickness of the deposits is highly variable and dips have not been determined. The deposits mainly consist of fine- to coarse-grained sand. The deposits may have resulted from sea level fluctuations during Pleistocene glaciation.

Alluvial Deposits. Alluvial deposits are present in the river valleys of the study area. These deposits are the result of fluvial erosion of materials from higher elevations. Thickness of the deposits is variable, but may average about 20 feet in the Strong River alluvial plain. The deposits mainly consist of clay, sand, and gravel eroded from terrace deposits and from the Citronelle, Hattiesburg, and Catahoula Formations.

Ground Water Movement

Both confined and unconfined conditions occur in the aquifers of the study area. Aquifers in alluvial deposits, terrace deposits, the Citronelle Formation, and much of the Hattiesburg Formation are probably under unconfined conditions. Parts of the upper sand trend of the Catahoula Formation, particularly near the river valleys, may also be under unconfined conditions. However, the lower sand in the Catahoula Formation is under confined conditions.

Ground water movement in unconfined aquifers is influenced greatly by topography. Ground water generally moves from areas that are topographically high to areas that are topographically low. In the study area, most of the movement of unconfined ground water is toward the Strong River (Boswell and Arthur 1988). Limited water-level data for the lower sand of the Catahoula Formation indicate flow in the lower sand may also be toward the Strong River or toward pumping wells.

ANALYSIS OF GROUND WATER WITHDRAWAL

Analysis of the effect of ground water withdrawal is based on pumpage and aquifer data from 10 wells screened in the lower sand of the Catahoula Formation. About 0.53 million gallons of water per day currently (1995) is withdrawn from these 10 wells. The analysis was made using the Theis nonequilibrium equation (Theis 1935) and applying the principle of superposition. The Theis nonequilibrium equation is a solution to the radial form of the diffusion equation for a given set of initial and boundary conditions. This method is applicable because pumping tests for the wells indicated that the aquifer is under confined and generally non-leaky conditions in the study area. The Theis nonequilibrium equation computes drawdown in a confined aquifer at a specified distance from a pumping well. To perform the analysis, pumpage of the well, length of time pumping occurred, and transmissivity and storage coefficient of the aquifer must be known. Because the diffusion equation is linear, the principle of superposition can be used to determine total drawdown caused by multiple wells being pumped simultaneously by summing the drawdown determined for each individual well.

The study area was discretized into an equally spaced grid. Each grid cell was 264 feet on a side for a total of 12,000 grid cells (Figure 4). This discretization provided the resolution necessary to delineate the surface of combined drawdown from multiple wells and to place each well (shown in Figure 4) in the center of a grid cell. The Theis nonequilibrium equation was applied at the center of each cell for each individual well using numerical approximations. Drawdown for each well in each cell was summed to produce a composite drawdown map.

Drawdown was calculated using a well radius of 1 foot in cells that contained a well; however, the analysis does not account for drawdown near a well caused by other factors, such as turbulent flow or regional drawdown. A storage coefficient of 0.0002 was determined by an aquifer test only at well J6 (Slack and Darden 1991). This value was used for each well in the analysis.

Analysis of 1994 Conditions

Analysis of 1994 conditions was based on the pumpage records and aquifer properties determined for each well. The Theis nonequilibrium equation is based on the assumption that the aquifer is homogeneous and isotropic. For the analysis of each individual well, this assumption was made. The Theis nonequilibrium equation was applied using the value of transmissivity determined from an aquifer test for each individual well for each cell in the grid. The total drawdown in each cell was then determined by summing the drawdown caused by each individual well. An alternative method would be to assume a single average value of transmissivity for all of the wells; however, error likely is reduced by using site specific values of transmissivity for each individual well because calculated drawdown is greatest at the center of a well and decreases exponentially with distance from the well.

The calculated drawdown surface (Figure 5) indicates three general cones of depression. One cone is in the northwestern D'Lo area, one cone in the south-central Mendenhall area, and one cone about 11/2 miles east of Mendenhall. A generalized view of the drawdown surface (Figure 6) shows the coalescing nature of the drawdown cones caused by multiple wells.

Because the computed drawdown surface is a composite of drawdowns from wells that began pumping at different times, drawdown measured at the oldest wells should provide the best verification. The oldest wells are J6, D38, E29, J34, and D51. Water-level measurements cannot be made at well J6 due to reworking of the well. Water-level measurements made in fall 1994 indicate total drawdown of about 39 feet for well D38, 42 feet for well D51, and 39 feet for well J34. The analysis indicated a total drawdown of about 42 feet at well D38, 40 feet at well D51, and 37 feet at well J34, which compares closely to measured values of drawdown. However, well E29 had a measured drawdown of about 15 feet and a calculated drawdown of about 35 feet. Review of the aquifer-test data confirmed the values used in the analysis, but it is possible that the transmissivity for well E29 is in error because the well was pumped only 1 hour during the test and possible sources of recharge might not have been revealed. An upward inflection may have started in the drawdown curve at the very end of the test.

Only one value of storage coefficient (0.0002) was available and this value was used at all wells; therefore, a sensitivity analysis to the change in the storage coefficient was made. Decreasing the storage coefficient from 0.0002 to 0.0001 resulted in an average increase in drawdown of about 3.4 feet. Increasing the storage coefficient from 0.0002 to 0.0003 resulted in an average decrease in drawdown of about 1.9 feet.

Because the Theis nonequilibrium equation is based on the assumption of a homogeneous aquifer and site specific transmissivities were used for each individual well in the analysis, sensitivity analysis was performed using a constant transmissivity of 1,306 feet squared per day (the arithmetic mean of the transmissivities of each individual well). The resulting calculated drawdown surface was similar in both shape and magnitude to the drawdown surface using site-specific transmissivities. In general, the site-specific transmissivity drawdown surface was about 1 foot closer to the observed values. A maximum difference between the two surfaces of about 9 feet occurred in the D'Lo area, with the average difference being about 0.9 foot.

SUMMARY

The cities of Mendenhall and D'Lo, in Simpson County, Mississippi, rely on ground water for their public supply and industrial needs. Most of the water comes from an aquifer of Miocene age. In 1991, the U.S. Geological Survey, in cooperation with the Pearl River Basin Development District and the Mississippi Department of Environmental Quality, Office of Land and Water Resources, began an investigation, in part, to describe the hydrogeology and analyze effects of ground water withdrawals by making a drawdown map of the Miocene aquifer within the Mendenhall-D'Lo area.

The study area covers about 30 square miles in Simpson County, south-central Mississippi. Geologic units that crop out in the study area range from Tertiary to Quaternary in age. The sediments include alluvial and fluvial gravel, sand, and silt; deltaic sand, silt, and clay; and prodeltaic and marginal marine clays. The geologic units, from oldest to youngest, are the Catahoula and Hattiesburg Formations of Miocene age; the Citronelle Formation of Pliocene or Pleistocene age; terrace deposits probably of Pleistocene age; and alluvium of Holocene age.

The significant withdrawals of ground water in the study area are from 10 wells screened in the lower sand of the Catahoula Formation. About 0.53 million gallons of water per day currently (1995) is withdrawn from these 10 wells. Analysis of the effect of ground water withdrawal was made using the Theis nonequilibrium equation and applying the principle of superposition. The study area was discretized into an equally spaced grid and drawdown was calculated at the center of each grid cell for each individual well. Analysis of 1994 conditions was based on the pumpage records and aquifer properties determined for each well. The calculated drawdown surface indicates three general cones of depression. One cone is in the northwestern D'Lo area, one in the south-central Mendenhall area, and one about 11/2 miles east of Mendenhall.

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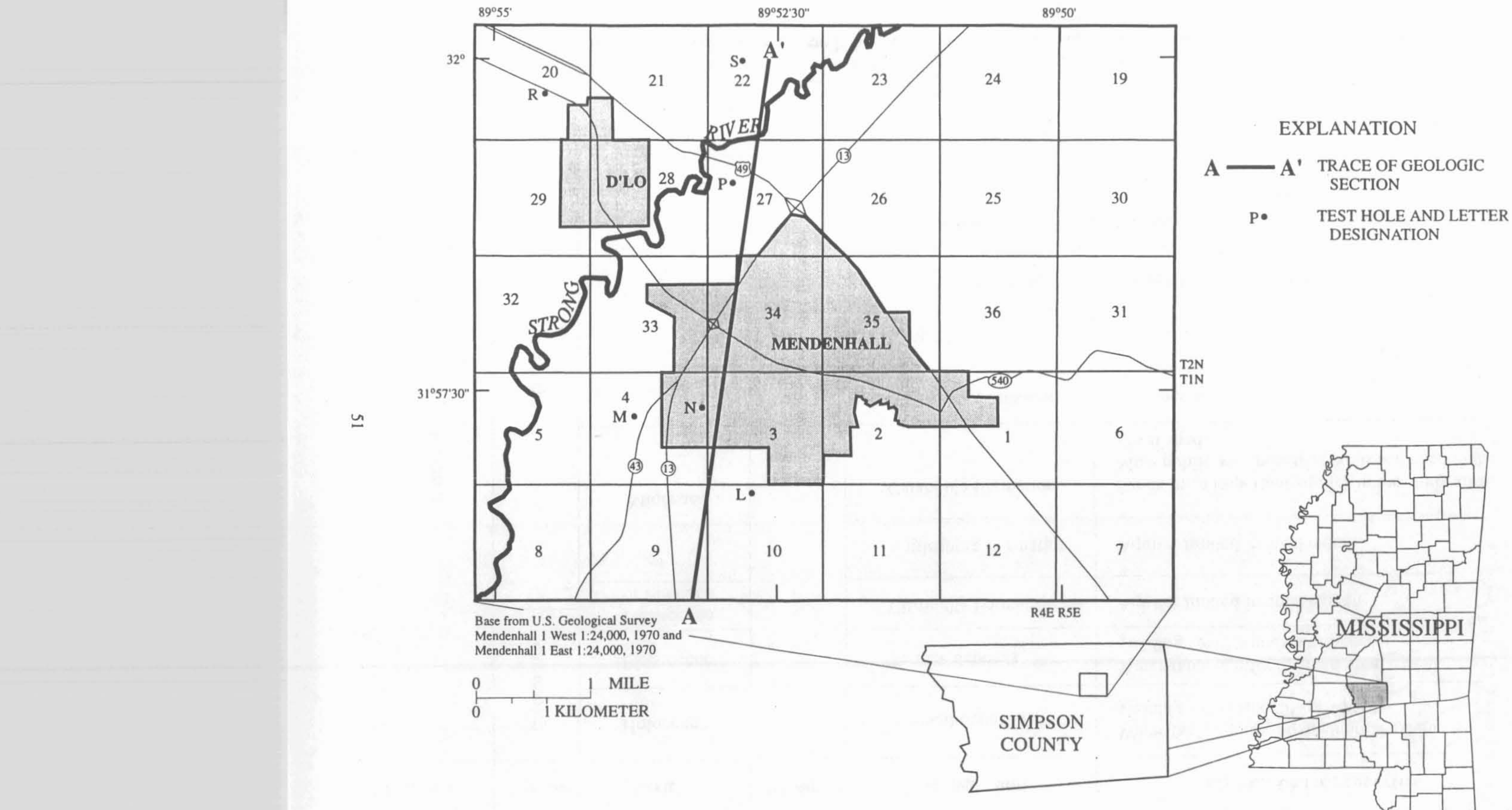

Figure 1. Location of the study area, trace of geologic section, and location of test holes.

Erathem	System	Series	Group	Geologic unit	Hydrogeologic properties
Cenozoic	Quaternary	Holocene		Alluvial deposits	Water-table aquifer of small areal extent yielding small amounts of water.
		Pleistocene		Terrace deposits	Water-table aquifer of small areal extent yielding small amounts of water.
	Tertiary	Pleistocene or Pliocene		Citronelle Formation	Aquifer limited in areal extent.
		Miocene		Hattiesburg Formation	Aquifer limited in areal extent.
				Catahoula Formation	Sands form important aquifer in the study area. Most public and industrial wells screened in the lower sand.
		Oligocene	Vicksburg	Bucatunna Formation	Not an aquifer.
				Byram Formation	Not an aquifer.
				Glendon Limestone	Generally not an aquifer.
				Mint Spring Formation	Potentially an aquifer capable of yielding small amounts of water.

Figure 2. Geologic units and principal aquifers in the study area (modified from Gilliland and Harrelson, 1981).

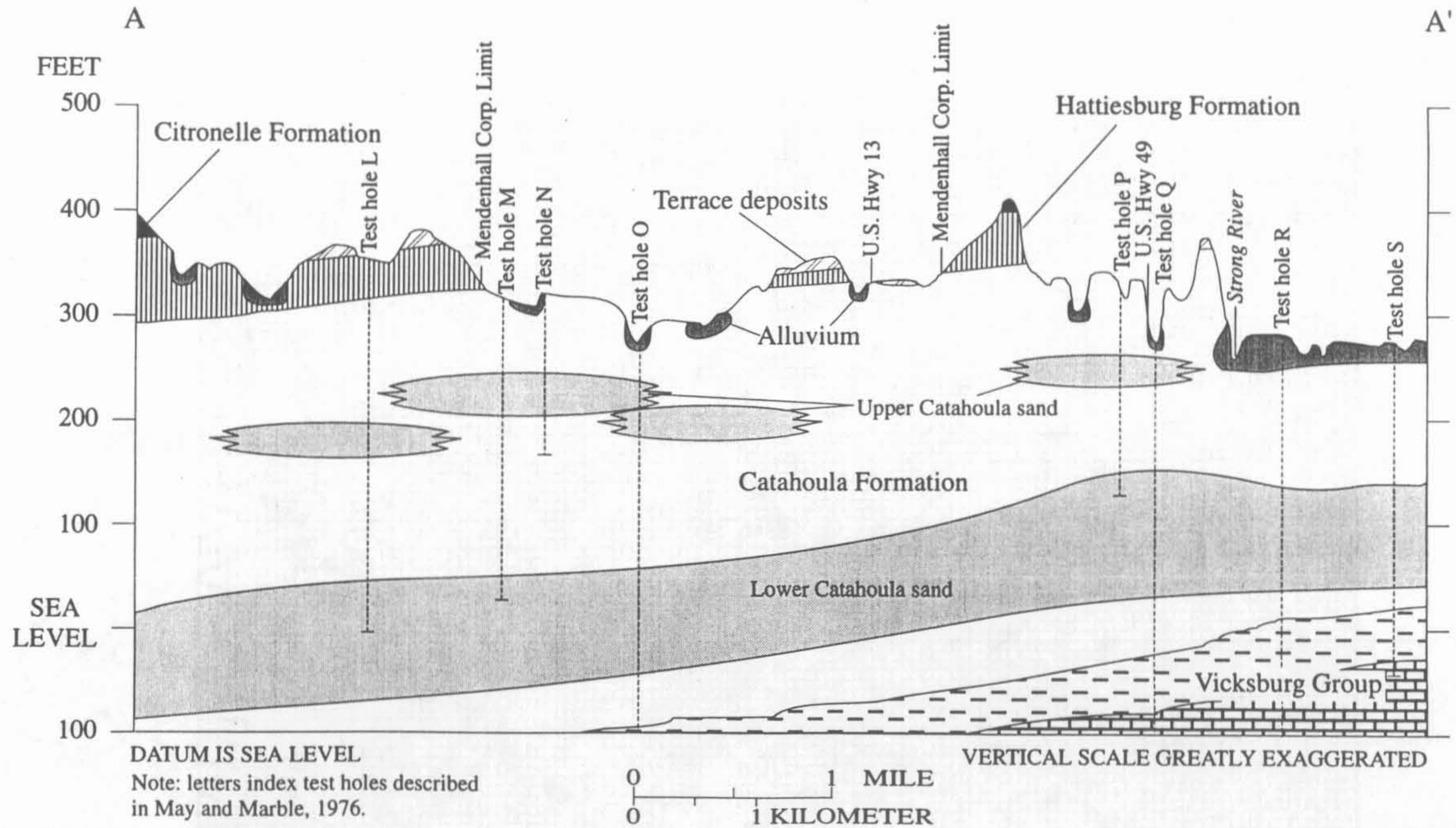

Figure 3. Geologic section showing relation of the geologic units in the study area (modified from May and Marble, 1976).

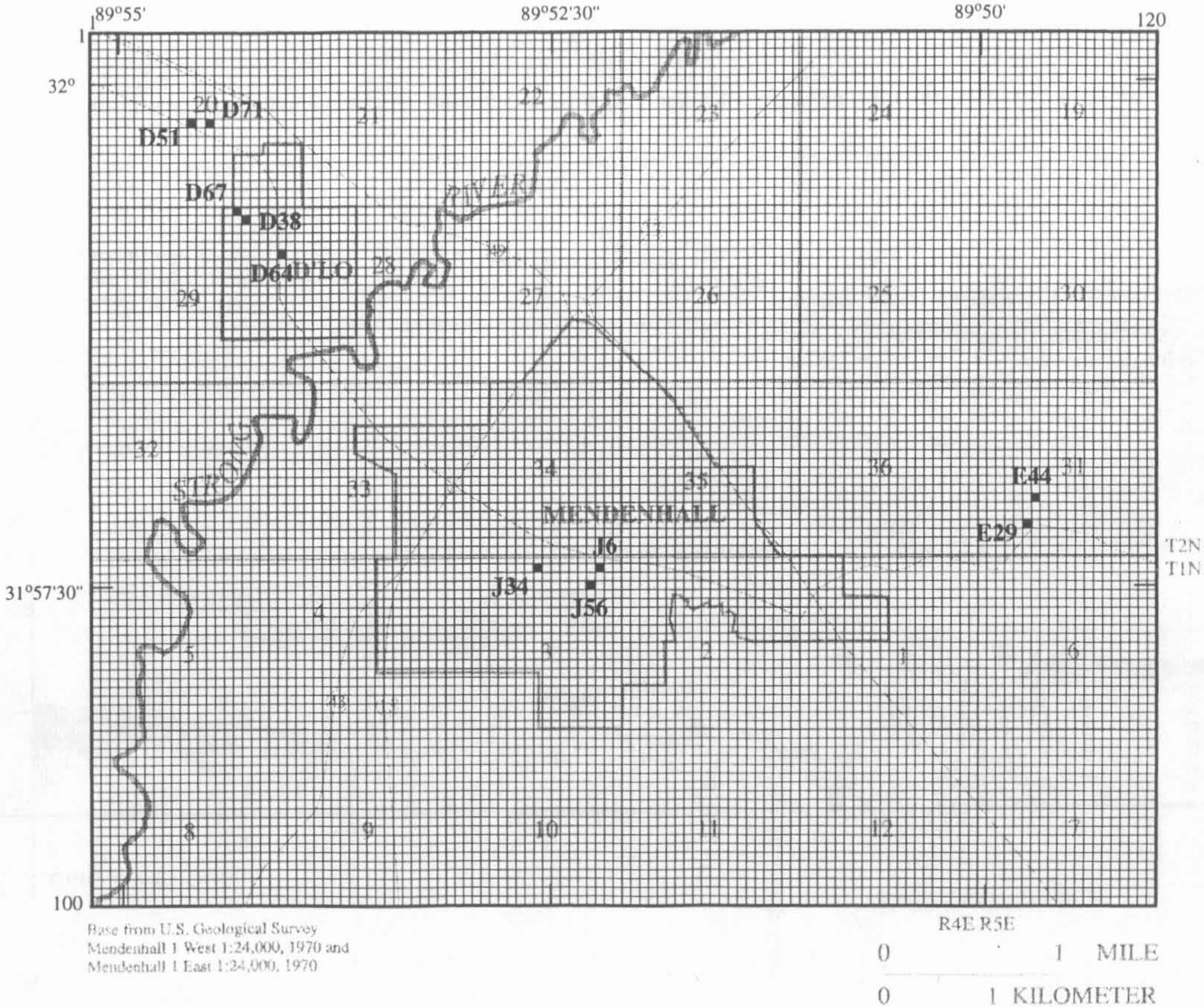

Figure 4. Grid cells and well locations used for drawdown calculations.

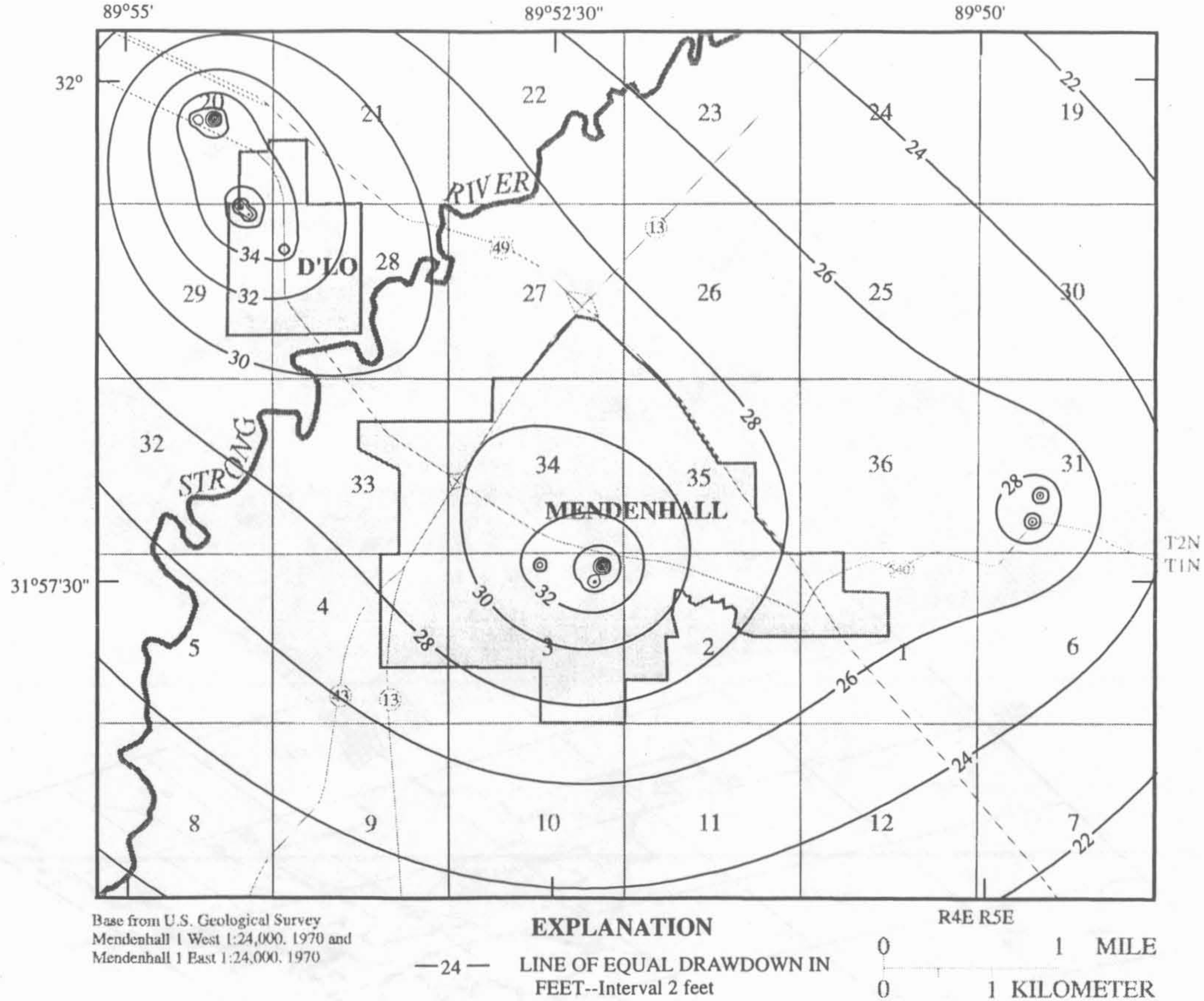

Figure 5. Calculated drawdown of water levels for 1994 conditions.

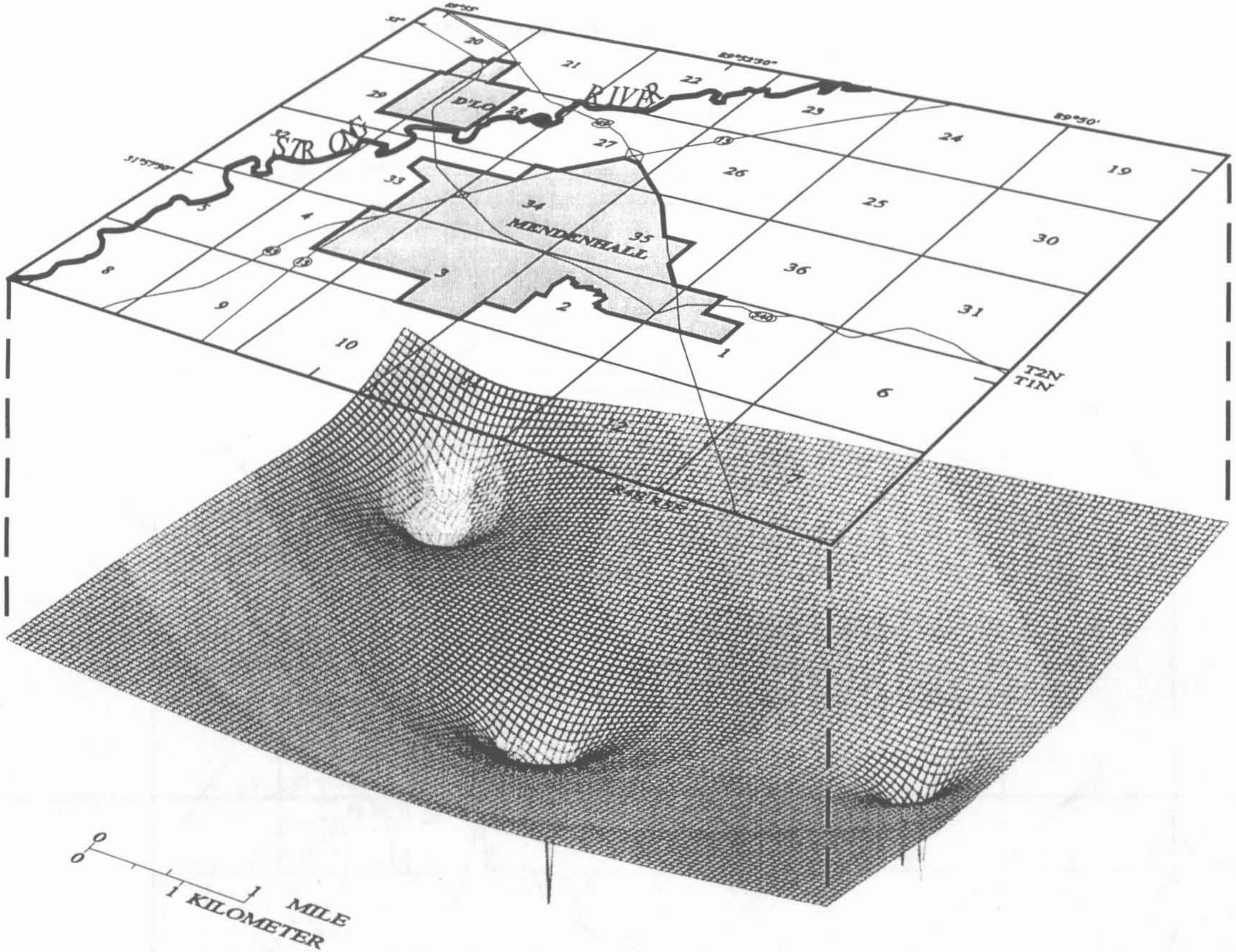

Figure 6. Generalized drawdown surface of the study area for 1994 conditions viewed from the southeast.