PROGRESS REPORT ON THE GROUND-WATER, SURFACE-WATER, AND QUALITY-OF-WATER MONITORING PROGRAM, BLACK MESA AREA, NORTHEASTERN ARIZONA—1987-88

By Robert J. Hart and John P. Sottilare

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CONVERSION FACTORS

For readers who use metric units, conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
square mile (mi^2)	2.590	square kilometer (km^2)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

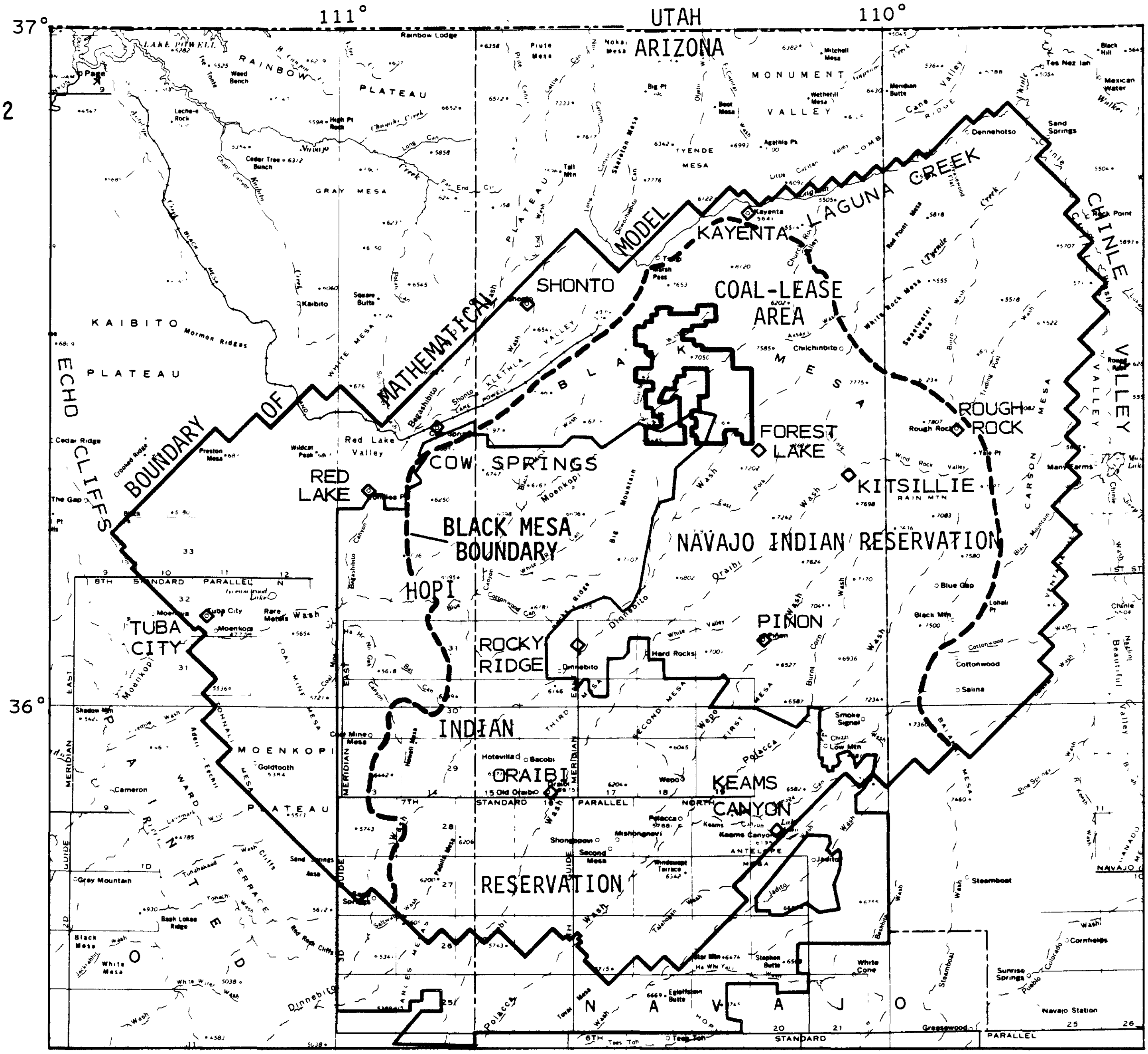
The Black Mesa monitoring program is designed to determine long-term effects on the water resources of the area resulting from withdrawals of ground water from the N aquifer by the strip-mining operation of Peabody Coal Company. Withdrawals by Peabody Coal Company increased from 95 acre-feet in 1968 to 3,832 acre-feet in 1987. The N aquifer is an important source of water in the 5,400-square-mile Black Mesa area on the Navajo and Hopi Indian Reservations.

Water levels in the confined area of the aquifer declined as much as 95.1 feet near Keams Canyon from 1965 to 1988. Part of the decline in the measured municipal wells may be due to local pumping. During 1965-88, water levels in wells that tap the unconfined area of the aquifer have not declined significantly and have risen in many areas. Chemical analyses indicate no significant changes in the quality of water from wells that tap the N aquifer or from springs that discharge from several stratigraphic units, including the N aquifer, since pumping began at the mine.

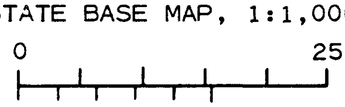
INTRODUCTION

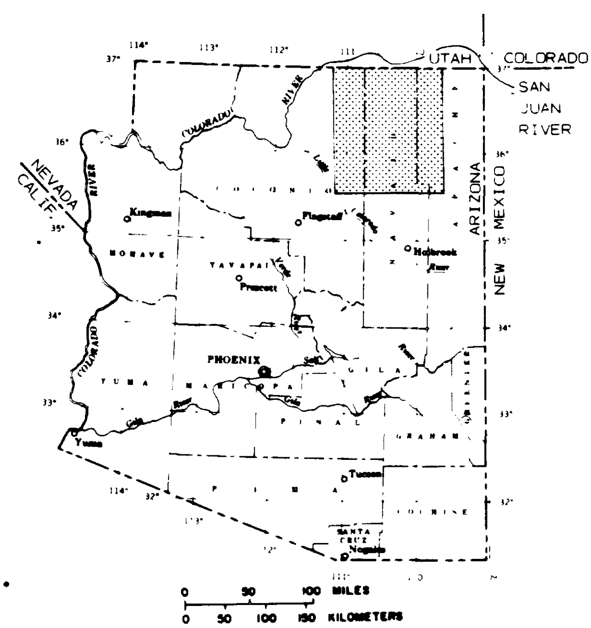
The N aquifer is an important source of water in the 5,400-square-mile Black Mesa area on the Navajo and Hopi Indian Reservations in northeastern Arizona (fig. 1). The aquifer consists of three rock formations that have been historically referred to as the N aquifer. The major water-bearing rock formations are the Navajo Sandstone of Jurassic and Triassic(?) age and Lukachukai Member of the Wingate Sandstone of Triassic age. The Kayenta Formation underlies the Navajo Sandstone and yields small amounts of water (fig. 2).

On the northern part of the mesa, Peabody Coal Company operates a strip mine in a lease area of about 100 square miles. When operation of the mine began in 1968, the company pumped about 95 acre-feet of ground water from the N aquifer; in 1987, 3,832 acre-feet was pumped. Withdrawals from the N aquifer for municipal use increased from an estimated 70 acre-feet in 1965 to about 2,400 acre-feet in 1987. The Navajo and Hopi Tribes became concerned about the long-term effects of withdrawals from the N aquifer on supplies for domestic and municipal purposes. These and other concerns about the effects of strip mining led to the water-resources investigation of the Black Mesa area by the U.S. Geological Survey in cooperation with the Arizona Department of Water Resources in 1971. In 1983, the U.S. Bureau of Indian Affairs joined the cooperative effort.



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAP, 1:1,000,000





INDEX MAP SHOWING AREA OF REPORT (SHADED)

Figure 1.--Location of study area.

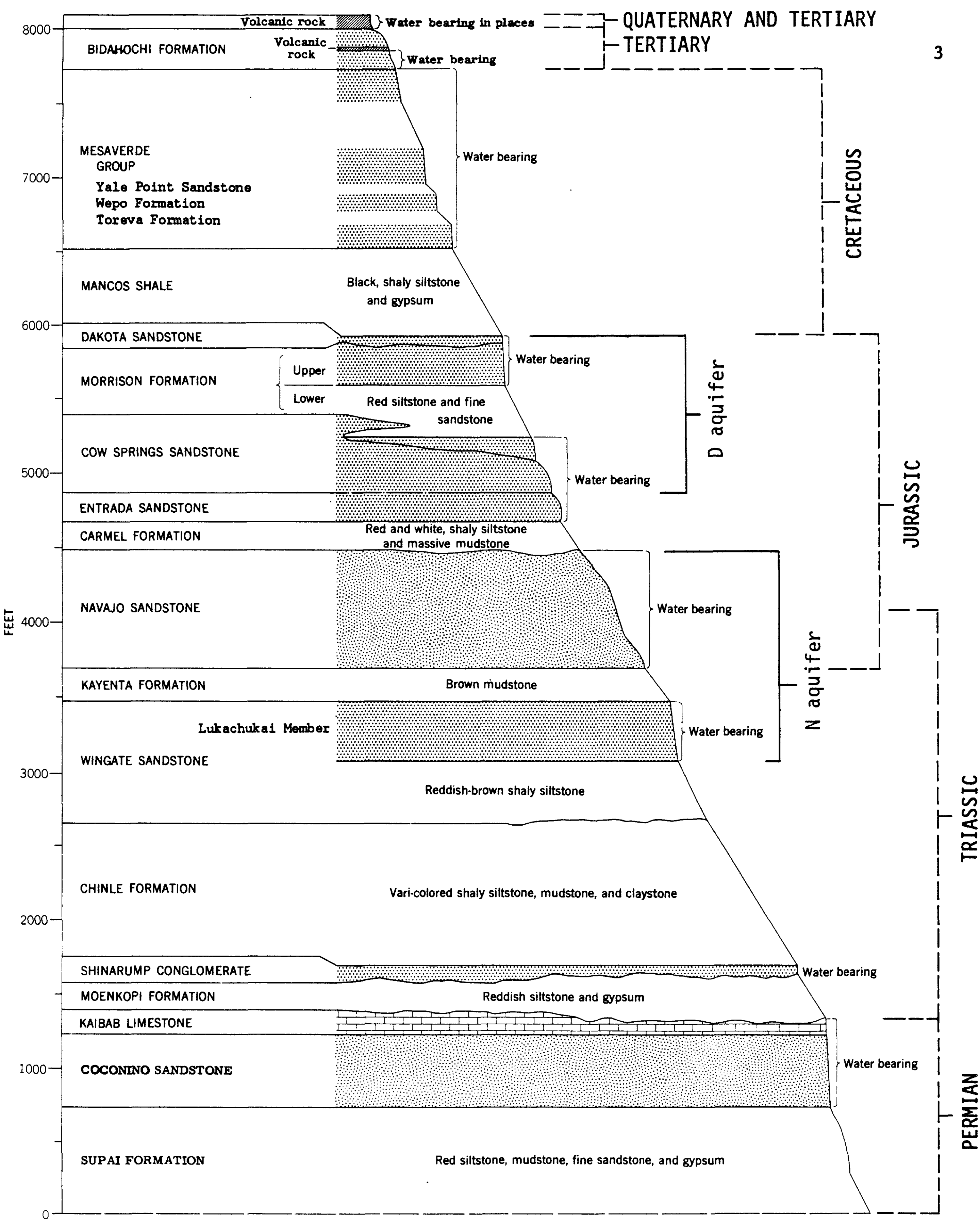


Figure 2.--Rock formations of the Black Mesa area.

The cooperation and assistance of the Navajo and Hopi Tribes and Peabody Coal Company are gratefully acknowledged. The Navajo Tribal Utility Authority; Peabody Coal Company; the Hopi Tribe, and the Western Navajo Agency, Chinle Agency, and Hopi Agency of the U.S. Bureau of Indian Affairs assisted in the collection of pumpage data and testing of flowmeters. The Hopi Tribe, the Navajo Tribal Utility Authority, and the U.S. Bureau of Indian Affairs assisted in the collection of water-level data.

Purpose and Scope of the Report

This report covers the progress of the ground-water, surface-water, and quality-of-water monitoring program, Black Mesa area, northeastern Arizona, from July 1, 1987, to June 30, 1988. Except for some earlier data that are used for comparison, only new data will appear in this report. The scope of the work included water-level measurements, chemical analyses of ground water and spring water, compilation of pumpage data, accuracy tests of flowmeters, and measurement of spring and surface-water discharge. These data were collected to determine the effects of industrial and nonindustrial pumpage from the N aquifer.

Previous Reports on the Program

Six progress reports have been prepared by the U.S. Geological Survey on the monitoring phase of the program (U.S. Geological Survey, 1978; G.W. Hill, hydrologist, U.S. Geological Survey, written commun., 1982, 1983; Hill, 1985; Hill and Whetten, 1986; Hill and Sottilare, 1987). Most of the data obtained from the monitoring program is contained in these reports except for stream-discharge and sediment-discharge data from Moenkopi Wash collected prior to the 1986 water year, which were published in Water Resources Data for Arizona (U.S. Geological Survey, 1976-88). Eychaner (1983) showed the results of a mathematical model that was developed to simulate the flow of ground water in the N aquifer. The model was used to predict the effects of withdrawals through the year 2014. The model was converted to a new model program and recalibrated by using revised estimates of selected aquifer parameters and a finer spatial grid (Brown and Eychaner, 1988). The new model was used to predict effects of five pumping scenarios through the year 2051. The monitoring program is essential for checking the model simulations and determining water quality of the N aquifer as water levels decline.

HYDROLOGIC-DATA COLLECTION, 1987-88

Monitoring activities include continuous or periodic measurements of (1) ground-water levels in the confined and unconfined areas of the N aquifer; (2) major withdrawals from the confined and unconfined areas; (3) ground-water quality of the N aquifer in the coal-lease area; (4) discharge and chemical quality of selected springs that flow from the various formations, including the N aquifer; and (5) surface-water discharge. The surface-water and water-quality data-collection sites are shown in figure 3.

Ground-Water Levels

Ground-water levels in nonindustrial wells in the confined area of the N aquifer have continued to decline since 1968 when Peabody Coal Company began withdrawals from wells in the area. Water-level data collected from December 1987 to May 1988, however, showed that water levels in several nonindustrial wells in the confined area of the N aquifer had risen or had not changed since last measured during water year 1987. These wells are 8T-500 (BM3), Chilchinbito PM3, 8K-443, 10R-111, and 10T-258, and Keams Canyon 2 (fig. 4, table 1). Water levels in Keams Canyon 2 increased 18.9 feet since previously measured in water year 1987. Water levels in observation well BM6, about 15 miles south of the mine well field, had declined about 2.7 feet since previously measured in water year 1987. Most of the observation and nonindustrial wells in the northeastern section of the confined area of the N aquifer showed record declines.

Part of the decline in municipal wells probably is caused by local pumping. Pumping from the Kayenta municipal well field also may affect water levels in observation well 8T-500 (BM3). Withdrawals are not made from any observation wells.

Significant water-level changes have not occurred in wells in the unconfined area of the N aquifer since pumping began at the mine. However, well 3T-333 at Tuba City had a decline of 9 feet, which probably is the result of local pumping (fig. 4, table 1).

Eychaner (1983) developed a mathematical model of the N-aquifer system on the basis of available information about the aquifer. Water-level changes were simulated for several nonindustrial wells and continuous-record observation wells that penetrate the N aquifer. During 1985, the model was rerun with measured withdrawals for 1980-84 to check the continued agreement of measured and simulated water levels. Results of these model runs are given in the 1987 progress report (Hill and Sottilare, 1987). Brown and Eychaner (1988) recalibrated the 1983 model using a finer grid that provided more detail near Kayenta, Tuba City, Keams Canyon, Oraibi, and the coal-lease area.

Simulated water-level changes for 1965-84 using the 1988 model generally agree with water-level changes measured in all six continuous-record observation wells (fig. 5) and are nearly identical to water-level changes simulated by the 1983 model. In both models, the greatest inconsistency between measured and simulated water levels occurred at well 8T-500 (BM3). Changes in the location and the amount of pumpage for Kayenta have influenced the water levels in well BM3. The parallel trends of the observed and simulated water levels however indicate that the 1988 model is a reasonable representation of the actual ground-water conditions in the study area.

Withdrawals from the N Aquifer

The three categories of ground-water withdrawal from the N aquifer are industrial (Peabody Coal Company) from the confined area, nonindustrial from the confined area, and nonindustrial from the unconfined

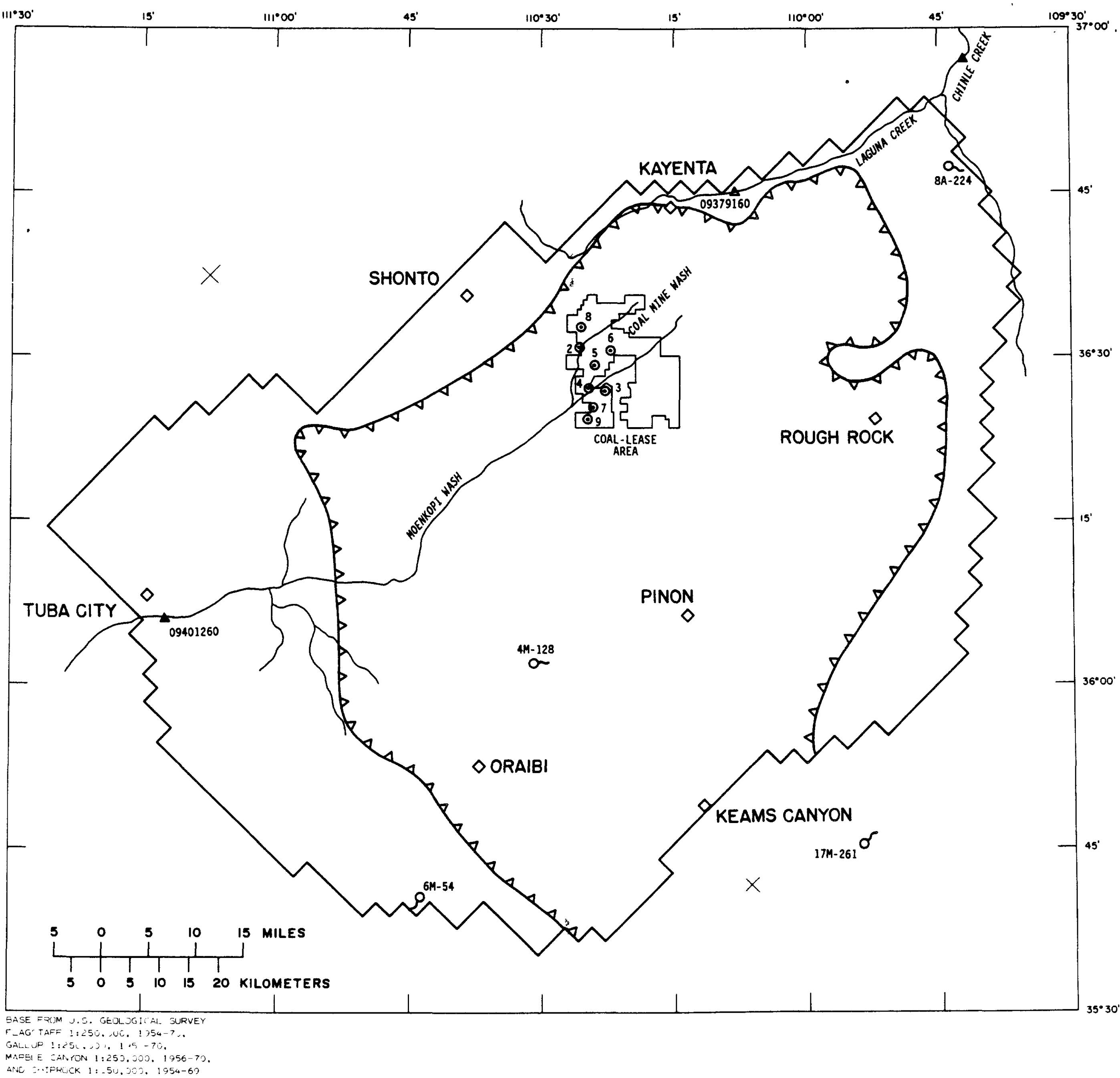


Figure 3.--Surface-water and water-quality data-collection sites, 1987-88.

EXPLANATION

Symbol	Explanation
⊙ 9	WELL OWNED BY PEABODY COAL COMPANY IN WHICH WATER-QUALITY SAMPLE WAS COLLECTED—9, is well number
6M-54	SPRING AT WHICH DISCHARGE WAS MEASURED AND WATER-QUALITY SAMPLE WAS COLLECTED—6M-54, is spring identification number
▲ 09401260	STREAMFLOW-GAGING STATION OPERATED BY THE U.S. GEOLOGICAL SURVEY AT WHICH SURFACE-WATER DATA WERE COLLECTED—09401260, is station number
△ 09379160	LOW-FLOW MEASUREMENT SITE—09379160, is site-identification number
CONFINED / UNCONFINED	APPROXIMATE BOUNDARY BETWEEN CONFINED AND UNCONFINED CONDITIONS—From Eychaner (1983)
	BOUNDARY OF MATHEMATICAL MODEL—From Eychaner (1983)

Figure 3

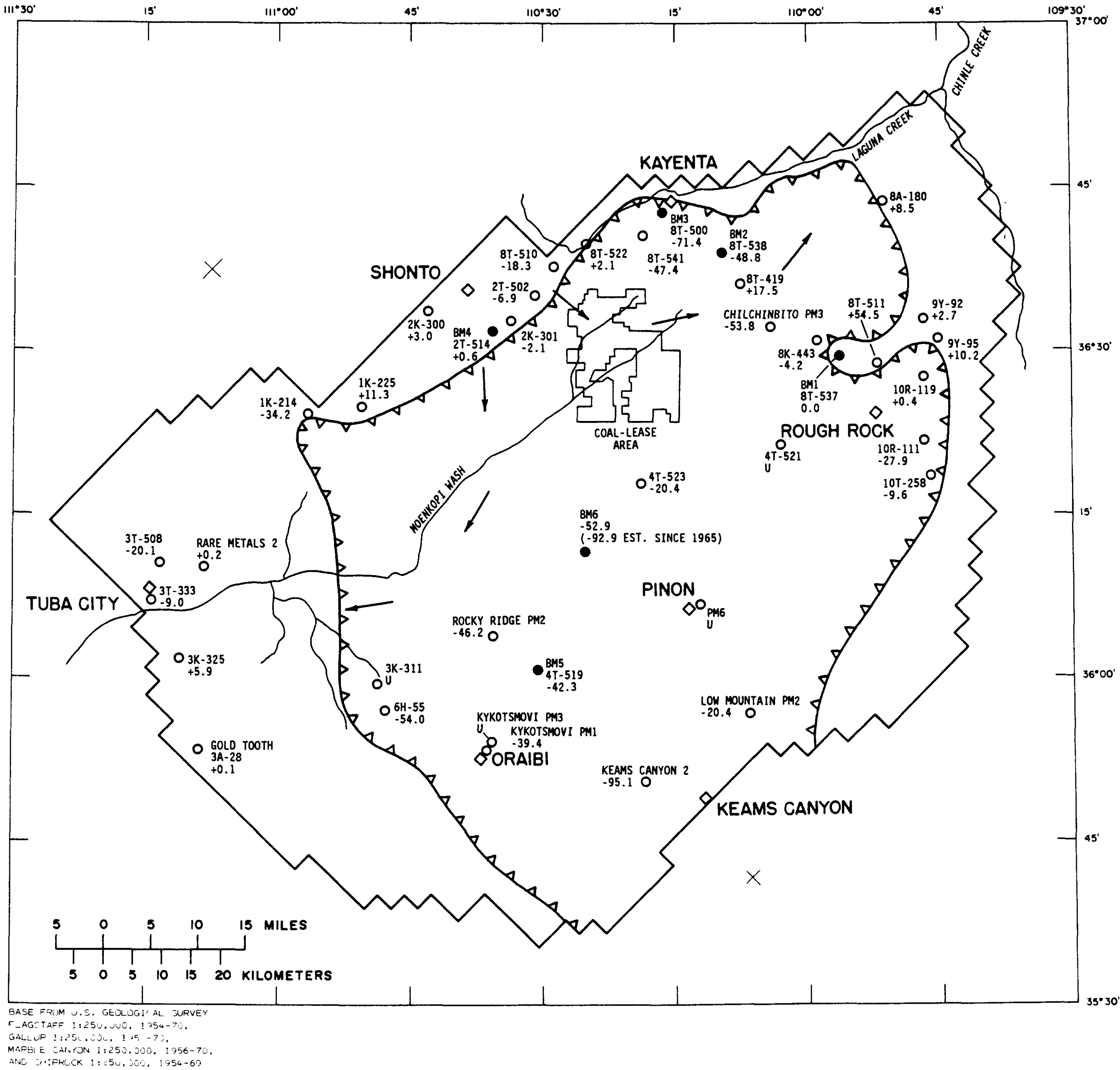


Figure 4.--Water-level changes in wells that tap the N aquifer, 1953-88.

E X P L A N A T I O N

4T-523 -20.4	WELL IN WHICH DEPTH TO WATER WAS MEASURED ANNUALLY—First entry, 4T-523, is Bureau of Indian Affairs identification number; second entry, -20.4, is change in water level, in feet, between measurements made during the prestress period and measurements made during 1987-88. U, unable to measure
8T-500 BM3	CONTINUOUS WATER-LEVEL RECORDING SITE (OBSERVATION WELL) MAINTAINED BY THE U.S. GEOLOGICAL SURVEY—First entry, 8T-500, is Bureau of Indian Affairs identification number; second entry, (BM3), is U.S. Geological Survey identification number
CONFINED UNCONFINED	APPROXIMATE BOUNDARY BETWEEN CONFINED AND UNCONFINED CONDITIONS—From Eychaner (1983)
	GENERALIZED DIRECTION OF GROUND-WATER FLOW
	BOUNDARY OF MATHEMATICAL MODEL—From Eychaner (1983)

Figure 4

Table 1.--Water-level changes in wells that tap the N aquifer, 1982-88 water years

Location	U.S. Bureau of Indian Affairs field number	Pre-stress water level, in feet below land surface	Water-level change, in feet below land surface						
			1982 water year	1983 water year	1984 water year	1985 water year	1986 water year	1987 water year	1988 water year
Tuba City	3T-333	23.0	-5.0	-5.1	-11.7	-13.7	-10.5	-11.8	-9.0
Do.	3K-325	208	+4.3	+3.9	+4.6	+4.2	+15.2	+4.7	+5.9
Gold Tooth	3A-28	230	-----	-1.4	0.0	-8.6	+9.2	-3.3	+0.1
Rocky Ridge	PM2	432	-30.4	-34.4	-----	-39.8	-41.1	-44.1	-46.2
Kykotsmovi	PM1	[1]220	-----	-31.0	-38.7	-30.2	-----	-37.9	-39.4
Do.	PM3	[2]210	-12.2	-----	-----	-----	-11.9	([9])	([9])
Keams Canyon	2	292.5	-75.7	-84.9	-----	-----	-81.4	-114	-95.1
Low Mountain	PM2	551	-----	-8.9	-12.2	-14.9	-17.4	-19.4	-20.4
Pinon	PM6	[3]743.6	-----	([9])	-----	-----	[10]-39.7	([9])	([9])
Forest Lake	4T-523	[4]1,096.0	-----	+1.6	-----	-----	-17.2	-19.6	-20.4
Kitsillie	4T-521	[5]1,254	-----	-----	-----	-----	-69.6	([9])	([9])
White Mesa Arch	1K-214	188	-34.2	-33.8	-33.6	-33.6	-22.2	-33.3	-34.2
Cow Spring	1K-225	60	+8.1	+8.0	+8.9	+9.7	+13.2	+10.6	+11.3
Shonto	2K-300	176.5	+2.8	+2.7	+3.2	+3.5	+4.3	+3.5	+3.0
Chilchinbito	PM3	405	-38.9	-50.3	-64.3	-73.2	-46.7	-55.4	-53.8
Rough Rock	8T-511	505	+53.6	([9])	+50.3	+49.8	+53.2	+53.8	+54.5
Do.	10R-111	170.0	-28.2	-28.7	-41.4	-29.8	-18.7	-31.0	-27.9
Do.	10T-258	301.0	-6.1	-12.2	-8.5	-13.8	+2.8	-16.3	-9.6
Do.	10R-119	256.6	+0.2	-0.2	+1.5	-0.9	+0.6	+1.3	+0.4
Do.	9Y-95	119.5	+4.2	+8.9	+9.8	+10.5	+14.7	+6.6	+10.2
Do.	9Y-92	168.8	+1.5	+1.1	-1.4	+0.9	+9.5	+1.1	+2.7
Northeast Rough Rock	8A-180	46.9	+2.2	+2.3	+2.7	+3.0	+4.3	+3.1	+8.5
BM5	4T-519	323.8	-----	-28.3	-30.5	-33.6	-35.8	-39.5	-42.3
BM6	BM6	[7]735.6	-26.0	-29.1	-36.1	-43.1	-46.9	-50.2	-52.9
Do.		[8]695.6	-66.0	-69.1	-76.1	-83.1	-86.9	-90.2	-92.9
Shonto Southeast	2K-301	283.9	-0.8	-1.3	-1.8	-----	-2.3	-1.6	-2.1
BM4	2T-514	217	+0.6	+0.2	+0.3	+0.6	+0.7	+0.7	+0.6
Sweetwater Mesa	8K-443	529.4	([9])	-2.7	-3.2	-4.1	-4.0	-4.2	-4.2
BM1	8T-537	374.0	([9])	([9])	-0.9	+0.2	-0.9	+0.1	0.0
Long House Valley	8T-510	[1]99	-18.2	-19.0	-8.3	-21.8	-16.8	-16.9	-18.3
Shonto Southeast	2T-502	[1]405.8	-14.1	-9.3	-9.1	-12.9	-8.8	-8.7	-6.9
BM2	8T-538	125.0	-27.0	-31.2	-35.7	-39.0	-43.5	-46.8	-48.8
Owl Spring	8T-419	438	+8.5	+8.3	+6.5	+16.0	+15.1	+17.5	+17.5
Marsh Pass	8T-522	125.5	+3.1	+2.9	+3.7	+4.5	+3.5	+2.4	+2.1
BM3	8T-500	60.0	-57.5	-59.5	-62.1	-69.5	-60.5	-76.0	-71.4
Kayenta West	8T-541	[5]227	-----	-12.5	-14.6	-22.6	-23.2	-34.8	-47.4
Howell Mesa	3K-311	463	([9])	+11.1	-4.2	+10.6	+13.7	([9])	([9])
Do.	6H-55	212	-55.8	-53.1	-54.0	-53.0	-53.4	-53.8	-54.0
Tuba City	Rare Met. 2	57	-4.1	-1.5	-1.4	-0.5	-0.5	-0.1	+0.2
Tuba NTUA 1	3T-508	[6]29.0	-21.1	-20.5	-17.4	-22.9	-29.8	------	-20.1

[1]1967 water level.
[2]1968 water level.
[3]1970 water level.
[4]1982 water level.
[5]1979 water level.
[6]1969 water level.
[7]1977 water level.
[8]Figure is estimated 1965 value.
[9]Unable to measure.
[10]Figure reported by Bureau of Indian Affairs.

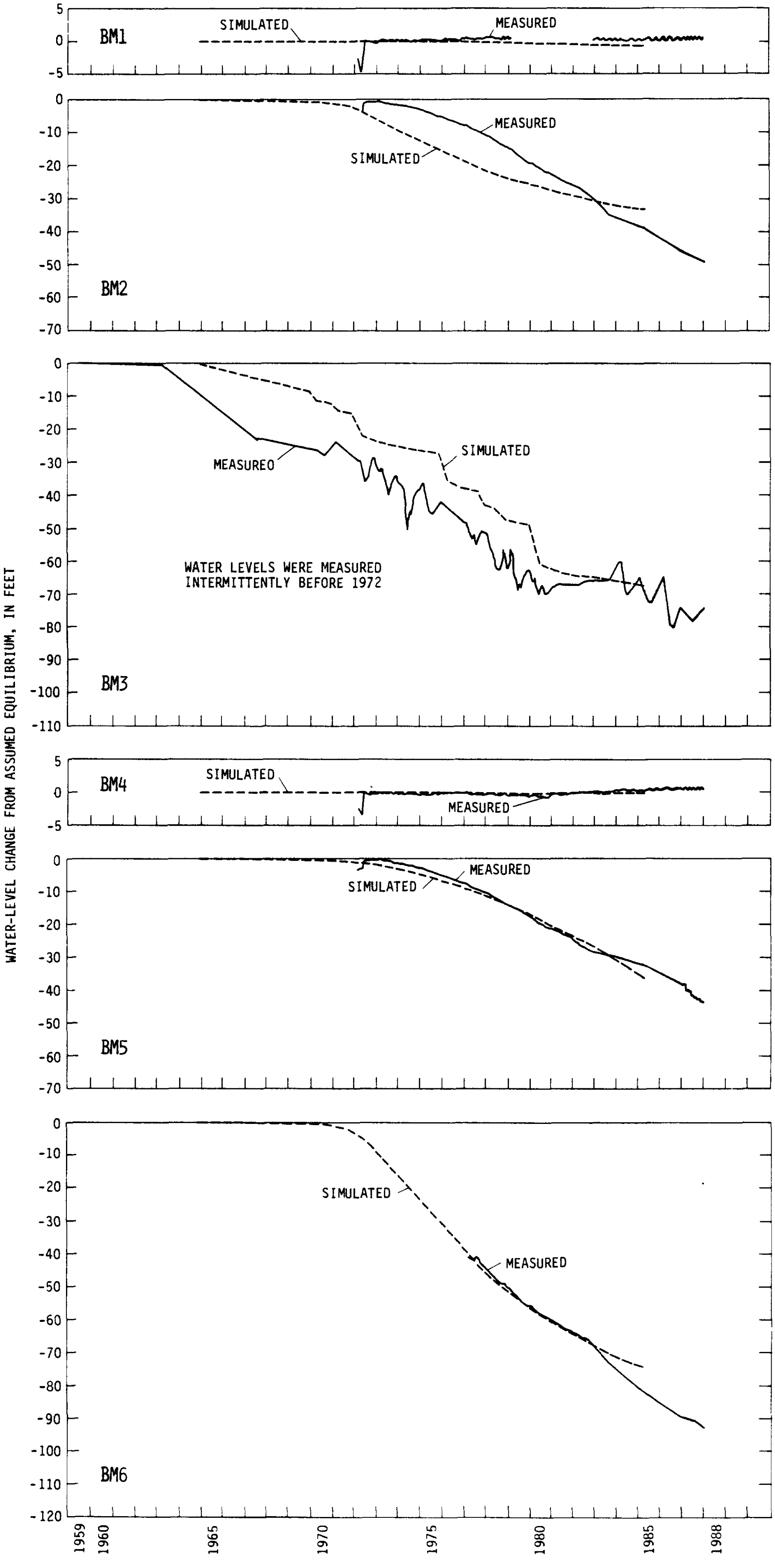


Figure 5.--Measured and simulated water-level changes for observation wells, 1959.

area. The primary interest is in withdrawals related to the mining operation and nonindustrial withdrawals of significant amounts. Pumpage data have not been collected from wells equipped with windmills.

The U.S. Geological Survey has continued its efforts to improve and ensure accuracy of withdrawal data from industrial and nonindustrial wells that penetrate the N aquifer in the study area. The U.S. Bureau of Indian Affairs, Navajo Tribal Utility Authority, and Hopi Tribe operate nonindustrial well systems that consist of about 70 wells. These well systems serve the Navajo and Hopi Tribes in the Black Mesa area. The industrial system, which includes eight wells—the Peabody Coal Company mine well field—withdraws water from the N aquifer within the study area. During 1988, the Geological Survey made an inventory of the wells and tested the accuracy of the flowmeters. This quality-assurance program was initiated during 1985-86 and is conducted every third year on all wells that penetrate the N aquifer except those with windmills.

Two methods were used to test the accuracy of flowmeters. Most meters were tested using a volumetric method. With this method, the volume of water pumped through the flowmeter was measured volumetrically over a period of time and compared with the flowmeter reading for the same period. Owing to the high discharge rates for a few wells, the flow rates were measured using a Cox flowmeter. Results were compared to the flowmeter readings. The results are shown as a percent difference of the metered pumpage from the measured pumpage (table 2). The following equation was used:

$$\frac{\text{Metered pumpage} - \text{measured pumpage}}{\text{Measured pumpage}} \times 100 = \text{percent difference.}$$

For the purpose of this study, the allowable limit between metered and measured pumpage should be no greater than ±10 percent.

Annual pumpage for the three categories of withdrawals from the N aquifer for 1965-87 is given in table 3. Withdrawals during the 1987 calendar year from nonindustrial and industrial well systems that pump from the N aquifer are given in table 4. Locations of these well systems are shown in figure 6.

Chemical Quality of Water from Wells that Tap the N Aquifer

A major concern on the part of some residents of the Black Mesa area has been the effect of withdrawals on the chemical quality of water in the N aquifer. Eychaner (1983) stated that some water may enter the N aquifer from the upper confining beds. He also stated that the driving force for such flow is present because the head in the overlying D aquifer in 1964 averaged about 300 feet higher than that in the N aquifer. Differences in the chemical composition of the waters of the D aquifer and the N aquifer indicate that the amount of downward leakage must be small (Eychaner, 1983). On the average, the concentration of dissolved solids in water from the D aquifer is about 7 times greater than that from the N aquifer, the concentration of chloride ions is 11 times greater, and the concentration of sulfate ions is 30 times greater (Eychaner, 1983).

Table 2.--Flowmeter test results for industrial and nonindustrial wells that tap the N aquifer, Black Mesa area, 1988

Well system	Well number[1]	Date tested	Test method	Measured pumpage (gal/min)	Metered pumpage (gal/min)	Percent difference	Meter name and number
			Navajo Tribal Utility Authority				
Tuba City	1	5-20-88	Volumetric	121	135	+11.6	Sparling 110635
Do.	2			(Well inoperable)			
Do.	3	5-20-88	do.	130	146	+12.3	Sparling 94420
Do.	4	5-20-88	do.	200	200	0	Sparling 94419
Do.	5	5-20-88	do.	257	261	+1.6	Sparling 94421
Do.	6	Well used only (as back up) during summer—need generator to run					
Red Lake	1	5-20-88	Volumetric	62.1	65.5	+5.5	Hersey 2" 6044826
Shonto	1	5-06-88	do.	59.3	60.3	+1.7	Rockwell 28945149
Shonto Junction	1	5-06-88	do.	87.1	91.5	+5.1	Brooks 2" 8403-23219-1
Do.	2	5-06-88	do.	98.2	100	+1.8	Trident 2" No serial number
Kayenta	1	4-13-88	do.	93.5	92.3	-1.3	Sparling meter
Do.	2	4-13-88	do.	26.4	25.7	-2.7	Sparling 63892
Do.	3	5-20-88	do.	115	115	0	Rockwell 28316
Do.	4	4-13-88	do.	90.0	78.9	-12.3	Rockwell 66844
Do.	5	4-13-88	do.	123	133	+8.1	Furnas electronic meter
Do.	6	4-13-88	do.	159	159	0	do.
Do.	7	4-13-88	do.	84.7	92.0	+8.6	do.
Dennehotso	1	5-06-88	do.	32.9	34.0	+3.3	Rockwell 2" 33447300
Chilchinbito	1	5-06-88	do.	47.6	48.0	+0.8	Rockwell 2" 1175064
Rough Rock	1	5-05-88	do.	27.3	27.2	-0.4	Rockwell 28832656
Forest Lake	1	5-06-88	do.	42.2	42.2	0	Hersey 6049985
Pinon	1	5-10-88	do.	81.8	84.4	+3.2	Hersey 6053321
Kitsillie	1	5-10-88	do.	40.0	40.0	0	Rockwell 2" 28945139
			Bureau of Indian Affairs				
Tuba City	PM4	6-03-88		Divider method (no meter)			
Do.	PM5	6-03-88	Volumetric	105	102	- 2.9	Rockwell 2" 32658702
Do.	PM6	6-03-88	do.	108	96.3	-10.8	Rockwell 2" 36880400
Red Lake	PM1	5-20-88	do.	37.2	41.2	+10.8	Hays 27821836
Do.	PM2	5-20-88	do.	30.5	31.6	+ 3.6	Rockwell 1½" 32722074
Shonto	PM2	5-04-88	do.	164	176	+ 7.3	Rockwell 3" 1255896
Do.	PM3	5-04-88	do.	92.3	90.0	- 2.5	Rockwell 1½" 36726380
Do.	PM4	5-04-88	do.	74.5	77.2	+ 3.6	Rockwell 1½" 36726377
Kayenta	PM2	5-04-88	do.	164	164	0	Rockwell 2" 36880398
Do.	PM3	5-04-88	do.	148	146	- 1.4	Rockwell 2" 36880399
Dennehotso	PM1	5-12-88	do.	59.4	62.3	+ 4.9	Hays 1" 17812583
Do.	PM2	5-12-88	do.	78.9	76.1	- 3.5	Rockwell 1½" 36726376
Chilchinbito	PM3	5-13-88	do.	23.7	25.3	+ 6.8	Hersey 1½" 5360645
Rough Rock	PM6	5-05-88	do.	55.1	59.4	+ 7.8	Hays 2" 17401735
Do.	PM5	5-05-88	do.	50.0	52.9	+ 5.8	Hays 2" 48035942
Do.	PM6	5-05-88	do.	44.3	43.6	- 1.6	Rockwell 1½" 25766405
Do.	PM7	5-05-88	do.	51.4	50.0	- 2.7	McCrometer 823317
Rocky Ridge	PM1	5-16-88	do.	46.2	40.7	-11.9	Hays 2" 47688053
Do.	PM2			Well out of service			
Pinon	PM6	5-10-88	do.	96.5	100	+ 3.6	Hays 3236250

See footnote at end of table.

Table 2.--Flowmeter test results for industrial and nonindustrial wells that tap the N aquifer, Black Mesa area, 1988--Continued

Well system	Well number[1]	Date tested	Test method	Measured pumpage (gal/min)	Metered pumpage (gal/min)	Percent difference	Meter name and number
				Bureau of Indian Affairs--Continued			
Low Mountain	PM1			(Not N aquifer)			
Do.	PM2	5-19-88	do.	42.1	44.1	+4.8	Trident 31537780
Keams Canyon	3	4-28-88	do.	75.0	75.7	+0.9	Sparling 115691
Do.	2	4-28-88	do.	76.1	70.1	-7.9	Sparling 115939
Hopi High School	1	4-28-88	do.	110	95.8	-12.9	Neptune 30033782
Do.	2			(Well inoperable)			
Do.	3	4-28-88	do.	114	115	+0.9	Neptune 30033783
Hotevilla	PM1	5-19-88	do.	47.6	49.5	+4.0	Rockwell 1½" 36726379
Do.	[2]PM2	4-28-88	do.	18.9	21.1	+11.6	Hays 5 No serial number
Second Mesa	[2]USPHS1	4-28-88	do.	100	75.0	-25.0	Arad 1½" 029114
Do.	PM2	4-28-88	do.	43.9	43.9	0	Arad 1½" 029154
				-Retested wells-			
Hotevilla	PM2	5-16-88	do.	19.0	19.7	+3.7	Rockwell 1½" 36726378
Second Mesa	USPHS1	5-25-88	do.	100	107	+7.0	Rockwell 2" Turbo 1266317
				Hopi Tribe			
Kykotsmovi	[2]PM1	4-20-88	do.	42.6	37.9	-11.0	Rockwell 36726381
Do.	PM2	4-20-88	do.	90.0	89.4	-0.8	Kent 77655836
Do.	PM3	4-20-88		(Well not in operation)			
Shipanlovi	1	4-20-88	Volumetric	101	96.4	-4.6	Kent 77655823
Mishongovi	1	4-20-88	do.	12.3	12.8	+4.4	Precision meter E569880
Shungopovi	1	4-20-88	do.	45.0	45.4	+0.9	Rockwell 25766390
Polacca	PM4 School well	5-25-88	do.	45.1	44.8	-0.7	Hersey 1½" 5440471
Do.	USPHS5	6-10-88	do.	216	191	-11.6	McCrometer 87-6-312
Do.	USPHS6			(Well inoperable)			
				-Retested well-			
Kykotsmovi	PM1	5-16-88	do.	45.2	45.6	+0.9	Rockwell 1½" 25956856
				Peabody Coal Co.			
Black Mesa	2	4-12-88	Cox	476	490	+2.9	McCrometer 81-6-1088
Do.	3	4-12-88	do.	583	590	+1.2	McCrometer 81-6-1087
Do.	4	4-12-88	do.	512	530	+3.5	S/N 570248
Do.	5	4-12-88	do.	577	615	+6.6	S/N 776782
Do.	6	4-12-88	do.	472	480	+1.7	S/N McCrometer 81-6-108
Do.	7	4-12-88	do.	562	560	-0.4	S/N 776776
Do.	8	4-12-88	do.	617	615	-0.3	S/N 776780
Do.	9	5-05-88	do.	539	565	+4.8	McCrometer 81-6-1082

[1]Well numbers do not necessarily coincide with Agency well numbers.
[2]Well retested after meter change.

Table 3.--Withdrawals from the N aquifer, 1965-87

[Measurements are in acre-feet. Data for 1965-79 from Eychaner, 1983]

Year	Industrial[1]	Nonindustrial[2,3]	
		Confined	Unconfined
1965	0	50	20
1966	0	110	30
1967	0	120	50
1968	95	150	100
1969	43	200	100
1970	740	280	150
1971	1,900	340	150
1972	3,680	370	250
1973	3,520	530	300
1974	3,830	580	362
1975	3,550	600	508
1976	4,180	690	645
1977	4,090	750	726
1978	3,000	830	930
1979	3,500	860	930
1980	3,540	910	880
1981	4,010	960	1,000
1982	4,740	870	965
1983	4,460	1,360	1,280
1984	4,170	1,070	1,400
1985	2,520	1,040	1,160
1986	4,480	970	1,260
1987	3,832	1,134	1,277

[1]Metered pumpage by Peabody Coal Company at their mine on Black Mesa.

[2]Does not include withdrawals from the wells equipped with windmills.

[3]Includes estimated pumpage, 1965-73, and metered pumpage, 1974-79, at Tuba City, metered pumpage at Kayenta and estimated pumpage at Chilchinbito, Rough Rock, Pinon, Keams Canyon, and Kykotsmovi prior to 1980; metered and estimated pumpage furnished by the Navajo Tribal Utility Authority and the U.S. Bureau of Indian Affairs and collected by the U.S. Geological Survey, 1980-85; and metered pumpage furnished by the Navajo Tribal Utility Authority, the U.S. Bureau of Indian Affairs, Kykotsmovi Village Administration, and the U.S. Geological Survey, 1986-87.

Table 4.--Withdrawals from the N aquifer by well systems, Black Mesa area, 1987

[Measurements, in acre-feet, are flowmeter data. BIA, U.S. Bureau of Indian Affairs; NTUA, Navajo Tribal Utility Authority; USGS, U.S. Geological Survey; KVAO, Kykotsmovi Village Administration Office]

Location	Owner	Source of data	Confined aquifer well systems	Unconfined aquifer well systems
Tuba City	BIA	USGS		206
Chilchinbito	BIA	USGS	5.6	
Dennehotso	BIA	BIA		23.0
Kayenta	BIA	USGS	86.0	
Red Lake	BIA	BIA		8.8
Rocky Ridge	BIA	USGS	14.7	
Shonto	BIA	USGS		204
Pinon	BIA	BIA	31.2	
Rough Rock	BIA	BIA	30.3	
Hotevilla	BIA	USGS	26.4	
Second Mesa	BIA	USGS	10.3	
Hopi High School	BIA	USGS	18.5	
Keams Canyon	BIA	USGS	75.3	
Low Mountain	BIA	USGS	([1])	
Kayenta	NTUA	NTUA	622	
Chilchinbito	NTUA	NTUA	30.0	
Dennehotso	NTUA	NTUA		31.7
Shonto	NTUA	NTUA		22.0
Forrest Lake	NTUA	NTUA	10.1	
Shonto Junction	NTUA	NTUA		16.2
Tuba City	NTUA	NTUA		735
Red Lake	NTUA	NTUA		30.1
Rough Rock	NTUA	NTUA	11.2	
Pinon	NTUA	NTUA	34.3	
Kitsillie	NTUA	NTUA	7.3	
Mine Well Field	Peabody	Peabody	3,832	
Polacca	Hopi	USGS	37.8	
Kykotsmovi	Hopi	KVAO	58.3	
Shungopovi	Hopi	USGS	13.1	
Shipaulovi	Hopi	USGS	18.5	
Mishongovi	Hopi	USGS	1.3	

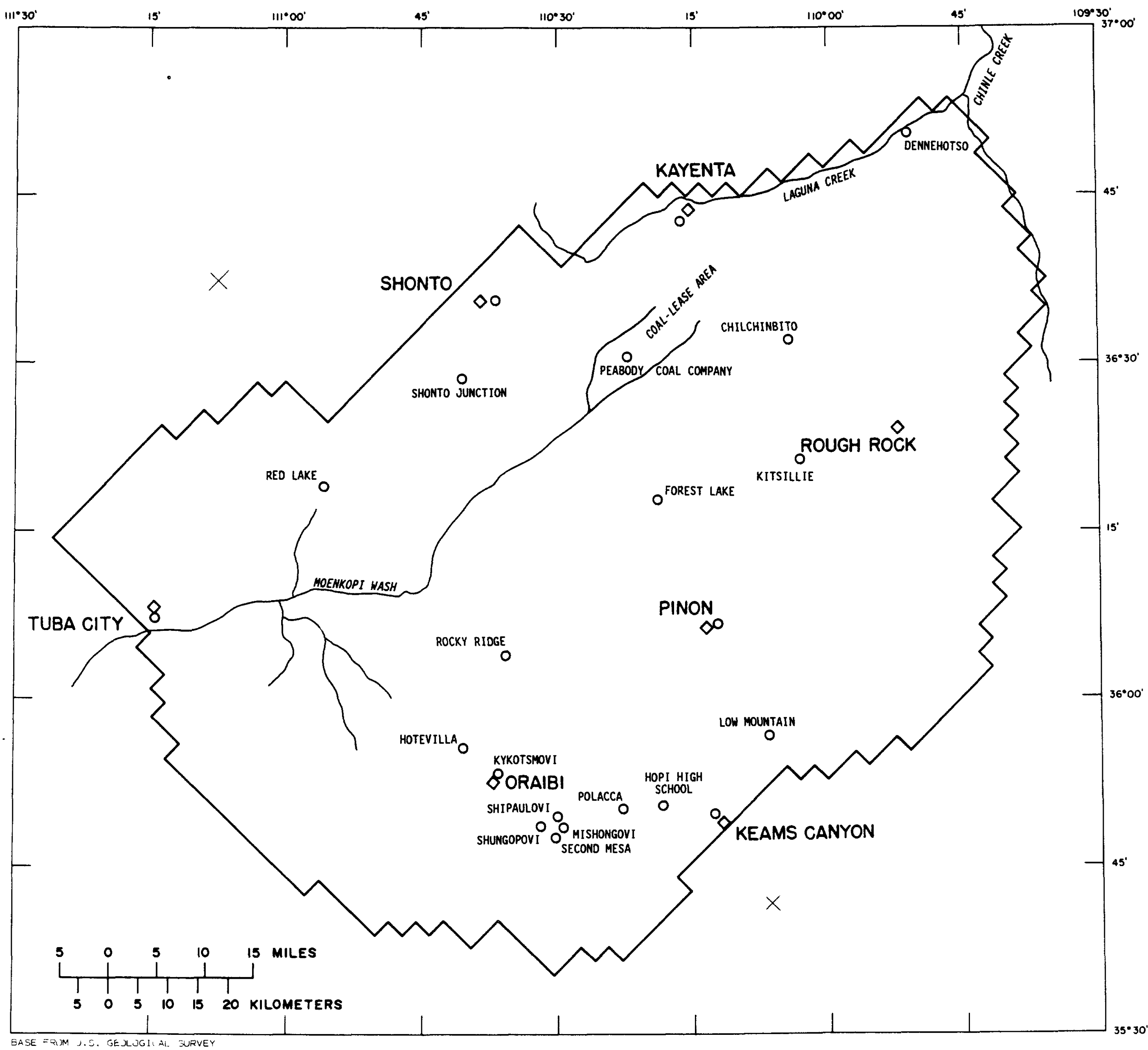
[1]New well installed in 1988, no data available.

Any increase in the leakage rate as a result of pumping from the N aquifer should appear first as an increase in the dissolved-solids concentrations in the water from Peabody wells (Eychaner, 1983). Other indicators of leakage caused by stress on the N aquifer are increases in specific conductance, concentrations of dissolved chloride, and concentrations of dissolved sulfate.

In 1987-88, all Peabody Coal Company industrial wells (2-9) were sampled for major ions and fluoride. All of these wells penetrate the N aquifer. On the basis of the analyses of water samples collected from 1967 to 1988 by the Geological Survey, no significant changes have occurred in the quality of water in the mine wells. Chemical analyses of the water from these wells are shown in tables 5 and 6.

Discharge and Chemical Quality of Springs

The effect of withdrawals from the N aquifer on the water quality of springs used for domestic purposes is another major concern of some



BASE FROM U.S. GEOLOGICAL SURVEY
FLAGSTAFF 1:250,000, 1954-70,
GALLUP 1:250,000, 195 -70,
MARBLE CANYON 1:250,000, 1956-70,

Figure 6.--Location of well systems monitored for withdrawals from the N aquifer, 1987.

Table 5.--Chemical analyses of Peabody Coal Company industrial wells that tap the N aquifer, Black Mesa area, 1987-88

Well number	Identification number	Date of sample	Temperature (°C)	Specific conductance (µS/cm)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)
Peabody Well 2	363005110250901	12-02-87	32	149	8.8	99	0.94
Peabody Well 3	362625110223701	12-02-87	32.5	171	9.2	81	.80
Peabody Well 4	362647110243501	12-02-87	32	194	9.2	97	.97
Peabody Well 5	362901110234101	01-05-88	32	270	9.4	116	.86
Peabody Well 6	363007110221201	01-05-88	34	173	9.1	89	.64
Peabody Well 7	362456110242301	01-05-88	32	240	9.5	96	.74
Peabody Well 8	363130110254501	01-05-88	29.5	790	8.2	135	2.1
Do.	do.	03-03-88	29.5	438	7.8	100	1.3
Peabody Well 9	362333112500001	12-02-87	32	148	9.0	73	.72

Well number	Identification number	Date of sample	Phosphorus, ortho, dissolved (mg/L as P)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
Peabody Well 2	363005110250901	12-02-87	<0.01	8.9	0.17	26
Peabody Well 3	362625110223701	12-02-87	<.01	3.9	<.01	35
Peabody Well 4	362647110243501	12-02-87	<.01	4.8	<.01	41
Peabody Well 5	362901110234101	01-05-88	.01	3.3	.04	61
Peabody Well 6	363007110221201	01-05-88	<.01	4.3	.05	38
Peabody Well 7	362456110242301	01-05-88	<.01	3.9	.10	49
Peabody Well 8	363130110254501	01-05-88	<.01	31	6.2	130
Do.	do.	03-03-88	.07	22	3.3	71
Peabody Well 9	362333112500001	12-02-87	.09	3.6	.03	31

Well number	Identification number	Date of sample	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)
Peabody Well 2	363005110250901	12-02-87	0.9	5.0	9.1	0.2
Peabody Well 3	362625110223701	12-02-87	.8	3.6	6.1	.2
Peabody Well 4	362647110243501	12-02-87	.8	5.0	13	.2
Peabody Well 5	362901110234101	01-05-88	.9	5.1	22	.3
Peabody Well 6	363007110221201	01-05-88	.8	2.4	9.1	.2
Peabody Well 7	362456110242301	01-05-88	.8	4.4	18	.2
Peabody Well 8	363130110254501	01-05-88	5.1	7.2	250	.3
Do.	do.	03-03-88	3.2	4.8	120	.3
Peabody Well 9	362333112500001	12-02-87	.7	2.8	4.1	.3

Well number	Identification number	Date of sample	Silica, dissolved (mg/L as SiO_2)	Boron, dissolved (µg/L as B)	Iron, dissolved (µg/L as Fe)
Peabody Well 2	363005110250901	12-02-87	21	20	3
Peabody Well 3	362625110223701	12-02-87	19	20	4
Peabody Well 4	362647110243501	12-02-87	21	20	5
Peabody Well 5	362901110234101	01-05-88	21	40	8
Peabody Well 6	363007110221201	01-05-88	22	30	5
Peabody Well 7	362456110242301	01-05-88	21	30	6
Peabody Well 8	363130110254501	01-05-88	18	90	14
Do.	do.	03-03-88	20	40	55
Peabody Well 9	362333112500001	12-02-87	19	30	22

Table 6.--Selected parameters from chemical analyses of water from Peabody Coal Company wells that tap the N aquifer, Black Mesa area, 1967-74 and 1980-88

Well number	Year	Specific conductance (µS/cm)	Dissolved-solids concentrations, residue at 180°C (mg/L)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)
2	1967	221	[1]144	5.0	21
	1980	225	144	11	20
	1986	172	---	2.6	8.1
	1987	149	113	5.0	9.1
3	1968	236	[1]154	4.0	17
	1980	230	151	3.5	14
	1986	175	---	2.4	9.7
	1987	171	111	3.6	6.1
4	1974	200	140	3.8	13
	1980	230	139	4.3	13
	1986	205	---	4.2	12
	1987	194	135	5.0	13
5	1968	224	[1]149	3.5	16
	1980	210	134	2.9	9.5
	1986	398	---	8.0	28
	[2]1986	602	338	12.0	62
	1987	270	168	4.6	21
	1988	270	184	5.1	22
6	1968	201	[1]333	3.0	13
	1980	260	160	3.5	15
	1986	182	---	2.3	9.6
	1988	173	127	2.4	9.1
7	1972	222	[1]141	2.5	20
	1980	210	136	3.7	11
	1986	217	---	3.6	12
	1988	240	151	4.4	18
8	1980	420	283	4.8	100
	1983	440	278	4.8	100
	1984	436	264	4.7	100
	1986	445	---	4.9	110
	[3]1988	790	516	7.2	250
	[4]1988	438	300	4.8	120
9	1986	181	---	3.1	4.9
	1987	148	102	2.8	4.1

[1]Dissolved-solids concentrations from 1974.

[2]Volume of well bore not completely displaced prior to sampling.

[3]Well pumped for 16 hours at 470 gallons per minute.

[4]Well pumped for 20 hours at 600 gallons per minute.

residents of the reservations. Many springs on Black Mesa discharge from several stratigraphic units including the Navajo Sandstone where these units crop out.

Four springs were selected for discharge measurements and water-quality analyses during 1987. The springs were Shonto Spring (6M-54, Navajo Sandstone), Spring near Dennehotso (8A-224, Navajo Sandstone), Hard Rocks Spring (4M-128, Wepo Formation), and Tuye Spring (or spring near Steamboat, 17M-261, Dakota Sandstone). Shonto Spring was previously sampled in 1952 and 1984, Spring near Dennehotso in 1984, Hard Rocks Spring in 1952 and 1982, and Tuye Spring in 1949 and 1984. Discharge measurements for these springs are as follows:

Spring	Bureau of Indian Affairs Number	Year	Discharge, in gallons per minute
Shonto	6M-54	1952	1 (estimated)
		1984	0.67
		1987	Collection well (unmeasurable)
Dennehotso	8A-224	1984	2
		1987	5
Hard Rocks	4M-128	1952	1 (estimated)
		1982	Not measured
		1987	2
Tuye	17M-261	1949	Collection well (unmeasurable)
		1984	do.
		1987	do.

On the basis of the analyses of water samples collected from the early 1950's to 1987 by the U.S. Geological Survey, no significant changes have occurred in the quality of water in these springs. Chemical analyses for the springs for all years sampled are shown in table 7. Discharges and chemical analyses of other springs have been reported previously (G.W. Hill, written commun., 1982, 1983; Hill, 1985; Hill and Whetten, 1986; Hill and Sottilare, 1987).

Surface-Water Data

Outflow from the N aquifer appears mainly as surface flow in Moenkopi Wash and Laguna Creek and as springs near the boundaries of the aquifer (Davis and others, 1963). Data were collected from the continuous-record streamflow stations on Moenkopi Wash at Moenkopi (09401260) and Chinle Creek near Mexican Water (09379200) and from the low-flow measurement site on Laguna Creek near Church Rock (fig. 3).

The average discharge of low-flow measurements made on Moenkopi Wash during November through February in the 1988 water year was 3.6 cubic

Table 7.--Chemical analyses of selected springs, Black Mesa area, 1949-87

Spring name	U.S. Bureau of Indian Affairs field number	U.S. Geological Survey identification number	Rock formation	Date of sample	Temperature (°C)	Specific conductance (μS/cm)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	Nitrogen NO_2+NO_3 dissolved (mg/L as N)
Shonto Spring	6M-54	354032110443901	Navajo Sandstone	07-09-52	22.0	1,080	---	---	----
				06-26-84	20.5	990	7.3	133	3.8
				11-16-87	10.0	910	7.7	146	3.6
Spring near Dennehotso	8A-224	364656109425400	Navajo Sandstone	06-27-84	18.0	195	8.1	51	1.6
				11-17-87	11.5	178	8.0	65	1.4
Hard Rocks Spring	4M-128	360157110300501	Wepo Formation	08-01-52	21.0	541	---	---	----
				06-10-82	13.0	525	7.3	140	4.2
				11-18-87	14.5	525	7.6	106	3.3
Tuye Spring (spring near Steamboat)	17M-261	354523109504301	Dakota Sandstone	07-10-49	18.0	222	---	---	----
				06-26-84	18.0	280	7.6	112	0.47
				11-18-87	8.5	241	7.5	113	.48

Spring name	U.S. Bureau of Indian Affairs field number	U.S. Geological Survey identification number	Rock formation	Date of sample	Phosphorus ortho, dissolved (mg/L as P)	Hardness (mg/L as $CaCO_3$)	Hardness noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
Shonto Spring	6M-54	354032110443901	Navajo Sandstone	07-09-52	----	328	192	105	16
				06-26-84	0.02	---	---	94	13
				11-16-87	.01	---	---	94	13
Spring near Dennehotso	8A-224	364656109425400	Navajo Sandstone	06-27-84	.03	---	---	27	3.9
				11-17-87	.01	---	---	25	3.9
Hard Rocks Spring	4M-128	360157110300501	Wepo Formation	08-01-52	----	160	48	46	11
				06-10-82	.07	160	58	45	12
				11-18-87	<.01	---	---	43	12
Tuye Spring (spring near Steamboat)	17M-261	354523109504301	Dakota Sandstone	07-10-49	----	112	14	34	6.7
				06-26-84	.03	---	---	44	5.2
				11-18-87	.03	---	---	37	5.0

Table 7.--Chemical analyses of selected springs, Black Mesa area, 1949-87--Continued

Spring name	U.S. Bureau of Indian Affairs field number	U.S. Geological Survey identification number	Rock formation	Date of sample	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Percent sodium	Sodium+ Potassium, dissolved (mg/L as Na+K)
Shonto Spring	6M-54	354032110443901	Navajo Sandstone	07-09-52	-----	2.6	42	109
				06-26-84	100	---	-----	-----
				11-16-87	89	---	-----	-----
Spring near Dennehotso	8A-224	364656109425400	Navajo Sandstone	06-27-84	4.8	---	-----	-----
				11-17-87	4.7	---	-----	-----
Hard Rocks Spring	4M-128	360157110300501	Wepo Formation	08-01-52	-----	1.7	41	51
				06-10-82	56	2.0	43	-----
				11-18-87	56	---	-----	-----
Tuye Spring (spring near Steamboat)	17M-261	354523109504301	Dakota Sandstone	07-10-49	-----	3	0.1	1.8
				06-26-84	5.9	---	-----	-----
				11-18-87	5.7	---	-----	-----

Spring name	U.S. Bureau of Indian Affairs field number	U.S. Geological Survey identification number	Rock formation	Date of sample	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)
Shonto Spring	6M-54	354032110443901	Navajo Sandstone	07-09-52	----	82	281	0.5
				06-26-84	1.8	64	260	.6
				11-16-87	1.9	59	270	.6
Spring near Dennehotso	8A-224	364656109425400	Navajo Sandstone	06-27-84	1.1	2.8	7.1	.3
				11-17-87	1.0	3.4	7.5	.2
Hard Rocks Spring	4M-128	360157110300501	Wepo Formation	08-01-52	----	32	91	.4
				06-10-82	2.2	37	110	.2
				11-18-87	2.2	35	109	.3
Tuye Spring (spring near Steamboat)	17M-261	354523109504301	Dakota Sandstone	07-10-49	----	3.0	11	.4
				06-26-84	1.3	4.0	15	.3
				11-18-87	1.2	4.4	18	.3

Table 7.--Chemical analyses of selected springs, Black Mesa area, 1949-87--Continued

Spring name	U.S. Bureau of Indian Affairs field number	U.S. Geological Survey identification number	Rock formation	Date of sample	Silica, dissolved (mg/L as SiO_2)	Boron, dissolved (µg/L B)	Iron, dissolved (µg/L Fe)	Dissolved solids: Residue at 180°C mg/L)	Dissolved solids: Sum of constituents (mg/L)
Shonto Spring	6M-54	354032110443901	Navajo Sandstone	07-09-52	17	---	--	716	---
				06-26-84	15	120	20	643	649
				11-16-87	16	130	5	656	---
Spring near Dennehotso	8A-224	364656109425400	Navajo Sandstone	06-27-84	13	20	5	112	112
				11-17-87	13	20	5	108	---
Hard Rocks Spring	4M-128	360157110300501	Wepo Formation	08-01-52	17	---	--	337	---
				06-10-82	14	60	3	---	358
				11-18-87	15	80	6	360	---
Tuye Spring (spring near Steamboat)	17M-261	354523109504301	Dakota Sandstone	07-10-49	18	---	--	136	---
				06-26-84	15	20	6	159	161
				11-18-87	15	20	5	148	---

feet per second, which is equivalent to about 2,602 acre-feet per year. The average of all measurements made during the same period from 1976 to 1988 was 3.2 cubic feet per second. Low flow in Moenkopi Wash during November through February has remained fairly constant since the streamflow station was established in 1976. Mean daily discharges during the 1986 water year are shown in table 8. Mean daily discharges for previous water years have been published in Water Resources Data for Arizona (U.S. Geological Survey, 1977-88).

Chinle Creek, which is along the northeast perimeter of the study area, receives water from the N aquifer principally from Laguna Creek. Laguna Creek flows along the north boundary of the study area and flows into the Chinle Creek about 5 miles above the gaging station near Mexican Water (fig. 3). The average discharge of low-flow measurements made on Chinle Creek for November through February in the 1987 water year was 3.6 cubic feet per second or about 2,602 acre-feet per year. The average discharge of low-flow measurements for the same months during water years 1977-88 was 7.4 cubic feet per second or about 5,348 acre-feet per year. The mean daily discharges for the 1986 water year are shown on table 9. All previous mean daily discharges have been published in Water Resources Data for Arizona (U.S. Geological Survey, 1964-88).

The average discharge of low-flow measurements made on Laguna Creek during November through February since the station was established in 1981 is 3.4 cubic feet per second or about 2,460 acre-feet per year. Only one low-flow measurement was made during the same months in the 1988 water year; the discharge for that measurement was 1.89 cubic feet per second. Continuous streamflow data are not collected at this station.

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Table 8.--Discharge data, Moenkopi Wash at Moenkopi, 1986 water year

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1985 TO SEPTEMBER 1986
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1.2	13	16	5.6	3.0	2.8	3.6	3.6	.36	.00	.00	1.6
2	1.2	2.2	10	5.6	3.0	2.8	3.6	2.5	.20	.00	.00	.17
3	1.0	2.2	5.6	5.6	3.0	2.8	3.6	2.5	.17	.00	.00	.15
4	.36	2.2	3.6	5.6	3.0	2.8	3.6	2.8	.20	.00	.00	.10
5	.20	2.2	4.4	16	3.0	2.8	3.6	2.5	.20	.08	.00	.00
6	.12	1.6	4.4	3.6	3.0	2.8	3.6	2.5	.17	2.2	.00	.00
7	.12	1.6	3.6	3.0	3.0	2.8	3.6	2.0	.02	.02	.00	.00
8	.12	2.2	3.6	3.0	3.0	2.8	3.6	2.0	.00	.00	.00	.00
9	.12	2.8	3.6	3.0	3.0	2.8	3.0	1.8	.00	.00	.00	1,070
10	3.6	2.8	3.6	3.0	2.0	2.2	2.8	1.6	.00	.00	.00	238
11	2.8	2.8	3.6	3.0	2.5	2.2	2.8	1.6	.00	.00	.36	38
12	2.2	2.8	3.6	3.0	3.0	2.2	2.8	1.6	.00	.00	1.0	16
13	1.6	2.8	3.6	3.0	3.0	2.2	2.8	1.2	.00	.00	.20	8.4
14	1.6	2.8	3.6	3.0	3.0	2.2	2.8	1.0	.00	.00	6.8	2.2
15	1.6	2.8	4.4	3.0	3.0	2.2	2.5	1.0	.00	.00	6.8	1.0
16	1.6	2.8	10	3.0	3.5	2.2	2.5	1.0	.00	23	.36	1.0
17	1.6	4.4	3.6	3.0	4.0	2.2	2.5	1.2	.00	24	.00	.80
18	1.6	8.4	3.6	3.0	4.0	2.2	2.5	1.2	.00	4.4	.00	.80
19	1.6	5.6	3.6	3.0	4.5	1.6	2.5	1.0	.00	.27	.00	.80
20	1.6	3.6	3.6	3.0	4.4	1.6	2.5	1.0	.00	83	.00	.47
21	1.6	3.6	3.6	3.0	4.0	1.6	2.5	.80	.00	155	.00	.47
22	1.6	2.2	3.6	2.8	3.5	1.6	2.5	.80	.00	134	.00	.47
23	1.6	2.2	3.6	3.0	3.0	1.6	2.2	.80	.00	34	.00	16
24	1.6	2.2	3.6	3.0	3.0	1.6	2.0	.80	.00	47	11	499
25	1.6	4.4	3.6	3.0	3.0	1.6	2.0	.80	.00	47	240	88
26	1.6	36	3.6	3.0	2.8	1.6	2.0	.80	.00	4.4	127	16
27	1.6	8.0	3.6	3.0	2.8	1.6	2.0	.60	.00	2.2	10	8.4
28	1.6	2.8	3.6	3.0	2.8	10	2.0	.60	.00	.47	112	2.8
29	1.6	2.8	3.6	3.0	---	3.6	2.0	.60	.00	.17	100	2.8
30	1.6	182	3.6	3.0	---	3.6	2.0	.60	.00	.00	170	2.2
31	1.6	---	4.4	3.0	---	3.6	---	.47	---	.00	8.4	---
TOTAL	43.44	317.8	142.0	116.8	88.8	80.2	82.0	43.27	1.32	561.21	793.92	2,015.63
MEAN	1.40	10.6	4.58	3.77	3.17	2.59	2.73	1.40	.044	18.1	25.6	67.2
MAX	3.6	182	16	16	4.5	10	3.6	3.6	.36	155	240	1,070
MIN	.12	1.6	3.6	2.8	2.0	1.6	2.0	.47	.00	.00	.00	.00
AC-FT	86	630	282	232	176	159	163	86	2.6	1,110	1,570	4,000

CAL YR 1985 TOTAL 1563.83 MEAN 4.26 MAX 182 MIN .00 AC-FT 3,100
WTR YR 1986 TOTAL 4286.38 MEAN 11.7 MAX 1,070 MIN .00 AC-FT 8,500

Table 9.--Discharge data, Chinle Creek near Mexican Water, 1986 water year

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1985 TO SEPTEMBER 1986
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.5	5.7	171	14	3.4	2.0	19	6.5	.20	.00	.00	157
2	.5	5.7	110	20	.20	1.4	15	9.6	.10	.00	.00	176
3	.4	6.2	52	11	.30	1.4	41	14	.00	.00	.00	133
4	.4	6.2	36	13	.20	1.5	171	12	.00	.00	.00	110
5	.4	5.3	24	8.4	.00	1.2	123	8.0	.00	46	.00	17
6	.3	5.7	21	8.4	1.0	1.4	119	6.0	.00	17	.00	21
7	.10	6.2	19	11	1.0	1.2	106	4.0	.00	1.8	.00	44
8	5.0	6.2	18	15	1.0	1.5	73	2.0	.00	.40	.00	147
9	5.0	5.7	18	13	1.0	1.2	50	1.0	.00	.90	.00	580
10	20	5.7	10	15	1.0	1.4	40	.50	.00	.40	.00	771
11	600	4.8	7.2	18	1.0	2.0	21	.50	.00	.00	.00	189
12	200	6.5	4.1	19	1.0	2.0	18	.50	.00	.00	.00	62
13	100	6.2	4.8	15	3.0	4.1	5.3	.30	.00	.00	147	21
14	60	11	3.4	10	5.0	4.8	2.0	.30	.00	.00	74	15
15	20	17	2.8	10	5.0	6.5	1.1	.20	.00	.00	20	8.4
16	10	6.5	1.8	10	5.0	5.7	1.5	2.2	.00	19	7.2	5.7
17	5.0	7.6	1.4	10	5.0	8.8	1.5	14	.00	9.6	.40	1.0
18	4.0	9.2	2.5	10	5.0	7.2	1.5	2.2	.00	.50	.20	1.0
19	4.0	12	4.4	10	5.0	6.9	2.0	1.4	.00	10	.10	1.0
20	4.0	6.9	3.4	10	5.0	9.2	2.0	.60	.00	142	.00	1.0
21	4.0	4.4	3.7	10	3.1	5.3	2.0	.40	.00	30	10	.90
22	4.0	3.7	1.5	10	2.0	3.7	2.5	.20	.00	191	8.0	.90
23	4.0	4.8	3.7	5.3	4.4	2.0	3.0	.30	.00	160	.90	1.8
24	4.0	11	5.7	12	2.0	.90	8.0	.40	.00	488	19	150
25	3.7	15	12	13	2.5	.80	8.0	.30	.00	124	436	768
26	3.7	14	14	11	1.2	.50	4.8	.30	.00	12	25	110
27	3.7	74	12	12	2.0	2.5	17	.20	.00	.10	7.2	82
28	3.7	52	9.6	17	2.2	1.2	20	.20	.00	.00	62	39
29	4.1	38	5.0	9.2	---	1.0	8.0	.20	.00	.00	134	15
30	4.1	127	3.0	8.4	---	.30	4.8	.10	.00	.00	255	12
31	4.8	---	15	14	---	.30	---	.20	---	.00	74	---
TOTAL	1083.40	490.2	600.0	372.7	68.50	89.90	891.0	88.60	.30	1,252.70	1,280.00	3,640.70
MEAN	34.9	16.3	19.4	12.0	2.45	2.90	29.7	2.86	.010	40.4	41.3	121
MAX	600	127	171	20	5.0	9.2	171	14	.20	488	436	771
MIN	.10	3.7	1.4	5.3	.00	.30	1.1	.10	.00	.00	.00	.90
AC-FT	2150	972	1190	739	136	178	1,770	176	.6	2,480	2,540	7220

CAL YR 1985 TOTAL 25713.59 MEAN 70.4 MAX 2,280 MIN .00 AC-FT 5,100
WTR YR 1986 TOTAL 9857.97 MEAN 27.0 MAX 771 MIN .00 AC-FT 19,550