POTENTIAL HYDROLOGIC EFFECTS OF A DRAINAGE SYSTEM IN MCMILLAN DELTA AND WATER IMPOUNDMENT IN BRANTLEY RESERVOIR, EDDY COUNTY, NEW MEXICO

By Thomas M. Crouch and G.E. Welder

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1988

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CONVERSION FACTORS

Inch-pound units used in this report may be converted to metric (International System) units by using the following conversion factors:

Multiply	By	To obtain
acre	0.4047	hectare
acre-foot	0.001233	cubic hectometer
acre-foot per year	0.001233	cubic hectometer per year
cubic foot per second	0.02832	cubic meter per second
foot	0.3048	meter
foot per day	0.3048	meter per day
foot squared per day	0.0929	meter squared per day
gallon per minute	0.06309	liter per second
inch	2.540	centimeter
mile	1.609	kilometer
square mile	2.590	square kilometer

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

From 1983 to 1986, the U.S. Geological Survey conducted a study in cooperation with the U.S. Bureau of Reclamation to determine the potential effects of a proposed drainage system in McMillan delta and of water impoundment at Brantley Reservoir. The potential effect of a new lined channel of the Pecos River in McMillan delta would be an increase in the amount of water for use downstream less than about 11,000 acre-feet per year. This increase includes overflow of 300 acre-feet from the present Pecos River channel, seepage from the bed of the Pecos River of 3,600 acre-feet, and tributary inflow of 7,100 acre-feet.

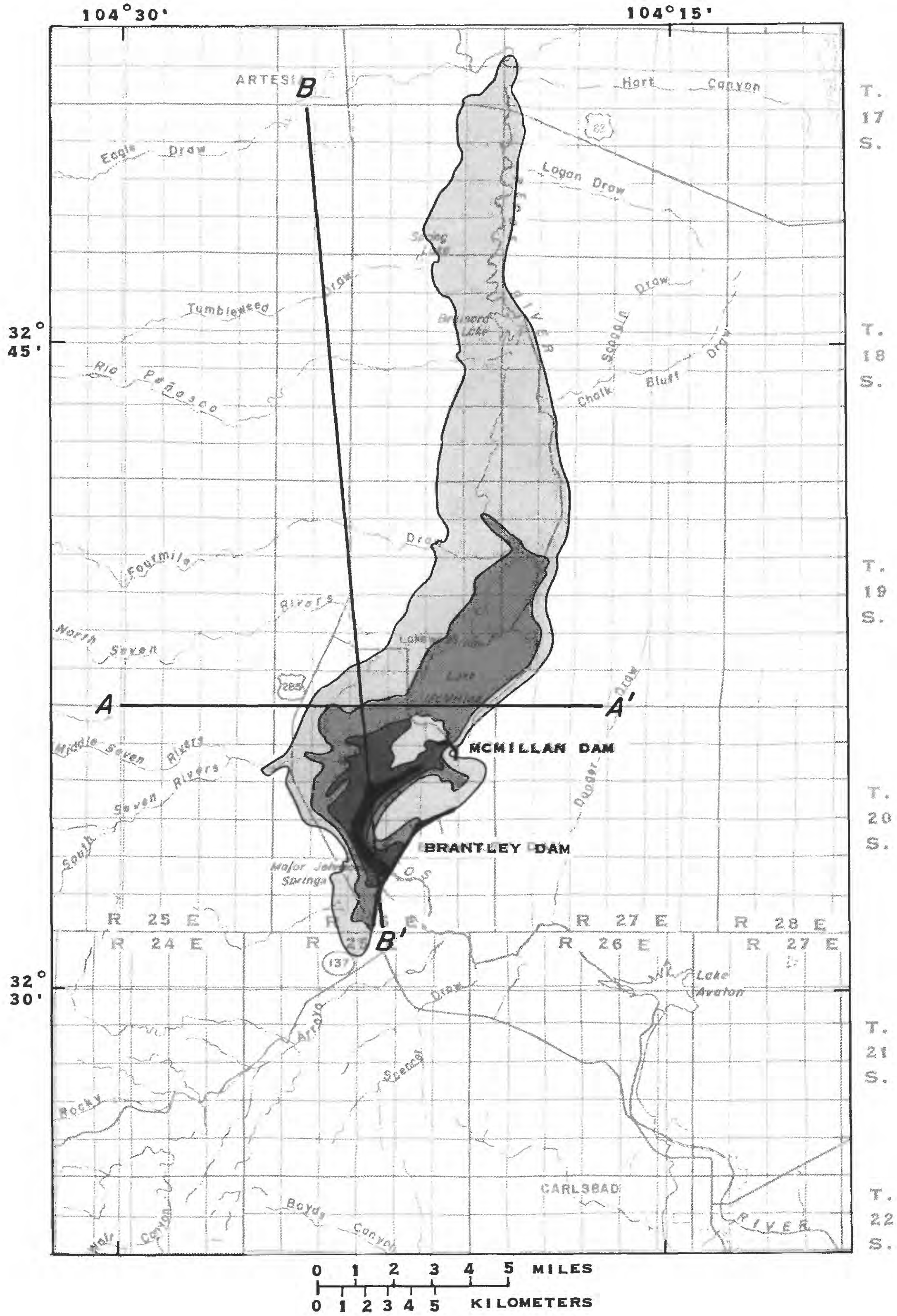
The potential effect of drains, which would be feasible only for 6 square miles at the north end of Brantley Reservoir where the average water-table depth is about 7 feet, would be about 6,100 acre-feet of additional water within the first few years. In order to drain this much water, the drains would have to be channeled to a lower level 6 to 8 miles to the south.

The effects of water impoundment in Brantley Reservoir will be increases in ground-water storage in the alluvial, artesian, and Major Johnson Springs aquifers. The actual amount of increased storage will depend on the time that the reservoir pool remains at various levels. Major Johnson Springs probably will cease to flow at the conservation-pool level, and southward ground-water leakage from the Major Johnson Springs aquifer could increase. It is expected that large amounts of water will move in and out of storage in the Major Johnson Springs aquifer as the Brantley Reservoir pool changes from minimum-pool to conservation-pool levels.

A ground- and surface-water monitoring network would be needed to determine changes in ground-water storage caused by Brantley Reservoir. Water levels in selected wells need to be measured periodically during operation of the reservoir. Additional streamflow-gaging stations need to be established, and surface-water samples need to be collected and analyzed to determine changes caused by a drainage system and Brantley Reservoir.

INTRODUCTION

In 1958, the U.S. Congress authorized construction of a drainage system and clearing of vegetation to reduce water lost to phreatophytes in the reach of the Pecos River from near Artesia to Lake McMillan, N. Mex. (fig. 1), referred to as the McMillan delta in this report. The legislation stipulated that no water-salvage work could take place in the area until provisions were made to replace water storage belonging to the Carlsbad Irrigation District. Brantley Dam, under construction downstream from Lake McMillan, will provide the necessary storage. When Brantley Dam is completed in 1988, work on the drainage system could begin.



104°30'
104°15'
ARTESIA
B
B'
A
A'
Hart Canyon
Eagle Draw
Logan Draw
Tumbleweed Draw
Draw
Scoggin
Chalk Bluff Draw
Rio Peñasco
RIVER
Fourmile Draw
North Seven Rivers
Middle Seven Rivers
South Seven Rivers
Major Johnson Springs
MCMILLAN DAM
BRANTLEY DAM
Dagger Draw
Lake Avalon
Arroyo
Spencer
Rocky
Boyds Canyon
Canyon
CARLSBAD
RIVER
32° 45'
32° 30'
T. 17 S.
T. 18 S.
T. 19 S.
T. 20 S.
T. 21 S.
T. 22 S.
R 25 E
R 24 E
R 27 E
R 26 E
R 28 E
R 27 E
285
82
137
0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

EXPLANATION

AREAS TO BE COVERED BY BRANTLEY RESERVOIR

Minimum pool
(altitude 3,224.5 feet)

Initial conservation pool
(altitude 3,255.3 feet)

Conservation pool after 100 years
(altitude 3,271.0 feet)

Maximum pool
(altitude 3,303.5 feet)

A —— A' LINE OF HYDROGEOLOGIC SECTION--Sections are shown in figure 3

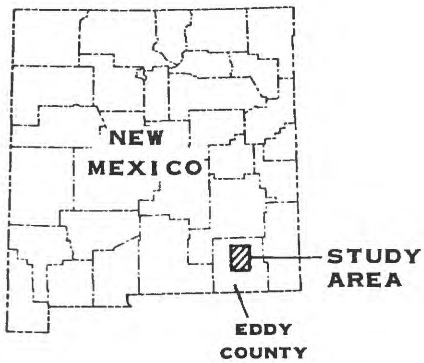


Figure 1.--Location of the study area.

Purpose and Scope

From July 1983 to July 1986, the U.S. Geological Survey conducted a study in cooperation with the U.S. Bureau of Reclamation to determine the potential effects of a proposed drainage system and of water impoundment at Brantley Reservoir on the ground- and surface-water resources in Eddy County, New Mexico. The purpose of this report is to describe the results of that study. Specific objectives are to:

1. Provide data on the depth to the water table and soil characteristics that could be used in determining whether to construct a drainage system.

2. Estimate the probable maximum quantity of water that could be salvaged by a new channel for the Pecos River or drains in McMillan delta.

3. Discuss possible changes in the shallow aquifer of the Roswell Basin, which includes the Major Johnson Springs aquifer, and the relation of these changes to the stage of Brantley Reservoir.

4. Identify needs for monitoring ground- and surface-water conditions in the delta and reservoir area after water is impounded in Brantley Reservoir.

Location of Study Area

The study area extends from just north of U.S. Highway 82 near Artesia, N. Mex., to just south of Carlsbad, N. Mex. (fig. 1). When McMillan Dam was constructed in 1893, the north shore of the lake extended about 7 miles north of its present position almost to the mouth of the Rio Peñasco (fig. 1). Since 1893, 1 to 5 feet of silt (Cox and Havens, 1974, pl. 2A) has been deposited in what was formerly the upstream part of Lake McMillan. The present storage capacity of the lake is less than one-third of its original capacity.

Brantley Dam, which is scheduled for completion in 1988, is 4.5 miles downstream from McMillan Dam (fig. 1). McMillan delta is within the maximum reservoir surface area (altitude 3,303.5 feet above sea level) of Brantley Reservoir. The delta is upstream from the initial conservation-pool level (altitude 3,255.3 feet); after 100 years, the conservation pool (estimated altitude 3,271 feet) of Brantley Reservoir will extend northward into the delta (fig. 1).

Geology

Quaternary, Tertiary (?), and Permian sedimentary rocks are the geologic units pertinent to this study. The sequence, lithology, and hydrology of these units are summarized in figure 2. Hydrogeologic sections through the area are shown in figure 3. The following description is a brief summary of the structure of the area. More complete descriptions are available in the references shown in figure 2.

The sedimentary rocks in the area of study are on the northwestern shelf of the Permian Basin, a large structure that extends far into Texas (Cys, 1975, fig. 20). The shelf deposits of the southern part of the study area dip southeastward into the smaller Delaware Basin southeast of Carlsbad. Each of the formations of the Guadalupian Series (fig. 2) grades toward the Delaware Basin from a shelf-evaporite facies to a shelf-carbonate facies and then to a reef facies that encircles the Delaware Basin (Motts, 1968, fig. 7). The facies change from predominantly evaporite to the northwest to predominantly carbonate to the southeast in the lower member of the Permian Seven Rivers Formation occurs just southeast of Brantley Dam. The dam was built on the overlying, less permeable, predominantly carbonate Azotea Tongue of the Seven Rivers Formation.

Alluvial deposits of Quaternary and Tertiary (?) age in the area north of Lake McMillan (fig. 4) are underlain by eastward- to southeastward-dipping Permian Queen and Grayburg Formations (fig. 3). The Permian Tansill and Yates Formations and upper part of the Seven Rivers Formation, however, were removed by erosion prior to deposition of the quartzose conglomerate of Fiedler and Nye (1933) and to some extent by subsurface solution of evaporites in these formations after deposition of younger rocks. The Orchard Park terrace deposits of Fiedler and Nye (1933), which are present just west of the Lakewood terrace flood plain, probably were removed by erosion prior to deposition of the Lakewood terrace deposits of Fiedler and Nye (1933). Thus, the sediments above the Seven Rivers Formation in the flood plain north of McMillan Dam are the quartzose conglomerate, possibly part of the Blackdom terrace deposits of Fiedler and Nye (1933), and the Lakewood terrace deposits, which include the McMillan delta silt and clay (fig. 4). Lyford (1973, fig. 13) indicated that the post-Seven Rivers Formation sediments in the flood plain range in thickness from about 50 to 300 feet.

Acknowledgments

The cooperation of Mr. Lawrence King, Manager of the Brantley Project, and the staff of the Carlsbad office of the U.S. Bureau of Reclamation is greatly appreciated. They provided geohydrologic information and helped with drilling of observation wells in McMillan delta.

Erathem	System	Series	Subdivision (thickness, in feet)	Lithology	Hydrology
Cenozoic	Quaternary	Holocene	Lakewood terrace deposits of Fiedler and Nye (1933) (5-50)[1,2]	Brown silt and lenses of gravel, sand, and clay. Upper 1 to 5 feet in flood plain of Pecos River north of Lake McMillan is deltaic silt and clay deposited since 1893.[3]	Generally does not yield water to wells. Recharge from Pecos River and tributary flood overflow enhanced by dessication cracks. Supports abundance of saltcedar.
Cenozoic	Quaternary	Pleistocene	Orchard Park terrace deposits of Fiedler and Nye (1933) (0-20)[1,2]	Silt, clay, sand, and gravel.	May yield small quantities of water to wells if saturated.
Cenozoic	Quaternary	Pleistocene	Blackdom terrace deposits of Fiedler and Nye (1933) (0-20)[1,2]	Gravel, conglomerate, sandstone, clay, and silt.	Part of alluvial aquifer of Roswell Basin where saturated. See below.
Cenozoic	Quaternary / ? / Tertiary(?)	Pleistocene / ? / Pliocene(?)	Quartzose conglomerate of Fiedler and Nye (1933) (100-300)[1,2,4]	Conglomerate, sandstone, gravel, sand, shale, and clay.[1] May be equivalent in age to Gatuña Formation that is present downstream from and near right abutment of Brantley Dam.[5]	Principal unit in alluvial aquifer of Roswell Basin. Has maximum saturated thickness of 300 feet. Yields 325-2,200 gallons per minute to wells.[6]
Paleozoic	Permian	Guadalupian	Artesia Group: Tansill Formation (100-200)[7]	Dolomite, shale, and sandstone. Present 1 to 3 miles east of Pecos River.	Not a source of ground water in study area.
Paleozoic	Permian	Guadalupian	Artesia Group: Yates Formation (260-524)[5]	Anhydrite, gypsum, sandstone, siltstone, and dolomite. Present 0.5 to 3 miles east of Pecos River.	Yields very mineralized water to a few stock wells.[5]
Paleozoic	Permian	Guadalupian	Artesia Group: Seven Rivers Formation: Azotea Tongue (local use) (0-530)[5]	Dolomite, sandstone, siltstone, and sedimentary breccia. Present in the vicinity of Brantley Dam and along the east side of the Pecos River.	The Seven Rivers Formation contains more gypsum to the north and northeast of and more dolomite to the south of Brantley Dam. It forms the bluff that borders McMillan delta and the Pecos River flood plain in the east. Solution and breccia zones in the Azotea Tongue and lower member make up the Major Johnson Springs aquifer, which yields large quantities of water to springs 1.5 miles upstream from Brantley Dam. The Major Johnson Springs aquifer is hydraulically connected with the alluvial aquifer of the Roswell Basin.[6]
Paleozoic	Permian	Guadalupian	Artesia Group: Seven Rivers Formation: Lower member (0-550)[5]	Gypsum, anhydrite, dolomite, siltstone, and sandstone. Present in same area as Azotea Tongue.	
Paleozoic	Permian	Guadalupian	Artesia Group: Queen Formation (360-420)[7]	Sandstone, siltstone, and dolomite.	Lower part of Queen Formation and upper part of Grayburg Formation make up the artesian aquifer of Roswell Basin south of T. 18 S.[6]
Paleozoic	Permian	Guadalupian	Artesia Group: Grayburg Formation (360-420)[7]	Dolomite and sandstone.	
Paleozoic	Permian	? / Leonardian	San Andres Limestone (1,200-2,000)[6]	Limestone and dolomite.	Contains main part of artesian aquifer of Roswell Basin north of T. 17 S. Yields 450-3,300 gallons per minute to wells.[6]

1 Morgan, 1938, p. 13-17.
2 Fiedler and Nye, 1933, p. 10-12, 112.
3 Cox and Havens, 1974, p. E6.
4 Bretz and Horberg, 1949, p. 478.
5 U.S. Bureau of Reclamation, 1984, unpublished data.
6 Welder, 1983, p. 11, 14, fig. 4.
7 Tait and others, 1962, fig. 2.

Figure 2.--Generalized stratigraphic section in the vicinity of Brantley Dam and Reservoir.

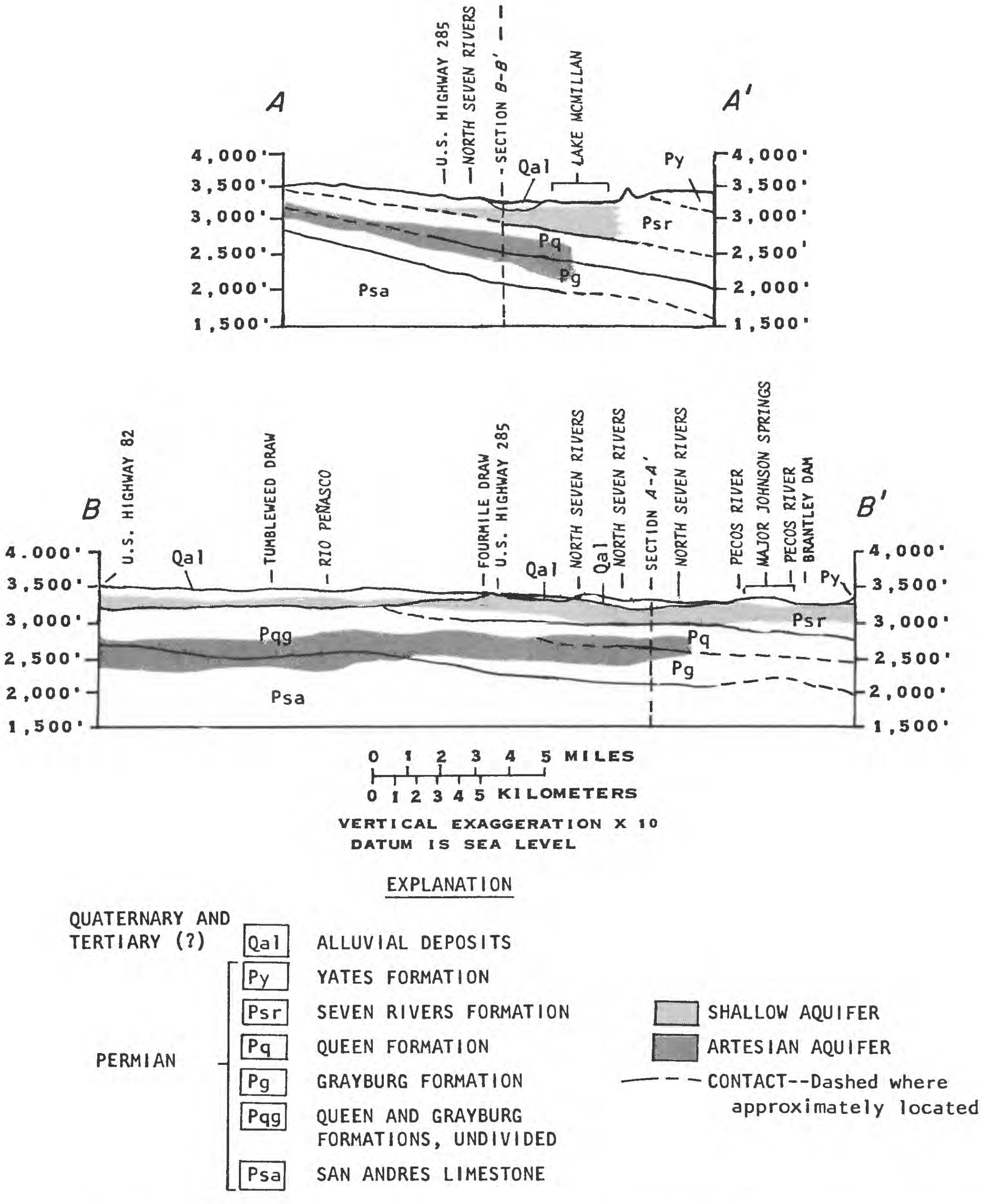


Figure 3.--Generalized hydrogeologic sections (modified from Welder, 1983, fig. 4). See figure 1 for location of sections.

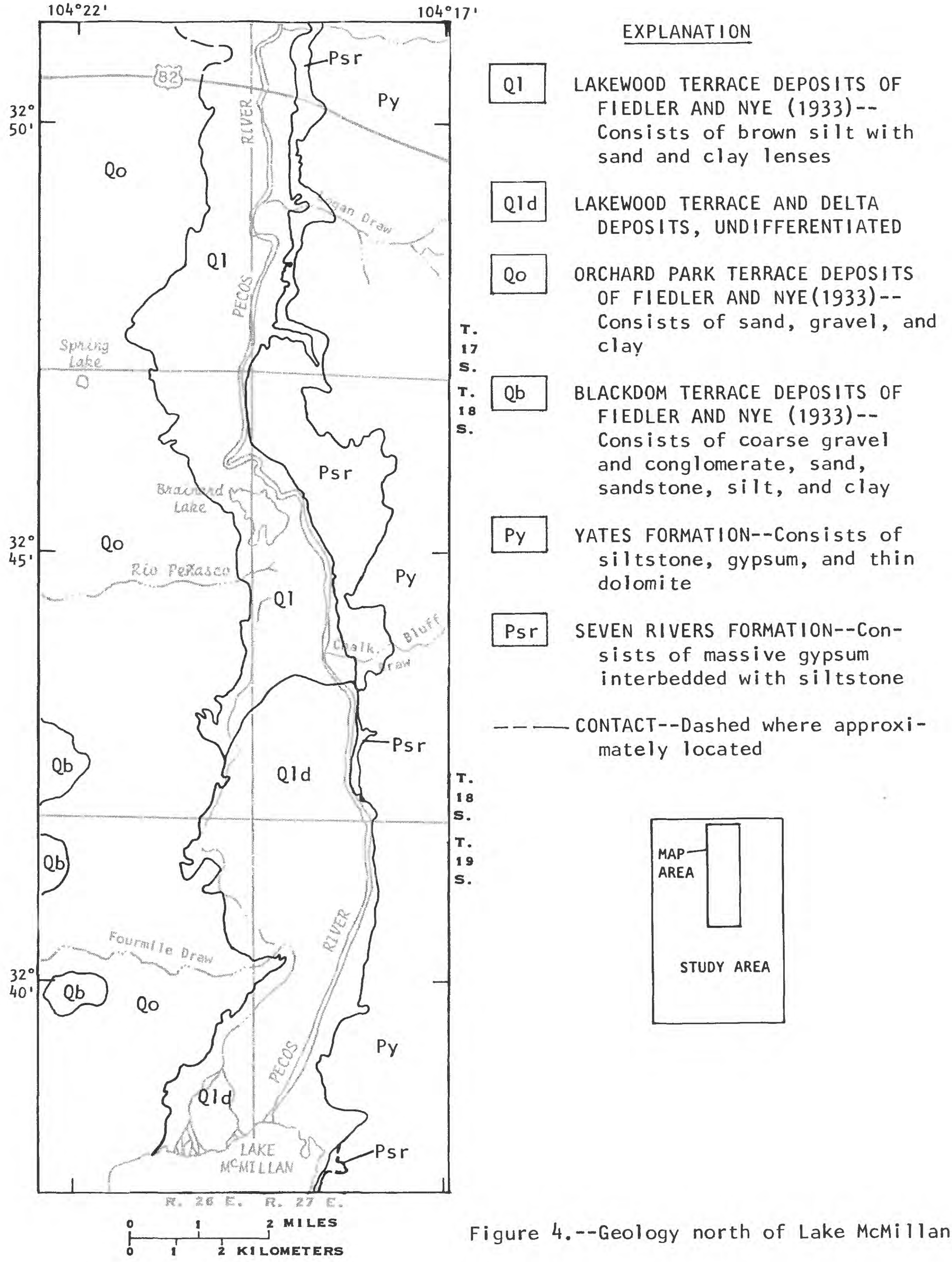


Figure 4.--Geology north of Lake McMillan.

GROUND-WATER HYDROLOGY

All of the area of investigation in this study is within the declared boundaries of the Roswell ground-water basin, as defined by the New Mexico State Engineer Office, except for a few square miles southwest of the Brantley Dam spillway. The Roswell ground-water basin consists of a shallow aquifer underlain by leaky confining beds that are underlain by a deep artesian aquifer (fig. 3). The shallow aquifer underlies an area about 67 miles long and 12 miles wide, and the artesian aquifer underlies an area about 90 miles long and 30 miles wide. The principal means of discharge from both aquifers is through wells; in 1978 there were about 1,500 relatively large-yield wells in the basin (Welder, 1983, p. 6). About 95 percent of the water used in the basin is ground water, most of which is used for irrigation (Welder, 1983, p. 7).

Shallow Aquifer

The shallow aquifer as referred to in this report and by Welder (1983) includes two parts:

(1) A primarily alluvial, unconfined aquifer extends from about 40 miles north of the study area to the vicinity of McMillan Dam. Some small areas of small to moderate permeability in the Seven Rivers Formation underlying the alluvium near Lake McMillan or at the surface to the west and northwest of the lake are hydraulically connected to and considered part of the alluvial aquifer.

(2) The Major Johnson Springs aquifer, a very permeable aquifer developed by solution and collapse of the lower member and Azotea Tongue of the Seven Rivers Formation, extends about 10 miles south from Lake McMillan (fig. 5).

The alluvial aquifer is composed of valley-fill deposits of conglomerate, gravel, sand, clay, and silt. The quartzose conglomerate is the main part of the aquifer. Water-producing zones in the uppermost 50 feet of the confining beds in parts of the Roswell Basin probably are hydraulically connected with the alluvial aquifer. In addition, the alluvial aquifer overlies and is in hydraulic connection with the Major Johnson Springs aquifer in the northern part of T. 20 S., R. 26 E. and probably for some distance to the north (fig. 5).

In contrast to the alluvial aquifer, the Major Johnson Springs aquifer is almost entirely in solution and breccia zones of the bedrock of the Seven Rivers Formation. Part of the Major Johnson Springs aquifer is confined by the Azotea Tongue of the Seven Rivers Formation in the vicinity of Brantley Dam (G.I. Haskett, U.S. Bureau of Reclamation, written commun., 1984). Haskett defined the extent of the Major Johnson Springs aquifer on the basis of the relation of water-level changes in observation wells to changes in river stage and the relatively flat potentiometric surface throughout the aquifer at altitudes of about 3,210 to 3,220 feet. The areal extent of the known part of the aquifer is about 32 square miles (fig. 5). Because of the erratic development of permeable zones in the aquifer, definite dimensions of the aquifer have not been determined.

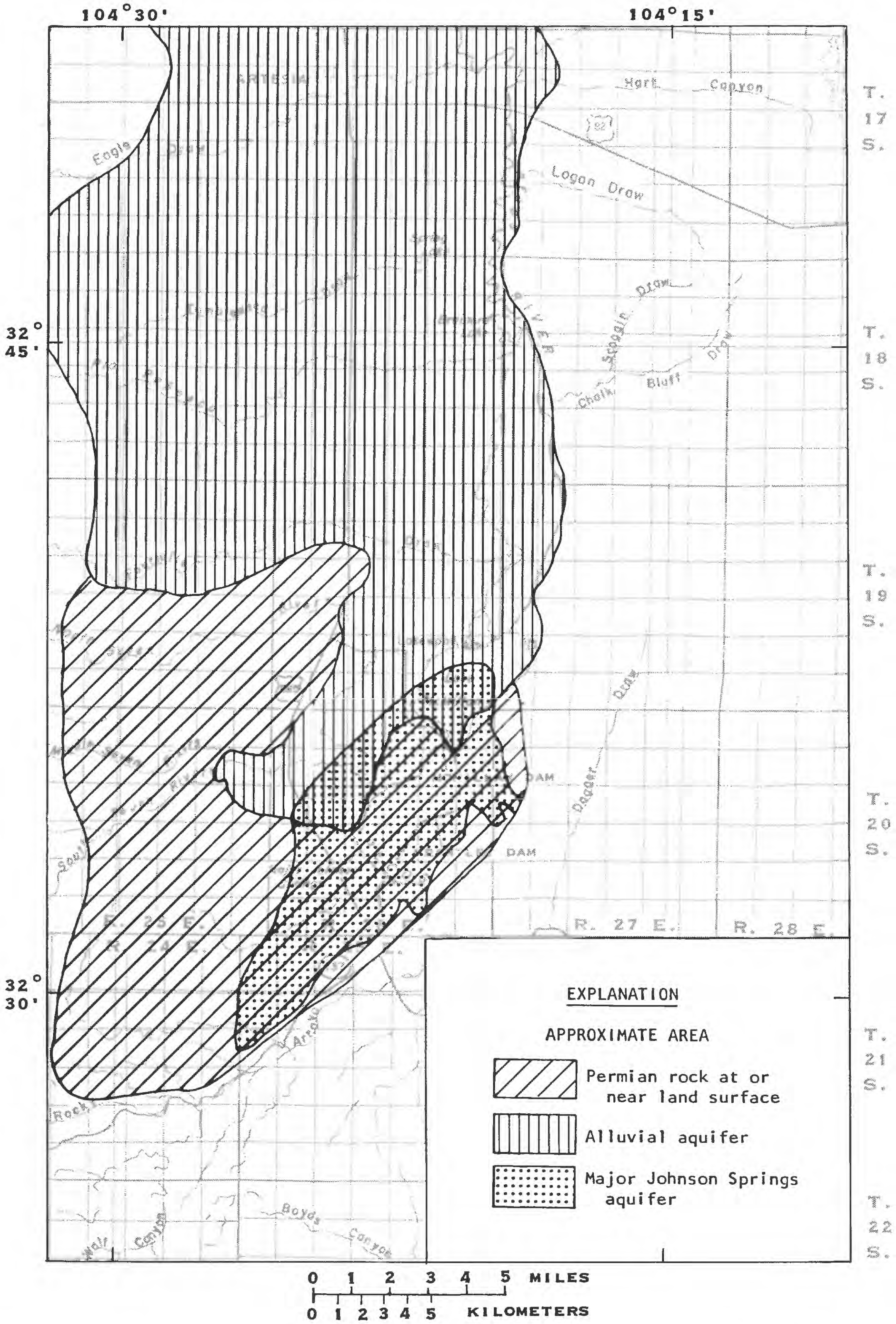


Figure 5.--Approximate area of Permian rock at or near land surface and alluvial and Major Johnson Springs aquifers.

Unpublished data from the U.S. Bureau of Reclamation indicate that transmissivity of the Seven Rivers Formation ranges from 275 to 20,500 feet squared per day in the area of the Major Johnson Springs aquifer. The data also indicate that thickness ranges from 35 to 470 feet for breccia and solutioned rock in the vicinity of the Major Johnson Springs aquifer.

Cushman (1965, p. 37) calculated that the average specific yield of the Major Johnson Springs aquifer between altitudes of 3,207 and 3,216 feet was about 0.17 and that the transmissivity was about 6,500,000 feet squared per day. The aquifer properties were for a part of the aquifer between Major Johnson Springs and McMillan Dam and may not be representative of the entire aquifer. The Major Johnson Springs aquifer only extends a short distance southeast of Brantley Dam to the facies change of the lower member from evaporite to carbonate lithology.

The principal sources of recharge to the shallow aquifer are upward leakage from the artesian aquifer and return flow from irrigation. Upward leakage, however, in the Pecos River flood plain between Highway 82 and T. 18 S. (an area being considered for drain construction) apparently is negligible (Welder, 1983, fig. 25). Additional recharge to the shallow aquifer is from precipitation, seepage from the Pecos River south of a point about 3 miles downstream from Highway 82, and seepage through the bed of Lake McMillan.

Major Johnson Springs aquifer receives water from the alluvial aquifer to the north, possibly from upward leakage from the artesian aquifer, and from seepage from the Pecos River and Lake McMillan (Cox, 1967, p. 46). In addition, Major Johnson Springs aquifer may be receiving small amounts of water from Permian rocks at or near land surface shown in figure 5, which correspond to parts of ground-water zones 1 and 3 of Cox (1967, pl. 4).

Natural discharge from the shallow aquifer is to the Pecos River and to Major Johnson Springs. Additional discharge by evapotranspiration in the flood plain of the Pecos River also occurs. Major Johnson Springs aquifer also may be discharging to the south through leaks in the Azotea Tongue of the Seven Rivers Formation (G.I. Haskett, U.S. Bureau of Reclamation, written commun., 1984).

The altitude and configuration of the water table in the shallow aquifer (fig. 6) indicate that ground-water flow in most of the study area is to an elongate trough. The axis of the trough trends southeastward from Artesia to the west part of the Pecos River flood plain, then southward around the west side of Lake McMillan to the Major Johnson Springs aquifer, and finally to discharge points at Major Johnson Springs. The ground-water trough is an unusual feature that has been present at least since 1938 (Welder, 1983, fig. 16). The trough probably is controlled by a zone of greater permeability in the basal quartzose conglomerate or evaporite solution zones in the Seven Rivers Formation that tend to drain the overlying, less permeable alluvial deposits. If the trough were not there, ground water would flow eastward to the Pecos River and the river would be a gaining stream along more of the reach south of Highway 82.

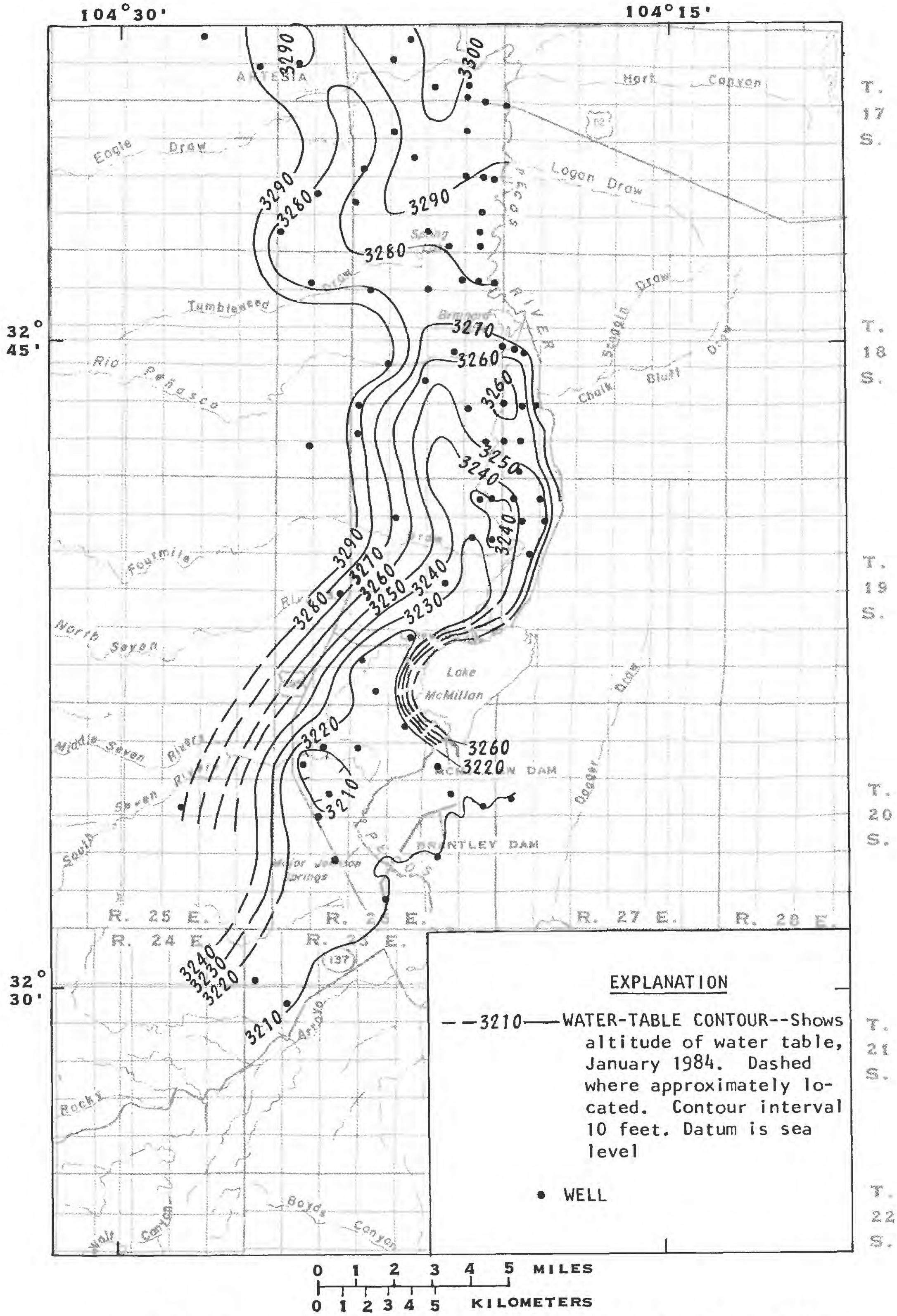


Figure 6.--Configuration of the water table in the shallow aquifer, January 1984.

The depth of the water table north of Lake McMillan ranges from about 5 feet in the north part of the flood plain to about 30 feet at places in the south part of the flood plain (figs. 7 and 8). Annual fluctuations of the water table are as much as 9 feet (fig. 9). Water-table fluctuations are affected locally by flow from the Pecos River and its tributaries onto the flood plain, by seepage from the streambed of the Pecos River and from Lake McMillan, by evapotranspiration, and by ground-water withdrawals for irrigation west of the flood plain.

Artesian Aquifer

The artesian aquifer generally consists of one or more erratically developed water-producing zones in carbonate rock of Permian age (Welder, 1983, p. 7). The San Andres Limestone contains the main part of the aquifer in the northern part of the study area; south of T. 18 S., the main part of the aquifer is in the Queen and Grayburg Formations (figs. 2 and 3).

Water recharges the artesian aquifer where the San Andres Limestone crops out 20 to 30 miles west of the Pecos River. Fractures, sinkholes, and small solution openings in the San Andres Limestone capture intermittent streamflow and divert it to the subsurface. The water then flows downdip and into the permeable zones in the upper part of the San Andres Limestone, the Grayburg Formation, and the lower part of the Queen Formation. A decrease in permeability in the vicinity of the Pecos River forms the eastern boundary of the artesian aquifer. Water in the eastern part of the artesian aquifer seeps upward through the leaky confining beds of the Artesia Group (fig. 2) and into the shallow aquifer.

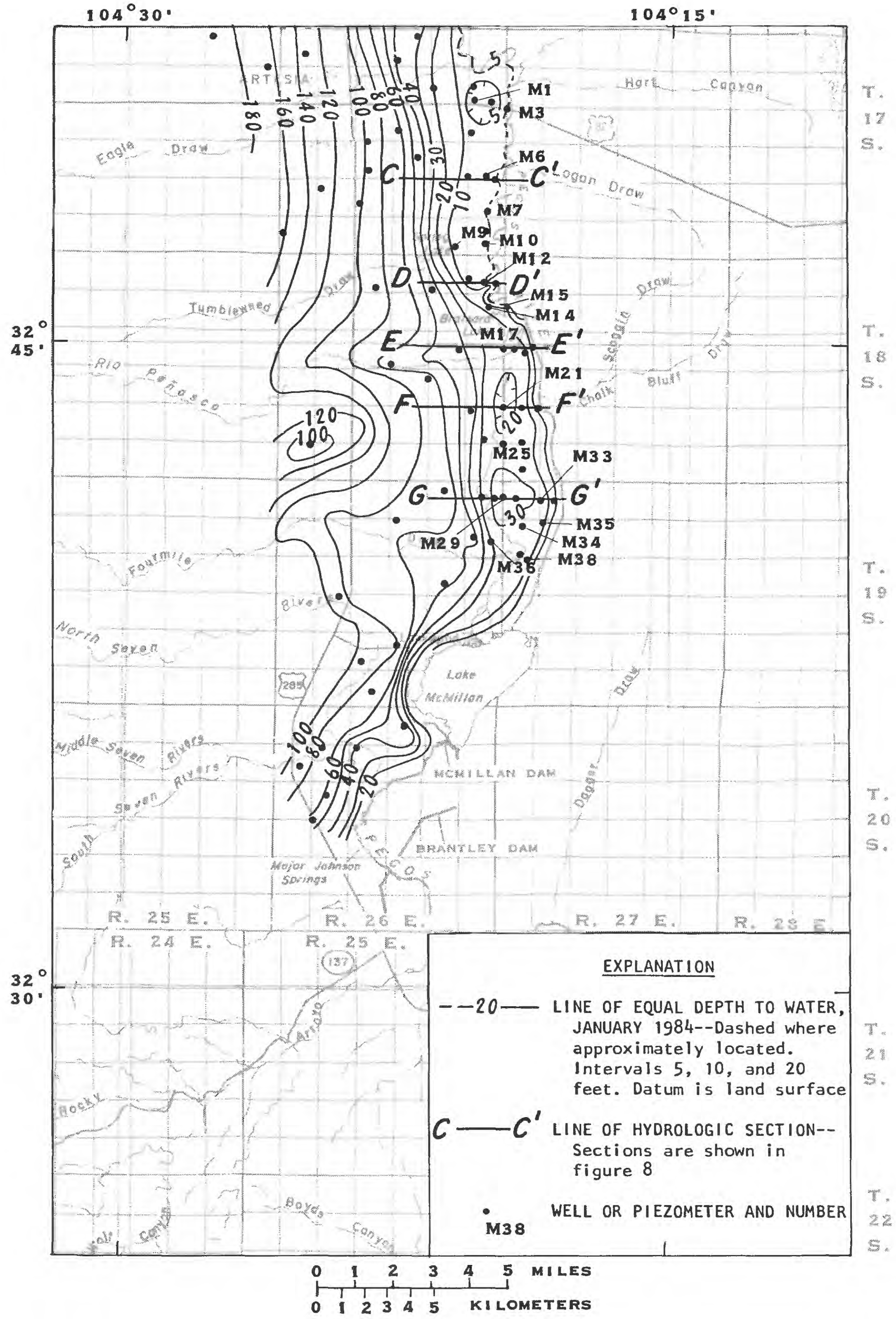


Figure 7.--Depth to water in the shallow aquifer, January 1984.

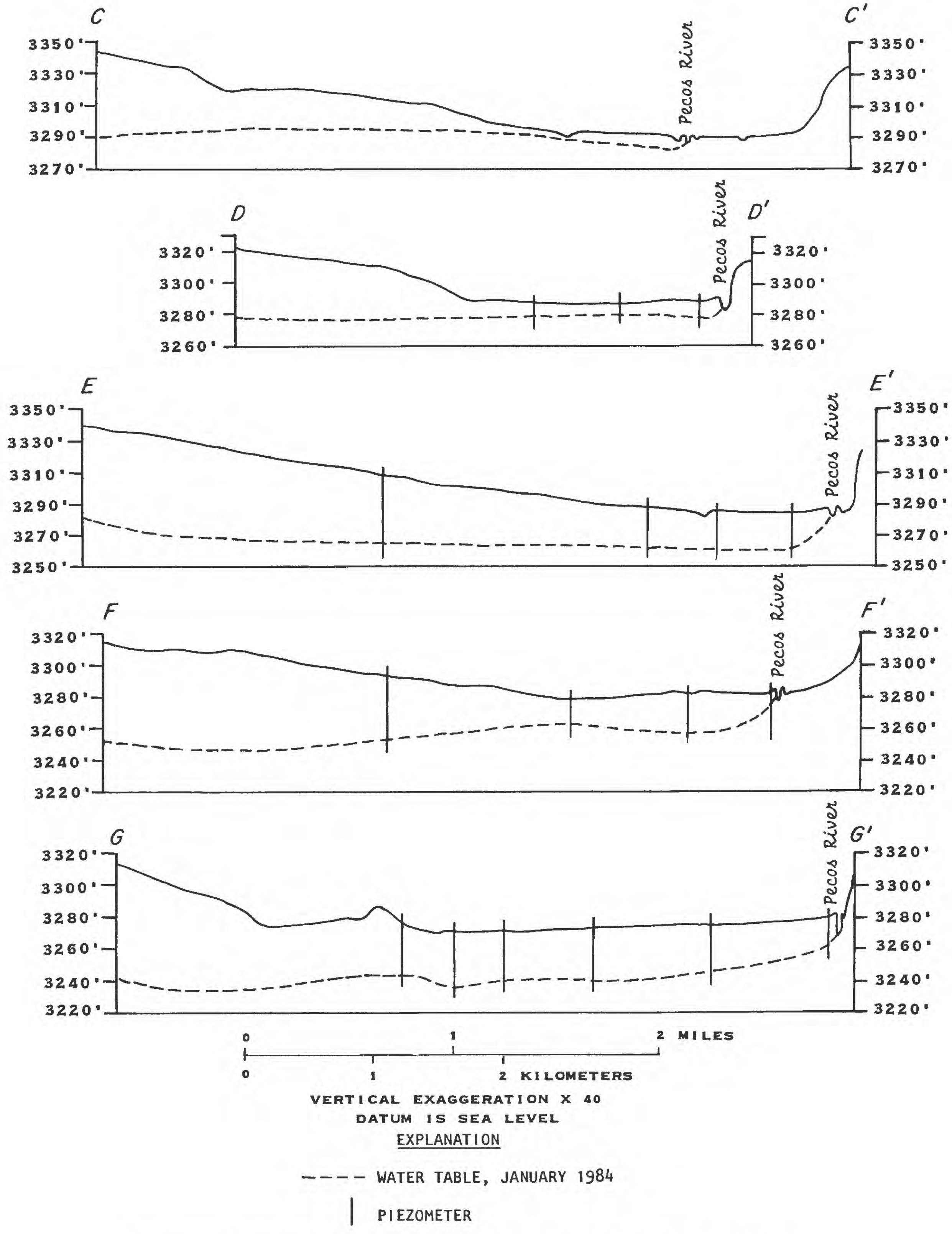


Figure 8.--Hydrologic sections north of Lake McMillan.
See figure 7 for location of sections.

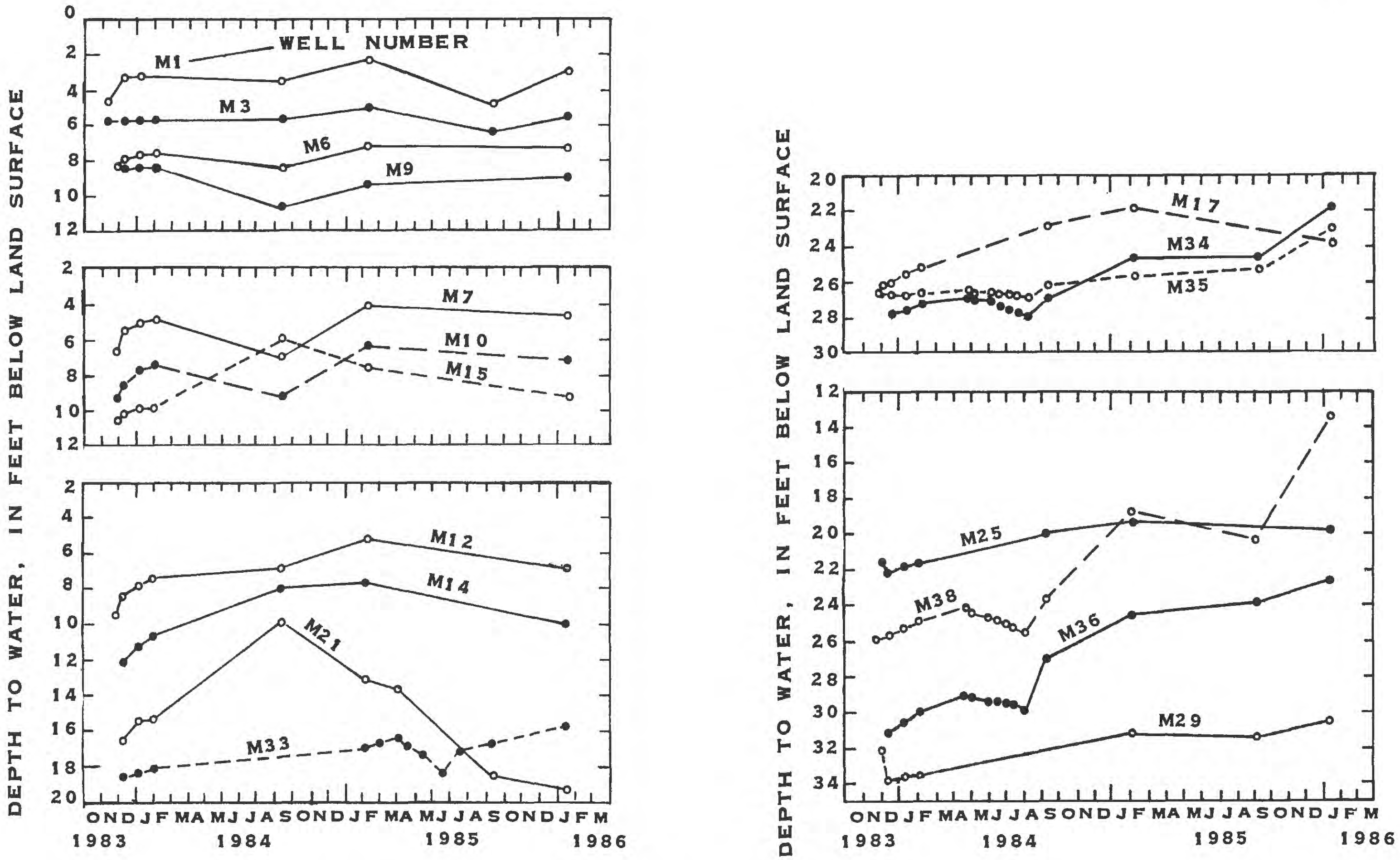


Figure 9.--Water levels in selected wells or piezometers completed in the shallow aquifer along the Pecos River flood plain. See figure 7 for location of wells and piezometers.

SURFACE-WATER HYDROLOGY

The major natural components of the surface-water system in the study area are the Pecos River, a perennial stream; several tributaries that drain the highlands west of the river and that flow in their lower reaches in response to precipitation; and Major Johnson Springs (fig. 10). The major manmade components of the surface-water system are McMillan Dam and Lake McMillan and Brantley Dam and Reservoir.

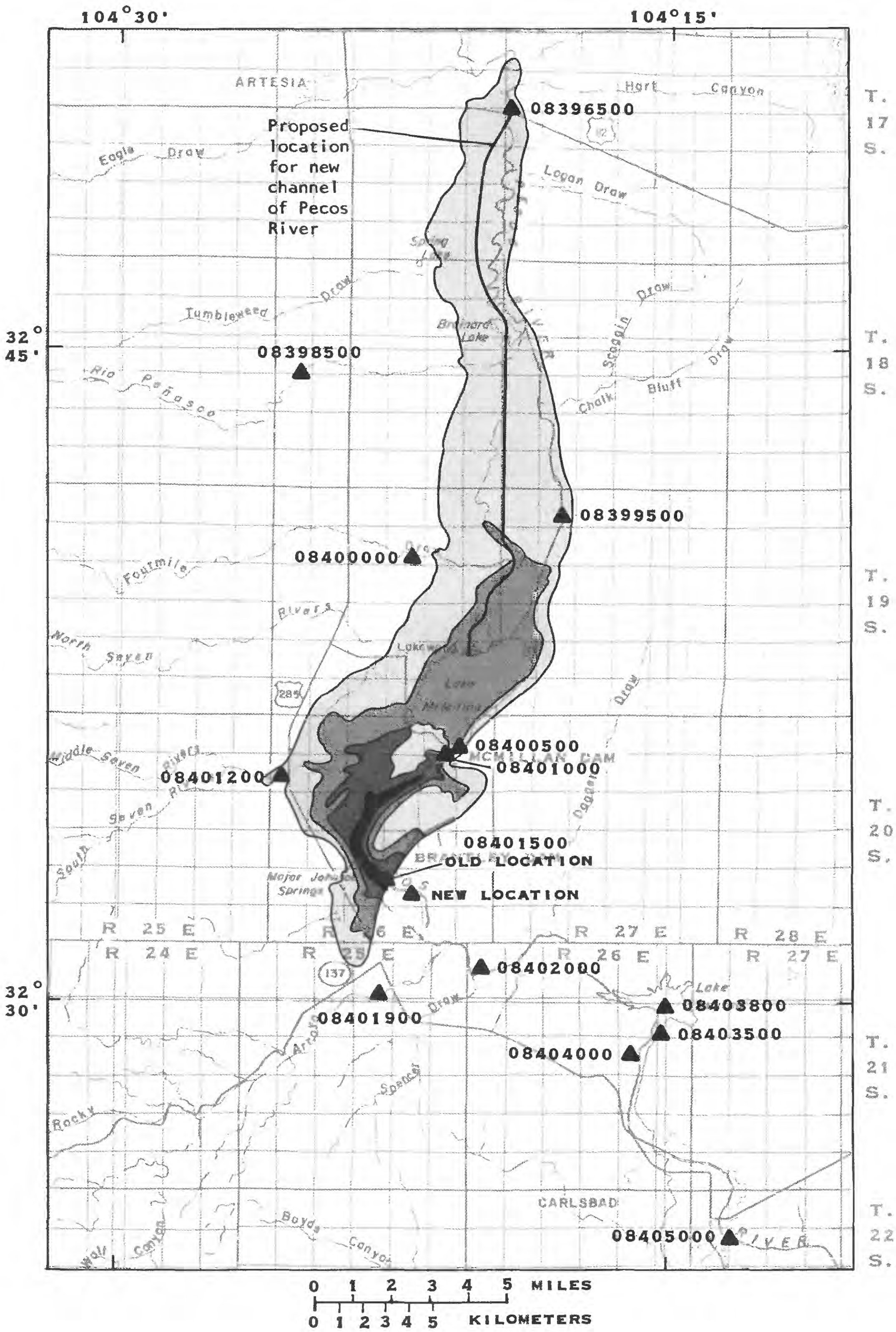
Pecos River and Tributaries

The average annual (calendar year) discharge of the Pecos River at the Artesia streamflow-gaging station (station number 08396500, fig. 10) for 1938-85 is 164,980 acre-feet. The main channel of the Pecos River ranges in width from about 40 to 80 feet and descends 94 feet from an altitude of 3,292 feet at the Artesia streamflow-gaging station to an altitude of 3,198 feet at the old location of the streamflow-gaging station below Major Johnson Springs (08401500). (The station was relocated downstream from Brantley Dam in 1985.) In 1949 and the early 1950's, Kaiser Channel was constructed along the eastern edge of the flood plain for about 9 miles north of Lake McMillan, and most of the river south of Highway 82 was dredged and bordered with dirt levees. These channel improvements reduced overbank flow and resultant loss of water by evapotranspiration in the flood plain to some extent, but the channel cannot contain discharges in excess of about 1,500 cubic feet per second. In several places north of Lake McMillan, the river channel is on or near bedrock (fig. 4), and leakage from the river to the Seven Rivers Formation could be occurring. Elsewhere north of Lake McMillan, the river flows over alluvium, and water seeps directly into the alluvial aquifer. In general the river is a gaining stream through the Roswell Basin downstream to about 3 miles south of Highway 82. The only other place where the stream gains water in the study area is along the 1.5-mile reach upstream from Brantley Dam where Major Johnson Springs flows into the river.

Rio Peñasco and Fourmile Draw are the principal tributaries that discharge water to the flood plain of the Pecos River north of Lake McMillan. North, South, and Middle Seven Rivers join and enter the Pecos River between Major Johnson Springs and McMillan Dam (fig. 10). The discharge from these tributaries and the Pecos River is described in more detail later in this report.

Major Johnson Springs

Major Johnson Springs is a series of springs that issue from the Seven Rivers Formation and the bed of the Pecos River along a 1.5-mile reach in sec. 21, T. 20 S., R. 26 E. (fig. 10). These springs probably are the southernmost discharge point for the Roswell ground-water basin and the main discharge point for the Major Johnson Springs aquifer.


104°30'
104°15'
32° 45'
32° 30'
ARTESIA
Proposed location for new channel of Pecos River
08396500
08398500
08399500
08400000
08400500
08401000
08401200
08401500
OLD LOCATION
NEW LOCATION
08401900
08402000
08403800
08403500
08404000
08405000
MCMILLAN DAM
CARLSBAD
T. 17 S.
T. 18 S.
T. 19 S.
T. 20 S.
T. 21 S.
T. 22 S.
R 25 E
R 24 E
R 26 E
R 25 E
R 27 E
R 26 E
R 28 E
R 27 E
Eagle Draw
Logan Draw
Tumbleweed Draw
Rio Peñasco
Fourmile Draw
North Seven Rivers
Middle Seven Rivers
South Seven Rivers
Chalk Bluff Draw
Scoggin Draw
Hart Canyon
Rocky
Boyds Canyon
Spencer
0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

EXPLANATION

AREAS TO BE COVERED BY BRANTLEY RESERVOIR

Minimum pool
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Initial conservation pool
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Conservation pool after 100 years
(altitude 3,271.0 feet)

Maximum pool
(altitude 3,303.5 feet)

08399500 GAGING STATION AND STATION NUMBER

Figure 10.--Location of gaging stations and new channel of the Pecos River.

W.E. Hale (U.S. Geological Survey, written commun., 1959) estimated that the water from the shallow aquifer north of Major Johnson Springs contributed about 15 cubic feet per second to the springs in 1947, 1948, 1952, and 1954. Cushman (1965, p. 25) assumed that the total base flow of Major Johnson Springs in part of 1957 and 1964 was 10 cubic feet per second. Cushman's estimate included leakage from the Pecos River upstream from the Kaiser Channel gaging station (station number 08399500, fig. 10) and excluded leakage from the Pecos River downstream from the Kaiser Channel streamflow-gaging station and from Lake McMillan. Cox (1967, p. 38) indicated that the average base flow of Major Johnson Springs for 1953-59 was 13 cubic feet per second, of which 5 cubic feet per second was leakage from the Pecos River upstream from the Kaiser Channel gaging station and 8 cubic feet per second was from the shallow aquifer to the north. All of the previous investigators had to contend with losses between Major Johnson Springs and the gaging station at Damsite 3 (08402000), about 3 1/2 miles downstream from the springs (fig. 10).

Two periods when Lake McMillan was dry for a time sufficient to ensure that there was no leakage from the lake to Major Johnson Springs were July 1-31 and October 8-27, 1976. The average discharge from the springs was 11 cubic feet per second in July and 28 cubic feet per second in October. If leakage from the Pecos River between the Artesia gaging station and Lake McMillan was 6 cubic feet per second, the shallow aquifer contributed an average of 5 cubic feet per second to spring flow at Major Johnson Springs during July and 22 cubic feet per second during October. Assuming July represents summer (6-month) conditions and October represents winter (6-month) conditions, the shallow aquifer contributed an average of 13.5 cubic feet per second to Major Johnson Springs flow in 1976. The estimated leakage from the river could be in error because the lag time for travel to the springs and the quantity of water lost to transpiration are not known. Corrections for these unknowns, which would cause a variation in the 1976 discharge of 13.5 cubic feet per second, were not attempted in this study.

Another possible source of Major Johnson Springs water, in addition to water from the shallow aquifer and leakage from the Pecos River and Lake McMillan, could be water from the artesian aquifer through a direct conduit to the Major Johnson Springs aquifer. In January 1975, water levels in wells completed in the artesian aquifer were 0 to 40 feet higher than water levels in wells completed in the shallow aquifer between Artesia and Major Johnson Springs (Welder, 1983, fig. 25). Water-level measurements made in January 1984 indicated that the hydraulic-head difference between the shallow aquifer and the artesian aquifer was about the same as in 1975 and that upward leakage through the confining beds probably was occurring over a large area. The nearest place where an artesian and a shallow well are close together is about 2 miles northwest of the springs. The artesian hydraulic head is about 30 feet higher than the shallow hydraulic head at that point. No wells have been drilled through the Major Johnson Springs aquifer and the upper confining part of the Queen Formation to confirm the presence of the artesian aquifer beneath the springs or to determine hydraulic-head difference between the artesian and shallow aquifers at the springs. Several shallow piezometers have been installed by the U.S. Bureau of Reclamation in the Major Johnson Springs aquifer around the springs. The hydraulic head of the springs probably is close to the head in the Major Johnson Springs aquifer, which ranged from about 3,210 to 3,220 feet in January 1984 (fig. 6). Test-drilling data collected by the U.S. Bureau of Reclamation indicate that the upper part of the Queen Formation has a very small hydraulic conductivity and that the artesian aquifer, if present beneath the springs, may not be directly connected with the springs. These factors do not, however, rule out widespread upward leakage from the artesian aquifer at a relatively slow rate.

McMillan Dam and Lake McMillan

McMillan Dam was constructed in 1893. Because of weaknesses in the dam, it was rehabilitated in 1909. The earthfill dam, which is 57 feet high and 2,114 feet long, created an original reservoir capacity of 90,000 acre-feet (Pecos River Commission, 1961, p. 67). According to Denis, Beal, and Allen (1985, p. 302), the maximum capacity of Lake McMillan without spillage in 1984 was 33,620 acre-feet at a lake surface altitude of 3,267.7 feet, based on a 1964 capacity survey. The capacity of Lake McMillan probably has been further reduced by silt deposition since 1964.

Water in Lake McMillan is perched; at high lake stages, seepage through the bottom of the lake causes large rises in water levels in piezometers in the southern part of McMillan delta. The discharge of Major Johnson Springs fluctuates with the stage of Lake McMillan (Cox, 1967, fig. 5). McMillan Dam will be breached after Brantley Dam is completed, which will tend to eliminate the present perched-water condition of Lake McMillan at least when the stage of Brantley Reservoir is not high enough to inundate the bed of Lake McMillan.

Brantley Dam and Reservoir

The Brantley project is described in the final environmental statement prepared by the U.S. Bureau of Reclamation [1982]. Most of the following details about the dam and reservoir are taken from that report. The primary purpose of the Brantley project is to assure dam safety; additional benefits will be derived from irrigation, flood control, fish and wildlife, and recreation. Brantley Dam will be operated in accordance with the Pecos River Compact and the laws of the States of New Mexico and Texas.

Brantley Dam is a combination earthfill and concrete structure that is 4 miles long and 143.5 feet high. It is located in secs. 14, 22, 23, 27, 28, and 33, T. 20 S., R. 26 E. and sec. 3, T. 21 S., R. 25 E. (figs. 1 and 10), about 12 miles northwest of Carlsbad.

Brantley Reservoir will have a minimum-pool volume of 2,000 acre-feet. Initially the surface area of the minimum pool will be about 260 acres at an altitude of 3,224.5 feet (figs. 1 and 10). After deposition of sediment for 100 years, the minimum pool is expected to have a surface area of about 1,390 acres at an altitude of 3,262 feet.

Brantley Reservoir will have a conservation pool of 40,000 acre-feet for irrigation use to supplement the Carlsbad Irrigation District storage at Lake Avalon, Lake Sumner, and Santa Rosa Lake and to replace storage lost at Lake McMillan. Lake Sumner and Santa Rosa Lake are north of the study area. Initially, the conservation pool (plus 2,000 acre-feet for the minimum pool) will have a surface area of about 3,100 acres at an altitude of 3,255.3 feet (fig. 10). After 100 years, the conservation pool is expected to have a surface area of about 8,600 acres at an altitude of 3,271.0 feet; its shoreline will extend about 3 miles north of the present north shoreline of Lake McMillan (fig. 10).

The total initial controlled reservoir capacity, including storage for the minimum pool, sediment, conservation, and flood control, will be 348,500 acre-feet at an altitude of 3,283.0 feet; the surface area will be about 21,300 acres. At the altitude of the maximum pool (3,303.5 feet), the reservoir shoreline would extend 1.5 miles north of Highway 82 near Artesia (fig. 10).

POTENTIAL HYDROLOGIC EFFECTS OF A DRAINAGE SYSTEM IN MCMILLAN DELTA

The McMillan project proposed by the Bureau of Reclamation included a new channel for the Pecos River and an adjacent cleared floodway. In addition, a system of ground-water drains was considered in the area of shallow ground water in the Pecos River flood plain south of Highway 82 (fig. 7). Ground-water drains might lower the water table in areas where it is shallow enough for gravity drainage to the Pecos River and reduce ground-water use by phreatophytes.

New Channel for Pecos River

The new channel could be designed to carry Pecos River flow and overflow (flow that exceeds the capacity of the existing main Pecos River channel) and the occasional large discharges of the Rio Peñasco and Fourmile Draw. A preliminary location for a new channel is shown in figure 10.

Overflow and Channel Losses from the Pecos River

Parts of the main Pecos River channel between the Artesia and the Kaiser Channel streamflow-gaging stations (08396500 and 08399500, fig. 10) overflow when discharge at the Artesia gaging station exceeds about 1,500 cubic feet per second. Some additional overflow may occur between the Kaiser Channel gaging station and Lake McMillan when flow at that station exceeds 1,500 cubic feet per second. The overflow spreads into numerous shallow channels and ponds across the flood plain, mostly west of the main channel. Some of the overflow may reach Lake McMillan, depending on its magnitude and duration. The remainder evaporates or infiltrates the flood-plain alluvium. The water that infiltrates is either consumed by evapotranspiration or flows into the ground-water trough to the west (fig. 6) and then south to discharge at Major Johnson Springs. Because Pecos River overflow is only partly consumed by evapotranspiration, the amount of overflow exceeds (and, therefore, places an upper limit on) consumption by evapotranspiration from this source. The total overflow can be estimated from gaging-station records assuming, for the purpose of establishing an upper limit of overflow, that all discharge in excess of 1,500 cubic feet per second is overflow.

The discharge records of the Pecos River near Artesia (station 08396500) were analyzed to determine the percentage of average annual discharge that exceeds 1,500 cubic feet per second and other selected discharges (table 1). For example, during water years 1951-63, 10.3 percent of the annual discharge resulted from daily mean discharges that exceeded 2,000 cubic feet per second. Data in table 1 indicate that discharges at rates in excess of 1,500 cubic feet per second have been insignificant in recent years. Discharges in excess of 1,500 cubic feet per second constituted 12.4 percent of the average annual discharge during water years 1951-63, an average of about 18,100 acre-feet per year. These discharges decreased to 2.8 percent of the average annual discharge during water years 1974-83 and to only 0.3 percent during water years 1980-84, only about 300 acre-feet per year. More than 97 percent of Pecos River discharge was carried in the main channel during 1974-83, and about 99.7 percent was carried in the channel during 1980-84.

Table 1. Average annual discharge of the Pecos River near Artesia in excess of selected discharges

Water years	Average annual discharge (acre-feet)	Percentage of annual discharge exceeding specified discharge, in cubic feet per second			
		1,200	1,500	1,800	2,000
1951-63	146,000	14.5	12.4	11.0	10.3
1964-73	110,600	5.7	4.0	2.8	2.2
1974-83	100,900	3.5	2.8	2.2	1.9
1980-84	108,600	.8	.3	.1	.02

Percentages of annual discharge exceeding discharges other than 1,500 cubic feet per second are included in table 1 to show that channel-capacity variation would make only small differences in overflow if discharge characteristics continue as in recent years. During 1974-83, the existing 1,500-cubic-foot-per-second channel overflowed only about 900 acre-feet of water a year more than a 2,000-cubic-foot-per-second channel would have overflowed. During 1980-84, the difference in overflow would have been only about 300 acre-feet per year. If recent flow characteristics continue, only small amounts of overflow would be prevented by increasing the capacity of the main Pecos River channel or by constructing a new channel to augment or replace the existing channel.

Regulation by upstream reservoirs may have changed flow characteristics at the Artesia gaging station. Discharge at this station is regulated by three reservoirs: (1) Lake Sumner, completed in 1939, capacity (1973) 101,600 acre-feet; (2) Two Rivers Reservoir, completed in 1963, capacity (1963) 166,200 acre-feet; and (3) Santa Rosa Lake, completed in 1980, capacity (1980) 447,100 acre-feet.

Another way in which water is lost from the Pecos River is by losses from the main channel. These losses include evaporation from the stream surface and seepage through the channel bed. The estimated average annual evaporation loss from the 17-mile-long main channel of the Pecos River from Artesia to Lake McMillan was about 1 cubic foot per second during 1964-83 based on data provided by the New Mexico Interstate Stream Commission (written commun., 1984). Channel-bed seepage occurs along about 14 miles of the channel from a point about 3 miles south of Highway 82 to the north end of Lake McMillan. Comparison of Pecos River discharge at the streamflow-gaging station near Artesia and at the Kaiser Channel station near Lakewood, which are about 12 miles apart, shows that total channel losses from this reach averaged about

4 cubic feet per second during 1964-83. The estimated total channel losses from the 5-mile reach from the Kaiser Channel gage to Lake McMillan were about 2 cubic feet per second for the same period. Total channel losses within the 17-mile reach from near Artesia to Lake McMillan of about 6 cubic feet per second minus the evaporation loss of 1 cubic foot per second indicate a channel-seepage loss of about 5 cubic feet per second (about 3,600 acre-feet per year) within this reach. This loss is an approximate upper limit of loss to phreatophytes by channel seepage. However, some of this seepage loss moves west into the water-table trough and then southward to Major Johnson Springs, where it discharges back to the Pecos River.

These analyses indicate that conveyance of Pecos River water through the McMillan delta to Brantley Reservoir would be increased about as much by lining the existing channel (an increase of about 3,600 acre-feet per year) as by constructing a larger lined channel. A larger lined channel theoretically would prevent the 3,600-acre-foot-per-year seepage loss and the 300-acre-foot-per-year channel-overflow loss. This estimate does not include tributary inflow and drain-network water, which are described in the following sections.

Flow from Tributaries of the Pecos River

The major tributaries to the Pecos River between Artesia and Brantley Dam are ephemeral streams that carry significant discharges for only short periods after major precipitation events. Most of the inflow in this reach is from the west in the Rio Peñasco, Fourmile Draw, and South Seven Rivers (fig. 10). All three streams are gaged by the U.S. Geological Survey within a few miles of the Pecos River. The only significant ungaged tributary since 1964 is North Seven Rivers. North and South Seven Rivers will flow directly into the initial minimum and conservation pools of Brantley Reservoir; Rio Peñasco and Fourmile Draw will continue to flow onto the Pecos River flood plain (fig. 10). Discharges of these two streams onto the flood plain are disbursed in the same manner as Pecos River overflow, and a drainageway could minimize spreading and infiltration into the flood plain. The average annual discharges of these tributaries provide an estimated upper limit of water consumed by evapotranspiration from this source.

The discharge records of Rio Peñasco at Dayton (08398500) and Fourmile Draw near Lakewood (08400000) (fig. 10) were analyzed to determine discharge characteristics during 1964-83. The Rio Peñasco had an average annual discharge of 3,700 acre-feet and Fourmile Draw averaged 3,363 acre-feet. The Rio Peñasco had flow on 438 days. On 346 of those days, daily mean discharge was 1 cubic foot per second or less, averaged 0.08 cubic foot per second, and totaled only 54 acre-feet. Fourmile Draw had flow on 99 days. On 39 of those days, daily mean discharge was 1 cubic foot per second or less, averaged 0.34 cubic foot per second, and totaled only 26 acre-feet. The 20 largest daily mean discharges for each stream during the 20 years were ranked in order of decreasing magnitude. Some of these discharges, along with cumulative discharge and cumulative percentage of the 20-year total discharge, are shown in table 2. These streams had most of their discharge on only a few days during the 20-year period. The Rio Peñasco had 80 percent of its discharge on only 8 days or 0.11 percent of the time. Fourmile Draw had 80 percent of its discharge on only 5 days or 0.07 percent of the time. Most of the discharge of these streams during these few days occurred at large rates, and some of that discharge probably reached Lake McMillan and would also have reached Brantley Reservoir. The remainder of the discharge either evaporated or infiltrated the flood plain where it was consumed by evapotranspiration or flowed into the ground-water trough and eventually discharged at Major Johnson Springs.

Table 2. Large discharges of Rio Peñasco and Fourmile Draw, 1964-83

	Rio Peñasco (08398500)			Fourmile Draw (08400000)		
		Cumulative discharge			Cumulative discharge	
Rank of daily mean discharges	Daily mean discharge, in acre-feet	Acre-feet	Percentage of 20-year total discharge	Daily mean discharge, in acre-feet	Acre-feet	Percentage of 20-year total discharge
1	18,800	18,800	25.4	25,800	25,800	38.3
2	13,400	32,200	43.5	9,480	35,300	52.5
3	10,300	42,500	57.4	7,280	42,600	63.3
4	6,740	49,200	66.5	6,510	49,100	73.0
5	3,970	53,200	71.9	4,720	53,800	79.9
6	2,520	55,700	75.3	3,970	57,800	85.9
7	1,900	57,600	77.8	1,980	59,700	88.7
8	1,550	59,200	80.0	1,950	61,700	91.7
20	446	67,800	91.6	123	66,100	98.2
99	-	-	-	.02	67,300	100.0
438	.02	74,000	100.0	-	-	-

Approximately 80 percent of the discharge of these two tributaries during 1964-83 occurred at daily mean discharges of 2,000 to 13,000 cubic feet per second. Much of this discharge occurred simultaneously on the two streams at combined daily mean discharges of 3,000 to 22,500 cubic feet per second. Maximum instantaneous discharges were considerably greater, exceeding 29,000 cubic feet per second for each stream on the same day. A channel with a capacity of greater than 20,000 cubic feet per second would be needed to carry most of the combined discharge of the tributaries and the Pecos River.

Estimated Salvage of Water with a New Channel

If all of the overflow and seepage of the main Pecos River channel and all of the discharge of the Rio Peñasco and Fourmile Draw were conveyed to Brantley Reservoir by a large, lined channel, the estimated increase in within-bank flow to the reservoir would be:

Pecos River overflow ....300 acre-feet per year
(1980-84 average)

Pecos River seepage ....3,600 acre-feet per year
(1964-83 average)

Tributary runoff ....7,100 acre-feet per year
(1964-83 average)

Total ....11,000 acre-feet per year

Whereas it might be possible to convey all this water to Brantley Reservoir, not all could be considered as salvage. As used here, salvage is gain of water for beneficial use at the expense of nonbeneficial evapotranspiration. Any part of the Pecos River overflow and tributary discharge that would flow to Brantley Reservoir without a new channel could not be considered as salvage because having reached the reservoir it would remain available for beneficial use. Also, any water that would infiltrate from these sources and flow as ground water to discharge at Major Johnson Springs without a new channel also would reduce the amount of indicated salvage. An estimate of salvageable water from these sources has not been made because sufficient surface- and ground-water data do not exist to allow water-budget estimates. However, it is reasonable to expect that much of the water in question is not lost to nonbeneficial evapotranspiration and therefore is not salvageable.

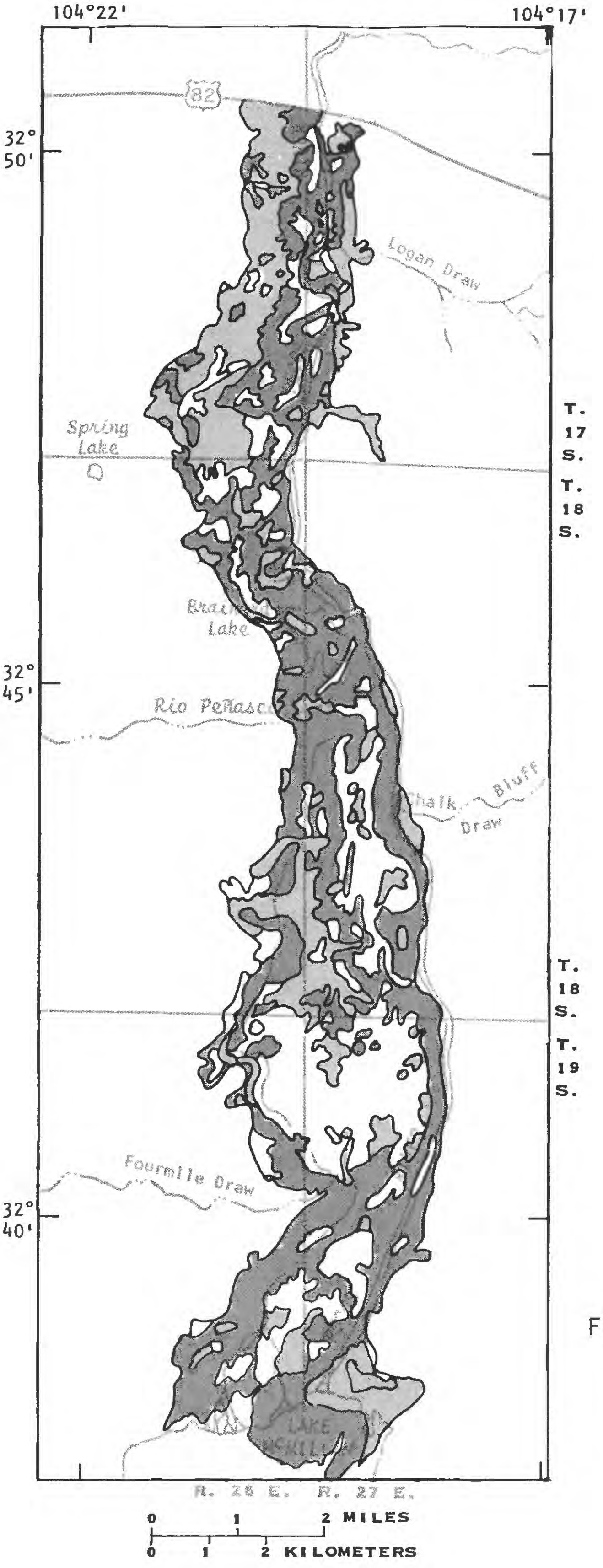
One result of preventing overflow or channel-seepage losses of the Pecos River and tributaries would be to lower ground-water levels, which would diminish the benefit of a ground-water drain system. Lowering of ground-water levels could also have an adverse effect on ground-water users near the west side of the flood plain.

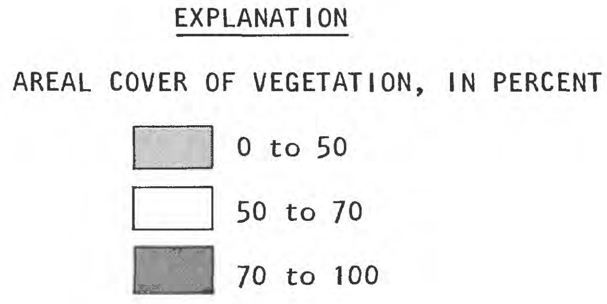
Ground-Water Drains

Ground-water drains could salvage water by lowering the water table and decreasing phreatophyte water use and evaporation (evapotranspiration). The amount of salvage would depend on the initial depth to the water table and the increase in that depth by drainage. The average depth to water in the Pecos River flood plain is about 7 feet in the first 5 miles south of Highway 82 and about 25 feet in the remaining 10 miles to Lake McMillan (fig. 7). The areal cover of vegetation in the McMillan delta and, thus, the areas where evapotranspiration losses may be greatest, are shown in figure 11. A vegetation cover of 56 percent was calculated for the northern 5 miles of the flood plain, an area of 4,056 acres. Water salvage by lowering of the water table is impractical in the remainder of the flood plain to the south where the water table generally is too deep for gravity drainage.

Geohydrologic Factors Related to Drains

The design of a drainage system would be based primarily on soil characteristics, especially particle size and hydraulic conductivity (permeability). Soil samples of flood-plain sediments were taken at 27 boreholes upstream from Lake McMillan (fig. 12). Samples were taken at 1-foot depth intervals or of each significant soil bed, if less than 1 foot thick. The samples were classified by microscopic examination. Representative samples of the finer grained soil groups were analyzed in a U.S. Geological Survey laboratory; results are shown in table 3. The laboratory analyses verify the visual classification of clay and silt and indicate that considerable amounts of clay are present in the silt. The soils in the area where water levels average 7 feet in depth predominantly are silt beds with some clay and sand beds. An expected range of hydraulic conductivity for silt, clay, and mixtures of sand, silt, and clay is provided by the U.S. Water and Power Resources Service (1981, p. 29). The middle of this range provides a hydraulic conductivity for silts of 0.01 foot per day. Freeze and Cherry (1979, p. 29) reported a hydraulic-conductivity range of 0.001 to 13 feet per day for silt and loess. A hydraulic conductivity of about 0.005 foot per day, near the smaller end of this range, probably is more appropriate. However, these values probably are less than the average for the silt at depths that would be drained. Larger hydraulic conductivities are indicated by rapid recoveries of water levels in test holes at completion of augering, perhaps due to large secondary permeabilities caused by burrows or fractures in the soils. Additional soils analyses would be required to design a drainage system for specific localities in the flood plain.





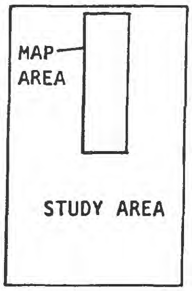
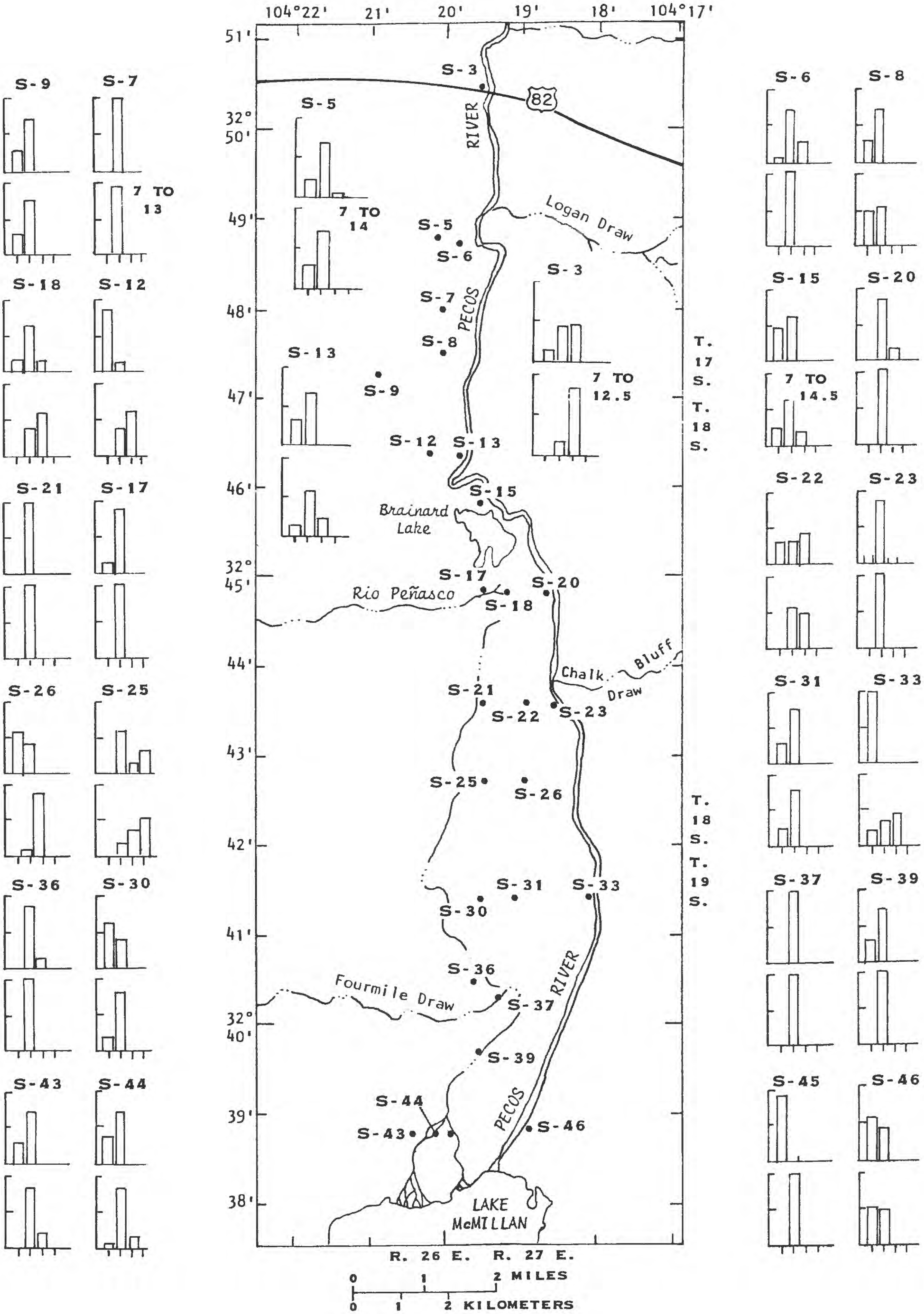


Figure 11.--Areal cover of vegetation, in percent, north of Lake McMillan on Pecos River flood plain.


104°22'
21'
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32° 50'
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43'
42'
41'
32° 40'
39'
38'
82
RIVER
PECOS
Logan Draw
Brainard Lake
Rio Peñasco
Chalk Bluff Draw
Fourmile Draw
LAKE McMILLAN
T. 17 S.
T. 18 S.
T. 19 S.
R. 26 E.
R. 27 E.
0 1 2 MILES
0 1 2 KILOMETERS
S-3
S-5
S-6
S-7
S-8
S-9
S-12
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S-43
S-44
S-45
S-46
7 TO 13
7 TO 14
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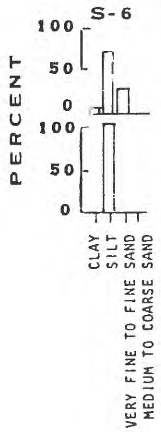
7 TO 14.5

EXPLANATION

S-5• SOIL-TEST BOREHOLE AND NUMBER

SOIL GRAIN-SIZE GRAPH:



BOREHOLE NUMBER

GRAPH FOR 0- to 7-FOOT DEPTH INTERVAL

GRAPH FOR 7- to 15-FOOT DEPTH INTERVAL OR 7 FEET TO DEPTH INDICATED

GRAIN-SIZE CLASSES

Class	Size, in millimeters*
Clay	Less than 0.004
Silt	0.004 to 0.062
Very fine to fine sand	0.062 to 0.25
Medium to coarse sand	0.25 to 1.0

*To convert millimeters to inches, multiply by 0.03937

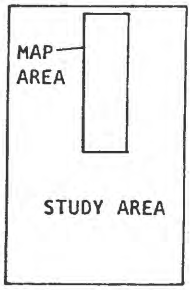


Figure 12.--Soil grain size of flood-plain sediments north of Lake McMillan.

Table 3. Particle-size analyses of representative soil samples of Pecos River flood-plain alluvium

Class name	Size range (millimeters[1])	Classification: Coarse silt (percent)	Fine silt (percent)	Heavy clay (percent)
Gravel	>2.0	1.9	0.3	-
Medium to very coarse sand	0.25 - 2.0	0.7	0.5	-
Very fine to fine sand	0.062 - 0.25	27.3	10.9	0.1
Medium to coarse silt	0.016 - 0.062	47.6	36.3	3.6
Very fine to fine silt	0.0039 - 0.016	3.9	19.4	18.6
Coarse clay	0.0020 - 0.0039	2.8	9.8	72.2
Very fine to medium clay	<0.0020	15.8	22.8	5.5

[1] To convert millimeters to inches, multiply by 0.03937.

A drain network that would lower the water table an average of 5 feet would need to have a drainage base level somewhat lower than the new average water level (fig. 13). The January 1984 water table (fig. 6) slopes from an altitude of about 3,300 feet at Highway 82 to about 3,280 feet 5 miles to the south. If drain levels needed to be 8 feet lower than the present water table, for example, the water would have to be channeled 6 to 8 miles to the south to provide gravity flow into the existing Pecos River channel or a new channel.

Estimated Salvage of Water with Drains

A ground-water drain network, whether of a few deep channels or more numerous shallow channels, would recover a volume of water that would depend on the specific yield, average water-level decline, and area over which the decline would occur. Average specific yield of six wells from Artesia to Lake McMillan (Cox and Havens, 1974, p. E14) was 0.32. The area that is practical in which to install drains covers about 6 square miles. If the average water-table decline were 5 feet, approximately 6,100 acre-feet of water would be recovered. This amount probably would be recovered within the first few months to years after the drainage network was installed, depending on the average hydraulic conductivity of the sediments and spacing of the drains. Once equilibrium was reached, average recovery would be considerably less than during the initial period.

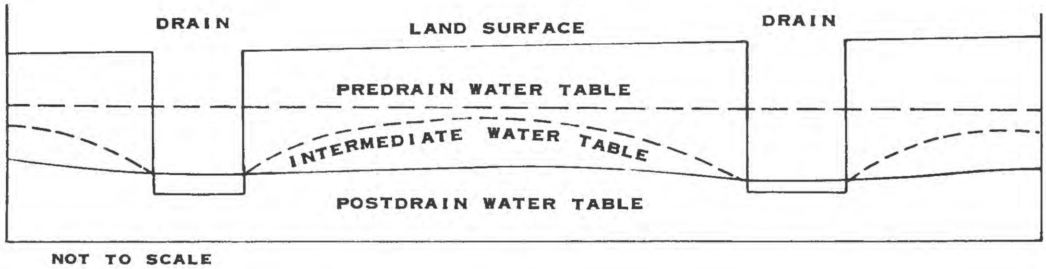


Figure 13.--Schematic diagram of effect of drains on water table.

POTENTIAL HYDROLOGIC EFFECTS OF WATER IMPOUNDMENT IN BRANTLEY RESERVOIR ON AQUIFERS AND SPRINGS

The average quantity of water impounded in Brantley Reservoir probably will exceed the average quantity of water stored in Lake McMillan because the capacity of Lake McMillan is relatively small. In time, sediment accumulation in Brantley Reservoir will raise and increase the area of any given storage pool and extend the pool northward. Initially, breaching of McMillan Dam will shift recharge to the shallow aquifer from the leaky bed of Lake McMillan southward toward Brantley Dam. During the first years after Brantley Dam is completed, water in the conservation pool will reach only to McMillan Dam. Floods, however, could cause the shoreline temporarily to move north past Lake McMillan. Seepage to the water table during floods will recharge the shallow aquifer and cause the water table to rise.

The natural southern outlet of the ground-water system at Major Johnson Springs will be eliminated as the hydraulic head of the springs is exceeded by higher reservoir heads. The southern part of the ground-water trough (fig. 6) will tend to fill up. Water probably will flow quickly in and out of the Major Johnson Springs aquifer as water is impounded and released as a part of the bank storage of Brantley Reservoir.

Shallow Aquifer

Leakage from the reservoir to the shallow aquifer can occur through pore spaces between grains of silt, sand, and gravel in the aquifer; desiccation cracks in the silt and clay; animal burrows; sinkholes; and permeable zones in the Seven Rivers Formation. Leakage is possible from the reservoir for any stage higher than about 3,210 feet. The initial conservation-pool level (altitude 3,255.3 feet) will provide a hydraulic head that tends to cause filling of the unsaturated part of the aquifer to a level of about the 3,255-foot water-level contour (fig. 14). At that level, the aquifer beneath an area of 30 to 35 square miles could be recharged. At higher reservoir levels, more of the aquifer could be recharged. Another source of recharge to the aquifer will be ground water flowing from areas of higher hydraulic head in the aquifer to the north and west, which will no longer be able to discharge (or will discharge more slowly) at Major Johnson Springs.

Water-level declines in the alluvial aquifer from 1938 to 1975 ranged from 0 to 90 feet in the study area (Welder, 1983, fig. 21). The greatest declines occurred 5 to 6 miles west of the Pecos River in the areas where irrigation withdrawals were greatest. The dewatered part of the alluvial aquifer acts as a receptacle, a part of which will tend to be refilled as reservoir levels result in conditions for recharging the aquifer.

The actual amount of leakage to the alluvial aquifer will depend on the time that the reservoir level remains at various altitudes. If the reservoir level is lowered to less than that of the prior recharge level in the aquifer, water will then tend to discharge from the aquifer. Some of the recharge water in the aquifer, however, will tend to continue to flow away from the reservoir and not have time to discharge before the reservoir level is raised again. Thus, the long-term effect will be to increase ground-water storage in the alluvial aquifer.

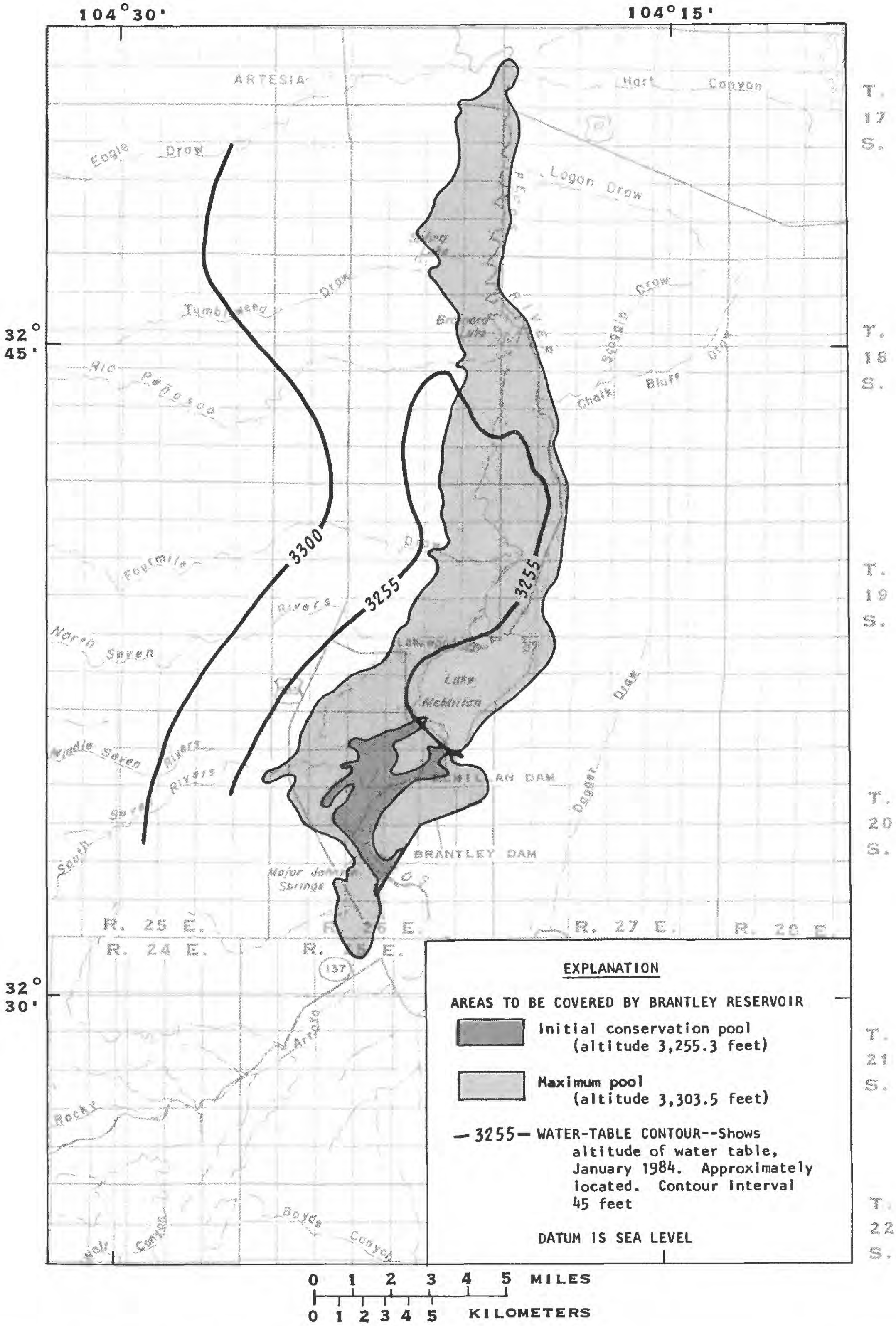


Figure 14.--Relation of Brantley Reservoir levels to water-table contours in the shallow aquifer.

Ground-water withdrawals from the shallow aquifer for irrigation will decrease as a result of agricultural land being retired within the Brantley Reservoir area. This decrease probably will cause either a slowing in the rate of decline in or a rise in the water table in the shallow aquifer.

The potential effects of water impoundment in Brantley Reservoir on the Major Johnson Springs aquifer are somewhat similar to the potential effects on the alluvial aquifer. Water levels in the adjacent aquifers will tend to rise to the level of the reservoir. Shifting of the reservoir pool southward from Lake McMillan will place reservoir water directly in contact with very permeable rocks of the Major Johnson Springs aquifer. Water will flow into that aquifer and the alluvial aquifer to the north. When the reservoir level is decreased, some water will flow back out of the aquifer at a rate that depends on aquifer characteristics and operation of the reservoir. G.I. Haskett (U.S. Bureau of Reclamation, written commun., 1984) indicated that the present southeastward leakage of 4 cubic feet per second from the Major Johnson Springs aquifer would increase to 7.2 cubic feet per second when the initial conservation-pool altitude is 3,255.3 feet.

It is probable that more than 42,000 acre-feet (the combined capacities of the minimum and conservation pools) of water will be stored and released between altitudes of 3,210 and 3,255.3 feet because of the large permeability and large storage capacity of the Major Johnson Springs aquifer. Assuming that 24 of the 32 square miles of the Major Johnson Springs aquifer are under water-table conditions and that on the average 16 square miles have a 45-foot thickness of unsaturated permeable rock that would be saturated when the reservoir level rises from 3,210 to 3,255.3 feet, it is expected that large amounts of water would tend to drain into the Major Johnson Springs aquifer from the initial conservation pool. The time and quantity of water involved in this inflow-outflow process are unknown because of the complexity of the hydrologic system. The best way to determine the potential effects of impounding water in Brantley Reservoir is through a comprehensive monitoring system.

Artesian Aquifer

As water levels and hydraulic heads in the shallow aquifer rise, upward leakage from the artesian aquifer will decrease. Where the shallow-aquifer hydraulic heads become higher than the artesian-aquifer hydraulic heads, downward leakage will occur. The long-term effects of water impoundment in Brantley Reservoir on the artesian aquifer will be to increase ground-water storage in the aquifer.

Major Johnson Springs

The impoundment of water in Brantley Reservoir at the minimum-pool level (altitude 3,224.5 feet) will reduce or stop the flow of Major Johnson Springs. The initial conservation-pool level (altitude 3,255.3 feet) very likely will stop the springs from flowing, which would eliminate the spring-flow contribution to the Pecos River and increase storage in the shallow aquifer.

HYDROLOGIC MONITORING NETWORK

A monitoring network in the Brantley Reservoir area is needed to determine changes in ground-water storage and surface-water discharge that might occur due to impoundment of water and construction of a drainage system. Existing wells and gaging stations will provide many of the network requirements.

Ground Water

To monitor ground-water-level changes that might occur as a result of Brantley Reservoir, a network could consist of wells where water levels are measured periodically and selected wells where water levels are recorded continuously. The network would monitor water levels in the artesian aquifer, the alluvial aquifer, the Major Johnson Springs aquifer, and the areas southeast of the possible leakage conduits under Brantley Dam. The U.S. Bureau of Reclamation has numerous observation wells completed in the Major Johnson Springs aquifer and to the southeast that are suitable for monitoring water levels. Wells and piezometers to the north in which water levels have been measured periodically before and during this study are shown in figure 15. The following monitoring of wells north of the Bureau of Reclamation's observation-well network might be considered:

1. Measure water levels in all wells and piezometers in T. 19 S. and southward (fig. 15) each January prior to the first major storage in Brantley Reservoir and within 1 month prior to initiation of that storage. Measure water levels in five or six selected piezometers north of T. 19 S. at the same intervals.

2. Operate two continuous water-level recorders in wells completed in the alluvial aquifer and two in wells completed in the artesian aquifer as indicated in figure 15.

3. During the first major storage and release cycle in Brantley Reservoir, measure water levels in the above wells as frequently as required to record significant changes in ground-water storage in affected areas. Frequency of measurement needs to be based on changes in water levels measured in the wells equipped with continuous recorders.

4. Measure additional water levels in wells north of T. 19 S. if significant water-level changes are measured in the area during the first storage and release cycle.

5. Monitor subsequent storage and release cycles on the basis of the nature of the response of the aquifers during the first cycle.

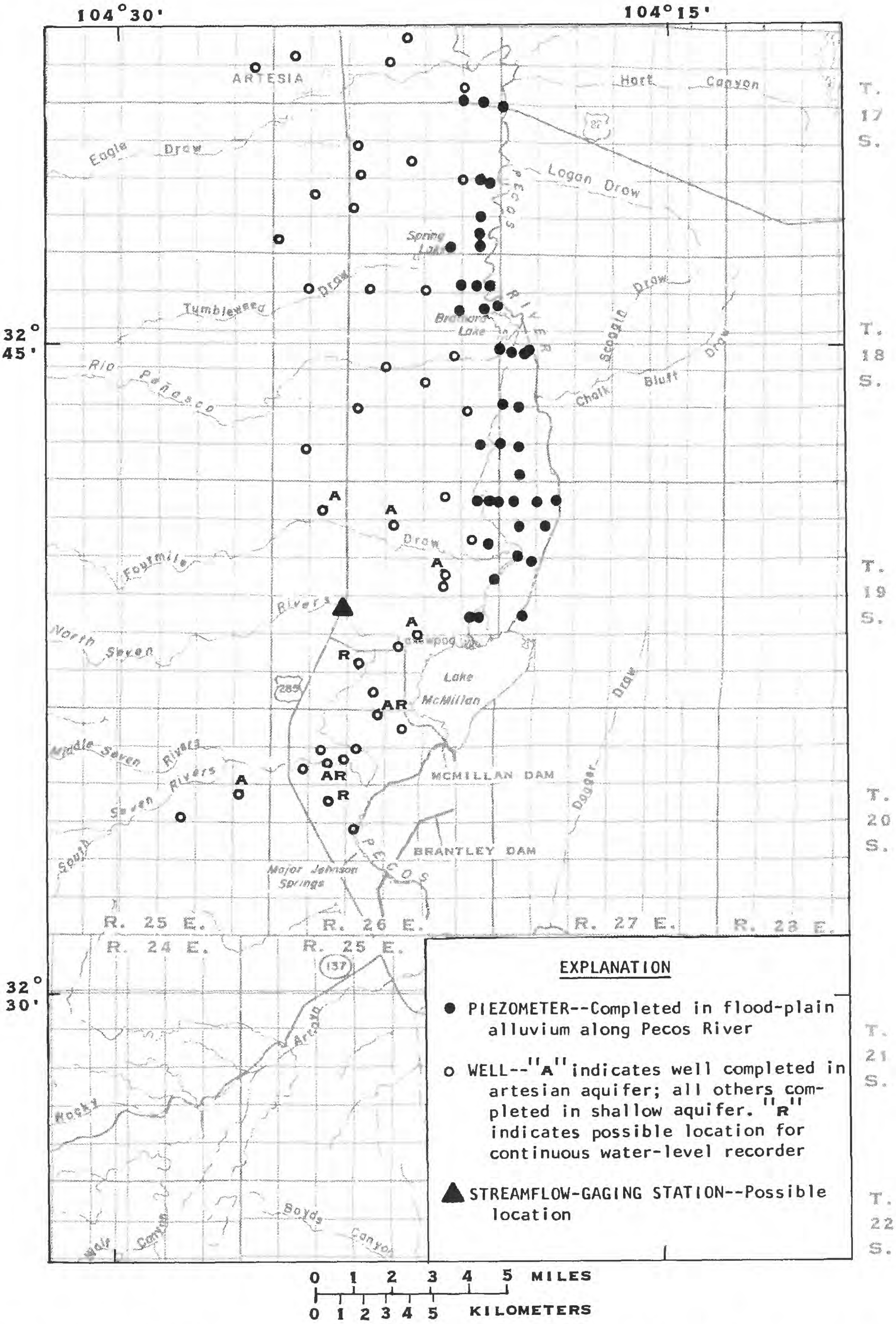


Figure 15.--Possible ground- and surface-water monitoring network. See figure 10 for location of existing surface-water gaging stations.

Surface Water

To monitor changes in discharge that might occur as a result of Brantley Reservoir, the following actions might be considered:

1. Continue stream gaging at existing stations shown in figure 10 and listed in table 4. The Pecos River gaging station below McMillan Dam (08401000) and the Lake McMillan stage gage (08400500) will be abandoned upon transfer of Lake McMillan storage to Brantley Reservoir.

2. Establish a continuous-record gaging station on North Seven Rivers in the near future (fig. 15).

3. If a new channel is constructed, install a continuous-record gaging station near its mouth at the Brantley Reservoir conservation pool.

4. If a network of ground-water drains is constructed, install a continuous-record gaging station near the network's mouth.

5. Monitor precipitation and evaporation in the vicinity of Brantley Dam.

6. Make frequent silt surveys of Brantley Reservoir in the first few years of operation in order to determine the rate of sedimentation.

7. Collect water samples for chemical and suspended-sediment analysis downstream from Brantley Dam each quarter until a more appropriate collection schedule can be determined.

Table 4. Existing streamflow-gaging stations and lake stage-gaging stations

Station name	Station number
Pecos River near Artesia	08396500
Rio Peñasco at Dayton	08398500
Pecos River (Kaiser Channel) near Lakewood	08399500
Fourmile Draw near Lakewood	08400000
Lake McMillan near Lakewood	08400500
Pecos River below McMillan Dam	08401000
South Seven Rivers near Lakewood	08401200
Pecos River below Major Johnson Springs near Carlsbad	08401500
Rocky Arroyo at highway bridge, near Carlsbad	08401900
Pecos River at Damsite 3, near Carlsbad	08402000
Carlsbad Main Canal at head, near Carlsbad	08403500
Lake Avalon near Carlsbad	08403800
Pecos River below Avalon Dam	08404000
Pecos River at Carlsbad	08405000

Reference: Denis, Beal, and Allen (1985, p. 290-317).

SUMMARY AND CONCLUSIONS

Potential hydrologic effects of a proposed drainage system in the McMillan delta and of water impoundment by Brantley Dam were studied from 1983 to 1986 by the U.S. Geological Survey in cooperation with the U.S. Bureau of Reclamation. The drainage system in McMillan delta considered by the U.S. Bureau of Reclamation consists of a new Pecos River channel and adjacent cleared floodway from Highway 82 east of Artesia to Lake McMillan and a network of ground-water drains in the shallow water-table zone in the northern part of the maximum Brantley Reservoir pool area. The drainage system would be underlain by terrace and deltaic deposits in the Pecos River flood plain. These deposits overlie and are in hydraulic connection with the shallow aquifer of the Roswell ground-water basin. The shallow aquifer consists of alluvial deposits north of the vicinity of Major Johnson Springs (referred to as the alluvial aquifer) and bedrock deposits in the vicinity of Brantley Dam (referred to as the Major Johnson Springs aquifer). The shallow aquifer is separated from a deep artesian carbonate aquifer by leaky bedrock confining beds.

Ground-water flow in the alluvial aquifer in the study area is toward an elongate trough west of the Pecos River that extends south from Artesia to Major Johnson Springs. Flow in the Major Johnson Springs aquifer is to Major Johnson Springs and possibly southward through several locally permeable zones in a relatively impermeable carbonate facies that generally impedes southward ground-water flow. The Major Johnson Springs aquifer extends only to the facies change in the lower member of the Seven Rivers Formation from evaporite to carbonate lithology a short distance southeast of Brantley Dam and is confined by the upper part of the carbonate facies beneath the damsite.

Conclusions regarding the construction and potential hydrologic effects of the proposed drainage system are:

1. If discharge characteristics of the Pecos River, Rio Peñasco, and Fourmile Draw continue as in recent years, an average annual discharge of about 7,400 acre-feet onto the Pecos River flood plain between Artesia and Brantley could occur. Combined instantaneous discharges in excess of 30,000 cubic feet per second are likely to occur, and much larger discharges are possible. A new channel of sufficient capacity could convey part of this discharge directly to the reservoir. The two tributaries contributed 7,100 acre-feet of the overflow. During 1964-83, the Rio Peñasco had 80 percent of its total discharge on only 8 days and Fourmile Draw had 80 percent of its total discharge on only 5 days.

2. Annually, about 3,600 acre-feet of water has been seeping from the Pecos River bed between Artesia and Lake McMillan. This seepage loss could be prevented by a new lined channel or by lining the existing channel. Only water that would evaporate or be consumed by nonbeneficial phreatophytes could be considered as salvage.

3. Not all of the 11,000 acre-feet per year that could be attributed to the new channel would be salvaged because:

   a. Some overflow onto the flood plain would flow to Brantley Reservoir even without the new channel.

   b. Some water that would infiltrate the ground would flow to Major Johnson Springs. If the springs cease to flow as a result of Brantley Reservoir storage, this infiltration would then increase ground-water storage.

4. If siltation in Brantley Reservoir raises the conservation-pool altitude to 3,271 feet, Fourmile Draw will flow directly into the pool, and the lower part of a new channel will become unnecessary.

5. Construction of a new channel would lower water levels under the flood plain by eliminating the infiltration that results from overflows from the Pecos River and inflow from the tributaries to the west. Lining of the new channel or the existing Pecos River channel also would lower water levels by eliminating infiltration through the channel bed.

6. A network of ground-water drains could be constructed to lower water levels in a 6-square-mile area of the Pecos River flood plain immediately south of Highway 82. Ground-water levels could be lowered by drainage canals that are deeper than the present water table, which averages about 7 feet below land surface. The depth and spacing of such canals would be determined by detailed soils and hydrologic analyses. A 5-foot decline in ground-water level by drainage canals over a 6-square-mile area would yield about 6,100 acre-feet of water within the first few years. The drains would need to extend 6 to 8 miles to the south to ensure drainage of this much water. After ground-water levels declined, the yield would be considerably less than during the initial period.

Conclusions regarding the potential hydrologic effects of water impoundment in Brantley Reservoir on aquifers and springs are:

1. Potential for leakage from Brantley Reservoir to the alluvial aquifer for any reservoir level greater than about 3,210 feet is possible. At the initial conservation-pool altitude of 3,255.3 feet, about 30 to 35 square miles of the alluvial aquifer will be subject to receiving potential recharge. Part of the aquifer dewatered by irrigation withdrawals from 1938 to 1975 probably would resaturate when reservoir levels are sufficiently raised.

2. The effect of water impoundment in Brantley Reservoir on the Major Johnson Springs aquifer will be to raise water levels, increase ground-water storage quickly, and increase possible leakage from the aquifer to the southeast. It probably will require more than 42,000 acre-feet of water to fill the conservation pool because of the large storage capacity of the Major Johnson Springs aquifer. Assuming that 24 of the 32 square miles of the aquifer are under water-table conditions and that 16 square miles have a 45-foot thickness of unsaturated aquifer that would be saturated when the reservoir altitude rises from 3,210 to 3,255.3 feet, it is expected that large amounts of water would recharge the aquifer at the initial conservation-pool level.

3. The long-term effect of water impoundment on the artesian aquifer will be to increase storage in the aquifer.

4. The impoundment of water at the initial conservation-pool altitude of 3,255.3 feet probably will stop spring flow at Major Johnson Springs. The spring flow, which now contributes to the flow of the Pecos River, has averaged about 13.5 cubic feet per second in recent years. Upon cessation of the spring flow, this water will accumulate as ground-water storage in the shallow aquifer (though not necessarily accumulating at a rate of 13.5 cubic feet per second).

A ground- and surface-water monitoring network is needed to determine changes in ground-water storage caused by changes in Brantley Reservoir stages and changes in surface-water inflow and outflow. Ground-water levels can be monitored by periodically measuring water levels in existing wells or by installing recorders on selected wells in the alluvial, Major Johnson Springs, and artesian aquifers. Selected wells could be monitored annually until 1 month before the first major storage and release cycle in Brantley Reservoir, then more frequently during that cycle. The ground-water monitoring network may need to be expanded if water levels in measured wells indicate that significant changes in water levels may be extending to areas beyond those wells.

The existing surface-water gaging network could be continued. A few of the existing gaging stations will be abandoned upon transfer of Lake McMillan storage to Brantley Reservoir. A gaging station on North Seven Rivers could provide needed data. Evaporation and precipitation measurements near Brantley Dam and quarterly water-quality analyses of the Pecos River downstream from Brantley Dam also would be useful.

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