FLOOD AND RECHARGE RELATIONSHIPS OF THE LOWER RIO PUERCO, NEW MEXICO

by

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Submitted for partial completion of the requirements for a Masters degree in Geoscience with specialization in Hydrology

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July 15, 1983

ABSTRACT

The Rio Puerco, largest tributary of the Rio Grande in New Mexico, drains a watershed area of 7,350 mi^2 (19,040 km^2) in the northwest quadrant of the state. Field work performed in 1982 and 1983 on the river's lower reach between the mouth of the Rio San Jose and Bernardo, New Mexico, has shown that the complex interrelationships between flood discharge, climate, vegetation and geology, and their effects on channel hydrology and infiltration, have changed during the last 50 years. Since the phreatophyte saltcedar (Tamarix sp.) was introduced in 1927 the channel has narrowed, the inner floodplain has developed, the streambed has aggraded and floods are smaller and more frequent in the 31 mile (50 km) reach between Rio Puerco and Bernardo, New Mexico.

Auger-hole drilling in the Rio Puerco valley west of Belen, New Mexico revealed that the valley fill of late Pleistocene to Holocene age is more than 135.8 ft (41.4 m) thick, that the recent channel alluvium along the channel of 1929 is as much as 20 ft (6 m) thick and that a perched zone of saturation exists below the channel.

Hydraulic conductivities of 23 channel sand samples range from 7.4 ft/day (2.25 m/day) to nearly 109 ft/day (33 m/day) in sediments with total silt and clay contents of less than 22 percent.

Monitoring of piezometers placed across the channel from July, 1982 to June, 1983 has demonstrated that the elevation and growth rate of the perched water table are functions involving several variables, including discharge, hydraulic conductivity, phreatophyte activity and the thickness and continuity of clay beds beneath the channel. Over the period of record, this water table rose more than 7.4 ft (2.25 m) despite variable and intermittent discharge.

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ACKNOWLEDGMENT

Early drafts of this paper were reviewed by John W. Hawley and David W. Love of the New Mexico Bureau of Mines and Mineral Resources, and by Alison C. Simcox and Gerardo W. Gross of the New Mexico Institute of Mining and Technology. Their comments and assistance are greatly appreciated. I am also indebted to John P. Borland and Emilio Pargas of the U. S. Geological Survey for hydrographic and discharge information about the Rio Puerco and to the Huning Land Trust for permission to work on their property. Funds for this study were supplied by the New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico.

PURPOSE OF STUDY

The major purpose of this study is to determine the effects of floods, climate, vegetation and geology on channel hydrology and infiltration in the lower Rio Puerco basin in central New Mexico. Subsidiary objectives were the geologic description of the valley fill and recent channel alluvium at a site 7 miles (11.3 km) west of Belen, New Mexico, the determination of the present elevation of the regional water table in the Rio Puerco valley, the detailed surveying of two cross-sections at Popalito meander in Valencia County and photographic documentation of sedimentary and hydrologic features of the Rio Puerco arroyo.

INTRODUCTION

The Rio Puerco, largest of the New Mexico tributaries to the Rio Grande, drains a watershed area of 7,350 mi^2 (19,040 km^2) in the northwest quadrant of the state (fig. 1). This region includes parts of the Colorado Plateau, Basin and Range, and Southern Rocky Mountain physiographic provinces. From its source 10,500 ft (3,200 m) above sea level in Sandoval County, the Rio Puerco flows southward for about 170 river miles (274 km) through a varied landscape of steep canyons, narrow alluvial valleys and sloping mesas to join the Rio Grande near the community of Bernardo. Results of a study of the lower Rio Puerco extending from the mouth of the Rio San Jose southward to the confluence of the Rio Puerco and the Rio Grande at Bernardo, New Mexico are presented in this paper. Work was concentrated in southern Valencia County in the Rio Puerco segment extending from New Mexico Highway 6 to the Socorro County line (fig. 1b).

The gradient of the Rio Puerco is about 78 ft/mile (14.8 m/km) in the reach above the confluence with Arroyo Chico, 13 ft/mile (2.5 m/km) to the confluence with the Rio San Jose and about 8 ft/mile (1 m/km) to its mouth at the Rio Grande (fig. 2). Annual precipitation in its basin ranges from an average of 7 inches (180 mm) in the lower elevations to over 17 inches (430 mm) in the mountainous areas. Much of the rainfall, which occurs as a result of convective thunderstorms from July through October, produces rapid runoff, flash flooding and severe erosion. The river

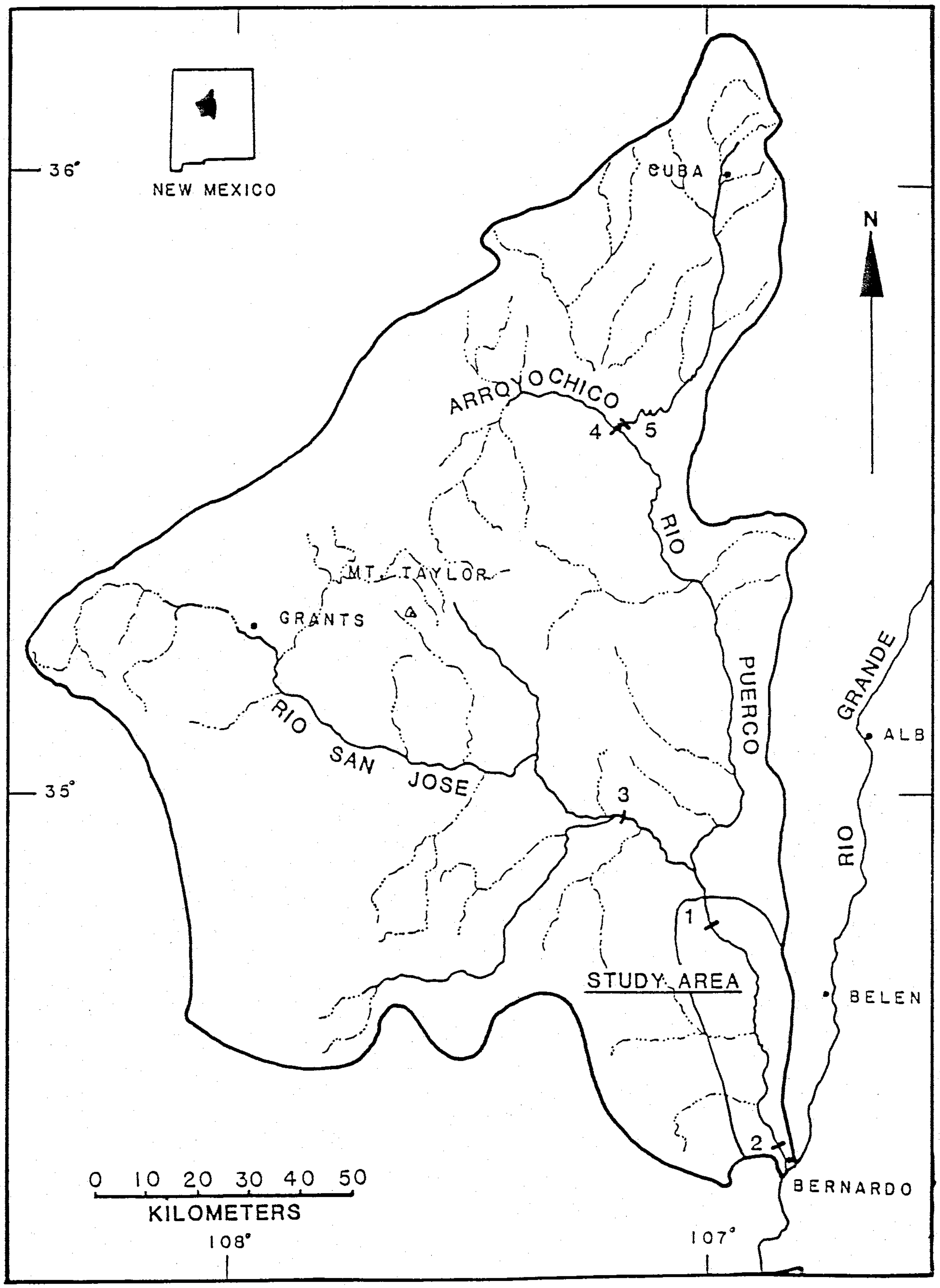
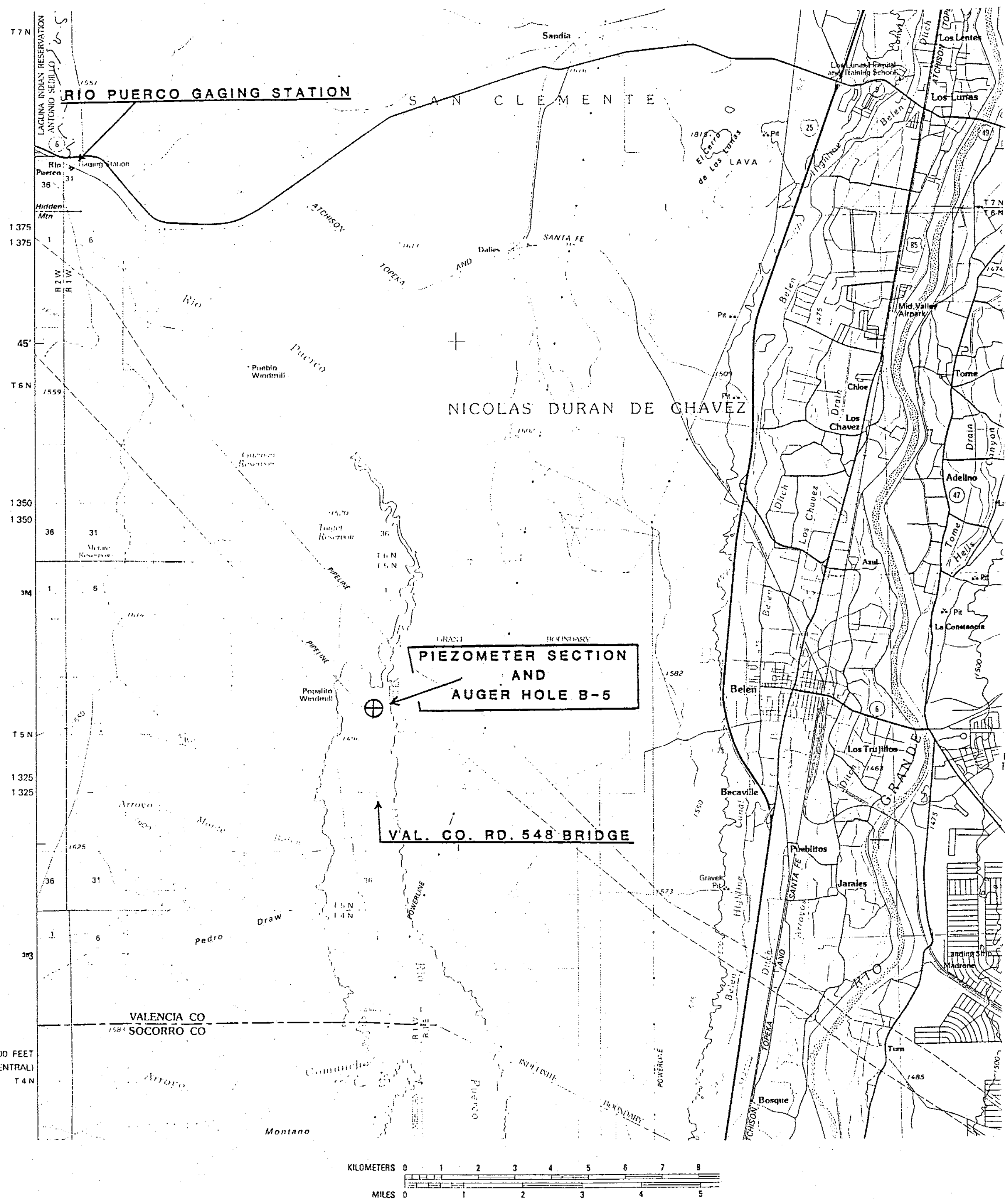


Figure 1. The Rio Puerco drainage basin showing the location of the study area. Numbers 1 through 5 are the locations of stream gaging stations: (1) Rio Puerco at Rio Puerco, (2) Rio Puerco near Bernardo, (3) Rio San Jose at Correo, (4) Arroyo Chico near Guadalupe, and (5) Rio Puerco above Arroyo Chico near Guadalupe.



SCALE 1:100 000

CONTOUR INTERVAL 50 METERS
SUPPLEMENTARY CONTOUR INTERVAL 25 METERS

FIGURE 1b. LOCATION MAP OF THE LOWER RIO PUERCO STUDY AREA

MODIFIED FROM THE USGS BELEN METRIC 1:100,000 SCALE MAP, 1979

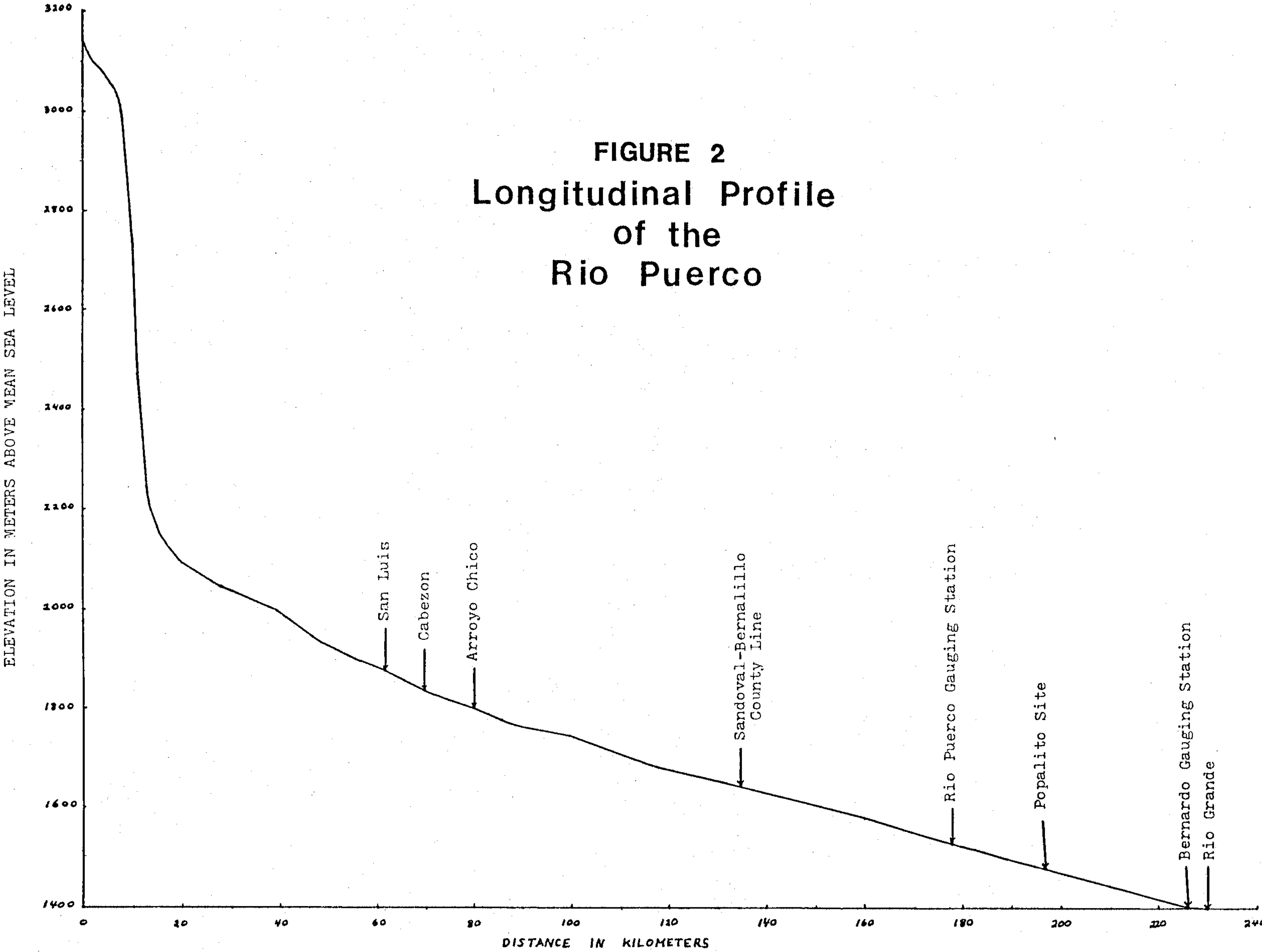


FIGURE 2
Longitudinal Profile of the Rio Puerco

is notorious for its high concentrations of suspended sediment, and is a major contributor to sediment deposition in the middle Rio Grande valley from San Acacia to Elephant Butte Reservoir, 80 miles (129 km) from its mouth.

The Rio Puerco is a losing stream, that is, it loses water through its bed. The records of surface-water flow from 1940 to 1976 at the Rio Puerco and Bernardo gaging stations show that an average of about 1.7 $X10^{6}$ ft^{3}/mile/year (30,000 m^{3}/km/year) is lost by infiltration in the 48 miles (78 km) of channel between these two stations. Flood and recharge relationships in an alluvial river system, such as the Rio Puerco, depend upon many factors, including geology and geomorphology, peak discharge, flow duration, climate, vegetation, and the occurrence and movement of groundwater in underlying sediments.

PHYSIOGRAPHY OF THE LOWER RIO PUERCO DRAINAGE BASIN

The lower Rio Puerco valley below the confluence of the Rio San Jose lies between two upland areas underlain by thick deposits of late Cenozoic basin fill: the Llano de Albuquerque to the east and a gently sloping plain to the west called the Llanos del Rio Puerco. The surface of the Llano de Albuquerque is partly covered by a caliche cap more than one meter thick that developed during the past 500,000 to 600,000 years on deposits of the upper Santa Fe Group-Sierra Ladrones Formation (Machette, 1978). Quaternary basalt flows and cinder cones emplaced about 0.140 $\pm$.038 million years ago cover an area of about 30 mi^2 (78 km^2) on the Llano de Albuquerque in Valencia and Bernalillo Counties (Kelley and Kudo, 1978). Surface-water drainage from the Llano de Albuquerque in this area contributes little water to the Rio Puerco, but is locally significant for erosion of tributary arroyos or for construction of alluvial fans. Large arroyos west of the valley, such as Comanche and Alamito Arroyos in Socorro County, are capable of discharging large amounts of runoff into the Rio Puerco during the summer months.

GEOLOGY OF THE LOWER RIO PUERCO

A detailed description of the late Cenozoic geology of the lower Rio Puerco region is beyond the scope of this study. The reader is referred to reports by Bryan and McCann (1937, 1938), Kelley and Wood (1946), Wright (1946), Spiegel (1955), Titus (1963), Kelley (1977), Tedford (1981), Hawley and others (1982), Love and others (1982), Young (1982) and Love and Young (1983).

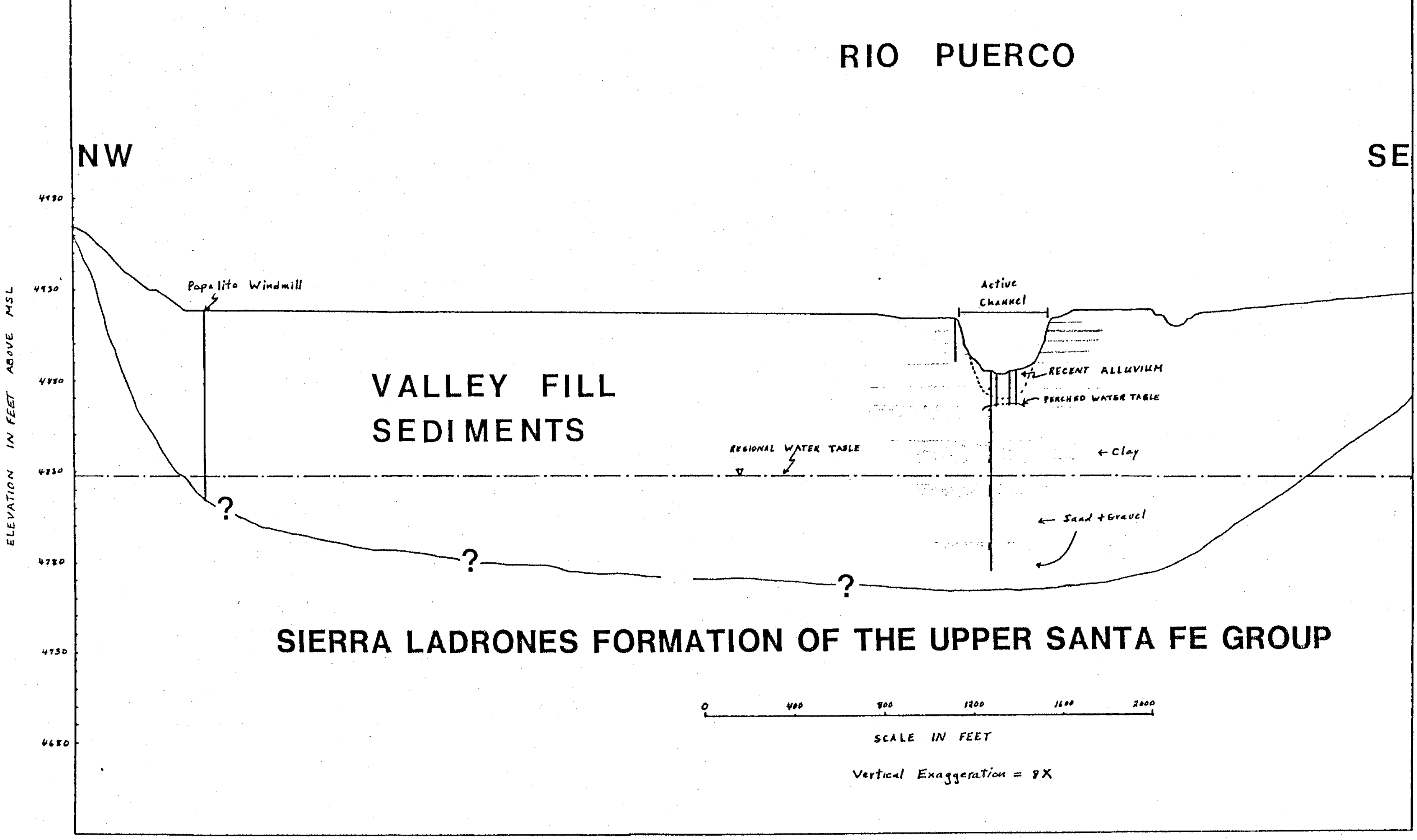
The Rio Puerco is incised into Santa Fe Group sediments in the Albuquerque basin. The Santa Fe Group is a thick accumulation of terrestrial sediments that were deposited in intermontane basins during late Oligocene to middle Pleistocene time. The exposed basin fill is mainly the Sierra Ladrones Formation of Pliocene and Pleistocene age and consists of thinly bedded, pale to reddish-brown sand, silt, clay and conglomerate. Volcanic flows and sills are interbedded with the sediments, which are often poorly indurated. The Santa a Fe Group within the Albuquerque basin has been penetrated to great depths by test wells. One such well, Shell Isleta No. 2, drilled in the vicinity of the Isleta volcanic center in 1979 and 1980, penetrated 21,266 feet (6,482 m) of Cenozoic rocks (Black, 1982). Much of this section is probably Santa Fe basin fill with a thin overlay of Quaternary surface deposits.

Geology of the Valley Fill

The lower Rio Puerco flows southward through a broad valley two to three kilometers wide, carved into basin fill sediments of the Sierra Ladrones Formation of the upper Santa Fe Group (fig. 3). The size of the valley and the thickness of its alluvial fill suggest there was a major period of stream degradation in response to changes in climate and vegetation, and to changes in base level in the Rio Puerco drainage basin and along the Rio Grande. The exact timing of maximum erosion of the Rio Puerco valley is not known, but it is conceivable that it took place during latest Pleistocene time when the Rio Grande channel flowed at a level 65 to 100 ft (20 to 30 m) below its present floodplain (Love and others, 1982; Davie and Spiegel, 1967)

The alluvium of the Rio Puerco valley represents successive cycles of alluviation and entrenchment within Holocene and perhaps latest Pleistocene time. Radiocarbon dating of archaeological sites, commonly within one meter of the valley fill surface, indicates that the valley floor had aggraded almost to its present level 2,000 to 3,000 years ago (Love and others, 1982). Radiocarbon dating of sediments in Tapia Canyon, an ephemeral tributary of the Rio Puerco northwest of Albuquerque, brackets the last major period of alluviation between 2500 and 1000 years before the present (Shepherd, 1978). Love and others (1982) document late cutting and backfilling of channels as much as 20 ft (6 m) deep during the Pueblo IV occupation period about 600

FIGURE 3 Schematic cross-section of the lower Rio Puerco valley west of Belen, New Mexico



years ago.

Maximum aggradation of the valley alluvium is characterized by floodplain deposits of laminated dark-brown silt, clay and fine sand as much as 5 ft (1.5 m) thick. Periodic heavy discharges overflowed shallow banks of the Rio Puerco in the past, spreading sediment-laden water over the entire floodplain surface, especially in low-lying areas. Samples of floodplain deposits obtained in T5N.R1W.26.223, about 2,165 ft (660 m) west of the present channel, show an average silt and clay content of 98 percent at its base, 96 percent in the mid-section and 91 percent at the top; along the valley margin these deposits are frequently overlain by tributary alluvium, colluvium and eolian sand.

Figure 4 is a geologic well-log of valley-fill sediments in T5N.R1W.13.1344 in Valencia County. Although this well was drilled to a depth of 110.5 ft (33.7 m) at a location 25.3 ft (7.7 m)) below the surface of the valley fill, it failed to reach the underlying sediments of the Santa Fe Group. Therefore, the thickness of the fill at this site is greater than 135.8 ft (41.4 m). The fill consists of unconsolidated sand, silt, gravel and clay, which ranges from pale to dark grayish-brown in color; some of the clayey beds are red. Gravel deposits are more common below a depth of 70 ft (21 m). Table 1 shows the approximate composition, color, gravimetric water content and ratio of sand to silt and clay at five clay intervals.

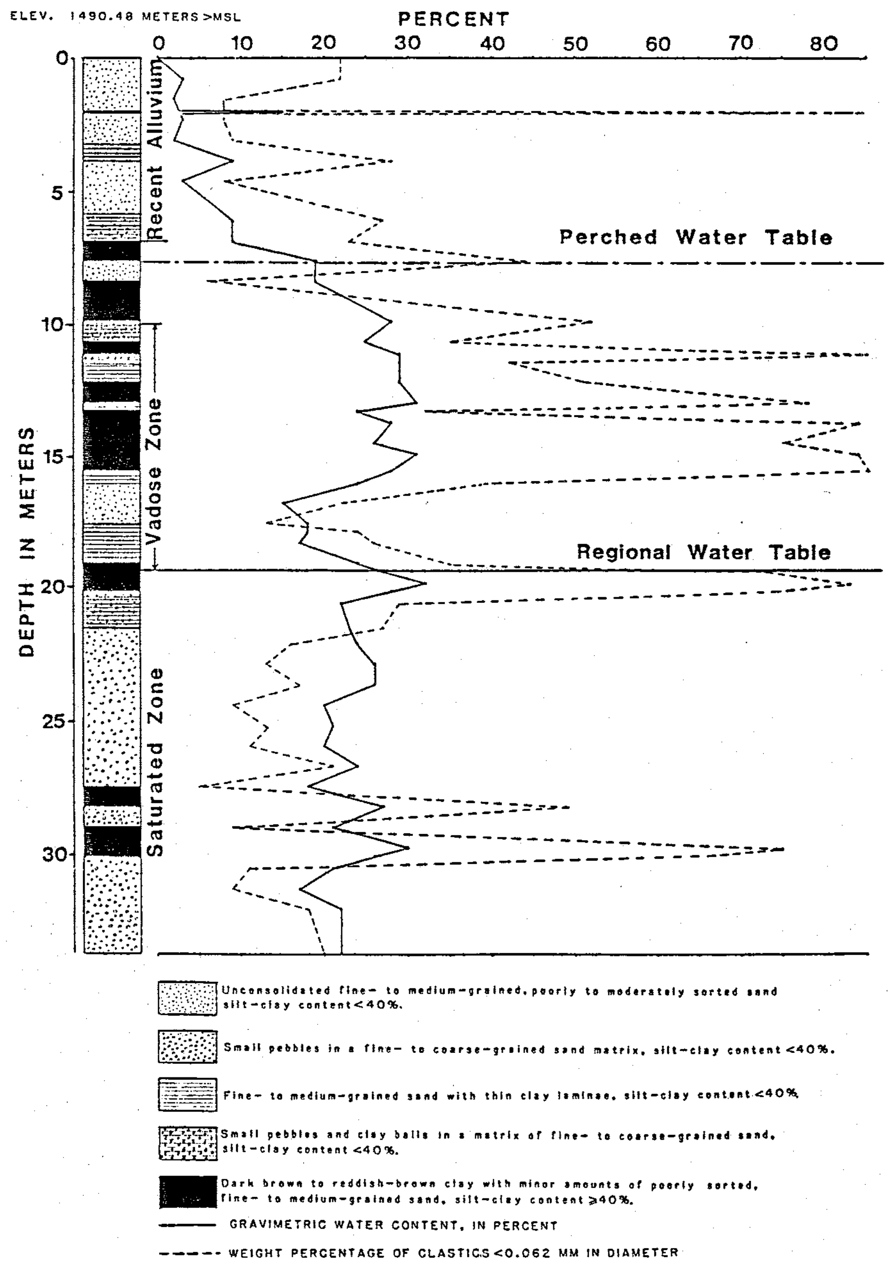


Figure 4. Geologic well-log of Rio Puerco valley fill

Table 1. Characteristics of selected clay zones of Rio Puerco valley fill

Location: T5N.R1W.13.1344, 55.5 ft (16.9 m) west of stake B, on the west bank of the Rio Puerco channel, Valencia County, New Mexico.
Date: July 10, 1982
Elevation of ground surface: 4890.02 ft (1490.48 m) above sea level
Total Depth of Hole: 110.5 ft (33.7 m)

Depth (meters)	Approximate Ratios, in Percent Illite %	Mont. %	M. L. %	Kaol. %	Color	w %	Sand %	Silt-Clay %
3.2-3.8	9.5	10	16	64.5	10YR4/3	16	20	80
12.2-12.9	13	20	3	64	10YR4/2	31	22	78
14.5-14.9	13	18	2	67	10YR4/2	31	16	84
19.4-19.8	9	16	18.5	56.5	10YR4/3	32	17	83
29.0-29.7	13	22.5	4.5	60	10YR4/2	25	25	75

NOTE: Approximate ratios of illite, montmorillonite, mixed layers of clay minerals and kaolinite determined by x-ray diffraction of slide samples.
w = Gravimetric water content by weight, in percent
Sand = Weight percent of clastics having grain diameter >0.062 mm.
Silt-Clay = Weight percent of clastics having grain diameter <0.062 mm.

The most abundant constituent of the clays is kaolinite, followed by smaller amounts of illite, montmorillonite and mixed layers of clay minerals. The relative proportions of these minerals do not change significantly with depth. In addition, x-ray diffraction showed high amounts of quartz, feldspar, calcite and dolomite, but little or no chlorite in clay and silt-sized sediments. The composition and maximum diameter of clasts of the basal gravel samples are shown in Table 2. In general, the majority of pebbles consist of quartz, basalt, limestone and shale with very low amounts of obsidian or rhyolite.

The recent alluvium beneath the channel of the lower Rio Puerco consists of about 18 ft (5.5 m) of unconsolidated, fine to medium sand and intercalated clay layers underlain by 1.5 ft (0.5 m) of medium- to coarse-grained sand, thalweg gravels as much as 2.4 inches (6 cm) in diameter and armored clayballs. Geologic descriptions of ten auger holes drilled in the recent alluvium of the Rio Puerco channel may be found in Appendix A.

Table 2. Clast composition of basal gravels in Rio Puerco valley fill, west of Belen, New Mexico

Depth (meters)	Qtz. %	Gran. %	Bas. %	Rhy. %	Obsid. %	LS %	SS %	SH %	Other %	Total %	n	Diam. (cm)
30.0-30.5	37.1	11.4	8.6	0.0	0.0	14.3	20.0	5.7	2.9	100	35	2.5
30.0-31.2	20.3	10.9	20.3	1.6	0.0	14.1	9.4	17.2	6.2	100	64	3.0
31.2-32.0	30.0	12.1	13.1	0.0	0.9	19.6	13.1	5.6	5.6	100	107	4.7
32.0-32.8	31.7	14.6	19.5	0.0	2.4	7.3	19.5	2.4	2.4	99.8	41	5.1
32.8-33.7	18.0	10.0	17.1	0.9	1.8	19.8	15.3	11.7	5.4	100	111	4.4

NOTE: Samples obtained from auger hole B5 in T5N.R1W.13.1344, Valencia County, New Mexico on 10 July, 1982.
Ground surface elevation = 4890.02 ft (1490.48 m) above sea level.
Clast sizes in diameter column are maximum values in centimeters.

Description of Active Channel

Bryan (1928, 1940, 1941) and Bryan and McCann (1938) were the first to examine geomorphic changes in the Rio Puerco channel that have occurred since the the mid-19th century. Later investigators (Tuan, 1966; Patton, 1973; Schumm, 1977; Elliot, 1979) looked at climatic and vegetative factors governing erosion and sedimentation processes of the Rio Puerco and other rivers in the Southwest. Detailed descriptions of the geomorphological evolution of the lower Rio Puerco valley based on archaeological evidence are available (Love and others, 1982; Betancourt, 1980).

The lower Rio Puerco has developed an active inner channel and floodplain within an arroyo 150 to 820 ft (46 to 250 m) wide between walls of Holocene valley fill 26 to 43 ft (8 to 13 m) high. Common sedimentologic features of the channel and floodplain include sandbars, ripples and dunes, meandering thalweg, natural levees, oxbows, eolian sand and point-bar deposits. Sand deposited by the stream is generally light brown (10YR6/4 in the Munsell color charts, 1975 ed.) whereas clay sediments commonly range from reddish brown (2.5YR4/4) to dark brown (10YR4/3). Geologic descriptions of auger-hole samples from Rio Puerco recent alluvium are in Appendix A of this report.

The channel meanders throughout much of its length. In 1979, sinuosity of the lower 31 miles (50 km) between the Rio Puerco and Bernardo gages averaged 1.57 (ratio of stream length to straight-line distance). Based on photographs taken in 1954 and 1979, it has been estimated that more than 90 percent of the modern channel has shifted laterally during the past 35 years (Love and others, 1982).

HYDROLOGY OF THE LOWER RIO PUERCO

Peak Discharge

Nine gaging stations are located on the Rio Puerco and its tributaries. The locations of five principal stations discussed in this report are given in Figure 1. Daily discharge and peak flood data for these sites are available in Water-Supply Papers and Water-Data Reports published each year by the U. S. Geological Survey. The longest continuous record, from November, 1939 to the present, is from the Bernardo gaging station, 3 miles (4.8 km) northwest of the confluence of the Rio Puerco and the Rio Grande. Continuous records at the Rio Puerco gaging station date from March, 1934 to December, 1976. Intermittent discharge records exist for both sites as early as 1910.

Figure 5 shows the flood record of the lower Rio Puerco for the water years 1929 and 1934 to 1982 (a water year extends from October 1st to September 30th). During this period, peak discharges averaged 9,082 cfs (257.2 m^3/s) at Rio Puerco and 5,664 cfs (160.4 m^3/s) at Bernardo. Over the 37-year period from 1940 to 1976, peak flows averaged 7,101 cfs (201 m^3/s) at Rio Puerco and 5,405 cfs (153 m^3/s) at Bernardo. Most floods occurred during the month of August, followed by lower frequencies in September and October.

Since 1940, a cyclic pattern in peak discharge (fig. 3) has emerged with years of low peak discharge in 1948, 1962 and 1978 (at 14- to 16-year intervals) and years of

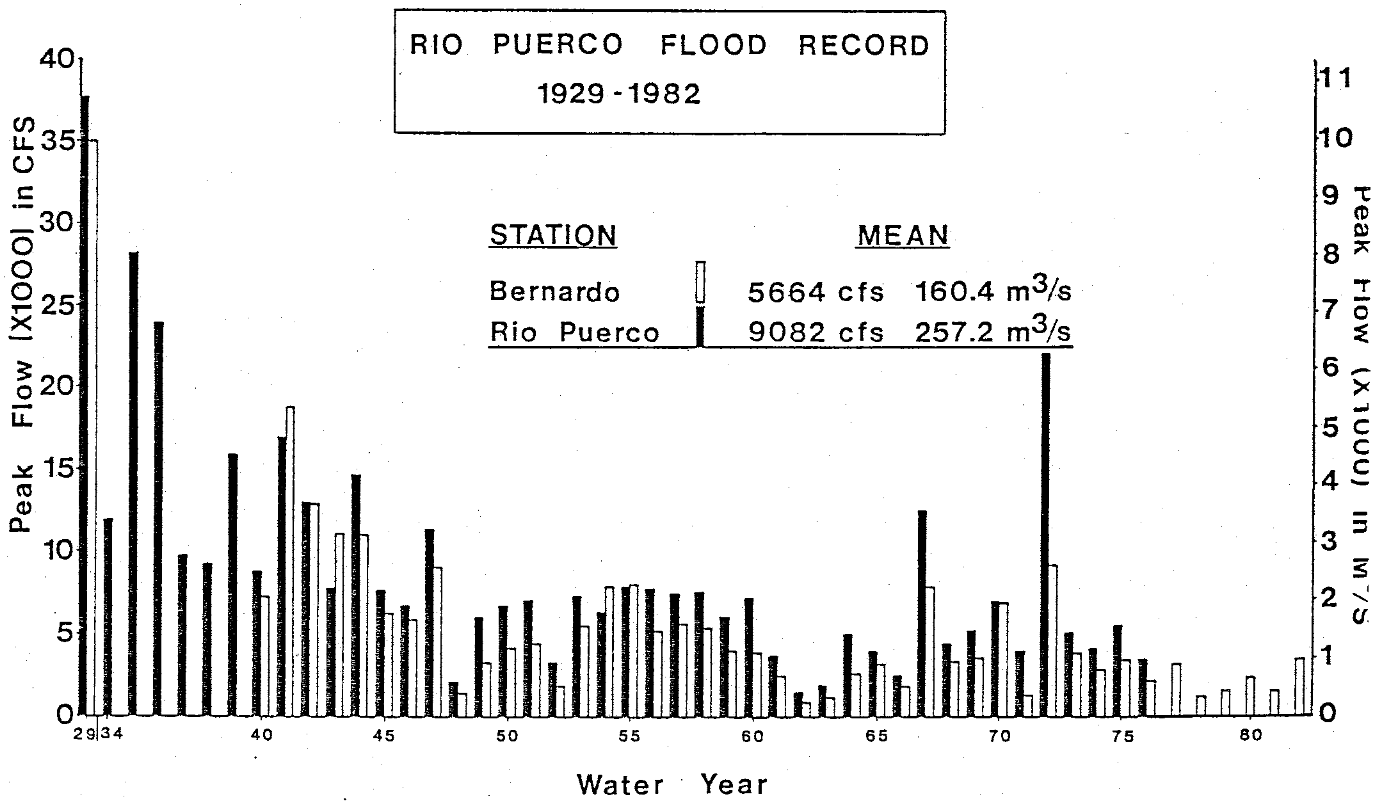


Figure 5. Annual peak discharges of the lower Rio Puerco for water years 1929, and 1934 to 1982

high flow in 1941, 1955 and 1972 (at 14- to 17-year intervals). Data obtained before 1934 is not sufficiently reliable for trend analysis.

Large reduction in discharge is possible when tributary inflow between Rio Puerco and Bernardo is small. For example, peak flow in 1967 was 38 percent lower at Bernardo than it was at Rio Puerco. Bank and floodplain storage, streambed infiltration and evapotranspiration are all factors that contribute to this reduction of flow. In 1941, 1943 and 1954, discharge was higher at Bernardo than at Rio Puerco. Heavy flows from large, east-flowing tributaries such as Comanche and Alamito Arroyos in northern Socorro County were responsible for this increase.

The time it takes for a flood crest to travel along the Rio Puerco depends on discharge, slope and channel shape. Hydrographs (continuous chart recordings of river stage over time) of major floods from 1940 to 1976 show that the average flood crest traveled from the mouth of Chico Arroyo to the Rio San Jose in 20 hours, from the Rio San Jose to the Rio Puerco gage station in two hours, and from Rio Puerco to Bernardo in 14 hours, at an average velocity of 5 ft/s (1.5 m/s) (Corps of Engineers, 1978).

Figure 6 gives frequency curves for the five gaging stations along the main reach of the Rio Puerco and its tributaries. These curves relate flood magnitude to frequency of occurrence over the flood record.

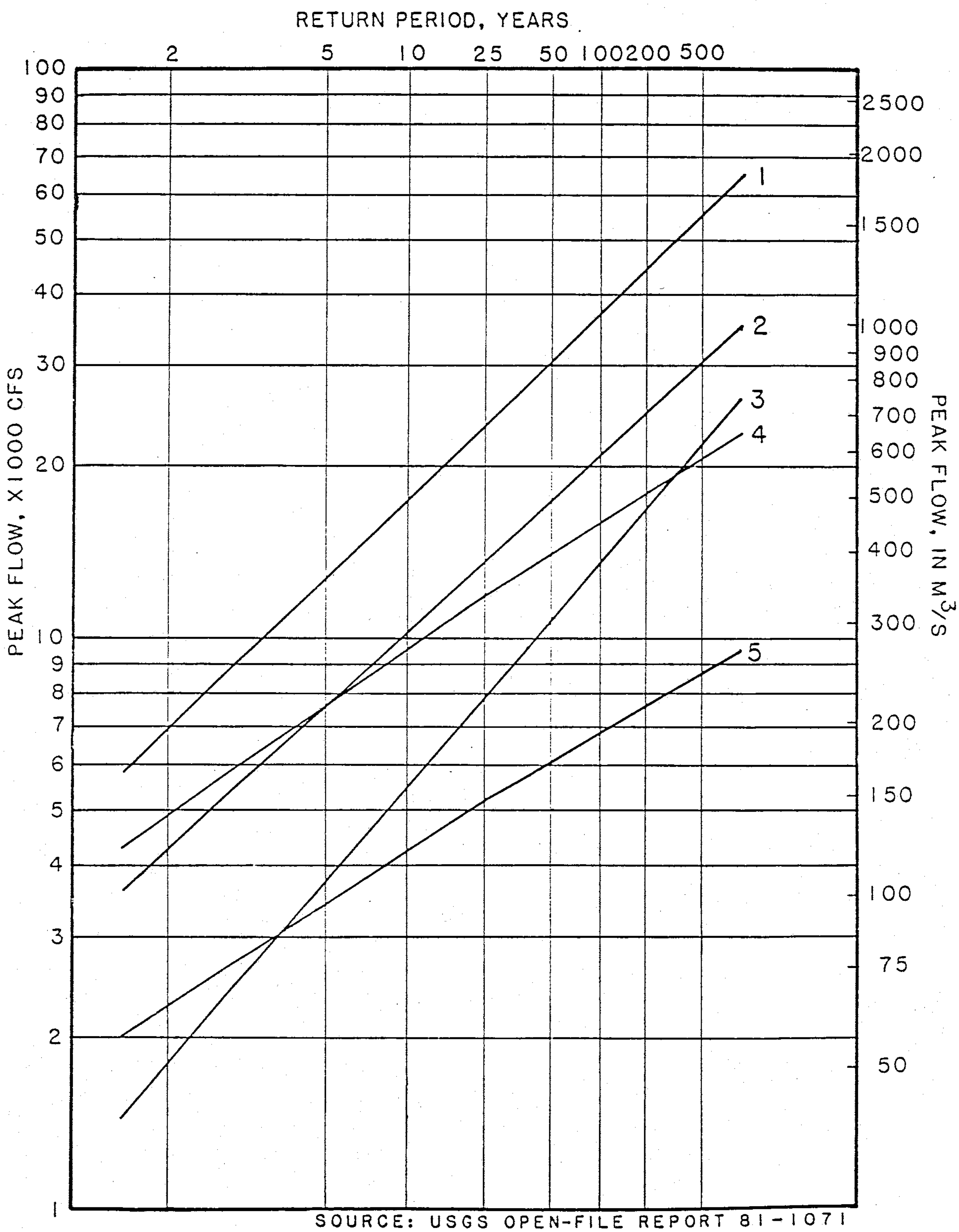


Figure 6. Pearson Type III distribution curves at five stream gaging stations in the Rio Puerco basin. Such curves represent estimates of the cumulative distribution of the flood record and relate flood magnitude to frequency of occurrence. See Figure 1 for gage station locations.

Flow Duration

Using the criteria suggested by Hedman and Osterkamp (1982), streams that have flow from 10 to 80 percent of the time are intermittent; those that flow less than 10 percent of the time are ephemeral. Most intermittent streams with drainage areas larger than 500 mi^2 (1,295 km^2) will have discharge more that 10 percent of the time because of prolonged snowmelt at higher elevations and greater runoff during the summer months. From 1940 to 1976, the Rio Puerco flowed an average of 55 percent of the time at the Rio Puerco gage. From 1940 to the present, the stream flowed an average of 30 percent of the time at the Bernardo gage. The difference between the two gages is caused by evapotranspiration and channel losses.

Runoff in the higher elevations of the Rio Puerco watershed flows into three main tributaries north of the study area: Arroyo Chico, which drains an area of 1,390 mi^2 (3,600 km^2) north of Mount Taylor; Rio Puerco north of Arroyo Chico, which flows south from highlands in the San Pedro Peaks- Nacimiento Mountains region; and Rio San Jose, which flows east and southeast from the Mount Taylor-Zuni Mountains region. An analysis of average monthly discharge records from 1952 to 1979 showed that flow contributions to the lower reach of the Rio Puerco averaged 40 percent from above Arroyo Chico, 32 percent from Arroyo Chico and 28 percent from the Rio San Jose.

Although all three tributaries are important sources of inflow to the lower reach throughout the flow period, individual dominance is generally seasonal. From December through April, most flow stems from the Rio San Jose basin, which has many springs; from late spring to early summer, flow is dominated by the Rio Puerco above Arroyo Chico in the form of meltwater runoff; and from late summer to early autumn, flow is dominated by runoff from thunderstorms in the Arroyo Chico basin.

Flood History

On October 4, 1913, the Rio Puerco reached a gage height of 9.5 ft (2.9 m) at the Rio Puerco gaging station, but discharge was not determined at this or other stations. To provide better discharge records, a concrete control was built a short distance downstream from the gage in 1922.

During the night of August 12, 1929, a large flood swept through the valleys of the Rio Puerco, Rio Salado (see Simcox, 1983) and Rio Grande and entered the northern end of Socorro Valley. By midnight of August 13, the crest of the flood had passed San Marcial and destroyed valuable cropland and several villages, including San Acacia, San Antonito and San Marcial. On August 9th and 10th, torrential rains had fallen on the west and north slope of Mount Taylor in the Rio Puerco watershed. Precipitation records at Crownpoint, Bluewater and Jemez Springs show rainfall totals of 3.20 inches (81 mm), 3.57 inches (91 mm) and 2.56 inches (65 mm), respectively. Flow velocities along the lower reach of the Rio Puerco approached 8.8 ft/sec (10 km/hr) as water surged toward the Rio Grande at Bernardo (New Mexico State Engineer, 1930).

The maximum discharge of the Rio Puerco at Rio Puerco station was computed by a broadcrested-weir formula (New Mexico State Engineer, 1930):

Depth (D) = 16.02 ft (4.88 m)

Width (W) = 182 ft (55.5 m)

Weir Constant (C) = 2.70

Discharge = $CWD^{3/2}$ = 31,509 cfs (892.3 m^3/s)

At Bernardo gaging station, three miles upstream from the mouth of the Rio Puerco, the maximum discharge was computed from the slope-area method:

Section Width = 518 ft (157.9 m)

Section Area = 4,006.5 ft (372.2 m)

Slope = .00175

Kutter's coefficient of roughness "n" = .035

Discharge (by Kutter's formula) = 30,643.7 cfs (867.8 m^3/s)

The largest flood since 1880 occurred on September 23, 1929, only 42 days after the flood of August 12. Widespread and heavy rains fell over the entire Rio Grande drainage area from Socorro north to the Colorado state line from September 21st to 23rd. The Rio Puerco contributed a greater share (58 percent) to the total flood than in the preceding flood. Computation of the maximum discharge at the Rio Puerco gaging station by weir formula yielded 37,700 cfs (1,068 m^3/s) at a gage height of 18 ft (5.5 m). The flood also damaged cropland and settlements in the middle Rio Grande valley, washed out the Atchison, Topeka and Santa Fe Railroad trestle west of Los Lunas, New Mexico and destroyed the gage recorder. The maximum discharge of the flood at Bernardo was estimated to be 35,000 cfs (991 m^3/s) by the slope-area method (New Mexico State Engineer, 1930).

The third largest flood since 1880 occurred on August 21, 1935 after heavy rainfall fell over the headwaters of the Rio Puerco and the Rio San Jose during early and mid-August. A peak discharge of about 28,000 cfs (800 m^3/s) was recorded at the Rio Puerco gage on August 21st. Nearly 40 percent of this discharge was contributed by the Rio San Jose, which had a recorded flow of 11,000 cfs (312 m^3/s) at Correo, New Mexico. This discharge, although large for the Rio San Jose, was smaller than that of September 23, 1929.

A smaller flood occurred on August 4, 1936. A general storm over the Rio Puerco watershed produced a peak flow of 24,000 cfs (680 m^3/s) at the Rio Puerco gaging station and, together with the Rio Grande, attained a peak of 27,400 cfs (776 m^3/s) at San Acacia, about 10 miles (16 km) downstream of the confluence of the two rivers.

Record high rainfall produced large floods in May, September and October of 1941. The heaviest flow occurred at 3 pm on September 23rd at the Rio Puerco gage and 11 pm on the same day at Bernardo with peak discharges of 16,900 cfs (479 m^3/s) and 18,800 cfs (532 m^3/s), respectively. The large increase in flow over the lower reach of the Rio Puerco is attributed to heavy storm runoff in eastward-flowing tributaries, such as Comanche and Alamito Arroyos north of Bernardo. This demonstrates that widespread rainfall over the lower Rio Puerco basin, as well as areas to the north, can reduce the time for a floodcrest to travel from Rio Puerco to Bernardo from 14 hours to 8 hours.

Extensive thunderstorm activity over both the Rio Grande and Rio Puerco basins produced peak discharges of 7,610 cfs (215 m^3/s) on August 10, 1967 in the Rio Grande near Bernardo and 12,600 cfs (357 m^3/s) on August 12th at the Rio Puerco gage. A record level of discharge for the Rio Puerco above Arroyo Chico occurred on July 29, 1967, with a flow of 6,940 cfs (179 m^3/s). This is the largest flood on record for that tributary.

Heavy rains in the Arroyo Chico watershed on September 12, 1972 produced a peak discharge of 15,200 cfs (430 m^3/s), the highest flow on record for the Arroyo Chico gage near Guadalupe, New Mexico. The flood increased in intensity as it flowed downstream, producing a peak discharge of 22,200 cfs (629 m^3/s) with a gage height of 5.35 ft (1.63 m) at the Rio Puerco gage on September 13th. A discharge of 9,220 cfs (261 m^3/s), with a gage height of 14.5 ft (4.42 m) was recorded at the Bernardo gage on September 14th. Although the instantaneous flood peak was 58 percent higher at Rio Puerco than at Bernardo, the total volume of the flow was actually quite similar. Therefore, it took a shorter time for the same volume to pass the Rio Puerco gage station.

Effects of Floods on Channel Morphology

Large floods have great erosive and destructive power. They cause widening and deepening of the Rio Puerco channel and transport large quantities of sediment into the middle Rio Grande valley. During a rising flood stage, an increase in flow velocity and shear stress on the streambed results in channel scour. The whole width of the flow tends to cut downward as the stage rises; sediment tends to fill the channel again during the falling stage (Leopold and others, 1964). Auger holes drilled in the position of the 1929 flood thalweg in T5N, R1W reveal channel deposits 10 to 20 ft (3 to 6 m) below the level of the present streambed (fig. 7; Appendix A). These mark the maximum extent of channel incision of the Rio Puerco into valley fill since entrenchment began over a century ago.

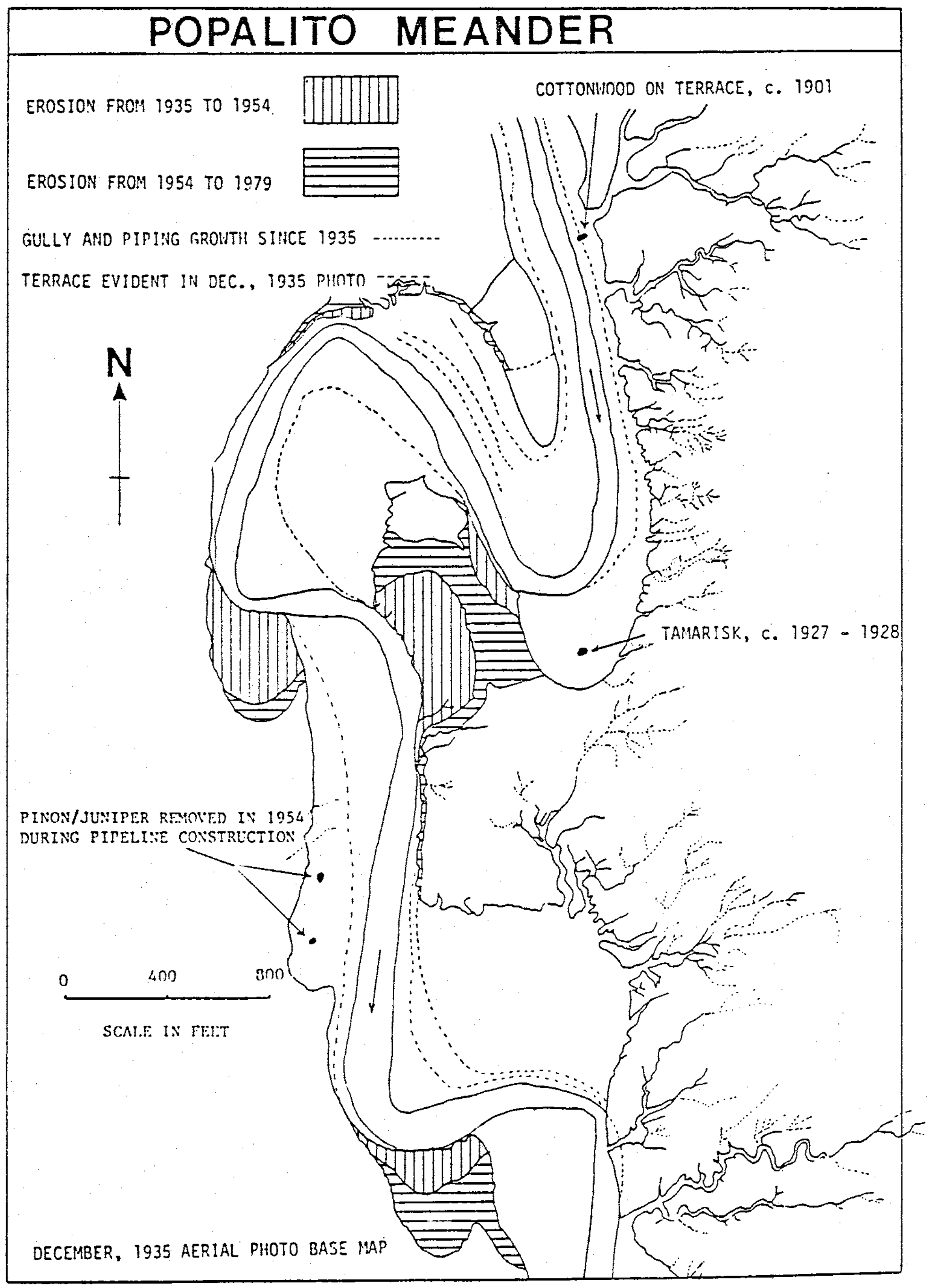


Figure 7. Geomorphic changes of Popalito meander and Rio Puerco channel since 1935

QUALITY OF WATER

Chemical analyses of surface and ground water in the Rio Puerco study area have been published by the U. S. Geological Survey in annual reports and by Spiegel (1955) and Titus (1963). These analyses indicate that such water is generally suitable for livestock but unsuitable for human use. Both surface and ground water contain high levels of sulfate and total dissolved solids, the concentrations of which tend to increase with depth.

During field studies in 1982 and 1983, three water samples from Popalito windmill, auger hole B-5S and the Rio Puerco (see fig. 1b) were obtained by the author. They were analyzed for basic chemical constituents by the New Mexico Bureau of Mines and Mineral Resources in Socorro. In addition, periodic field measurements of temperature, pH, salinity, specific conductivity, oxidation-reduction potential and sediment volume in percent were made from 25 August, 1982 to 24 February, 1983. The results of these analyses, which agree well with published data, are shown in Tables 10 and 11 in Appendix D.

Sulfate in natural waters may come from many sources. In igneous rocks, the most common sulfur minerals are sulfides of heavy minerals which are in part oxidized in the weathering process to give soluble sulfates which are later transported by water (Hem, 1959, p. 100). Some shales may contain sulfur in the form of ferrous sulfide. Natural waters in the Rio Puerco basin have high concentrations of sulfate where calcium sulfate in the form of gypsum and anhydrite is abundant. Formations such as the Chinle of Triassic age and the Mancos of Cretaceous age are rich in such evaporate deposits.

The U. S. Public Health Service (1962) states that in water used for human consumption under conditions subject to the Federal quarantine regulations, the level of total dissolved solids should not exceed 500 ppm for water of good chemical quality. A maximum level of 1,000 ppm may be tolerated if better quality is not available. The total dissolved solids in water samples from the study area (Table 10, Appendix D) exceed this standard by as much as three to seven times.

The ratio of calcium to magnesium computed from equivalents per million for natural waters range from about 5:1 to about 1:1. High values for the ratio indicate that the water obtains calcium from limestone or other calcium carbonate precipitates or from gypsum minerals available for solution. Low values of the ratio suggest that magnesium silicate minerals are being dissolved or that dolomitic rocks are being attacked (Hem, 1959, p. 82). Calcium-magnesium ratios for the three samples shown in Table 10 were 2.6, 3.4 and 2.9, respectively, occupying an intermediate position in the range of ratios discussed above.

HISTORIC CHANGES IN VEGETATION

The principal vegetation of the Rio Puerco arroyo is willow (Salix sp.), rabbitbush (Chrysothamnus nauseosus), cottonwood (Populus fremontii) and saltcedar (Tamarix gallica). In 1927, the latter species was introduced 32 miles (51.5 km) upstream from the mouth for erosion control (Bryan and Post, 1928), but has caused profound changes in riparian vegetation, channel geometry and streamflow. Saltcedar thrives in areas that have a gently sloping or flat river bank with a gradually receding flood flow during the growing season (April to October). A mature tree may produce up to 600,000 seeds, which are capable of germinating quickly on a floodplain or water surface (Bowser, 1957). According to Renner (1915), who observed tamarisk growth during the construction of the Suez Canal in Egypt, roots may go as deep as 30 m.

Along streams in the southwestern United States, a dense stand of saltcedar usually indicates that the water table is within 13 to 23 ft (4 to 7 m) of the surface (Horton and Campbell, 1974). Although the amount of water used by saltcedar in the lower Rio Puerco is not known, figures cited in studies of other southwestern streams may be comparable. A study in the Safford Valley of the Gila River in Arizona during 1943 and 1944 showed that under favorable conditions, the annual rate of water use by saltcedar was more than 9 acre-ft/acre (2.74 X10^6 m^3/km) when the depth to water was 4 ft (1.2 m) to about 7 acre-ft/acre (2.1 $X10^6$ m^3/km) when the water level was at a depth of 8 ft (2.4 m) (Gatewood and others, 1950). In a later study near Buckeye, Arizona, van Hylckama (1974) reported annual water consumptions of 7 acre-ft/acre when depth to water was 4.9 ft (1.5 m) to 3.3 acre-ft/acre (1.0 $X10^6$ m^3/km) when the depth to water was 8.9 ft (2.7 m). Site differences in annual water use are caused by variations in growth density, length of the growing season and soil-moisture salinity.

Temperature largely controls saltcedar growth and transpiration. Gatewood and others (1950) determined that saltcedar transpiration practically ceased in the autumn on days when the maximum air temperature was less than 23°C and began again in the spring when temperatures rose above 23°C.

Aerial photographs taken by the Soil Conservation Service in 1935 show sparse saltcedar growth along the Rio Puerco channel. North of the Valencia-Socorro County line, densities of less than 20 trees per kilometer of channel were not uncommon; however, the density of saltcedars, already high in the middle Rio Grande valley, tended to increase to the south. A large stand of saltcedar on the Rio Puerco in 1935, consisting of groups of several hundred trees, existed in the western half of sec. 30, T4N, R1E, between Comanche and Alamito Arroyos. Larger concentrations of saltcedar growth were present farther south in sec. 18, T3N, R1E at the mouth of Mariano Draw.

After 1941, during a period of lower peak discharges, consolidation and rapid growth of this phreatophyte accelerated upstream along the banks and inner-floodplain. By 1954, dense stands had developed in the channel north of Arroyo Chico. The long-term effects of saltcedar growth along the lower Rio Puerco include increases in area inundated by floods, sediment deposition in areas of saltcedar growth, channel stabilization and reduction of streamflow magnitude.

OCCURRENCE AND MOVEMENT OF GROUND WATER

In general, infiltration of water varies directly with the hydraulic conductivity of the porous material, area perpendicular to flow and hydraulic gradient, but varies inversely with water viscosity. The hydraulic conductivity of saturated geologic materials is relatively constant over time below the water table but is a function of negative pressure head or capillary forces above the water table (Bouwer, 1964). Several authors have evaluated factors that influence rates of infiltration from losing streams in the southwestern United States (for example, Keppel and others, 1962; and Burkham, 1970). These include the hydraulic conductivity of the streambed, stream area and depth of the channel, velocity of streamflow, river stage, temperature, entrapment of air in channel sediments, and the relation of the water table to the stream.

Hydraulic Conductivity of the Streambed and Recent Alluvium

The Rio Puerco flows across moderately to well-sorted, fine- to medium-grained sand along most of its reach; however, during periods of low flow the channel bottom accumulates silt and clay between sand grains that tend to reduce hydraulic conductivity. Several investigators (Burkham, 1970; Moore and Jenkins, 1966) examined grain-size distributions in streambeds and reported that the upper several centimeters of sand was siltier and less permeable than that below. For my study, I used a constant-head permeameter, sieves and hydrometer to measure grain size and permeability. In an area located in the western half of sec. 13, T5N, R1W, moderate to high hydraulic conductivities were found in the upper 6.5 ft (2 m) of the channel alluvium, which consists mainly of moderately sorted, fine- to medium-grained sand. The hydraulic conductivities of 23 samples taken on the streambed surface at 82 ft (25 m) intervals to a depth of 6 cm range from 7.4 ft/day (2.25 m/day) to nearly 109 ft/day (33 m/day), with a mean of 52 ft/day (15.7 m/day) (fig. 8; table 3). Samples obtained at depths of 1.5, 3.3, 5.0 and 6.6 ft (0.5, 1.0, 1.5 and 2.0 m) in channel sands in T5N.R1W.13.1344 produced hydraulic conductivities of 34.3, 20.0, 34.3 and 45.5 ft/day (10.4, 6.0, 10.4 and 13.8 m/day), respectively. In a study of solute distributions within a soil profile, Biggar and Nielsen (1976) determined that 100 observations were necessary to estimate the hydraulic

FIGURE 8 LOCATION OF HYDRAULIC CONDUCTIVITY SAMPLES IN SEC. 13, T5N, R1W

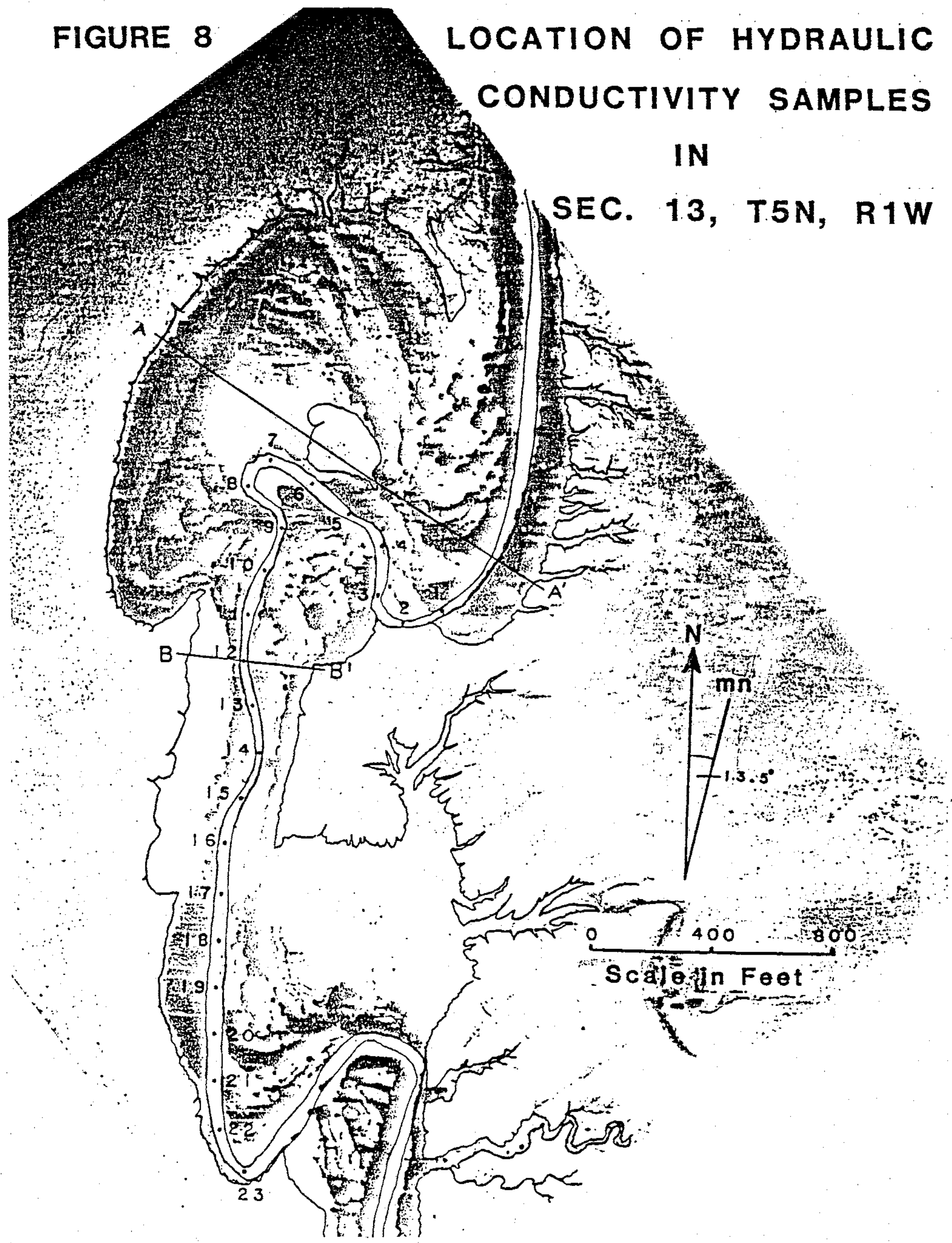


Table 3.

CONSTANT-HEAD PERMEAMETER ANALYSIS OF LOWER RIO PUERCO CHANNEL SANDS

Date: 13 January, 1983
Sample Location: T5N, R1W, Sec. 13, Valencia County, New Mexico

Sample No.	Hs (cm)	Hr (cm)	Ave. Time (seconds)	Q (cm3/s)	Hs-Hr (cm)	K (cm/s)	Sand %	Silt-Clay %
1	5.70	3.50	49.32	0.203	2.2	0.0220	94	6
2	5.30	3.50	112.49	0.089	1.8	0.0118	91	9
3	5.90	3.60	317.49	0.031	2.3	0.0032	79	21
4	5.85	3.55	66.71	0.150	2.3	0.0156	90	10
5	5.50	3.60	137.58	0.073	1.9	0.0091	86	14
6	5.90	3.60	30.40	0.329	2.3	0.0341	97	3
7	6.00	3.55	25.84	0.387	2.45	0.0377	88	12
8	5.95	3.65	106.91	0.094	2.3	0.0098	93	7
9	6.00	3.60	44.92	0.223	2.4	0.0222	95	5
10	5.65	3.60	45.66	0.219	2.05	0.0255	94	6
11	5.65	3.60	51.22	0.195	2.05	0.0227	93	7
12	5.90	3.60	33.37	0.300	2.3	0.0311	95	5
13	6.00	3.20	26.00	0.385	2.8	0.0348	93	7
14	5.95	3.18	129.08	0.077	2.77	0.0071	78	22
15	5.80	3.30	71.71	0.139	2.50	0.0141	89	11
16	5.80	3.18	105.19	0.095	2.62	0.0092	86	14
17	5.35	3.18	130.67	0.077	2.17	0.0089	88	12
18	5.70	3.20	391.75	0.026	2.5	0.0026	79	21
19	6.00	3.18	116.19	0.086	2.82	0.0077	79	21
20	5.90	3.20	111.14	0.090	2.70	0.0084	89	11
21	5.85	3.20	43.81	0.228	2.65	0.0218	94	6
22	5.15	3.18	47.32	0.211	1.97	0.0272	86	14
23	6.00	3.20	29.36	0.343	2.8	0.0310	95	5

NOTE: Samples 1-12: Water Temp.= 23.5 C, Kinematic Viscosity = 0.009294 cm2/s.
Kinematic Viscosity corrected to 20 C = 0.009193 cm2/s.

Samples 13-23: Water Temp.= 21.0 C, Kinematic Viscosity = 0.009863 cm2/s.
Kinematic Viscosity corrected to 20 C = 0.009760 cm2/s.

Calculation of Hydraulic Conductivity (K) = QL/A(Hs-Hr),
where Q = flow volume, sample length (L) = 5.1 cm,
sample area (A) = 19.635 cm2, Hs = sample head, Hr = reservoir head.

Viscosity Correction = K @ 20 C = K * (V/V @ 20 C).

conductivity within ±50% of its true value. Kiesling and others (1977) found that only 2 to 16 samples were required to estimate the average log of the hydraulic conductivity to within +10% of the estimated mean. The optimum number of samples at a given site depends on individual soil variability. Additional samples of Rio Puerco channel sediments should be analyzed to increase the accuracy of these estimates.

Figure 9 shows a strong correlation between hydraulic conductivity that is log-normally distributed and the percent of sand-sized grains that is normally distributed. In general, if silt and clay content is greater than 40 percent, the hydraulic conductivity of the Rio Puerco channel sands is likely to be about 3.3 ft/day (1 m/day) or less. Where horizontal clay laminae are present in channel sands, vertical hydraulic conductivities may be reduced to as low as 2.8 $X10^{-7}$ ft/day (8.6 $X10^{-8}$ m/day) (Freeze and Cherry, 1979).

Annual transmission losses average about 1.7 $X10^{6}$ ft^{3} /mile (30,000 m^{3} /km) from Rio Puerco gage to the Bernardo gage, a distance of 48 river miles (78 km). Very low flows of about 5 cfs (0.15 m^{3}/s) during the winter and spring are entirely lost through infiltration and evaporation; higher flows of less than 10 cfs (< 0.3 m^{3}/s) are lost during the summer months through infiltration, evaporation and phreatophyte activity. From 1940 to 1976, the only period for which records are available at both stations, peak

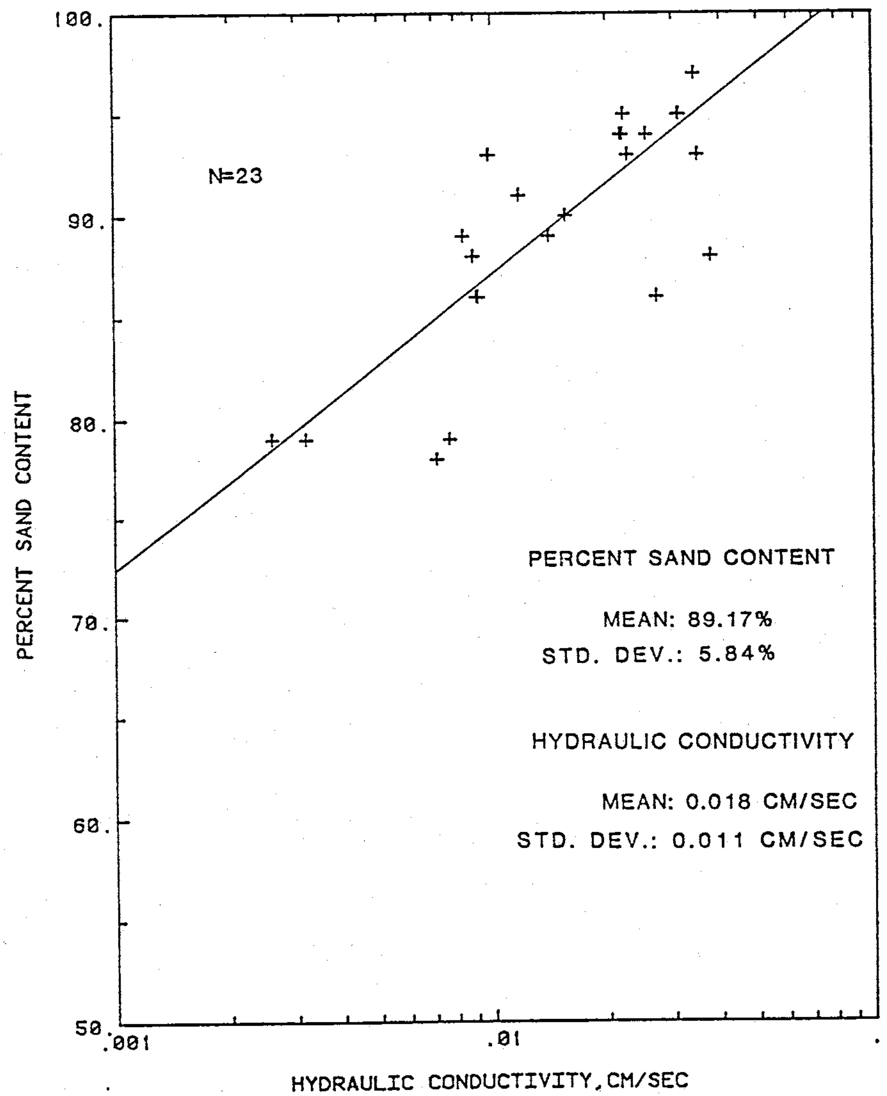


Figure 9. Relationship of hydraulic conductivity and sand content for channel sands of the lower Rio Puerco

discharges in the lower 31 miles (50 km) of the river were reduced by an average of 24 percent due to overbank storage, bank storage and evapotranspiration. This figure is mostly associated with short periods of high flow.

Perched Water-Table Fluctuations below the Streambed

Detailed study of a channel cross-section in T5N.R1W.13.1344, about 7 miles (11.3 km) west of Belen, New Mexico (fig. 1b), revealed a perched water table about 18 ft (5.5 m) below the streambed. Clay layers at the base of recent alluvium restrict the vertical movement of groundwater, creating a perched zone high above the regional water table, which is about 60 ft (18.3 m) below the channel (fig. 3). Titus (1963) found similar perched zones in the Rio Grande valley north of Belen, New Mexico.

The hydrographs of mean daily discharge of the Rio Puerco and the piezometric response of the perched water table to this flow are shown in Figures 10a and 10b. At least twice, on August 28th and September 19th, the river overflowed its banks with peak discharges of more than 2,260 cfs (64 m^3/s) and 3,600 cfs (102 m^3/s). Groundwater measurements from 14 July, 1982 to 6 June, 1983, given in Table 4, show the perched water table rising more than 7.4 ft (2.25 m) beneath the channel since day 48 (August 17, 1982). During the summer of 1982, the perched water table rose 4.98 feet (1.52 m) in 38 days or 0.13 ft/day (0.04 m/day). Channel discharge was dominated by variable flood runoff that ranged from zero to 1,540 cfs (43.6 m^3/s) at the Bernardo gage. No record exists for this period at the Rio Puerco gage, which was discontinued by the U. S. Geological Survey in December, 1976. Six years later on 10 December, 1982, the gage was reactivated by the Geological

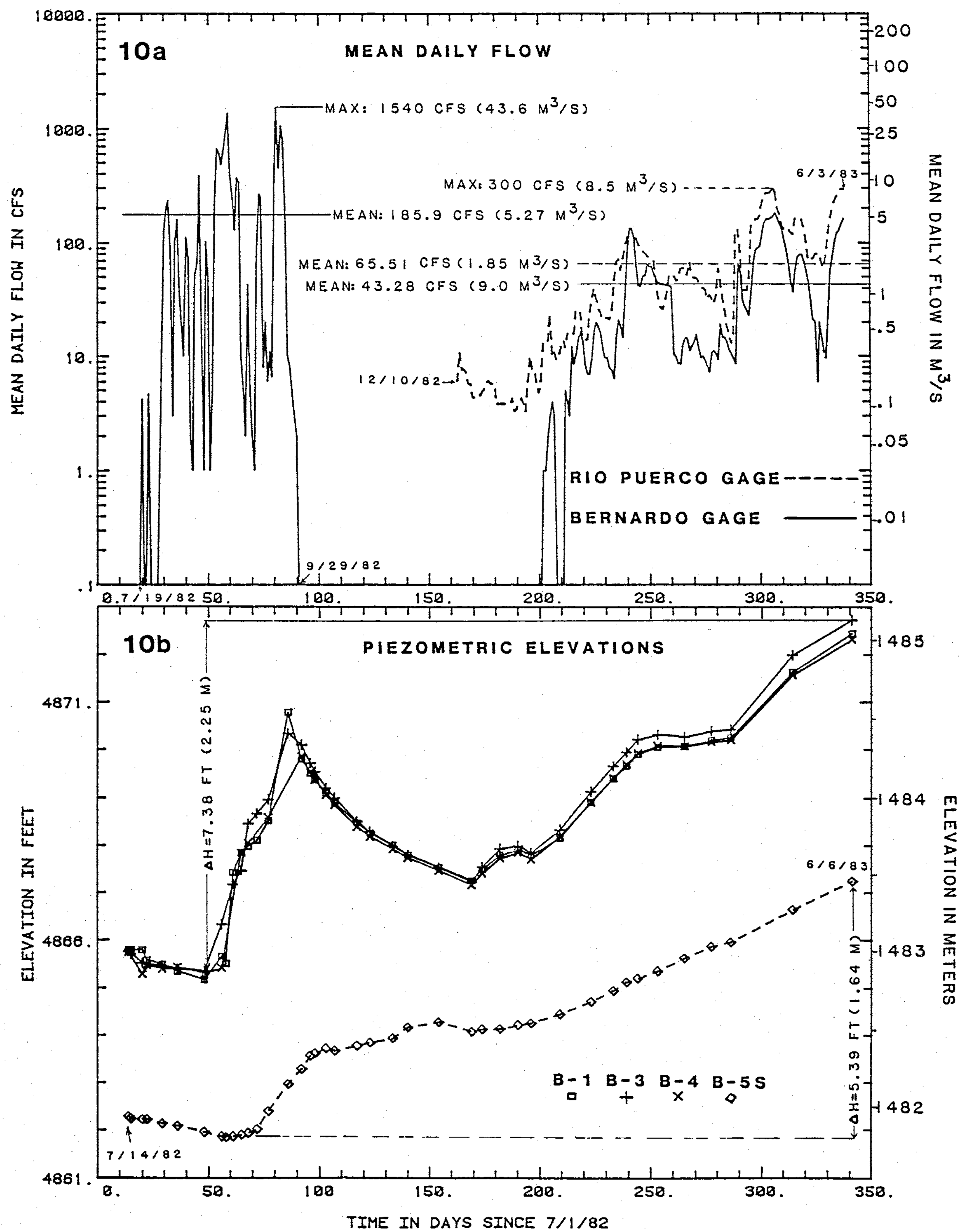


Figure 10a. Hydrographs for the Rio Puerco and Bernardo gages from 19 July, 1982 to 3 June, 1983

Figure 10b. Elevation of the perched water table from 14 July, 1982 to 6 June, 1983

Table 4.

Water-level elevations in feet above mean sea level for piezometers B-1 through B-5D and Popalito Windmill, Rio Puerco valley, T5N.R1W, Valencia County, New Mexico (July 14, 1982 through June 6, 1983). Piezometer water-level elevations were computed from depth measurements with a chalked, steel tape and leveling surveys based on U. S. Corps of Engineers survey data. The elevation of Popalito Windmill water levels were computed from depths below top of casing (reference elevation: 4,920 ft, Titus, 1963; U S G S Belen NW 7.5 minute quad., 1952).

Date	Time	B-1	B-3	B-4	B-5S	B-5D	Popalito Windmill
7-14-82	1026-1216	4865.80	4865.76	4865.73	4862.29	4863.22	
7-15-82	1013-1025	4865.79	4865.71	-------	4862.24	4863.12	
7-20-82	0740-0755	4865.79	4865.52	4865.28	4862.22	4862.99	
7-22-82	1035-1100	4865.58	4865.49	4865.47	4862.23	4862.72	
7-29-82	---------	4865.49	4865.46	4865.39	4862.14	4862.41	
8-5-82	1625-1650	4865.34	4865.40	4865.43	4862.09	4862.14	
8-17-82	1730-1800	4865.16	4865.35	4865.30	4861.96	4861.73	
8-25-82	1200-1233	4865.66	4866.33	4865.41	4861.87	4861.49	
8-27-82	1048-1057	4865.51	-------	-------	4861.86	4861.42	
8-30-82	1125-1144	4867.43	4867.17	-------	4861.87	4861.34	
9-3-82	1133-1151	4867.86	4867.47	4867.84	4861.90	4861.22	
9-6-82	1116-1132	4867.98	4868.45	4868.05	4861.94	4861.12	
9-10-82	1403-1406	4868.11	4868.66	-------	4862.02	4861.01	
9-15-82	1127-1143	4868.51	4868.95	4868.58	4862.39	4860.87	
9-24-82	1135-1156	4870.78	4870.33	-------	4862.96	4860.66	
9-30-82	1415-1432	4869.80	4870.09	4869.85	4863.28	4860.52	
10-4-82	1115-1125	4869.50	4869.71	4869.52	4863.56	4860.36	
10-6-82	1508-1518	4869.36	4869.53	4869.35	4863.62	4860.30	
10-11-82	1033-1043	4869.09	4869.19	4869.04	4863.72	4860.20	
10-15-82	1151-1200	4868.88	4868.99	4868.83	4863.67	4860.06	
10-25-82	1100-1111	4868.47	4868.50	4868.38	4863.78	4859.91	
10-31-82	1106-1119	4868.26	4868.29	4868.18	4863.84	4859.81	
11-10-82	1225-1236	4868.01	4867.99	4867.92	4863.93	4859.64	4826.75
11-17-82	0845-0855	4867.80	4867.81	4867.73	4864.17	4859.50	4826.83
12-1-82	0937-0950	4867.54	4867.53	4867.46	4864.28	4859.26	4826.90
12-16-82	1043-1105	4867.27	4867.23	4867.16	4864.08	4859.02	4826.92
12-21-82	1217-1231	4867.50	4867.55	4867.41	4864.13	4858.89	4826.95
12-29-82	1314-1329	4867.81	4867.94	4867.73	4864.14	4858.79	4826.59
1-6-83	1415-1426	4867.91	4868.00	4867.85	4864.22	4858.67	4826.62
1-12-83	1551-1600	4867.80	4867.85	4867.70	4864.26	4858.59	4826.68
1-25-83	1525-1542	4868.16	4868.33	4868.20	4864.45	4858.42	4826.75
2-8-83	0829-0842	4868.91	4869.12	4868.89	4864.72	4858.21	4826.81
2-18-83	1419-1435	4869.40	4869.65	4869.40	4864.95	4858.06	4826.76
2-24-83	1339-1349	4869.66	4869.94	4869.69	4865.13	4857.94	4826.75
3-1-83	1524-1537	4869.90	4870.21	4869.92	4865.21	4857.88	-------
3-10-83	1619-1627	4870.05	4870.31	4870.08	4865.36	4857.75	4826.30
3-22-83	1540-1558	4870.07	4870.26	4870.06	4865.63	4857.44	-------
4-3-83	0813-0851	4870.19	4870.39	4870.15	4865.87	4857.37	-------
4-12-83	1305-1315	4870.25	4870.42	4870.19	4865.97	4857.35	-------
5-10-83	1020-1031	4871.64	4872.00	4871.58	4866.65	4857.05	4826.80
6-6-83	1517-1529	4872.45	4872.73	4872.33	4867.25	4856.75	4826.60

Survey and the New Mexico Bureau of Mines and Mineral Resources, which agreed to maintain the site for research purposes. By coincidence, flow resumed on this date at the piezometer location 12.6 miles (20.3 km) south of the gage at Rio Puerco and remained continuous through 6 June, 1983. During this flow period, the perched water table rose 4.88 feet in 145 days or 0.03 ft/day (0.01 m/day) to within 10.60 ft (3.23 m) of the streambed. The mean daily flow at the Rio Puerco and the Bernardo gages was 65.5 and 43.3 cfs (1.85 and 9.0 m^3/s), respectively, or over four times less than the mean daily discharge of the summer of 1982.

The perched water table overlies a vadose or unsaturated zone confined between clay layers in the upper valley fill beneath the channel. Figure 4 shows the approximate boundaries of this zone in auger hole B-5 between 33 and 62 feet (10 and 19 m) below the surface. Samples of moist sand and clay with volumetric water contents from 15 to 31 percent were obtained from this vadose interval during drilling. In addition, the water level in piezometer B-5D (fig. 12) has dropped steadily since emplacement on 10 July, 1982 at an average rate of 0.014 ft/day (0.0043 m/day). This piezometer is screened at a depth of 39.41 feet (12.01 m) below the channel bottom. Piezometer B-5S is screened about 10 feet (3 m) above the B-5D screen yet shows no such decrease in water levels. Based on this limited data, the transition from saturated to unsaturated conditions at this site occurs between about 29 to 39 feet (8.8 to 11.9 m) below the channel.

The growth rate of the perched water table mound beneath the Rio Puerco is clearly influenced by stream discharge. One- and two-dimensional flow studies of infiltration dynamics in ephemeral streams by Abdulrazzak and Morel-Seytoux (1982), Morel-Seytoux and Khanji (1974) and Bouwer (1978) have indicated that the Green and Ampt model of infiltration adequately defines the travel of the wetting front below the stream channel. The depth of ponding (river stage) is a decisive factor in how much recharge takes place. High river stages subject the streambed to more flow over its surface area at greater hydrodynamic pressures. If the depth to the water table is not too small, the wetting front will travel at a velocity approximately equal to the hydraulic conductivity of the channel sediments and its width will be slightly greater than the channel width (Abdulrazzak and Morel-Seytoux, 1982). Once the wetting front merges with the water table, the incoming recharge will flow below the water table in a horizontal direction (Bouwer, 1962; Vauclin and others, 1979). Although resistance to infiltration will increase as the ground water mound develops, the mound tends to dissipate because of the hydraulic-head gradient in the horizontal direction which moves water away from the zone of recharge (Abdulrazzak and Morel-Seytoux, 1982). The development of perched ground-water zones in other channel areas would depend, among other factors, on channel geometry, variations between vertical and horizontal hydraulic conductivity within the recent alluvium, phreatophyte activity, thickness and lateral continuity of clay beds beneath the channel and the degree of saturation.

Regional Water Table

The depth of the regional water table below the channel of the Rio Puerco varies appreciably within the study area. Titus (1963, p. 101) reported a depth of approximately 35 feet at the Rio Puerco gage in 1956. Proceeding south, the depth increases to 110 feet near Pueblo windmill at T6N.R1W.15.313, declines to 60 feet east of Popalito windmill at T5N.R1W.14.231, and is only 20 feet below the channel near the Padilla well just north of the Socorro County line. South of this area, the height of the regional water table becomes increasingly shallow, and no distinct perched water zones are likely to exist.

Ground water in the lower Rio Puerco valley moves generally east between Rio Puerco gage and Pueblo windmill at a gradient of about 30 ft/mile (5.7 m/km) (Titus, 1963, plate 3). South of Pueblo windmill the direction of ground-water flow is predominantly southeast at a gradient of only 5 ft/mile (0.95 m/km) indicating either greater transmissivities or thicknesses of saturated valley fill or upper Santa Fe Group deposits in this area.

Table 5 gives the record of water-level measurements in the study area in wells measured by Titus in 1956 and by this writer in 1982 and 1983. In addition, Figures 11 and 12 give hydrographs of ground-water elevations at Pueblo and Popalito wells determined with a water-level recorder and chalked steel tape, respectively. Over the period of

Table 5.

RECORDS OF STOCK WELLS IN THE RIO PUERCO STUDY AREA

WELL LOCATION	WELL ELEVATION (FEET)	WELL DEPTH (FEET)	DEPTH TO WATER (FEET)	WATER ELEVATION (FEET)	DATE MEASURED	REMARKS
T4N.R1W.12.341 (Padilla Well)	4874	60.0+	57.6	4816.4	5-9-56	Titus, 1963 Reported yield: 5 gpm
			59.1	4814.9	12-29-82	Heath
T5N.R1W.14.231 (Popalito Well)	4920	108.5	90.7	4829.3	5-24-56	Titus, 1963 Reported yield: 5 gpm
			93.25	4826.75	11-10-82	Heath
			93.17	4826.83	11-17-82	
			93.10	4826.90	12-1-82	
			93.08	4826.92	12-16-82	
			93.05	4826.95	12-21-82	
			93.41	4826.59	12-29-82	
			93.38	4826.62	1-6-83	
			93.32	4826.68	1-12-83	
			93.25	4826.75	1-25-83	
			93.19	4826.81	2-8-83	
			93.24	4826.76	2-18-83	
			93.25	4826.75	2-24-83	
			93.70	4826.30	3-10-83	
			93.20	4826.80	5-10-83	
			93.40	4826.60	6-6-83	
T6N.R1W.14.112	5021	226	184.2	4836.8	2-10-56	Titus, 1963
			180.35	4840.65	5-10-83	Heath (depth below top of casing)
T6N.R1W.15.313 (Pueblo Windmill)	5002	216	P174.4	4827.6	2-13-56	Titus, 1963
	5003.65*		169.60	4834.05	6-21-83	Heath
			169.63	4834.02	6-28-83	
T7N.R1W.31.124 (Rio Puerco Well)	5048	96.9	74.1	4973.9	2-10-56	Titus, 1963 Reported yield: 2 gpm (Well no longer exists)

*Top of casing = 1.65 ft above ground level

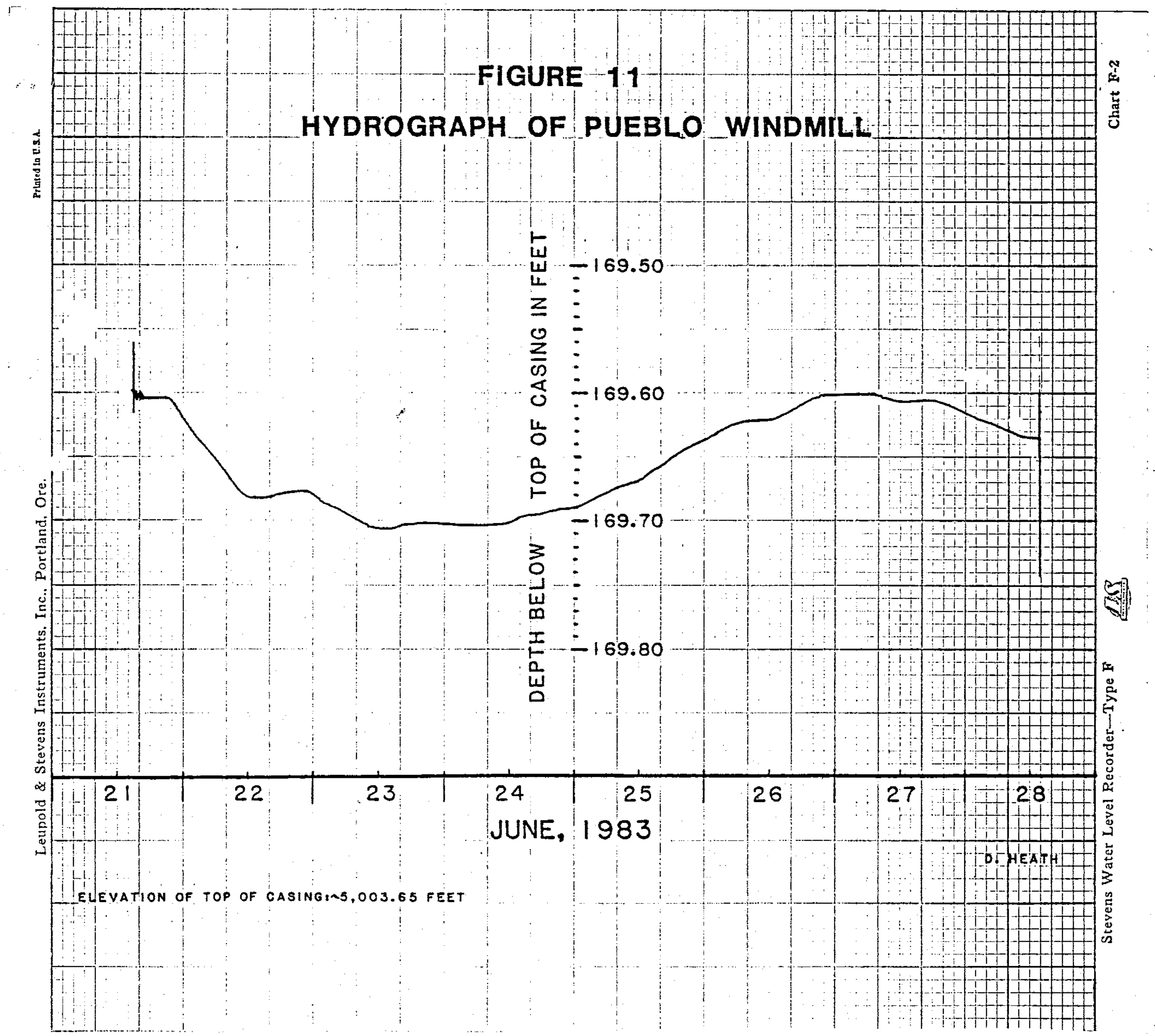


FIGURE 11
HYDROGRAPH OF PUEBLO WINDMILL

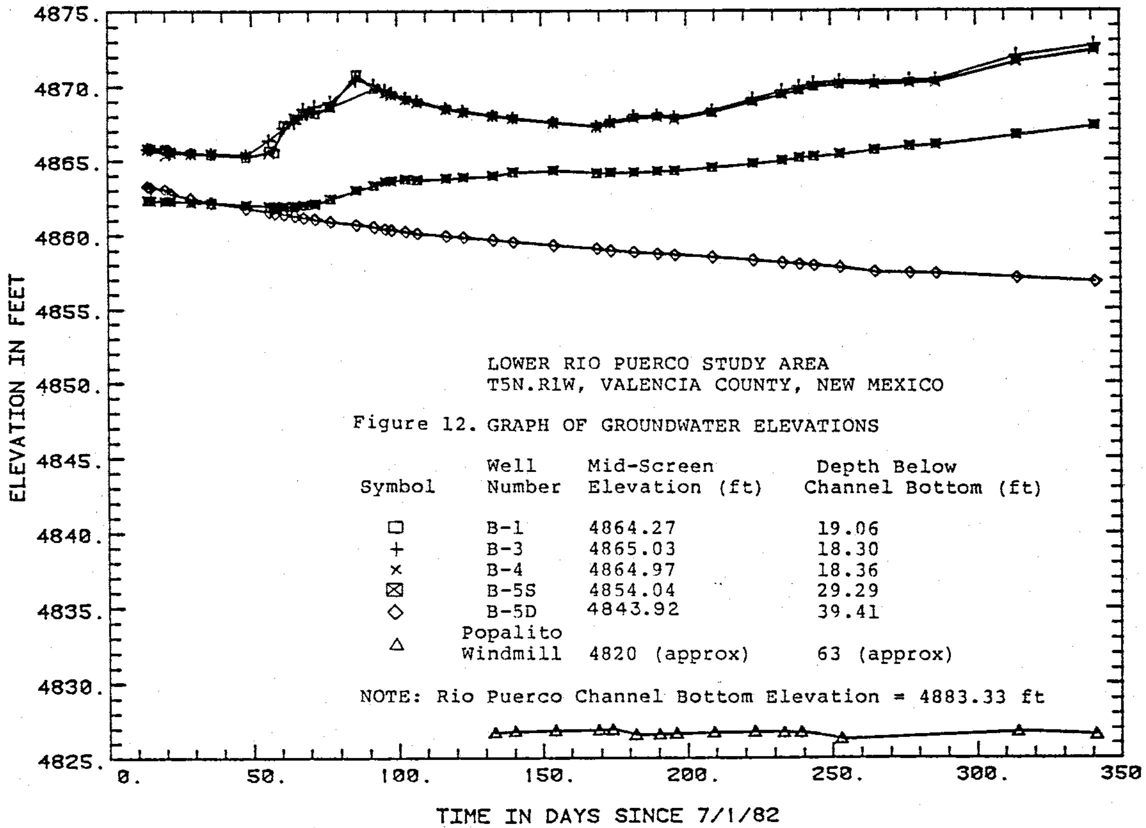


Figure 12. GRAPH OF GROUNDWATER ELEVATIONS

measurement at these wells, changes in water level were less than one foot. Differences between these recent measurements and those of Titus in 1956 may be due to pumping conditions, dissimilar elevation references or to actual changes in water level.

Most wells tapping the upper Santa Fe Group or Rio Puerco valley fill are stock wells equipped with windmills. Within the study area, Titus (1963) reported yields of 5 gpm or less but larger yields (>100 gpm) are probably possible in wells sufficiently equipped and developed to handle higher discharges.

CONCLUSIONS

The results of this study support the following conclusions:

1. Exploratory drilling in July, 1982 showed that the Rio Puerco valley fill, 7 miles (11.3 km) west of Belen, New Mexico, is more than 135.8 ft (41.4 m) thick.

2. Thicknesses of recent channel alluvium commonly range between 10 and 20 ft (3 and 6 m) near or along the channel of 1929, but less in other areas. The 1929 flood, largest since 1880, widened and deepened the arroyo to a large degree. Channel lag deposits frequently delineate the contact between older valley fill and recent alluvium in the Rio Puerco channel.

3. The rapid spread of the phreatophyte Tamarix since 1927 has fostered the development of a narrow channel and inner floodplain, aggradation of the streambed, and the reduction of flood magnitude along the reach between Rio Puerco and Bernardo, New Mexico.

4. Discharge records indicate that the lower Rio Puerco is an intermittent stream flowing an average of 55 percent of the time at Rio Puerco gage and 30 percent of the time at Bernardo gage. Most of the discharge occurs from July through October.

5. Hydraulic conductivities of Rio Puerco channel sands at a site 7 miles (11.3 km) west of Belen, New Mexico range from 7.4 ft/day (2.25 m/day) to nearly 109 ft/day (33 m/day) in sediments with clay and silt contents of less than 22 percent.

6. Average infiltration rates of about 5 cfs (0.15 m^3/s) during the winter season and 10 cfs (0.3 m^3/s) during the summer months were determined along the 48 mile (78 km) reach (channel distance) between the Rio Puerco and Bernardo gaging stations.

7. A perched water table in T5N.R1W.13.134 underlies the Rio Puerco streambed at a depth of about 18 ft (5.5 m) and fluctuates in response to channel discharge.

8. Recent measurements of water levels in wells within the study area in 1982 and 1983 show that the elevations of the regional water table in the Rio Puerco valley are essentially similar to those measured in 1956.

RECOMMENDATIONS FOR FUTURE WORK

In the course of this study, many possibilities for future work in the Rio Puerco basin have become apparent.

Seismic transsects across the Rio Puerco valley should be made to help define subsurface structure, the thickness of the valley fill and the configuration of regional and perched water tables beneath the channel.

Existing measurement facilities, such as the Rio Puerco gage and the piezometer section, should be maintained on a regular basis. It is important to increase the amount of hydrologic data for future flood routing and infiltration studies, including a model incorporating hydraulic conductivity and river stage.

Additional auger holes and piezometers should be constructed in other sections of the Rio Puerco channel. The knowledge about geologic and hydrologic conditions upstream and downstream from the existing site will augment the modeling of subsurface-flow regimes in the lower Rio Puerco valley. These holes will also provide access points for tracer tests to determine ground-water flow velocities and dispersion rates.

At least two deep wells should be drilled in the Rio Puerco valley fill east and west of the river in the area west of Belen, New Mexico. Such wells, equipped with 0.008 or 0.010 inch slot screens, should reach the underlying upper Santa Fe Group deposits, and be developed, pumped and tested to ascertain the transmissive and storage capabilities of the aquifer. Water samples from the tests should be analyzed for chemical composition, and recorders mounted on the surface could continuously monitor fluctuations in the regional water table.

Scour chains should be installed in narrow reaches of the channel bed to record scour and fill during flood events.

Detailed surveys of the Rio Puerco arroyo, such as those performed in this study, should be made to examine changes in arroyo geomorphology over time. Permanent reference and bench marks should be installed for future surveys.

Incremental tree-ring cores from cottonwood and saltcedar vegetation will help determine the relative ages of historic channel movements, especially for periods not shown in aerial photographs. On the basis of the age-area distribution of floodplain vegetation, a model could be constructed to describe channel migration and sediment transport in the Rio Puerco arroyo. Such studies have been successfully performed on other rivers by Sigafoos (1964) and Everitt (1968).

Periodic current-meter discharge measurements at the existing piezometer section or at the Valencia County Road 548 bridge will provide rating curve data. Available current meters could be used for this purpose. A properly updated rating curve would provide more accurate discharge information at channel sites between the Rio Puerco and Bernardo gage stations.

Rain gages should be installed at Rio Puerco and the Popalito area west of Belen, New Mexico to provide more precipitation data for the lower reach.

Additional samples of channel sediments should be obtained for permeability tests, not only along the surface but at different depths below the streambed. Future models of infiltration and recharge capacities cannot work without accurate hydraulic conductivity data of recent channel alluvium.

REFERENCES CITED

Abdulrazzak, M. J. and Morel-Seytoux, H. J., 1982, Recharge from an ephemeral stream following wetting front arrival to water table: Colorado Water Resources Research Institute, pub. CER81-82MJA-HJM64, 20 p.

Betancourt, J. L., 1980, Historical overview of the lower Rio Puerco Rio Salado drainages, New Mexico, in Wimberly, M. and Eidenbach, P., eds., Reconnaissance study of the archaeological and related resources of the lower Puerco and Salado drainages, central New Mexico: Human Systems Research, Inc., Tularosa, New Mexico, p. 23-58.

Biggar, J. W. and Nielsen, D. R., 1976, Spatial variability of the leaching characteristics of a field soil: Water Resources Research, Vol. 12, No. 1, p. 78-84.

Black, B. A., 1982, Oil and gas exploration in the Albuquerque basin, in Grambling, J. A. and Wells, S. G., eds., New Mexico Geological Society Guidebook 33, p. 313-324.

Bouwer, H., 1962, Analyzing groundwater mound by resistance network: American Society of Civil Engineers Proceedings, Journal of the Irrigation and Drainage Division, vol. 88, no. IR3, p. 15-36.

Bouwer, H., 1964, Unsaturated flow in ground-water hydraulics: American Society of Civil Engineers Proceedings, Journal of Hydraulics Division, v. 90, no. HY5, p. 121-243.

Bouwer, H., 1978, Groundwater hydrology: New York, McGraw-Hill Book Company, 480 p.

Bowser, C. W., 1957, Introduction and spread of the undesirable tamarisk in the Pacific southwest section of the United States and comments concerning the plant's influence upon indigenous vegetation: Paper given at Pacific Southwest Regional Meeting, American Geophysical Union, February 15, 1957, 9 p.

Bryan, K., 1928, Historical evidence of changes in the channel of the Rio Puerco, a tributary of the Rio Grande in New Mexico: Journal of Geology, v. 36, p. 265-282.

Bryan, K., 1940, Erosion in the valleys of the Southwest: New Mexico Quarterly, v. 10, p. 227-232.

Bryan, K., 1941, Pre-Columbian agriculture in the Southwest, as conditioned by periods of alluviation: Annals of the Association of American Geographers, v. 31, p. 219-242.

Bryan, K. and McCann, F. T., 1937, The Ceja del Rio Puerco--a border feature of the Basin and Range province in New Mexico, part I, Stratigraphy and structure: Journal of Geology, v. 45, p. 801-828.

Bryan, K. and McCann, F. T., 1938, The Ceja del Rio Puerco--a border feature of the Basin and Range province in New Mexico, part II, Geomorphology: Journal of Geology, v. 46, p. 1-16.

Bryan, K. and Post, G. M., 1928, Erosion and control of silt on the Rio Puerco, New Mexico: Albuquerque, Unpublished report to the Chief Engineer, Middle Rio Grande Conservancy District.

Burkham, D. E., 1970, A method for relating infiltration rates to streamflow rates in perched streams: U. S. Geological Survey Professional Paper 700-D, p. D266-D271.

Corps of Engineers, 1978, Report on review survey for flood control and allied purposes, Rio Grande and tributaries: Rio Puerco and Rio Salado, New Mexico: Dept. of the Army, Albuquerque District Corps of Engineers, 60 p., 3 plates, 8 appendices.

Culbertson, J. K. and Dawdy, D. R., 1964, A study of fluvial characteristics and hydraulic variables, middle Rio Grande, New Mexico: U. S. Geological Survey Water-Supply Paper 1498-F, 74p.

Davie, W., Jr. and Spiegel, Z. E., 1967, Geology and water resources of Las Animas Creek and vicinity, Sierra County, New Mexico: State Engineer Hydrographic Survey Report.

Elliott, J. G., 1979, Evolution of large arroyos: The Rio Puerco of New Mexico (M.S. Thesis): Fort Collins, Department of Earth

Resources, Colorado State University, 105 p.

Everitt, B. L., 1968, Use of the cottonwood in an investigation of the recent history of a floodplain: American Journal of Science, vol. 266, p. 417-439.

Folk, R. L., 1974, Petrology of sedimentary rocks: Austin, Texas, Hemphill Publishing Company, 182 p.

Freeze, R. A. and Cherry, J. A., 1979, Groundwater: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 604 p.

Gatewood, J. S., Robinson, T. W., Colby, B. R., Hem, B. R., and Halpenny, L. C., 1950, Use of water by bottom-land vegetation in lower Safford Valley, Arizona: U. S. Geological Survey Water-Supply Paper 1103, 210 p.

Hawley, J. W., Love, D. W. and Wells, S. G., 1982, Second day: Road log segment II-A: Albuquerque to Correo via El Cerro de los Lunas and Rio Puerco: New Mexico Geological Society Guidebook 33, p. 38-70.

Hedman, E. R. and Osterkamp, W. R., 1982, Streamflow characteristics related to channel geometry of streams in western United States: U. S. Geological Survey Water-Supply Paper 2193, 17 p.

Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U. S. Geological Survey Water-Supply Paper 1473, 269 p.

Horton, J. S. and Campbell, C. J., 1974, Management of phreatophyte and riparian vegetation for maximum multiple use values: U. S. Department of Agriculture Forest Service Research Paper RM-117, 23 p.

Keisling, T. C., Davidson, J. M., Weeks, D. L. and Morrison, R. D., 1977, Precision with which selected soil physical parameters can be estimated: Soil Science, vol. 124, no. 4, p. 241-248.

Kelley, V. C., 1977, Geology of the Albuquerque basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources Memoir 33, 59 p.

Kelley, V. C. and Wood, G. H., Jr., 1946, Lucero Uplift, Valencia, Socorro and Bernalillo counties, New Mexico: U. S. Geological Survey Oil and Gas Investigations Preliminary Map 47.

Kelley, V. C. and Kudo, A. M., 1978, Volcanoes and related basalts of the Albuquerque basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources Circular 156, 30 p.

Keppel, R. V. and Renard, K. G., 1962, Transmission losses in ephemeral stream beds: American Society of Civil Engineers Proceedings, Journal of the Hydraulics Division, vol. HY3, p. 59-68.

Leopold, L. B., Wolman, M. G. and Miller, J. P., 1964, Fluvial processes in geomorphology: San Francisco, W. H. Freeman and Co., 522 p.

Love, D. W., Hawley, J. W. and Young, J. D., 1982, Preliminary report on the geomorphic history of the lower Rio Puerco in relation to archaeological sites and cultural resources of the lower Hidden Mountain dam site, in Eidenbach, P., ed., Inventory survey of the lower Hidden Mountain floodpool, lower Rio Puerco drainage, central New Mexico: Tularosa, New Mexico, Human System Research, Inc., p. 21-65.

Love, D. W. and Young, J. D., 1983, Progress report of the late Cenozoic geologic evolution of the lower Rio Puerco: New Mexico Geological Society Guidebook 34 (in press).

Machette, M. N., 1978, Late Cenozoic geology of the San Acacia-Bernardo area, in Hawley, J. W., compiler, Guidebook to the Rio Grande rift in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources Circular 163, p. 135-137.

Moore, J. E. and Jenkins, C. T., 1966, An evaluation of the effect of ground-water pumpage on the infiltration rate of a semipervious streambed: Water Resources Research, vol. 2, no. 4, p. 691-696.

Morel-Seytoux, H. J. and Khanji, J., 1974, Derivation of an equation of infiltration: Water Resources Research, vol. 10, no. 4, p. 795-800.

New Mexico State Engineer, 1916, Second report of the State Engineer of New Mexico: Santa Fe, State of New Mexico, 106 p.

New Mexico State Engineer, 1930, Ninth biennial report: Santa Fe, State of New Mexico, p. 244-288.

National Oceanographic and Atmospheric Administration, 1929-1983, Climatological data for New Mexico: Asheville, North Carolina, National Oceanic and Atmospheric Administration, Environmental Data and Information Service (published monthly).

Nordin, C. F. and Curtis, W. F., 1962, Formation and deposition of clay balls, Rio Puerco, New Mexico: U. S. Geological Survey Professional Paper 450-B, p. B-37 to B-40.

Patton, P. C., 1973, Gully erosion in the semiarid west (M.S. Thesis): Fort Collins, Colorado State University, 129 p.

Pease, D. S., 1975, Soil survey of Valencia County, New Mexico, eastern part: U. S. Department of Agriculture, Soil Conservation Service, 121 p.

Renner, O., 1915, Wasserversorgung der Pflanze in Handworterbuch der Natur Wissenschaftler, v. 10, p. 538-577.

Schumm, S., 1977, The fluvial system: New York, John Wiley and Sons, 338 p.

Shepherd, R. G., 1978, Distinction of aggradational and degradational fluvial regimes in valley-fill alluvium, Tapia Canyon, New Mexico, in Miall, A. D., ed., Fluvial sedimentology: Canadian Society of Petroleum Geologists Memoir 5, p.277-286.

Sigafoos, R. S., 1964, Botanical evidence of floods and floodplain deposition: U. S. Geological Survey Professional Paper 485-A, 35 p.

Simcox, A. C., 1983, The Rio Salado at flood: New Mexico Geological Society Guidebook 34 (in press).

Spiegel, Z. E., 1955, Geology and ground-water resources of northeastern Socorro County, New Mexico: New Mexico Bureau of Mines and Mineral Resources Ground-Water Report 4, 99 p.

Tedford, R. H., 1981, Mammalian biochronology of the late Cenozoic basins of New Mexico: Geological Society of America Bulletin, Part I, v. 92, p. 1008-1022.

Titus, F. B., 1963, Geology and ground-water conditions in eastern Valencia County, New Mexico: New Mexico Bureau of Mines and Mineral Resources Ground-Water Report 7, 113 p.

Tuan, Yi-Fu, 1966, New Mexico gullies: a critical review and some recent observations: Annals of the Association of American Geographers, v. 56, p. 573-597.

U. S. Geological Survey, 1981, Summary of basin and flood characteristics for unregulated basins in New Mexico: Open-file Report 81-1071.

U. S. Geological Survey, 1961-1982, Water resources data, New Mexico, (annual reports).

U. S. Geological Survey, 1934-1960, Water-supply papers 764-1713, (annual reports).

U. S. Public Health Service, 1962, Drinking water standards: U. S. Government Printing Office, p. 2152-2155.

Van Hylckama, T. E. A., 1974, Water use by saltcedar as measured by the water budget method: U. S. Geological Society Professional Paper 491-E, 30 p.

Vauclin, M. D., Khanji, J., Vachaud, G., 1979, Experimental and numerical study of a transient two-dimensional unsaturated-saturated water table recharge problem: Water Resources Research, v. 15, no. 5, p. 1089-1101.

Wentworth, C. K., 1922, A scale of grade and class terms for clastic sediments: Journal of Geology, v. 30, p. 377-392.

Wolman, M. G. and Leopold, L. B., 1957, River floodplains: some observations on their formation: U. S. Geological Survey Professional Paper 282-C, p. 87-107.

Wright, H. E., 1946, Tertiary and Quaternary geology of the lower Rio Puerco area, New Mexico: Geological Society of America Bulletin, v. 57, p. 383-456.

Young, J. D., 1982, Late Cenozoic geology of the lower Rio Puerco, Valencia and Socorro Counties, New Mexico (MS Thesis): Socorro, New Mexico Institute of Mining and Technology, 126 p.

APPENDIX A

Table 6.

Auger Hole Data, Lower Rio Puerco, Valencia County, New Mexico

AUGER HOLE	DATE DRILLED	ELEVATION (FT)	TOTAL DEPTH (FT)	SCREEN DEPTH (FT)	LOCATION*
B-1	6-16-82	4888.72	24.60	23.45-25.45	1.65 ft E of B
B-2	6-17-82	4883.33	10.13	Scour Chain	23.0 ft E of B
B-3	6-18-82	4888.61	24.50	22.58-24.58	47.0 ft E of B
B-4	6-23-82	4887.89	21.71	21.92-23.92	86.7 ft E of B
B-5D	7-10-82	4890.02	110.50	44.60-47.60	55.5 ft W of B
B-5S	7-10-82	4890.04	110.50	34.50-37.50	55.5 ft W of B
B-6	10-4-82	4889.39	21.65		31.8 ft W of B
B-7	10-6-82	4915.20	17.40		145.3 ft W of B
B-8	11-17-82	4888.86	21.65		108.1 ft E of B
B-9	11-17-82	4889.03	22.30		150.9 ft E of B
B-10	11-17-82	4889.34	23.80		203.9 ft E of B

*NOTE: Reference-marker stake B is located on west bank of active channel at T5N.R1W.13.1344, 11.4 km west of Belen, Valencia County, New Mexico.

Table 7. Geologic description of auger holes B-1 through B-10 and no. 548

LOWER RIO PUERCO STUDY AREA, VALENCIA COUNTY, NEW MEXICO

DESCRIPTION OF AUGER HOLE B-1
LOCATION: T5N.R1W.13.1344, 0.5 m east of Stake B on west bank of active channel, 11.4 km west of Belen, New Mexico.
ELEVATION: 1490.08 meters above mean sea level
DATE DRILLED: 16 June, 1982

NOTE: Depth is given in meters, tenths and hundredths of meters; depth accuracy is 0.01 meters.

Sample colors determined with Munsell Soil Color Charts (1975 ed.).

W = gravimetric soil-water content of samples (sealed in plastic containers during transport to laboratory) for the drilling date, given in percent. Eq.: W = (Mw - Md)/Md X 100, where Mw = weight of sample obtained from hole and Md = weight of sample dried at 105 C for at least 24 hours.

Depth (meters)	Color (Munsell)	w (%)	Description
0.00-0.17	10YR5/4	5	Poorly sorted, yellowish brown, sandy clay loam
0.17-0.28	10YR5/4	7	ditto
0.28-0.39	10YR5/4	6	ditto
0.39-0.49	10YR5/4	11	ditto
0.49-0.59	10YR5/4	10	ditto
0.59-0.75	10YR5/4	10	ditto, with saltcedar roots (Tamarix sp.)
0.75-0.90	10YR5/4	6	ditto
0.90-1.05	10YR4/3	21	Poorly sorted, dark brown, sandy clay loam
1.05-1.20	10YR5/4	16	Poorly sorted, yellowish brown, sandy clay loam
1.20-1.40	10YR5/4	26	ditto
1.40-1.45	10YR5/4	22	Yellowish brown clay with roots and some fine sand
1.45-1.52	10YR5/4	26	ditto
1.52-1.62	10YR5/4	27	ditto
1.62-1.75	10YR5/4	21	ditto
1.75-1.86	10YR5/4	9	Moderately sorted, yellowish brown, very fine to fine sand
1.86-2.16	10YR5/4	25	Yellowish brown silt and clay with some fine sand
2.16-2.27	10YR5/4	14	Poorly sorted, yellowish brown, very fine to fine sand
2.27-2.40	10YR5/4	8	Moderately sorted, yellowish brown, fine to medium sand

2.40-2.53	10YR5/4	9	ditto, with roots
2.53-2.67	10YR5/4	6	ditto
2.67-2.80	10YR5/4	8	ditto
2.80-2.95	10YR5/4	33	Yellowish brown clay with some red streaks
2.95-3.06	10YR5/4	20	Poorly sorted sandy clay loam
3.06-3.14	10YR5/4	28	Yellowish brown clay with minor amounts of fine sand
3.14-3.25	10YR5/4	22	Poorly sorted sandy clay loam
3.25-3.41	10YR5/4	31	Yellowish brown clay with minor amounts of fine sand
3.41-3.60	10YR5/4	25	ditto
3.60-3.70	10YR5/4	35	Yellowish brown clay
3.70-3.90	10YR5/4	28	ditto
3.90-4.00	10YR5/4	24	ditto
4.00-4.18	10YR5/4	22	ditto, with minor amounts of fine sand
4.18-4.28	10YR5/4	24	Yellowish brown clay
4.28-4.39	10YR5/4	25	ditto
4.39-4.50	10YR5/4	26	ditto
4.50-4.64	10YR5/4	12	Moderately sorted, yellowish brown, very fine to medium sand
4.64-4.86	10YR5/4	11	ditto
4.86-4.99	10YR5/4	7	ditto
4.99-5.10	10YR5/4	10	ditto
5.10-5.54	10YR5/4	7	ditto
5.54-6.11	10YR5/4	6	ditto
6.11-6.30	10YR5/4	13	ditto
6.30-6.38	10YR5/4	31	Poorly sorted, yellowish brown clay with fine to coarse sand and small pebbles <1.0 cm diameter
6.38-6.50	10YR4/3	32	Dark brown clay with some red or gray streaks
6.50-6.56	10YR4/3	33	ditto
6.56-6.62	10YR4/3	32	ditto
6.62-6.70	10YR4/3	30	ditto
6.70-6.81	10YR4/3	26	ditto
6.81-6.96	10YR5/4	27	Yellowish brown clay with minor amounts of silt and very fine sand
6.96-7.10	10YR5/4	33	ditto, with some red or gray streaks
7.10-7.32	10YR5/4	29	ditto
7.32-7.50	10YR5/4	34	ditto
7.50			Total depth of auger hole B-1

LOWER RIO PUERCO STUDY AREA, VALENCIA COUNTY, NEW MEXICO

DESCRIPTION OF AUGER HOLE B-2
LOCATION: T5N.R1W.13.1344, mid-channel, 7 meters east of Stake B on west bank of active channel, 11.4 km west of Belen, New Mexico.
ELEVATION: 1488.44 meters above mean sea level
DATE DRILLED: 17 June, 1982

NOTE: Depth is given in meters, tenths and hundredths of meters; depth accuracy is 0.01 meters.

Sample colors determined with Munsell Soil Color Charts (1975 ed.).

W = gravimetric soil water content of samples (sealed in plastic containers during transport to laboratory) for the drilling date, given in percent. Eq.: W = (Mw - Md)/Md X 100, where Mw = weight of sample obtained from hole and Md = weight of sample dried at 105 C for 24 hours.

95/5: Ratio of sand to silt-clay content, in percent, determined by wet-sieving with a no. 230 mesh with 0.062 mm openings.

Depth (meters)	Color (Munsell)	w (%)	Description
0.00-0.26	10YR5/4	9	Poorly sorted, yellowish brown mid-channel surface deposits of clay, silt and fine to medium sand; moist but unsaturated; 95/5
0.26-0.39	10YR5/4	12	Moderately sorted, yellowish brown, fine to medium sand (mean diameter: approx. 0.15 mm); moist but unsaturated; 96/4
0.39-0.63	10YR5/4	10	ditto, hydraulic conductivity of sample from 0.50-0.56 m depth = 0.012 cm/sec; 95/5
0.63-0.76	10YR5/4	7	ditto; 98/2
0.76-0.88	10YR5/4	13	ditto; 92/8
0.88-0.90	10YR5/4	20	Thin, yellowish brown clay lamina; 21/79
0.90-1.75	10YR5/4	11	Moderately sorted, yellowish brown, fine to medium sand; moist but unsaturated; hydraulic conductivities of samples from 1.00-1.06 and 1.50-1.56 m depths are 0.012 and 0.007 cm/sec, respectively; 95/5
1.75-1.88	10YR5/3	14	Moderately sorted, brown, fine to medium sand; 96/4
1.88-2.00	10YR5/3	26	Poorly sorted, fine to medium sand with minor clay; unsaturated; 97/3
2.00-2.12	10YR5/3	22	ditto; 97/3
2.12-2.25	10YR5/4	25	Poorly sorted, yellowish brown, fine to medium sand; moist but unsaturated; 97/3
2.25-2.39	10YR5/4	24	ditto; 97/3
2.39-2.50	10YR5/4	23	ditto; 96/4
2.50-2.62	10YR5/4	29	Poorly sorted, yellowish brown, fine to coarse sand and granules < 4 mm diameter, underlain by a thin clay lamina 3 cm thick; saturated and caving
2.62-2.75	10YR5/4	26	Moderately sorted, yellowish brown, fine to medium sand; saturated and caving; 92/8
2.75-2.86	10YR5/4	25	Poorly sorted, yellowish brown, fine to coarse sand and small granules with clay from 2.84 to 2.86 m depth; saturated and caving
2.86-2.99	10YR5/4	26	Poorly sorted, yellowish brown, fine to medium sand and clay; saturated and caving; 68/32
2.99-3.09	10YR5/4	28	Yellowish brown clay and poorly sorted, fine to medium sand; saturated; 28/72
3.09			Total depth of auger hole B-2

LOWER RIO PUERCO STUDY AREA, VALENCIA COUNTY, NEW MEXICO

DESCRIPTION OF AUGER HOLE B-3
LOCATION: T5N.R1W.13.1344, on east bank of the Rio Puerco, 14.3 meters east of Stake B (on west bank of active channel), 11.4 km west of Belen, New Mexico.
ELEVATION: 1490.05 meters above mean sea level
DATE DRILLED: 18 June, 1982
HOLE DIAMETER: 7.62 cm
NOTE: Depth is given in meters, tenths and hundredths of meters; minimum resolution is 0.01 m.

Sample colors determined with Munsell Soil Color Charts (1975 ed.).

Clast description described according to Wentworth size classes.

W = gravimetric soil water content of samples (sealed in plastic containers during transport to laboratory) for the drilling date, given in percent. Eq.: W = (Mw - Md)/Md X 100, where Mw = weight of sample obtained from hole and Md = weight of sample dried at 105 C for 24 hours.

Depth (meters)	Color (Munsell)	w (%)	Description
0.00-0.13	10YR6/4	3	Poorly sorted, light yellowish brown, fine to medium sand with minor clay and silt
0.13-0.19	10YR6/3	4	Poorly sorted, pale brown, very fine to medium sand with minor clay and silt
0.19-0.53	10YR5/4	5	Moderately sorted, yellowish brown, fine to medium sand, moist but unsaturated
0.53-0.95	10YR5/4	6	ditto
0.95-1.53	10YR5/4	7	ditto
1.53-1.67	10YR5/4	9	ditto, with increased clay content
1.67-1.78	10YR5/4	8	ditto
1.78-1.90	10YR5/4	12	ditto, with increased clay content
1.90-2.02	10YR5/4	8	ditto
2.02-2.14	10YR5/4	7	ditto
2.14-2.38	10YR5/4	6	ditto
2.38-2.62	10YR5/4	8	ditto
2.62-2.76	10YR4/2	29	Poorly sorted, dark grayish brown clay with minor amounts of very fine to fine sand; unsaturated
2.76-2.88	10YR5/4	11	Moderately sorted, yellowish brown, fine to medium sand; moist but unsaturated
2.88-3.12	10YR5/4	7	ditto
3.12-3.24	10YR5/4	19	ditto, with increased clay content; unsaturated
3.24-4.09	10YR5/4	7	ditto
4.09-4.19	10YR5/4	10	ditto
4.19-5.95	10YR5/4	7	ditto, with carbonaceous material at 4.98 m
5.95-6.05	10YR5/4	8	ditto, with pebbles < 4.5 cm diameter
6.05-6.15	10YR5/4	20	Poorly sorted, yellowish brown, sandy clay loam
6.15-6.30	10YR5/4	21	ditto
6.30-6.40	10YR5/4	16	Poorly sorted, yellowish brown, fine to coarse sand and small pebbles
6.40-6.50	10YR5/4	15	ditto
6.50-6.79	10YR5/4	24	Poorly sorted, yellowish brown, medium to coarse sand with clayballs; saturated
6.79-6.98	10YR5/4	22	Moderately sorted, yellowish brown, fine to medium sand and minor clay; saturated
6.98-7.36	10YR5/4	19	Poorly sorted, yellowish brown, medium to very coarse sand and minor clay; saturated
7.36-7.40	10YR5/4	17	ditto, with pebbles > 20 mm in diameter
7.40-7.47	10YR5/4	18	ditto, with pebbles > 30 mm in diameter
7.47			Total depth of auger hole B-3

LOWER RIO PUERCO STUDY AREA, VALENCIA COUNTY, NEW MEXICO

DESCRIPTION OF AUGER HOLE B-4
LOCATION: T5N.R1W.13.1344, 26.43 meters east of Stake B (on the west bank of the active channel), 11.4 km west of Belen, New Mexico.
ELEVATION: 1489.83 meters above mean sea level
DATE DRILLED: 23 June, 1982
NOTE: Depth is given in meters, tenths and hundredths of meters; minimum resolution is 0.01 m.

Sample colors determined with Munsell Soil Color Charts (1975 ed.).

Clast decriptions are according to Wentworth (1922) size classes.

W = gravimetric soil water content of samples (sealed in plastic containers during transport to laboratory) for the drilling date, given in percent. Eq.: W = (Mw - Md)/Md X 100, where Mw = weight of sample obtained from hole and Md = weight of sample dried at 105 C for 24 hours.

Depth (meters)	Color (Munsell)	w (%)	Description
0.00.015	10YR5/2	8	Poorly sorted, grayish brown, very fine to medium sand with minor clay; surface deposits of swale east of main channel
0.15-0.19	10YR5/4	10	Yellowish brown clay with minor silt and fine sand; overbank flood deposits in swale east of main channel
0.19-0.31	10YR5/4	17	ditto
0.31-0.43	10YR5/4	15	ditto
0.43-0.52	10YR5/4	16	ditto
0.52-0.68	10YR5/4	15	Poorly sorted, yellowish brown, fine sand with clay balls
0.68-0.75	10YR5/4	4	Moderately sorted, yellowish brown, fine to medium sand
0.75-0.92	10YR5/4	23	Poorly sorted, yellowish brown fine sand with clay at 0.86 m (< 1.0 cm thick)
0.92-1.04	10YR5/4	16	Poorly sorted, sandy clay loam
1.04-1.18	10YR5/4	6	Moderately sorted, yellowish brown, fine to medium sand
1.18-1.30	10YR5/4	16	Poorly sorted, sandy clay loam
1.30-1.40	10YR5/4	11	ditto
1.40-1.51	10YR5/4	9	ditto
1.51-1.64	10YR5/4	17	ditto
1.64-2.30	10YR5/4	4	Moderately sorted, yellowish brown, fine to medium sand

2.30-2.42	10YR5/4	8	ditto
2.42-2.66	10YR5/4	3	ditto
2.66-2.76	10YR5/4	2	ditto
2.76-2.80	10YR5/4	3	ditto
2.80-2.82	10YR5/4	9	Yellowish brown clay lamina
2.82-3.84	10YR5/4	2	Moderately sorted, yellowish brown, fine to medium sand
3.84-4.00	10YR5/4	5	ditto, but with small pebbles (< 2 cm diameter)
4.00-4.01	10YR5/4	10	Yellowish brown, thin clay lamina
4.01-4.40	10YR5/4	3	Poorly sorted, yellowish brown, fine to coarse sand and small pebbles (< 2 cm diameter)
4.40-4.69	10YR5/4	2	Moderately sorted, yellowish brown, fine to medium sand
4.69-4.78	10YR5/4	3	ditto
4.78-4.88	10YR5/4	2	ditto, but fine to coarse sand
4.88-4.97	10YR5/4	3	Poorly sorted, yellowish brown, medium to coarse sand (with clay balls at base)
4.97-5.05	10YR5/4	7	ditto
5.05-5.15	10YR5/4	12	ditto
5.15-5.21	10YR5/4	9	Poorly sorted, yellowish brown, coarse sand and small pebbles
5.21-5.32	10YR5/4	3	ditto
5.32-5.50	10YR5/4	4	ditto
5.50-5.70	10YR5/4	11	ditto, with increased clay content
5.70-5.95	10YR5/4	7	Poorly sorted, yellowish brown, medium to coarse sand
5.95-6.10	10YR5/4	4	ditto
6.10-6.23	10YR5/4	7	ditto
6.23-6.38	10YR5/4	17	ditto, with increased clay content
6.38-6.52	10YR5/4	17	ditto, with small pebbles (<3 cm in diameter); caving at 6.45 meters
6.52-6.62	10YR5/4	20	ditto, perched water table @ 6.53 meters depth
6.62			Total depth of auger hole B-4

RIO PUERCO STUDY AREA
DESCRIPTION OF AUGER HOLE B-5
LOCATION: T5N.,R1W.,13.1444, 16.9 meters west of Stake B, on west bank of Rio Puerco channel.
ELEVATION: 1490.48 meters above mean sea level
DATE DRILLED: July 10, 1982
NOTE: Depth is given in meters, tenths and hundredths of meters, converted from original depth determinations in feet and tenths of feet by the constant 0.3048. Maximum resolution is 0.05 m (0.16 ft) from 0.00 to 6.45 m depth, drilled by a hand bucket auger, and 0.762 m (2.5 ft) from 6.45 to 33.7 meters depth, drilled by a truck-mounted power auger.

Sample colors determined with Munsell Soil Color Charts (1975 ed.).

w = gravimetric soil water content of samples (sealed in plastic containers during transport to laboratory), given in percent.

Sand(%) = weight percentage of clastics with a grain diameter >0.062 mm, determined by heat drying, wet sieving in a 230-mesh, 8" sieve and heat drying/weighing of residue.

Silt+Clay(%) = weight percentage of clastics <0.062 mm in diameter.

Depth (meters)	Color (Munsell)	w (%)	Sand (%)	Silt+Clay (%)	Description
0.0-1.45	10YR4/3	3	78	22	Colluvium, dark brown, sandy clay loam
1.45-2.00	10YR6/4	2	92	8	Fine to medium, light yellowish brown sand (125-350 um)
2.00-2.10	5YR4/6	15	15	85	Yellowish red to greenish brown mottled clay
2.10-2.75	10YR6/4	2	91	9	Fine to medium, moderately sorted, light yellowish brown sand (125-250 um)
2.75-3.16	10YR6/3	9	72	28	Fine to medium, moderately-sorted, pale brown sand (125-350 um)
3.16-3.79	10YR4/3	16	20	80	Dark brown clay; Xray diffraction analysis: Illite 9.5%, Montmorillonite 10%, Mixed Layers 16%, Kaolinite 64.5%
3.79-5.70	10YR6/3	9	73	27	Fine to medium, pale brown sand
5.70-5.85	10YR6/3	13	65	35	Fine to medium, pale brown sand; a few clay balls
5.85-6.05	10YR3/3	19	94	6	Medium to coarse, poorly-sorted, dark brown sand with pebbles (<1.0 cm)
6.05-6.40	10YR3/3	14	77	23	Medium to coarse, poorly-sorted, dark brown clay with silt
6.40-7.62	10YR5/4	19	56	44	Medium to coarse, poorly-sorted, yellowish brown sand with pebbles <0.5 cm) and mottled clay
7.62-8.38	10YR5/4	19	94	6	Medium to coarse, moderately-sorted, subangular to subrounded, yel-

					lowish brown sand
8.38-9.91	10YR3/3	28	48	52	Dark brown clay, with poorly-sorted, subangular to subrounded, medium to coarse sand
9.91-10.67	10YR5/3	25	65	35	Medium to coarse, poorly-sorted, brown sand with clay and small pebbles (<0.5 cm)
10.7-11.1	10YR4/3	29	15	85	Dark brown clay, with fine sand
11.1-11.4	10YR5/4	29	58	42	Yellowish brown clay, with poorly-sorted, fine to medium sand
11.4-12.2	10YR5/4	28	49	51	Yellowish brown clay, with fine sand (125-250 um)
12.2-12.9	10YR4/2	31	22	78	Dark grayish brown clay, with fine to coarse, poorly-sorted sand (125-1000 um); Xray diffr. analysis: Illite 13%, Montmorillonite 20%, Mixed Layers 3%, Kaolinite 64%; Chlorite absent
12.9-13.3	10YR5/4	24	68	32	Fine, yellowish brown sand (62.5-250 um), with clay streaks
13.3-13.7	10YR3/2	28	16	84	Very dark, grayish brown clay, with fine sand (125-177 um)
13.7-14.5	10YR4/4	26	25	75	Dark yellowish brown clay, with very fine sand (62.5-125 um)
14.5-14.9	10YR4/2	31	16	84	Dark grayish brown clay, with moderately-sorted fine sand (125-177 um) Xray diffr. analysis: Illite 13%, Montmorillonite 18%, Mixed Layers 2%, Kaolinite 67%; Chlorite absent
14.9-15.5	10YR4/2	28	15	85	Dark grayish brown clay, with moderately-sorted, very fine to fine sand (62.5-250 um)
15.5-16.0	10YR5/4	24	61	39	Fine, yellowish brown sand (125-250 um), in a clay matrix
16.0-16.8	10YR5/4	15	78	22	Fine to medium, yellowish brown, poorly-sorted sand (125-350 um), with clay laminae and some small pebbles (<0.4 cm)
16.8-17.5	10YR5/4	18	87	13	Fine to coarse, yellowish brown, poorly-sorted sand (177-500 um) with some small pebbles (<0.4 cm)
17.5-17.8	10YR5/3	18	76	24	Fine to medium, brown, poorly-sorted sand (125-350 um) with thin clay laminae and some small pebbles (<1.0 cm)
17.8-18.3	10YR5/3	17	74	26	Fine, brown, moderately-sorted sand (125-177 um), with thin clay laminae
18.3-19.1	10YR5/3	24	65	35	Fine, brown, moderately-sorted sand

					(125-250 um), with thin clay laminae
19.1-19.4	10YR3/3	27	27	63	Dark brown clay, with moderately-sorted, fine sand (125-177 um)
19.4-19.8	10YR4/3	32	17	83	Dark brown clay, with minor amounts of poorly-sorted, fine to medium sand (125-250 um); Xray diffr. analysis: Illite 9%, Montmorillonite 16%, Mixed Layers 18.5%, Kaolinite 56.5%
19.8-20.1	10YR4/1	28	26	74	Dark gray clay, with poorly-sorted, fine to medium sand (125-350 um)
20.1-20.6	10YR5/3	22	71	29	Fine, brown, moderately-sorted sand (125-177 um), with clay laminae and some pebbles (<2.0 cm)
20.6-21.5	10YR5/3	23	73	27	Fine to medium, brown, poorly-sorted sand (125-350 um), with clay laminae and some small pebbles (<1.0 cm)
21.5-22.1	10YR4/2	24	84	16	Fine to medium, dark grayish brown, poorly-sorted sand (125-500 um), with some small pebbles (<1.0 cm)
22.1-22.9	10YR5/4	26	87	13	Fine to medium, yellowish brown, poorly-sorted sand (125-350 um), with some small pebbles (<2.0 cm)
22.9-23.6	10YR5/4	26	83	17	Fine to medium, yellowish brown, poorly-sorted sand (125-350 um)
23.6-24.4	10YR5/4	20	91	9	Medium to coarse, yellowish brown, poorly-sorted sand (250-2000 um), with some small pebbles (<1.0 cm)
24.4-25.1	10YR5/4	21	87	13	Medium to coarse, yellowish brown, poorly-sorted sand (250-2000 um), with some small pebbles (<0.5 cm)
25.1-25.9	10YR5/4	20	89	11	Medium to coarse, yellowish brown, poorly-sorted sand (250-2000 um), with small pebbles (<4.0 cm)
25.9-26.7	10YR5/4	24	79	21	Fine to medium, yellowish brown, poorly-sorted sand (125-350 um), with some pebbles (<2.5 cm)
26.7-27.4	10YR5/4	18	95	5	Medium to coarse, yellowish brown, poorly-sorted sand (250-1000 um), with some small pebbles (2.5 cm)
27.4-28.2	10YR5/4	27	51	49	Fine to medium, yellowish brown, poorly-sorted sand (125-350 um)
28.2-29.0	10YR5/4	21	91	9	Fine to medium, yellowish brown, moderately-sorted sand (125-250 um)
29.0-29.7	10YR4/2	30	25	75	Dark, grayish brown clay, with moderately-sorted, very fine to fine sand (62.5-177 um); Xray diffr. analysis: Illite 13%, Montmorillonite 22.5, Mixed Layers 4.5, Kaolinite

					60%; Chlorite absent
29.7-30.0	10YR4/2	26	34	66	Dark grayish brown clay, with fine to medium, moderately-sorted sand (125-350 um)
30.0-30.5	10YR4/2	21	89	11	Fine to medium, dark grayish brown, poorly-sorted sand (125-500 um), with small pebbles (<2.5 cm) consisting of quartz, granite, basalt, limestone, sandstone, chalcedony and shale
30.5-31.2	10YR4/2	17	91	9	Ditto, but pebbles <3.0 cm
31.2-32.0	10YR4/2	22	82	18	Ditto, but pebbles <4.7 cm
32.0-32.8	10YR4/2	22	81	19	Ditto, but pebbles <5.1 cm
32.8-33.7	10YR4/2	22	80	20	Ditto, but pebbles <4.4 cm
33.7					Total depth of hole; elevation above sea level = 1456.8 meters

LOWER RIO PUERCO STUDY AREA, VALENCIA COUNTY, NEW MEXICO

DESCRIPTION OF AUGER HOLE B-6
LOCATION: T5N.R1W.13.1344, 9.69 meters west of Stake B (on west bank of active channel), 11.4 km west of Belen, New Mexico
ELEVATION: 1490.29 meters above mean sea level
DATE DRILLED: 4 October, 1982
NOTE: Depth is given in meters, tenths and hundredths of meters; minimum resolution is 0.01 meters.

Sample colors determined with Munsell Soil Color Charts (1975 ed.).

Clast descriptions are according to Wentworth (1922) size classes.

Depth (meters)	Color (Munsell)	Description
0.00-0.01	10YR5/2	Grayish brown clay and silt overbank deposits
0.01-0.55	10YR4/3	Poorly sorted, dark brown, moist, sandy clay loam
0.55-0.65	10YR5/3	Brown clay (predominantly kaolinite, with lesser amounts of illite and montmorillonite).
0.65-1.10	10YR4/3	Poorly sorted, dark brown, moist, sandy clay loam
1.10-2.20	10YR3/3	Dark brown, dry, flaky clay
2.20-2.35	10YR6/3	Pale brown, fine sand
2.35-2.45	10YR3/3	Dark brown clay
2.45-2.75	10YR6/3	Moderately sorted, pale brown fine sand with intermittent, thin (<1.0 cm) clay laminae
2.75-2.80	10YR5/4	Poorly sorted, yellowish brown, sandy clay
2.80-3.60	10YR6/4	Light yellowish brown, fine sand with intermittent thin (<1.0 cm) clay laminae
3.60-3.70	10YR4/3	Dark brown clay
3.70-4.05	10YR6/4	Moderately sorted, light yellowish brown, fine sand
4.05-4.10	5YR4/4	Reddish brown clay
4.10-4.28	10YR4/4	Poorly sorted, dark yellowish brown, sandy clay loam
4.28-4.50	10YR6/4	Moderately sorted, light yellowish brown, fine sand
4.50-5.05	10YR4/4	Poorly sorted, dark yellowish brown, sandy clay loam
5.05-5.12	10YR4/3	Dark brown clay
5.12-5.30	10YR4/4	Poorly sorted, dark yellowish brown, fine to medium sand with clay balls and small (<4 cm) pebbles
5.30-5.61	10YR4/4	ditto, with small (< 3 cm) pebbles
5.61-5.95	10YR4/3	Dark brown clay (mottled with streaks of red and gray)
5.95-6.00	10YR4/3	Poorly sorted, dark brown, fine to medium sand with clay, roots and small (<2 cm) pebbles; saturated
6.00-6.50	10YR4/3	Moderately sorted, dark brown, fine to medium sand; perched water table @ 6.23 meters depth at 1430
6.50-6.60	10YR4/3	Dark brown mottled clay with yellowish brown and gray streaks; saturated
6.60		Total depth of auger hole B-6

LOWER RIO PUERCO STUDY AREA, VALENCIA COUNTY, NEW MEXICO

DESCRIPTION OF AUGER HOLE B-7
LOCATION: T5N.R1W.13.134, in valley fill, one meter west of Rio Puerco Arroyo, 44.29 m west of stake B (on west bank of active channel), 11.4 km west of Belen, New Mexico.
ELEVATION: 1498.15 meters above mean sea level
DATE DRILLED: 6 October, 1982
NOTE: Depth is given in meters, tenths and hundredths of meters; minimum resolution is 0.01 meters.

Sample colors determined with Munsell Soil Color Charts (1975 ed.).

Clast descriptions are according to Wentworth (1922) size classes.

Depth (meters)	Color (Munsell)	Description
0.00-0.20	10YR6/3	Pale brown silt and fine sand
0.20-1.25	7.5YR4/2	Poorly sorted, dark brown, sandy clay loam
1.25-2.18	10YR7/3	Poorly sorted, very pale brown, fine sand with many thin (<1.0 cm), pale brown clay laminae (10YR6/3)
2.18-2.45	10YR5/4	Moderately sorted, yellowish brown, fine sand
2.45-2.60	10YR7/3	Poorly sorted, very pale brown, fine sand with many thin (<1.0 cm), pale brown clay laminae (10YR6/3)
2.60-2.65	10YR5/4	Yellowish brown clay
2.65-2.68	10YR6/4	Moderately sorted, light yellowish brown, fine sand
2.68-2.70	10YR5/4	Yellowish brown clay
2.70-2.78	10YR6/4	Moderately sorted, light yellowish brown, fine sand
2.78-2.80	10YR5/4	Yellowish brown clay
2.80-2.82	10YR6/4	Poorly sorted, light yellowish brown, fine sand
2.82-2.85	10YR5/4	Yellowish brown, moist, sandy clay loam
2.85-2.87	10YR6/4	Poorly sorted, light yellowish brown, fine sand
2.87-2.91	10YR5/4	Yellowish brown clay
2.91-2.96	10YR6/4	Poorly sorted, light yellowish brown, fine sand
2.96-3.08	10YR5/4	Yellowish brown clay
3.08-3.11	10YR6/4	Poorly sorted, light yellowish brown, fine sand
3.11-3.15	10YR5/4	Yellowish brown clay
3.15-3.27	10YR6/4	Poorly sorted, light yellowish brown, fine sand
3.27-3.39	10YR5/4	Yellowish brown clay
3.39-3.46	10YR6/4	Poorly sorted. light yellowish brown, fine sand
3.46-3.47	10YR5/4	Yellowish brown clay
3.47-3.56	10YR6/4	Poorly sorted, light yellowish brown, fine sand
3.56-3.65	10YR5/4	Yellowish brown clay
3.65-3.76	10YR6/4	Poorly sorted, light yellowish brown, fine sand
3.76-4.50	10YR6/4	Moderately sorted, light yellowish brown, fine sand
4.50-4.51	7.5YR4/4	Brown, thin clay lamina
4.51-4.72	10YR6/4	Poorly sorted. light yellowish brown, fine sand
4.72-4.77	7.5YR4/2	Brown, sandy clay
4.77-5.00	5YR4/3	Poorly sorted, reddish brown, fine to medium sand in a moderately-cemented clay matrix
5.00-5.30	10YR4/4	Dry, hard, dark yellowish brown clay with reddish brown streaks (5YR5/4)
5.30		Total depth of auger hole B-7

LOWER RIO PUERCO STUDY AREA, VALENCIA COUNTY, NEW MEXICO

DESCRIPTION OF AUGER HOLE B-8
LOCATION: T5N.R1W.13.1344, 32.9 meters east of Stake B (on west bank of active channel), 11.4 km west of Belen, New Mexico.
ELEVATION: 1490.12 meters above mean sea level
DATE DRILLED: 17 November, 1982

NOTE: Depth is given in meters, tenths and hundredths of meters; minimum resolution is 0.01 meters.

Sample colors determined with Munsell Soil Color Charts (1975 ed.).

Clast descriptions are according to Wentworth (1922) size classes.

Depth (meters)	Color (Munsell)	Description
0.00-0.90	10YR5/4	Moderately sorted, yellowish brown, fine to medium, moist sand
0.90-4.40	10YR7/4	Moderately sorted, very pale brown, fine to medium, dry sand
4.40-5.01	10YR5/4	Moderately sorted, yellowish brown, fine to medium, moist sand
5.01-5.20	10YR5/4	Poorly sorted, yellowish brown,medium to coarse sand with small to large pebbles (0.4 to 6.4 cm diameter) and clayballs
5.20-6.12	10YR5/4	Poorly sorted, yellowish brown, medium to coarse sand
6.12-6.60	10YR5/4	Poorly sorted, yellowish brown, medium to coarse sand with small to medium pebbles (<3.0 cm diameter) and clayballs; water saturated and caving
6.60		Total depth of auger hole B-8

LOWER RIO PUERCO STUDY AREA, VALENCIA COUNTY, NEW MEXICO

DESCRIPTION OF AUGER HOLE B-9
LOCATION: T5N.R1W.13.1344, 46.0 meters east of Stake B (on west bank of active channel), 11.4 km west of Belen, New Mexico
ELEVATION: 1490.18 meters above mean sea level
DATE DRILLED: 17 November, 1982

NOTE: Depth is given in meters, tenths and hundredths of meters; minimum resolution is 0.01 meters.

Sample colors determined with Munsell Soil Color Charts (1975 ed.).

Clast descriptions are according to Wentworth (1922) size classes.

Depth (meters)	Color (Munsell)	Description
0.00-1.45	10YR5/4	Moderately sorted, yellowish brown, fine to medium, moist sand
1.45-5.30	10YR7/4	Moderately sorted, very pale brown, fine to medium, dry sand
5.30-5.70	10YR5/4	Poorly sorted, yellowish brown, medium to coarse sand with small to large pebbles (0.4 to 5.0 cm diameter) and clayballs
5.70-6.45	10YR5/4	Poorly sorted, yellowish brown, medium to coarse sand
6.45-6.80	10YR5/4	Poorly sorted, yellowish brown, medium to coarse sand with small to medium pebbles (<3.0 cm diameter) and clayballs; saturated and caving
6.80		Total depth of auger hole B-9

LOWER RIO PUERCO STUDY AREA, VALENCIA COUNTY, NEW MEXICO

DESCRIPTION OF AUGER HOLE B-10
LOCATION: T5N.R1W.13.1344, 62.15 meters east of Stake B (on west bank of active channel), 11.4 km west of Belen, New Mexico.
ELEVATION: 1490.27 meters above mean sea level
DATE DRILLED: 17 November, 1982

NOTE: Depth is given in meters, tenths and hundredths of meters; minimum resolution is 0.01 meters.

Sample colors determined with Munsell Soil Color Charts (1975 ed.).

Clast descriptions are according to Wentworth (1922) size classes.

Depth (meters)	Color (Munsell)	Description
0.00-0.70	10YR5/4	Moderately sorted, yellowish brown, fine to medium, moist sand
0.70-1.23	10YR7/4	Moderately sorted, very pale brown, fine to medium, dry sand
1.23-1.25	10YR5/4	Poorly sorted, yellowish brown, sandy clay loam
1.25-6.30	10YR7/4	Moderately sorted, very pale brown, fine to medium sand (carbonaceous material from 4.5 to 4.9 meters depth)
6.30-6.40	10YR5/4	Poorly sorted, yellowish brown, medium to coarse sand with small to medium pebbles (<3.0 cm diameter) and clayballs
6.40-7.15	10YR5/4	Poorly sorted, yellowish brown, medium to coarse sand
7.15-7.25	10YR5/4	Poorly sorted, yellowish brown, coarse sand with small pebbles (<4.0 cm diameter) and clayballs
7.25		Total depth of auger hole B-10

LOWER RIO PUERCO STUDY AREA, VALENCIA COUNTY, NEW MEXICO

DESCRIPTION OF AUGER HOLE No. 548 Bridge
LOCATION: T5N.R1W.25.1122, 30 meters south of north rail of Valencia County Road 548 Bridge, midway between the active thalweg and west bank of the Rio Puerco, approximately 12 km west of Belen, New Mexico,
DATE DRILLED: 22 December, 1982
NOTE: Depth is given in meters, tenths and hundredths of meters; depth accuracy is 0.01 meters.

Sample colors determined with Munsell Soil Color Charts (1975 ed.).

Clast description according to Wentworth (1922) size classes.

Depth (meters)	Color (Munsell)	Description
0.00-2.50	10YR5/4	Moderately sorted, yellowish brown, fine to medium sand
2.50-2.75	10YR4/3	Dark brown sandy clay loam with roots (Tamarix sp.)
2.75-3.05	10YR5/4	Poorly sorted, yellowish brown, medium to coarse sand with small pebbles (<2.1 cm diameter), subrounded, with clayballs
3.05-3.40	10YR5/4	ditto, but free of clay
3.40-3.45	10YR4/3	Dark brown clay
3.45-4.90	10YR5/4	Poorly to moderately sorted, yellowish brown, fine to medium sand with intermittent thin clay laminae (<1.0 cm thick)
4.90-5.40	5YR5/4	Reddish brown clay with minor coarse sand
5.40-6.10	10YR5/4	Poorly sorted, yellowish brown, sandy clay loam with streaks of gray (10YR5/1) clay
6.10-6.45	10YR5/4	Poorly sorted, yellowish brown, medium to coarse sand with small pebbles (<2.0 cm diameter)
6.45-6.70	10YR5/4	Poorly sorted, yellowish brown, coarse sand with small pebbles and clayballs
6.70-6.93	10YR5/4	Moderately sorted, yellowish brown, fine to medium sand
6.93-7.02	10YR5/4	Poorly sorted, yellowish brown, medium to coarse sand with small pebbles (<3.0 cm diameter) and clayballs; saturated and caving
7.02		Total depth of auger hole

APPENDIX B

Table 8.

GRAIN-SIZE DISTRIBUTION OF RIO PUERCO CHANNEL SAND

Sample 1. Mid-channel sands at 5 cm depth, on B-B' section line, 22.97 ft (7.00 m) east of Stake B, T5N.R1W.13.1344, Valencia County, New Mexico.
Initial weight of sample: 100.04 grams.
Sieve diameter: 8 inches
Date: October, 1982

Sieve Mesh	Opening (mm)	Phi (Ø)	Wt. (grams)	Cum. Wt. (grams)	Ind. Wt. (%)	Cum. Wt. (%)
30	0.600	0.75	-----	-----	-----	-----
40	0.425	1.25	-----	-----	-----	-----
60	0.250	2.00	2.67	2.67	2.69	2.69
100	0.150	2.75	35.25	37.92	35.59	38.25
140	0.106	3.25	34.44	72.36	34.74	73.00
200	0.075	3.75	17.19	89.55	17.34	90.34
270	0.053	4.25	6.19	95.74	6.24	96.58
Pan	<0.053	>4.25	3.39	99.13	3.42	100.00

Ø5 = 2.15
Ø16 = 2.42
Ø25 = 2.65
Ø50 = 2.90
Ø75 = 3.30
Ø84 = 3.52
Ø95 = 4.10

Graphic Mean (Folk, 1974, p. 45) = (Ø16+Ø50+Ø84)/3 = (2.42+2.90+3.52)/3 = Ø2.95 (0.130 mm): fine sand

Inclusive Graphic Standard Deviation (Folk, 1974, p. 46) = (Ø84-Ø16)/4 + (Ø95-Ø5)/6.6 = (3.52-2.42)/4 + (4.10-2.15)/6.6 = Ø0.57: moderately well sorted

Inclusive Graphic Skewness (Folk, 1974, p. 47) = (Ø16+Ø84-2Ø50)/2(Ø84-Ø16) + (Ø5+Ø95-2Ø50)/2(Ø95-Ø5) = (2.42+3.52-5.80)/2(3.52-2.42) = 0.15: fine-skewed

Graphic Kurtosis (Folk, 1974, p. 48) = (Ø95-Ø5)/2.44(Ø75-Ø25) = (4.10-2.15)/2.44(3.30-2.65) = 1.23: mesokurtic

GRAIN-SIZE DISTRIBUTION OF RIO PUERCO CHANNEL SAND

Sample 2. Mid-channel sands at 5 cm depth, 50 ft (15.24 m) south (downstream) of B-B' section line, T5N.R1W.13.1344, Valencia County, New Mexico.
Initial weight of sample: 102.00 grams.
Sieve diameter: 8 inches
Date: October, 1982

Sieve Mesh	Opening (mm)	Phi (Ø)	Wt. (grams)	Cum. Wt. (grams)	Ind. Wt. (%)	Cum. Wt. (%)
30	0.600	0.75	-----	-----	-----	-----
40	0.425	1.25	0.01	0.01	0.01	0.01
60	0.250	2.00	9.48	9.49	9.38	9.39
100	0.150	2.75	42.94	54.43	42.49	51.88
140	0.106	3.25	25.36	77.79	25.10	76.98
200	0.075	3.75	14.32	92.11	14.17	91.15
270	0.053	4.25	5.82	97.93	5.76	97.00
Pan	<0.053	>4.25	3.12	101.05	3.08	100.00

Ø5 = 1.90
Ø16 = 2.17
Ø25 = 2.35
Ø50 = 2.72
Ø75 = 3.20
Ø84 = 3.47
Ø95 = 4.05

Graphic Mean = (Ø16+Ø50+Ø84)/3 = (2.17+2.72+3.47)/3 = Ø2.79 (0.15 mm): fine sand

Inclusive Graphic Standard Deviation = (Ø84-Ø16)/4 + (Ø95-Ø5)/6.6 = (3.47-2.17)/4 + (4.05-1.90)/6.6 = Ø0.65: moderately well sorted

Inclusive Graphic Skewness = (Ø16+084-2Ø50)/2(Ø84-Ø16) + (Ø5+Ø95-2Ø50)/2(Ø95-Ø5) = (2.17+3.47-5.44)/2(3.47-2.17) + (1.90+4.05-5.44)/2(4.05-1.90) = 0.195: fine-skewed

Graphic Kurtosis = (Ø95-Ø5)/2.44(Ø75-Ø25) = (4.05-1.90)2.44(3.20-2.35) = 1.04: mesokurtic

GRAIN-SIZE DISTRIBUTION OF RIO PUERCO CHANNEL SAND

Sample 3. Mid-channel sands at 5 cm depth, 100 ft (30.48 m) south (downstream) from the B-B' section line, T5N.R1W.13.1344, New Mexico.
Initial weight of sample: 102.48 grams.
Sieve diameter: 8 inches
Date: October, 1982

Sieve Mesh	Opening (mm)	Phi (Ø)	Wt. (grams)	Cum. Wt. (grams)	Ind. Wt. (%)	Cum. Wt. (%)
30	0.600	0.75	0.01	0.01	0.01	0.01
40	0.425	1.25	0.16	0.17	0.16	0.17
60	0.250	2.00	8.09	8.26	7.94	8.11
100	0.150	2.75	33.67	41.93	33.05	41.16
140	0.106	3.25	32.10	74.03	31.51	72.67
200	0.075	3.75	17.41	91.44	17.09	89.76
270	0.053	4.25	6.90	98.34	6.77	96.53
Pan	<0.053	>4.25	3.53	101.87	3.46	100.00

Ø5 = 1.87
Ø25 = 2.45
Ø16 = 2.25
Ø50 = 2.88
Ø75 = 3.30
Ø84 = 3.52
Ø95 = 4.10

Graphic Mean = (Ø16+Ø50+Ø84)/3 = (2.25+2.88+3.52)/3 = Ø2.88 (0.14 mm): fine sand

Inclusive Graphic Standard Deviation = (Ø84-Ø16)/4 + (Ø95-Ø5)/6.6 = (3.52-2.25)/4 + (4.10-1.87)/6.6 = Ø0.65: moderately well sorted

Inclusive Graphic Skewness = (Ø16+Ø84-2Ø50)/2(Ø84-Ø16) + (Ø5+Ø95-2Ø50)/2(Ø95-Ø5) = (2.25+3.52-5.76) 2(3.52-2.25) + (1.87+4.10-5.76)/2(4.10-1.87) = 0.05: near-symmetrical

Graphic Kurtosis = (Ø95-Ø5) 2.44(Ø75-Ø25) = (4.10-1.87) 2.44(3.30-2.45) = 1.075: mesokurtic

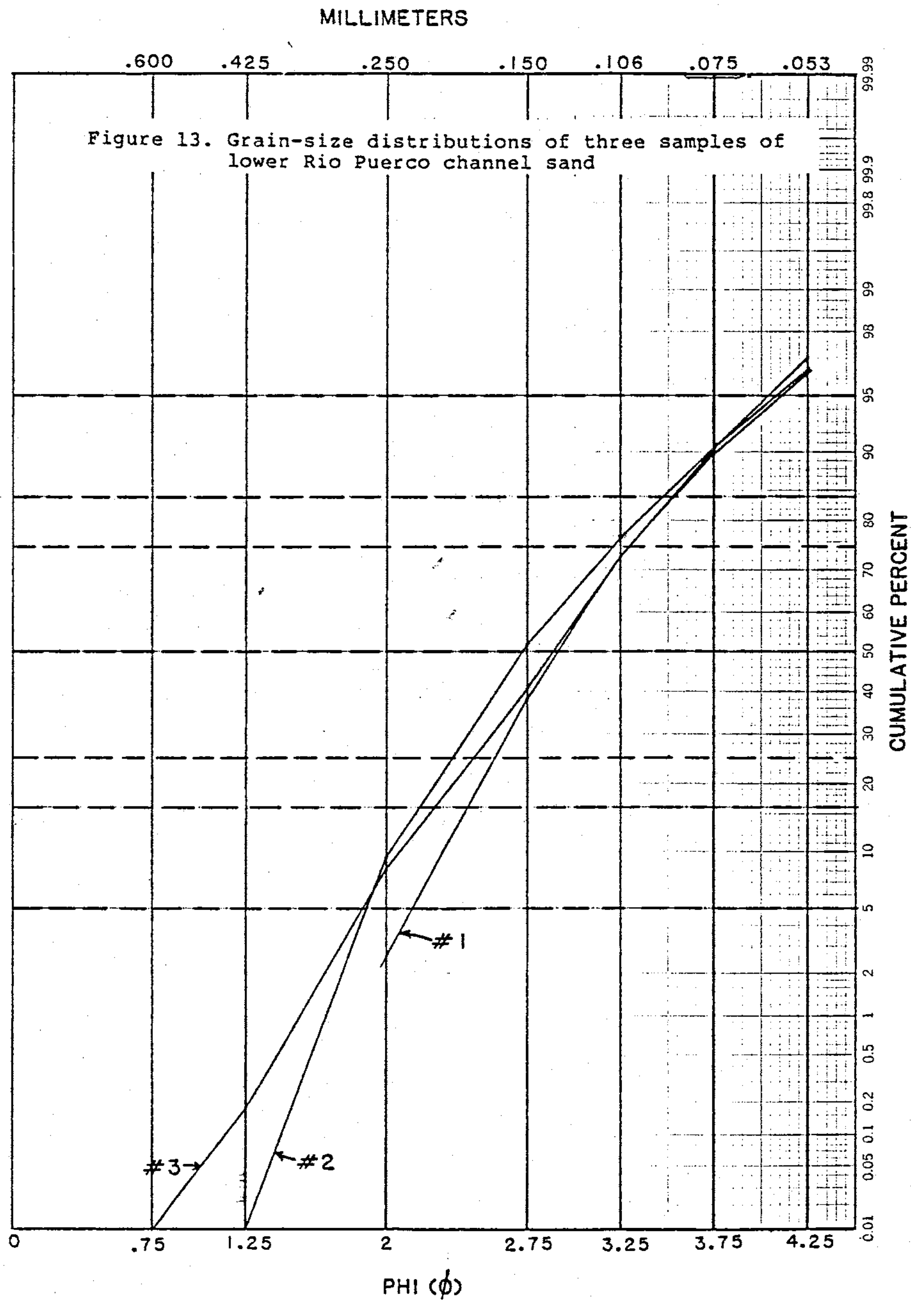


Figure 13. Grain-size distributions of three samples of lower Rio Puerco channel sand

APPENDIX C

Table 9. Method of semi-quantitative clay mineral analysis of Rio Puerco valley-fill clays

My method for semi-quantitative clay mineral analysis of Rio Puerco valley fill clays is that suggested by George Austin of the N. M. Bureau of Mines and Mineral Resources. Sedimented slides of the five sample intervals in auger hole B-5 were run on the Bureau's Rigaku XRD Geiger-Rex X-ray Diffractometer four ways:
(1) no treatment--2° to 35° 2ø at 2° 2ø/minute,
(2) no treatment--24° to 26° 2ø at 0.4° 2ø/minute,
(3) ethylene glycol-24 hours--2° to 15° 2ø at 2° 2ø/minute, and
(4) 375°C - 0.5 hour--9.5° to 8°, then 2° to 15° 2ø at 2° 2ø/minute.

The following table shows the peak heights above background taken on the four runs for the five clay samples in September, 1982:

Run		Clay Sample				
		B-5-5	B-5-17	B-5-21	B-5-30	B-5-44
No treatment:						
12.4°	K(1)	54.5	52.5	60.5	37.5	46.0
17.8°	I(2)	9.0	11.0	14.0	7.5	13.5
18.4°-18.9°	C(3)	----	----	----	----	----
Slow, no treatment:						
24.9°	K(2)	37.0	46.5	55.0	29.0	41.0
25.1°	C(4)	----	----	----	----	----
Ethylene Glycol-24 hours:						
5.2°	M(1)	34.0	65.0	66.0	43.0	69.5
8.8°	I(1G)	8.0	10.5	12.0	6.0	10.0
Heated at 375°C -0.5 hours:						
8.8°	I(1H)	30.0	29.0	30.0	29.0	24.0

Relative proportions of illite, montmorillonite, chlorite, mixed-layer clay minerals and kaolinite were calculated as follows (in parts of 10):

illite = (I(1G)/T) X 10

montmorillonite = ((M(1)/4)/T X 10

chlorite = (C(3)/I(2)) X (I(1G)/T) X 10

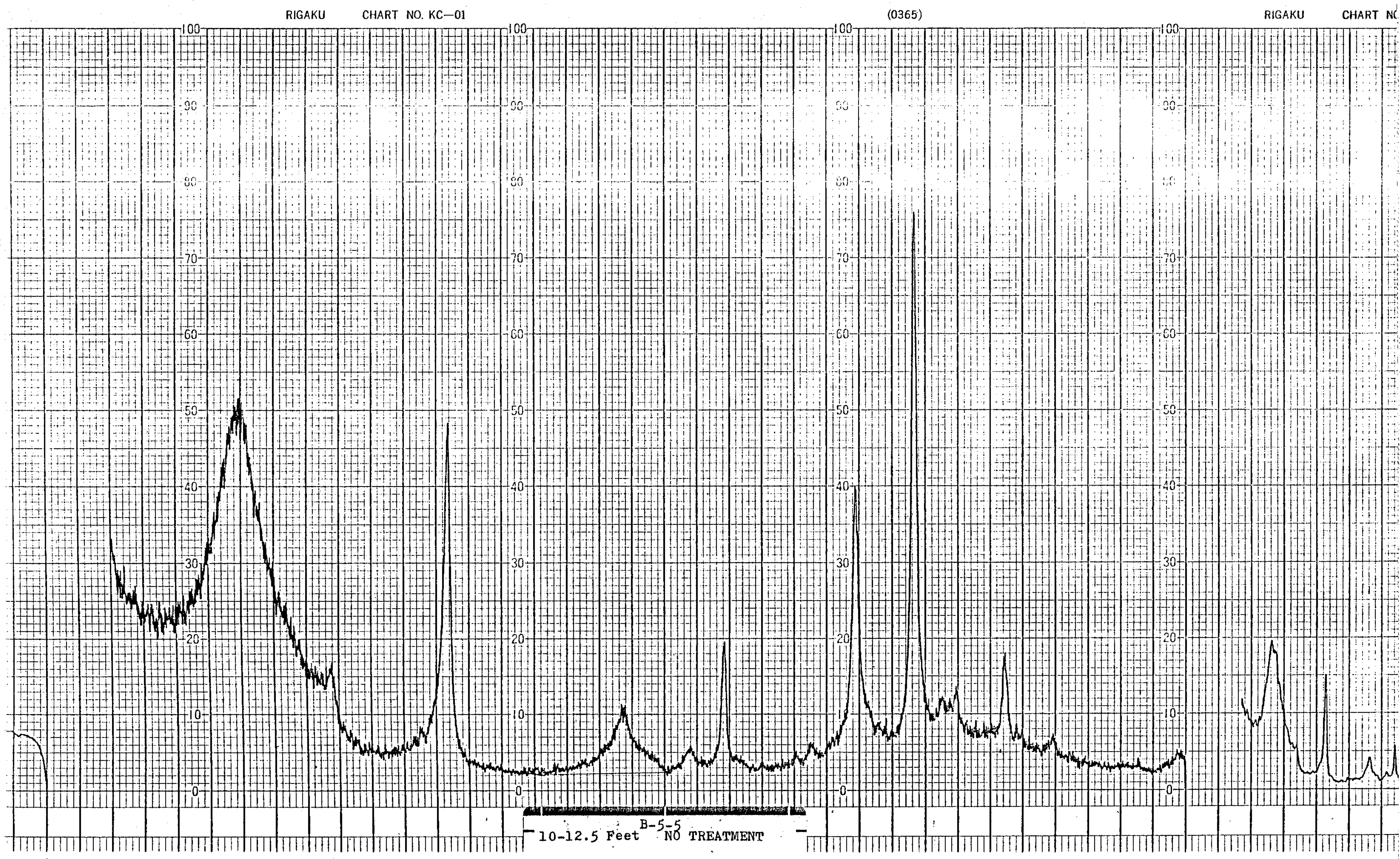
mixed-layer clay minerals = (I(1H) - (I(1G) + (M(1)/4))/T X 10

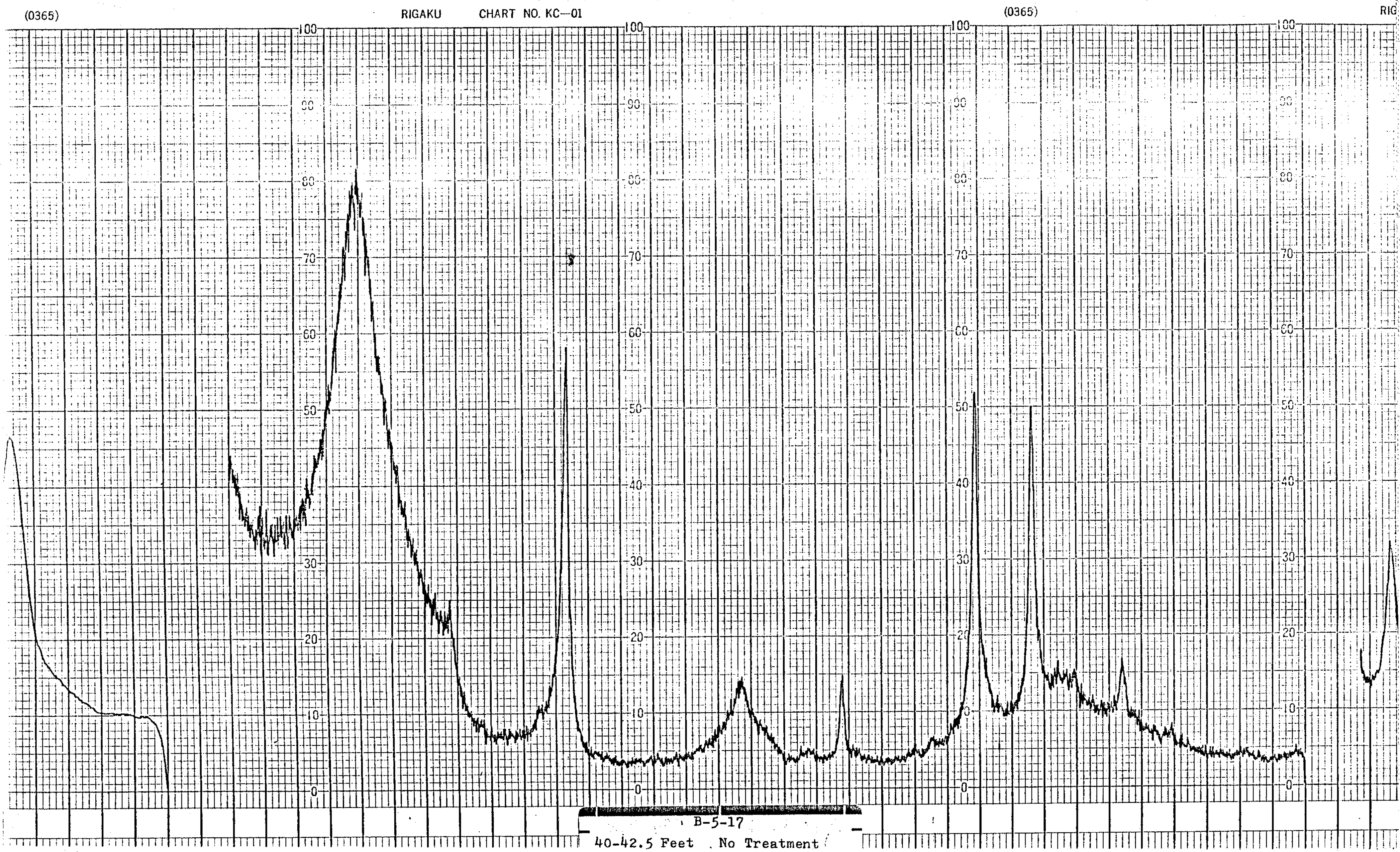
kaolinite = (K(1)/T) X 10

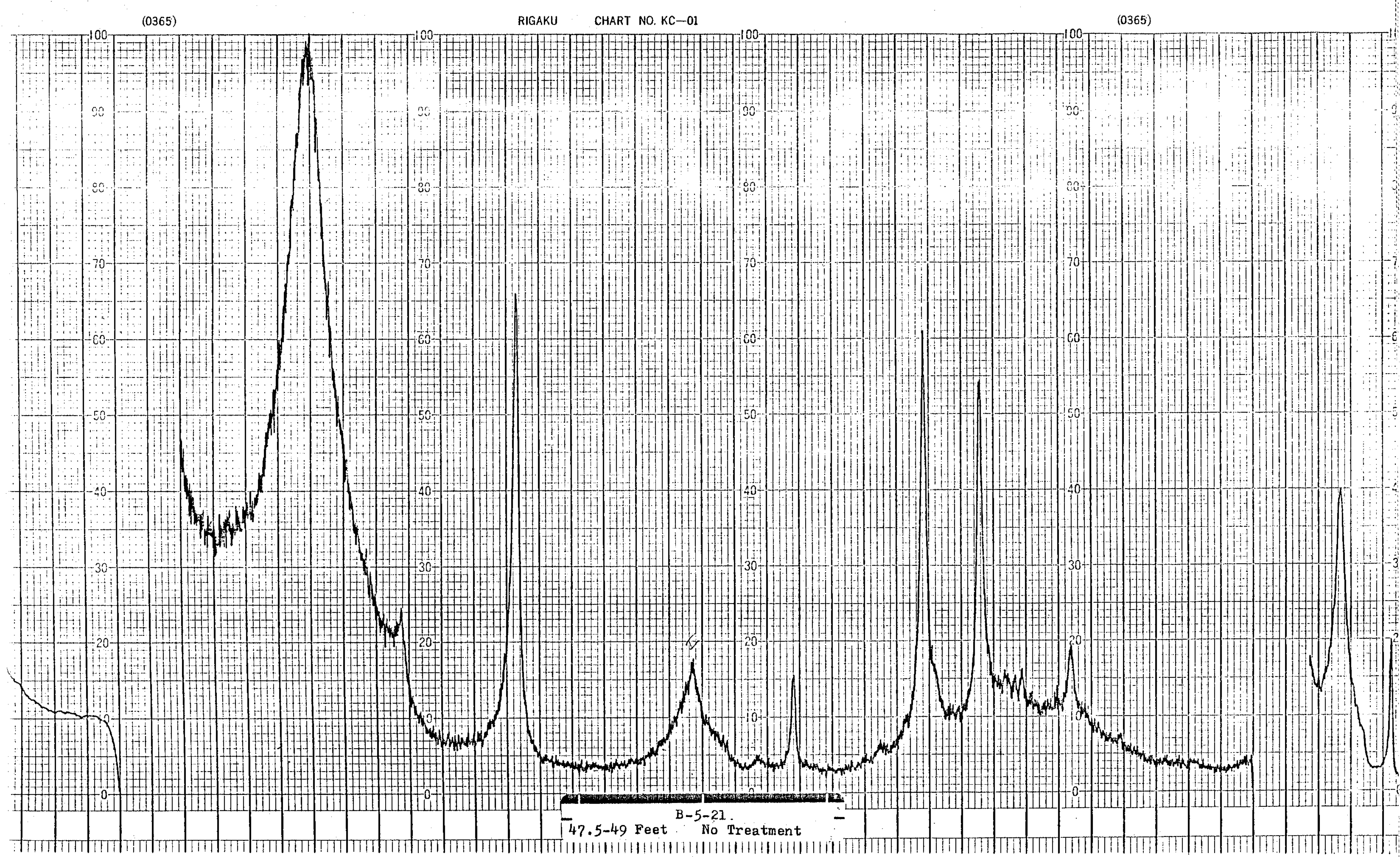
where T (total counts) = I(1H) + K(1)

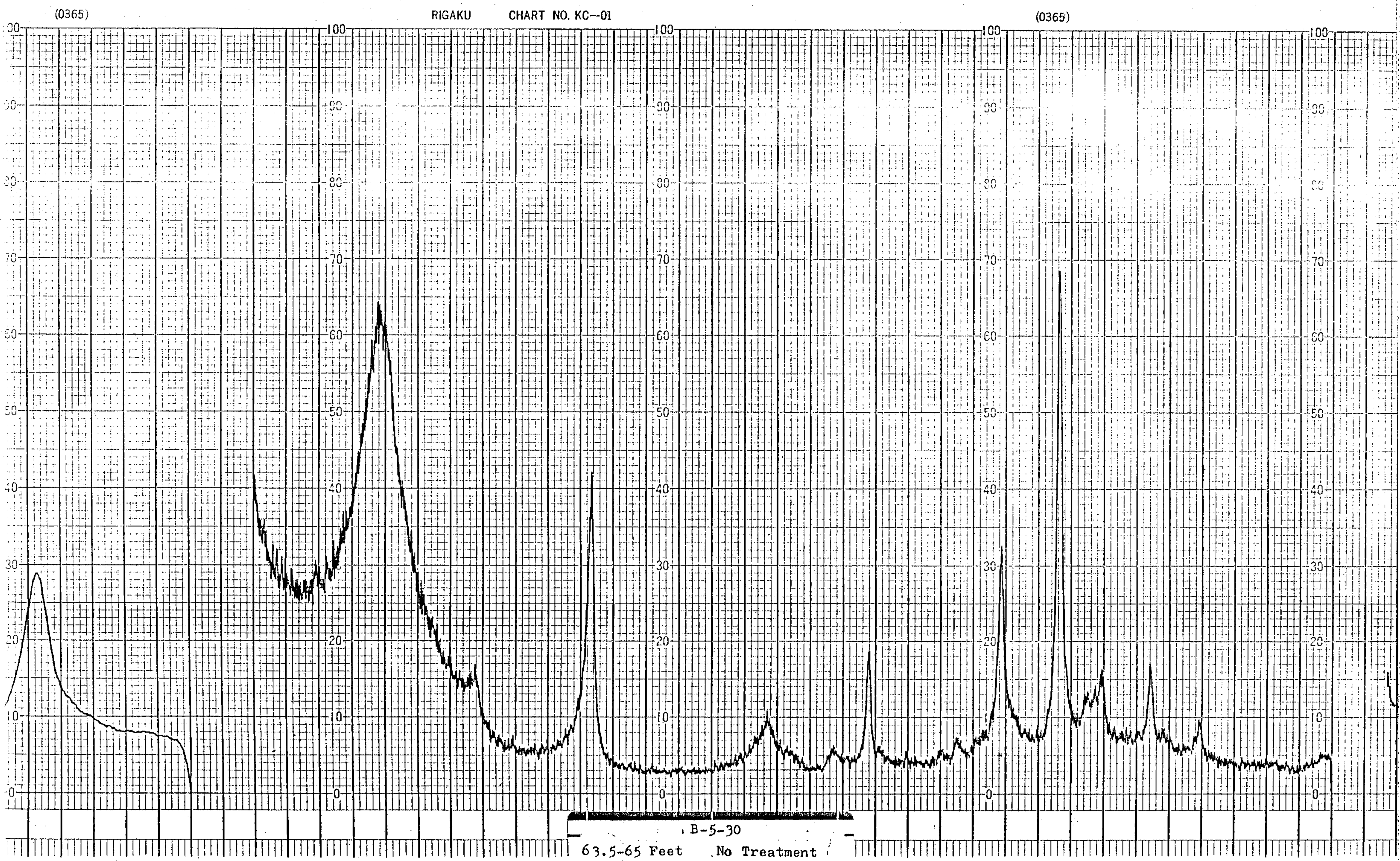
The results of the calculations using these equations may be found in Table 1. Chlorite levels in the five intervals sampled were insignificant and were not calculated.

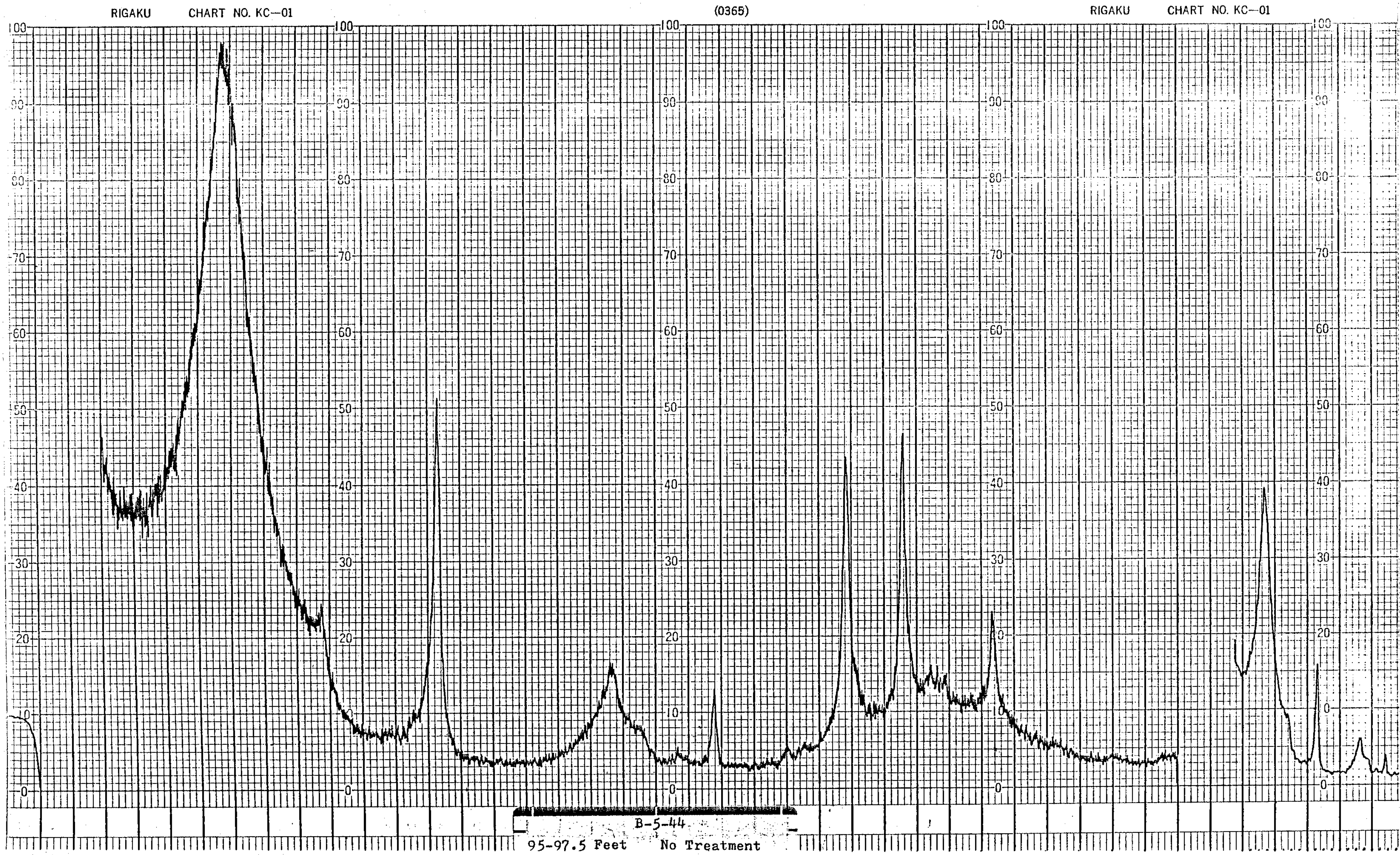
X-ray diffractometer graphs for the samples cited above follow this page.


RIGAKU
CHART NO. KC—01
(0365)
B-5-5
10-12.5 Feet NO TREATMENT

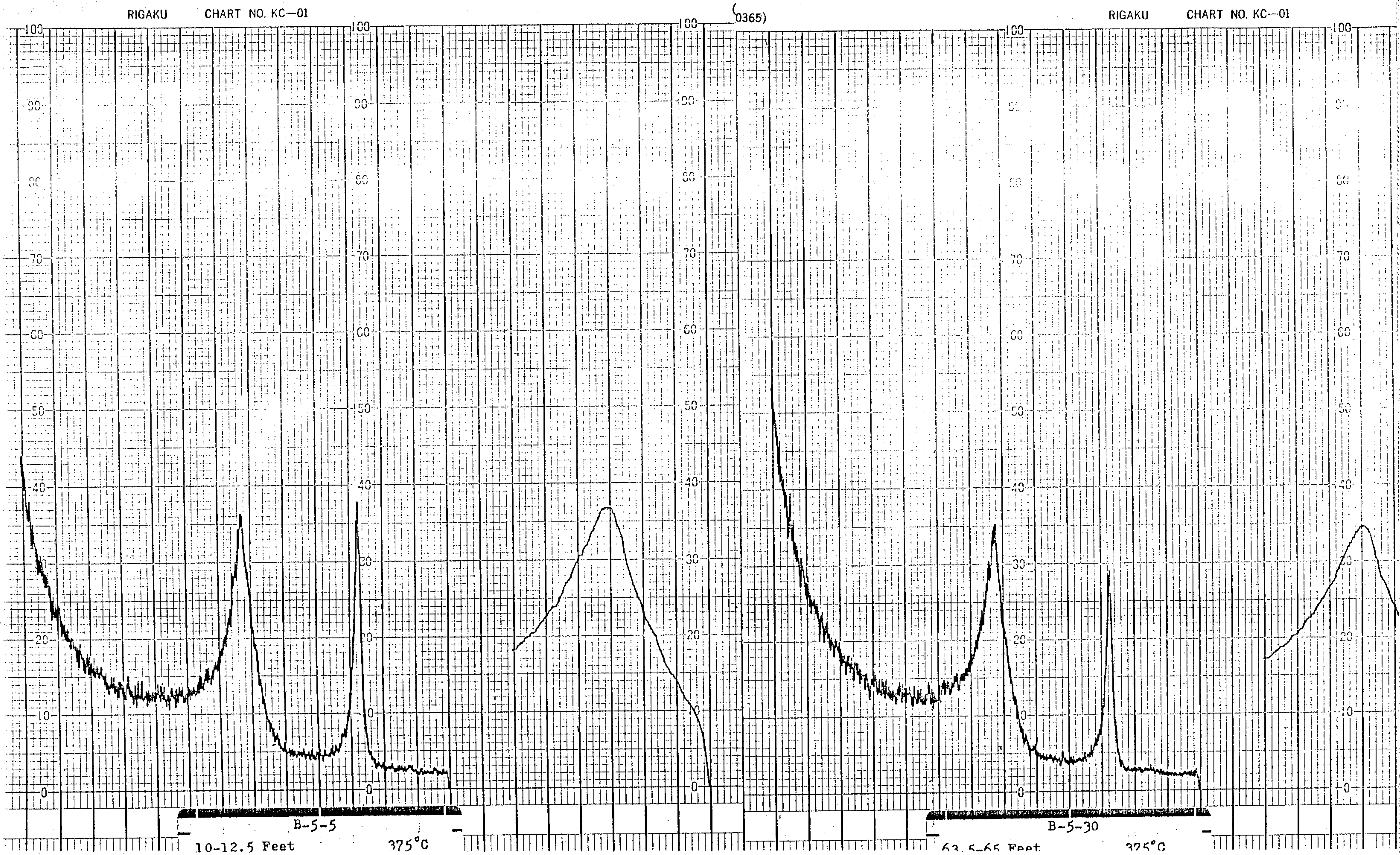

(0365)
RIGAKU CHART NO. KC—01
(0365)
RIG
100
90
80
70
60
50
40
30
20
10
0
B-5-17
40-42.5 Feet . No Treatment

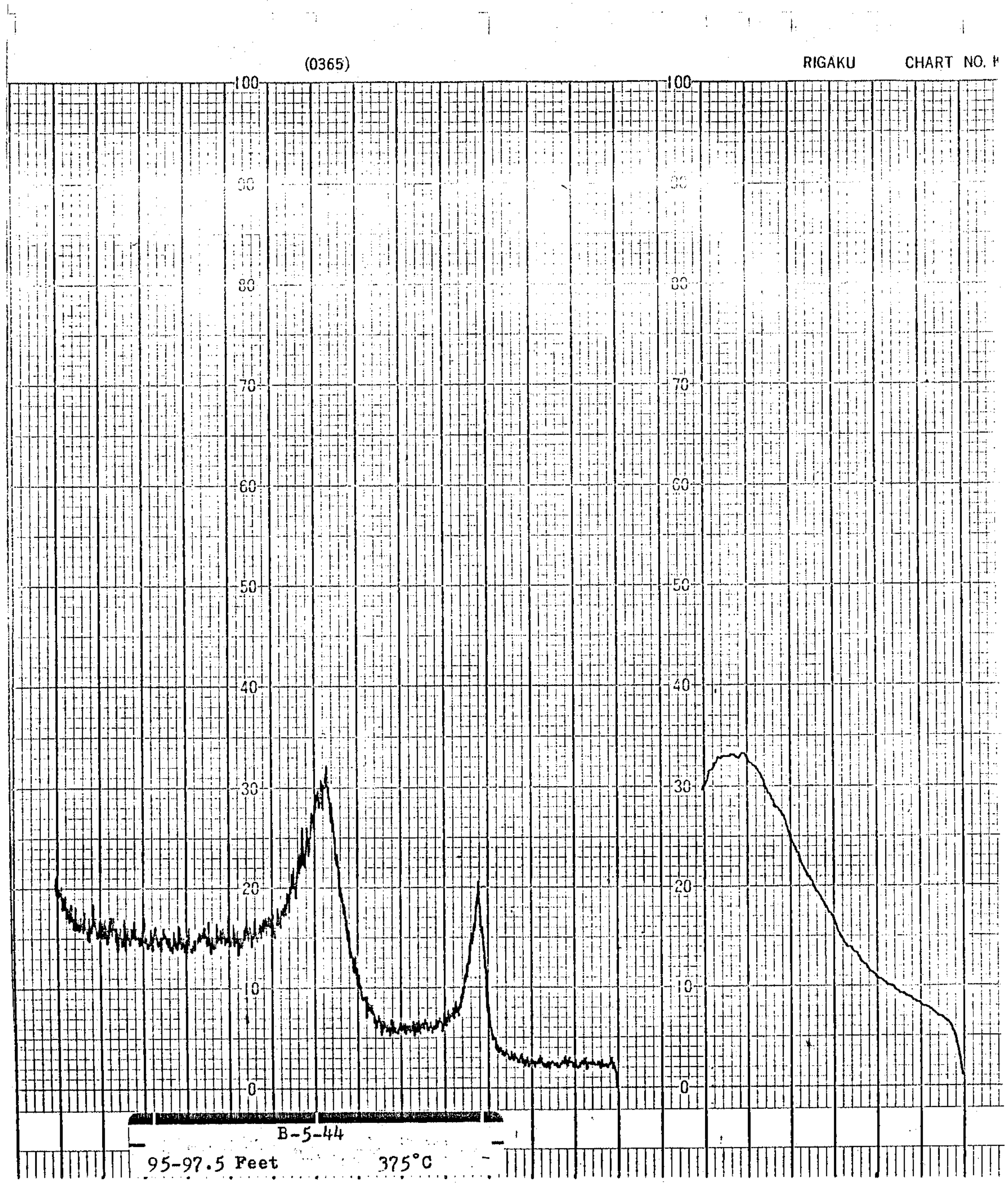

(0365)
RIGAKU CHART NO. KC—01
(0365)
100
90
80
70
60
50
40
30
20
10
0
B-5-21
47.5-49 Feet No Treatment

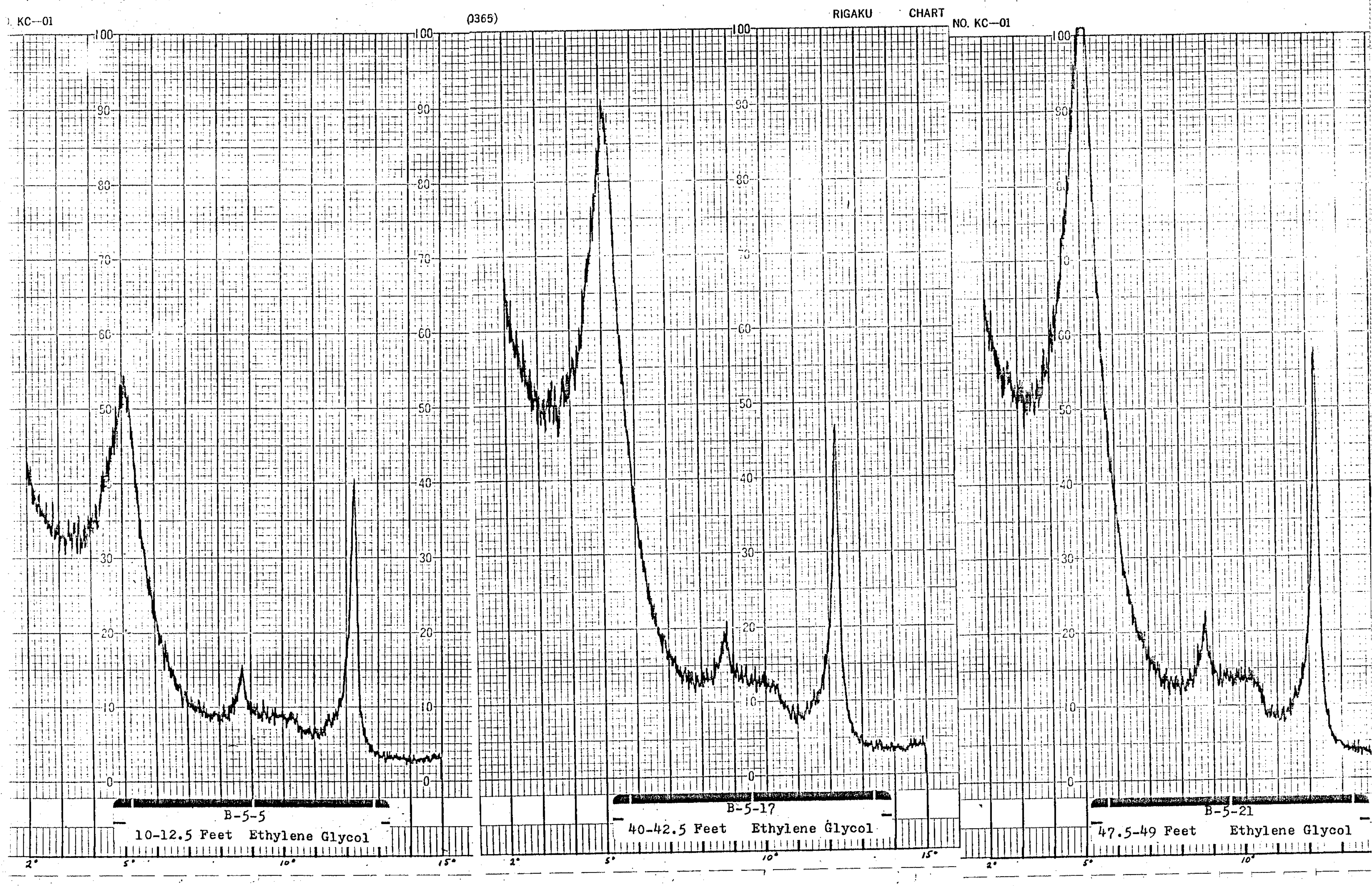

(0365)
RIGAKU CHART NO. KC—01
(0365)
B-5-30
63.5-65 Feet No Treatment



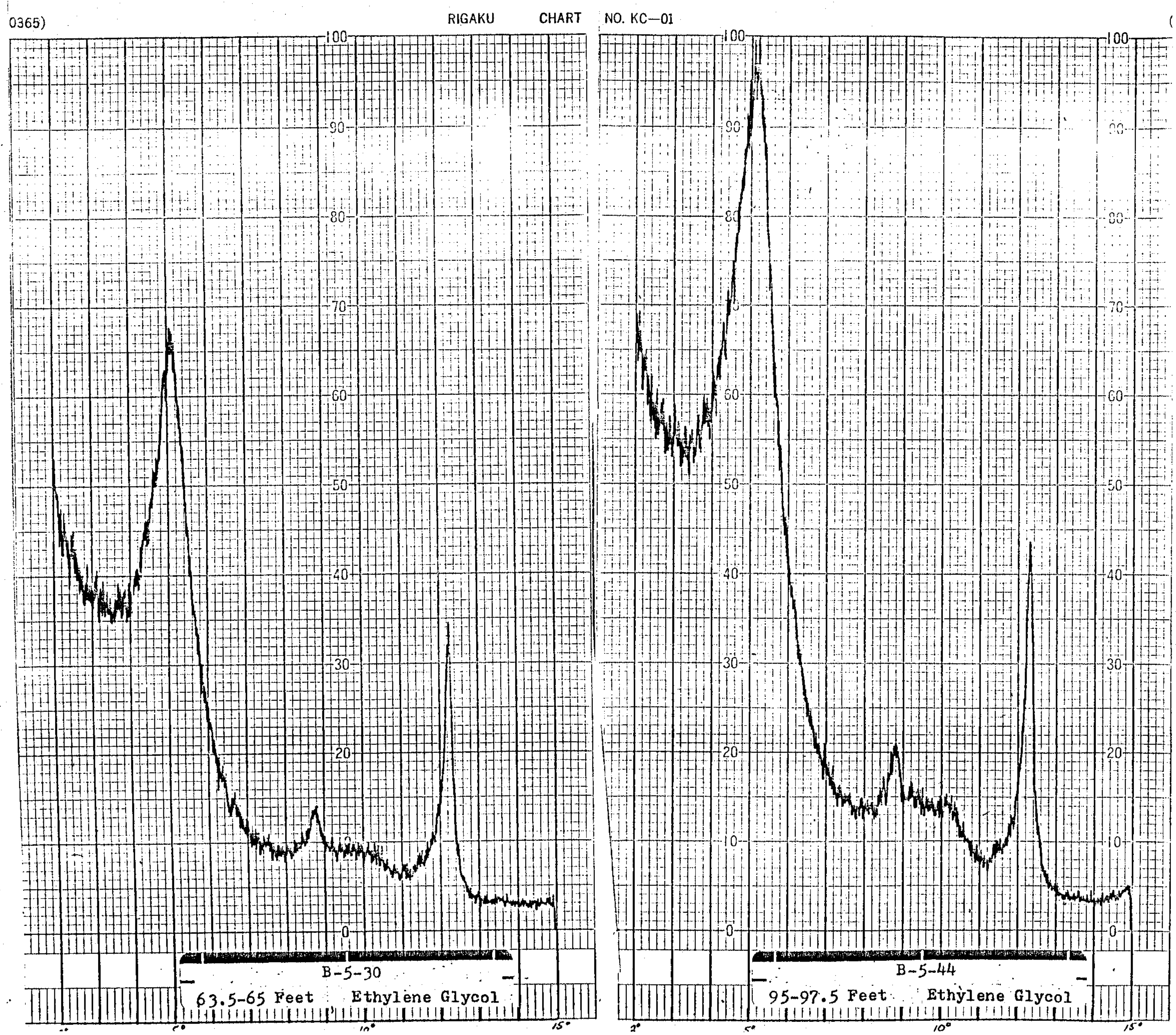
RIGAKU CHART NO. KC—01
(0365)
RIGAKU CHART NO. KC—01
B-5-44
95-97.5 Feet No Treatment


RIGAKU
CHART NO. KC—01
(0365)
B-5-5
10-12.5 Feet
375°C
B-5-30
63.5-65 Feet
375°C


(0365)
RIGAKU CHART NO.
100
90
80
70
60
50
40
30
20
10
0
B-5-44
95-97.5 Feet
375°C



KC--01
(0365)
RIGAKU CHART
NO. KC--01
B-5-5
10-12.5 Feet Ethylene Glycol
B-5-17
40-42.5 Feet Ethylene Glycol
B-5-21
47.5-49 Feet Ethylene Glycol


0365)
RIGAKU CHART NO. KC—01
100
90
80
70
60
50
40
30
20
10
0
B-5-30
63.5-65 Feet Ethylene Glycol
10°
15°
B-5-44
95-97.5 Feet Ethylene Glycol
2°
5°
10°
15°

APPENDIX D

Table 10.

ANALYSIS OF WATER CHEMISTRY IN VICINITY OF POPALITO WINDMILL

Location: 5.1W.14.231, Valencia County, New Mexico

Analysis performed by N.M. Bureau of Mines and Mineral Resources, N.M. Institute of Mining and Technology, Socorro, N. M.

Constituent	(1) mg/l	(1) epm	(2) mg/l	(2) epm	(3) mg/l	(3) epm
TDS	3594	---	2790	---	1474	---
Cond.	3400*	---	3000*	---	1600*	---
pH	7.2	---	7.25	---	7.5	---
CO_3	0	0	0	0	0	0
HCO_3	367	6	328	5.38	218	3.57
Cl	225	6.35	203	5.72	45	1.23
SO_4	1829	38.1	1523	31.71	696	14.5
NO_3	14.4	0.24	4.0	0.06	5.3	0.08
F	0.39	0.02	2.5	0.13	2.3	0.12
Na	488	21.2	438	19.05	215	9.35
K	9.5	0.2	7.75	0.2	6.75	0.2
Mg	117	9.6	65	5.35	34	2.8
Ca	495	24.7	360	18.0	165	8.23
Fe	0.5	---	---	---	0.3	---
Mn	0.01	---	0.09	---	=0.01	---

NOTES

(1) Sample from Popalito Windmill, depth from 93.17 to 108.5 feet below surface, 11/17/82.

(2) Sample from Piezometer B-5S, depth from 26.11 to 38.5 feet below surface, 11/10/82.

(3) Sample from the Rio Puerco at Site B, 3500' ESE of Popalito Windmill, 8/27/82.

* Specific Conductivity in micromhos.

Table 11.

TABLE OF FIELD WATER CHEMISTRY ANALYSIS FOR THE LOWER RIO PUERCO

DATE	TIME	Temp. (C)	SAL. (‰)	pH	ORP (mv)	COND (umhos)	SED (%)	STAGE (feet)	LOCATION
8-25-82	1330	23.0	1.5	7.4	-20	1400	20.5	31.80	Val. Co. Rd. 548 Br.
8-27-82	1110	20.5	<1.0	7.6	-50	1600	19.8	28.64	Val. Co. Rd. 548 Br.
8-30-82	1345	23.5	<1.0	7.8	-55	1400	23.0	32.13	Val. Co. Rd. 548 Br.
9-3-82	1230	22.5	<0.5	7.5	-40	980	21.2	32.50	Val. Co. Rd. 548 Br.
9-6-82	1205	21.0	<1.0	7.4	-20	1450	20.9	32.17	Val. Co. Rd. 548 Br.
9-10-82	1440	19.0	<0.5	7.6	-50	790	19.8	31.10	Val. Co. Rd. 548 Br.
9-15-82	1050	16.3	1.0	8.4	-70	1520	21.4	32.96	Val. Co. Rd. 548 Br.
9-24-82	1148	19.5	1.0	8.1	-51	1110	20.8	33.50	Val. Co. Rd. 548 Br.
11-10-82	1315	15.0	2.1	7.3		2980			Piezometer B-5S
12-20-82	1200	7.5						33.35	Val. Co. Rd. 548 Br.
1-12-83	1640	0.0						33.10	Val. Co. Rd. 548 Br.
1-25-83	1113	0.2	2.0	8.5	-79	1960			Rio Puerco Gage
1-25-83	1635	3.5	1.9	8.4	-81	1710			Val. Co. Rd. 548 Br.
2-24-83	1045	5.0	1.2	7.75	-50	1270			Rio Puerco Gage
2-24-83	1209	7.0	1.2	8.35	-70	1270			Val. Co. Rd. 548 Br.
2-24-83	1700	8.0	1.3	8.25	-60	1470			Bernardo Gage

APPENDIX E

Table 12.

ANNUAL CHANGE IN DISCHARGE VOLUME FOR THE LOWER RIO PUERCO (1940-1976)

Water Year	Rio Puerco Gage (acre-feet)	Bernardo Gage (acre-feet)	Loss (-) or Gain (+) (acre-feet)
1940	43350	38320	-5030
1941	144000	126200	-17800
1942	55490	51110	-4380
1943	25940	30970	+5030
1944	40850	41820	+970
1945	20800	26960	+6160
1946	27900	30760	+2860
1947	59240	65440	+6200
1948	14160	10730	-3430
1949	30460	28210	-2250
AVERAGE	46219.0	45052.0	-1167.0
1950	12710	12000	-710
1951	23320	23060	-260
1952	17100	13350	-3750
1953	34860	34150	-710
1954	79740	78340	-1400
1955	80470	85270	+4800
1956	13030	12280	-750
1957	91410	87680	-3730
1958	49510	44150	-5360
1959	24870	21470	-3400
AVERAGE	42702.0	41175.0	-1527.0
1960	23170	17560	-5610
1961	28310	22130	-6150
1962	12760	10150	-2610
1963	22800	19900	-2900
1964	19550	18580	-970
1965	31640	30410	-1230
1966	18570	19260	+690
1967	79920	77650	-2270
1968	34510	27630	-6880
1969	26740	26210	-530
AVERAGE	29797.0	26951.0	-2846.0
1970	28920	26710	-2210
1971	13210	9130	-4080
1972	61050	61510	+460
1973	67810	60310	-7500
1974	5630	6100	+470
1975	38680	39160	+480
1976	9330	7950	-1380
AVERAGE	32090.0	30124.3	-1965.7
AVERAGE (1940-1976)	38157.0	36287.8	-1869.2

DATA SOURCE: U. S. Geological Survey, 1941-1961, Surface-water supply of the United States, 1940-1960: U. S. Geological Survey Water-Supply Papers 899-1713; and U. S. Geological Survey, 1961-1976, Water-resources data, New Mexico (published annually).

Table 13.

TABLE OF PEAK-FLOW REDUCTION AND TRAVEL TIMES FOR THE LOWER RIO PUERCO (1956 - 1976)

RIO PUERCO GAGE			BERNARDO GAGE				
Date	Time (hours)	Q (cfs)	Date	Time (hours)	Q (cfs)	Red. %	Travel Time (hours)
8-17-56	1930	7720	8-18-56	1900	5200	32.6	23.5
7-27-57	2000	6280	7-28-57	0630	4350	30.7	10.5
8-7-57	1100	6520	8-7-57	2140	5680	12.9	10.7
8-18-57	1300	6320	8-18-57	2020	5340	15.5	7.3
8-25-57	1630	7480	8-26-57	0200	5170	30.9	9.5
10-21-57	0730	7600	10-21-57	2300	5340	29.7	15.5
11-5-57	1030	6320	11-5-57	2030	4750	24.8	10.0
5-24-59	0600	6080	5-27-59	1830	4020	33.9	12.5
10-18-60	1910	2150	10-19-60	0415	1690	21.4	13.1
8-19-61	0130	3700	8-19-61	1430	2470	33.2	13.0
9-10-61	1900	3670	9-11-61	0540	1640	55.3	10.7
9-19-61	2030	3310	9-20-61	0745	1740	47.4	11.2
9-29-62	1550	1550	9-29-62	2240	900	41.9	6.8
8-4-63	0940	1930	8-5-63	0110	1210	37.3	15.5
7-12-64	1440	5040	7-13-64	0800	2640	47.6	17.3
8-13-64	1700	2780	8-14-64	0650	1850	33.4	13.8
8-3-65	0010	4080	8-3-65	1845	3210	21.3	18.6
9-3-65	0900	2870	9-3-65	2100	1970	31.4	12.0
8-2-66	2320	2570	8-3-66	1030	1750	31.9	11.2
8-12-67	1315	12600	8-13-67	1600	7860	37.6	26.7
9-9-67	0230	6500	9-9-67	1930	3250	50.0	17.0
8-2-68	0200	4480	8-2-68	1315	3280	26.8	11.2
8-12-68	1915	3360	8-13-68	0700	2960	11.9	11.7
8-14-68	2345	2540	8-15-68	0945	2140	15.7	10.0
8-1-69	1645	5250	8-2-69	0630	3170	39.6	13.7
8-31-69	1745	4560	9-1-69	0300	3250	28.7	9.2
10-23-69	0945	7100	10-24-69	1130	6940	2.2	25.7
8-27-72	1900	5040	8-28-72	1200	3470	31.1	17.0
10-19-72	1530	5410	10-20-72	0430	2210	59.1	13.0
7-15-72	1800	5080	7-16-73	2300	3920	22.8	29.0
8-4-74	0045	4240	8-4-74	1330	2980	29.7	12.7
7-23-76	2230	1045	7-24-76	1530	770	26.3	18.0
8-19-76	2345	3560	8-20-76	1300	2280	36.0	13.2

Mean peak-flow at Rio Puerco Gage = 4810.1 +2317.5 cfs
Mean peak-flow at Bernardo Gage = 3315.1 +1721.2 cfs
Mean reduction in peak-flow = 31.2 +12.4%
Mean travel time of peak-flow crest = 14.3 +5.4 hours

Source of peak-flow data: U. S. Geological Survey, 1957-1961, Surface-water supply of the United States, 1956-1960: U. S. Geological Survey Water-Supply Papers 1443-1713; and U. S. Geological Survey, 1961-1976, Water-resources data, New Mexico (published annually).

Table 14.

TABLE OF AVERAGE TRIBUTARY DISCHARGE TO THE LOWER RIO PUERCO BASIN

	(1)		(2)		(3)		
MONTH	AVE. Q	%	AVE. Q	%	AVE. Q	%	TOTAL
October	598.01	23.5	1086.22	42.7	856.99	33.7	2541.22
November	171.45	40.2	123.85	29.1	130.68	30.7	425.98
December	59.02	20.8	33.73	11.5	192.29	67.7	284.04
January	98.00	28.9	65.41	19.3	175.36	51.8	338.77
February	553.84	40.3	599.08	43.6	222.07	16.1	1374.99
March	1101.71	53.2	726.13	35.1	242.08	11.7	2069.92
April	1048.11	74.6	172.70	12.3	184.14	13.1	1404.95
May	2000.66	86.5	107.48	4.7	203.44	8.8	2311.58
June	561.61	59.9	195.45	20.8	180.46	19.3	937.52
July	1013.82	21.0	2684.47	55.5	1134.26	23.5	4832.55
August	1664.93	13.6	6939.80	56.5	3668.11	29.9	12272.84
September	748.11	16.6	2549.59	56.5	1213.00	26.9	4510.70
ANNUAL AVERAGE:	801.60	39.9	1273.58	32.3	700.24	27.8	

(1): Rio Puerco above Arroyo Chico (1952-1979), n = 28 years.

(2): Arroyo Chico near Guadalupe, New Mexico (1944-1979), n = 36 years.

(3): Rio San Jose at Correo, New Mexico (1944-1979), n = 36 years.

DATA SOURCE: Discharge information from U. S. Geological Survey, 1944-1960, Surface-water supply of the United States: Water-supply papers 1009-1713, and U. S. Geological Survey, 1961-1979, Water-resources data, New Mexico, (published annually).

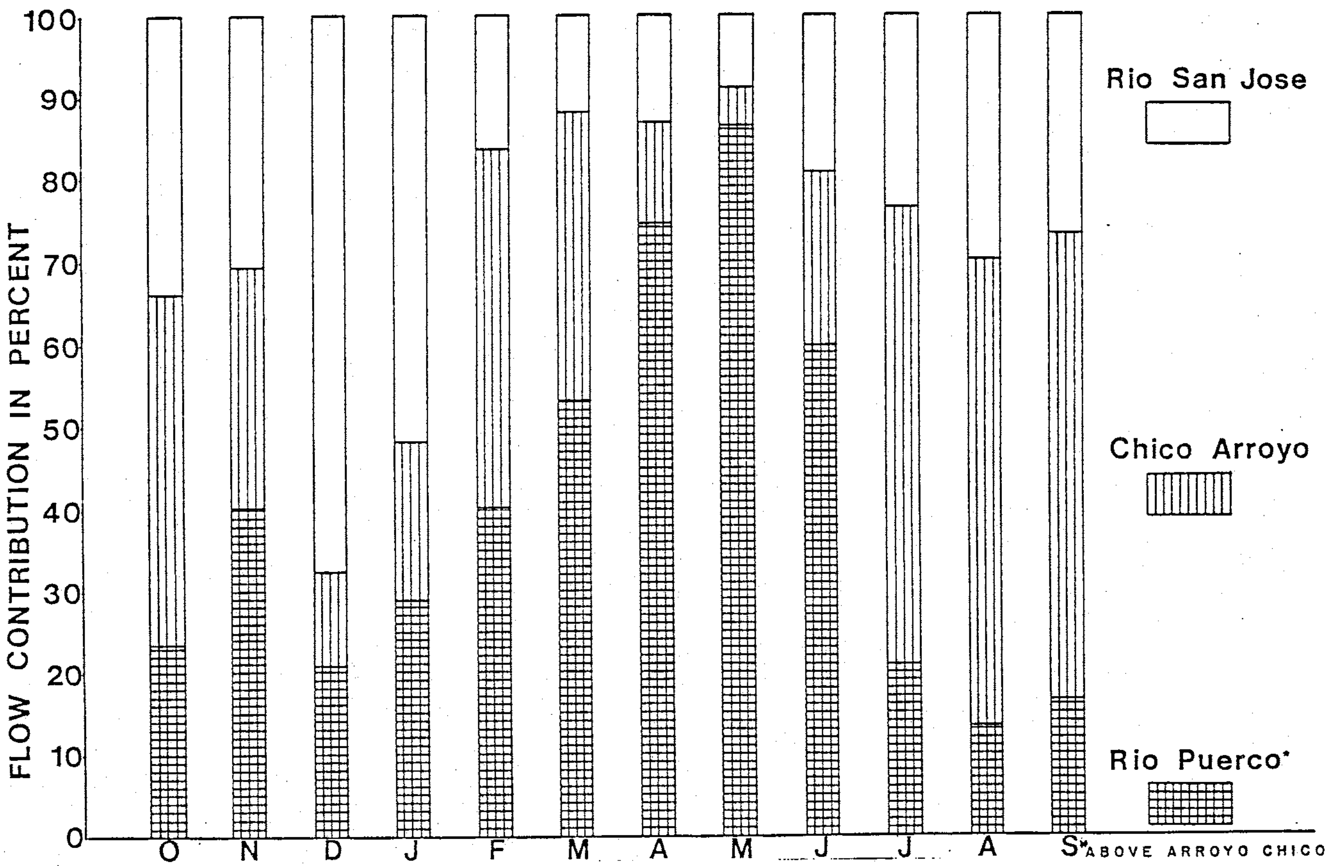
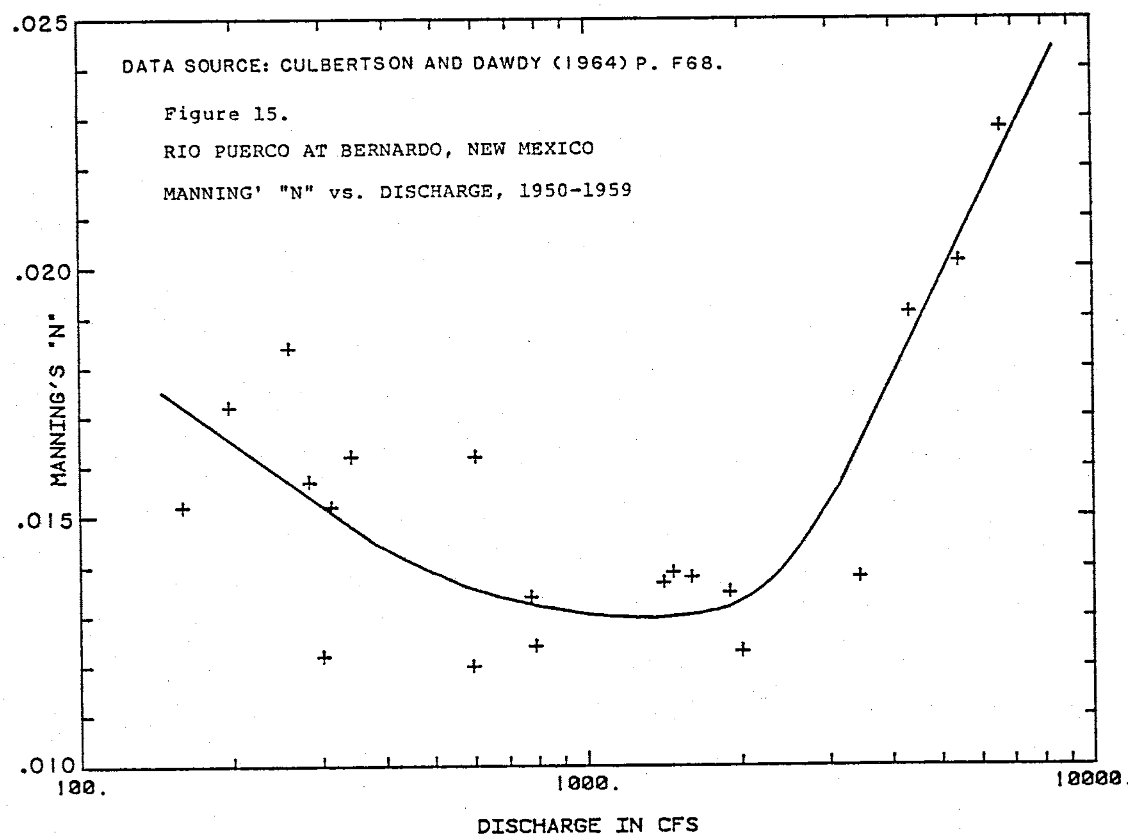


Figure 14. Historic flow contributions of three tributaries in the upper Rio Puerco basin, in percent


DATA SOURCE: CULBERTSON AND DAWDY (1964) P. F68.
Figure 15.
RIO PUERCO AT BERNARDO, NEW MEXICO
MANNING' "N" vs. DISCHARGE, 1950-1959
.025
.020
.015
.010
MANNING'S "N"
100.
1000.
10000.
DISCHARGE IN CFS

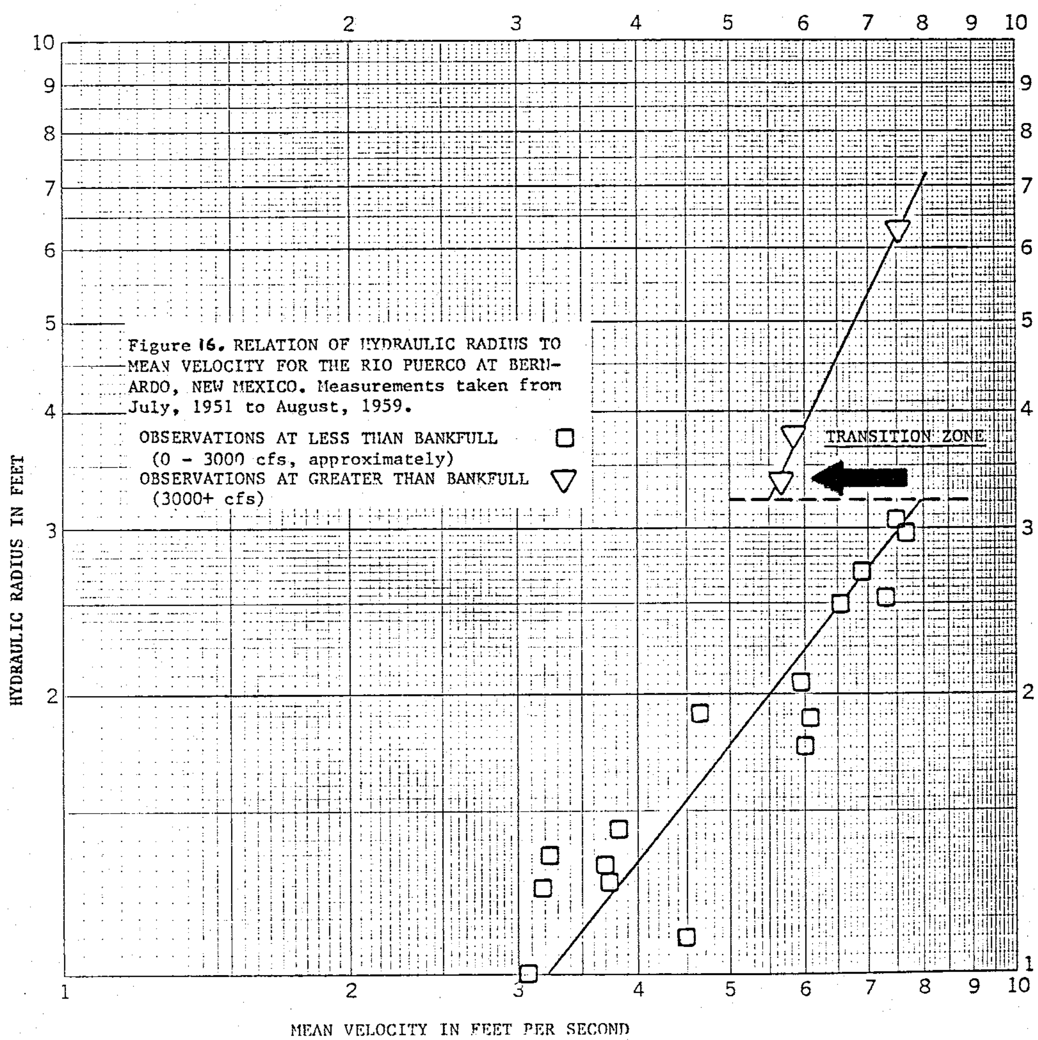


Figure 16. RELATION OF HYDRAULIC RADIUS TO MEAN VELOCITY FOR THE RIO PUERCO AT BERNARDO, NEW MEXICO. Measurements taken from July, 1951 to August, 1959.

Source: Culbertson and Dawdy (1964, p. F68)

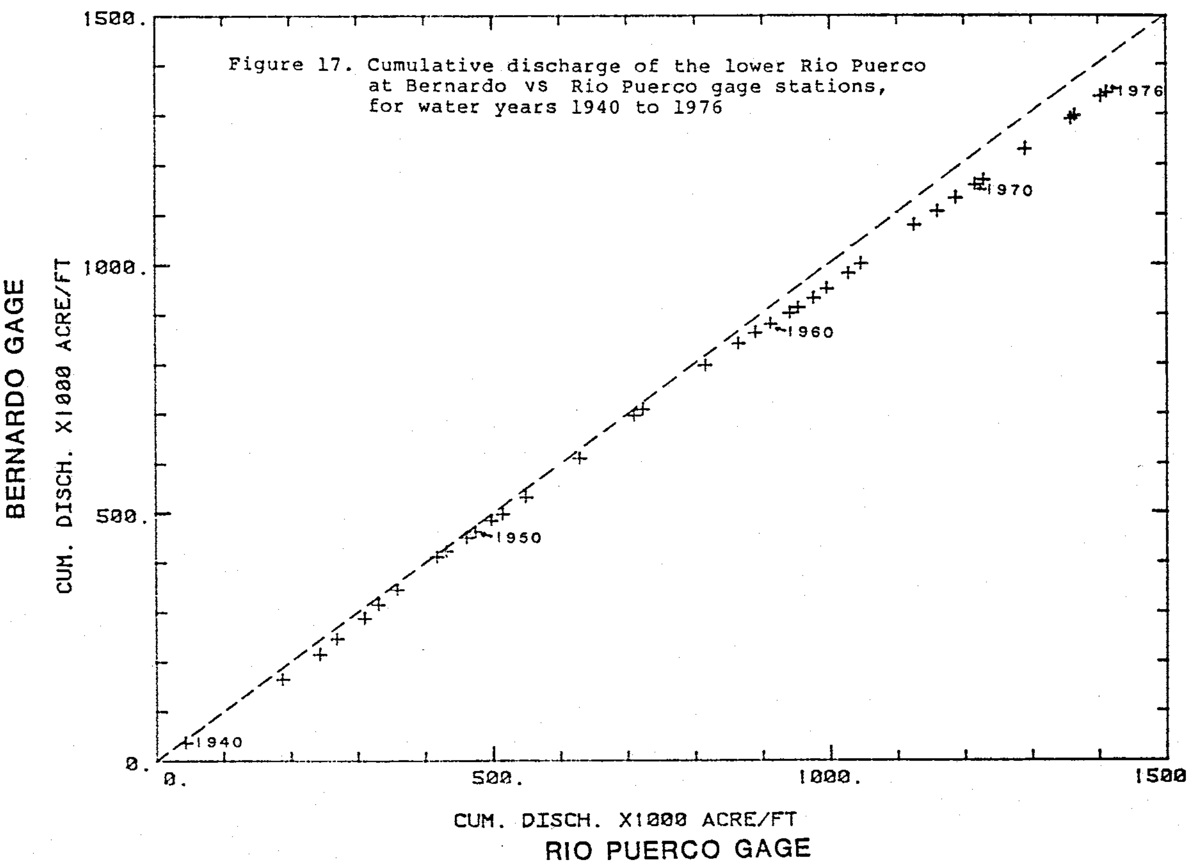
Table 15.

CUMULATIVE DISCHARGE OF THE LOWER RIO PUERCO
AT RIO PUERCO AND BERNARDO GAGING STATIONS
(WATER YEARS 1940-1976)

Water Year	Cum. Discharge (acre/ft/year)	Cum. Discharge (acre/ft/year)
1940	43,350	38,320
1941	187,350	164,520
1942	242,840	215,630
1943	268,780	246,600
1944	309,630	288,420
1945	330,430	315,380
1946	358,330	346,140
1947	417,570	411,580
1948	431,730	422,310
1949	462,190	450,520
1950	474,900	462,520
1951	498,220	485,580
1952	515,320	498,930
1953	550,180	533,080
1954	629,920	611,420
1955	710,390	696,690
1956	723,420	708,970
1957	814,830	796,650
1958	864,340	840,800
1959	889,210	862,270
1960	912,380	879,830
1961	940,690	901,990
1962	953,450	912,140
1963	976,250	932,040
1964	995,800	950,620
1965	1,027,440	981,030
1966	1,046,010	1,000,290
1967	1,125,930	1,077,940
1968	1,160,440	1,105,570
1969	1,187,180	1,131,780
1970	1,216,100	1,158,490
1971	1,229,310	1,167,620
1972	1,290,360	1,229,130
1973	1,358,170	1,289,440
1974	1,363,800	1,295,540
1975	1,402,480	1,334,700
1976	1,411,810	1,342,650

NOTE: Discharge data for water years 1940 through 1960 from U. S. Geological Survey, 1941-1961, Surface-water supply of the United States, 1940-1960: U. S. Geological Survey Water-Supply Papers 898-1712.

Discharge data for water years 1961 through 1976 from U. S. Geological Survey, 1961-1976, Water-resources data, New Mexico (published annually).



CUMULATIVE DISCHARGE OF THE LOWER RIO PUERCO

Table 16. Suspended sediment vs. discharge for the lower Rio Puerco at Bernardo and Rio Puerco gaging stations for water years 1948 to 1981

RIO PUERCO AT RIO PUERCO GAGE STATION, NEW MEXICO
SUSPENDED-SEDIMENT VS. DISCHARGE

WATER YEAR	CFS-DAYS	TONS/YEAR
1949	15356	5994000
1950	6406	2568000
1951	11711	4121630
1952	8629	3538790
1953	17572.2	6893383
1954	40207.1	14317097

Data source: U. S. Geological Survey, 1950-1955, Quality of surface waters of the United States, western Gulf of Mexico basins: Water Supply Papers 1133 through 1352.

RIO PUERCO AT BERNARDO GAGE STATION, NEW MEXICO
SUSPENDED-SEDIMENT VS. DISCHARGE

WATER YEAR	CFS-DAYS	TONS/YEAR
1948	5293	1634000
1949	14246	5760000
1950	6049	2753000
1951	11622.7	4613496
1952	6727.9	2953332
1953	17218.6	6953247
1954	39501.1	14778779
1955	42993.3	18315560
1956	6194.7	3423769
1957	43345	18054868
1958	22255	8072030
1959	10827	5038884
1960	8853.7	4156507
1961	11169.3	4548008
1962	5116.2	1448532
1963	10028.1	3026277
1964	9344	2741566
1965	15332.9	3807918
1966	9710.2	3528632
1967	39146.3	12257979
1968	13928.4	4940551
1969	13216.2	4919348
1970	13466.5	2822326.01
1971	4603.04	1888660.9
1972	31011.6	9490326.8
1973	30405.6	7958370.6
1974	3073.1	1141388
1975	19742	6829450.57
1976	4009.5	1734453
1977	12121	4355708
1978	1997.7	478525.8
1979	12954.7	3496563.75
1980	9403.07	1810746.5
1981	8006.12	2093080

Data source: Water years 1948 to 1964, U. S. Geological Survey Water-Supply Papers 1133 through 1957; water years 1965 to 1981, U. S. Geological Survey Water-Resources Data for New Mexico, (water quality records).

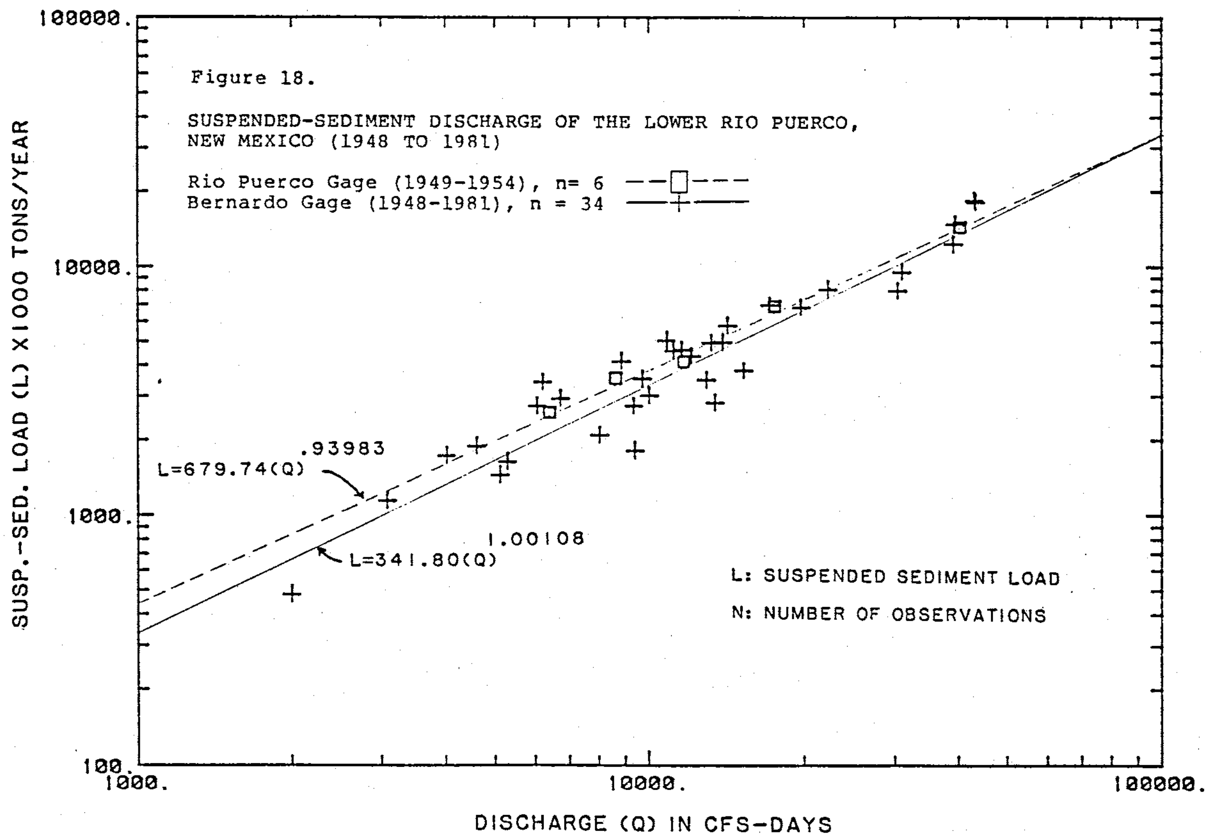

100000.
10000.
1000.
100.
1000.
10000.
100000.
SUSP.-SED. LOAD (L) X1000 TONS/YEAR
DISCHARGE (Q) IN CFS-DAYS
Figure 18.
SUSPENDED-SEDIMENT DISCHARGE OF THE LOWER RIO PUERCO,
NEW MEXICO (1948 TO 1981)
Rio Puerco Gage (1949-1954), n= 6
Bernardo Gage (1948-1981), n = 34
L=679.74(Q) .93983
L=341.80(Q) 1.00108
L: SUSPENDED SEDIMENT LOAD
N: NUMBER OF OBSERVATIONS

Table 17.

CHANNEL SINUOSITY OF THE LOWER RIO PUERCO BETWEEN RIO PUERCO AND BERNARDO GAGING STATIONS USING RECENT MAP AND QUADRANGLE DATA

Map	Distance channel (miles)	straight (miles)	Channel Sinuosity
Rio Puerco Quad	8.06	5.37	1.50
2*	0.208	0.199	1.05
3	2.20	1.77	1.24
4	3.00	1.93	1.55
5	2.42	1.50	1.62
6	1.13	0.69	1.64
7	1.235	0.78	1.58
8	2.03	1.48	1.37
10	2.20	1.46	1.51
12	2.58	1.46	1.76
14	3.61	1.64	2.21
17	2.92	1.515	1.93
19	2.95	1.64	1.80
21	2.12	1.51	1.41
23	1.79	1.24	1.44
La Joya, N. M.	5.49	3.03	1.81
Abeytas, N. M.	4.48	3.58	1.25
Total Distance:	48.42	30.79	Average: 1.57

Channel distance from Rio Puerco Gage to B-B' section at Popalito: 18.89 miles; straight distance: 12.60 miles; average sinuosity: 1.50.

Channel distance from B-B' section to Bernardo Gage: 29.53 miles; straight distance: 18.19 miles; average sinuosity: 1.62.

U. S. Geological Survey 7.5 Minute Quadrangles: La Joya, N. M., and Abeytas, N. M. were revised with orthophotographs taken in 1977. The Rio Puerco, N. M. quadrangle was revised with orthophotographs taken on 21 June, 1975; scale 1:24,000.

*U. S. Army Corps of Engineers Hidden Mountain Dam Project maps based on aerial photographs taken on 30 June, 1979; scale: 1 inch = 400 feet.

APPENDIX F

Table 18.
HYDROGRAPH DATA FOR RIO PUERCO AT RIO PUERCO GAGING STATION
(10 DECEMBER, 1982 TO 3 JUNE, 1983)

Date	Day*	Gage Ht (ft)	Mean Daily Flow (cfs)	(m3/s)
12/10/82	163	0.56	6.1	0.17
12/11/82	164	0.64	11	0.31
12/12/82	165	0.60	7.6	0.21
12/13/82	166	0.60	7.6	0.21
12/14/82	167	0.59	7.2	0.20
12/15/82	168	0.55	5.7	0.16
12/16/82	169	0.55	5.7	0.16
12/17/82	170	0.50	4.3	0.12
12/18/82	171	0.50	4.3	0.12
12/19/82	172	0.50	4.3	0.12
12/20/82	173	0.50	4.3	0.12
12/21/82	174	0.52	4.8	0.14
12/22/82	175	0.53	5.1	0.14
12/23/82	176	0.55	5.7	0.16
12/24/82	177	0.56	6.1	0.17
12/25/82	178	0.55	5.7	0.16
12/26/82	179	0.55	5.7	0.16
12/27/82	180	0.55	5.7	0.16
12/28/82	181	0.48	3.8	0.11
12/29/82	182	0.48	3.8	0.11
12/30/82	183	0.48	3.8	0.11
12/31/82	184	0.48	3.8	0.11

MEAN: 32.6 cfs (0.92 m3/s)
PEAK FLOW: 21 cfs (0.59 m3/s), G.H. = 0.73 ft, on 25, 26, 27 December.

Date	Day*	Gage Ht (ft)	Mean Daily Flow (cfs)	(m3/s)
1/1/83	185	0.48	3.8	0.11
1/2/83	186	0.48	3.8	0.11
1/3/83	187	0.48	3.8	0.11
1/4/83	188	0.50	4.3	0.12
1/5/83	189	0.46	3.3	0.09
1/6/83	190	0.47	3.5	0.10
1/7/83	191	0.49	4.0	0.11
1/8/83	192	0.50	4.3	0.12
1/9/83	193	0.48	3.8	0.11
1/10/83	194	0.46	3.3	0.09
1/11/83	195	0.56	6.1	0.17
1/12/83	196	0.63	10	0.28
1/13/83	197	0.60	7.6	0.21
1/14/83	198	0.60	7.6	0.21
1/15/83	199	0.55	5.7	0.16
1/16/83	200	0.52	4.8	0.14
1/17/83	201	0.56	6.1	0.17
1/18/83	202	0.67	13	0.37
1/19/83	203	0.67	13	0.37
1/20/83	204	0.66	13	0.37
1/21/83	205	0.75	24	0.68
1/22/83	206	0.63	10	0.28
1/23/83	207	0.64	11	0.31
1/24/83	208	0.62	9.3	0.26
1/25/83	209	0.63	10	0.28
1/26/83	210	0.65	12	0.34
1/27/83	211	0.68	14	0.40
1/28/83	212	0.65	12	0.34
1/29/83	213	0.70	16	0.45
1/30/83	214	0.69	15	0.42
1/31/83	215	0.70	16	0.45

MONTHLY MEAN: 8.8 cfs (0.25 m3/s)
PEAK FLOW: 116 cfs (3.28 m3/s), G.H. = 1.04 ft, on 0340-21 January.

2/1/83	216	0.79	16	0.45
2/2/83	217	0.76	26	0.74
2/3/83	218	0.75	24	0.68
2/4/83	219	0.75	24	0.68
2/5/83	220	0.68	14	0.40
2/6/83	221	0.68	14	0.40
2/7/83	222	0.68	14	0.40
2/8/83	223	0.75	24	0.68
2/9/83	224	0.80	32	0.91
2/10/83	225	0.83	40	1.10
2/11/83	226	0.80	32	0.91
2/12/83	227	0.77	27	0.76
2/13/83	228	0.75	24	0.68
2/14/83	229	0.73	21	0.59
2/15/83	230	0.73	21	0.59
2/16/83	231	0.74	22	0.62
2/17/83	232	0.73	21	0.59
2/18/83	233	0.75	24	0.68
2/19/83	234	0.85	46	1.30
2/20/83	235	0.92	68	1.93
2/21/83	236	0.93	72	2.04
2/22/83	237	0.89	57	1.61
2/23/83	238	0.93	72	2.04
2/24/83	239	0.97	88	2.49
2/25/83	240	1.03	112	3.17
2/26/83	241	1.03	112	3.17
2/27/83	242	1.03	112	3.17
2/28/83	243	1.03	112	3.17

MONTHLY MEAN: 45.4 cfs (1.29 m3/s)
PEAK FLOW: 112 cfs (3.17 m3/s), G.H. = 1.03 ft, on 0700-23 February.

3/1/83	244	1.02	108	3.06
3/2/83	245	0.99	96	2.72
3/3/83	246	0.98	92	2.60
3/4/83	247	0.96	84	2.38
3/5/83	248	0.95	80	2.27
3/6/83	249	0.94	76	2.15
3/7/83	250	0.93	72	2.04
3/8/83	251	0.93	72	2.04
3/9/83	252	0.92	68	1.92
3/10/83	253	0.85	46	1.30
3/11/83	254	0.80	32	0.91
3/12/83	255	0.77	27	0.76
3/13/83	256	0.76	26	0.74
3/14/83	257	0.79	30	0.85
3/15/83	258	0.82	38	1.08
3/16/83	259	0.87	52	1.47
3/17/83	260	0.88	54	1.53
3/18/83	261	0.87	52	1.47
3/19/83	262	0.85	46	1.30
3/20/83	263	0.86	49	1.39
3/21/83	264	0.90	60	1.70
3/22/83	265	0.90	60	1.70
3/23/83	266	0.90	60	1.70
3/24/83	267	0.87	52	1.47
3/25/83	268	0.92	68	1.93
3/26/86	269	0.87	52	1.47
3/27/83	270	0.86	49	1.39
3/28/83	271	0.86	49	1.39
3/29/83	272	0.82	46	1.30
3/30/83	273	0.84	43	1.22

3/31/83	274	0.83	40	1.13

MONTHLY MEAN: 57.4 cfs (1.62 m3/s)
PEAK FLOW: 148 cfs (4.19 m3/s), G.H. = 1.12 ft, on 1030-27 March.

4/1/83	275	0.82	38	1.08
4/2/83	276	0.80	32	0.91
4/3/83	277	0.81	35	0.99
4/4/83	278	0.80	32	0.91
4/5/83	279	0.78	29	0.82
4/6/83	280	0.81	35	0.99
4/7/83	281	0.90	60	1.70
4/8/83	282	0.85	46	1.30
4/9/83	283	0.80	32	0.91
4/10/83	284	0.76	26	0.74
4/11/83	285	0.71	18	0.51
4/12/83	286	0.70	16	0.45
4/13/83	287	0.67	13	0.37
4/14/83	288	0.70	16	0.45
4/15/83	289	1.05	120	3.40
4/16/83	290	1.08	132	3.74
4/17/83	291	0.94	76	2.15
4/18/83	292	0.84	43	1.22
4/19/83	293	0.82	38	1.08
4/20/83	294	0.82	38	1.08
4/21/83	295	0.86	49	1.39
4/22/83	296	1.10	140	3.96
4/23/83	297	1.10	140	3.96
4/24/83	298	1.15	160	4.53
4/25/83	299	1.15	160	4.53
4/26/83	300	1.18	172	4.87
4/27/83	301	1.28	228	6.46
4/28/83	302	1.34	264	7.48
4/29/83	303	1.35	270	7.65
4/30/83	304	1.35	270	7.65

MONTHLY MEAN: 90.9 cfs (2.57 m3/s)
PEAK FLOW: 312 cfs (8.84 m3/s), G.H. = 1.42 ft, on 1100-30 April.

5/1/83	305	1.37	282	7.99
5/2/83	306	1.40	300	8.50
5/3/83	307	1.35	270	7.65
5/4/83	308	1.22	192	5.44
5/5/83	309	1.19	176	4.98
5/6/83	310	1.10	140	3.96
5/7/83	311	1.07	128	3.62
5/8/83	312	1.08	132	3.74
5/9/83	313	1.08	132	3.74
5/10/83	314	1.05	120	3.40
5/11/83	315	1.04	116	3.28
5/12/83	316	1.15	160	4.53
5/13/83	317	1.17	164	4.64
5/14/83	318	1.15	160	4.53
5/15/83	319	1.15	160	4.53
5/16/83	320	1.08	132	3.74
5/17/83	321	1.00	100	2.83
5/18/83	322	0.93	72	2.04
5/19/83	323	0.94	76	2.15
5/20/83	324	0.93	72	2.04
5/21/83	325	0.95	80	2.27
5/22/83	326	0.95	80	2.27
5/23/83	327	0.95	80	2.27
5/24/83	328	0.91	64	1.81
5/25/83	329	0.90	60	1.70
5/26/83	330	0.95	80	2.27
5/27/83	331	1.05	120	3.40

5/28/83	332	1.15	160	4.53
5/29/83	333	1.23	198	5.61
5/30/83	334	1.29	234	6.63
5/31/83	335	1.33	258	7.31

MONTHLY MEAN: 145.1 cfs (4.11 m3/s)
PEAK FLOW: 318 cfs (9.01 m3/s), G.H. = 1.43 ft, on 0600-2 May.

6/1/83	336	1.36	276	7.82
6/2/83	337	1.39	294	8.33
6/3/83	338	1.38	288	8.16

MEAN: 286 cfs (8.10 m3/s)
PEAK FLOW: 330 cfs (9.35 m3/s), G.H. = 1.45 ft, on 2115-2 June.

*Days since 1 July, 1982.
Gage heights determined with a Leupold and Stevens model A-35 continuous-strip recorder. Gage datum = 5,008.59 ft (1,526.618 m). Discharge data determined from USGS Rating Table #9, based on 31 discharge measurements made during the 1964-65 water year and all measurements above 1,000 cfs. Since 1954, it is well defined except for flows between 0.00 and 5.0 cfs. The discharges determined herein are preliminary only and are not to be considered official data--Douglas L. Heath.

Table 19.

HYDROGRAPH DATA FOR BERNARDO GAGING STATION
(17 JANUARY TO 3 JUNE, 1983)

Date	Day*	Gage Ht (ft)	Mean Daily Flow (cfs)	(m3/s)
1/17/83	201	5.15	0.0	0.00
1/18/83	202	5.26	1.0	0.03
1/19/83	203	5.26	1.0	0.03
1/20/83	204	5.33	2.0	0.06
1/21/83	205	5.39	3.0	0.08
1/22/83	206	5.44	4.0	0.11
1/23/83	207	5.39	3.0	0.08
1/24/83	208	5.33	2.0	0.06
1/25/83	209	5.15	0.0	0.00
1/26/83	210	5.15	0.0	0.00
1/27/83	211	5.15	0.0	0.00
1/28/83	212	5.48	5.0	0.14
1/29/83	213	5.44	4.0	0.11
1/30/83	214	5.39	3.0	0.08
1/31/83	215	5.70	12.3	0.35
MEAN FLOW: 2.7 cfs (0.08 m3/s)				
2/1/83	216	5.60	8.5	0.24
2/2/83	217	5.65	10.4	0.30
2/3/83	218	5.75	14.6	0.41
2/4/83	219	5.79	16.5	0.47
2/5/83	220	5.72	13.2	0.37
2/6/83	221	5.60	8.5	0.24
2/7/83	222	5.55	6.9	0.20
2/8/83	223	5.55	6.9	0.20
2/9/83	224	5.63	9.6	0.27
2/10/83	225	5.80	17.0	0.48
2/11/83	226	5.85	20.0	0.57
2/12/83	227	5.82	18.1	0.51
2/13/83	228	5.78	16.1	0.46
2/14/83	229	5.68	11.5	0.33
2/15/83	230	5.63	9.64	0.27
2/16/83	231	5.62	9.62	0.27
2/17/83	232	5.58	7.88	0.22
2/18/83	233	5.57	7.57	0.21
2/19/83	234	5.53	6.33	0.18
2/20/83	235	5.75	14.6	0.41
2/21/83	236	5.87	21.1	0.60
2/22/83	237	5.83	18.8	0.53
2/23/83	238	5.75	14.6	0.41
2/24/83	239	6.00	29.5	0.83
2/25/83	240	6.50	79.0	2.24
2/26/83	241	6.85	134.0	3.80
2/27/83	242	6.85	134.0	3.80
2/28/83	243	6.71	110.6	3.10
MONTHLY MEAN: 27.7 cfs (0.78 m3/s)				
3/1/83	244	6.40	67.0	1.90
3/2/83	245	6.15	41.5	1.17
3/3/83	246	6.15	41.5	1.17
3/4/83	247	6.25	51.0	1.44
3/5/83	248	6.25	51.0	1.44
3/6/83	249	6.37	63.7	1.80
3/7/83	250	6.35	61.5	1.74

3/8/83	251	6.35	61.5	1.74
3/9/83	252	6.07	53.0	1.50
3/10/83	253	6.22	48.0	1.36
3/11/83	254	6.18	44.2	1.25
3/12/83	255	6.17	43.3	1.23
3/13/83	256	6.17	43.3	1.23
3/14/83	257	6.16	42.4	1.20
3/15/83	258	6.15	41.5	1.17
3/16/83	259	6.15	41.5	1.17
3/17/83	260	6.14	40.6	1.15
3/18/83	261	5.65	10.4	0.29
3/19/83	262	5.63	9.64	0.27
3/20/83	263	5.60	8.50	0.24
3/21/83	264	5.60	8.50	0.24
3/22/83	265	5.70	12.3	0.35
3/23/83	266	5.75	14.6	0.41
3/24/83	267	5.75	14.6	0.41
3/25/83	268	5.67	11.2	0.32
3/26/83	269	5.70	12.3	0.35
3/27/83	270	5.72	13.2	0.37
3/28/83	271	5.77	15.6	0.44
3/29/83	272	5.70	12.3	0.35
3/30/83	273	5.63	9.64	0.27
3/31/83	274	5.64	10.0	0.28

MONTHLY MEAN: 32.2 cfs (0.91 m3/s)

4/1/83	275	5.61	8.88	0.25
4/2/83	276	5.58	7.78	0.22
4/3/83	277	5.56	7.26	0.21
4/4/83	278	5.66	10.8	0.31
4/5/83	279	5.67	11.2	0.32
4/6/83	280	5.65	10.4	0.29
4/7/83	281	5.62	9.26	0.26
4/8/83	282	5.84	19.4	0.55
4/9/83	283	5.75	14.6	0.41
4/10/83	284	5.75	14.6	0.41
4/11/83	285	5.72	13.2	0.37
4/12/83	286	5.68	11.5	0.33
4/13/83	287	5.65	10.4	0.29
4/14/83	288	5.63	9.64	0.27
4/15/83	289	5.60	8.50	0.24
4/16/83	290	6.39	65.9	1.87
4/17/83	291	6.30	56.0	1.59
4/18/83	292	6.03	31.7	0.90
4/19/83	293	5.98	28.2	0.80
4/20/83	294	5.93	24.9	0.70
4/21/83	295	5.90	23.0	0.65
4/22/83	296	6.10	37.0	1.05
4/23/83	297	6.40	67.0	1.90
4/24/83	298	6.55	86.0	2.44
4/25/83	299	6.58	90.2	2.55
4/26/83	300	6.60	93.0	2.63
4/27/83	301	6.79	123.4	3.49
4/28/83	302	6.94	150.2	4.25
4/29/83	303	7.00	161.0	4.56
4/30/83	304	7.00	161.0	4.56

MONTHLY MEAN: 45.5 cfs (1.29 m3/s)

5/1/83	305	7.02	165.2	4.68
5/2/83	306	7.05	171.5	4.86
5/3/83	307	7.10	182.0	5.15
5/4/83	308	7.00	161.0	4.56
5/5/83	309	6.91	144.8	4.10
5/6/83	310	6.83	130.4	3.69

5/7/83	311	6.65	101.0	2.86
5/8/83	312	6.55	86.0	2.43
5/9/83	313	6.37	63.7	1.80
5/10/83	314	6.20	46.0	1.30
5/11/83	315	6.10	37.0	1.05
5/12/83	316	6.30	56.0	1.59
5/13/83	317	6.46	74.2	2.10
5/14/83	318	6.50	79.0	2.24
5/15/83	319	6.50	79.0	2.24
5/16/83	320	6.41	68.2	1.93
5/17/83	321	6.29	55.0	1.58
5/18/83	322	6.18	44.2	1.25
5/19/83	323	6.05	33.2	0.94
5/20/83	324	5.87	21.1	0.60
5/21/83	325	5.85	20.0	0.56
5/22/83	326	5.90	23.0	0.65
5/23/83	327	5.85	20.0	0.56
5/24/83	328	5.75	14.6	0.41
5/25/83	329	5.66	10.8	0.31
5/26/83	330	5.63	9.64	0.27
5/27/83	331	5.92	24.3	0.69
5/28/83	332	6.30	56.0	1.59
5/29/83	333	6.47	75.4	2.13
5/30/83	334	6.65	101.0	2.89
5/31/83	335	6.77	120.2	3.40
MONTHLY MEAN: 77.2 cfs (2.19 m3/s)				
6/1/83	336	6.82	128.6	3.64
6/2/83	337	6.90	143.0	4.05
6/3/83	338	7.00	161.0	4.56
MEAN: 144.2 cfs (4.08 m3/s)				

*Days since 1 July, 1982.
Gage heights determined with a Leupold and Stevens model A-35 continuous-strip recorder. Gage datum = 4,722.34 ft (1,439.369 m). Gage height for zero flow = 5.15 feet (1.57 m). Discharge data was determined from USGS Rating Table #23, based on 16 discharge measurements made during the 1979 water year, and is fairly well defined between 3.0 and 3,000 cfs. The discharges shown herein are only preliminary and are not official data--Douglas L. Heath.

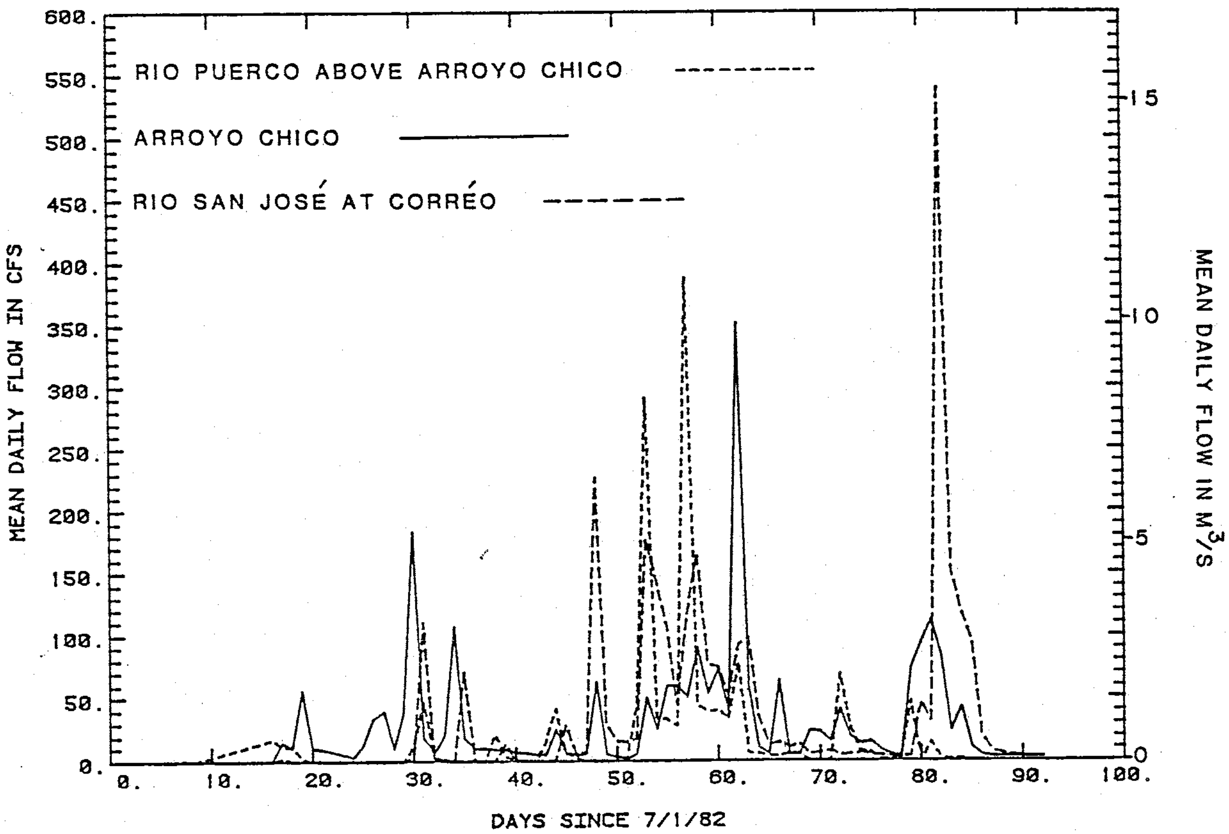
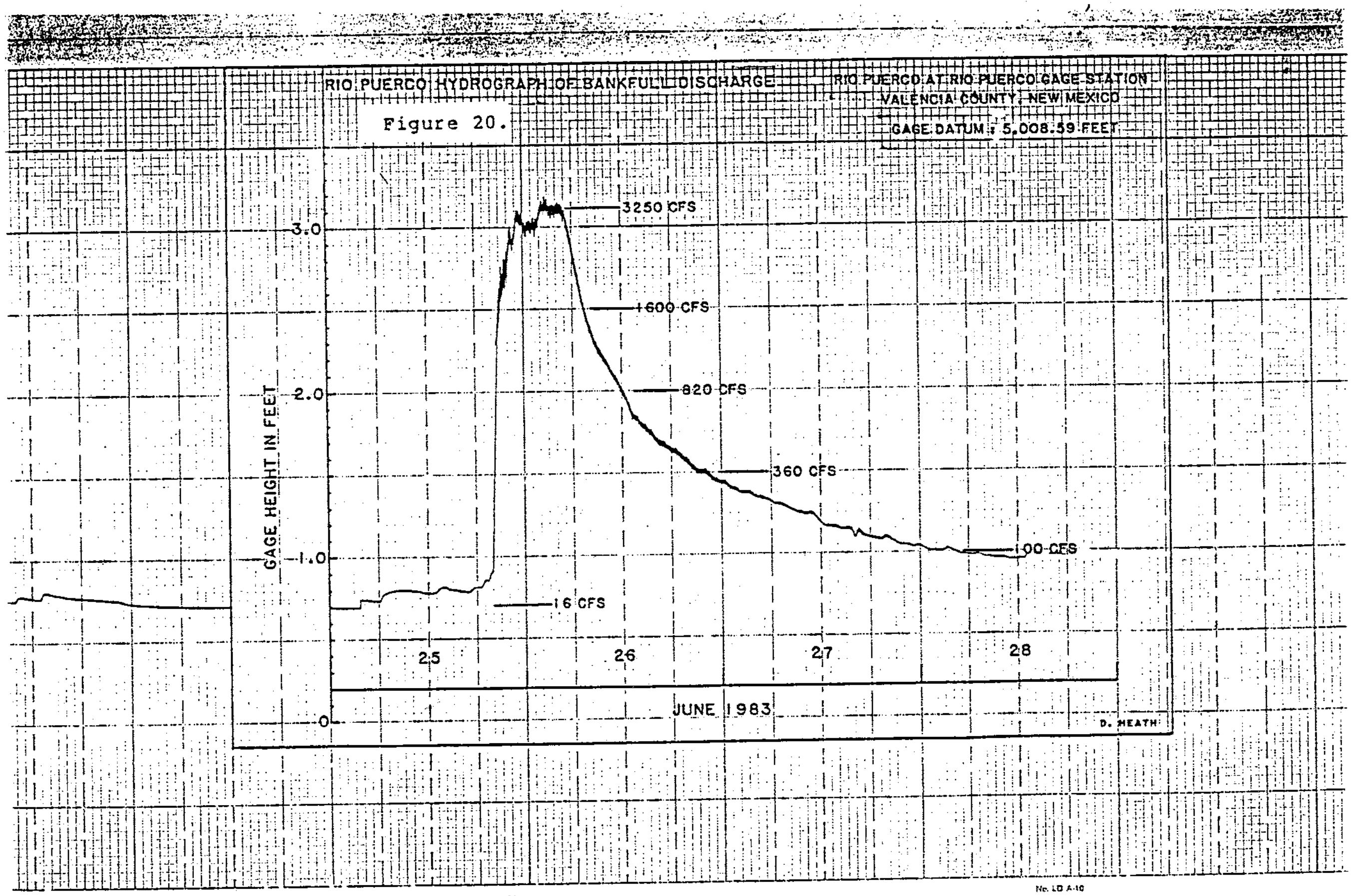


Figure 19. Hydrographs of the Rio Puerco above Arroyo Chico, Arroyo Chico and Rio San Jose at Correo gage stations from July to September, 1982


RIO PUERCO HYDROGRAPH OF BANKFULL DISCHARGE
RIO PUERCO AT RIO PUERCO GAGE STATION
VALENCIA COUNTY, NEW MEXICO
GAGE DATUM : 5,008.59 FEET
Figure 20.
3250 CFS
1600 CFS
820 CFS
360 CFS
100 CFS
16 CFS
3.0
2.0
1.0
0
GAGE HEIGHT IN FEET
25
26
27
28
JUNE 1983
D. HEATH

APPENDIX G

Table 20.

SURVEY DATA OF A-A' CROSS-SECTION, T5N.R1W.13, VALENCIA COUNTY, NEW MEXICO

DATE: February 18 and March 1, 1983; surveyed by James Boyle and Douglas Heath

R (degrees)	Z (degrees)	DIS (ft)	FS (ft)	N (ft)	E (ft)	ELEV (ft)	REMARKS
205-55-00	90-11-25	828	6.14	7270	5739	4915.21	Stake at west end of Rio Puerco valley fill, west end of B-B' cross-section
209-34-15	95-37-50	260	14.30	7723	6085	4884.32	Water shot
285-17-10	90-14-40	760	6.80	8275	5592	4914.06	Top of valley fill, west end of A-A' cross-section
284-57-00	90-18-30	755	15.78	8268	5594	4904.25	Top of colluvium
284-22-50	91-17-45	730	18.65	8250	5613	4888.93	Base of colluvium, edge of floodplain
282-39-40	91-32-55	700	18.50	8217	5630	4886.67	West edge of ponded water in abandoned meander
284-15-35	91-38-05	642	20.21	8208	5690	4885.56	Middle of water, top of clay
290-36-35	93-20-15	501	6.50	8191	5844	4888.43	Edge of floodplain
290-30-35	93-15-15	492	5.46	8185	5851	4890.70	Break in slope
298-29-00	93-16-30	203	12.52	8048	6109	4899.95	Point bar
310-37-35	93-18-45	188	13.94	8065	6149	4899.26	Break in slope
312-39-40	93-16-55	175	11.87	8058	6162	4902.17	Break in slope
327-28-55	93-17-05	136	8.68	8041	6215	4907.59	Break in slope
336-58-10	90-22-35	126	6.63	8037	6239	4916.64	Top of island
062-12-15	86-42-00	76	4.38	7932	6334	4924.15	High point of island
074-16-15	89-34-40	172	5.29	7921	6438	4919.53	Break in slope
043-05-25	29-23-05	119	6.59	7979	6359	4918.80	Lower mark
Set @ Island #2 stake,		HI=4.71,		N=7858.1,	E=6426.5,		Elev.=4914.91
275-14-55	89-50-50	175	4.88	7913	6260	4915.21	Island #1 stake
000-07-35	92-45-00	67	19.34	7923	6442	4897.02	Top of colluvium
020-58-40	100-23-35	78	18.39	7922	6469	4887.21	Edge of floodplain
074-32-05	96-03-05	227	9.14	7867	6652	4886.58	Floodplain
085-25-30	91-17-30	504	20.52	7783	6925	4887.72	Top of west levee
085-20-35	91-36-50	528	21.64	7781	6949	4883.09	Edge of water
085-20-20	91-39-45	540	21.70	7779	6960	4882.23	Mid-channel
084-25-20	91-30-00	558	21.79	7785	6980	4883.20	Edge of water
086-56-30	91-28-40	576	17.88	7758	6993	4886.87	Top of east levee
080-41-00	90-41-15	719	20.59	7811	7144	4890.39	Edge of floodplain
080-12-45	90-27-15	731	18.65	8716	7156	4895.17	Top of colluvium (fan apex)
080-17-25	89-39-50	733	8.67	7815	7158	4915.26	Top of valley fill at east end of A-A' cross-section

Table 21.

SURVEY DATA OF B-B' CROSS-SECTION, T5N.R1W.13.1344, VALENCIA COUNTY, N. M.

DATE: 18 February, 1983; surveyed by James Boyle and Douglas Heath

R (degrees)	Z (degrees)	DIS (ft)	FS (ft)	N (ft)	E (ft)	ELEV (ft)	REMARKS
212-19-20	90-03-00	624	8.12	5000	5000	4910.22	U. S. Army Corps of Engineers benchmark HMD-22
345-59-15	89-41-48	610	9.05	5438	5444	4913.07	Loop from benchmark
170-01-45	90-11-06	588	5.94	6635	5466	4913.07	Loop from benchmark
010-11-10	89-51-15	691	7.46	7270	5739	4915.21	Stake on west abutment of Rio Puerco valley fill, auger hole B-7
085-59-45	88-03-40	19	15.07	7267	5758	4905.11	Midslope
087-13-45	88-46-15	40	23.20	7263	5778	4897.22	Break in slope
085-33-35	98-21-45	80	17.40	7258	5817	4890.48	High-water mark of 19 September, 1982 flood
089-08-15	98-26-55	89	16.44	7251	5825	4890.02	Auger hole B-5
087-33-50	98-27-40	113	13.56	7249	5849	4889.39	Auger hole B-6
085-59-35	98-16-35	147	9.74	7247	5883	4888.72	Auger hole B-1
084-21-30	98-25-25	156	12.78	7250	5892	4884.01	West edge of water
084-21-15	98-22-50	168	11.84	7298	5904	4883.33	Mid-channel
084-10-50	98-14-20	180	9.90	7247	5916	4884.00	East edge of water
084-54-45	98-04-10	193	3.97	7243	5928	4888.61	Auger hole B-3
084-26-20	95-05-20	231	11.15	7240	5967	4887.89	Auger hole B-4
084-15-30	95-04-50	253	8.27	7238	5989	4888.86	Auger hole B-8
086-33-50	94-28-30	295	7.48	7221	6029	4889.03	Auger hole B-9
084-14-50	92-33-30	346	14.73	7226	6082	4889.34	Auger hole B-10
087-53-40	92-17-40	400	14.00	7194	6131	4889.50	East edge floodplain
088-53-55	92-02-50	415	7.07	7184	6145	4897.62	Top of colluvium
087-38-45	89-45-00	425	7.12	7191	6157	4914.28	Top of east abutment, Rio Puerco valley fill, east end of B-B' cross-section

Table 22.

CROSS-SECTION OF THE RIO PUERCO CHANNEL ALONG SECTION B-B', T5N.R1W.13.1344, VALENCIA CO., NEW MEXICO
11 October, 1982 (postflow)

Hor. (ft)	Vert. (ft)	Hor. (ft)	Vert. (ft)
0.00	0.00	25.00	5.48
1.00	0.29	26.00	5.45
2.00	0.33	27.00	5.61
3.00	0.85	28.00	5.61
4.00	0.89	29.00	5.71
5.00	1.54	30.00	5.61
6.00	2.07	31.00	5.71
7.00	2.72	32.00	5.64
8.00	3.35	33.00	5.28
9.00	3.77	34.00	4.92
10.00	4.03	35.00	4.69
11.00	4.00	36.00	4.43
12.00	5.05	37.00	4.03
13.00	5.28	38.00	3.71
14.00	5.45	39.00	3.28
15.00	5.41	40.00	3.12
16.00	5.38	41.00	2.75
17.00	5.31	42.00	2.30
18.00	5.41	43.00	1.64
19.00	5.35	44.00	0.98
20.00	5.48	45.00	0.33
21.00	5.38	46.00	0.16
22.00	5.35	47.00	0.10
23.00	5.45	47.75	0.00
24.00	5.41		

Channel Area = 180.62 sq ft (16.78 sq m)
Hydraulic Radius = 3.56 ft (1.085 m)
Wetted Perimeter = 50.75 ft (15.47 m)
Width/Depth = 8.36

Table 23.

CROSS-SECTION OF THE RIO PUERCO CHANNEL AT THE VALENCIA COUNTY ROAD 548 BRIDGE (NORTH RAIL), T5N.R1W.25.1122
25 October, 1982 (postflow)

Horizontal (ft)	Vertical (ft)	Horizontal (ft)	Vertical (ft)
0.00	0.00	31.00	5.35
1.00	0.18	32.00	4.91
2.00	0.41	33.00	4.96
3.00	0.63	34.00	4.72
4.00	1.04	35.00	4.65
5.00	1.82	36.00	4.48
6.00	2.59	37.00	4.40
7.00	3.04	38.00	3.93
8.00	3.32	39.00	3.50
9.00	3.51	40.00	3.18
10.00	4.34	41.00	2.59
11.00	4.73	42.00	1.89
12.00	5.14	44.00	0.83
13.00	5.83	45.00	0.52
14.00	5.70	46.00	0.67
15.00	5.67	47.00	0.71
16.00	5.63	48.00	0.78
17.00	5.55	49.00	0.51
18.00	5.52	50.00	0.25
19.00	5.49	51.00	0.22
20.00	5.50	52.00	0.12
21.00	5.40	53.00	0.00
22.00	5.37		
23.00	5.35		
24.00	5.28		
25.00	5.30		
26.00	5.32		
27.00	5.31		
28.00	5.37		
29.00	5.32		
30.00	5.44		

Channel Area = 183.63 sq ft (17.06 sq m)
Hydraulic Radius = 3.30 ft (10.06 m)
Wetted Perimeter = 55.71 ft (16.98 m)
Width/Depth = 9.09

PLATES 1 - 37

PLATE 1: The Rio Puerco channel at Popalito meander in 1935. This is an enlargement of aerial photograph no. 494 made by the U. S. Soil Conservation Service. Scale: 1 inch = 400 feet (121.9 m). The photograph is alligned with the true north-south axis.

PLATE 2: The same channel 19 years later. This is an enlargement of aerial photograph no. 5542 taken by the U. S. Army Map Service on 31 January, 1954. Scale: 1 inch = 400 feet (121.9 m).

PLATE 3: The meander as it appeared on 30 May, 19[illegible] This is an enlargement of U. S. Army Corps Engineers aerial photograph no. 11-008. Scale: inch = 400 feet (121.9 m).

PLATE 4: Aerial photograph of the Rio Puerco channel south of the Popalito meander 7 miles (11.3 km) west of Belen, New Mexico. The Rio Puerco valley fill surface is visible in the foreground. Since entrenchment began over two centuries ago, gullies have rapidly cut headward into the unconsolidated, coalescing fan and floodplain deposits east of the channel in response to tributary runoff west of the Llano del Albuquerque. The abandoned meander at the center of the photograph was formed before 1935. (View to ENE, 25 June, 1982)

PLATE 5: Convective thunderstorm activity during the summer months contributes substantially to flooding on the Rio Puerco and its tributaries. The view here is south from Popalito meander located in T5N.R1W.13. Ladron Peak (elev. 9,176 ft, 2,796.8 m) dominates the horizon. (September, 1982)

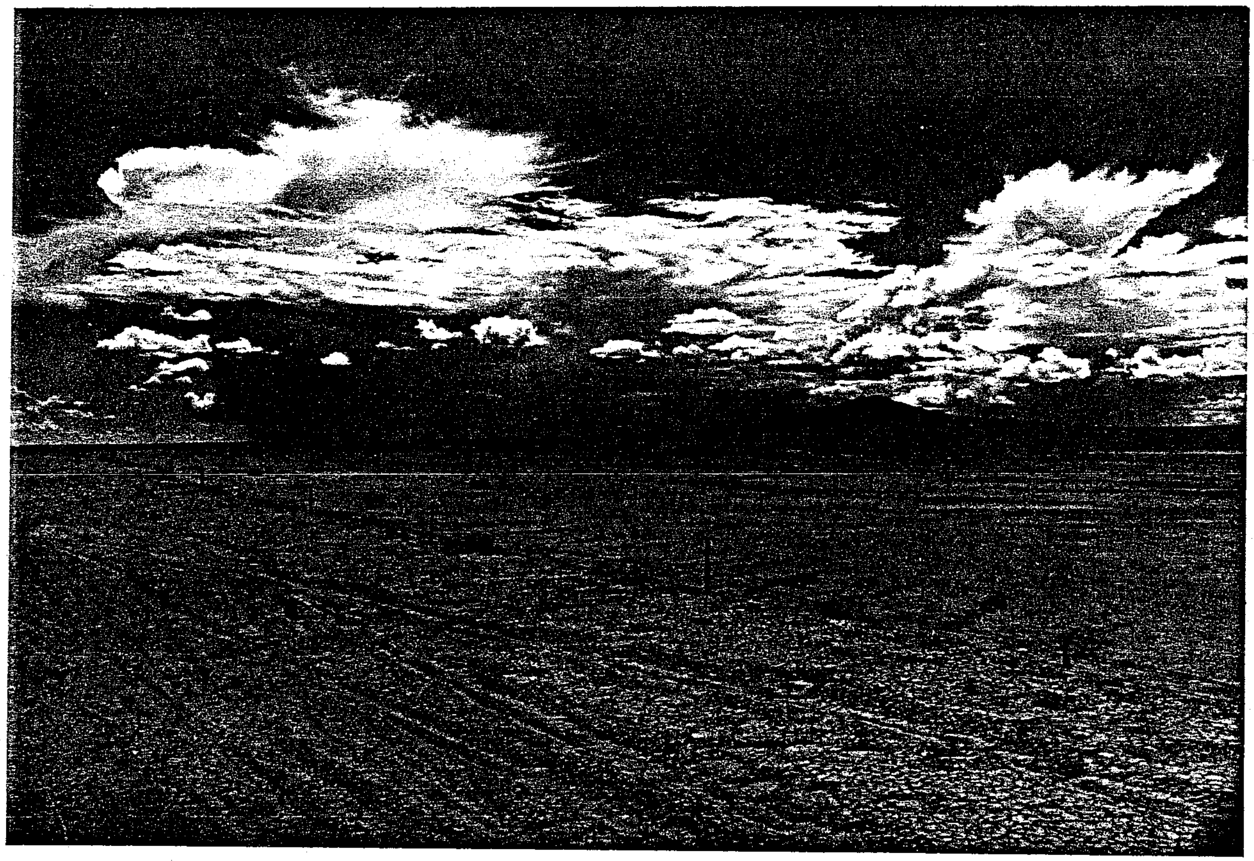


PLATE 6: Near-bankfull flow of the lower Rio Puerco at 1105 am, 27 August, 1982. The view is downstream from cross-section B-B', approximately 8,000 ft (2,438 m) north of the Valencia County Road 548 bridge. Bankfull flow at this location is approximately 3,000 cfs (85 m3/s). Channel dimensions are: width = 47.75 ft (14.6 m), depth = 5.7 ft (1.7 m), wetted perimeter = 50.75 ft (15.47 m), bankfull area = 180.6 sq ft (16.8 sq m). The following day, the Rio Puerco crested 0.5 ft (0.15 m) over its banks at this location.

PLATE 7: Small to large pebbles found in recent alluvium in auger hole B-8 about 60 ft 18.3 m) east of the present channel at 16.50 to 17.16 ft (5.01 to 5.20 m) depth. Such pebbles, which vary in size, roundness, sphericity and composition, are common in Rio Puerco thalweg deposits laid down by floodwaters.

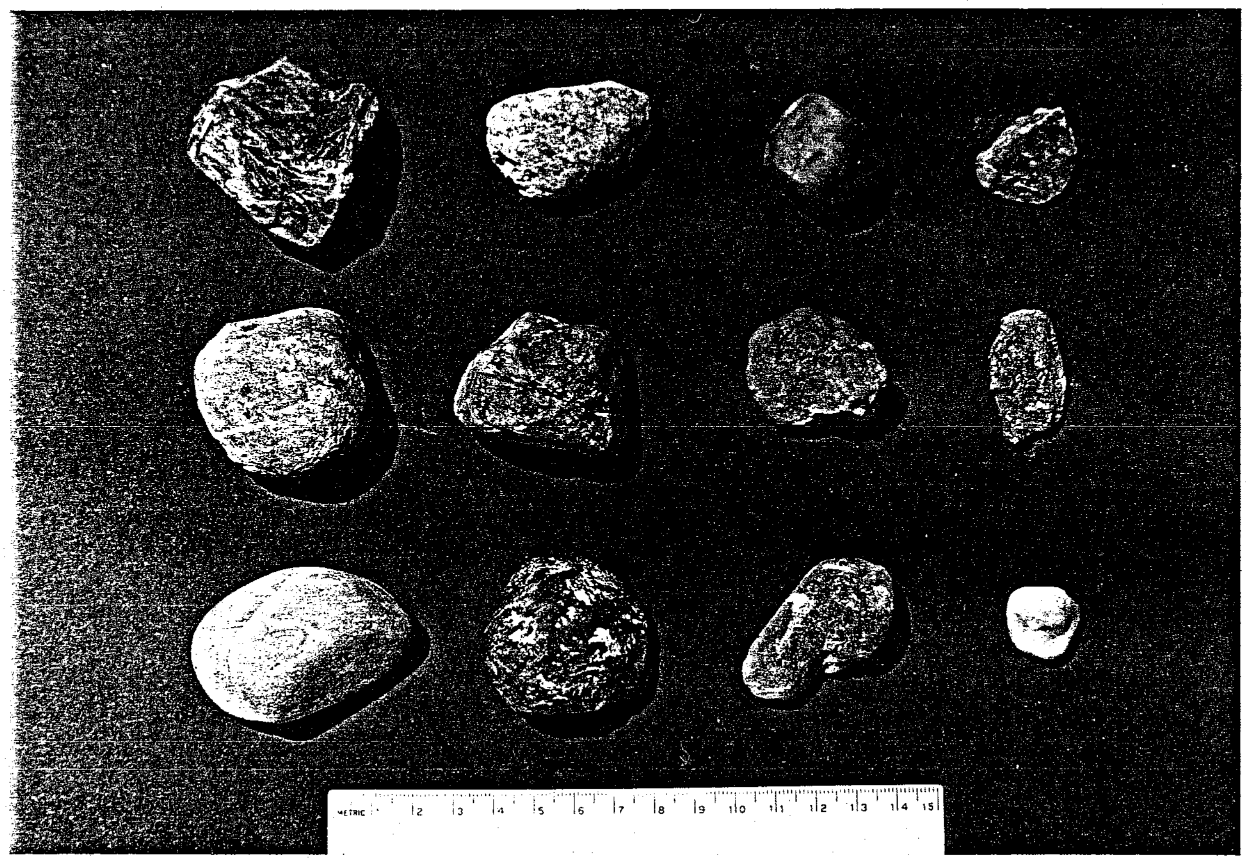

METRIC 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

PLATE 8: Photograph of the lower Rio Puerco at T5N.R1W.13.14324, the cutoff location of the Popalito meander neck in valley-fill alluvium. Channel avulsion occurred between 1954 and 1960, according to aerial photographs and incremental tree-ring dates from saltcedar (Tamarix sp.) growing in the former channel. A remnant inlier of valley-fill is visible on the right. (View to northwest, 25 October, 1982).

PLATE 9: Ponding of floodwaters in abandoned channel at Popalito meander in T5N.R1W.13. This photograph was taken 25 October, 1982, 36 days after the flood of 19 September. Maximum water depths exceeded 1.5 ft (0.46 m) after the floodwaters spilled over the banks of the adjacent active channel. By October 25th, the water depth had decreased to about 0.8 ft (0.24 m). The line at the lower left delineates the high water mark of the flood. Such accumulations of sediment-rich water from periodic overbank flooding promote rapid deposition of silt and clay particles in low-lying abandoned channels within the Rio Puerco arroyo. A shallow pit, dug in January, 1981 between the saltcedar and arroyo walls shown in this photograph, revealed that over 5 ft (1.5 m) of silt and clay had been deposited since channel avulsion occurred between 1957 and 1960. Over this period, the average vertical accretion rate of suspended sediments has been 0.24 ft (7.3 cm) per year. (View west)

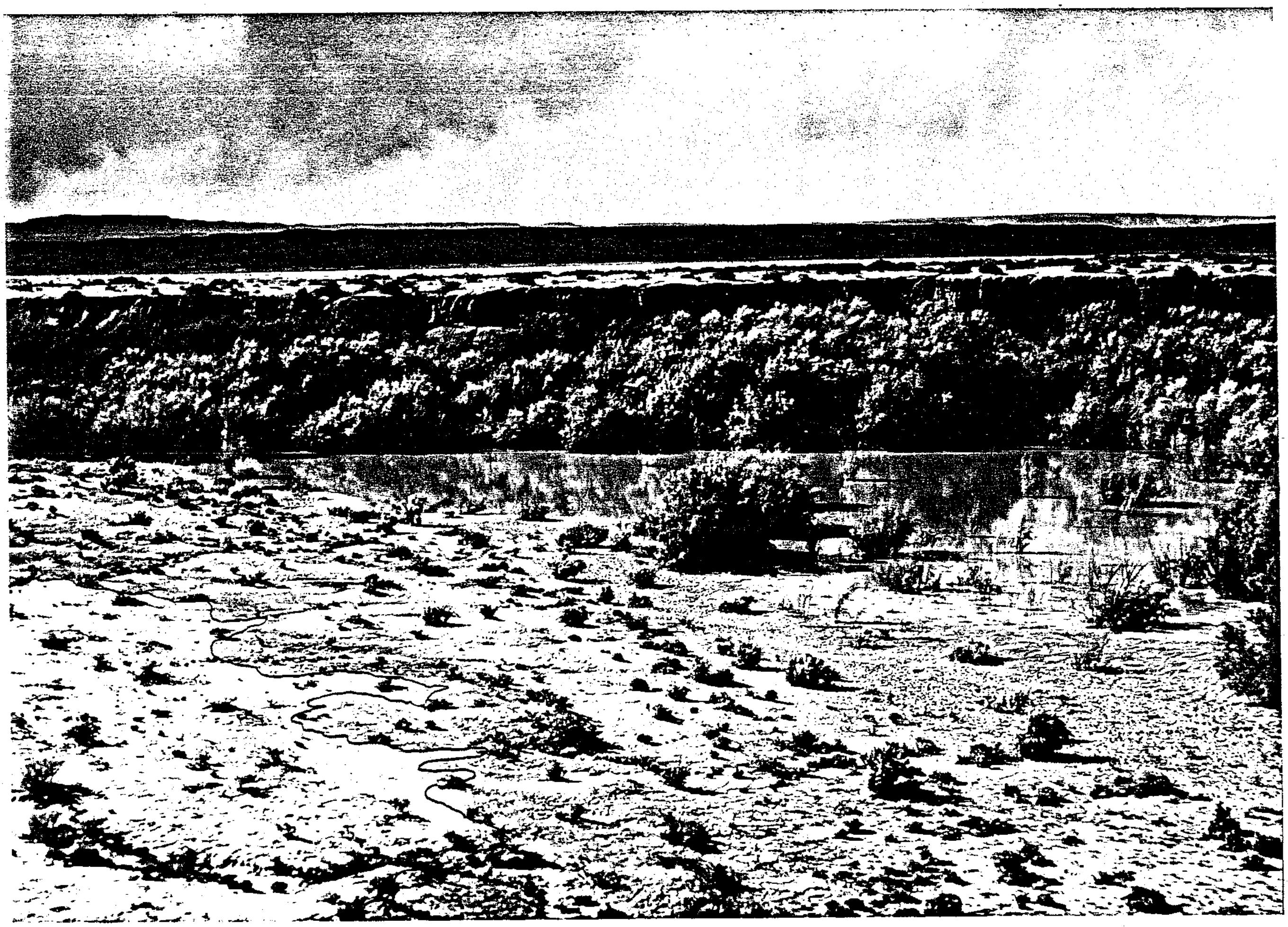


PLATE 10: Photograph of Rio Puerco valley-fill remnant (in background) and former point-bar (in foreground) within the Popalito meander. View is to the east from T5N.R1W.13.13243, along the A-A' line of section at an elevation of 4,890 ft (1490.47 m). The maximum high water level during the flood of 19 September, 1982 is delineated by the line in the near distance. (Photo: 25 October, 1982)

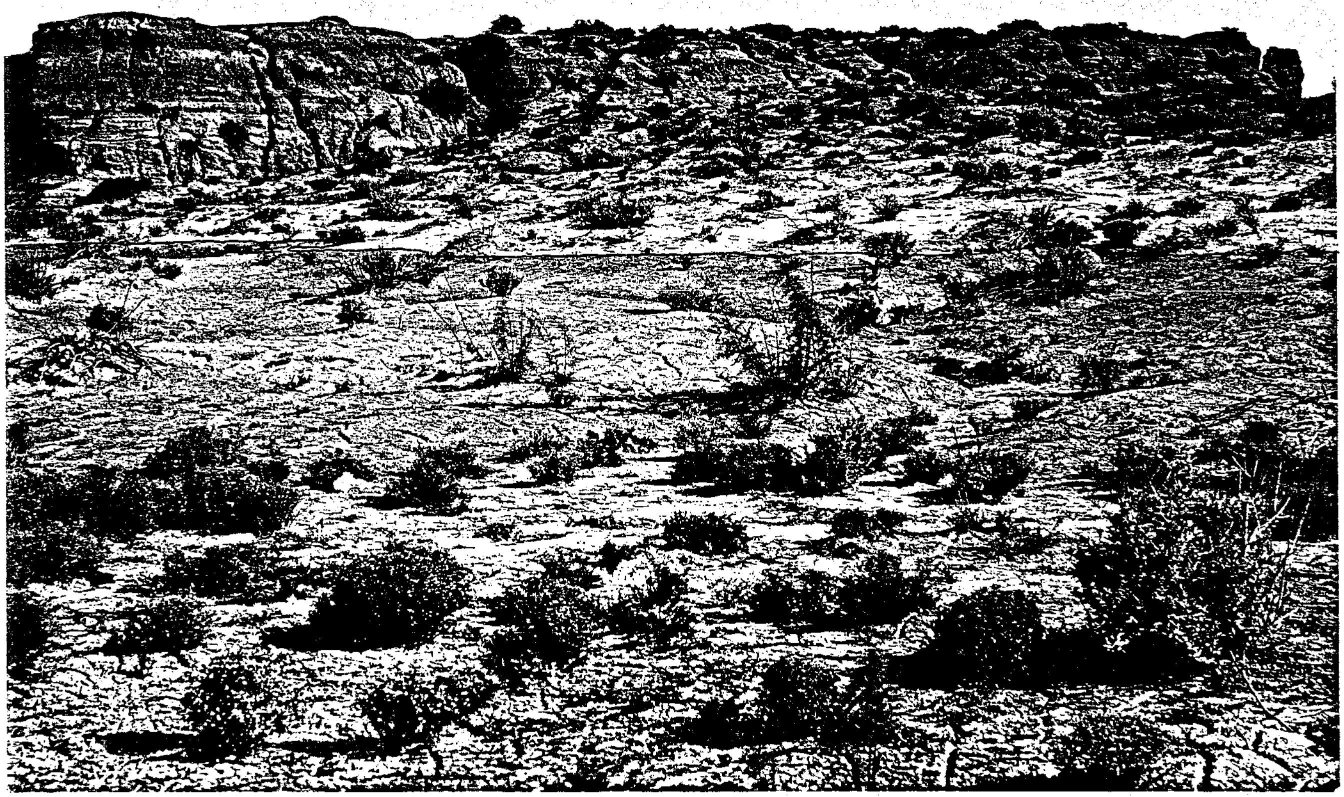


PLATE 11: Remnant inlier of Rio Puerco valley fill at the center of the Popalito meander. The landslide of unconsolidated sand, silt and clay occurred in September, 1982 after heavy rains. Such slides are common expressions of slope instability within the arroyo. Location: T5N.RIW.13.1411 (View to the south, 25 October, 1982)

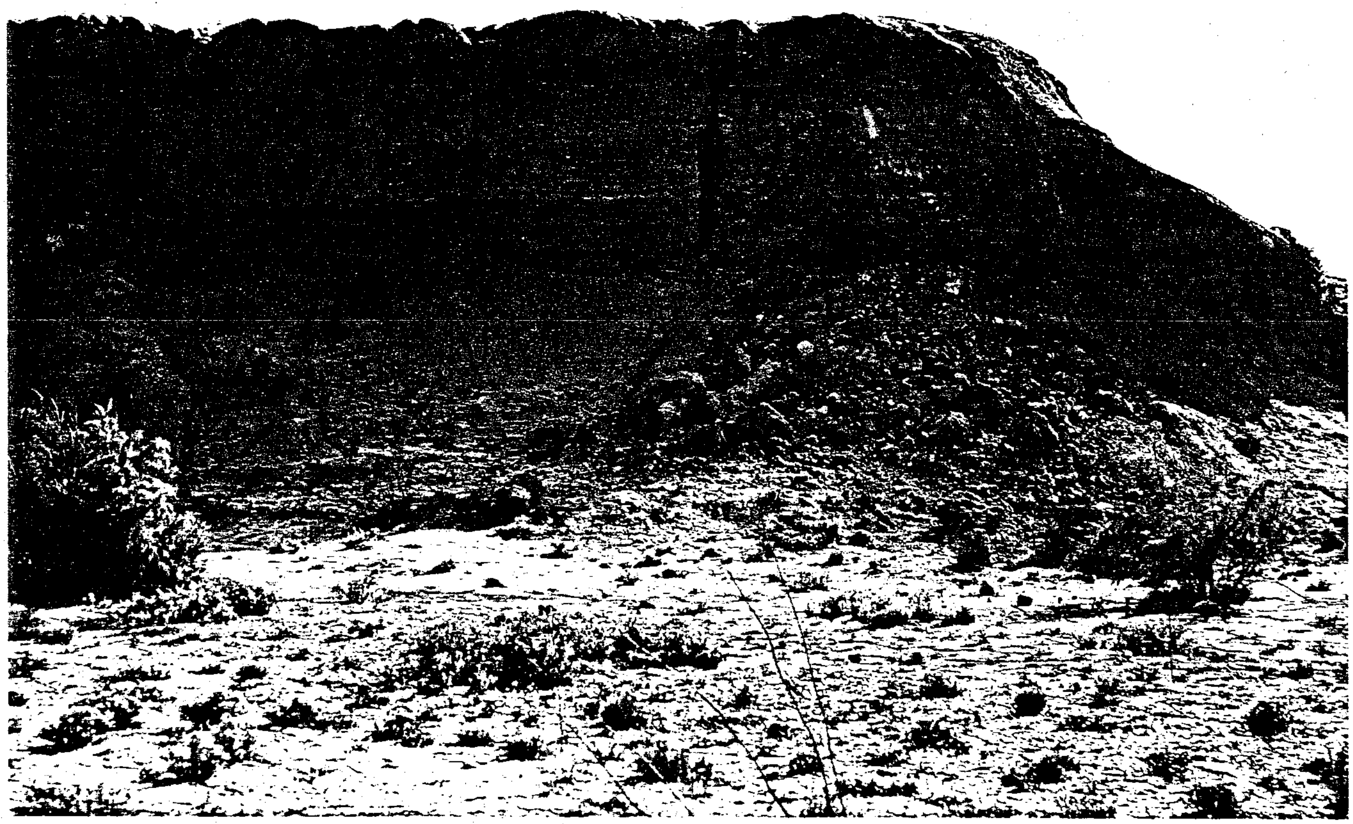


PLATE 12: Point-bar terraces of the lower Rio Puerco channel at T5N.R1W.13.143, 7 miles (11.3 km) west of Belen, New Mexico on 25 October, 1982. The bar, which consists of moderately sorted, fine- to medium-grained sand, has formed on the convex side of the bend by lateral accretion. Deposition is related to the existence of helicoidal flow associated with the channel bend (Wolman and Leopold, 1957, p. 91). The point-bar has grown westward since the channel shifted position about 23 years ago. The topmost surface is approximately 6 ft (1.9 m) above the channel bottom at right. The stepped appearance of the bar reflects fluctuating channel discharge before flow ended on 29 September, 1982. (View to south)

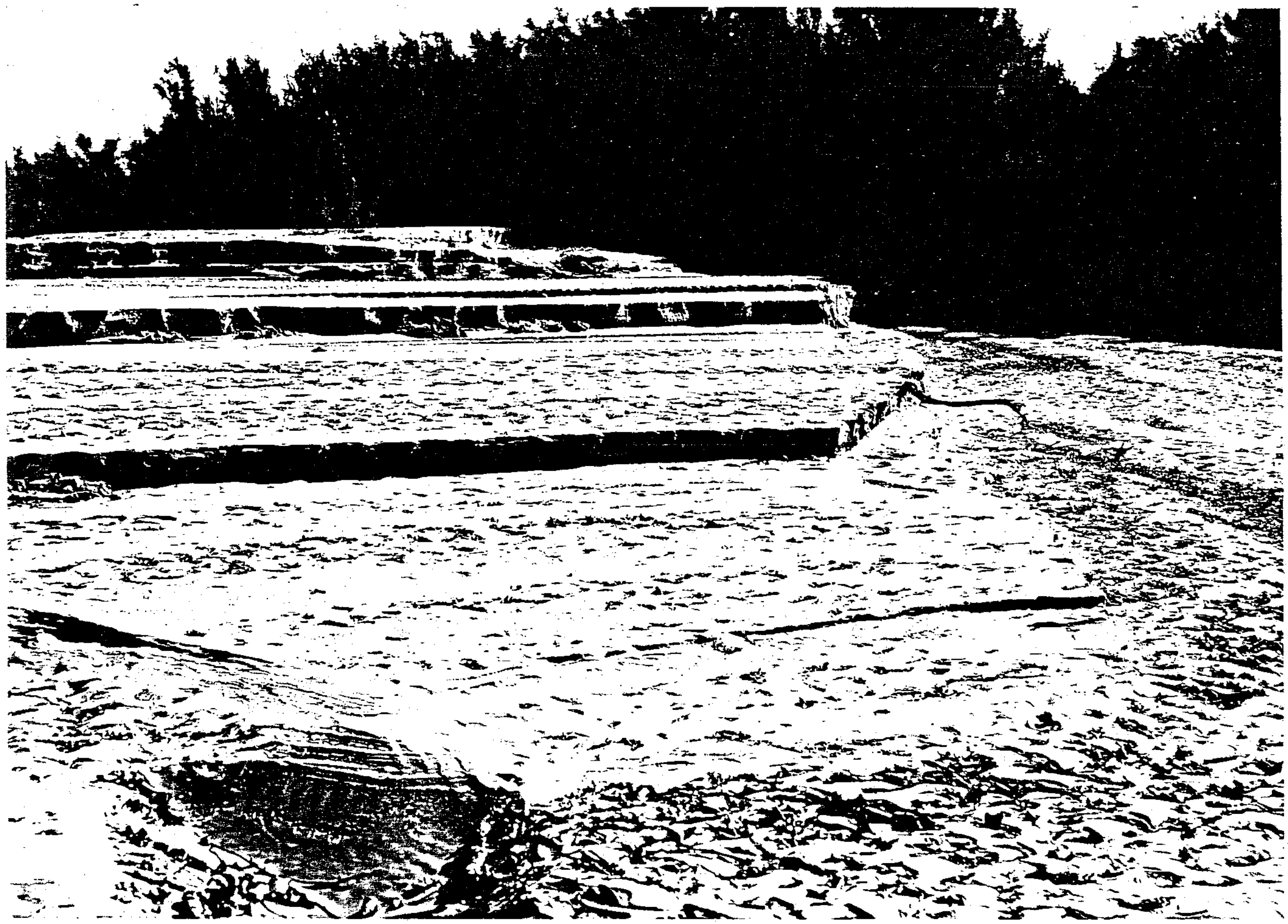


PLATE 13: Section of Rio Puerco valley fill at the east end of cross-section B-B', south of Popalito meander. The sequence consists of unconsolidated massive clay and clay laminae (10YR6/3, reddish-brown clay: 2.5YR4/3), and fine- to medium-grained sand (10YR6/4), revealing a complex history of low and high energy sedimentary environments during the Holocene. Scale: 15 ft (4.6 m) from surface to top of colluvium at base. The elevation of the top of the section is 4,914.3 ft (1,497.9 m) above sea level. Aerial photographs reveal that the section was cut after 1935. (View east, 11 October, 1982)

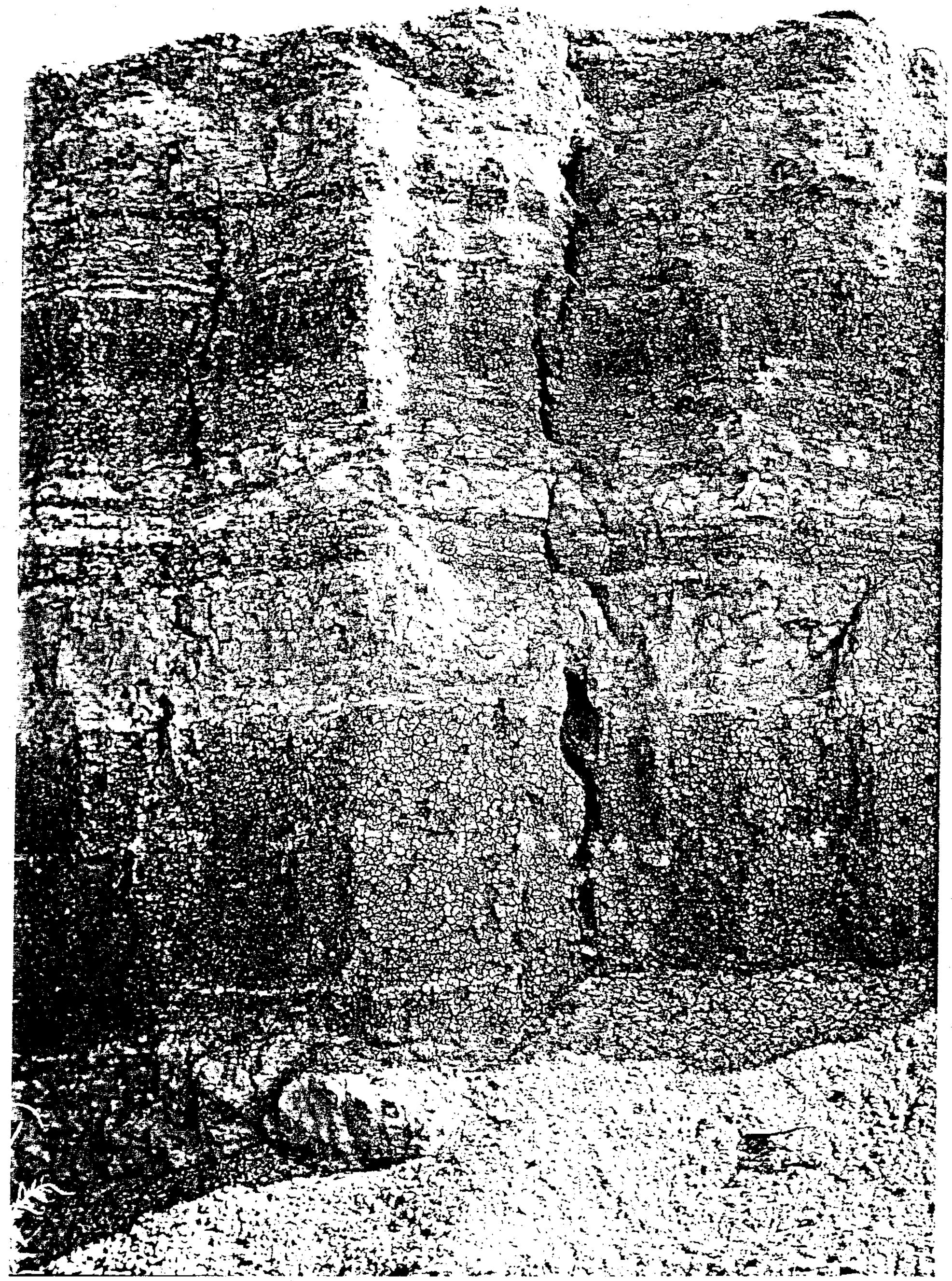
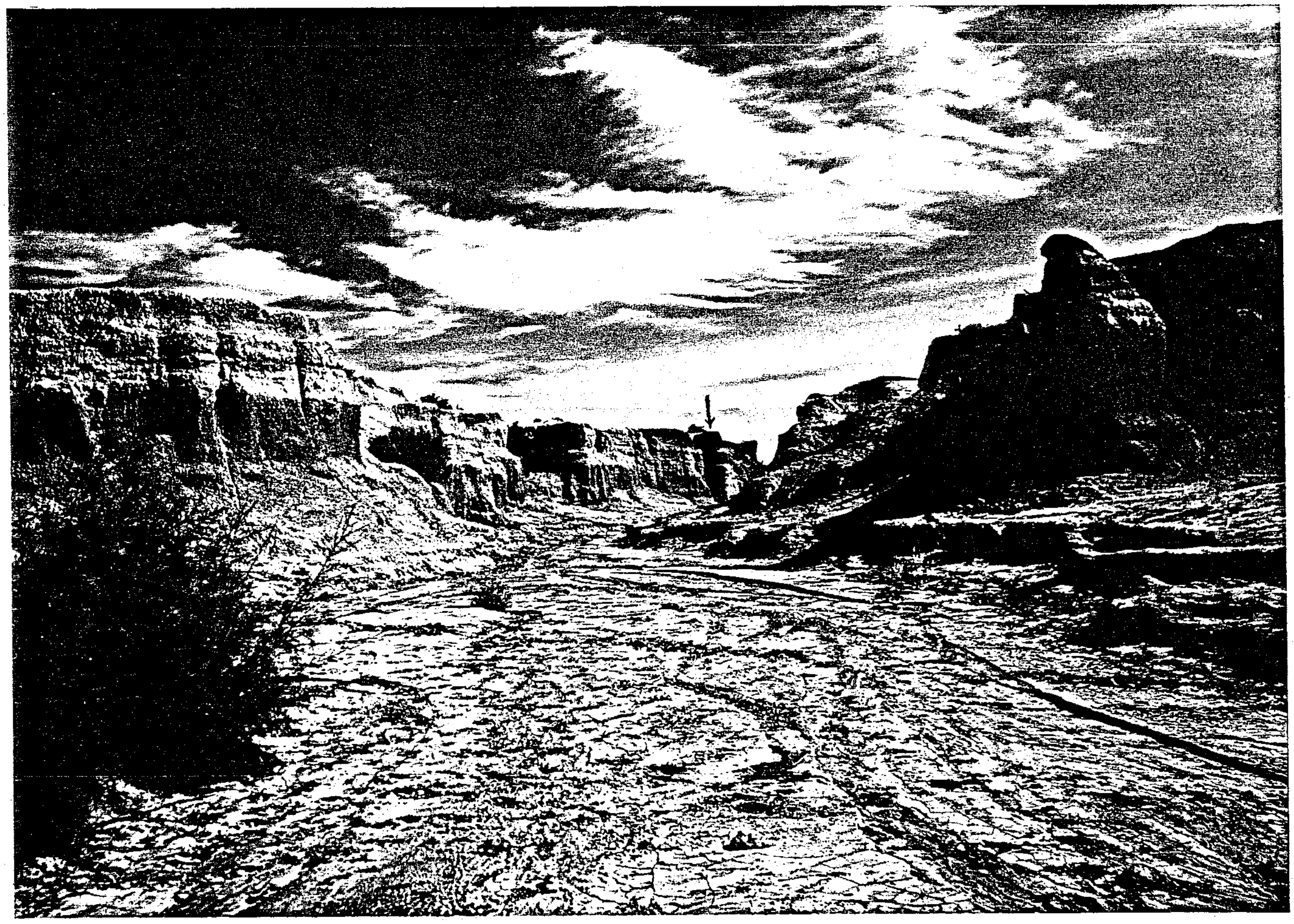


PLATE 14: Dessicated surface of suspended-load deposits in mid-channel of the lower Rio Puerco on 25 October, 1982. Flow had ceased at this location (cross- section B-B') 27 days earlier on 29 September, 1982. Such deposits, underlain by fine- to medium-grained channel sand, are typically <1cm thick at this location. Lens cap diameter is 5.5 cm.

PLATE 15: ABOVE: Tributary arroyo system in lower Rio Puerco valley fill, southeast of Popalito meander at T5N.R1W.13.32 and east of the active channel, showing interbeds of silty-clay loam and fine- to medium-grained sandy alluvium. BELOW: Detail of upper valley-fill deposits located by arrow in center of above photograph. Fine- to medium-grained, moderately sorted sandy channel- fill is overlain by reddish-brown, silty-clay loam about 3.3 ft (1 m) thick. Festoon cross-bedding and individual clay laminae are visible. (View to northeast, 25 October, 1982)



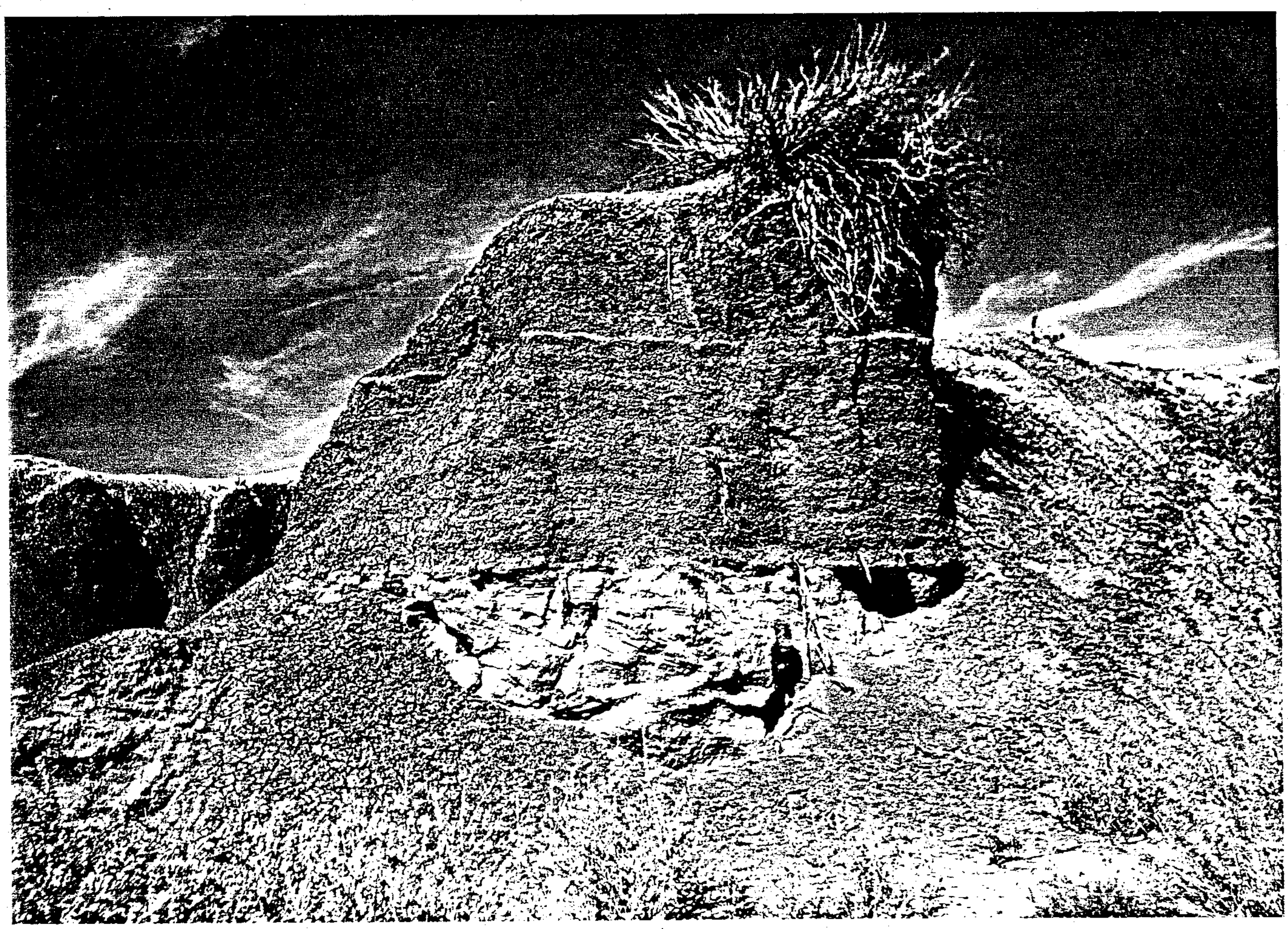


PLATE 16: Clayball genesis originates with calving of fragments from clay laminae exposed in valley fill or channel alluvium within the Rio Puerco arroyo or its tributaries. These fragments become rounded as they roll downstream and are deposited in groups or bars roughly parallel to the channel. The distance between deposits ranges from 4 to 8 times the channel width. See Nordin and Curtis (1962) for details about the formation and deposition of clayballs in the lower Rio Puerco near Bernardo, New Mexico. (Location: T5N.R1W.13.341; 31 October, 1982)

PLATE 17: Mid-channel scouring of clayball and gravel deposit at T5N.R1W.13.14134 in the lower Rio Puerco, 31 October, 1982. Lens cap diameter is 5.5 cm.

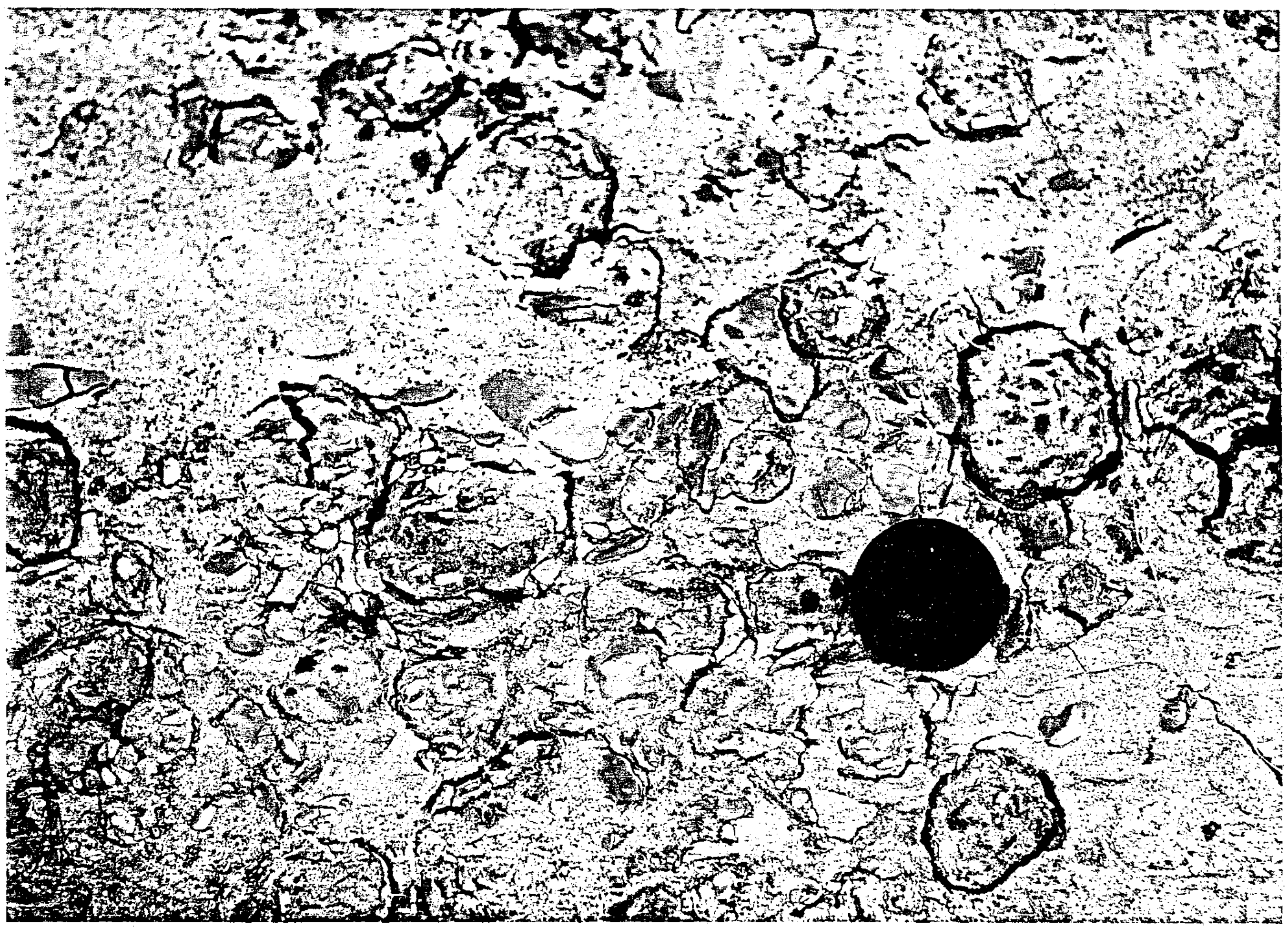


PLATE 18: Mass-wasting of lower Rio Puerco valley-fill at T5N.R1W.13.34133, 1.2 miles (1.93 km) north of Valencia County Road 548 bridge, has exposed former cut-and-fill channel deposits overlain by a thick unit of vertical accretion deposits about 6.5 ft (2 m) thick. Aerial photographs taken since 1935 show that the rate of southward lateral channel migration in this area has averaged about 11 ft (3.3 m) per year. Elevation of the top of the sequence is about 4,912 ft (1,497.2 m) above sea level. (View to south, 31 October, 1982; photo: Alison C. Simcox)

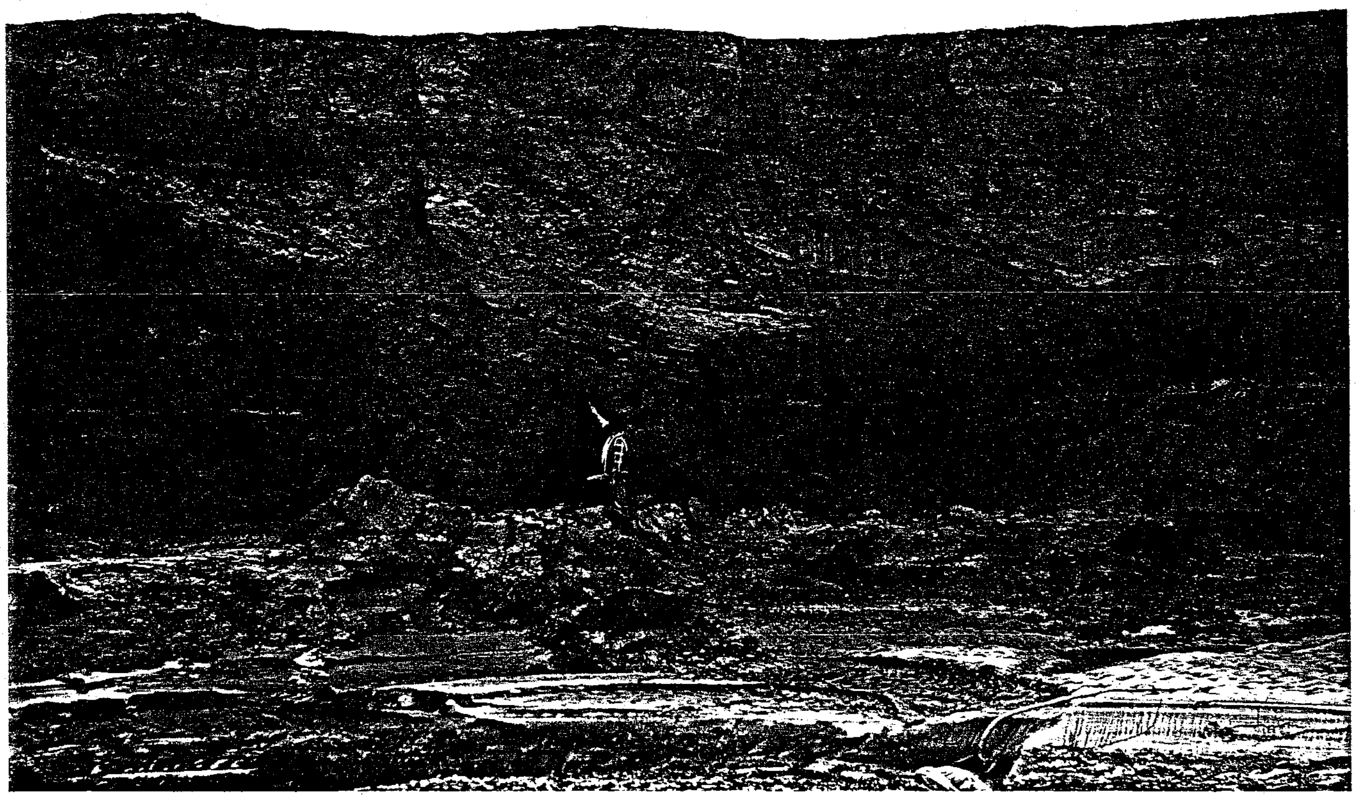


PLATE 19: Detail of base of the channel-fill deposit shown in preceding plate (near hammer held by author). The clay fragment is the result of the same erosional processes that later produced the exposure. Lens cap diameter is 5.5 cm. (Photo: 31 October, 1982)

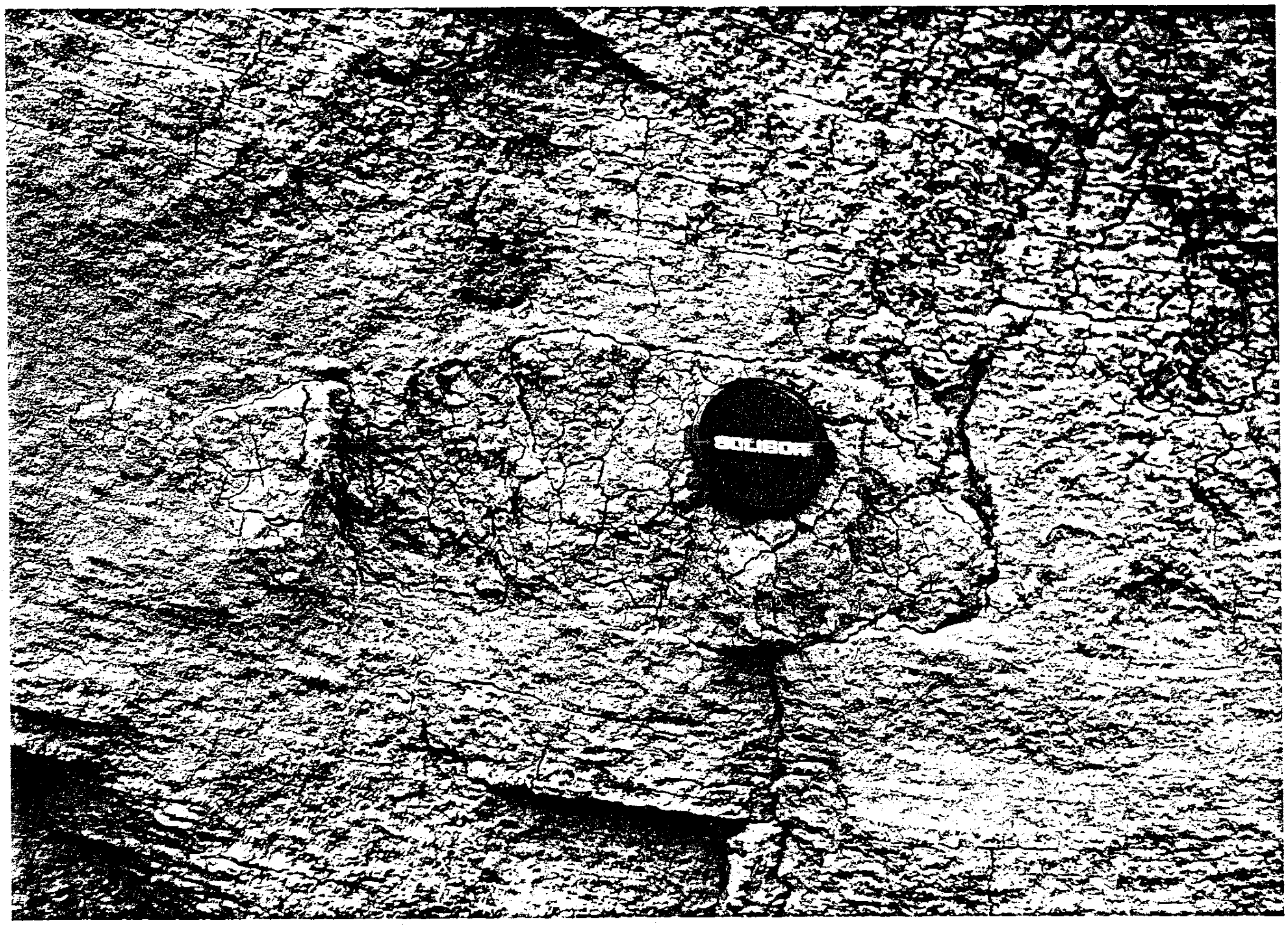

SOLIGOR

PLATE 20: Photograph of aggradational-channel deposits preserved in entrenched walls of Rio Puerco arroyo in T5N.R1W.24.324, approximately 1,640 ft (500 m) north of the Valencia County Road 548 bridge. Thin zones of thalweg-gravel laminae laterally grade abruptly into lamina sets of fine- to medium-grained sand and light-brown suspended load deposits. The sequence is overlain by floodplain and alluvial fan deposits of reddish-brown, silty-clay loam approximately 6.5 ft (2 m) thick. Recent point-bar deposits are at lower right. A similar sequence exists near the mouth of Comanche Arroyo in northern Socorro County. The rod in center of photo is 25 ft (7.62 m) in length. (View is south, 8 February, 1983)

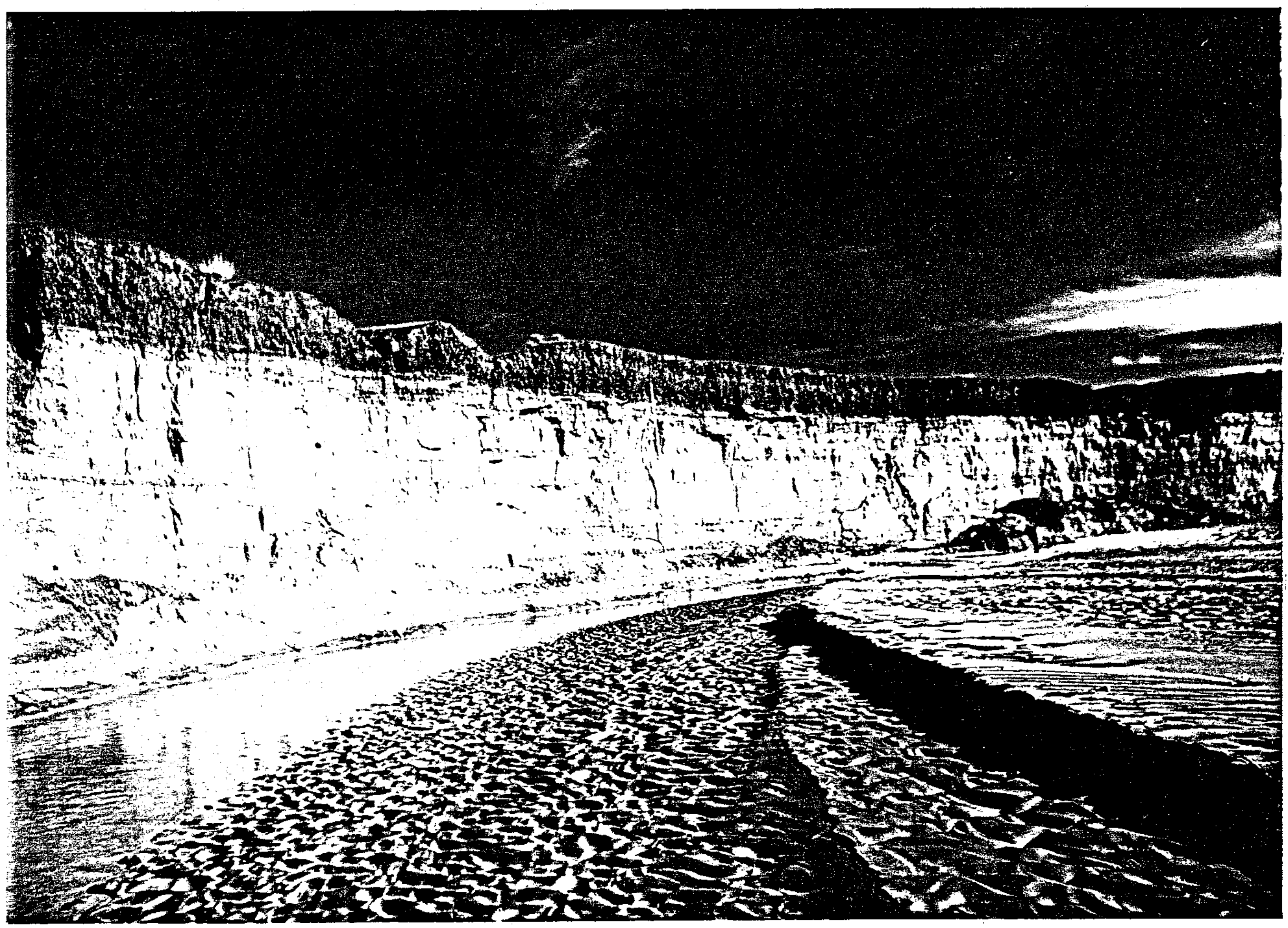


PLATE 21: Gullying of Rio Puerco valley fill east of the channel and north of the Valencia County Road No. 548 bridge, 25 October, 1982. Surface sediments consist of unconsolidated, stratified, fine- to medium-textured, silty-clay loam that has washed from soils of the Tome-Armijo and Tome-Adelino associations (Pease, 1975, p. 29). Runoff is rapid and the rate of water erosion is severe. Ladron Peak is visible on the horizon. (View to the south- southwest)

PLATE 22: Dust blowing east from Monte Belen Arroyo across the lower Rio Puerco valley in T5N.R1W on 24 February, 1983. High winds frequently carry sand, silt and clay particles from the channel beds of dry tributaries east and west of the Rio Puerco, particularly during the spring months. (View to the south from Valencia County Road 548)

PLATE 23: Photograph of a 12-foot exposure of the lower Rio Puerco valley fill in the east wall of a gully, 2,150 ft (660 m) west of the active channel in T5N.R1W.26.223. The sequence is overlain by silty-clay loam about 3.3 ft (1 m) thick. Elevation of the valley fill surface is about 4,897 ft (1,492.6 m). Scale in feet (red numerals). (View east, 31 October, 1982)

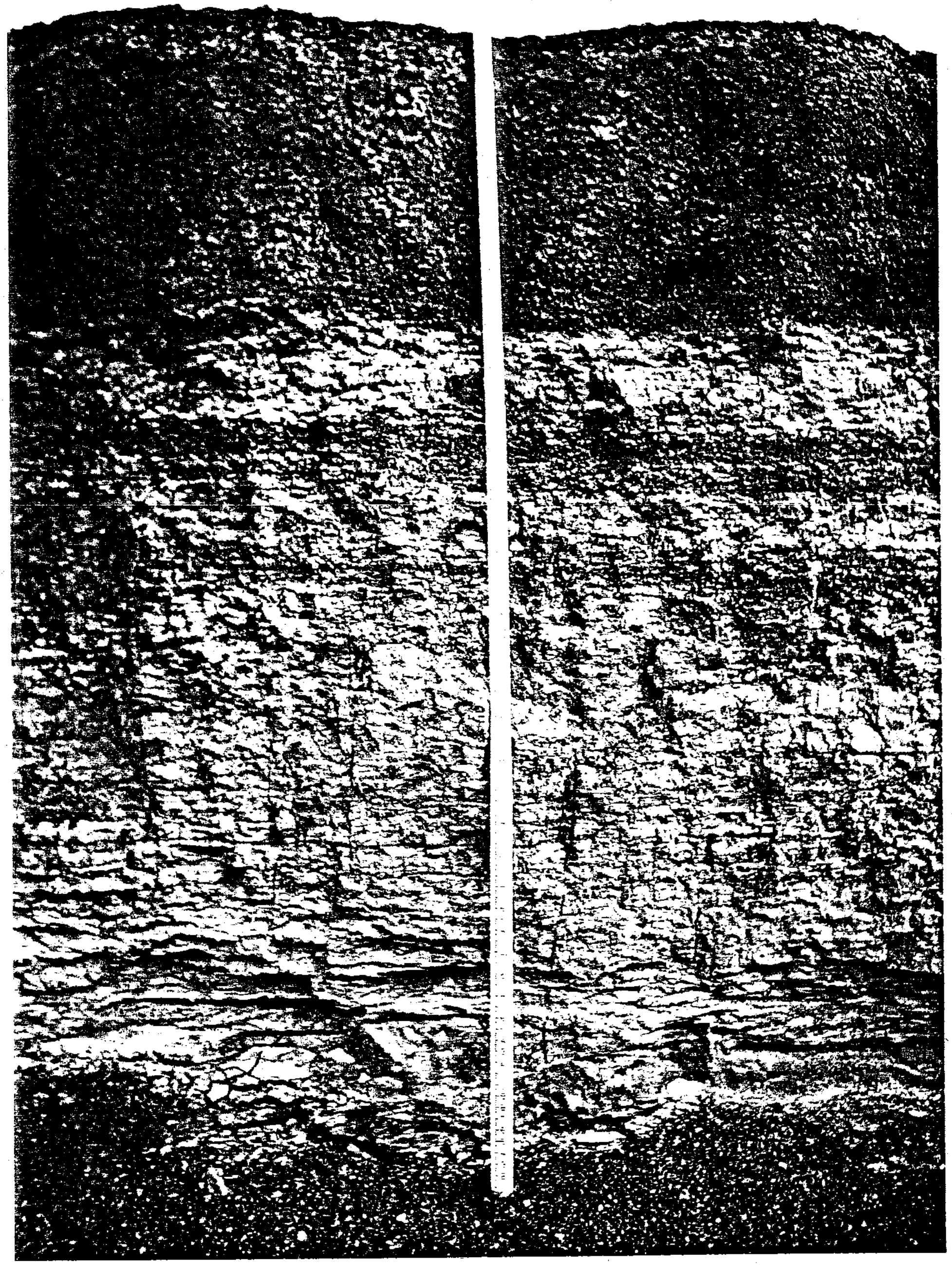
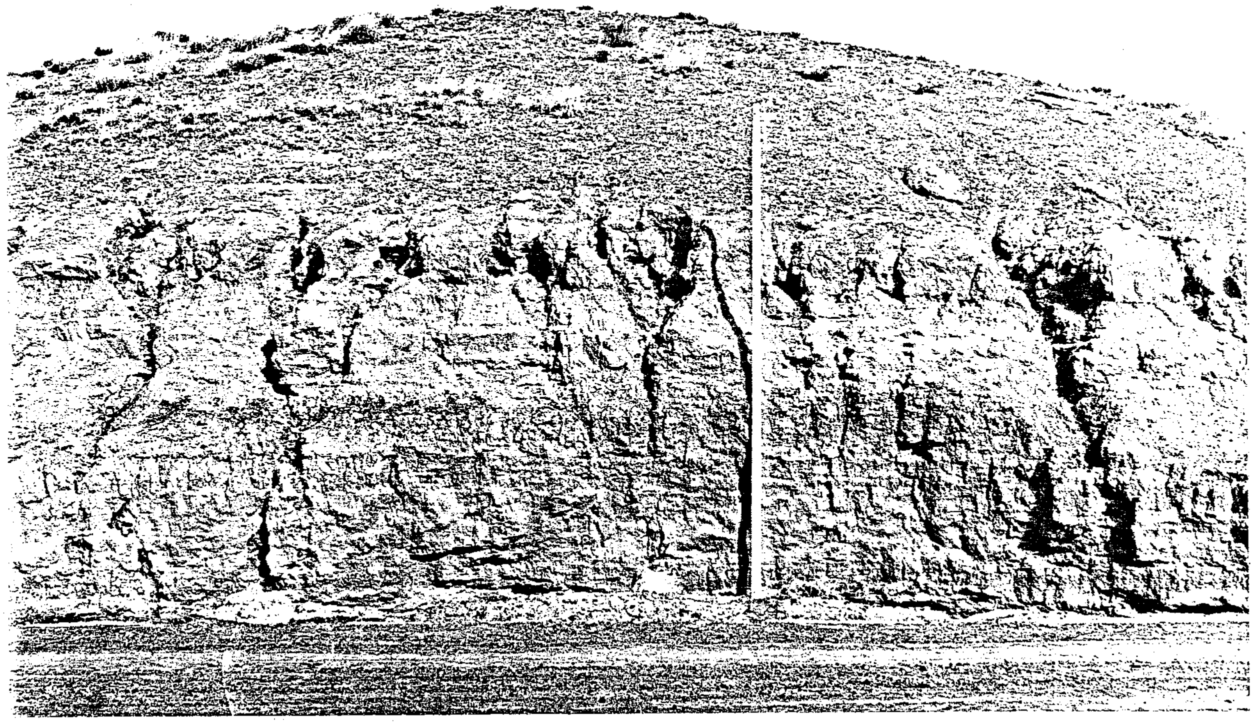


PLATE 24: Surface of the Rio Puerco valley floodplain, 660 m west of the arroyo in T5N.R1W.26.223. Elevation: 4,900 ft (1,493.5 m) above mean sea level. Pease (1975, p. 46, see Plate 25 for reference) has classified this soil as the Tome-Armijo association, which occurs as long, narrow areas along the lower Rio Puerco. According to Pease it is 60 percent Tome clay loam and 25 percent Armijo clay. The soil is strongly alkaline and saline. Permeability is low; runoff is rapid. Surface samples of the reddish-brown (5YR5/4) soil had an average silt-clay content of about 91 percent. The regional water table is over 70 ft (21 m) deep at this location. Length of hammer: 30 cm. (10 March, 1983)

PLATE 25: ABOVE: Roadcut exposure of the upper Santa Fe Group, 1.81 miles (2.92 km) west of the Rio Puerco on Valencia County Road No. 548 in T5N.R1W.22.32224, at an elevation of 5,060 ft (1,542.3 m) or 160 ft (48.8 m) above the valley fill surface to the east. The unconsolidated sediments, which consist of poorly sorted, buff to reddish-brown sand, gravel, silt and clay, are covered with a veneer of terrace gravel, classified as the Caliza-Bluepoint complex by Pease (1975). Rod length is 11 feet (3.35 m). (View to the north, 29 December, 1982) BELOW: Detail of the upper Santa Fe Group deposits shown above. Scale in feet, tens and hundredths of feet.



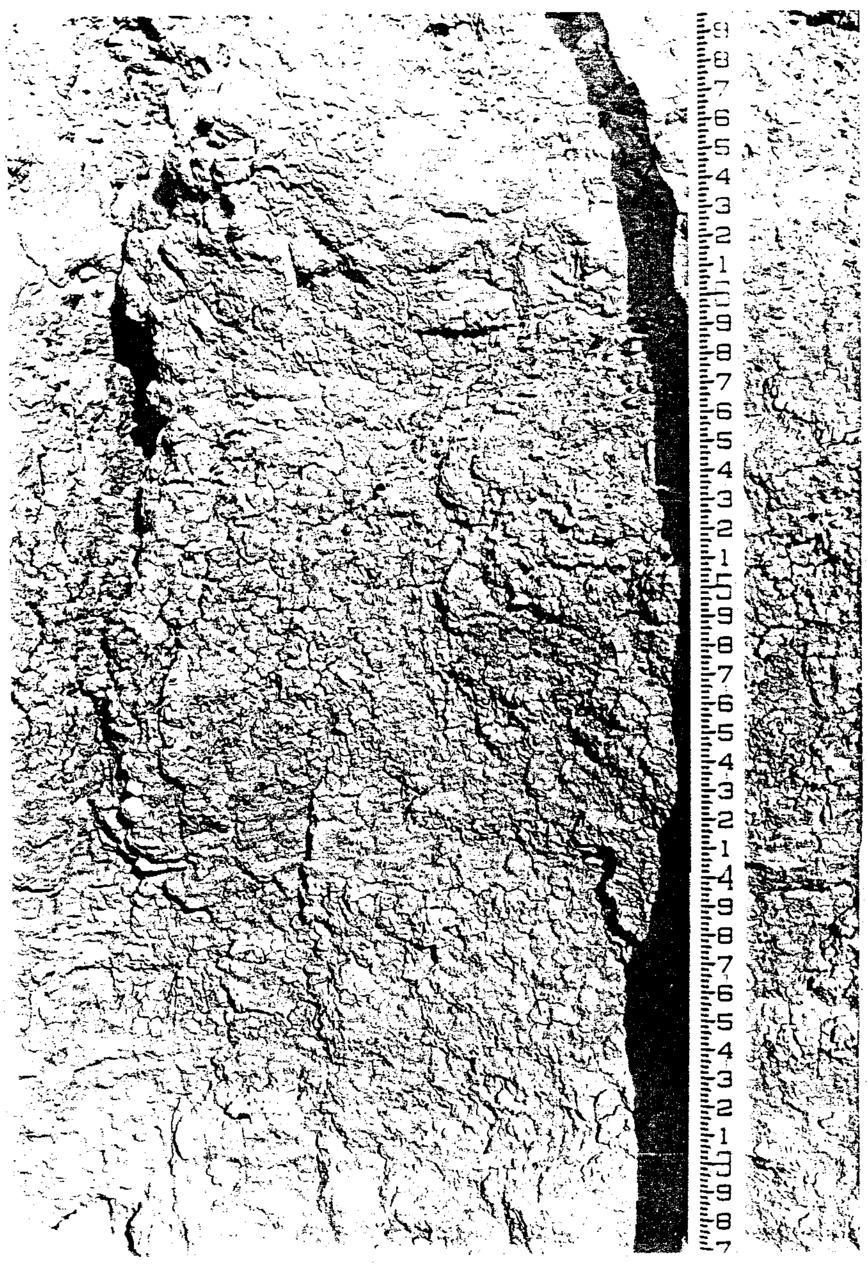


PLATE 26: Detail of Rio Puerco terrace gravels on upper Santa Fe Group deposits west of the Rio Puerco (near roadcut shown in Plate 25). Pebble and cobble composition includes basalt, limestone, sandstone, chert, shale, chalcedony, petrified wood, obsidian, granite, and metamorphics, among others. Clast diameters range up to 40 cm in some cases. Surface elevation: 5,060 ft (1,542.3 m) or approximately 160 ft (48.8 m) above the Rio Puerco valley floor to the east. Length of hammer: 30 cm. (10 March, 1983)

PLATE 27: A grove of cottonwood trees (Populus fremontii) growing on the east bank of the lower Rio Puerco at T5N.R1W.13.12423, 350 feet (107 m) north of Popalito meander. A cottonwood tree, growing on the opposite side of this grove (not visible in photograph) on a terrace of valley fill deposits 6.5 ft (2 m) above the present bank and about 20 ft (6.1 m) below the valley-fill surface, yielded an incremental tree-ring date of 81 +10 years, indicating the minimum age of the terrace to be between 71 to 91 years. Most of the trees at this site germinated after 1935. According to Everitt (1968, p. 421), tree-ring dates from cottonwood have a possible error of +10 years. Such trees are true phreatophytes and typically grow in areas where the water-table ranges from 4 to 30 feet (1.2 to 9.1 m) below the land surface (Meinzer, 1927, p. 58). The species will tolerate water of moderate salinity. (View to southeast, 8 February, 1983).

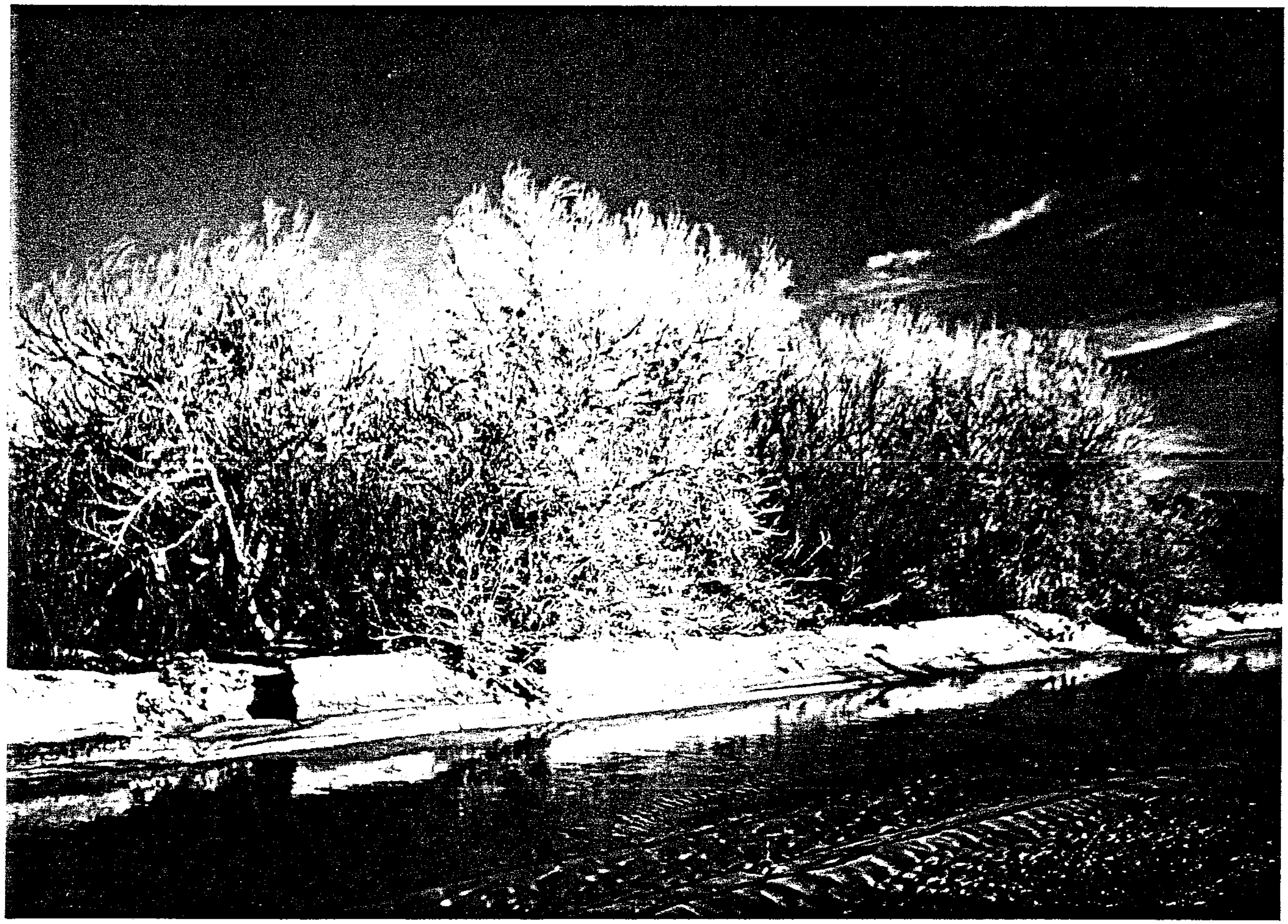
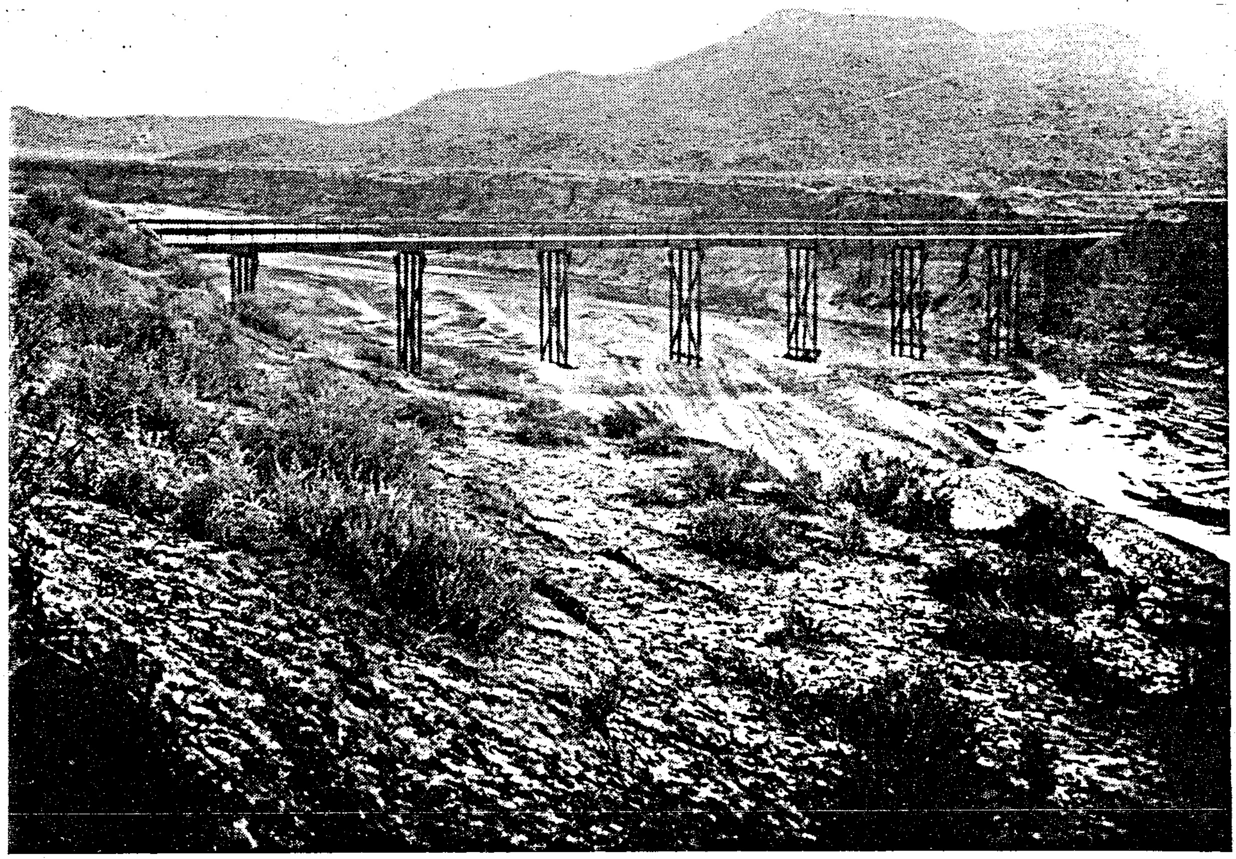


PLATE 28: The oldest known saltcedar tree (Tamarix sp.) in the Popalito study area. Incremental tree-ring corings show growth began about 1927 or 1928, before the floods of August 12th and September 23rd in 1929. The tree is located on the present inner-floodplain of the Rio Puerco at T5N.R1W.13.144 in Valencia County. The rod length is 25 ft (7.675 m). Due to perspective, the tree appears shorter than the rod. Actually, it is about 30 ft (9.1 m) in height. (View north, 8 February, 1983)

PLATE 29: ABOVE: Photograph of the N.M. State Highway 6 bridge crossing the Rio Puerco west of Los Lunas, New Mexico in 1916. Hidden Mountain (elev. 5,507 ft, 1,678.5 m) dominates the horizon. The photograph was published as the frontispiece to the Second Annual Report of the New Mexico State Engineer, 1914-1916, Santa Fe, New Mexico. This bridge was destroyed by flooding sometime before 1930 and rebuilt at its present location north of the railroad trestle.

The arroyo shown in this early photograph is that of the Type 1 category (Elliott, 1979), characterized by a broad and flat-bottomed channel actively widened by periodic shifting of the sediment-laden stream. Low flow channels were often multiple and anastomosing. The width of the channel was subject to constant readjustment, since the banks were not yet stabilized by vegetation. BELOW: The same site as it appeared on June 28, 1983. Saltcedar (Tamarix sp.), introduced here in 1927, is growing thickly along the inner-channel. The arroyo has evolved into the Type 2 category and is more mature in its development. The sinuous, narrow channel flows through alluvial deposits up to 25 ft (7.5 m) thick. Moderation of peak and annual discharges since the 1940's has allowed vegetation to become more firmly established, which in turn has increased channel stability and the deposition of suspended material. The new floodplain is modified by point-bar and bed migration. Type 2 channels generally have lower width/depth ratios and slopes. In addition, bends have smaller radii of curvature (Elliott, 1979).



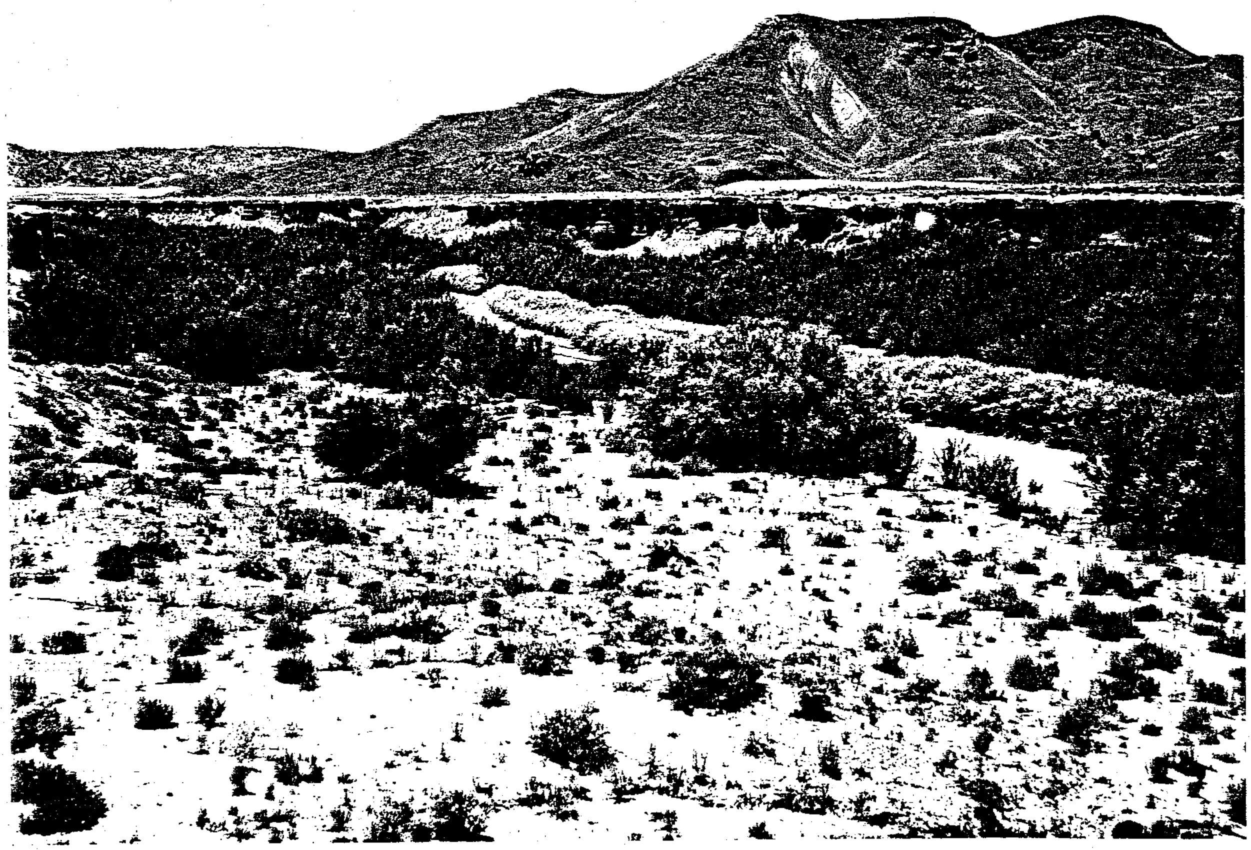


PLATE 30: The Rio Puerco at Rio Puerco gage station (in W1/2 of Sec. 31, T7N, R1W, projected) on downstream end of pier nearest left abutment of railroad bridge on the A.T. and Santa Fe Railroad mainline, in San Clemente Grant, 7 miles (11.3 km) downstream from the Rio San Jose. Gage datum is 5,008.59 ft (1,526.618 m) above sea level. Flow passes over the 255 ft (77.7 m) long weir, 12 ft (3.66 m) downstream from the gage. The weir is broad-crested and horizontal, except for the flat V-notch 0.5 ft deep and 26 ft (7.9 m) wide at the top. The station was established on 7 September, 1910 on a railroad trestle later destroyed by the floods of August-September, 1929. The present trestle was constructed in 1930. On 1 December, 1976, the U.S. Geological Survey discontinued the station, but on 10 December, 1982 it was reactivated by agreement of the U.S.G.S. in Albuquerque, New Mexico and the New Mexico Bureau of Mines in Socorro. Because of the concrete control, rating curve-discharge calculations are subject to fewer errors than at Bernardo, New Mexico. (View to the northeast, 24 February, 1983)

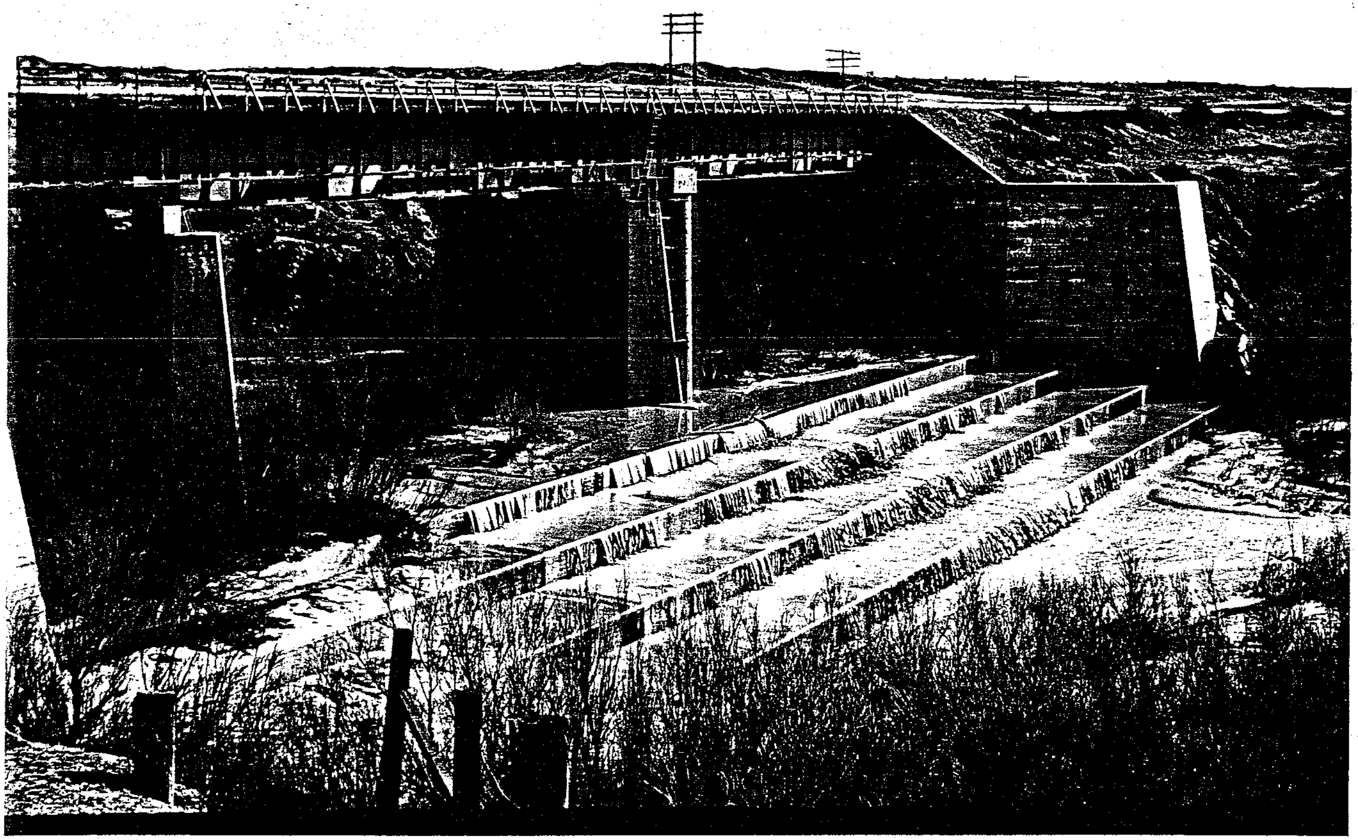


PLATE 31: The recorder housing and stilling well of the Rio Puerco gage station. The 36-inch by 31-ft corrugated steel well, 42-inch by 42-inch metal recorder shelter and ladders were installed 13 October, 1958. The high water mark on the bridge support indicates a gage height of 18 feet (5.5 m) achieved by the flood of 23 September, 1929. (View to the northeast, 24 February, 1983)

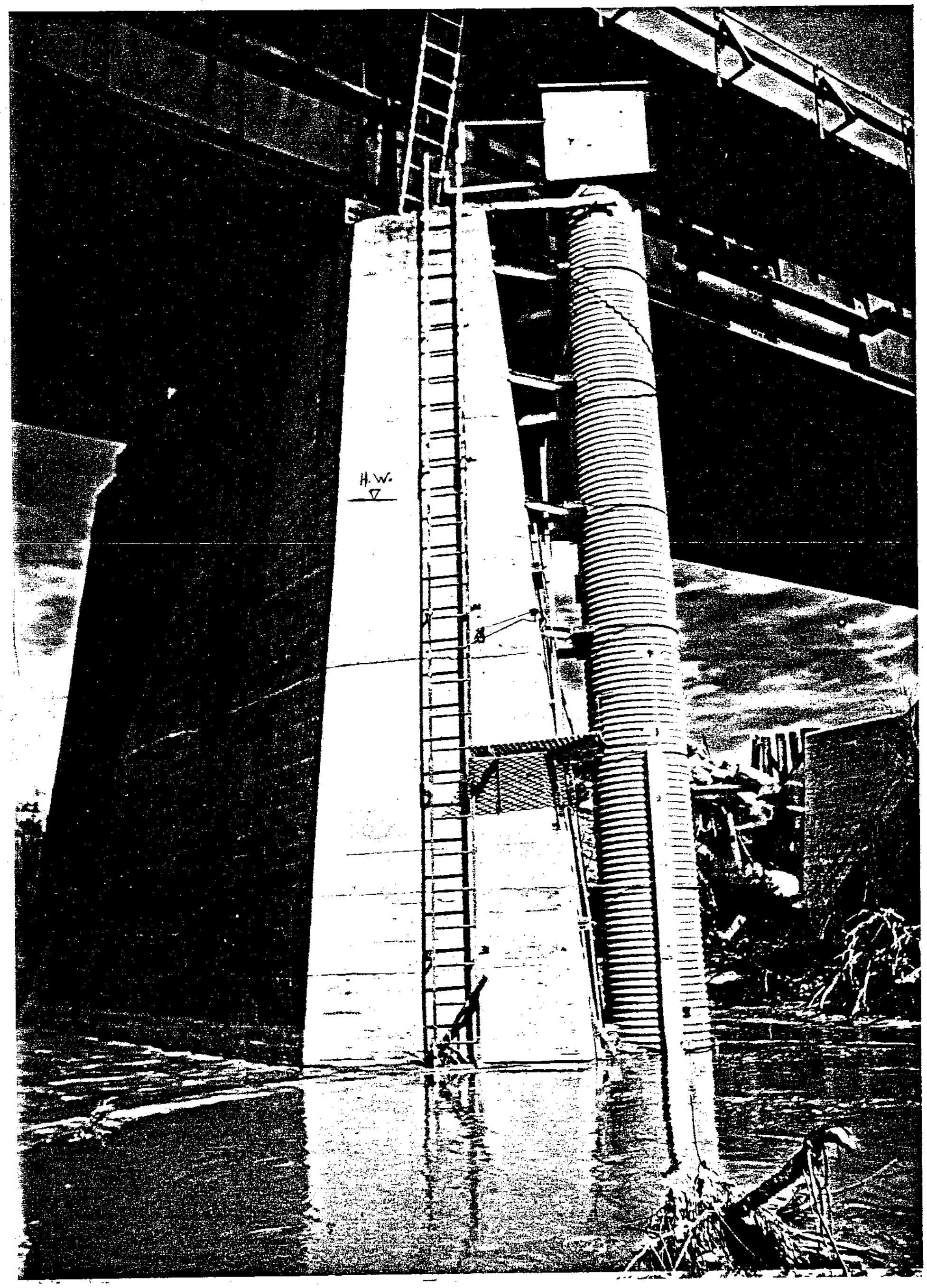

H.W.

PLATE 32: Rio Puerco at Rio Puerco stream gaging station on the mainline trestle of the A.T. and Santa Fe Railroad west of Los Lunas, New Mexico. The horizontal line indicates a gage height of 18 feet (5.5 m), the maximum high water level of the flood of 23 September, 1929 having an estimated discharge of 37,700 cfs (1,068 m /s). (View to the north, 24 February, 1983)

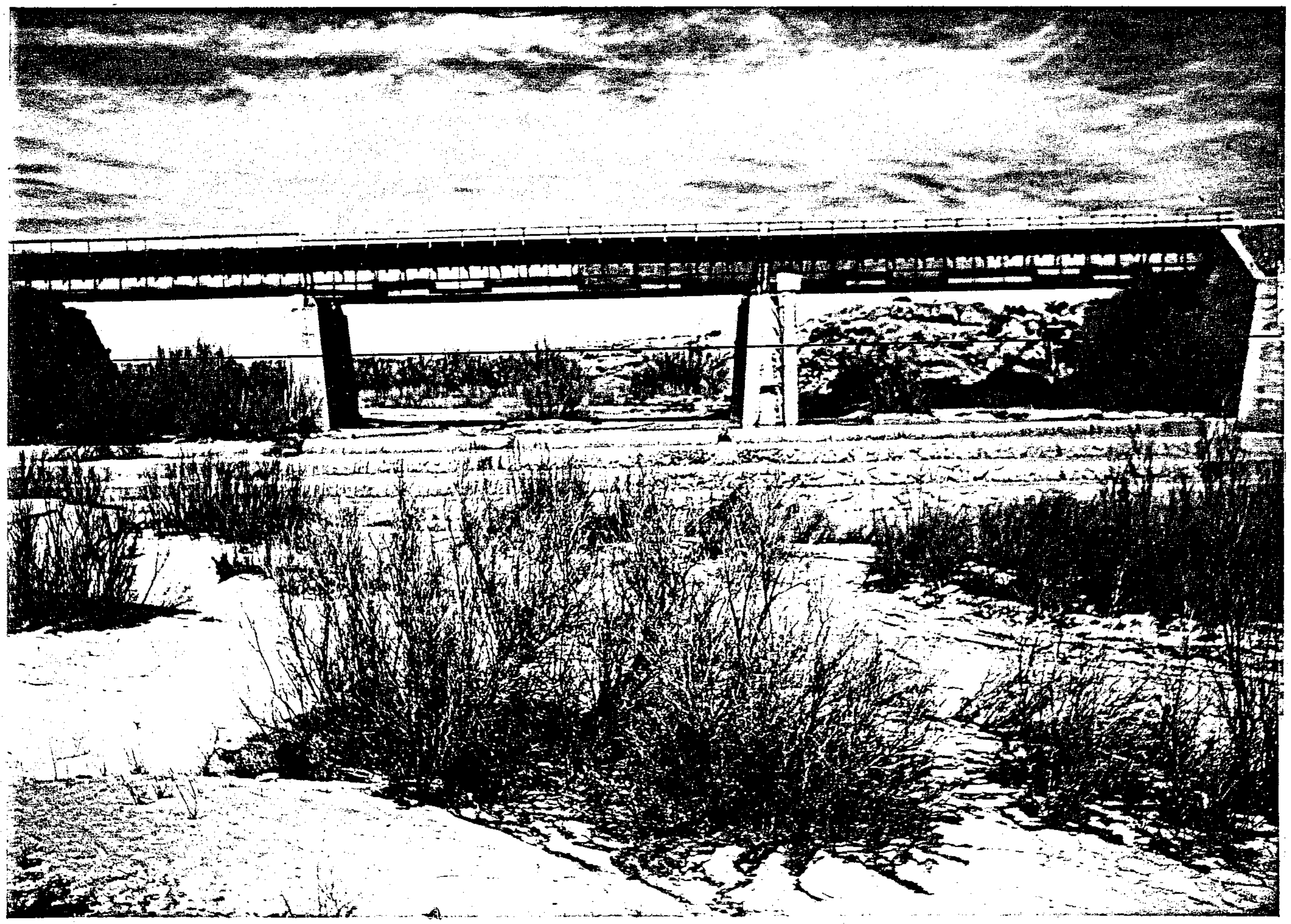


PLATE 33: Lewis Madrid and assistant of the U.S. Geological Survey office in Albuquerque, N.M. measuring the stream discharge of the Rio Puerco at 1050 am on 10 December, 1982, 500 yards (460 m) south of the Rio Puerco gage station. The discharge, as determined by use of a Pygmy meter, was determined to be 5.3 cubic feet per second (0.15 m3/s). Despite flow here and at Popalito meander the channel at Bernardo remained dry on this date.

PLATE 34: The Bernardo streamgaging station on the lower Rio Puerco at the old U.S. 85 bridge, .5 mile (.8 km) upstream from Interstate 25, 1.2 miles (1.9 km) southwest of Bernardo, New Mexico, 3 miles (4.8 km) upstream from the mouth and 16 miles (25.8 km) south of Belen, New Mexico. Gage datum is 4,722.34 ft (1439.369 m) above mean sea level. The station was established on 31 October, 1939. The present recorder and stilling well were installed on 21 May, 1952 following a relocation of the channel in January, 1952 by the New Mexico State Highway Department. (View upstream to the northwest, 25 October, 1982).

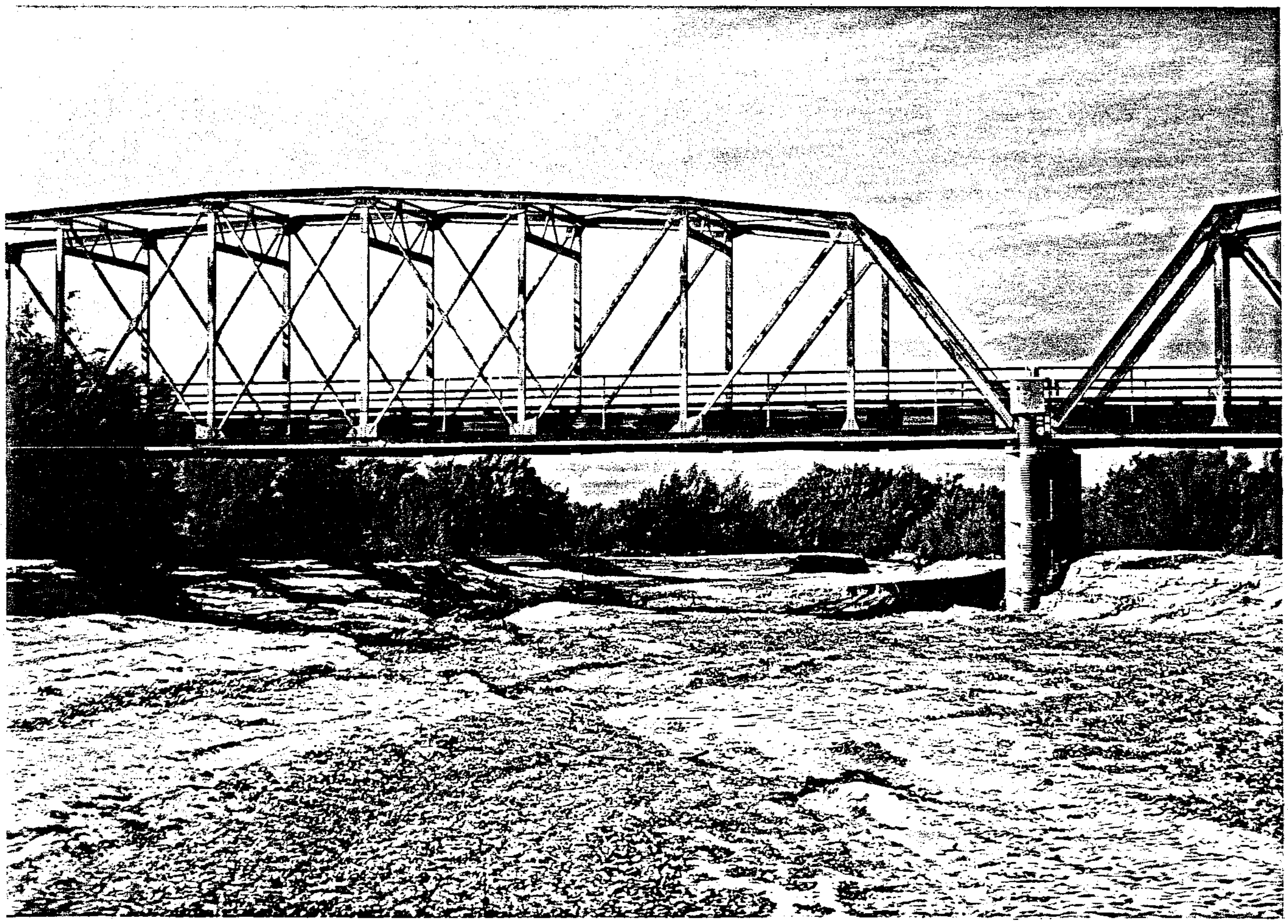
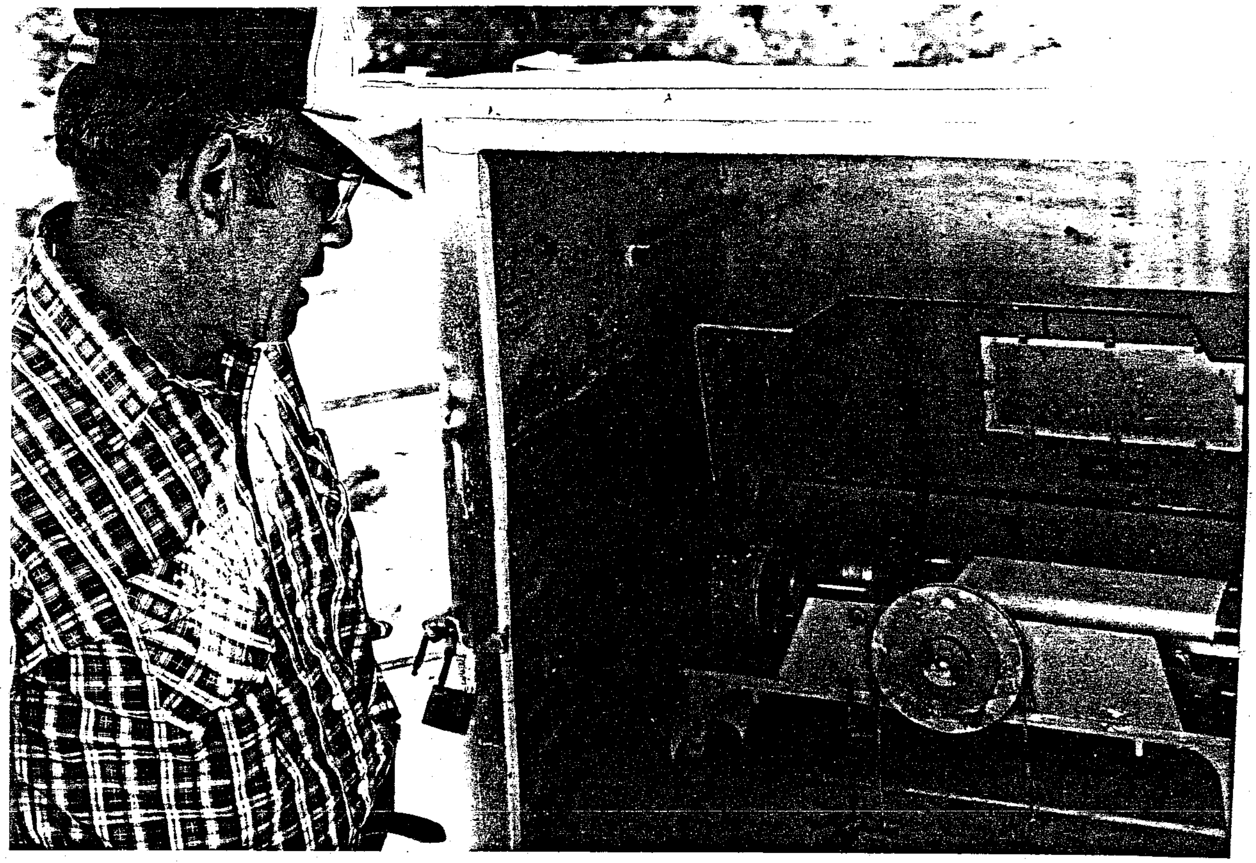


PLATE 35: ABOVE: Emilio Pargas of the U.S. Geological Survey examining the Bernardo gage station recorder on the lower Rio Puerco. The instrument is a Leupold and Stevens model A-35 continuous-strip recorder connected to a float assembly below. Mr. Pargas maintains this and other gage stations in the middle Rio Grande district on a regular basis.

BELOW: Detail of the recorder housing and stilling well of the Bernardo gage station on the downstream side of old U.S. 85 bridge. The stilling-well base is subject to heavy siltation after high flows and must be regularly dug out to free the recorder float over the flow season. The high water mark of the 19 September, 1982 flood (approximately 3600 cfs, or 102 m3/s) is visible on the bridge support. (View to north, 25 October, 1982).



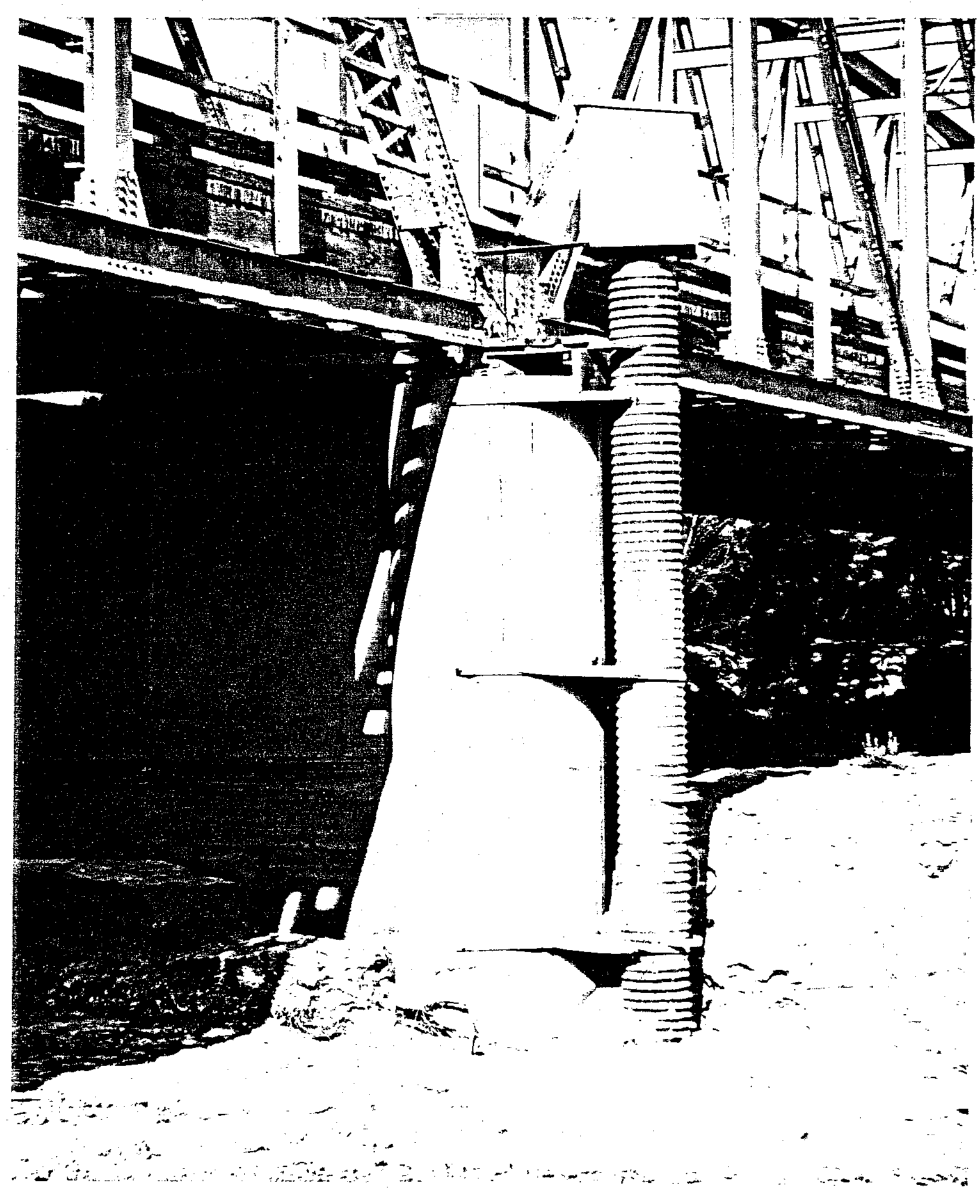


PLATE 36: Installation of B-5D piezometer in the west bank of the lower Rio Puerco at T5N.R1W.13.1344, 55.5 ft (16.9 m) west of stake B, not visible in photograph. The piezometer consists of 1" diameter Celanese PVC tubing set into the 110.5 foot (33.7 m) auger hole. However, sand caving prevented penetration beyond 47.6 ft (14.5 m). Piezometer B-5S was set into the same hole at a depth of 37.5 ft (11.4 m) to measure perched-zone hydraulic gradients at a shallower depth. Both piezometers have screens 3 ft (0.9 m) in length. After the water levels had stabilized, a weekly schedule of steeltape measurements of water depth began on 14 July, 1982 (photo by Dave Love, 10 July, 1982).

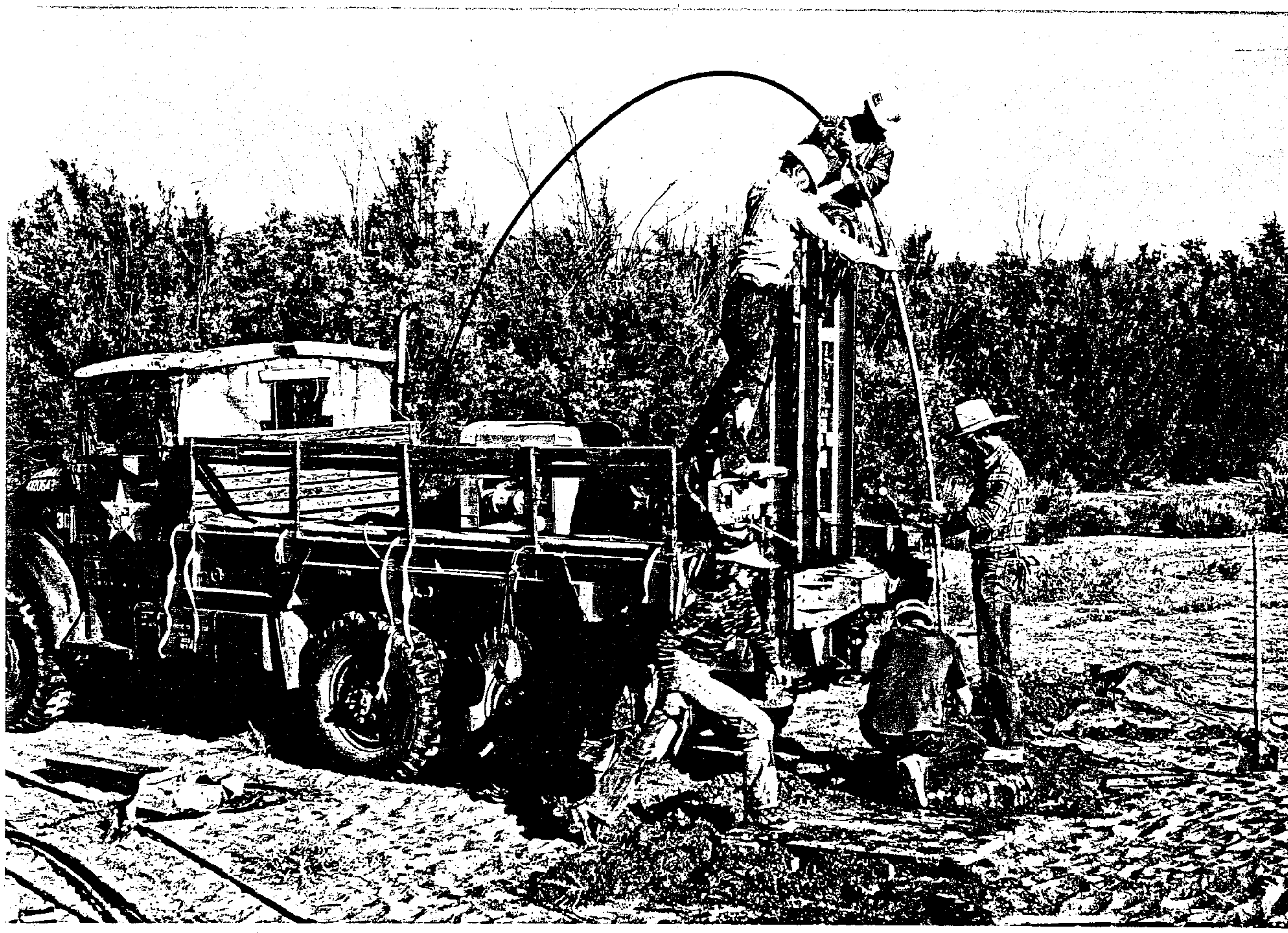


PLATE 37: Jim Boyle, a graduate student of hydrology at the New Mexico Institute of Mining and Technology, surveying the A-A' cross-section at Popalito meander on 1 March, 1983. Such surveys provide important information for future research about erosion rates and fluvial processes of the Rio Puerco.