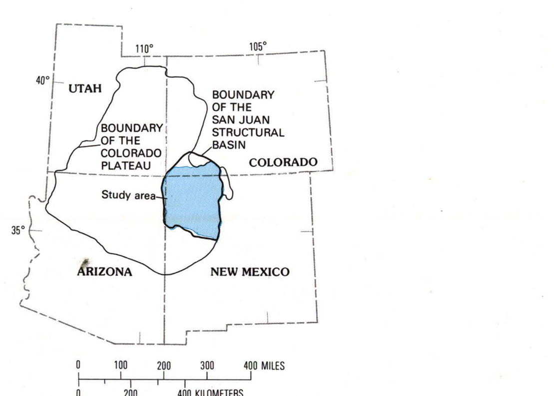
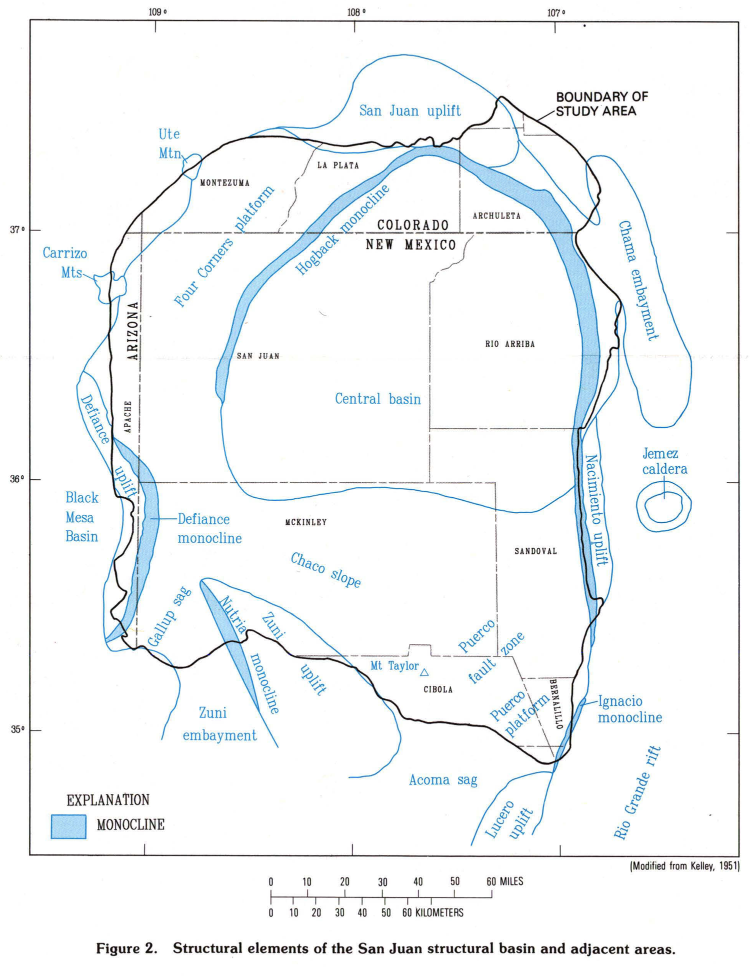
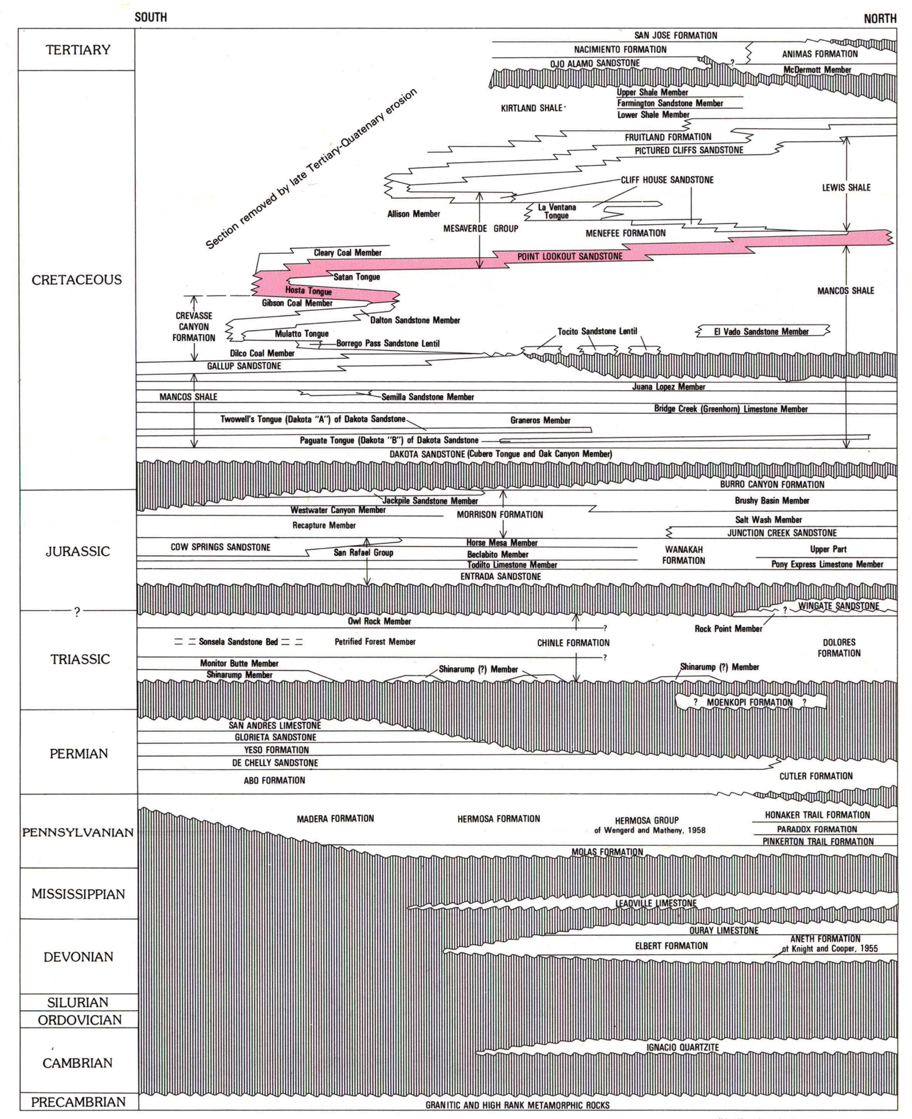


Figure 1. Location of San Juan structural basin, Colorado Plateau, and study area.



(Modified from Kelley, 1951)

Figure 2. Structural elements of the San Juan structural basin and adjacent areas.



(Modified from Molenaar, 1977a,b, and 1989)

Figure 3. Time- and rock-stratigraphic framework and nomenclature.

CONVERSION FACTORS

Multiply inch-pound unit	By	To obtain metric unit
inch	25.40	millimeter
foot	0.3048	meter
foot per day	0.3048	meter per day
foot squared per day	0.09290	meter squared per day
gallon per minute	0.06309	liter per second
gallon per minute per foot	0.2070	liter per second per meter
mile	1.609	kilometer
pound per square inch	6.8948	kilopascal
square mile	2.590	square kilometer

Temperature in degrees Celsius (°C) can be converted to temperature in degrees Fahrenheit (°F) by using the following equation:

$$°F = 1.8 \times °C + 32$$

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

INTRODUCTION

This report is one in a series resulting from the U.S. Geological Survey's Regional Aquifer-System Analysis (RASA) study of the San Juan structural basin that began in October 1984. Previous reports in the series describe the hydrogeology of the Dakota Sandstone (Craigg and others, 1989), Morrison Formation (Dam and others, 1990), Gallup Sandstone (Kernodle and others, 1989), Menefee Formation (Levings and others, 1990), and Cliff House Sandstone (Thorn and others, 1990), in the San Juan structural basin. The purposes of the RASA (Welder, 1986) are to: (1) Define and evaluate the aquifer system; (2) assess the effects of past, present, and potential ground-water use on aquifers and streams; and (3) determine the availability and quality of ground water.

This report summarizes information on the geology and the occurrence and quality of water in the Point Lookout Sandstone, one of the primary water-bearing units in the regional aquifer system. Data used in this report were collected during the study or were derived from existing records in the U.S. Geological Survey's computerized National Water Information System (NWIS) data base, the Petroleum Information Corporation's data base, and the Dwight's ENERGYDATA Inc. BRIN data base. Although all data available for the Point Lookout Sandstone were considered in formulating the discussions in the text, not all those data could be plotted on the illustrations.

The San Juan structural basin is in New Mexico, Colorado, Arizona, and Utah and has an area of about 21,600 square miles (fig. 1). The structural basin is about 140 miles wide and about 200 miles long. The study area is that part of the structural basin that contains rocks of Triassic or younger age and, therefore, is less areally extensive than the structural basin. Triassic through Tertiary sedimentary rocks are emphasized in this study because the major aquifers in the basin are present in these rocks. The study area is about 140 miles wide (about the same as the structural basin), 180 miles long, and has an area of about 19,400 square miles.

Altitudes in the study area range from about 4,500 feet in San Juan County, Utah, to about 11,000 feet in Cibola County, New Mexico. Annual precipitation in the high mountainous areas along the north and east margins of the basin is as much as 45 inches, whereas annual precipitation in the lower altitude, central basin is generally less than 8 inches. Mean annual precipitation in the study area is about 12 inches.

Data obtained from documents published by the U.S. Bureau of the Census, 1980 and 1985, were used to estimate the population of the study area. The population of the study area in 1970 was estimated to be about 134,000. The population rose to about 194,000 in 1980, 212,000 in 1982, 221,000 in 1984, and then fell to about 210,000 in 1985. The economy of the basin is supported by exploration and development of petroleum, natural gas, coal, and uranium resources; urban enterprise; farming and ranching; tourism; and recreation. The rise and fall in population were related to changes in the economic strength of the mining, petroleum, and natural-gas industries, and support services. Uranium mining and milling activities grew rapidly until the late 1970's when most uranium-mining activity ended in the study area. Likewise, the oil and gas industry prospered until about 1983 and then declined rapidly, also affecting many jobs in support industries.

REGIONAL GEOLOGIC SETTING OF THE SAN JUAN STRUCTURAL BASIN

The San Juan structural basin is a northwest-trending asymmetric structural depression formed during the Laramide orogeny (Late Cretaceous-early Tertiary) at the eastern edge of the Colorado Plateau (fig. 1). Structural boundaries of the basin are well defined in many places, whereas, in some areas, the basin merges gradually into adjacent depressions or uplifts (Kelley, 1951, p. 124). The structural boundaries principally consist of large, elongate, domal uplifts; low, marginal platforms; and abrupt monoclines as shown in figure 2 and defined by Kelley (1951, p. 124–127). Faulting is common especially along the southeastern part of the basin. Maximum structural relief in the basin is about 10,000 feet (Kelley, 1951, p. 126). The present structural elements of the basin had developed by middle Tertiary time (Kelley, 1951, p. 130).

The San Juan structural basin contains a thick sequence of sedimentary rocks ranging in age from Cambrian through Tertiary, but principally from Pennsylvanian through Tertiary (fig. 3). The maximum thickness of the sequence of rocks is about 14,000 feet (Fassett and Hinds, 1971, p. 4). These sedimentary rocks dip basinward from the basin margins toward the troughlike structural center or deepest part of the basin. Older sedimentary rocks crop out around the basin margins and are successively overlain by younger rocks toward the center of the structural basin. Volcanic rocks of Tertiary age and various deposits of Quaternary age also are present.

GEOLOGY OF THE POINT LOOKOUT SANDSTONE

The Point Lookout Sandstone is of Late Cretaceous age (fig. 3) and crops out beyond the margins of the central basin (fig. 2). The outcrops typically form cliffs, cap mesas and buttes, or form erosion-resistant dip slopes and hogbacks (as along the base of the Hogback monocline in fig. 2). The Point Lookout Sandstone, named by Collier (1919) for exposures on Mesa Verde in southwestern Colorado, is the lowermost formation of the classical three-part Mesaverde Group of the San Juan structural basin (Point Lookout Sandstone, Menefee Formation, and Cliff House Sandstone). The Point Lookout Sandstone is the most extensive regressive marine beach sandstone in the basin (Molenaar, 1977b, p. 164). It conformably overlies the Mancos Shale throughout the basin (fig. 3); the contact is characterized by a distinct offshore marine transition zone consisting of interbedded thin sandstones, siltstones, and shales (Shetiwy, 1978; Craigg, 1980; Wright, 1984). The Menefee Formation conformably or disconformably overlies the Point Lookout, and intertonguing locally occurs at the contact (Tabet and Frost, 1979).

In the southern part of the San Juan Basin, the Point Lookout Sandstone is separated into two units by the Satan Tongue of the Mancos Shale (fig. 3). The upper unit is the main body, or by common usage, the Point Lookout Sandstone. The lower unit is the Hosta Tongue, which is a transgressive marine beach sandstone. The main body and Hosta Tongue merge along the southern margin of the basin (fig. 3) into a combined unit about 250 feet thick (Sears and others, 1941; Beaumont and others, 1956, p. 2,154). The Hosta Tongue is of limited areal extent, pinching out 30 miles northeast of its outcrop (Beaumont, 1971, p. 22; Craigg, 1980); the Hosta Tongue attains a maximum thickness of about 160 feet (Beaumont and others, 1956, p. 2,155).

The Point Lookout Sandstone generally consists of a sequence of light-gray, thick- to very thick bedded, very fine to medium-grained, locally crossbedded sandstone (Shetiwy, 1978; Craigg, 1980; Wright, 1984). Thin interbeds of dark marine shale also occur, especially in the lower part of the unit.

Thickness of the Point Lookout Sandstone is variable. Beaumont (1971, p. 22) reported thickness to range irregularly from about 100 feet in the southern part of the basin to about 350 feet near the Colorado-New Mexico State line. Molenaar (1977a) reported a maximum thickness of 300 feet. Stone and others (1983, p. 34) reported a range from 40 to 415 feet in New Mexico.

Data used to compute the depth to and the altitude of the top of the Point Lookout Sandstone were obtained primarily from oil- or gas-test holes from the Petroleum Information Corporation's data base with supplemental information from water wells from NWIS and from outcrop altitudes. The locations of the test holes and water wells are shown in figure 4.

Depth to the top of the Point Lookout Sandstone ranges from zero in areas of outcrop to about 6,000 feet below land surface in the northeastern part of the study area (fig. 5). The increase in depth in the area northeast of Grants, New Mexico, reflects the local topography of Mt. Taylor.

A structure-contour map differs from a depth-to-top map in that a structure-contour map represents some particular geologic horizon referenced to a horizontal datum, thus, the effects of topography are removed. In the configuration of the top surface of the Point Lookout Sandstone, the datum used is sea level.

The configuration of the top of the Point Lookout Sandstone is shown on the structure-contour map (fig. 6). The overall structure of the basin also is shown in figure 6. The top of the Point Lookout Sandstone decreases from a maximum altitude of about 8,000 feet above sea level along the north-central basin margin to about 500 feet above sea level in the northeastern part of the study area.

WATER IN THE POINT LOOKOUT SANDSTONE

The Point Lookout Sandstone is a source of water for domestic and livestock use in areas where drilling depths and pumping levels are economically feasible and where water quality is acceptable. These water wells generally are on or near the outcrop areas. Oil is being produced from the Point Lookout Sandstone in localized parts of the basin. Some of the oil-test holes may produce water, but the quality is not acceptable for domestic or livestock use.

The altitude of the potentiometric surface of the Point Lookout Sandstone at selected water wells, springs, and oil- or gas-test holes is shown in figure 7. The altitude of the potentiometric surface in the water wells was determined from measured or reported depths to water or was calculated from pressure-gage readings on flowing wells. Interpretation of completion data for the water wells shown indicates that these wells derive water only from the Point Lookout Sandstone. The water-well and spring data were collected from 1949 to 1989. The altitude of the potentiometric surface in oil- or gas-test holes was calculated by analyzing shut-in pressures from drill-stem tests conducted from 1951 to 1982; the data were obtained from Petroleum Information Corporation. Drill-stem tests were selected for analysis if the length of time allowed for shut-in pressures to stabilize was greater than 1 hour.

The object of a drill-stem test is to determine the potential for oil or gas production, not to determine the potentiometric surface. Therefore, the best water-producing zones commonly are bypassed, with the result that the hydrologic data are from less permeable zones; however, the data generally are all that are available for aquifers in the deeper parts of the basin.

The final shut-in pressure was converted to equivalent-freshwater hydraulic head according to the procedure outlined by Miller (1976, p. 17). The following equation was used:

$$h = (FSIP \times X) - PRD + LS \qquad (1)$$

where h is the altitude of the potentiometric surface, in feet above sea level;
$FSIP$ is the final, bottom-hole shut-in pressure, in pounds per square inch, measured by the pressure-recording device;
X is a factor to convert FSIP to equivalent-freshwater hydraulic head, in feet;
PRD is the depth to the pressure-recording device, in feet below land surface; and
LS is the altitude of the land surface, in feet above sea level.

A factor of 2.307 feet of water per pressure increment of 1 pound per square inch was used for X. This value assumes the water is at a temperature of 4 degrees Celsius with a density of 1.0 gram per cubic centimeter.

Water in the Point Lookout Sandstone occurs under both water-table and artesian conditions. Potential recharge to the aquifer is from infiltration of precipitation on outcrops, from infiltration of streamflow on outcrops, and from vertical leakage of water through confining beds.

No areas of large stress from ground-water development are known to exist. The water levels in figure 7 are shown, along with year of measurement, to provide the reader with the most recent data available. General ground-water gradients may be determined for localized areas if sufficient data exist.

Reported transmissivity of the Point Lookout Sandstone ranges from 0.4 foot squared per day (Craigg, 1980) to 236 feet squared per day (Dames and Moore, 1977). Dames and Moore reported a storage coefficient of 0.000041 from drawdown in an observation well. The average hydraulic conductivity calculated from oil and gas wells in the deeper parts of the basin is 0.0058 foot per day (Reneau and Harris, 1957).

The reported or measured discharge from 17 water wells completed in the Point Lookout Sandstone ranges from 1 to 75 gallons per minute and the median is 10 gallons per minute. The specific capacity of six of these wells ranges from 0.02 to 1.67 gallons per minute per foot of drawdown and the median is 0.25 gallon per minute per foot of drawdown. The distribution of these data is shown in figure 8.

The locations of and hydrographs for four selected wells that derive water only from the Point Lookout Sandstone and have four or more water-level measurements are shown in figure 9. Reference numbers in figure 9 correlate well locations with hydrographs. The official site identification (SITE ID) used to identify each well in the NWIS data base is posted on the hydrographs. The hydrographs show only short-term changes in water level. Short-term fluctuations primarily result from periodic changes in discharge from wells and from seasonal changes in recharge.

Well 1 is a test well drilled by the U.S. Geological Survey in 1987. This well is completed in the confined part of the aquifer. The well was drilled to determine (1) the vertical hydraulic gradient between the Point Lookout and Gallup Sandstones (fig. 3); (2) what impact nearby withdrawal of water from the Gallup Sandstone has on water levels in the Point Lookout Sandstone; and (3) aquifer properties and water quality. The first two water-level measurements show drawdown resulting from prolonged discharge from the test well. Discharge from the well was discontinued in November 1987 and the remaining measurements only show seasonal fluctuations in water level. Wells 2, 3, and 4 are completed in or near the outcrop of the Point Lookout Sandstone and water in the vicinity of these wells occurs under unconfined conditions. Well 2 is used to provide water for livestock. Variations of water level in this well reflect seasonal or annual changes in water withdrawal rates. No long-term changes are apparent in the record for this well. Wells 3 and 4 are coal-exploration holes that were converted to ground-water-level observation wells. The only influences on water levels in these wells are precipitation on the outcrop and changes in stream stage in nearby arroyos.

QUALITY OF WATER FROM THE POINT LOOKOUT SANDSTONE

Water-quality data discussed in the following section were collected during 1948–1987. Distribution of data reflects the locations of water wells near the outcrop where drilling depth is economically feasible. Well records were checked to assure, to the extent possible, that a particular sample represents water only from the Point Lookout Sandstone and not a mixture of water from other aquifers. Data presented on the illustrations do not represent the total amount of available data for the Point Lookout Sandstone. If more than one analysis exists for a single well, the most recent analysis is shown on the illustration. Selected water-quality properties and constituents are presented in table 1. The minimum, maximum, and median values were calculated for the most recent analysis for those wells that have multiple analyses.

Temperature data are displayed in figure 10 and presented in table 1. Most of the temperature data are from water wells drilled where the Point Lookout Sandstone crops out within the basin. A bottom-hole temperature obtained during a drill-stem test on a gas-test hole in the eastern part of the basin also is shown.

Selected secondary (nonenforced contaminant level) drinking-water standards are shown in table 2 (U.S. Environmental Protection Agency, 1986b); these standards are exceeded for all the constituents as shown by the maximum values listed in table 1. From a total of 37 samples for pH, 22 (59 percent) exceeded the standard (table 2). Out of a total of 43 samples for sulfate, 16 samples (37 percent) exceeded the secondary drinking-water standard. Only 1 sample for chloride out of 49 samples (2 percent) exceeded the standard in table 2. From 44 samples for fluoride, 9 samples (20 percent) exceeded the secondary drinking-water standard. One of 44 fluoride samples (2 percent) exceeded the primary drinking-water standard of 4 milligrams per liter (U.S. Environmental Protection Agency, 1986a). Twenty-nine samples (69 percent) from a total of 42 samples for dissolved-solids concentration exceeded the secondary drinking-water standard. No samples for nitrate exceeded the primary drinking-water standard of 10 milligrams per liter (U.S. Environmental Protection Agency, 1986a).

Dissolved-solids concentrations in water from the Point Lookout Sandstone for water wells and oil- or gas-test holes are shown in figure 11 and listed in table 1. The dissolved-solids concentration of water from water wells was calculated from the summation of the major ion concentrations in the water and generally exceeds the secondary drinking water standard of 500 milligrams per liter (table 2). An exception is in the southeastern part of the basin where the concentrations in four of six samples were less than the standard. The dissolved-solids concentration in water obtained during drill-stem tests from oil- or gas-test holes was determined by weighing the residue remaining after evaporation, a technique different from the summation of major ions. The data from oil- or gas-test holes were obtained from Dwight's ENERGYDATA Inc. BRIN data base and ranged from 4,987 to 31,700 milligrams per liter, exceeding the secondary drinking water standard (table 2). The collection of water samples during drill-stem tests does not represent the optimum sampling conditions; however, these data are the only available data in parts of the basin and do provide a qualitative value of the dissolved-solids concentration of water in the Point Lookout Sandstone.

The specific conductance of water can be measured at the sampling site and used to estimate dissolved-solids concentration (Hem, 1985, p. 66–68). Dissolved-solids concentration in water from the Point Lookout Sandstone can be estimated by multiplying the field-determined value of specific conductance by 0.64. This number represents the median value of the ratio of dissolved solids to specific conductance for samples from only the Point Lookout Sandstone.

Chemical-constituent diagrams for the Point Lookout Sandstone are displayed in figure 12. Alkalinity is the capacity of the solution to neutralize a strong acid (Hem, 1985, p. 106). Alkalinity from the Point Lookout Sandstone consists primarily of the ions, bicarbonate, and to a small degree, carbonate. Generally, two types of water are represented in the Point Lookout Sandstone: a sodium bicarbonate water and a sodium sulfate bicarbonate water. Generally, a sodium bicarbonate water occurs near the outcrop, and a sodium sulfate bicarbonate water occurs away from the outcrop. An exception to this pattern is shown in the southwestern part of the study area where a sodium sulfate water occurs near the outcrop. Calcium, magnesium, and chloride concentrations in water from water wells generally are insignificant; however, concentrations in some samples do exceed the secondary drinking water standard for chloride but no pattern of occurrence is apparent.

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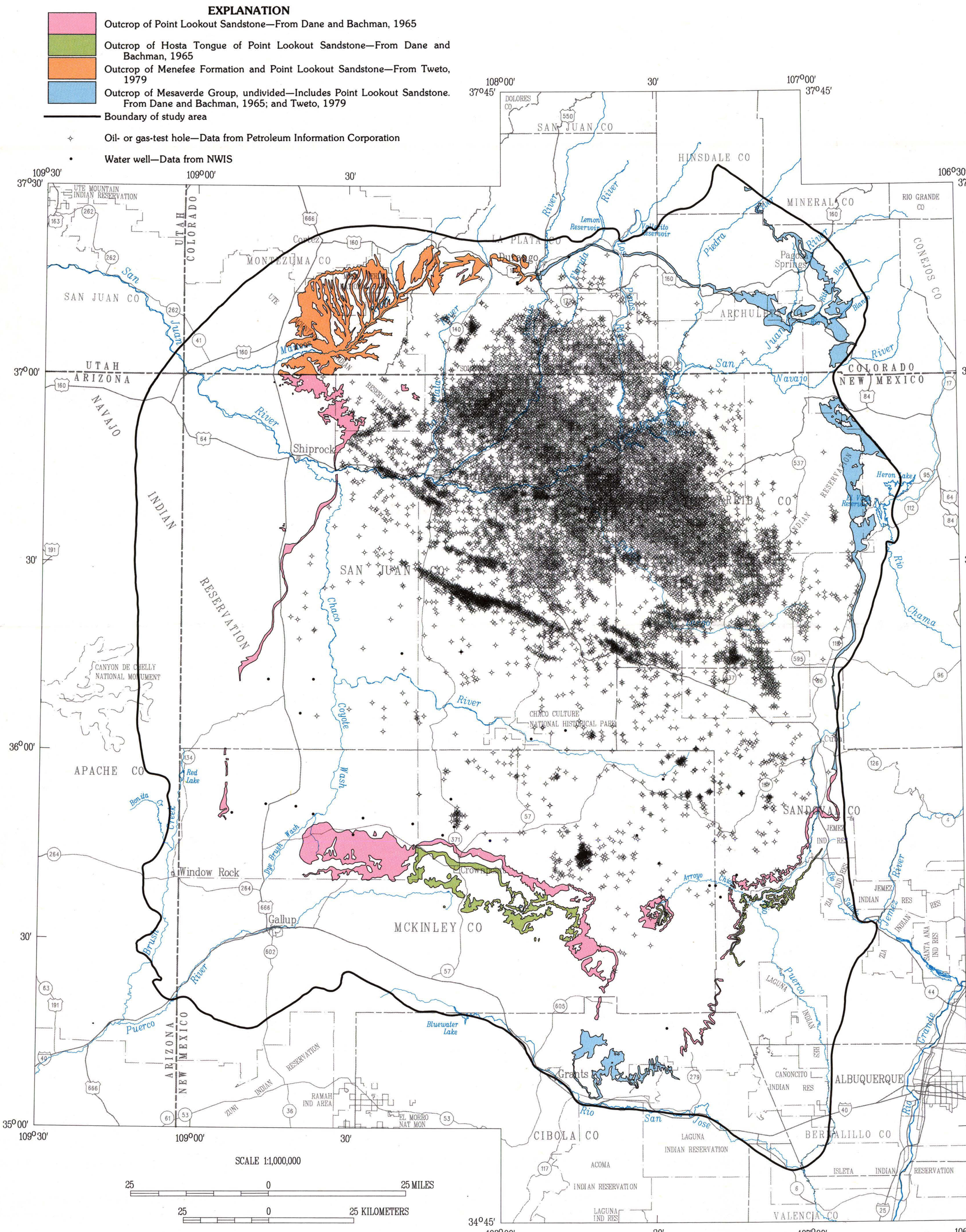

Figure 4. Location of oil- or gas-test holes and water wells used to compile depth to and altitude of the top of the Point Lookout Sandstone.

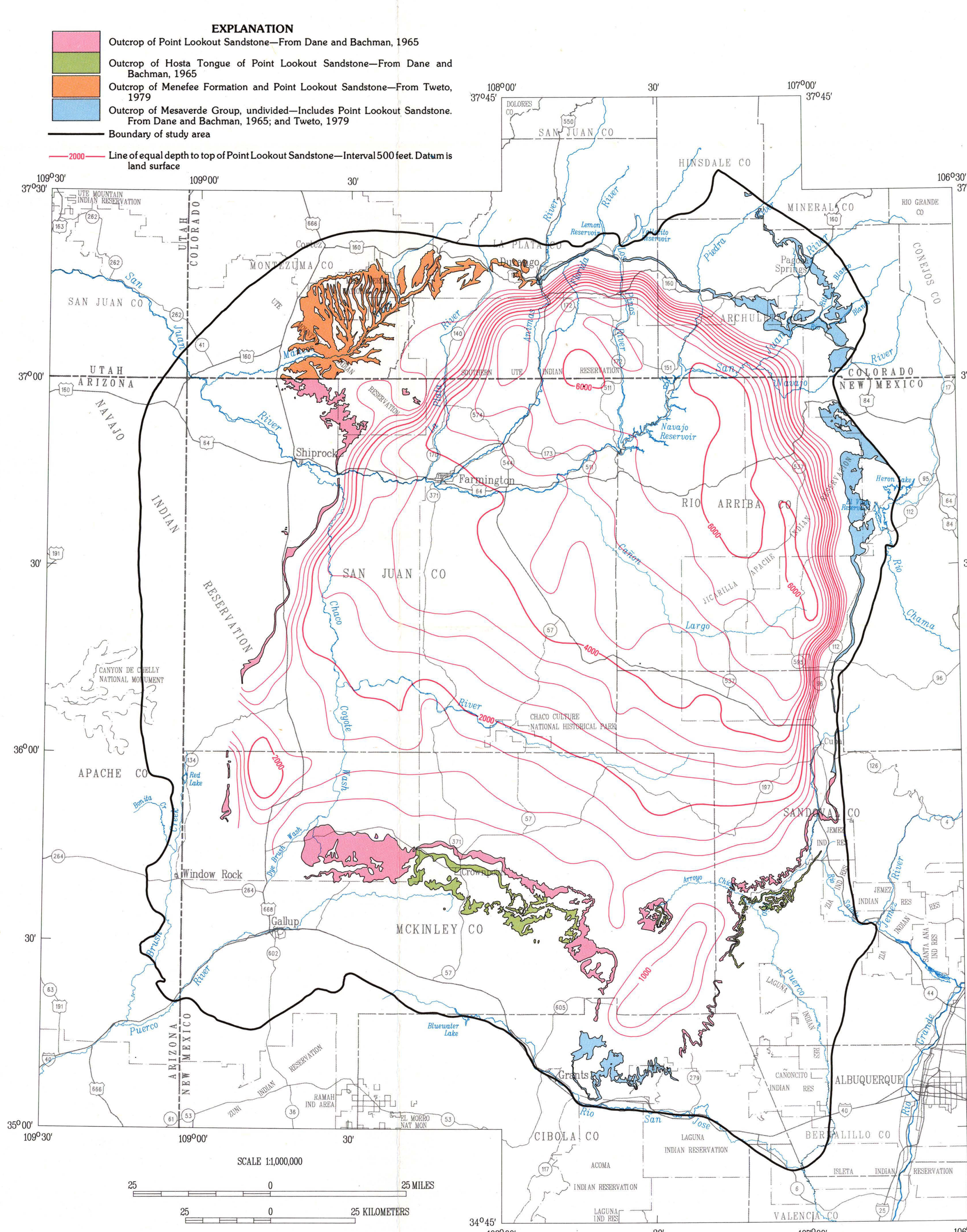

Figure 5. Approximate depth to the top of the Point Lookout Sandstone.

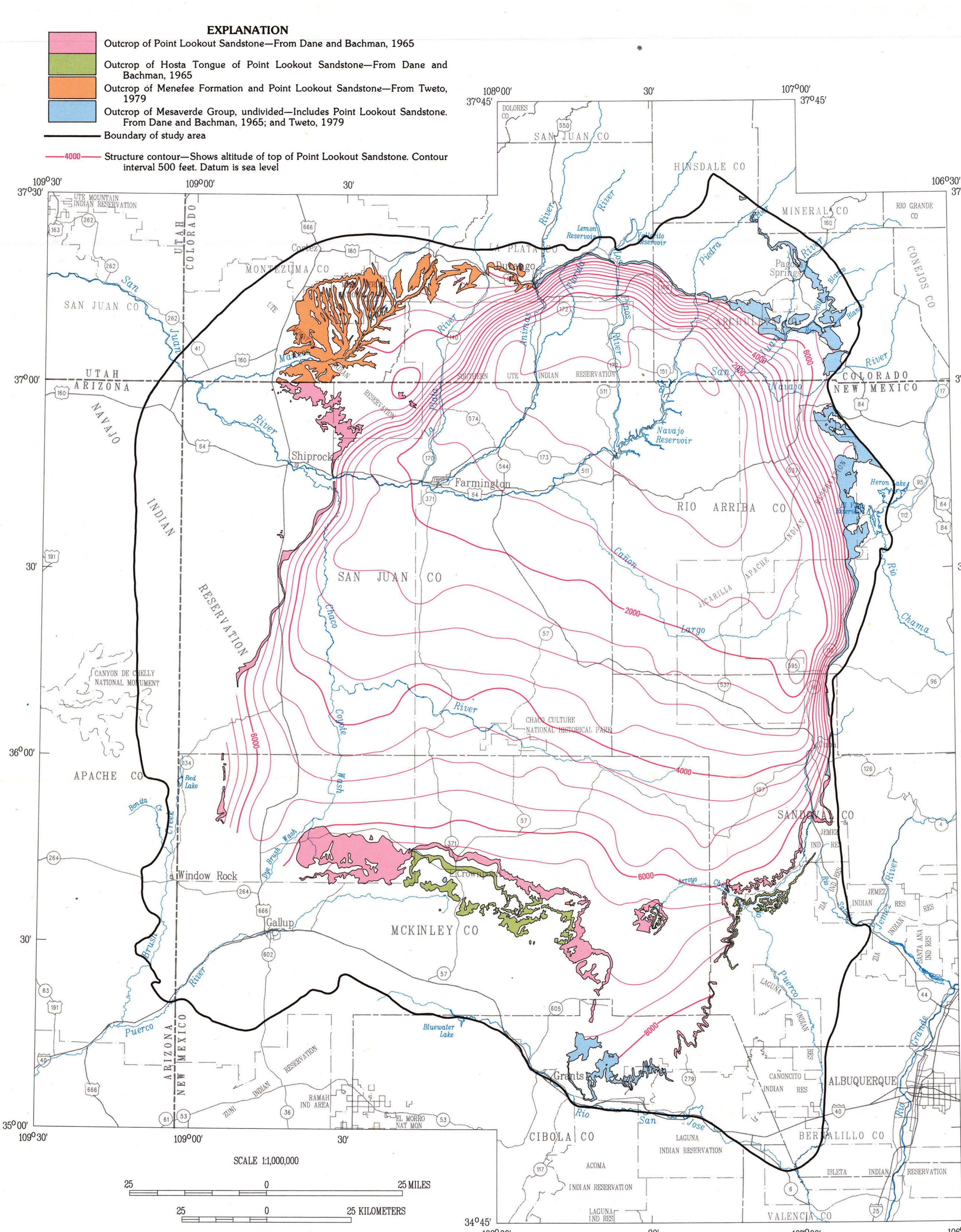

Figure 6. Approximate altitude and configuration of the top of the Point Lookout Sandstone.

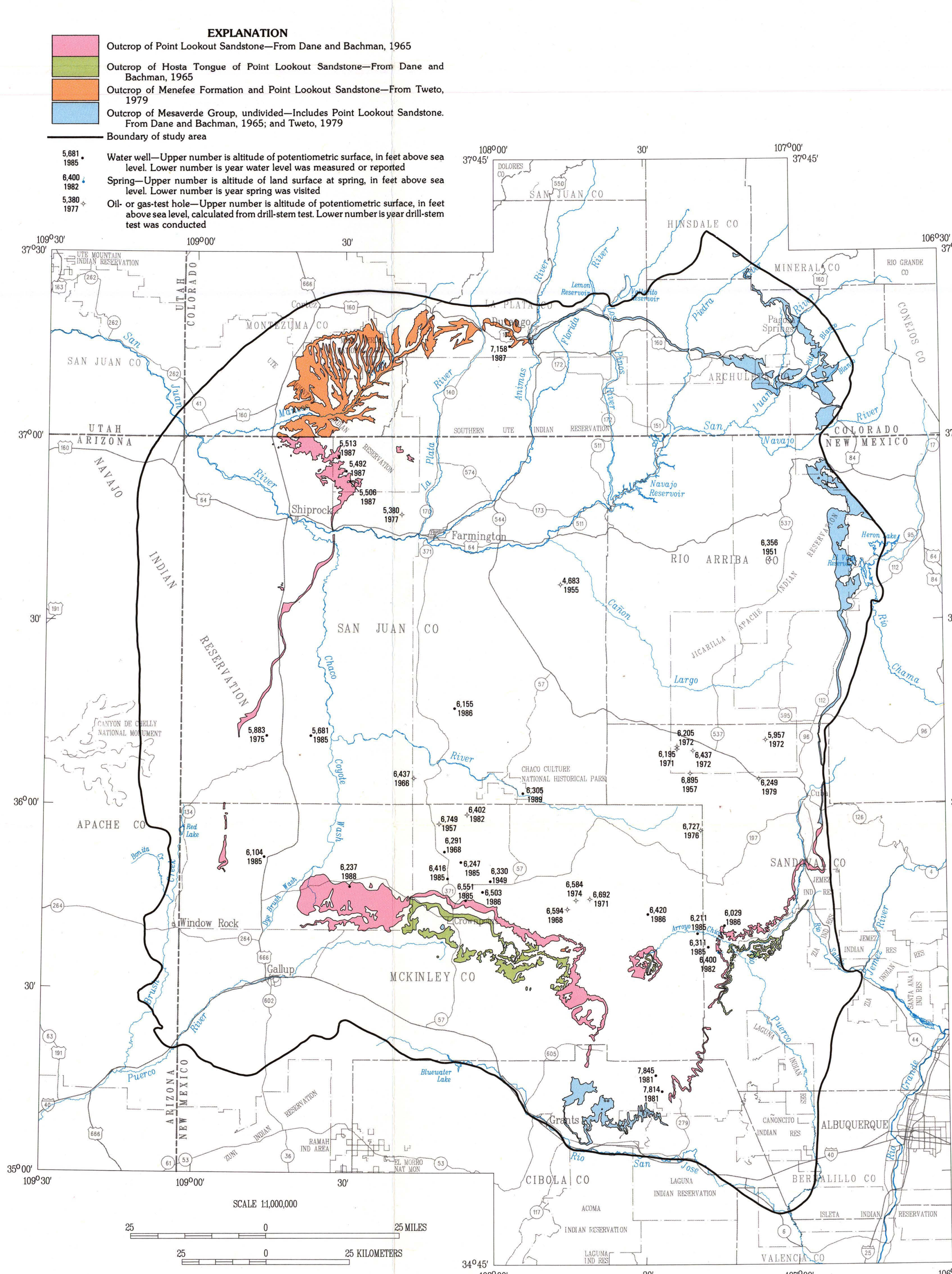

Figure 7. Altitude of potentiometric surface of the Point Lookout Sandstone at selected water wells, springs, and oil- or gas-test holes.

Base from U.S. Geological Survey, 1:100,000 Digital Data
Universal Transverse Mercator Projection, zone 12

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HYDROGEOLOGY OF THE POINT LOOKOUT SANDSTONE IN THE SAN JUAN STRUCTURAL BASIN, NEW MEXICO, COLORADO, ARIZONA, AND UTAH

By
Steven D. Craigg, William L. Dam, John Michael Kernodle,
Condé R. Thorn, and Gary W. Levings
1990