Geology and Ground-Water Resources of the Douglas Basin Arizona

By D. R. COATES *and* R. L. CUSHMAN

With a section on

CHEMICAL QUALITY OF THE GROUND WATER

By J. L. HATCHETT

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By D. R. Coates and R. L. Cushman

ABSTRACT

The Douglas basin is part of a large northwest-trending intermontane valley, known as the Sulphur Spring Valley, which lies in southeastern Arizona, and extends into northeastern Sonora, Mexico. Maturely dissected mountains rise abruptly from long alluvial slopes and culminate in peaks 3,000 to 4,000 feet above the valley floor. Bedrock in the mountain areas confines drainage on the east and west, and an arc of low hills to the north separates the basin from the Willcox basin of the Sulphur Spring Valley. Drainage of the 1,200 square miles in the Douglas basin is southward into Mexico through Whitewater Draw.

The mountains include igneous, metamorphic, and sedimentary rocks ranging in age from pre-Cambrian to Tertiary, including Paleozoic and Mesozoic sedimentary rocks that total about 10,000 feet in thickness. The older rocks have been metamorphosed, and all the bedrock has been affected by igneous intrusion, largely in Mesozoic time, and by structural movements, largely in Cenozoic time and extending into the Quaternary period. By the early part of Cenozoic time the major structural features were formed, and mountain ranges had been uplifted above the valley trough along northwest-trending fault zones. Since that time the physiographic features have resulted through erosion of the mountain blocks and the deposition, in places, of more than 2,800 feet of unconsolidated rock debris in the valley.

Ground-water supplies of the Douglas basin are developed largely in the saturated zone of the valley-fill sediments. The ground water in the valley fill occurs in thin lenses and strata of sand and gravel, which are interbedded with large thicknesses of silt and clay. Scattered gypsum beds and extensive caliche deposits appear at the surface and occur within the valley fill at various depths. Although the valley-fill sediments are as much as 2,800 feet thick, the uppermost 300 feet or so are the most permeable.

Ground water originates as precipitation in the mountain areas. The water collects in streams that lose much of their flow into the coarse sediments that fringe the mountains. Part of the water ultimately percolates into the zone of saturation. High evaporation rates, vegetative use, and the presence of caliche and clay at shallow depth in the interstream areas of the valley floor prevent important recharge of the ground-water reservoir from direct rainfall or seepage of water applied for irrigation. The total recharge into the ground-water reservoir of the Douglas basin was about 20,000 acre-feet in 1951.

Ground water is discharged from the basin by evapotranspiration, by effluent seepage into Whitewater Draw and underflow out of the basin, and by pumping. In 1951, the total amount of ground water discharged was about 50,000 acre-feet, of which more than 41,000 acre-feet was pumped from wells. Ground water used in excess of recharge is withdrawn from storage, causing a decline in the water table. Maximum declines have occurred in the heavily pumped Elfrida area, where a decline of more than 11 feet occurred in the 5-year period 1947–51, inclusive.

Most irrigation wells in the Douglas basin are less than 200 feet in depth and usually produce less than 400 gpm (gallons per minute). The average specific capacity of the wells is about 12 gpm per foot of drawdown. Although water in some parts of the basin is artesian, all irrigation wells must be pumped.

Ground water in the basin is generally of excellent to good quality for irrigation use. In small areas along the southern part of Whitewater Draw and east of Douglas the ground water is high in dissolved-solids content. Although most of the water is hard, it is generally satisfactory for domestic use. In many areas the fluoride content is more than 1.5 ppm (parts per million).

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The need for factual information concerning the ground-water resources of Arizona is becoming increasingly urgent. Ground-water studies in Arizona by the Geological Survey began about the turn of the century. A district office was established at Tucson in July 1939, under an arrangement of financial cooperation with the State of Arizona. This report is one of a series prepared under a cooperative agreement with the Arizona State Land Department. The report includes discussion of the geology, ground-water resources, and quality of ground water in the Douglas basin, Cochise County.

The report represents the combined work of many of the personnel of the Ground Water Branch of the Geological Survey, from the beginning of the investigation in January 1946 to the completion of field work in March 1952. Others who contributed substantially in collecting data on which this report is based, or in preparation of the report, include H. M. Babcock, M. B. Booher, S. C. Brown, O. B. Coulson, J. H. Feth, R. S. Jones, A. E. Robinson, and J. I. Webster.

The study was under the general supervision of O. E. Meinzer and A. N. Sayre, successive chiefs of the Ground Water Branch of the Geological Survey, and under the immediate supervision of S. F. Turner and L. C. Halpenny, successive district engineers. The quality-of-water phase of the work was under the general supervision of S. K. Love, chief of the Quality of Water Branch of the Geological Survey, and under the immediate supervision of J. D. Hem, district chemist.

ACKNOWLEDGMENTS

Appreciation is expressed to all coworkers who helped in the collection of data and in the preparation of this report. Organi-

zations that have been especially helpful in supplying needed information from their files include the Arizona Edison Co., the City of Douglas Water Works, the U. S. Department of Agriculture, the Phelps Dodge Corp., the Rural Electrification Administration, and the University of Arizona. Thanks are given also to the many well drillers who willingly supplied copies of their drilling logs. Many residents of the Douglas basin have provided invaluable assistance and information.

LOCATION AND EXTENT OF THE AREA

The Douglas basin is in Cochise County in southeastern Arizona (fig. 1). The basin is part of the Sulphur Spring Valley, a large

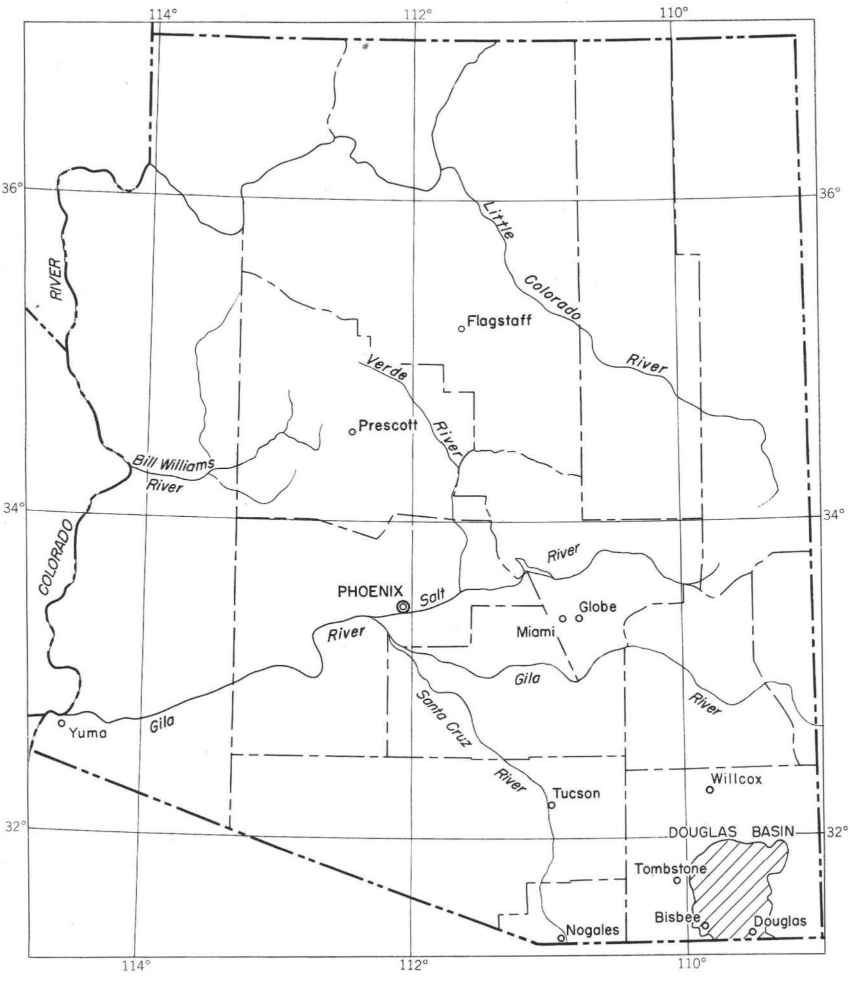


Figure 1. --Map of Arizona showing location of Douglas basin.

northwest-trending intermontane trough which extends into northeastern Sonora, Mexico. For this report the Douglas basin is considered to be that portion of the drainage basin of Whitewater Draw north of the international boundary, although the basin extends south into Mexico. Highland areas that form the drainage divides of the basin are the Chiricahua, Pedregosa, and Perilla Mountains in the east; the Dragoon and Mule Mountains in the west; and in the north, a series of ridges and buttes, the most prominent of which are Six Mile Hill, Township Butte, the Pearce Hills, and Turkey Creek Ridge. The basin averages about 40 miles in length and 30 miles in width and has an area of about 1,200 square miles.

CLIMATE

The Douglas basin has a semiarid climate similar to that of other parts of southern Arizona (Smith, 1945). The climate in the valley portion of the basin is characterized by low precipitation, high evaporation, and large daily fluctuations in temperature. The hot summer days are tempered by breezes and low humidity, and the nights are cool. Winter temperatures are mild, although the night temperatures occasionally go below freezing. These generalizations for the valley are in sharp contrast to the climate of the mountains, which constitute about one-third of the total area of the basin. Climatic conditions in the mountains are more rigorous, and snow is common at higher altitudes during the winter.

The United States Weather Bureau maintains temperature and rainfall stations at Douglas and Bisbee (table 1). Rainfall stations are also maintained at Leslie and Rucker Canyons. Climatic conditions in the vicinity of the Douglas station, altitude 3,973 feet, are considered representative for most of the valley. The mean annual rainfall there is 12.74 inches, of which about 8 inches occurs in the summer months during brief, intense thunderstorms. April, May, and June are the driest months, and the average total precipitation in this period is about 1 inch. The mean annual temperature is 62.5°F. The wind blows mostly from the southwest at an average velocity of 7.1 miles per hour. The growing season averages 212 days at Douglas; the last killing frost of the spring usually occurs in early April and the first killing frost of fall early in November. Douglas receives an average of 3,800 hours of sunshine a year. Conditions of low humidity in the region are indicated by evaporation measurements made at Willcox, 24 miles north of Pearce. The annual evaporation at Willcox averages 84.59 inches, about seven times the annual precipitation there.

The Bisbee station, altitude 5,350 feet, is considered to represent typical climatic conditions in the lower parts of the mountain areas. At Bisbee the mean annual rainfall is 19.15 inches and the mean annual temperature is 61.3°F.

HISTORY OF DEVELOPMENT

A full account of early development in the Douglas basin is given by Meinzer and Kelton (1913). The basin is included in the area acquired from Mexico by the Gadsden Purchase of 1853. It remained largely an Indian reservation until 1876 when the Chiricahua Apaches were moved to the San Carlos Reservation and the Sulphur Spring Valley was returned to the public domain.

Development of ranches began about 1872 when Fort Grant was moved to the northern part of the Sulphur Spring Valley, but extensive settlement of the Douglas basin did not begin until the building of the railroad from Bisbee to the copper smelters at the newly developed townsite of Douglas in 1902. The principal industries in the basin up to 1910 were mining and cattle raising. Farming started after 1910 when the first irrigation wells were drilled. The farming economy of the Douglas basin is dependent on the availability of ground water. Agricultural acreage has expanded rapidly in recent years, from about 3,000 acres in 1940 to more than 14,000 acres in 1951. About 75 percent of the 1951 acreage was devoted to cotton.

PREVIOUS INVESTIGATIONS

The earliest study of the Douglas basin that is referred to in this report is that of Ransome (1904), who described the geology of the Bisbee area. The most comprehensive study of the basin was made by Meinzer and Kelton (1913). Many of the conclusions reached as a result of this early work are applicable at present and, whenever possible, unnecessary duplication is avoided in this report. The U. S. Bureau of Agricultural Economics (1940) prepared a report on the water supply of the Douglas basin. Other works that have been used include those of Darton (1925), Wilson (1927), Gilluly, Cooper, and Williams (1955), and Cederstrom (1946), and the geologic map of the State of Arizona (Darton, 1924). A Geological Survey report on the ground-water resources of the Gila River basin and adjacent areas[1] contains a resume of the data presented here.

[1]Halpenny, L. C., and others, 1952, Ground water in the Gila River basin and adjacent areas, Arizona—a summary: U. S. Geol. Survey Open-File Report.

METHODS OF INVESTIGATION

The section on geology of the Douglas basin includes data from previous investigations in addition to the results of reconnaissance geologic mapping by geologists of the Ground Water Branch in areas where mapping was incomplete. The geology was recorded on topographic maps and aerial photographs and was later transferred to the base map (pl. 1). Geologic mapping in the mountain areas was on a reconnaissance scale, as there was no need to map in detail the various rock units.

Records have been collected for 475 of the more than 500 wells of all types that exist in the Douglas basin. Records of representative wells are shown in table 2. Included in the well-record file of the district office at Tucson are more than 200 well logs, which indicate the type of rock material encountered at various depths. Table 3 is a compilation of characteristic well logs. To determine changes in the position of the water table, the Survey makes water-level measurements in 23 observation wells four times a year and in 21 observation wells once a year. All water-level measurements are made with a steel tape from fixed measuring points. The observation-well measurements, in addition to hundreds of others made during the last 5 years, give an accurate record of depth to water in the basin. These data were used in compiling a depth-to-water map (pl. 1), a water-table contour map (pl. 2), and a map showing the decline of the water table (pl. 3). Data for the water-table contour map were obtained by determining the altitude above sea level of the land surface at more than 200 wells by spirit leveling and correlating that information with water-level measurements. A pumpage inventory for the Douglas basin is compiled annually from records of power consumption by pumps and from measurements of well discharges. Chemical analyses were made of 129 samples of water collected from various wells, springs, and streams. Table 4 includes 40 of the analyses.

WELL-NUMBERING SYSTEM

In this report, wells are numbered in accordance with the General Land Office subdivision system, and the well numbers show the locations by township, range, and section. A graphic illustration of the well-numbering system is shown in figure 2. The capital letter indicates the position of the area with respect to the Gila and Salt River base line and meridian. The first numeral of the well number indicates the township, the second the range, and the third the section in which the well is located. The lowercase letters following the section number indicate the position of

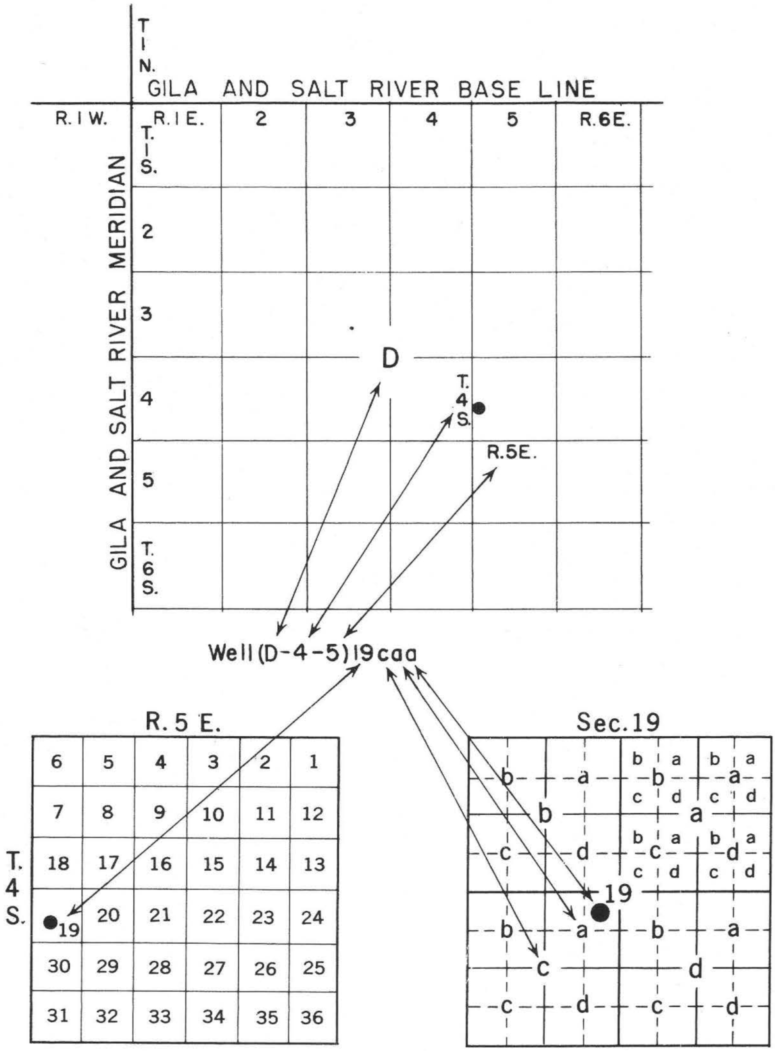


Figure 2. —Sketch showing well-numbering system in Arizona.

the well within the section. The first letter denotes the quarter section, the second the quarter-quarter section, and the third the quarter-quarter-quarter section (10-acre tract). All letters are assigned in a counterclockwise direction, beginning in the northeast quarter.

GEOLOGY AND ITS RELATION TO GROUND WATER

GEOMORPHOLOGY

The Douglas basin is part of the Mexican Highland section of the Basin and Range physiographic province (Fenneman, 1931). The section is an area characterized by isolated and dissected fault-block mountains separated by debris-filled desert valleys. The valley and mountain areas provide a convenient division for description of the Douglas basin. The central area consists of a relatively flat valley floor about 35 miles long and 15 miles wide whose axis trends northwest. This part of the basin is hereafter referred to as "the valley." The valley slopes are gentle and concave upward from the axis to the sharply defined mountain fronts. The valley trough slopes southward about 10 feet per mile from an altitude of about 4, 300 feet at the north end of the basin to 3, 900 feet at the Mexican border. The Chiricahua, Swisshelm, Dragoon, Mule, Perilla, and Pedregosa Mountains are built of bedrock and project above the valley floor. These bedrock areas lie above altitudes of 4, 700 feet and comprise about 360 square miles or about 30 percent of the total area of the basin. The mountains are maturely dissected and have steep, well-drained forested slopes. The highest and most rugged are the Chiricahua Mountains, culminating in Chiricahua Peak whose altitude is 9,795 feet. In the other ranges the highest altitudes are 7, 185 feet in the Swisshelm Mountains, 7,150 feet in the Dragoon Mountains, 7,400 feet in the Mule Mountains, 6, 385 feet in the Perilla Mountains, and 6, 510 feet in the Pedregosa Mountains.

Whitewater Draw, which derives its name from the white caliche deposits along the bank, drains the Douglas basin. The headwaters of Whitewater Draw are in Rucker Canyon in the Chiricahua Mountains. The uppermost channel is V-shaped, is geologically youthful, and has a steep profile. The slope downstream flattens appreciably into that of a mature stream in Rucker Canyon, after passing from volcanic rocks to sedimentary rocks. A continuous channel is maintained from the source, around the northern end of the Swisshelm Mountains, and to the cultivated lands northeast of Elfrida where the channel loses its identity. The channel again becomes well defined at a point about 2 miles southwest of Elfrida. From this point Whitewater Draw continues southward into Mexico where it is tributary to the Yaqui River, which flows into the Gulf of California. In the southern part of the Douglas basin the channel of Whitewater draw has been offset to the east because a greater load of sediments has entered the valley from the Mule Mountains to the west than has come from the Perilla Mountains to the east. Perennial flow in Whitewater Draw occurs in only two places in the basin: in the upper 3 miles of Rucker Canyon; and in the 2-mile reach immediately north of the international border.

Tributary streams in the basin are ephemeral, and most of the stream channels disappear before reaching the central part of the valley floor. Many of the larger washes, such as Leslie Creek and Mud Springs Draw, do not have continuous channels from their sources to their confluence with Whitewater Draw. However, in the vicinity of Douglas and for a few miles north of Douglas, several streams issuing from the mountains have been able to establish a junction with Whitewater Draw. These channels have steep banks and are cut about 15 feet below the general level of the valley floor. Whitewater Draw is incised to a maximum depth of about 25 feet northwest of Douglas.

Maximum runoff occurs during the thunderstorm season in the summer, but generally each period of runoff after a storm is short. Other streamflow occurs in the spring with the melting of mountain snow. Streamflow from the mountains generally is dissipated in distributaries and as sheet runoff on alluvial fans and pediments, or infiltrates into the coarse sand and gravel near the mountain front.

Coalescing alluvial fans occur along some of the mountain fronts, and are most prominent on the east front of the Mule Mountains. Gently sloping bedrock surfaces, called rock pediments, are exposed along the west base of the Perilla Mountains (pl. 1) and probably occur, concealed by alluvium, along the Swisshelm Mountains. The terraces that are common and characteristic of many other southern Arizona basins are lacking in the Douglas basin. In general, the long alluvial slopes continue smoothly to the central valley floor, except for local development of small, indeterminate benches a few feet in height. The continuity of the slope is broken by buttes and outliers. These hills are particularly concentrated along the drainage divide that extends from the northern tip of the Swisshelm Mountains to the Pearce area. The outliers are erosional remnants of an older topography now partly buried by valley fill.

Many Indian artifacts have been found along Whitewater Draw. The oldest finds have been determined to be more than 10,000 years old (Sayles and Antevs, 1941, p. 55). If there had been a period of great erosion in post-Pleistocene time, it probably would have obliterated many of the Indian relics and would have cut terraces. In the Recent epoch, therefore, there is strong suggestion that it has been characterized by interrupted aggradation until the 19th century when widespread gullying began.

During Quaternary time, erosion has been the dominant activity in the upland areas and deposition has been dominant in the valley. The upper slopes of the valley have been created in part by the erosive retreat of the mountain fronts. The intermittent streams in the basin are now eroding the land and the Douglas basin is expanding slowly northward at the expense of the aggrading, interior-draining Willcox basin.

The decade 1880-90 saw the beginning of important changes in the valley of the Douglas basin, as well as in many other parts of the Southwest. Gregory (1917, p. 130), Bryan (1925, p. 339), and Thornthwaite and others (1942, p. 102-104) fix the period of the 1880's as the beginning of the gullying that is currently occurring in the Southwest. William Cowan, a pioneer rancher in the Sulphur Spring Valley, dates the beginning of channel cutting in Whitewater Draw after 1884 (Meinzer and Kelton, 1913, p. 28). Other oldtime residents of the valley also date the cutting before 1900. Causal relationships for the recent cycle of arroyo cutting are imperfectly known and controversial. The two theories most widely advanced to explain the beginning of the recent gullying are overgrazing and climatic variations.

In 1884 there were 300,000 cattle in the Territory of Arizona, and by 1893 this number had increased to 800,000 (Thornber, 1910, p. 338). The possibility exists that, with the increase in cattle in the 1880's, much of the range grass was destroyed and the range soil was disturbed by the animals' hoofs (Sauer, 1930, p. 387) thus reducing the resistance of the land to erosion (Thornthwaite and others, 1942, p. 123). It is known that the character of the vegetation in the valley of the Douglas basin has changed since it was first described in writing. Parry and Schott (1857, p. 17) reported patchy growth of coarse grass in the valley and hackberry and walnut trees in a side wash, but made no mention of the mesquite groves which had become extensive by the time of the investigation by Meinzer (Meinzer and Kelton, 1913, p. 89). These groves occupied about the same area in 1910 as now, except where they have been cleared for cultivation. Oldtime residents in the valley agree that mesquite did not get a foothold until about 1900. Changes in erosion and sedimentation may have resulted from such an upsetting of the delicate balance of nature by overgrazing and change in vegetal cover.

The effects of climatic variations upon the erosion cycle are difficult to evaluate. Fragmentary records from some U. S. Weather Bureau stations (Trask and others, 1950, p. 420) indicate that the rainfall was much greater during the first 4 years of the 1880-90 decade than it was during the whole period of record. Statistical analysis by Leopold (1951, p. 351) has shown for some areas in the Southwest prior to 1900 "a relatively high frequency of large rains." Thus, the increased precipitation in the early 1880's with a higher frequency of storms of great intensity, falling on impoverished rangelands of poor cover and broken sod may have combined to trigger a new cycle of gullying.

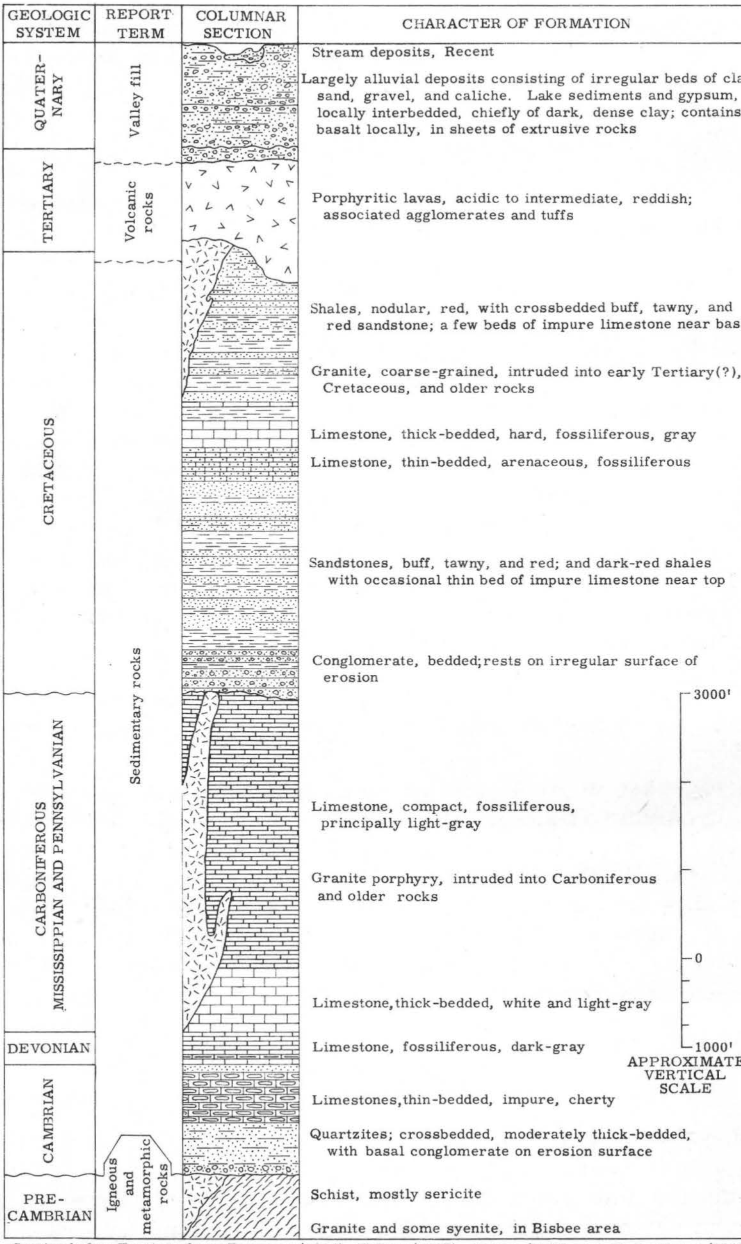
It has been suggested that differential uplift of mountain areas offers at least a partial explanation for gullying (see Gregory, H. E., in Knechtel, 1938, p. 189). Earthquake and faulting activity is known to have occurred on May 3, 1887, throughout much of the Southwest. Earthquake tremors were felt in a large region from El Paso, Tex., west of Centerville, Calif., and from Globe, Ariz., south to Guaymas, Mexico. The Tombstone Epitaph newspaper on May 4 and 8, 1887, carried vivid accounts of earthquake activity throughout the Sulphur Spring Valley. It was reported that "hundreds of water veins opened in the earth with a sufficient quantity to supply 100,000 cattle." In the Dragoon Mountains there was a severe shock and great noise, and "huge boulders were thrown down the mountain." Artesian conditions were reported "to have been disrupted at Soldier's Hole." In spite of these reports the writer believes that such activity has had no far-reaching effects in the Douglas basin.

HISTORY AND WATER-BEARING CHARACTERISTICS OF ROCK UNITS

The sequence of rock units in the Douglas basin is shown in the geologic column (fig. 3). The following paragraphs briefly discuss these units according to the groups by which they were mapped (pl. 1), the oldest being presented first. The geologic column shows more subdivisions than are considered in the following discussion. The units were combined for the present report into groups, the members of which have relatively uniform water-bearing characteristics.

SCHIST

During pre-Cambrian time thousands of feet of sediments, mostly silt and sand, were deposited in southern Arizona. After consolidation into rock, these strata were severely distorted by igneous intrusions, folding, and faulting, and were metamorphosed into schists. The pre-Cambrian schists are well exposed in several areas in the Dragoon Mountains and at Bisbee in the Mule Mountains. The schist in the Douglas basin has been correlated with the Pinal schist in other parts of Arizona (Ransome, 1904, p. 2).



Section below Tertiary from Ransome (1904), Wilson (1927), Darton (1933), and Cederstrom (1946)

Figure 3. —Columnar section showing relation of rock types and geologic names.

Schists in this region rarely yield much water and, owing to the limited area of outcrop in the Douglas basin, they are of little or no significance as a source of ground water.

At the close of pre-Cambrian time a long interval of erosion started. Highland areas were eroded to a surface of low relief, setting the stage for the advance of the first seas of the Paleozoic era.

SEDIMENTARY ROCKS

In the Paleozoic era shallow seas, alternately advancing and retreating, left sediments of several kinds in the Douglas basin area. The early sediments were gravel and sand, and the later deposits were predominantly limestone, indicating progressively deeper and warmer conditions. After the deposition of more than 5,000 feet of conglomerate, quartzite, sandstone, shale, and limestone, the area was uplifted and the seas retreated, ending the era. Erosion continued during the first two periods of the Mesozoic era (Triassic and Jurassic periods) and ended with subsidence and the advance of marine water in Cretaceous time.

In Cretaceous time about 4,500 feet of fragmental sedimentary rocks and lesser thicknesses of limestone were deposited. These deposits represent the last marine transgression into the area.

The Paleozoic and Cretaceous sedimentary rocks yield water in quantity sufficient only for domestic and stock use. They do not supply any of the water used for irrigation. Along the slopes of the Mule and Perilla Mountains there are stock and domestic wells that penetrate the sedimentary rocks and have yields of several gallons of water a minute. In the mine workings at Bisbee, where the rocks are cavernous and have been broken by faults or joints, and where collection areas are large, some of the limestone formations yield millions of gallons of water daily. The Waddell-Duncan oil test (D-22-27)5b (see log, table 3) is the only well in the valley that has penetrated the entire thickness of valley fill. It encountered sedimentary rocks at a depth of 1,605 feet. The well yielded water under artesian pressure after passing through limestone of Mississippian age at a depth of 2,270 feet and flowed an estimated 100 gpm at a temperature of 129°F.

GRANITE

The nonvolcanic igneous rocks in the Douglas basin have all been shown as "granite" on the geologic map (pl. 1). Although several different types of intrusive rocks crop out in the area, precision in individual classification was unnecessary for description of the ground-water resources. In the larger granitic areas the rocks are thought to be of Cretaceous age (Cederstrom, 1946, p. 601), but it is reported that intrusive igneous rocks were formed during various geologic intervals (Wilson, 1927, p. 22-23; Darton, 1933, sheet 21; Ransome, 1904, areal geologic map).

In areas where granitic and associated intrusive rocks have been greatly fractured and deeply weathered, sufficient water may be obtained to supply small amounts to domestic and stock wells. The communities of Courtland and Gleeson were formerly supplied with water from areas where deep weathering had created local basins of loose granitic sand. According to Meinzer and Kelton (1913, p. 114-115), at Courtland more than 15,000 gpd (gallons per day) was pumped from such a source and as much as 3,200 gallons per hour after the summer rains. The water yield of the intrusive rocks of the area is insufficient for irrigation or other large-scale uses.

VOLCANIC ROCKS

Volcanic rocks of Cretaceous(?) and Tertiary(?) age in the Douglas basin occupy an area second in extent only to the valley fill. Volcanic rocks compose most of the mountain area on the east side of the basin, most of the hills along the northern drainage divide, and part of the rocks in the Dragoon Mountains. The volcanic sequence in the Chiricahua Mountains aggregates several thousand feet in thickness. These rocks consist of a wide variety of explosively erupted (pyroclastic) and lava-flow materials, mostly of acidic composition. Thin strata of sandstone are present, locally interbedded with the volcanic rocks, suggesting that volcanic activity was occasionally interrupted long enough to permit fluviatile deposition. A conspicuous landmark in the Pedregosa Mountains is Castle Dome, a volcanic plug which rises 805 feet above the surrounding land surface.

Water is present in small amounts where the lavas are well fractured, and in the pyroclastic materials where they are not cemented. Some springs in the mountain areas issue from volcanic rocks. In the concealed pediment areas on the east side of the basin, the only ground water that is known to be present occurs in small quantities in the volcanic rocks. Many test wells in this area did not yield water, and only a few wells obtain sufficient water even for domestic or stock use. If wells can be dug or drilled in areas where the rocks have been shattered or deeply weathered, the chances of obtaining a water supply are improved, as ground water commonly occupies such zones. There is no indication that the volcanic rocks in the basin contain ground water in quantities sufficient for irrigation or other large-scale uses.

VALLEY FILL

The valley fill constitutes about 70 percent of the area of the Douglas basin. Although the basalt (malpais) and gypsum are contemporaneous with parts of the valley fill they were mapped separately because of their possible local effect on ground-water conditions.

Events that caused the Cenozoic cycle of deposition were the post-Cretaceous disturbances which raised the mountains relative to the central trough. The partial filling of the trough has resulted from the accumulation of mountain debris, locally more than 2,800 feet thick. It is believed that some of the deeper strata filling the trough are of Tertiary age. The upper fill materials are predominantly of Quaternary age and some of the beds adjacent to washes and arroyos have been deposited during the Recent epoch. These deposits may be equivalent to beds described by Gilbert (1875, p. 540–541) as the Gila conglomerate, a term that covers a wide range in age and lithologic character.

The valley fill consists mostly of a large variety of sediments derived by erosion from rocks in the adjacent mountain areas (fig. 4). The beds are generally unconsolidated to poorly consolidated clay, silt, sand, gravel, and occasional boulders. The materials were carried downslope by streams and sheet runoff, the larger fragments being deposited near the mountain source and the smaller fragments farther away as the carrying power of the transporting water diminished. Ideally, there is a grain-size gradation of the valley fill, from coarse at the mountain front to fine in the center of the basin. Conditions of transportation and deposition of the fragments vary, however, with the carrying capacity of the streams, and this in turn varies in each stream with the intensity of the storm causing the runoff. As a result, an area covered during one flood with gravel may, after another storm, receive a deposit of silt or clay. Furthermore, the stream channels constantly shift but tend to be occupied by coarser grained materials than are found in adjacent interstream areas. The end result of such widely fluctuating conditions is deposition of lens-shaped and fingerlike strata which change markedly in texture and character both horizontally and vertically (fig. 4). Well logs throughout the valley reflect these conditions, and correlation of individual beds from well to well is usually impossible.

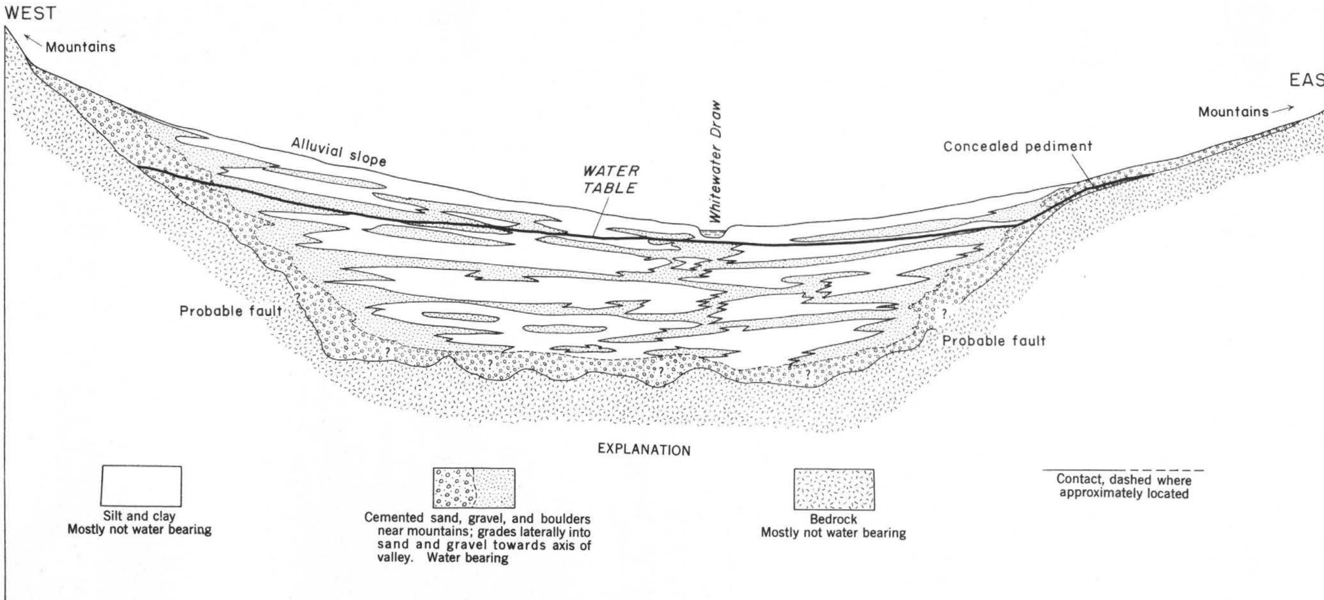


Figure 4.—Diagrammatic cross section of representative valley-fill conditions in Douglas basin.

There is a preponderance of clay throughout the alluvial fill in the Douglas basin, and statistical analyses of logs of many wells in the central part of the valley indicate that clay and silt may make up about 80 percent of the fill. Fine-grained deposits are especially abundant in the southern half of the Douglas basin and extend to depths of at least 1,000 feet. A lake of considerable size existed in the Willcox basin during the Pleistocene epoch. In the Douglas basin the gypsum and marl deposits east of Douglas, and the laminated clays now exposed in the banks of Whitewater Draw near Double Adobe (Sayles and Antevs, 1941, p. 34), indicate that standing water existed at least locally in that basin as well.

Caliche is present throughout most of the alluvium in the Douglas basin. Although it does not occur as a large, continuous blanket in the valley, it can be seen along most road cuts and stream channels, and it is mentioned in most of the driller's logs. The caliche tends to impede the downward movement of percolating water and thus to reduce recharge to the water-bearing beds.

Unconsolidated gravel and sand sediments in the valley fill of Tertiary and Quaternary age are the principal source of ground water in the Douglas basin and are the only beds that yield ground water in quantities sufficient for irrigation or other large-scale uses. The Recent alluvium along present stream channels is relatively thin and hence is capable of supplying only a small quantity of water sufficient for domestic or stock use in or near the mountain washes.

BASALT

Basaltic lava flows of Quaternary age crop out in a few small areas along the eastern margin of the valley. Basaltic lavas are known to occur also at depth, interbedded with the valley fill in an area of a few square miles in the vicinity of the city of Douglas. Thus, there were at least two periods of basaltic extrusion. The log of well (D–24–27)15bad is typical of the wells that penetrate the basalt. Basalt interbedded with valley fill has been reported in driller's logs in the city of Douglas area most commonly between 300 and 350 feet below the surface.

The areas of basalt are so small that they do not affect the general occurrence of ground water. On a restricted scale the basalt may influence ground-water conditions and cause, in part, minor ground-water anomalies such as are present in the Douglas area. Basalt is unimportant as an aquifer in Douglas basin but some of the interbedded sediments are water bearing, and in local areas the lava is sufficiently fractured to permit ground-water movement.

GYPSUM

Four small areas of gypsum have been mapped separately (pl. 1) because of the local effect of the gypsum on quality of the ground water. The gypsum deposits east of Douglas are of lacustrine origin and are interbedded with lake marls and sandy clays. The largest deposit, in sec. 11, T. 24 S., R. 28 E., is spoon-shaped, with strata that are 25 feet thick in the center and taper to feather edges. The gypsum is white and earthy and is characterized by an almost complete lack of grit and crystals. These deposits have been worked intermittently for many years. Small mining operations were in progress in the spring of 1952.

Fossil snails collected from the beds east of Douglas indicate (Teng-Chien Yen, personal communication, 1950) that the gypsum was deposited in a lake that existed in Douglas basin during middle or late Pleistocene time.

The gypsum deposits in Turkey Creek Ridge are different from those east of Douglas; at Turkey Creek Ridge the gypsum occurs largely in crystalline and fibrous forms. The deposits are crudely bedded and contain many veinlets of fibrous gypsum. The thickest measured section of gypsum was 6½ feet. The gypsum is white to brownish red, very gritty and rocky, and nonfossiliferous.

Gypsum is encountered at depth in wells at several places in the Douglas basin, and the chemical composition of the ground water in the vicinity is generally affected by such occurrence. The gypsum deposits do not themselves yield ground water in quantity but by solution they affect water in nearby aquifers. (See analysis (D-24-28)11bca, table 4.)

STRUCTURAL GEOLOGY

Structurally the Douglas basin is typical of the tectonic basins of the Basin and Range province. The alinement of the northwesterly trending mountain and valley areas has resulted from major movements along faults, which tilted the mountain blocks northeastward. A reflection of this structure is found in the Mule, Dragoon, Swisshelm, and Perilla Mountains, where the rock strata dip almost exclusively northeast.

The depth to which the rock floor of the valley has been downfaulted in relation to the mountain blocks can be inferred from previous studies and recent deep drilling. On the western side of the Douglas basin Ransome (1904, p. 9) records faults of 3,000-foot displacement. These faults were dated as pre-Cretaceous.

In the Bisbee district the mountain block has been tilted northeast about 15°. East of Bisbee parts of the sedimentary sequences of Paleozoic age were thrust at a later geologic time approximately 2 miles over strata of Cretaceous age. An oil test hole, (D–21–25) 25ad, was reported to have been drilled through a total valley-fill thickness of 2,835 feet and to have encountered rocks of Cretaceous age at that depth. A well, (D–22–26)27bbd, was drilled to a total depth of 1,604 feet, all in valley fill. Another oil test hole, (D–22–27)5b, penetrated the full thickness of valley fill at a depth of 1,605 feet and entered rocks of Pennsylvanian(?) age. These strata are structurally more than 2,000 feet lower than matching beds in the adjacent mountains to the east. Thus, the rock floor of the Douglas basin has probably been downfaulted at least 2,000 feet on the east and west sides of the structural trough; the trough is possibly asymmetrical and tilted westward; and the bedrock floor is locally more than 2,800 feet below the surface of the valley.

A separate downfaulted block lies between the Swisshelm and Chiricahua Mountains. In that small basin well (D–21–28)3baa encountered bedrock beneath 1,020 feet of valley fill. Other wells on the flanks of that basin passed through the valley fill at depths ranging from 870 to 1,100 feet. These relations are strongly suggestive of major faulting along the western slopes of the Chiricahua Mountains.

Displacement of Tertiary volcanic rocks by faulting, along both northwest and northeast lines, indicates that much of the major structural movement in the basin occurred in late Tertiary or early Quaternary time. Along the eastern border of the valley are a few basaltic dikes of Quaternary age having predominantly northeast strikes. It is probable that these dikes follow preexisting fault zones.

The northwest-trending arc of hills that extends from the Swisshelm Mountains to the vicinity of Pearce is partly related in origin to the northwest-trending fault pattern. These hills, which represent the remnants of the older landscape now largely buried by valley fill, are believed to represent a northwest extension of the structural block forming the Swisshelm Mountains.

The northwest-trending major faults have been emphasized in this report. There is also a pattern of minor fault structures striking northeast. Some faults have broken the continuity of the mountain blocks, creating a locally rugged topography and, in part, governing the location of some of the major canyons.

Folding of the sedimentary strata is less pronounced and is not as important as faulting in the structural history of the basin. The rocks of Paleozoic age in the Bisbee area were folded before or during the Mesozoic era. A later period of mountain building is indicated by the fact that Cretaceous rocks in the Bisbee area and in the Perilla and Swisshelm Mountains have been folded and faulted.

Bedrock structures are effective in controlling ground-water movement. The impervious mountain areas in the eastern and western parts of the Douglas basin prevent both leakage away from the basin and inflow from other basins. There is probably some ground-water movement southward among the hills that extend northwest from the Swisshelm Mountains, as discussed in the following section on ground-water resources.

GROUND-WATER RESOURCES

OCCURRENCE

The ground-water supplies that have been tapped in the Douglas basin are in the valley fill, in local areas of the hard-rock exposures, and in some of the hard rocks underlying the valley fill. These ground waters occur under unconfined (water table) conditions and under confined (artesian) conditions. The search for and the development of ground water in the basin indicates that the unconfined waters are easier to obtain and develop, especially in the large quantities that are needed for irrigation use.

UNCONFINED WATER

The valley fill is the source of supply for most of the water withdrawn from wells in the Douglas basin and contains the largest proven supply of unconfined water in the basin.

WATER IN VALLEY FILL

The main body of water as well as local areas of perched water are unconfined in the valley fill. The upper surface of the main body of unconfined water is the main water table. The depth to the main water table below land surface is the depth to water in all the irrigation wells and most of the domestic and stock wells in the fill. All of the valley-fill materials below the water table contain water, but the various materials comprising the valley fill have considerable differences in their water-storage, water-transmitting, and water-drainage capabilities.

The water-bearing characteristics of the materials depend on the grain size, the degree of sorting or lack of sorting of component particles, and the degree of consolidation by compaction or by cementation. The more permeable zones in the valley fill are those that are coarse grained, fairly well sorted, and unconsolidated. Consolidation of the materials generally increases with depth with a consequent decrease in permeability. There are local exceptions to this, but in general, the valley-fill materials below depths of 300 to 400 feet have not yielded water to wells in sufficient quantities to justify the cost of the drilling below those depths.

Ground water occurs below the water table in all the various combinations of gravel, sand, silt, and clay described earlier in the report. The more permeable valley-fill materials are the unconsolidated or poorly consolidated deposits of sand and gravel. These more permeable deposits are interconnected, as shown by the presence of a single main water table, but the connections may not be direct and may be by way of less permeable materials. These permeable sand and gravel deposits release their stored water readily to wells and, therefore, are recognized as being "zones" from which water is developed. Such zones are commonly reported in drillers' logs as "water strata." The "water strata" are discontinuous laterally because of the nature of the deposition of the valley fill, and therefore the water strata in nearby wells cannot be correlated with certainty either by altitude or depth below the surface.

In addition to storing water for ready release, these more permeable members, after they have been partially unwatered, collect water draining from the surrounding less permeable materials.

Form of the water table.—The form of the main water table in the Douglas basin resembles the form of the valley slopes, but has fewer irregularities and gentler gradients (fig. 4). The water table descends southward at a gradient of about 9 feet per mile from an altitude of about 4,200 feet in the vicinity of the buttes and ridges in the northern part of the basin to about 3,870 feet at the international boundary. (See plate 2.) The water table slopes downward from the east and west sides of the valley toward the axis at gradients ranging generally between 15 and 30 feet per mile. The gradient of the water table closely approximates the gradient of the valley floor along the axis of the valley, and there is but a relatively slight decrease southward in the depth to water (pl. 1). The upward slope of the water table from the axis toward the east or west sides of the valley is much less than the slope of the land surface, resulting in an increase in depth to water outward from the axis of the valley of about 30 feet per mile.

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Depth to water.— The depth to the main water table in the Douglas basin is least along the axis of the valley, ranging from several inches below the land surface near Whitewater Draw at the international boundary, to about 100 feet in the vicinity of the buttes and ridges in the northern part of the basin. (See plate 1.) Data about depth to water near the mountains were difficult to collect—there were few wells and many of them were sealed so that the water level could not be measured. In the central and southern parts of the basin, the depth to water near the mountain fronts is generally less on the east side than on the west side. On the east side of the valley the maximum depth to water is about 225 feet, generally about 2 miles valleyward from the hardrock-alluvium contact. Between this line and the mountain front the depth to water abruptly decreases, ranging from 50 to 100 feet below land surface. The cause of this sharp break is attributed to a pediment surface that is buried under a cover of valley fill. On the west side of the basin the depth to the water table becomes progressively greater toward the mountain front, reaching a depth of as much as 280 feet. The greatest measured depth to water in the Douglas basin in 1951 was 474 feet in well (D–18–28)22cba; however, a depth to water of as much as 800 feet has been reported in well (D–21–28) 3baa, which lies in the small valley between the Swisshelm and Chiricahua Mountains.

Perched water.—In local areas, small bodies of unconfined water are held in temporary storage above and separate from the main water table by relatively impervious zones of caliche, clay, or lava. Ground water occurring in this manner is called "perched water" and its upper surface is called a "perched water table." Perched waters are not uniformly distributed throughout the valley, but occur in small isolated areas near the mountain fronts, principally along major washes immediately downstream from the hard rock-alluvium contact. Wells deriving water from perched supplies are subject to rapid water-level fluctuations and, because of the limited storage capacity, are apt to go dry during periods of drought. Some of the larger areas of perched water are along Whitewater Draw between the Swisshelm and Chiricahua Mountains, and along Leslie Creek in T. 21 S., R. 28 E.

WATER IN HARD ROCKS

Ground water in the hard-rock areas of the Douglas basin occurs principally in weathered zones where the fractures and crevices act as minute conduits or for storage of water. The storage capacity and water-yielding characteristics of the rocks depend on the degree to which the conduits have been closed by the deposition of lime or silica cement. In general, where the hard rock is water bearing and is in contact with the valley fill, the water table extends from the valley fill into the weathered hard rock without an appreciable interruption. Some of the water percolating downward through the hard rocks encounters relatively impermeable zones, and moves laterally until it reaches the mountain slope and discharges as a seep or spring. There are several springs and seeps in the mountain areas of the Douglas basin, and probably there are many areas where water discharges from the hard-rock areas into the valley fill below the land surface.

CONFINED WATER

Any ground water under sufficient pressure to cause it to rise in a tightly cased well to a level appreciably above the water table in that vicinity is termed confined or artesian water. Contrary to popular belief, artesian conditions can exist although the pressure is insufficient to raise the water to or above the land surface and cause the well to flow. In general, the following conditions are necessary for the occurrence of artesian water: A confining bed or layer of relatively lower permeability must overlie a bed or layer having a much higher permeability than the confining bed; the confining bed must extend, uninterrupted by fractures or other breaks, to the area in which water is recharged to the underlying permeable stratum; the lower surface of the confining bed must slope downward away from the recharge area; the permeable stratum must be saturated with water from its lowest point to the vicinity of the recharge area.

Water in valley fill.— Unlike basins adjacent to the Douglas basin, deep drilling in the valley fill has not disclosed the presence of a competent confining bed in a large area or areas of the basin under which water can accumulate under pressure, and thus create an extensive artesian system. Although much of the valley-fill material in the Douglas basin is of low permeability, there are numerous permeable avenues throughout the fill that prevent an accumulation of water under considerable pressure. Water under pressure has been reported in deep wells in the basin, principally from T. 20 S., southward to the international boundary; however, there is little or no correlation of pressure, so that local rather than general artesian conditions are indicated. Water was encountered under artesian pressure in sand and gravel beds between 472 and 1,012 feet below the land surface in well (D-21-25) 1dd (table 3). At the time the well was drilled, in 1935, the artesian pressure was sufficient to cause the water to rise to the land surface and overflow the top of the casing, about 60 feet above the water table in that vicinity. Well (D–24–27)15baa penetrated permeable material at a depth of 833 feet, and the water rose in the well bore to within 40 feet of the land surface, or about 20 feet above the water table. Artesian conditions were encountered also at depths ranging from about 300 to about 500 feet in a group of wells drilled prior to 1910 in the SW$\frac{1}{4}$ sec. 14, T. 24 S., R. 27 E. Pressure heads in these wells ranged from slightly above the land surface to about 5 feet below the land surface. Flows were reported to range from 25 to 500 gpm.

Although artesian conditions exist in parts of the Douglas basin, it is likely that in most of the basin artesian pressure is lacking or is insufficient to raise water above the land surface.

SPRINGS

Springs occur principally in the Mule and Dragoon Mountains and in the saddle between them, and on the western slopes of the Swisshelm, Pedregosa, and Chiricahua Mountains. There were perhaps 35 permanent springs in the Douglas basin in 1951, as well as a number of wet-weather seeps and cienagas (swampy areas).

The geology of the springs in Douglas basin is not complex. Springs result from:

1. Obstruction of underflow by a rock barrier. The Leslie Creek spring, (D–21–28)21bc, and Antelope Spring, (D–20–24)21ca, are examples.

2. Incisement of stream channels below the water table. Springs can form where a stream channel has cut below the water table, a perched water table, or an aquifer confined between permeable beds. Springs of this general classification are Sycamore Spring, (D–19–29)14ad, spring (D–18–24)28cd, and spring (D–19–29)10dd.

3. Faults. In places the rock materials in a faulted zone are sufficiently fractured to act as an avenue for the escape of ground water under artesian pressure. Two examples of fault springs are, respectively, spring (D–20–28)13bd and spring (D–22–24)29bc.

The spring waters are of normal temperature (66° to 81°F) rather than thermal or hot. Yields range from less than 1 to 60 gpm.

ORIGIN

The origin of ground water in the Douglas basin is precipitation in the mountain areas and on the valley floor.

Annual precipitation is about 15 inches in most of the Dragoon, Perilla, and Pedregosa Mountains; about 19 inches in the Mule and Swisshelm Mountains; and a maximum of more than 26 inches in the higher parts of the Chiricahua Mountains. Most of the water is absorbed by the soil in the mountains and is either lost to the atmosphere by evaporation or is transpired by vegetation. The remainder of the water is channelized into small gullies and rills, then into progressively larger streams, and finally passes out of hard-rock areas of the mountains. At the mountain front there is a sharp reduction in the gradient of the channels, and the runoff quickly loses velocity. In some places the streamflow progresses several miles out into the valley, but in other localities much of the flow is lost in alluvial fans and is spread or dissipated in distributary channels. Thus, much of the recharge to the ground-water reservoir of the valley fill occurs near the mountains, where water percolates rapidly through permeable materials and reaches a sufficient depth below the zone of capillarity and root growth to eliminate losses by evaporation and transpiration.

Most of the recharge into the ground-water reservoir occurs in washes in a narrow zone along the mountain fronts. Seepage from streams into the coarse materials underlying the washes unites with water infiltrated from precipitation upon the alluvial fans and ultimately reaches the water table. Studies show that of the total amount of precipitation falling within the drainage area of the hard rocks, only a small percentage leaves the mountains as runoff. The factors that bear on this percentage are complex, as shown in studies such as those of Peterson (1945), Schwalen (1942), and Sonderegger (1929). Important physical features of the drainage areas include: (1) Altitude, (2) surface gradients, (3) size of area, (4) character of soil and subsoil, (5) seasonal changes in infiltration capacity of the soil, (6) quantity and type of vegetation, and (7) type and structure of bedrock. Meteorological and other conditions that affect the quantity of runoff are: (1) Amount, intensity, and distribution of precipitation, (2) temperature, and (3) evapotranspiration. Runoff in the drainage basins of Parker and Workman Creeks in central Arizona (Rich, 1951, p. 11), and in the drainage basin of Salt River above Roosevelt Dam (Cooperrider and Sykes, 1938, p. 45), was 13 and 14.5 percent, respectively, of the precipitation.

Runoff figures are available for the Rucker Canyon drainage area (U. S. Geol. Survey, 1948, p. 475–476). This area is in the

Chiricahua Mountains, where the altitude ranges from about 5,400 feet at the gaging station to about 9,800 feet on the crest. The mean annual rainfall is about 22 inches in this area (Smith, 1945, p. 90). Rucker Canyon has a drainage area of 40 square miles. Using these data, about 47,000 acre-feet of precipitation occurs annually, of which about 4,500 acre-feet, or about 10 percent, leaves the area as runoff. On the basis of these data, runoff percentages of 10 to 15 percent were chosen for the different mountain areas for computations in this report.

Most rain that falls on the valley fill is used by vegetation or is held in the soil until it is evaporated. Rainfall-penetration studies in desert plains by Shreve (1934, p. 150–51), Lee (see Sonderegger, 1929, p. 1310), and Turner[2] indicate that practically none of the rainfall on the valley floor reaches the water table. Factors that prevent recharge from direct precipitation in Douglas basin are rapid evaporation, vegetative use, and strata and lenses of impermeable clay and caliche near the land surface. Of the precipitation that falls upon the valley floor, only that part passing over the coarse-grained materials along the washes is believed to be a source of recharge to the ground-water reservoir.[3]

Part of the water applied to the land for irrigation is returned to the ground-water reservoir by seepage. Although this seepage constitutes only recirculation of part of the ground water, it must be considered in evaluating the available ground-water supply. In some basins in southern Arizona, estimates of recharge from irrigation water run as high as 25 percent of the total amount of water applied to crops.[4] Some of the tests upon which these estimates are based, however, were conducted in areas having conditions considerably more favorable for recharge than those in Douglas basin. It is believed that the same conditions that limit recharge from direct precipitation also limit recharge from irrigation in the Douglas basin.

The only avenue of known movement of ground water into the basin occurs in the vicinity of Turkey Creek, at the surface-water divide that separates the Douglas and Willcox basins (pl. 2). In a strip about a mile or so wide infiltration of surface water into the alluvium of Turkey Creek eventually moves as ground water into Douglas basin. The hard-rock barriers that separate the Douglas basin from other basins on the east and on the west effectively prevent movement of ground water between basins.

[2] Turner, S. F., and others, 1943, Ground-water resources of the Santa Cruz basin, Arizona: U. S. Geol. Survey Open-File Report, p. 35.

[3] Turner, 1943, op. cit., p. 45, 54.

[4] Turner, S. F., and others, 1946, Ground-water resources and problems of Safford basin, Arizona: U. S. Geol. Survey Open-File Report, p. 7.

MOVEMENT

The general movement of ground water in the Douglas basin is shown by the water-table contour map (pl. 2). The direction of movement is downslope and at right angles to the contours. The contours indicate that recharge occurs at the mountain fronts and that ground water moves toward the central part of the valley at a slight angle to the south. On reaching the axis of the valley the ground water moves southward, toward Mexico.

The rate of ground-water movement depends upon the gradient of the water table and upon the type of sediments the water moves through. In general the gradient of the water table is greatest near the mountains and becomes progressively less toward the valley (fig. 4). The close spacing of water-table contours may be indicative of abundant recharge, presence of extremely fine-grained materials, or thin, though permeable aquifers with low rates of transmissibility (ability to transmit water). Studies of the rate of ground-water movement (Slichter, 1905a, b; Smith, 1910, p. 126–154) indicate that the rate of flow is extremely variable and may range from a few inches to several feet per day. On the basis of these and other studies, the rate of ground-water movement in Douglas basin probably does not exceed a few feet per day and, in the central part of the valley where silt and clay materials comprise up to about 80 percent of the valley fill in many areas, the rate of movement is likely to be much slower.

The average slope of the water table is about 9 feet per mile in the central portion of the valley. Steeper gradients are present in the northern part of the basin and near the mountain areas (pl. 2). The direction of the water-table contours between Turkey Creek Ridge and Ash Creek Ridge indicates that ground water is reaching the main part of Douglas basin from recharge along Turkey Creek. The water-table contour map (pl. 2) also indicates that the northern limit of the ground-water reservoir cuts diagonally across the surface-water divide. Therefore, in this area some ground-water movement occurs both into and out of the Douglas basin. The closely spaced contours in the vicinity of the buttes and ridges are believed to be a reflection of local areas of low transmissibility, and the total amount of ground water moving between these bedrock areas is believed to be small.

The correlation of water-level data from the wells in the vicinity of the city of Douglas is difficult because many of the deeper wells exhibit artesian pressure, and the distinction between those wells and wells that reflect water-table conditions is not always clear cut. At the time of the Meinzer and Kelton report (1913) water-table contours in this area were uniform and conformable with those in the upper parts of the valley. However, by 1952 the water-table contours (pl. 2) in this vicinity were closely spaced, indicating a steepening of the water-table gradient, particularly on the west side of Whitewater Draw. This change in gradient is attributed primarily to the heavy municipal and industrial pumpage in this small area.

RECHARGE

The sources of recharge to the ground-water reservoir of Douglas basin have been described in the section entitled "Origin." The following paragraphs provide quantitative estimates that were made to evaluate the approximate amount of annual recharge from precipitation in mountain areas, precipitation on valley floor, and seepage from irrigation. Underground leakage is not considered as a separate topic, but is included in the section on "Precipitation in mountain areas."

PRECIPITATION IN MOUNTAIN AREAS

An estimate of the average annual quantity of recharge from precipitation in the mountain areas was made on the basis of partial data on precipitation in the mountains, an estimate of the portion that reaches the mountain fronts as runoff, and an estimate of the proportion of runoff that infiltrates to the ground-water reservoir.

The total average precipitation was computed as about 375,000 acre-feet per year on a hard-rock area of 360 square miles. To approximate the runoff, estimates of 10 to 15 percent were applied to the individual mountain ranges according to the factors listed on page 25. The sum of the estimates indicated that about 40,000 acre-feet of runoff enters the valley from the mountain areas in an average year. This includes recharge occurring between the surface-water divide and the ground-water divide in the northern part of the basin.

Only part of the runoff infiltrates into the coarse-grained sediments at the mountain front and percolates to the ground-water zone. Studies by Smith (1910, p. 118–119), U. S. Bureau of Agricultural Economics (1940, p. 42) and Babcock and Cushing (1942, p. 56) indicate that only about half the total runoff recharges the ground-water zone. The recharge from this source in Douglas basin was estimated as about 50 percent of the total runoff from the mountain areas, or about 20,000 acre-feet per year.

PRECIPITATION ON VALLEY FLOOR

It is estimated that about 2,000 acre-feet of water may reach the ground-water zone annually from precipitation on the valley floor. Nearly all the recharge from this source occurs along washes.

SEEPAGE FROM IRRIGATION

Tests in the Douglas basin by the Soil Conservation Service, U. S. Department of Agriculture (personal communication, 1951), indicated a complete lack of moisture penetration below a depth of 5 feet, even after heavy irrigation. Therefore, the quantity of water recharged to the ground-water reservoir from irrigation is believed to be negligible. The low recharge is a result of the tightness of the soil and the general fine-grained character of the alluvium, as indicated by the tests of the Soil Conservation Service.

DISCHARGE

Ground water is discharged from the valley fill of Douglas basin by evapotranspiration, flow out of the basin, and pumping from wells.

EVAPOTRANSPIRATION

The amount of evaporation of ground water in Douglas basin is believed to be negligible. The only area where the water table is near enough to the surface to permit evaporation is a narrow fringe on either side of the lower 2 miles of Whitewater Draw.

In western United States many plants grow where the depth to ground water is shallow. By sending roots below the water table the plants obtain a perennial supply of water. Plants that depend upon ground water for growth are termed "phreatophytes" (Meinzer, 1923, p. 55). The amount of ground water that may be utilized by vegetation is conditioned by the species of plant, the depth to which it can extend its roots, the density of plant growth, the length of the growing season, the depth to the water table, and the availability of surface water and soil moisture. The plants considered as potential phreatophytes in the basin are mesquite, salt bush, and some grasses. Of these plants mesquite is probably the only one capable of sending roots from 30 to more than 50 feet below the land surface. In order to determine the amount of ground water available for such vegetation, the mesquite areas were mapped and separated into areas where the water table was less than 30 feet below the land surface and areas where depth to water ranged from 30 to 50 feet. The characteristics of the individual trees and groves were noted, such as areal density and height, and frondage density.

In general, the mesquite in Douglas basin averages 4 to 5 feet in height, and less than 15 feet in diameter of crown area. In the zone where the depth to water is less than 30 feet below the land surface mesquite occupy an area of about 7 square miles and have an average areal density of about 40 percent. Where the water table is 30 to 50 feet below land surface the mesquite occupy an area of about 47 square miles and average about 30 percent areal density. Mesquite of 100-percent volume density in Safford Valley, where depth to water was about 10 feet, used a total of more than 3 acre-feet of water per acre in 1943–44 (Gatewood and others, 1950, p. 203). Owing to the greater depth to water in Douglas basin the use of ground water by mesquite of 100-percent density is assumed to be 1 acre-foot or less per acre per year. Another indication that ground-water use by mesquite in the Douglas basin is small is the noticeable uniformity in the size of mesquite under varying ground-water conditions. There is no apparent change or diminution in mesquite growth in areas where the depth to water exceeds 50 feet. It is probable, therefore, that much of the water used by mesquite in Douglas basin is derived from rainfall and from surface runoff. Total ground-water use by phreatophytes in Douglas basin was estimated to be between 8,000 and 13,000 acre-feet in 1951.

FLOW OUT OF BASIN

Discharge records for Whitewater Draw at the gaging station on U. S. Highway 80, west of the city of Douglas, are available for the years 1912–19, 1930–33, 1935–46, and 1948–51. The mean surface flow for all years of record is 8,740 acre-feet per year. The mean surface flow for the period 1947–51, is 6,100 acre-feet per year. Of this total flow, a study of the records indicates that less than 300 acre-feet per year constitutes seepage of ground water into the stream and remainder is flood-water runoff.

The main avenue of ground-water leakage from Douglas basin is southward into Mexico. It is believed that ground-water loss to adjacent basins is negligible because of the extensive hard-rock barriers. The determination of the quantity of ground water moving into Mexico annually can only be approximated from the data available. This computation is made difficult by complicating factors that include the heterogeneous character of the valley fill, the existence of buried lava flows near the border, and relatively heavy pumping by city of Douglas and Phelps Dodge Corp. wells in a small area. As a result, several unusual conditions exist locally: (1) the water level in shallow wells is shallower than in adjacent wells; (2) Whitewater Draw changes from an intermittent to a perennial stream at a point about 2 miles north of the international boundary; (3) the water surface in the draw corresponds in elevation to that in adjacent shallow wells, but is at a higher elevation than in nearby deep wells; and (4) the apparent direction of ground-water movement in the area west of Whitewater Draw and near the boundary is partially reversed with respect to the general pattern of ground-water movement in the basin.

The equation for underflow out of the basin is as follows: Underflow (in gallons per day) = transmissibility (in gallons per day per foot) x gradient (in feet per mile) x width of ground-water movement (in miles). Near the international boundary the following conditions are assumed: Coefficient of transmissibility of 40,000 gpd per foot; a gradient of 20 feet per mile; and a width of ground-water movement of $1\frac{1}{2}$ miles. Thus, the underflow leaving Douglas basin would be about 3 to 4 acre-feet per day, or about 1,400 acre-feet per year.

PUMPING FROM WELLS

Most of the ground water discharged from the Douglas basin is by pumping from irrigation wells. Locally, relatively large amounts of ground water are also pumped from the wells of the city of Douglas and the Phelps Dodge Corp. smelter. Minor ground-water withdrawals are made for stock and domestic use throughout the valley.

Ground water has been pumped in the basin for irrigation since 1910, but prior to 1939 pumpage for irrigation probably did not exceed 5,000 acre-feet annually. After 1945 pumpage for irrigation began to increase sharply. During the 5 years 1947–51, inclusive, ground-water pumpage in the basin more than doubled, as shown in the following table.[5] In 1951, a total of 14,300 acres was irrigated

Year	*Ground Water (acre-feet)*	*Year*	*Ground Water (acre-feet)*
1947	17,000	1950	35,000
1948	22,000	1951	38,000
1949	30,000		

[5]Halpenny, L. C., and Cushman, R. L., 1952, Pumpage and ground-water levels in Arizona in 1951: U. S. Geol. Survey Open-File Report, p. 3.

with about 38,000 acre-feet of ground water from about 270 wells (pl. 4). Irrigation wells in the basin range in diameter from 6 to 20 inches and in depth from 50 to more than 600 feet. The average diameter is 12 inches and the average depth is 160 feet. The average discharge of irrigation wells in the Douglas basin, based on 95 well-discharge measurements made throughout the valley, was about 380 gpm in 1951. Some wells yield as little as 80 gpm, and the maximum measured discharge was 1,500 gpm. The irrigation wells yield from 3 to 100 gpm per foot of drawdown, the average specific capacity in 65 representative wells being 12 gpm per foot of drawdown. Pumping lifts range from 50 feet near Whitewater Draw to more than 165 feet in wells 6 miles west of Douglas and in other wells east of McNeal. The nonpumping depth to water in irrigation wells ranges from 26 to 115 feet and averages 55 feet. Most of the pumps are powered with electricity but a few are powered by various petroleum-type units.

Figures supplied by the City of Douglas Water Department and by Phelps Dodge Corp. officials show a total withdrawal of 3,000 acre-feet in 1951 from the city and smelter wells. During the period 1947–51, the water requirements for the smelter remained nearly constant but pumpage for municipal use increased slightly.

Total ground water pumped from domestic and stock wells is about 500 acre-feet per year, calculated from an estimated average discharge of 2 gpm from about 300 wells that operate about half the time.

The total quantity of ground water withdrawn from wells in Douglas basin in 1951 was, therefore, about 41,000 acre-feet.

SPRINGS

The discharge of springs in the basin ranges from a negligible amount to as much as 60 gpm. The flow of the average spring is from 1 to 2 gpm. It is estimated that the total amount of water discharged by springs is less than 200 acre-feet per year. However, most of the water discharged flows only a few feet before percolating below the land surface, so that evaporation and transpiration losses are small.

Oldtime residents of the Douglas basin agreed that springs are now fewer in number and yield less water than in former years. Many of the springs shown on the topographic maps were dry in 1951. In some localities, windmills are used to withdraw water by pumping where springs had formerly existed. Examples are; Gadwell Spring, SE¼ sec. 31, T. 21 S., R. 24 E.; Mud Spring, NE¼ sec. 16, T. 22 S., R. 28 E.; and Outlaw Spring, center sec. 24, T. 20 S., R. 24 E. T. M. Watson (personal communication, 1952) reported that, in the early 1900's, Mud Spring discharged sufficient water to take care of all the cattle in a radius of many miles. It is now dry. It is generally concluded that the drought starting in 1941 is an important factor in the decline of spring discharge (Searles, 1951, p. 19–28).

SUMMATION OF RECHARGE AND DISCHARGE

In recent years there has been a general increase in irrigated acreage in the Douglas basin, and a corollary increase in the amount of ground water pumped. This pumping removes water from underground storage, a portion of which is replenished by annual recharge from precipitation and runoff. The fact that in recent years the amount of discharge has exceeded the amount of recharge is shown by the decline of water levels in wells. Any attempt to arrive at an estimate of the amount of ground water withdrawn from storage is limited by the availability of certain basic quantitative data. Although all the component items of recharge and discharge discussed in the text are estimates or approximations, they are believed to be of the proper order of magnitude.

On their basis, the amount of annual recharge from all sources in the Douglas basin is estimated to be about 20,000 acre-feet per year. The total amount of discharge, occurring by evapotranspiration, effluent seepage, underground flow out of the basin, and pumping, is believed to have been about 30,000 acre-feet in 1947 and about 50,000 acre-feet in 1951. During the past few years the increase in pumping has resulted in a greater annual discharge, whereas the amount of recharge has remained relatively constant. The difference between the amount of discharge and the amount of recharge represents approximately the amount of ground water removed from storage.

FLUCTUATIONS OF THE WATER TABLE

Under natural conditions a balance exists between water that is recharged to a ground-water basin and water that is discharged from the basin. Abnormal climatic conditions may cause an adjustment of the level of the water table to meet a changed situation, but the trend in years under natural conditions is for the establishment of equilibrium between ground-water gains and losses. When the natural state is radically disturbed by manmade conditions, however, the water table may fluctuate widely in local areas in response to the changes. When the total discharge is more than the recharge, depletion of storage in the ground-water reservoir occurs and the water table declines. Persistent pumping of water from storage is termed "ground-water mining." This practice has been followed in the Douglas basin at least since 1945. In 1951 the total ground-water use was more than double the estimated rate of recharge.

For the period 1947–51, the average decline of the water table was 6 feet in the heavily irrigated areas (pl. 3). Throughout the basin the decline ranged from about a foot near the mountains to a maximum of more than 11 feet northeast of Elfrida. Noticeable declines in the water table are also present in the area south and east of McNeal. The maximum decline of the water table since 1910 (Meinzer and Kelton, 1913, pl. 2) is 38 feet, east of Douglas. Declines in specific wells in the past decade are shown on the hydrographs (fig. 5).

From the water-table decline map (pl. 3) it was calculated that a total of 1,120,000 acre-feet of sediments had been dewatered in the period 1947–51. The coefficient of drainage of sediments in the Douglas basin may be about 8 percent, on the basis of data from other parts of Arizona[6] and from Piper (1939, p. 121). Accordingly, a coefficient of 8 percent was assumed for the area unwatered, although the average for the entire body of valley fill is likely to be much less. The total amount of ground water withdrawn from storage in the last 5 years was computed to be about 90,000 acre-feet, or an average of 18,000 acre-feet per year. This computed quantity is in the order of magnitude of the annual overdraft as indicated by the ground-water inventory.

With increased pumpage in recent years, more water has been withdrawn from storage each year. According to the tabulation summarizing recharge and discharge, the average annual overdraft—excess of discharge over recharge—during the period 1947–51 was more than 20,000 acre-feet, and was about 28,000 acre-feet in 1951. Less water has been available for use by phreatophytes each year, because of the declining water table. Another result of a declining water table is that less water will leave the basin as effluent seepage into Whitewater Draw and, eventually, as underflow.

The decline of the water table in the Douglas basin is believed to be due almost entirely to pumping from wells. Although rainfall since 1941 has generally been below normal, the drought is believed not to have been sufficiently intense to cause a large reduction in recharge. Some of the recharge that was received during

[6] Halpenny and others, 1952, op. cit., table 3.

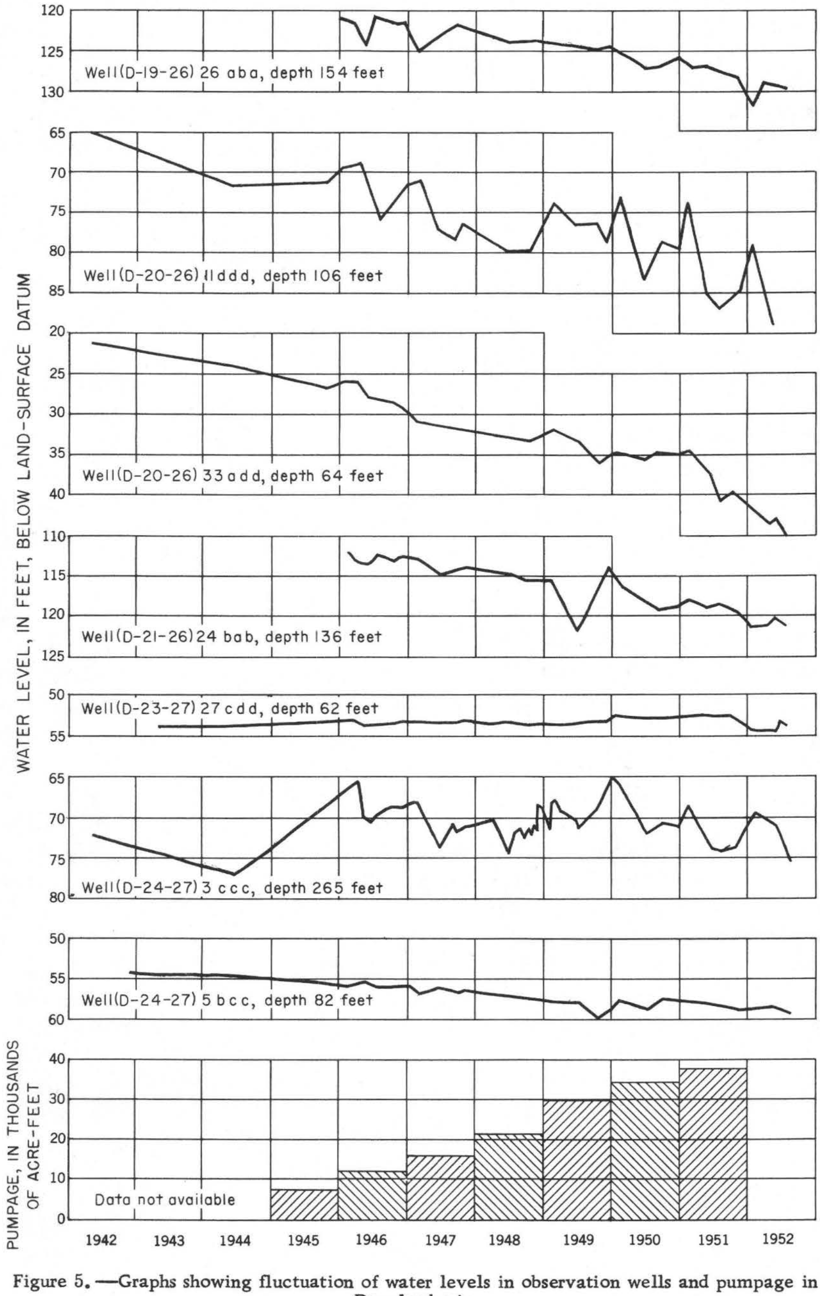

Figure 5.—Graphs showing fluctuation of water levels in observation wells and pumpage in Douglas basin.

the past 10 years probably has not yet reached the areas of heavy pumpage because of the slow rate of ground-water movement, so that the downward trend of water levels is mostly a result of localized conditions. Water levels in wells at some distance from the heavily pumped areas have remained nearly static for the past few years.

Well interference.—During the pumping of a well, ground water is withdrawn from the area immediately around the well. As pumping continues, more ground water is withdrawn from storage in the vicinity of the well, until the gradient of the water table from all directions is sufficiently steep to supply the pump without further local drawdown. The unwatered zone surrounding a pumping well is called a "cone of depression." The water-level decline is greatest near the well and gradually tapers off in all directions. The cone expands as more ground water is withdrawn from the pumped area. When a cone of depression merges with another cone from a nearby pumping well, interference occurs and a ground-water divide is created. The size of the cones of depression and the amount of well interference is dependent upon several factors, including the rate and quantity of water withdrawn and the permeability of the water-bearing sediments (Theis, 1938, p. 889–902).

The effects of well interference and the spread of cones of depression in the Douglas basin are well demonstrated by water-level data. Fluctuations of water level in wells that are not pumped reflect the extent of well interference resulting from seasonal withdrawal of ground water for irrigation. Well (D–20–26) 11ddd, with fluctuations of 12 feet (fig. 5), illustrates seasonal changes in water levels caused by pumping in nearby wells. Abandoned wells in the center of some heavily irrigated areas also show seasonal and yearly changes in water levels. There is a lack of rapid spread of cones of depression, during short-time pumping of some wells and this may be partly attributable to the clay which predominates in much of the valley fill. In February 1952, a pumping test was made on well (D–23–26)1ada which has a static water level of 65 feet. During a 32-hour period the well was continuously pumped at an average rate of 145 gpm, and a drawdown of 44 feet resulted in the pumped well. The water level in an abandoned well 700 feet north, however, did not change noticeably during the test.

QUALITY OF WATER

By J. L. Hatchett

CHEMICAL CHARACTER OF THE GROUND WATER

WELLS

Analytical data for water from 112 wells were used in preparing this section on the quality of water in the Douglas basin. Most of the sampled wells are in the valley fill of the central part of the valley (pl. 5). Table 4 lists 32 analyses of water from selected wells.

Water from 98 of the wells sampled contains 100 to 500 ppm of dissolved solids. The dissolved solids consist mostly of calcium, sodium, and bicarbonate. Water from the remaining 14 well samples had a dissolved-solids content of more than 500 ppm. The water from the wells along Whitewater Draw in this group contained mainly sodium, chloride, and sulfate, whereas the water from wells east of Douglas contained mainly calcium and sulfate. A deep well drilled as an oil test on the east side of the Douglas basin (D–22–27)5b is reported to yield water from limestone of Mississippian age. The dissolved solids in this water consist mostly of sodium, bicarbonate, and sulfate. As water from limestone ordinarily contains much more calcium than is present in this water, it is possible that the water in the well may have been more closely related to other aquifers.

SPRINGS

Water samples from 15 springs in the Douglas basin were analyzed. These waters contained from 100 to 500 ppm of dissolved solids, mostly calcium and bicarbonate. The formations from which the springs issue include sandstone, shale, limestone, volcanic rocks, and granite. Table 4 lists the analyses of water from six of these springs.

The streamflow in Whitewater Draw near the international boundary was sampled in sec. 28, T. 23 S., R. 27 E., and in sec. 10, T. 24 S., R. 27 E. (table 4; pl. 5). At the times of sampling, the flow was entirely effluent ground-water seepage. Both of the water samples contained over 500 ppm of dissolved solids. The water sample from sec. 28 contained mostly sodium and sulfate. The water sample from sec. 10 contained considerably more sodium and chloride than other dissolved constituents.

DISSOLVED-SOLIDS CONTENT OF THE GROUND WATER

The dissolved-solids content of the ground water in the Douglas basin is shown graphically on plate 5. This map was prepared by drawing a circle at the location of each well and spring for which a chemical analysis was available. The dissolved-solids content of the water is indicated by the amount of shading in the circle. If only the specific conductance of the water was determined for a particular well or spring, the approximate dissolved-solids content was calculated by multiplying the specific conductance (micromhos at 25° C) by 0.6.

SOURCE OF DISSOLVED SOLIDS

The source of most of the dissolved solids contained in the ground water of the basin is the minerals of the rock material that comprise the valley fill. The longer the ground water is in contact with these minerals the greater is the opportunity to dissolve them. If time were the only factor, the dissolved-solids content would be expected to increase uniformly with depth and distance from the recharge areas. However, such uniform changes are rare because the rocks of the valley fill are erosional products of many formations and are not homogeneous. Therefore, the composition and solubility of the minerals that are available for solution are also factors that affect the amounts of dissolved solids in the ground water.

Flow from mountain springs and runoff are lesser sources of dissolved solids in ground water of the valley fill. Evapotranspiration returns almost pure water to the atmosphere and thereby concentrates the dissolved solids in the remaining water or in the soil. The process does not increase or reduce the total quantity of soluble material in the basin.

The locally high dissolved-solids content of the ground water in the valley fill possibly is related to the presence of beds of evaporites. These beds were formed by evaporation of impounded water in basins that existed temporarily during the deposition of the valley fill, examples of which are the gypsum beds described on page 18. It is conceivable that in some areas highly mineralized water entered the basin during the periods of volcanic activity. These waters or deposits resulting from them would affect the quality of ground waters in the basin.

DISCHARGE OF DISSOLVED SOLIDS

It has been stated previously in this report that ground water leaves the Douglas basin by movement southward into Mexico. Although the quantity of ground water thus discharged is known to be relatively small, data available are insufficient to determine the amount of dissolved solids thus discharged.

COMPARISON OF RECENT ANALYSES WITH THOSE OF EARLIER YEARS

Few of the wells listed by Meinzer and Kelton (1913, p. 157–159) were sampled during the current investigation, as most of the old wells had been destroyed or could not be located. Comparison of data for the two periods is possible, however, at two places along the former El Paso & Southwestern Railroad. At Kelton junction the railroad well was sampled in 1910 and again, as well (D–19–25) 25ac, in 1946. At McNeal station the well that was sampled in 1910 was about one mile from well (D–21–26)24bab, which was sampled in 1946. The analyses, as shown in the following tabulation, indicate practically no difference in the constituents that were determined in the water samples in 1910 and in 1946.

Well	Date of collection	Parts per million		
		Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)
Kelton Junction	10-29-10	180	12	7
(D-19-25)25ac	5- 1-46	182	-------	7
McNeal Station	11-17-10	221	7	10
(D-21-26)24bab	3-27-46	222	12	9

Well (D–23–27)19dad was sampled in 1946, 1951, and 1952. The analyses show a considerable increase in dissolved-solids content of the water during these years. The well is close to a heavily pumped irrigation well. The heavy pumping may have caused movement of ground water toward the pumped well from a local area of highly mineralized water.

RELATION OF QUALITY OF WATER TO USE

IRRIGATION

Water being used for irrigation in most of the Douglas basin is "excellent to good" in quality as evaluated according to standards suggested by the U. S. Department of Agriculture (Wilcox, 1948, p. 26). Some of the water used for irrigation in the area along

Whitewater Draw, from T. 22 S. to the international boundary is in the "good to permissible" division. Two wells in this area yield water that is classified as "permissible to doubtful," and one well yields water classified as "doubtful to unsuitable."

Water having a boron content as much as 1 ppm is classified by Wilcox (1948, p. 27–28) as "permissible" to use in irrigating boron-sensitive crops, which include most fruit trees. This classification considers only the boron content but not other dissolved solids in the water. Only a few samples were analyzed for boron, all of which had less than 1 ppm boron.

DOMESTIC

Analyses made by the Geological Survey do not indicate the sanitary condition of the water analyzed. On the basis of the dissolved mineral content the water used in the basin for domestic purposes is generally of good quality. The ground water in the valley fill apparently increases in dissolved solids concentration as it moves southward toward the international boundary. Most of the water used for domestic purposes in the basin has less than 1,000 ppm of dissolved solids. This is the maximum amount considered acceptable for use as a municipal water supply and for drinking water to be used on interstate carriers (U. S. Public Health Service, 1946, p. 13). Water from a few wells along Whitewater Draw, about 6 miles north of Douglas, has more than 1,000 ppm of dissolved solids. Waters containing somewhat more than the suggested limits of dissolved mineral constituents have been used by many persons for long periods without apparent ill effects, although such waters might have a noticeable taste to one unaccustomed to them.

In most of the Douglas basin the ground water is fairly hard. The available analyses show that water from wells in most of the basin has a hardness of 100 ppm or more. The city of Douglas is supplied with water that is rather high in dissolved solids, but the water is unusually soft for the area, as it has less than 30 ppm of hardness as calcium carbonate. It would be expected that the water pumped from the city wells, which are west of Douglas near the international boundary, would be at least as hard as the water to the north. It is possible that the water has been softened by contact with cation-exchange minerals in the valley fill as it moves southward. Use of hard water for household purposes results in excessive consumption of soap. Detergents make it easier to wash dishes and clothes in hard water, or the water can be softened before use by various types of softeners. If hard water is used in hot-water tanks and boilers, objectionable scale is formed.

According to the U. S. Public Health Service standards (1946, p. 12) a satisfactory drinking water should not contain more than 1. 5 ppm of fluoride. Medical authorities agree that waters containing excessive amounts of fluoride can cause mottling of the tooth enamel of children who drink the water during the time their permanent teeth are forming. However, recent studies have shown that a small amount (about 1 ppm) of fluoride in drinking water may cause teeth to become more resistant to decay. Ground water containing more than 1. 5 ppm of fluoride is common in Douglas basin, as indicated by the available analyses. Therefore, it would be desirable to determine the fluoride content of drinking water to be used by families with young children.

Most of the nitrate present in ground waters of the Douglas basin probably is derived from sources other than contamination by human and animal wastes, although the presence of nitrate is sometimes an indication of such contamination. Waters containing more than about 45 ppm of nitrate are considered by some authorities (Maxcy, 1950) to be inadvisable for use in feeding infants, as the presence of a high nitrate concentration for such use has been associated with cases of methemoglobinemia, a "blue-baby disease." Only one of the samples analyzed (table 4) indicated a nitrate concentration in excess of 45 ppm.

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Table 1.—*Climatological data, Douglas basin*

[Data from Smith, 1945, p. 34, 36, 51, 53, 87, 88]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Douglas—altitude 3,973 feet													
Precipitation ______ in.__	0.62	0.77	0.45	0.26	0.22	0.54	3.19	2.86	1.31	0.77	0.81	0.94	12.74
Mean maximum temperature[1] ______ °F__	61.4	65.8	71.9	79.0	86.7	95.8	93.8	91.4	89.0	81.3	69.7	61.4	78.9
Mean minimum temperature[1] ______ °F__	29.2	33.0	37.3	42.7	49.6	59.2	65.8	64.4	59.2	46.8	35.7	30.2	46.1
Mean temperature[1] ______ °F__	45.3	49.4	54.6	60.8	68.2	77.5	79.8	77.9	74.1	64.0	52.7	45.8	62.5
Extreme maximum temperature ______ °F__	82	89	94	97	106	110	111	107	101	95	92	81	111
Extreme minimum temperature ______ °F__	-7	12	17	26	30	42	41	50	37	23	14	6	-7
Bisbee—altitude 5,350 feet													
Precipitation ______ in.__	1.15	1.37	0.95	0.45	0.25	0.61	4.17	4.63	2.10	1.08	1.01	1.38	19.15
Mean maximum temperature[2] ______ °F__	57.8	60.9	66.4	73.6	81.2	90.2	88.6	86.1	83.3	76.1	65.6	57.8	74.0
Mean minimum temperature[2] ______ °F__	34.6	36.7	40.7	46.0	53.7	62.2	64.1	62.4	58.9	50.1	40.9	35.4	48.8
Mean temperature[2] ______ °F__	46.0	48.5	53.3	59.8	67.2	76.1	76.3	74.1	71.3	63.0	53.1	46.5	61.3
Extreme maximum temperature ______ °F__	85	85	88	95	101	106	104	101	100	98	90	78	106
Extreme minimum temperature ______ °F__	8	11	23	28	32	38	53	47	41	28	16	13	8

[1] Means are for 50 years of record ending Dec. 31, 1940.
[2] Means are for 44 years of record ending Dec. 31, 1940.

Table 2.—*Records of representative wells and springs in Douglas basin*

Type of lift: C, cylinder; T, turbine; W, windmill; E, electric; G, gas; Dl, diesel.
Use of water: I, irrigation; D, domestic; S, stock; Ind, industrial; M, municipal; N, not used.
Remarks: H, see hydrograph, fig. 4; O, observation well; Ca, see chemical analysis, table 4; L, see log, table 3; Dm, discharge measured in gallons per minute; De, discharge estimated; Dr, discharge reported; Tt, transmissibility test in gallons per day per foot.

WELLS

Well no.	Owner	Depth of well (feet)	Diameter of well (inches)	Water level		Altitude of land surface at well (feet)	Type of lift	Use of water	Remarks
				Depth to water below land surface datum (feet)	Date measured				
(D-18-26)									
11bab	Mrs. Pressey	100	6	81.94	8-24-51	4,318	C, W	S	Ca.
15bcb	D. M. Ingle	110	6	89.30	6-28-51	4,292	C, W	D, S	Ca.
18bbb	—Stark	100	6	74.65	5-28-46	------	C, W	S	Ca.
21ddd	Frank Jeans	89	6	73.85	1-13-52	4,268	C, W	S	
22cba	------	------	6	474.00	9- 9-51	4,898	C, W	S	
(D-19-25)									
25acc	Lewis C. Grizzle	650	12	------	------	------	T, G	I, D	Ca, Dm585.
(D-19-26)									
1aaa	Frank Geer	------	6	124.03	8-14-51	4,324	C, W	D. S	Ca.
26aba	—	154	6	131.55	1-16-52	4,280	C, W	S	H.
29bab-2	George Berry	60	16	43.36	1-13-52	4,196	T, E	I	O.
30aab	John Morris	------	------	[1]90	------	------	T, E	I	Ca, Dm250.
(D-20-26)									
6abb-1	J. M. Peevey	72	12	49.60	1-17-52	------	T, E	I	Ca, Dm670.
11ddd	W. P. Cheek	106	10	49.10	1-14-52	4,298	C, W	D, S	H.
12bba	W. H. Seaver	150	10	94.62	12-31-51	4,232	T, E	D, S	Ca, O.
16daa	D. C. Sherman	133	16	48.28	1-18-52	4,150	T, E	I	L, Dm520.
33add-1	F. O. Mackey	64	16	38.78	1-14-52	4,124	T, E	I	H.
(D-20-27)									
18daa-2	L. I. Kennedy	600	14	81.90	1-29-52	------	T, E	I	L, Dm280.
(D-21-25)									
1ddb	Ralph Cowan	1,012	12	3.77	3- 7-52	4,121	C, W	S	L, artesian.
23aab	Clarence Davis	------	6	88.35	1-14-52	------	C, W	D, S	Ca.
25aaa	Webb Schoolhouse	------	8	67.75	1- 1-52	4,117	C, W	D	

(D-21-26)									
1bdc	Ames and Brockman	200	12	------	------	------	T, E	I	Ca, Dm260.
17ccc	Mrs. Yard	118	14	27.17	12-19-51	4,079	T, G	I	Dm550.
21dda	J. W. Franklin	154	12	60.90	12-27-51	4,101	T, E	I	Dm90.
23ab	L. C. Pinkard	505	20	95.94	1-25-52	4,161	T, E	I	L, De600.
24aab	McNeal Cemetery	136	8	121.43	1-14-52	4,196	C, W	I	Ca, H.
26dcd	J. K. Shearman	364	16	112.75	12-27-51	4,159	T, E	I, D	L, Dm330.
28ddc	Howard E. Ames	250	12	57.85	12-27-51	4,089	T, E	I	L, Dm280.
29dda	S. Pinedo	111	12	------	------	------	T, E	I	Ca, Dm390.
(D-21-27)									
13cdd	Jesse Eades	122	12	62.25	12-18-51	4,487	------	N	Ca.
28ccc	Ralph Cowan	300	6	222.79	12-20-51	4,293	C, W	S	L.
(D-21-28)									
3baa	S. S. Shattuck	1,517	------	[1]800	------	------	------	------	L.
(D-22-25)									
24da	—	------	------	[1]70	------	------	C, W	S	Ca.
(D-22-26)									
4daa	—Holman	250	12	67.68	12-10-51	4,094	T, G	I	L, Dm170.
5dda	E. M. Downs	100	12	42.39	1-14-52	------	T, E	I	Dm130.
28baa	J. E. Brophy	500	12	26.40	2- 5-46	------	T, E	I	Ca, De200.
27bca	W. W. Harsha	210	14	------	------	------	T, E	I	Ca.
34ada	Homer McBride	145	12	61.79	2- 2-52	------	T, E	I	Dm340, Tt9,000
(D-22-27)									
5b	Waddell-Duncan Oil Co.	4,210	11	0	8-31-51	------	------	S	Ca, L. Oil test, artesian flow, De100.
34cd	Douglas Airport	420	13	------	------	------	------	Ind.	L, Dr55.
(D-23-26)									
1aad	D. C. McDaniels	256	12	66.60	1-14-52	------	T, E	I	L, Dm145, Tt5,100.
3aab	H. P. Jacoby	75	10	------	------	------	T, E	I, D	Ca, Dm170.
12bbb	Dan C. Cravey	100	12	------	------	------	T, E	I	Ca, Dm150.
(D-23-27)									
19dad	W. E. Mason	39	Dug	29.97	12-11-46	------	------	N	Ca.
19dbc	Fred M. Schukraft	150	12	------	------	------	T, E	I	Ca.
24cbb	Harry Watson	197	6	179.30	12-28-51	4,091	------	------	
27cdd	—McGintry	62	Dug	54.15	1- 9-52	3,947	------	------	H.
(D-23-28)									
15ac	—Bloomquist	175	6	115.52	8-18-47	------	C, W	S	Ca.
30cc	Chap Howard	230	6	193.18	12-28-51	4,077	C, W	D, S	
(D-24-26)									
1bbd	—Clarkson	321	16	------	------	------	T, E	I	L.
1ccb	Walter Holland	110	6	111.65	1- 9-52	4,073	C, W	D, S	
6acc	J. C. Mulhern	210	6	184.63	1-31-52	4,217	C, W	D	O.

Table 2.—*Records of representative wells and springs in Douglas basin*—Continued

WELLS—Continued

Well no.	Owner	Depth of well (feet)	Diameter of well (inches)	Water level: Depth to water below land surface datum (feet)	Water level: Date measured	Altitude of land surface at well (feet)	Type of lift	Use of water	Remarks
(D-24-27)									
3ccc	Cochise Co. Hospital	265	6	69.70	1- 9-52	3,948		N	H.
3cdd	—	27	Dug	22.44	2-28-52	3,931	C, W	D, S	Ca.
4ccb	Leonard Burns	300	16				T, D	I	Dm360.
5bcc	L. L. Keith	82	Dug	58.37	1-14-52	4,000	C, W	D, S	Ca, H.
8bcc	George Hanigan	460	14	68.02	1- 9-52	4,009	T, E	I	Dm280, Tt9,500.
10dbb	City of Douglas	350	12	61.00	2-20-52	3,923	T, E	M	Ca, Dr1,000.
10dca	Ariz. State Highway Dept.	24	1	13.27	6-17-48				Ca, O.
13bbd	Southern Pacific RR.	250	13	101.05	1-15-52	3,970	T, E	Ind, D	L, Dr150.
15baa	Phelps-Dodge Corp.	950	12	62.90	2-20-52	3,933	T, E	Ind.	L, Dr950.
17aaa	R. M. Johnston	65	6	51.80	1- 9-52	3,979	C, W	D	O.
(D-24-28)									
7abc	Richard Mealins	335	12	151.83	2-20-52	4,026	T, E	I	L.
11bca	George Rogers	190	6	86.23	3-13-52		C, W	S	Ca.
14cda	George Rogers		6	62.10	2-11-52		C, W	D, S	Ca.
(D-24-29)									
18bcd	George Rogers	160	6	154.61	2-11-52		C, W	S	Ca.

SPRINGS

Spring no.	Owner	Flow (gpm)	Geologic source	Temperature (°F)	Improved	Use	Date investigated	Remarks
(D-18-24)								
28cd	—Stearns	½	Volcanic rocks		Yes	S	9-18-51	
34cc-1	—Stearns	2	Sandstone and tuff (?)	75	Yes	S	9-18-51	Ca, Walnut Spring.
(D-19-29)								
10dd	Sid Vail	15	Volcanic rocks	61			10- 4-51	Ca, In John Long Canyon.
14ad	Mrs. Dana	2	do		Yes	S	10- 2-51	Sycamore Spring.
21dc	—Ryers	2	do	69	Yes	D	10- 4-51	Ca, Tributary of Rucker Canyon.

(D-20-24) 21ca	J. Harmon	¼	do	76	Yes	S	9-19-51	Ca, Antelope Spring.
(D-20-28) 31bd	Jesse Eades	2	Limestone and shale	69	Yes	D, S	10- 5-51	
(D-21-28) 21bc	–Kimble	60	Alluvium	73	Yes	S	10- 3-51	Ca, Leslie Spring.
(D-22-24) 29bc	A. C. Stevenson	4½	Schist, sandstone contact	72	----	----	9-20-51	Ca.

EFFLUENT SEEPAGE ENTERING WHITEWATER DRAW

Surface water location no.	Flow (gpm)	Geologic source	Date investigated	Remarks
(D-23-27) 28cab	7	Alluvium	3-14-52	Ca.
(D-24-27) 10db	25	do	2-12-52	Ca.

[1] Water level reported.

Table 3.—*Logs of representative wells in Douglas basin*

	Thickness (feet)	Depth (feet)
(D–20–26)16daa		
Soil and clay	31	31
Sand, water	1	32
Clay	12	44
Sand, water	6	50
Clay	12	62
Sand, water	3	65
Clay	11	76
Sand, water	3	79
Clay	10	89
Sand and gravel	3	92
Clay	20	112
Sand and gravel	2	114
Clay	6	120
Clay and gravel	13	133
(D–20–27)18daa		
Sand, clay, and boulders	86	86
Sand	2	88
Clay	434	522
Granite	18	540
Gravel	8	548
Granite or blue quartz	22	570
Gravel	6	576
Granite	14	590
Sand and gravel with gold-bearing quartz	10	600
(D–21–25)1dd		
Adobe	56	56
Fine sand, first water	4	60
Hard clay	34	94
Sand, slight showing of water	2	96
Hard clay	94	190
Gravel	4	194
Sticky clay	86	280
Clay fault, fairly strong showing of water	5	285
Sandy clay	65	350
Clay, very sandy	10	360
Water, gravel, slight increase in water, hard clay	6	366
Hard clay	12	378
Clay and gravel mixed	96	472
Strong water strata, water raised within 5' of surface	12	484
Red clay, very sticky	16	500
Sand, gravel, and clay mixed	42	542
Light-gray clay, very hard	3	545
Sand and gravel, water raised within 3'6" of surface	17	562
Yellow clay, very sticky	66	628
Hard sand	2	630
Water, gravel and sand, water raised within 2'6" of surface	25	655
Red clay	6	661
Hard sand	12	673

	Thickness (feet)	Depth (feet)
***(D–21–25)1dd*—Con.**		
Yellow sticky clay	29	702
Red sticky clay	28	730
Dark-red clay with gravel embedded	95	825
Water gravel	9	834
Very hard clay with streaks of hard sand about one-inch thick	156	990
Gypsum with fine sand showing increase in water; the well started to run over at this depth	22	1,012
(D–21–26)23abb		
Top soil	5	5
Caliche and clay	10	15
Clay	77	92
Sand, gravel, and water	2	94
Clay	14	108
Gravel and water	3	111
Clay	49	160
Sand	2	162
Clay	39	201
Sand	3	204
Clay	96	300
Clay, tough and gravelly	30	330
Clay, sticky	16	346
Gravel	4	350
Clay	20	370
Clay	63	433
Gravel	4	437
Clay	9	446
Gravel	3	449
Clay	11	460
Gravel	16	476
Clay	6	482
Gravel	5	487
Clay	5	492
Gravel	9	501
Clay	4	505
(D–21–26)26dcd		
Top soil, black	4	4
Rocks, gray clay, and conglomerate	16	20
Clay, red and hard	50	70
Clay, soft and sandy	16	86
Sand and gravel, dry	6	92
Conglomerate, light-red and hard	17	109
Water	6	115
Clay, red and soft, and conglomerate	41	156
Water	2	158
Clay, gray, with hard and soft streaks	28	186
Conglomerate, light-red and soft	31	217
Clay, gray and soft	3	220
Conglomerate, light-brown and hard	35	255
Water	2	257

Table 3.—*Logs of representative wells in Douglas basin*—Continued

	Thickness (feet)	Depth (feet)
(D–21–26)26dcd—Con.		
Clay and conglomerate gray and hard	22	279
Clay, hard and in streaks, water rose 2 feet	1	280
Clay and conglomerate, gray and in streaks	58	338
Water	2	340
Clay and hard conglomerate, gray and in streaks	24	364
(D–21–26)28dcd		
Top soil	4	4
Clay, small amount of water at 54 feet	50	54
Clay	12	66
Clay	20	86
Sand and gravel with water	1	87
Clay	99	186
Clay, jointed	2	188
Clay, sandy with water	12	200
Clay	50	250
(D–21–27)28ccc		
Sand and gravel	18	18
Yellow clay, gravel imbedded	216	234
Gravel and clay (about 550 gal. water in 24 hours)	6	240
Tight clay	29	269
Sand and gravel (water rose to 225')	12	281
Hard brown clay	19	300
(D–21–28)3baa		
Fill	1,020	1,020
Limestone; water would bail out at 1,165 feet	180	1,200
Porphyry	65	1,265
Limestone	252	1,517
(D–22–26)4dad		
Soil, sandy	15	15
Clay, red	22	37
Clay and boulders	5	42
Sand and gravel	4	46
Clay and small rocks	19	65
Sand and gravel with water	2	67
Clay and small rocks	4	71
Clay, red	18	89
Sand and gravel with water	4	93
Clay and small rocks	23	116
Clay	19	135
Caliche	10	145
Clay and rocks	5	150
Caliche	16	166
Clay, red, with rocks	66	232
Sand and gravel with water	11	243
Clay, red	7	250
(D–22–27)5b		
Clay and silty sand	110	110
Red and gray pebbly sand	280	390
Red, silty sand	110	500
Red, coarse sand	120	620
Red and gray coarse sand	640	1,260
Gray and red sand	345	1,605
Interbedded limestone and quartzite	660	2,265
Pink quartzite and limestone	60	2,325
Limestone and shale	430	2,755
Red sandstone	130	2,885
Alternating beds sandstone and dolomite	210	3,095
Red-brown and gray dolomite	130	3,225
Various colored dolomite	70	3,295
Gray limestone	145	3,440
Gray sandstone	245	3,685
Various colored quartzite	120	3,805
Quartzite and sandstone	80	3,885
Arkosic quartzite	35	3,920
Granite	75	3,995
Granite	215	4,210
(D–22–27)34cd		
Soil	5	5
Red clay	25	30
Gray clay	35	65
Red clay	32	97
Conglomerate (clay, sand, gravel)	46	143
Hard pan (sandy clay)	50	193
Water gravel	2	195
Hard pan (sandy clay)	5	200
Clay	6	206
Sand and gravel, water	2	208
Hard pan (sandy clay)	3	211
Red clay	9	220
Water gravel	$1\frac{1}{2}$	$221\frac{1}{2}$
Clay, gravel and rock mixed	$15\frac{1}{2}$	237
Concrete light sandy clay	86	323
Hard pan and rocks (sand clay, rocks)	47	370
Several small water strata (clay and sand mixed)	38	408
Red clay	12	420
(D–23–26)1aa		
Soil and clay	60	60
Clay and sand with water	30	90
Gravel with water	20	110
Clay strata and sand strata with water	40	150
Clay, red	36	186
(D–24–26)1bbd		
Top soil	6	6
Gravel	24	30

Table 3.—*Logs of representative wells in Douglas basin*—Continued

	Thickness (feet)	Depth (feet)
(D–24–26)1bbd		
Gray clay	4	34
Gravel	4	38
Gray clay	21	59
Gravel	2	61
Gray clay	7	68
Gravel	7	75
Red clay	31	106
Gray clay	8	114
Water gravel	1	115
Gray clay	15	130
Red clay	4	134
Gray clay	21	155
Conglomerate	3	158
Gray clay	16	174
Red clay	1	175
Chalk	2	177
Red clay	4	181
Water gravel	3	184
Conglomerate	3	187
Gravel	10	197
Red clay	14	211
Water sand	5	216
Red clay	6	222
Sandstone	7	229
Red clay	12	241
Conglomerate	3	244
Water sand and gravel	9	253
Sandstone	2	255
Sand	3	258
Red clay	7	265
Water gravel	4	269
Conglomerate	5	274
Gray clay	2	276
Gravel	2	278
Gray clay	2	280
Conglomerate	17	297
Red clay	4	301
Gray clay	15	316
Sand	1	317
Red clay	4	321
(D–24–27)13bbd		
Soil	6	6
Gravely clay	6	12
Clay	24	36
Shale	6	42
Clay and gumbo	25	67
Shell rock and water	2	69
Clay	47	116
Shale	5	121
Water sand and gravel	3	124
Gravel and gumbo	18	142
Clay	11	153
Shale	7	160
Water sand and gravel	4	164
Gravely gumbo	16	180
Clay	7	187
Gravely gumbo	3	190
Clay	6	196
Water-bearing strata	6	202
Gravely gumbo	23	225
Water gravel and boulders	12	237
Gravely gumbo	13	250

	Thickness (feet)	Depth (feet)
(D–24–27)15baa		
Top soil	3	3
Sand soil—surface water	30	33
Gravel	27	60
Fine sand	8	68
Gypsum	2	70
Red, sticky clay	144	214
Light-brown clay	127	341
Malpais and clay	5	346
Malpais—surface water disappeared	18	364
Conglomerate	14	378
Malpais	17	395
Sand	3	398
Red clay	32	430
Brown clay	25	455
Sand	2	457
Finer sand	33	490
Light-brown clay	55	545
Hard sand	10	555
Coarse sand and gravel	4	559
Light-brown clay	6	565
Sand	35	600
Hard clay	14	614
Sand	12	626
Coarse sand and gravel	4	630
Hard clay	8	638
Hard sand	4	642
Coarse sand	5	647
Sticky clay	27	674
Hard sand and gravel	4	678
Sticky clay	12	690
Fine sand	4	694
Sticky clay	9	703
Hard sand	5	708
Sticky clay	2	710
Hard sand	6	716
Hard clay	15	731
Hard sand	16	747
Sticky clay	14	761
Hard sand	20	781
Very sticky clay	52	833
Struck water	------	833
Sand and gravel, water	23	856
Clay	32	888
Sand	47	935
Hard clay	15	950
(D–24–28)7abc		
Top soil	2	2
Caliche	3	5
Boulders and clay	29	34
Clay, red	9	43
Conglomerate	106	149
Gravel, water	3	152
Conglomerate	28	180
Gravel, water	6	186
Conglomerate	29	215
Gravel, water	2	217
Malpais (i. e., basalt)	105	322
Water	10	332
Clay, red	3	335

Table 4.—*Analyses of water from selected wells and springs in Douglas basin*

[Data in parts per million except specific conductance and percent sodium]

Location no.	Date of collection	Temperature (° F.)	Specific conductance (micromhos at 25° C.)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium
WELLS															
(D-18-26)															
11baa	5-30-46	67	196	----	20	5.1	16	107	7.6	4	0.8	3.3	110	71	33
15bbc	5-28-46	70	286	----	30	5.2	26	141	18	6	3.0	3.0	161	96	37
18bbb	5-28-46	70	500	----	33	14	61	236	23	23	1.2	25	296	140	49
(D-19-25)															
25acc	5- 1-46	78	347	----	------	------	---------	182	------	7	4.4	------	------	------	------
(D-19-26)															
1aaa	5-28-46	75	347	----	------	------	---------	161	------	17	4.4	------	------	------	------
30aab	2-12-52	69	261	37	34	7.0	10	129	10	8	2.0	3.8	176	114	16
(D-20-26)															
6aba	6-14-46	68	339	----	------	------	---------	[1]158	------	20	2.4	------	------	------	------
12bba	2-27-46	70	237	----	29	1.6	25	136	12	5	.8	.8	141	79	41
(D-21-25)															
23ab	2-12-52	69	613	30	36	7.6	86	202	42	59	2.8	11	374	121	61
(D-21-26)															
1bdc	5-29-46	70	516	----	56	18	30	250	39	20	1.6	2.3	290	214	24
24bab	3-27-46	73	383	----	38	13	30	222	11	9	1.6	5.8	218	148	31
29dda	6-15-46	68	686	----	64	27	43	[1]249	37	79	1.2	7.8	382	270	26
(D-21-27)															
13cdd	8-15-47	--------	563	31	69	12	39	254	50	21	.4	20	368	222	28
(D-22-25)															
24da	2-12-52	69	410	27	66	7.9	11	245	7.8	6	.0	4.5	251	197	11
(D-22-26)															
21ca	2- 5-46	--------	1,050	32	55	16	152	255	123	131	3.1	3.8	[2]642	203	62
27bca	6-17-46	68	500	----	53	13	35	201	40	36	.8	4.0	281	186	29
(D-22-27)															
5b	3- 7-51	129	1,420	8.5	30	10	290	[3]413	322	40	6.0	.1	910	116	84
(D-23-26)															
3aab	5-31-46	68	923	----	66	16	109	237	106	112	.7	2.7	529	230	51
12bbb	5-31-46	66	1,690	----	200	25	150	187	537	150	.1	5.9	1,160	602	35
(D-23-27)															
19dad	2- 5-46	--------	3,340	----	180	93	429	261	484	740	.6	.4	[2]2,060	832	53

Table 4.—*Analyses of water from selected wells and springs in Douglas basin*—Continued

Location no.	Date of collection	Temperature (°F.)	Specific conductance (micromhos at 25°C.)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium
WELLS—Continued															
(D-23-27)—Con.															
19dad	10-16-51	--------	4,630	----	-------	-------	---------	270	------	1,060	0.8	------	--------	-------	-------
19dad	5-28-52	80	7,130	26	380	212	966	249	1,140	1,790	1.0	4.2	4,640	1,820	54
19dbc	10-16-51	--------	2,500	----	-------	-------	---------	208	------	575	.7	------	--------	-------	-------
(D-23-28)															
15acc	8-18-47	80	634	----	63	34	31	368	35	14	.8	5.7	365	297	18
(D-24-26)															
1cb	2- 5-46	--------	623	----	62	17	51	264	49	44	.8	3.9	358	224	33
(D-24-27)															
3cdd	5-28-52	78	988	19	4.5	1.1	209	176	96	153	2.6	2.5	575	16	97
5bcc	2- 5-46	--------	623	----	-------	-------	---------	254	34	53	------	------	--------	-------	-------
10dbb	9-12-51	76	1,600	21	6.2	2.4	326	[4]172	183	288	3.2	1.8	[5]919	25	96
10dca	6-16-48	68	3,600	31	68	57	661	[6]291	774	550	1.6	21	2,310	404	78
(D-24-28)															
11bca	3-13-52	67	2,950	28	556	154	54	207	1,810	48	1.2	16	2,770	2,020	5
14cda	2-11-52	68	1,170	32	149	56	20	286	265	46	.8	85	795	602	7
(D-24-29)															
18bcd	3-13-52	78	779	31	85	41	27	269	200	6	.7	.2	524	380	15
SPRINGS															
(D-18-24)															
34cc.	9-18-51	75	585	18	96	14	14	326	46	6	.2	4.8	236	297	9
(D-19-29															
10dd	10- 4-51	61	176	31	22	4.0	8.5	70	26	3	.4	.4	129	79	21
21dc	10- 4-51	69	373	51	53	6.6	21	235	2.3	5	.9	.9	257	159	22
(D-20-24)															
21ca	9-19-51	76	618	45	71	15	47	332	42	14	.9	3.8	403	238	30
(D-21-28)															
21bc	10- 3-51	73	577	33	96	11	16	293	36	5	.4	42	383	284	11
(D-22-24)															
29bc	9-20-51	72	223	20	30	5.7	7.8	108	20	3	.6	.6	141	98	15

TABLE 4

EFFLUENT SEEPAGE ENTERING WHITEWATER DRAW

(D-23-27) 28cab	3-14-52	50	950	9.5	50	16	137	194	239	55	.6	1.3	604	191	61
(D-24-27) 10db	2-12-52	47	2,090	5.1	76	46	299	181	295	404	.9	1.7	1,220	378	63

[1] Includes equivalent of 8 ppm CO_3.
[2] 0.1 ppm boron present.
[3] Includes equivalent of 12 ppm CO_3.
[4] Includes equivalent of 21 ppm CO_3.
[5] 0.28 ppm Fe.
[6] Includes equivalent of 20 ppm CO_3.

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