Ground-Water Geology of Parts of Laramie and Albany Counties Wyoming, and Weld County, Colorado

By H. M. BABCOCK *and* L. J. BJORKLUND

With a Section on

CHEMICAL QUALITY OF THE GROUND WATER

By L. R. KISTER

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1367

A reconnaissance of the geology and ground-water resources of the Crow Creek and Lone Tree Creek drainage basins. Prepared as part of the program of the Department of the Interior for development of the Missouri River basin

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GROUND-WATER GEOLOGY OF PARTS OF LARAMIE AND ALBANY COUNTIES, WYOMING, AND WELD COUNTY COLORADO

By H. M. Babcock and L. J. Bjorklund

ABSTRACT

The area described in this report is in southern Laramie County and southeastern Albany County, Wyo., and in northwestern Weld County, Colo. It includes the part of the drainage basins of Crow Creek and Lone Tree Creek that lies upslope from the irrigation canals of the South Platte River irrigation system. Throughout most of the northern part of the area, the topography is typical of the High Plains and consists of a high, nearly flat, gently rolling surface. Most of the southern part of the area consists of a comparatively level lowland, which, in most places, is separated from the upland by an east-west-trending escarpment.

The rocks exposed in the report area range in age from Precambrian to Quaternary. The older sedimentary rocks, which are exposed in the extreme western part of the report area, dip steeply eastward and lie at great depths beneath the central and eastern parts of the area; the Fox Hills sandstone of Late Cretaceous age is the oldest formation that lies close enough to the land surface to be considered an important source of ground water. The Fox Hills sandstone and the Laramie formation, both of which are of Late Cretaceous age, yield moderate quantities of water under artesian pressure to a few wells in the southern part of the area. The Brule formation of Oligocene age yields moderate to large quantities of water in a few places where fissures, fractures, or zones of pebbles are penetrated by wells. The Ogallala formation of Pliocene age, which underlies most of the upland, yields moderate quantities of water to wells in an area west of the city of Cheyenne. East of Cheyenne, the saturated thickness of the Ogallala formation is not sufficient for that formation to yield large quantities of water to wells, but supplies adequate for stock and domestic use can be developed. The terrace deposits and the alluvium along the principal stream valleys are the source of water for most of the irrigation wells in the report area. Most of these wells are in the Carpenter-Hereford-Grover area in the Crow Creek valley.

The 84 irrigation wells in the report area include 65 in Weld County, Colo., and 19 in Laramie County, Wyo. During 1952, 78 of these wells were pumped—59 in Colorado and 19 in Wyoming. The total pumpage (approximately 7,000 acre-feet of water) irrigated about 3,500 acres of land—of this total, 2,050 acres are in Colorado and 1,450 acres are in Wyoming. The unconsolidated alluvium and terrace deposits in the Carpenter-Hereford-Grover area probably are the only aquifers in the report area in which additional wells of large yield could be developed.

The ground-water reservoir is recharged principally by infiltration of precipitation that falls within the area and by influent seepage from intermittent streams. Discharge from the ground-water reservoir is by evapotranspiration, streams, underflow out of the area, pumping wells, and springs.

Samples of water collected from wells that tap the Fox Hills sandstone had a relatively high concentration of sodium carbonate; samples from the Brule and Ogallala formations, like those from the terrace deposits and alluvium, were principally of the calcium bicarbonate type. Water from Crow and Lone Tree Creeks resembled that from the younger rocks in the area in both concentration and chemical character.

INTRODUCTION

PURPOSE OF THE INVESTIGATION

This investigation is one of several being made by the U. S. Geological Survey as part of a program for conservation, development, and use of water resources of the Missouri River basin. (See fig. 1.) The purpose of this investigation was to summarize

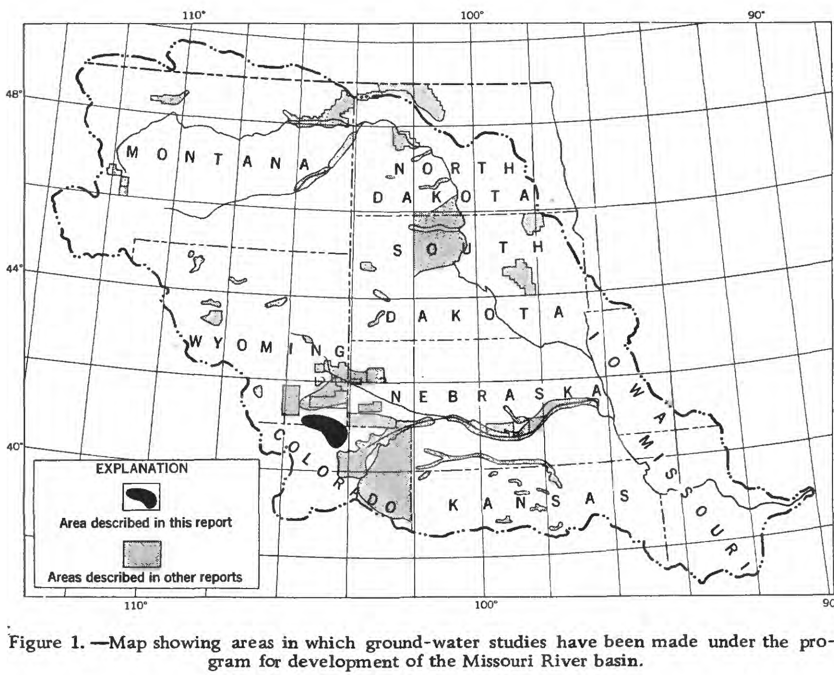

Figure 1.—Map showing areas in which ground-water studies have been made under the program for development of the Missouri River basin.

existing reports pertaining to ground-water supplies in the Crow Creek and Lone Tree Creek drainage basins; to collect and analyze additional data on public, industrial, and irrigation pumping; to delineate areas in which large-scale pumping may be increased or in which present or future ground-water withdrawals may exceed the perennial yield of the aquifers; to determine the chemical quality of the ground water and the geochemical relations; to ascertain the suitability of the water for domestic and irrigation use; and to recommend the extent and type of ground-water studies needed to guide future developments.

PREVIOUS INVESTIGATIONS

The area described in this report and other areas in southeastern Wyoming and northwestern Colorado in which ground-water studies have been made are shown in figure 2. Reports on

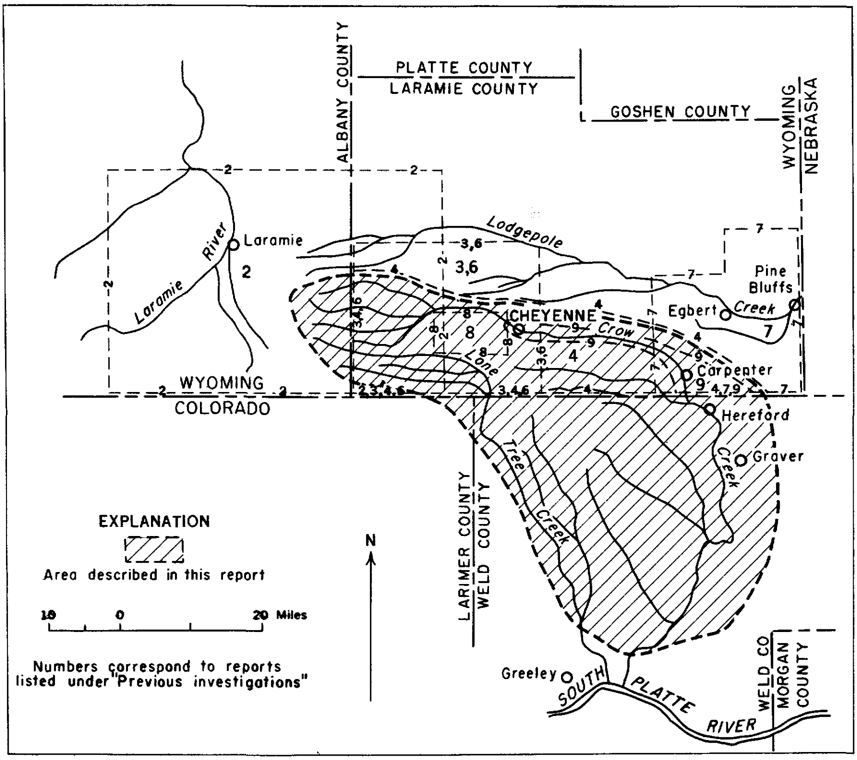

Figure 2.—Index map of southeastern Wyoming and northeastern Colorado showing area of this report and other areas in which ground-water studies have been made.

these investigations (see items 1–4, 6–9, below) and other literature pertaining to the regional geology or water resources (see items 5 and 10, below) are referred to in the text of this report and are listed in the following annotated bibliography:

1. Cady, R. C., 1935, Report on the test well at the Veterans Administration Facility, Cheyenne, Wyo.: U. S. Geol. Survey open-file report, Washington, D. C., and Cheyenne, Wyo. (Describes the geology and gives records of wells in the vicinity of Cheyenne; includes a sample log of the deep test well drilled at the V. A. Hospital; and contains chemical analyses of water collected at various depths during the drilling of the well.)

2. Darton, N. H., Blackwelder, Eliot, and Siebenthal, C. E., 1910, Description of the Laramie and Sherman quadrangles, Wyoming: U. S. Geol. Survey Geol. Atlas, folio 173. (Describes the geology and contains a brief discussion of the water-bearing properties of some of the geologic formations.)

3. Foley, F. C., 1943, Progress report on geology and ground-water resources of the Cheyenne area, Wyoming: U. S. Geol. Survey open-file report, Washington, D. C., and Cheyenne, Wyo. (Describes an area in southwestern Laramie County where a detailed study of the geology and ground-water resources was made in order to determine the possibilities of developing additional water supplies in the Cheyenne area. Gives the hydrologic properties of the water-bearing formations and discusses the occurrence, source, movement, and recovery of ground water. Includes a geologic map, water-table contour map, geologic sections, and graphs showing fluctuations of the water level in wells. Contains tables of well records and logs of wells and test holes.)

4. Knight, S. H., and Morgan, A. M., 1937, Report on the underground water resources of Crow Creek valley, Laramie County, Wyo.: Wyoming Geol. Survey. (Briefly discusses the water-bearing properties of the geologic formations exposed in the drainage basin of Crow Creek, within Laramie County, Wyo. Contains a map showing the geology, location of wells, and depth to water.)

5. Lohr, E. W., and Love, S. K., 1954, The industrial utility of public water supplies in the United States, 1952, pt. 2, states west of the Mississippi River: U. S. Geol. Survey Water-Supply Paper 1300. (This report contains descriptive information and analytical data on the public water supplies in the states west of the Mississippi River.)

6. Morgan, A. M., 1946, Progress report on geology and ground-water resources of the Cheyenne area, Wyoming: U. S. Geol. Survey open-file report, Washington, D. C., and Cheyenne, Wyo. (Discusses the occurrence, source, movement, quality, and recovery of ground water. Contains some additional information on wells and logs of wells not given in Foley's 1943 report.)

7. Rapp, J. R., Warner, D. A., and Morgan, A. M., 1953, Geology and ground-water resources of the Egbert-Pine Bluffs-Carpenter area, Laramie County, Wyo.: U. S. Geol. Survey Water-Supply Paper 1140. (Describes an area in the southeastern part of Laramie County where a detailed study of the geology and ground-water resources was made along the valleys of Lodgepole Creek and Crow Creek to determine the extent of ground-water development and the possibilities of additional development. Discusses the occurrence, source, movement, and chemical character of the ground water. Includes a geologic map, water-table contour map, depth-to-water map, and geologic sections. Contains results of chemical analyses, logs of wells and test holes, and well records.)

8. Theis, C. V., 1941, Preliminary memorandum on ground-water supply of Cheyenne, Wyo.: U. S. Geol. Survey open-file report, Washington, D. C., and Cheyenne, Wyo. (Describes the geology of the area west of Cheyenne and gives results of pumping tests made to determine the transmissibility of the aquifers from which the city wells obtain water.)

9. United States Bureau of Agricultural Economics, 1943, A war-time water facilities plan for the Carpenter area, Crow Creek drainage basin, Laramie County, Wyo.: U. S. Dept. Agriculture, Bureau Agr. Econ. (Discusses development of ground water for irrigation in the valley of Crow Creek in the vicinity of Carpenter, Wyo., and contains information on the cost of pumping water.)

10. United States Geological Survey, Water levels and artesian pressure in observation wells in the United States, pt. 5, Northwestern States: U. S. Geol. Survey Water-Supply Papers 910, 940, 948, 990, 1020, 1027, 1075, 1100, 1130, 1160, 1169, 1195, and 1225, for the years 1940–52, inclusive. Reports for 1953 and 1954 are in preparation. (Annual publications giving water levels and artesian pressures in observation wells.)

METHODS OF INVESTIGATION

Studies for this report were started in September 1952 under the general supervision of A. N. Sayre, chief of the Ground Water Branch of the U. S. Geological Survey, and G. H. Taylor, regional engineer in charge of the ground-water investigations in the Missouri River basin. The quality-of-water studies were made under the general supervision of S. K. Love, chief of the Quality of Water Branch, U. S. Geological Survey, and P. C. Benedict, regional engineer in charge of quality-of-water studies in the Missouri River basin. The field work for the investigation was completed in January 1953.

Records were obtained for 180 wells, including 122 wells of large-discharge that are used for irrigation, public supply, and industry. Well owners, tenants living on property where wells are situated, and drillers were interviewed regarding wells, and all available well logs were collected. Detailed information regarding depth of well, depth to water, geologic source of water, discharge, drawdown, and acreage irrigated was collected for most of the irrigation wells. A steel tape was used to measure the depth to water and the total depth of the wells. These measurements, as well as other information about the wells and reported data for those wells that were not measured, are included in tables 3 and 4 of this report. A study was made of well records previously obtained during ground-water investigations in Wyoming, and many of these records are included in the tabulation.

For several years prior to this investigation, measurements of water levels in observation wells in the vicinity of Cheyenne and Carpenter, Wyo., had been made by the U. S. Geological Survey in cooperation with the Wyoming State Engineer and the Cheyenne Board of Public Utilities. Because these measurements have already been published, they are not tabulated in this report; however, the discussion of water-level fluctuations in this report is based largely on a study of the published measurements.

Chemical analyses of water samples collected from nine wells in Weld County, Colo., were made in the laboratory of the U. S. Geological Survey at Lincoln, Nebr. Records of the chemical analyses of 11 samples of water collected during previous investigations in Wyoming also were studied.

WELL-NUMBERING SYSTEM

The wells listed in this report are numbered according to their location within the U. S. Bureau of Land Management's survey of the area. All wells are within the sixth principal meridian and baseline system. The first numeral of the well number denotes the township, the second denotes the range, and the third denotes the section in which the well is located. The lowercased letters following the well number show the location of the well within the section. The first letter indicates the quarter section and the second letter indicates the quarter-quarter section. These subdivisions are designated a, b, c, and d, the letters being assigned counterclockwise beginning in the northeast quarter of the section or quarter section. If two or more wells are located within the same quarter-quarter section, consecutive numbers, beginning with 1, follow the lowercased letters. (See fig. 3.)

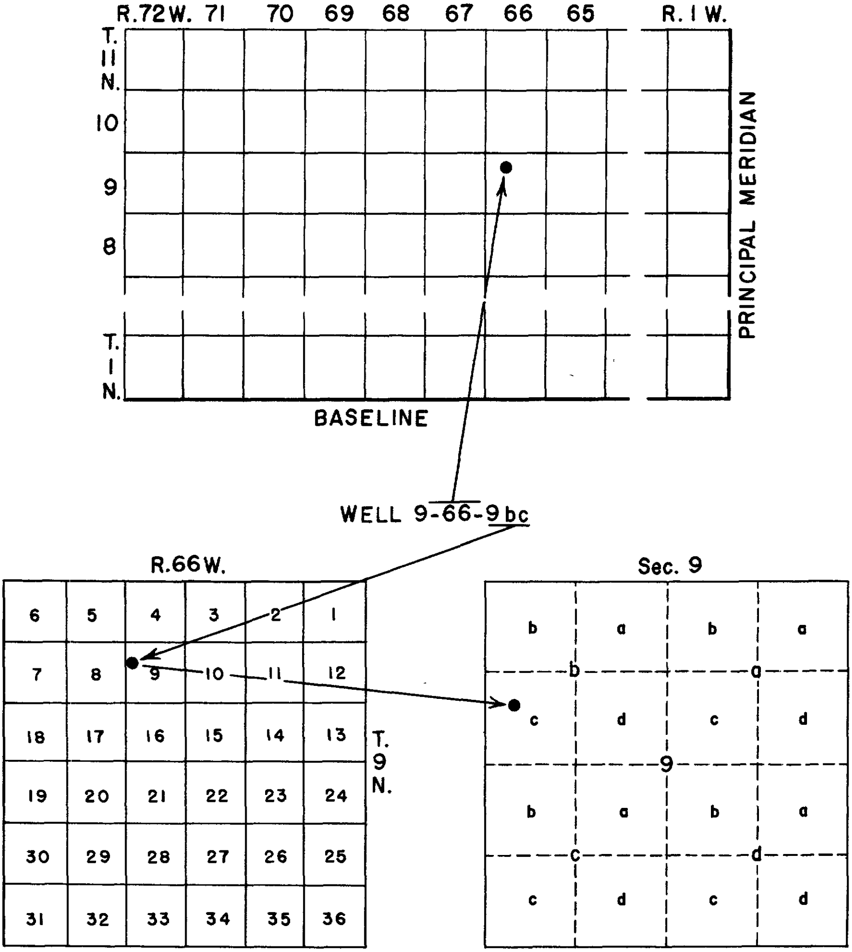

Figure 3. —Well-numbering system.

GEOGRAPHY

LOCATION AND EXTENT OF AREA

The area described by this report lies in southern Laramie County and southeastern Albany County, Wyo., and in northwestern Weld County, Colo., within Tps. 7 through 15 N., Rs. 61 through 72 W., sixth principal meridian and baseline. The maximum east-west length of the area is about 68 miles, and the maximum width (north-south) is about 50 miles. The area covers about 2,000 square miles and includes the part of the Crow Creek and Lone Tree Creek drainage basins that lies upslope from the irrigation canals of the South Platte River irrigation system in Colorado. (See pl. 1.)

TOPOGRAPHY AND DRAINAGE

The extreme northwestern part of the report area is in the Laramie Range of the Southern Rocky Mountains physiographic province, but the greater part of the area is in the High Plains and the Colorado Piedmont sections of the Great Plains physiographic province. The total relief of the area is estimated to be about 3,500 feet.

The Laramie Range is characterized by steep-walled valleys and rough, broken upland. A narrow lowland, extending northward from Granite Canyon and paralleling the mountain front, lies between the Laramie Range and the relatively flat High Plains. This lowland area is 3 to 7 miles wide and is bounded on the west by the Laramie Range and on the east by a steep escarpment. Southward from Granite Canyon to near the Wyoming-Colorado State line, the rocks forming the High Plains overlap directly onto the east flank of the Laramie Range. This area of overlap is known as the "Gang Plank."

Throughout most of the northern part of the report area the topography is typical of the High Plains and is characterized by a high, relatively flat, gently rolling surface. In many places a sharply defined escarpment forms the southern and eastern boundaries of the upland. The escarpment extends from the western part of the report area eastward along the Wyoming-Colorado State line to a point southwest of the town of Carpenter, where it veers sharply northwestward and terminates in the valley of Crow Creek. South and east of the upland is a lower lying wide plain, which occupies much of the southern part of the report area and which is characterized by a gently rolling topography of low relief.

Crow Creek, the largest stream in the area, rises in the extreme northwest corner of the area, flows eastward to the vicinity of Carpenter, and thence flows southward to its confluence with the South Platte River southwest of Greeley. Throughout much of its course in Wyoming it is a perennial stream, but from near Arcola, Wyo., to near Grover, Colo., it is an intermittent stream; downstream from Grover it is an ephemeral stream that flows only in direct response to precipitation. Many of the tributaries of Crow Creek that head on the High Plains or along the face of the steep escarpment have a perennial flow for a short distance away from the base of the escarpment.

Lone Tree Creek and its tributaries, Goose Creek and Duck Creek, rise in the Laramie Range. They flow eastward down the "Gang Plank" to the vicinity of Warrenton where they merge and turn toward the south. Formerly, these streams flowed eastward across the area and joined Crow Creek in the vicinity of Carpenter, but a stream working northward into the escarpment of the High Plains near Warrenton successively captured Duck, Goose, and Lone Tree Creeks and established the present drainage system. These three streams have a perennial flow in the mountains, but the flow disappears a short distance east of the foot of the mountains. In the eastern part of R. 68 W., a number of small springs and seeps issue in the channels of the streams and maintain a perennial flow for a short distance downstream. In Colorado, the western part of the area is drained by several tributaries of Lone Tree Creek. Most of these tributaries flow only in direct response to local precipitation, although some of them have a perennial flow along part of their course.

CLIMATE

The climate of the report area is characterized by low precipitation, a high rate of evaporation, low humidity, much sunshine and wind, and a wide range of temperature. The summer days are moderately hot, and the nights are cool. The winters are relatively mild but have occasional short periods of severe cold; generally, several blizzards occur each winter. The mean annual temperature at Cheyenne, Wyo., which is in the north-central part of the area, is 44.6° F.

The mean annual precipitation for 65 years of record (1888–1952) at Cheyenne is 14.99 inches. The maximum monthly precipitation normally occurs during May; the minimum normally occurs during January in the form of a light, dry snow. About 54 percent of the annual precipitation falls during April, May, June, and July, and only about 14 percent is received during November, December, January, and February. The minimum, average, and maximum monthly precipitation and the annual precipitation during the period of record for the station at Cheyenne are shown graphically in figure 4.

GEOLOGY

Rocks of Precambrian to Early Cretaceous age are exposed only in the extreme western part of the Crow Creek and Lone Tree Creek drainage basins. The older sedimentary formations dip steeply eastward and probably underlie most of the area at great depths. For a description of these formations the reader is referred to the studies listed under "Previous investigations."

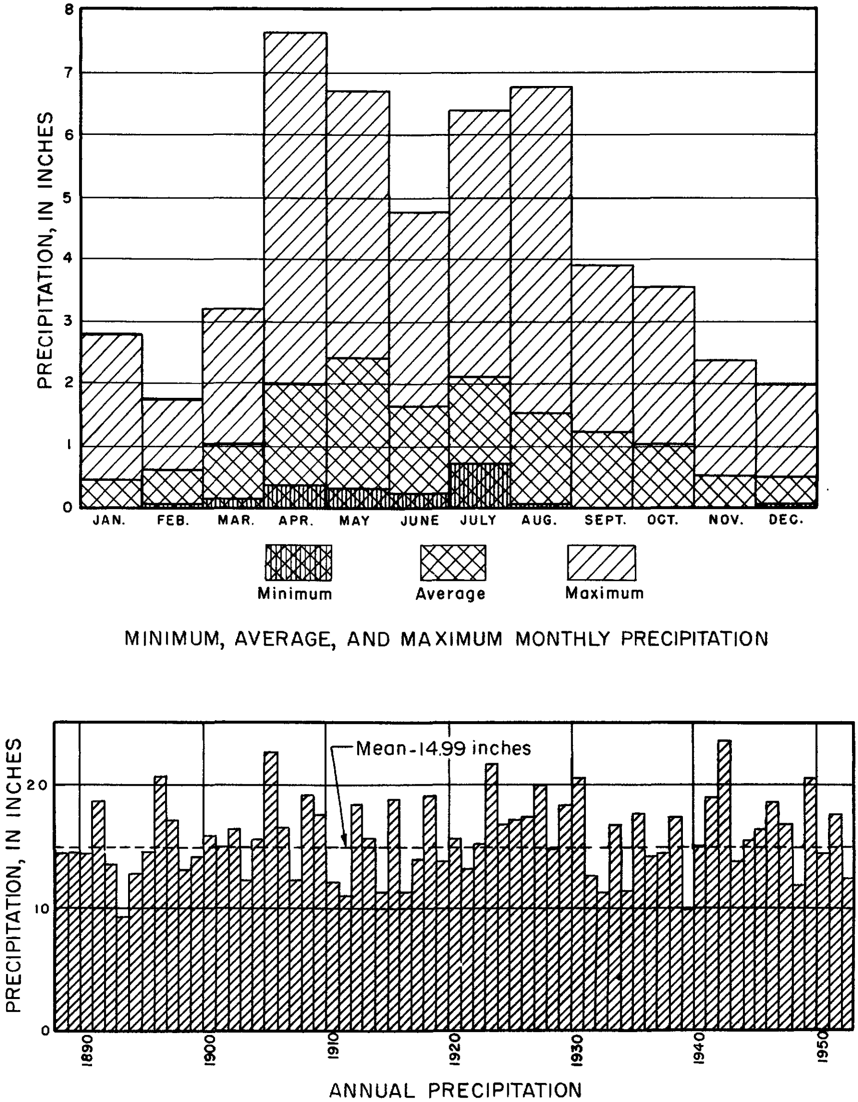

Figure 4.—Precipitation at Cheyenne, 1888–1952.

Only formations of Late Cretaceous age and younger are discussed in this report. These formations crop out or underlie the report area at relatively shallow depths and are the only economic sources of ground water in the area. Their age, thickness, physical characteristics, and importance as a source of water supply are summarized in table 1.

Table 1.—*Generalized section of the geologic formations exposed in the Crow Creek and Lone Tree Creek drainage basins*

System	Series	Subdivision	Thickness (feet)	Physical characteristics	Water supply
Quaternary	Recent and Pleistocene	Alluvium	0-60±	Coarse sand and gravel containing beds and lenses of silt and clay, cobbles, and a few boulders.	In many places yields adequate water supplies for irrigation.
	Pleistocene	Terrace deposits	0-150±	Lenticular beds of sand, gravel, silt, and clay; contain scattered cobbles and boulders.	In many places yield adequate water supplies for irrigation.
Tertiary	Pliocene	Ogallala formation	0-320±	Beds and lenses of clay, silt, sand, and gravel; poorly to well cemented. Very coarse conglomerate at the base.	Yields large supplies of water to municipal wells in the vicinity of Cheyenne.
	Miocene	Arikaree formation	0-80±	Massive to poorly bedded, fine- to medium-grained, loose to moderately cemented sand; contains lenses and concretions of well-cemented sandstone.	Yields water to a few domestic and stock wells.
	Oligocene	White River group: Brule formation	0-400±	Bentonitic, flesh-colored siltstone that locally is sandy or argillaceous; contains hard siltstone nodules in many places.	In some areas, yields large quantities of water to irrigation wells from fissures and fractures or from zones of pebbles beneath a cover of saturated gravel.
		White River group: Chadron formation	0-333(?)	In northwestern part of area, medium- to coarse-grained sandstone that locally is conglomeratic. In eastern part of area, variegated clay and soft shale that contains channel deposits of loose to well-cemented sandstone.	Not known to yield water to wells in the area; however, the sandstone channels probably would yield moderate quantities of water.
Cretaceous	Upper Cretaceous	Laramie formation	0-3,250(?)	Beds of light-gray to yellow-brown sandstone and beds of yellow-brown or gray to blue-gray soft shale and clay; contains crossbedded lenses of gray to buff sandstone and beds of coal.	Yields moderate supplies of water to a few wells; yields small supplies to most of the domestic and stock wells in the area.
		Fox Hills sandstone	0-250±	Predominantly medium-grained, buff to yellow-brown, poorly consolidated calcareous sandstone; contains beds of dark-gray to black gritty shale and beds of white massive sandstone.	Yields moderate supplies of water to several wells.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

CRETACEOUS SYSTEM

FOX HILLS SANDSTONE

The Fox Hills sandstone consists mainly of medium-grained, buff to yellow-brown, poorly consolidated calcareous sandstone interbedded with dark-gray to black gritty shale and white massive sandstone. Concretions are present in the sandstone beds. Because, in this area, the upper part of the Fox Hills sandstone is similar to the lower part of the overlying Laramie formation, it is difficult to distinguish one from the other. The plane of contact has been defined as the horizon above which the beds are composed predominantly of fresh- and brackish-water deposits containing coal and lignitic shale and below which the beds are predominantly marine.

The Fox Hills sandstone crops out only in the extreme southeastern part of the report area. It also crops out in a long, narrow belt that lies immediately west of, and approximately parallel to, the western boundary of the report area south of the Wyoming-Colorado State line. The formation probably is about 250 feet thick.

The Fox Hills sandstone yields moderate supplies of water to several wells in the area. The water is under artesian pressure and, hence, in wells, rises above the water-bearing bed.

LARAMIE FORMATION

The Laramie formation consists of beds of light-gray to yellow-brown sandstone and yellow-brown and gray to blue-gray soft shale and clay and contains lenses of crossbedded gray to buff sandstone and beds of coal. Sandstone concretions, which are cemented by limonite or calcium carbonate, are present throughout much of the formation. Beds of calcareous shale and clay, coal, and sandstone are abundant in the lower part of the formation. In the report area the thickness of the formation ranges from a featheredge to 3,250 feet, which was the thickness penetrated by an oil test well drilled in sec. 9, T. 12 N., R. 63 W.

The Laramie formation is exposed in the southern half of the report area. The northern boundary of the outcrop extends southeastward from about 3 miles north of Carr, Colo. (in the west-central part of the area) to about 7 miles south of Grover, Colo. (in the east-central part of the area).

The Laramie formation yields moderate supplies of water to a few wells in the area, and it yields small supplies to a great many more. It is the principal aquifer tapped by domestic and stock wells in the area. Although the formation generally yields only small supplies of water, moderate supplies probably can be developed from the lower part of the formation in places where a relatively thick section of sandstone is present. The water in sandstone beds that are overlain by relatively impervious material generally is under sufficient hydrostatic pressure to cause the water in wells to rise above the water-bearing bed.

TERTIARY SYSTEM

CHADRON FORMATION (WHITE RIVER GROUP)

The Chadron formation crops out in two places in the report area: (1) on the floor of the lowland that lies along the eastern margin of the Laramie Range in the northwestern part of the area, and (2) in a belt along the north margin of the lowland in the central part of the report area. In the former, the maximum thickness of the formation is about 40 feet. A well in the vicinity of Cheyenne, however, reportedly penetrated a thickness of 333 feet. In the latter, or central part of the report area, the thickness probably is about 100 feet.

In the northwestern part of the area the Chadron formation consists mainly of medium- to coarse-grained brown sandstone. It is conglomeratic in many places and generally is relatively coarse grained near its contact with Precambrian rocks. Locally, the formation contains volcanic ash and lenticular beds of siliceous limestone.

In the central part of the area, the Chadron formation generally is poorly exposed because it is mantled by slope wash and eolian deposits. However, a short distance outside the area (several miles east of Grover) the formation is well exposed—the following discussion of the lithic character of the Chadron formation is based on a study of these exposures. The formation consists mainly of green, brown, red, and gray soft silt and clay that locally may be sandy, and it contains greenish-gray to gray, loose to well-cemented channel deposits of gravel and sand, which are most abundant near the top and near the base of the formation. The channel deposits, which are relatively resistant to erosion, are not present where the formation crops out in the report area. The exposed soft clay of the formation is easily eroded by streams and forms that part of the lowland lying north and west of Grover.

No wells in the report area are known to tap the Chadron formation. In nearby areas, however, the formation supplies sufficient quantities of water for domestic and stock supplies.

BRULE FORMATION (WHITE RIVER GROUP)

The Brule formation in the report area is a moderately hard, compact, brittle bentonitic siltstone that locally is sandy or argillaceous. In places, the formation contains long, thin veins and geodes of calcite. Where the formation is hard and brittle, exposed surfaces are highly fractured; but where the formation is softer, the exposed surfaces generally consist of massive, relatively featureless beds containing hard siltstone nodules. Where the Brule formation is exposed, extensive erosion generally has produced badlands. In some places, a zone of loose material is present at the top of the formation where it is protected by a cover of younger deposits. This zone, which is as much as 15 feet thick, contains rounded pebbles of siltstone derived from the Brule formation. These pebbles are harder than most of the material in the Brule formation and apparently were derived from some of the more resistant beds or from the nodules that are scattered throughout the formation. Although the pebble layer probably is younger than the Brule formation, it is considered by the authors to be a part of the Brule.

Surficially, the Brule formation is cut by systems of joints. The joints are either horizontal (along bedding places) or vertical and, although they are most prominently developed where the formation is exposed, they occur also at the top of the formation where the Brule is mantled by younger stream deposits. In some places, nearly vertical fractures, or fissures, penetrate to unknown depths within the formation and possibly penetrate completely through it. Surface traces of these fractures, some of which are at least 1 foot wide and 1 mile long, are seen easily on aerial photographs, but they are difficult to detect and follow on the ground.

In the report area the Brule formation is exposed on the lower slopes of the escarpments and in parts of the valleys. The thickness of the Brule formation ranges from a featheredge to an estimated 400 feet.

The Brule formation yields water to several irrigation, municipal, and industrial wells and to many domestic and stock wells in the area. Because the Brule formation is primarily a siltstone, it is relatively impermeable except where jointed and fissured or where the zone of pebbles is present. The fractures and the pebble zone are good sources of ground water for irrigation, especially where the formation is overlain by deposits of saturated gravel.

ARIKAREE FORMATION

The Arikaree formation of Miocene age consists mainly of massive to poorly bedded, fine- to medium-grained, loose to moderately cemented, gray to brown sand containing lenses or pipy concretions of very hard, tough, brownish-gray to dark-gray sandstone that is cemented with calcium carbonate. Along the face of some of the escarpments, and on the hills north of Grover, a conglomerate, also thought to be of Miocene age and perhaps representing the Arikaree, lies unconformably on the Brule formation. This basal conglomerate is hard, well cemented, and indurated with calcium carbonate and some silica. Although somewhat similar in appearance to the basal part of the Ogallala formation, it lacks both the volcanic-rock and feldspar fragments that occur so abundantly in that formation.

Exposures of the Arikaree formation are present in the Wyoming part of the report area along the edge of the uplands in the valleys of Crow Creek and Porter Draw, and on the south-facing escarpment that lies west of the Carpenter-Hereford area.

The maximum thickness of the Arikaree formation in the report area probably is not more than 80 feet. It yields water for stock and domestic uses, but water supplies sufficient for irrigation probably could not be obtained from the formation because it has a low permeability and the zone of saturation is thin.

OGALLALA FORMATION

The Ogallala formation is of Pliocene age and consists of lenticular deposits of heterogeneous materials. It was laid down by streams that aggraded their old channels, spilled over into new channels, and left a series of braided sand and gravel deposits and many temporary lakes in which silt and clay were deposited. On the face of the escarpment, the exposed lower part of the Ogallala formation consists of a moderately to well-cemented, very coarse conglomerate that contains lenses of sand, silt, clay, and large chunks of siltstone. The middle part of the formation consists predominantly of well-cemented deposits of sand and fine gravel, which are known as "mortar beds." The upper part of the Ogallala formation consists of a series of lenticular beds of gravel, sand, and silty clay, which, in part, are relatively homogeneous. Fragments of feldspar and of volcanic rocks are present throughout most of the formation.

The Ogallala formation is the surface formation throughout most of the upland lying east of the Laramie Range and north of the Wyoming-Colorado State line. In the report area, the maximum thickness of the Ogallala formation probably exceeds 320 feet.

In places in the report area, where the zone of saturation in the Ogallala formation is sufficiently thick, wells of large discharge can be developed; the Ogallala formation yields water to 28 municipal wells west of Cheyenne. Sufficient water for domestic and stock use is obtained from the formation east of Cheyenne, but large-discharge wells probably cannot be developed in this part of the area because the zone of saturation is thin.

QUATERNARY SYSTEM

TERRACE DEPOSITS

All Quaternary deposits whose surfaces lie 60 feet or more above the level of the flood plains of the streams are referred to in this report as terrace deposits. These deposits consist of lenticular beds of unconsolidated sand, gravel, silt, and clay and contain scattered cobbles and boulders. The most notable are the terrace deposits in the vicinity of Hereford. These deposits are continuous with the "older deposits" as described by Rapp (Rapp, Warner, and Morgan, 1953, p. 44) in a report on the area north of the Wyoming-Colorado State line. Several of the wells near Hereford penetrate terrace deposits as much as 100 feet thick, but generally the deposits are somewhat thinner. An extensive terrace about 100 feet above the level of the flood plain of the stream is present in the vicinity of Carr. Although this terrace is quite extensive, the thickness of the terrace deposits probably does not exceed 50 feet. Elsewhere in the report area, high-lying terrace deposits are present as thin, scattered patches.

The terrace deposits in the vicinity of Hereford and Carpenter yield large quantities of water to irrigation wells, but the terrace deposits near Carr are high topographically and probably are too well drained to yield water in considerable quantity. The best possibilities for developing large supplies of water from the terrace deposits are in the Hereford-Carpenter vicinity northeast of the Crow Creek valley.

ALLUVIUM

The term "alluvium," as used in this report, includes not only the unconsolidated Quaternary deposits that underlie the flood plains of streams but also those beneath the stream terraces that are less than 60 feet above the flood plains; it includes, therefore, all those deposits in the vicinity of Carpenter that were described as younger terrace deposits by Rapp (Rapp, Warner, and Morgan, 1953, p. 45). The alluvium consists, for the most part, of sand and gravel, but it also contains some beds of silt and clay and some scattered cobbles and boulders. Near the outcrop of the Tertiary rocks, a large proportion of the alluvium is sand, silt, and clay.

Deposits of alluvium are thickest along the valley of Crow Creek between Carpenter and Grover; the maximum thickness is in the vicinity of Hereford, where about 60 feet is penetrated by wells. Elsewhere in the valley of Crow Creek and in the other stream valleys, the alluvium is relatively thin and generally does not exceed 30 feet in thickness. The alluvium yields large supplies of water to several irrigation wells in the report area.

GROUND WATER

OCCURRENCE

Ground water is the water in the zone of saturation beneath the land surface. It occupies the numerous openings—called voids, pores, or interstices—in the rock material and is the source of supply for wells and springs. Ground water in the report area is derived chiefly from water that falls as rain or snow. A part of the precipitation runs off directly into streams, a part evaporates, a part is returned to the atmosphere through transpiration by plants, and a small part percolates through the soil and underlying rocks to the zone of saturation from which it is discharged eventually by evaporation or as seepage into streams. In the more permeable rocks, such as the deposits of sand and gravel and the beds of sandstone, the individual pores are interconnected and are large enough for water to move through them with relative ease under the force of gravity and be yielded readily to wells. Locally, the relatively impermeable siltstone of the Brule formation contains fractures and fissures through which the water moves freely.

Most of the large-discharge wells in the Crow Creek and Lone Tree Creek drainage basins obtain water from the alluvium and terrace deposits and from the Ogallala formation; however, some of these wells derive water from fractures in the Brule formation, and a few obtain moderately large supplies of water from the Laramie formation and from the Fox Hills sandstone.

HYDROLOGIC PROPERTIES OF WATER-BEARING FORMATIONS

The quantity of water yielded and the rate at which the water is yielded from a water-bearing formation, or aquifer, depend principally upon the coefficient of storage and the permeability and thickness of the water-bearing material. The permeability varies greatly according to the size, shape, number, and degree of interconnection of the interstices in the water-bearing material, and the coefficient of storage varies with these factors and also according to whether the aquifer is confined by impermeable strata.

Permeability is the capacity of a water-bearing material to transmit water under pressure. The field coefficient of permeability may be expressed as the number of gallons of water per day (gpd), at the prevailing temperature of the water, that percolates laterally through each mile of the water-bearing bed (measured at right angles to the direction of flow) for each foot of saturated thickness and for each foot per mile of hydraulic gradient. The coefficient of transmissibility is an analogous property for a whole aquifer and may be expressed as the number of gallons of water per day, at the prevailing temperature of the water, that is transmitted through each mile of the water-bearing bed under a hydraulic gradient of 1 foot per mile; hence, the coefficient of transmissibility is the field coefficient of permeability multiplied by the thickness, in feet, of the zone of saturation.

The quantity of water that can be removed from storage in an unconfined water-bearing formation depends mainly upon the specific yield of the material. The specific yield is defined as the ratio of the volume of water yielded by gravity to the volume of the saturated material. Investigations have shown that typical saturated material drains rather slowly and that the rate of drainage is proportional to the permeability of the material.

Where an aquifer is confined between strata of low permeability, the water is under artesian pressure and the coefficient of storage is much smaller than it is under unconfined (water-table) conditions, because the water removed from storage represents water squeezed from fine-grained material, plus that derived by slight expansion of the water itself, as the head is lowered. In the report area, the water in the most productive aquifers is under water-table conditions in most places.

PUMPING TESTS

No tests have been made in the area to determine the coefficient of storage of the aquifers, but tests were made to determine the coefficient of transmissibility of the Ogallala formation in the area west of Cheyenne. Coefficients of transmissibility determined by pumping tests on 10 wells ranged from 1,060 to 34,300 and averaged 15,800 gpd per foot (Morgan, 1946, p. 21–22). Based on an average saturated thickness of approximately 155 feet, the average field coefficient of permeability of the Ogallala formation is 15,800 divided by 155, or about 100 gpd per square foot. No tests were made to determine the coefficient of permeability of either the alluvium or terrace deposits; however, it is known to be much higher than that of the Ogallala formation and probably is between 1,000 and 2,000 gpd per square foot. The sandstone beds in the Fox Hills and Laramie formations are less permeable than the Ogallala formation, and the coefficient of permeability probably is less than 50 gpd per square foot.

SPECIFIC CAPACITY OF WELLS

The specific capacity of a well is defined as the rate of yield per unit of drawdown, and generally it is expressed as the number of gallons per minute (gpm) that a well yields for each foot of drawdown of the water level in the well. Under water-table conditions, this relationship is approximately constant only when the drawdown is equivalent to a small fraction of the saturated thickness of the aquifer. The specific capacity depends also upon the construction and development of the well. However, a comparison of specific capacities is useful in estimating, in a general way, the permeability of aquifers and the relative efficiency of wells. The discharge and drawdown of many of the wells are given in the well records (table 4) at the end of this report.

In the report area, the wells in the unconsolidated sand and gravel of the alluvium and terrace deposits have the highest specific capacities, and most of the irrigation wells obtain water from these materials. The specific capacities of wells in the terrace deposits range from 19 to 72 and average about 33 gpm per foot. Specific capacities of wells in the alluvium range from 6 to 60 and average about 31 gpm per foot. The large specific capacities characterize wells in the terrace deposits and alluvium in the Carpenter-Hereford-Grover area, where the saturated thickness of the alluvium is greatest. Wells in the Ogallala formation in the area west of Cheyenne have specific capacities that range from 2 to 16 and average about 7 gpm per foot. No data are available regarding the specific capacities of wells in the Ogallala formation east of Cheyenne, but they probably would be less than those of the wells west of Cheyenne because the zone of saturation is thinner. Wells in the sandstone beds of the Fox Hills and Laramie formations have large drawdowns in proportion to their discharge; the average specific capacity for 3 wells in these formations is about 4 gpm per foot. Available data for 3 wells in the Brule formation show that 2 of these wells have a specific capacity of 15 and that the other has a specific capacity of 2 gpm per foot. Inasmuch as the siltstone of the formation is not sufficiently permeable to allow an appreciable amount of water to enter the wells, it is believed that the 2 wells having a specific capacity of 15 gpm per foot obtain water from fractures in the rock.

THE WATER TABLE

The water table is the upper surface of the zone of saturation in an unconfined aquifer; the piezometric surface is the imaginary surface to which water in a confined aquifer will rise in nonpumping wells that pierce the aquifer. The static water level in a well coincides with the water table under water-table conditions and with the piezometric surface under artesian conditions. If the piezometric surface is above the land surface, water will flow from wells that penetrate the aquifer.

Owing to the random arrangement of lenticular beds of sand, gravel, and clay, both water-table and artesian conditions exist in the Ogallala formation. However, except in a small area west of Cheyenne, where the piezometric surface is above the land surface, the water table and piezometric surface generally coincide, or are continuous, throughout the formation. Water encountered in the alluvium, terrace deposits, and the Brule formation generally is under water-table conditions. Water in the sandstone beds of the Fox Hills and Laramie formations generally is under artesian conditions but, in most places, it is not under sufficient pressure to flow from wells. Because only a few wells have been drilled into these formations, sufficient information is not available to determine accurately the shape and slope of the piezometric surfaces. Flowing wells possibly could be developed from these formations in parts of the area.

SHAPE AND SLOPE

In general, the water table is not level or uniform; instead, it is a warped, sloping surface. Irregularities in slope and in direction of slope are caused by differences in the thickness or permeability of the aquifer or by unequal additions or withdrawals of water.

Ground water moves in the direction of maximum slope of the water table or piezometric surface, and the rate of movement through a uniform cross section is proportional to that slope (hydraulic gradient) and to the permeability of the water-bearing material. The configuration of the water table is shown by contour lines (imaginary lines on the water table, every point of which is at the same altitude). No attempt was made during this study to collect the information needed to construct a water-table contour map of the entire area. However, water-table contour lines shown in the report of the Cheyenne area by Foley (1943, pl. 3) and in the report of the Egbert-Pine Bluffs-Carpenter area by Rapp, Warner, and Morgan (1953, pl. 1) are shown on plate 1 of this report.

The water table in the report area slopes toward the east and south and follows the general direction of the main drainage courses. A few miles west of Cheyenne the Ogallala formation thins toward the east and some of the ground water passing through the formation is forced to the surface and issues forth from numerous small springs. In his report on the Cheyenne area, Foley (1943, p. 51) refers to this series of springs as a "spring line," and he names it thus on plate 3 of his report. The southward-facing escarpment along the Wyoming-Colorado State line is the southern boundary of the Ogallala formation. Because the materials underlying the Ogallala are not capable of transmitting all the ground water, part of it is discharged through numerous springs and seeps at the base of the escarpment.

DEPTH BELOW LAND SURFACE

In the area described in this report, the depth to water depends largely upon the configuration of the land surface. In general, the higher the land surface, the greater the depth to water.

In the upland area, which is capped by the Ogallala formation, the depth to water ranges from only a few feet to about 250 feet. Generally, the water table is less than 50 feet below the land surface in the lowland area south of the east-west trending escarpment, less than 80 feet in the terrace deposits, and less than 30 feet in the alluvium.

The depth to water in wells is shown on plate 1 and in table 4. A map showing the depth to water in the vicinity of Carpenter is contained in the report on the Egbert-Pine Bluffs-Carpenter area (Rapp, Warner, and Morgan, 1953, pl. 2).

FLUCTUATIONS

The water table is not a stationary surface; it fluctuates when water is added to, or withdrawn from, the underground reservoir. If the discharge from a ground-water reservoir exceeds the recharge, the water table declines, and vice versa. Therefore, the fluctuations of the water table depend upon the rate at which the reservoir is depleted or replenished. A ground-water reservoir is in equilibrium when the recharge is equal to the discharge; under these conditions, the position of the water table is more or less fixed, although there are seasonal fluctuations.

No attempt was made during this investigation to observe the fluctuations of ground-water levels in the area, but measurements of the water level in several wells in the part of the area within Laramie County, Wyo., are given in the U. S. Geological Survey's annual publications of water levels and artesian pressures in observation wells. (See "Previous investigations" for list.) From the available data, it is concluded that no significant change in ground-water storage has occurred in recent years in any part of the report area except in the Cheyenne city well field. Water-level measurements made since 1941 in the Cheyenne city-supply wells, and in other observation wells in the vicinity of Cheyenne, show a water-level decline in both the old and new well fields. The annual amount of water pumped from wells, and the average nonpumping water level in both well fields, are shown in figure 5. The hydro-

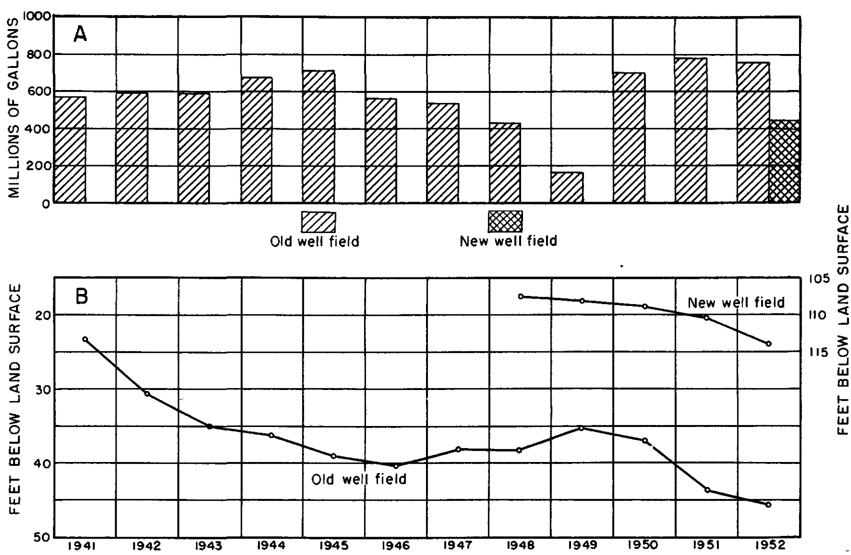

Figure 5. —Annual pumpage (A) and average nonpumping water level (B) in the Cheyenne municipal well fields.

graphs were prepared by determining the average annual water level for each well for each year of record. By averaging the yearly average water levels thus calculated, an average annual water level that was representative of each well field was obtained. Inspection of the graphs shows that water levels in the old wellfield declined continuously from 1941 (when pumping was first started) until 1946; inspection also shows that when the annual rate of withdrawal of ground water was decreased (during 1947, 1948, and 1949), the water level rose. The annual rate of pumping was increased again in 1950, and the water levels declined during 1950, 1951, and 1952. In the new field, the water level in wells declined rather slowly during 1949, 1950, and 1951 as the cone of depression of the old well field continued to expand. During 1952, several of the wells in the new well field were brought into production, which resulted in a sharp decline of the water table.

In the future, as additional wells are brought into use and as more water is pumped, the water table probably will continue to follow a pattern of decline similar to that in the old well field. The pronounced decline of the water table in the two well fields does not necessarily mean that the dependable yield of the aquifer has been exceeded—an initial lowering of the water table occurs when a well field is developed. The first water that is withdrawn from wells is largely from storage, but, as pumping continues and as the water table declines, the withdrawn water consists of increasing amounts of water that otherwise would have been discharged by natural means. This intercepted natural discharge is known as "captured," or "salvaged," water. Water levels in an area affected by water withdrawal will decline and the pumped water will continue to consist partly of water withdrawn from storage until the rate of capture equals the rate of withdrawal. If, however, the withdrawal rate continues to exceed the capture rate, the perennial yield will be exceeded and the water table will decline until the ground water in storage is depleted.

In the Carpenter-Hereford-Grover area, where a large amount of water is pumped for irrigation, the water table generally declines during the pumping season. During the succeeding nonpumping season, however, the ground-water reservoir is recharged by subsurface inflow from adjacent areas and by infiltration of precipitation to an extent that the water table is restored to approximately the prepumping level. The hydrograph of well 12–61–3ab (fig. 6), which penetrates the terrace deposits in the vicinity of Carpenter, shows water-level fluctuations that are typical for wells in that area. The hydrograph of well 12–63–3ba shows fluctuations of the water level in a well drilled into the Brule formation adjacent to the area where ground water is pumped for irrigation. The water level in this well appears to rise largely in

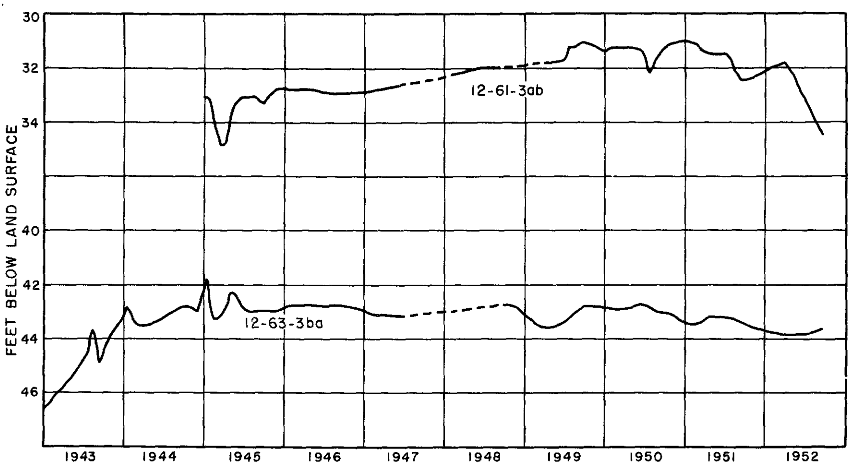

Figure 6.—Fluctuations of the water level in wells.

response to recharge from precipitation, and, apparently, it is affected only slightly by the seasonal withdrawal of ground water from the adjacent alluvium and terrace deposits.

RECHARGE

In the part of the area underlain by sediments of Tertiary and Quaternary age the ground water generally occurs under water-table conditions, and the direct infiltration of precipitation and seepage from streams are the principal means of recharge to the ground-water reservoir. Recharge to the ground-water reservoir in the upland area west of Cheyenne is discussed in considerable detail in the report on the Cheyenne area by A. M. Morgan (1946, p. 14–19). The following is an excerpt from this report:

> Sources of the ground water in the Ogallala formation are seepage from the streams that cross the outcrop area and direct penetration of rain and melting snow upon it. Penetration of rain and melting snow contributes some water throughout the exposed part of the formation, but contributions from this source are probably greatest in the western part of the area where the beds are most permeable and where nearly all of the arroyos are underlain by alluvium consisting principally of coarse sand and gravel. Runoff from the uplands is concentrated in the arroyos, from which the water seeps into the underlying alluvium and thence into the Ogallala beds below. Normally, a large part of the local runoff finds its way into the shallow alluvium beneath the numerous arroyos as they have surface flows only after exceptionally heavy rains. Much of the water that reaches the shallow alluvial deposits in the arroyos is later brought to the surface by capillarity and is evaporated, but a part seeps downward into the Ogallala.

Seepage from streams carrying water from the mountains takes place principally in the valleys of Lone Tree Creek, Goose Creek, and Duck Creek. Lone Tree, Goose, and Duck Creeks head in the mountains and flow onto the Ogallala formation where it laps up on the mountain front south of Granite Canyon. All three streams have perennial flows in the mountains which disappear within a short distance of the points where the streams issue onto the Plains. The water table slopes eastward and northeastward from those points, indicating movement toward Crow Creek and the perennial stretches of the various spring-fed streams east of the spring line. The Cheyenne well field and its recent extensions to the south and southwest are located between Lone Tree Creek and Crow Creek in a position to intercept the maximum amount of water moving through the formation.

* * *

The mean annual runoff per square mile of drainage basin was computed for Lone Tree Creek and applied to the basins of Goose and Duck Creeks to obtain the mean annual discharge. The following table shows the area of the drainage basins in the mountains, the mean annual discharge and the runoff per square mile of Lone Tree Creek, and the computed mean annual discharge of Goose and Duck Creeks.

	Area of drainage basin, in square miles	Runoff per square mile, in acre-feet	Mean annual discharge, in acre-feet
Lone Tree Creek	23	64.5	1,483
Goose Creek	6	64.5	387
Duck Creek	15	64.5	967
Total	44	64.5	2,837

Some of the water in the streams is evaporated in and along the channels, some probably seeps into older sedimentary beds along the mountain front, and some may escape as storm flow. It is believed, however, that most of the water carried by these streams finds its way into the Ogallala formation. A flow of 2,837 acre-feet a year is equivalent to about 2,500,000 gallons a day.

Recharge from precipitation cannot be measured directly. In large bodies of ground water, the effects of variations in recharge are smoothed out by slow movement of water through the aquifer, and the average recharge is balanced by an equivalent discharge. In such underground reservoirs the discharge therefore can be taken as an approximation of the average recharge. In the Cheyenne area most of the discharge from the Ogallala formation can be measured by measuring the pickup in the streams. Some water is also discharged through seeps along the escarpment immediately south of the Wyoming-Colorado line, where erosion has cut through the formation, and some percolates eastward and passes out of the area without reaching the surface. These quantities have been estimated on the basis of visible discharge and the capacity of the aquifer to transmit water out of the area.

From his analysis of data pertaining to discharge from the ground-water reservoir and recharge to it by seepage from streams in the Cheyenne area, Morgan estimated that about 6 percent (0.83 inch) of the local annual precipitation infiltrates to the ground-water reservoir.

A discussion of recharge to the ground-water reservoir in the vicinity of Carpenter is contained in a report on the Egbert-Pine Bluffs-Carpenter area by Rapp, Warner, and Morgan (1953, p. 22). The following quotation is taken from that report:

> In the Carpenter area the main sources of recharge are rainfall penetration and seepage from Crow Creek. The amount of water contributed by rainfall penetration alone was not determined but is believed to be relatively high. Crow Creek contributes about 3,600 acre-feet of water annually to the Carpenter area, but it is not known how much of this water crosses the Wyoming-Colorado State line into Colorado as underflow in the stream channel. The total amount of recharge available to the Carpenter area from both main sources is estimated at about 6,000 acre-feet per year.

Considerable additional study will be required to determine the amount of recharge in the Colorado part of the Carpenter-Hereford-Grover area.

The sandstone beds in the Fox Hills and Laramie formations are recharged where these beds are exposed. No attempt was made by the authors to map the outcrop of the two formations or to determine the amount of recharge to them.

DISCHARGE

Ground water is discharged from the report area by evapotranspiration, by seepage into streams, by springs and wells, and by underflow. The rate of discharge is affected by many factors, such as depth to the water table, the nature of the vegetative cover, and the season of the year.

Ground water is taken into the roots of plants directly from the zone of saturation or from the capillary fringe above the water table and is discharged from the plants by the process known as transpiration. The depth from which plants lift ground water ranges from a few inches for some grasses and field crops to more than 50 feet for some desert plants. In the report area, the discharge of ground water by evaporation and transpiration is limited mainly to the flood plains of Crow Creek, Lone Tree Creek, and a few of their main tributaries, where the water table is relatively close to the land surface. No attempt, however, was made to determine the amount of ground water discharged by these processes in the report area.

Crow Creek, Lone Tree Creek, and several of their tributaries are effluent streams in their upper reaches, deriving most of their surface flow from the ground-water reservoir. The stream channels generally are dry in their lower reaches, because some of the surface flow evaporates and the rest seeps into the alluvium. Foley (1943, p. 51–52) describes the discharge of ground water into the streams of the area, as follows:

Ground water is discharged from the Ogallala (?) formation in the Cheyenne area by springs, seeps, plants, and wells. Springs and seeps occur in the valleys of Duck, Goose, Lone Tree, and Swan Creeks east of the Spring line, and along Crow Creek from Silver Crown at least as far east as Cheyenne. Springs and seeps occur also along the escarpment south of the Colorado-Wyoming Line and in some of the valleys that cut back into the escarpment. Much of the water in the Ogallala (?), however, percolates directly into the streams. Normally the channels of the streams are dry above the Spring line. In Crow Creek, however, there is usually a flow across the entire width of the Cheyenne area.

* * *

Spot measurements of the flow of the streams in the Cheyenne area that receive ground-water discharge from the Ogallala (?) formation were made late in November, 1942. The aggregate effluent seepage from the Ogallala at this time amounted to about 10.9 cubic feet a second—7,000,000 gallons a day.

No attempt was made during this investigation to determine the total amount of ground water discharged into the streams, but throughout much of the report area it was observed that some ground water was being discharged into the streams and that the rate of such discharge was greatest in the upper reaches of the streams and along the base of the escarpments.

About 11,000 acre-feet of ground water was pumped in the report area during 1952. Of this amount, about 7,000 acre-feet was for irrigation, about 3,600 acre-feet was for municipal use by Cheyenne, and the remaining 400 acre-feet was for all other uses. The amount of ground water pumped annually by the city of Cheyenne since pumping started in 1941 is shown graphically in figure 5.

PRESENT DEVELOPMENT FOR IRRIGATION

A canvass of wells made during the study shows that 84 irrigation wells are in the report area. Of the 84 wells, 65 are in Weld County, Colo., and 19 are in Laramie County, Wyo.; most of them are in the Carpenter-Hereford-Grover area. The location of the wells is shown on plate 1, and pertinent information about the wells is given in table 4. All irrigation wells in the area at the end of 1952 were included in the inventory.

The cumulative number of irrigation wells in the area from 1907 through 1952, based on reported construction dates of wells, is shown graphically in figure 7. Most of the wells (about 85 percent) have been constructed since 1940.

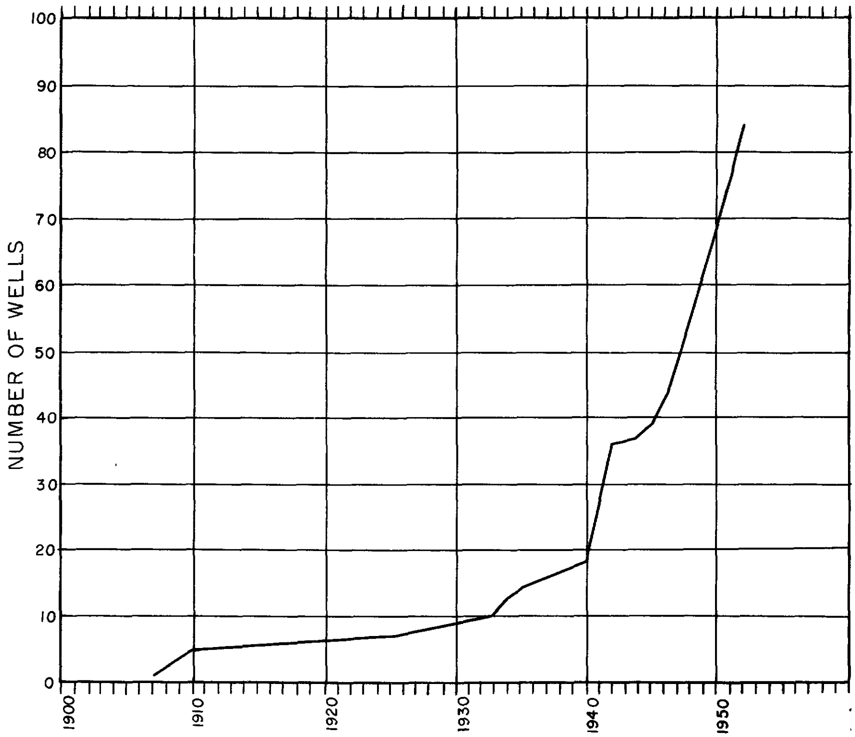

Figure 7.—Cumulative number of irrigation wells.

Of the 78 irrigation wells pumped during 1952, 59 are in Colorado and 19 are in Wyoming. A total of about 7,000 acre-feet of water was pumped by these wells to irrigate about 3,500 acres; of this total acreage, about 2,050 is in Colorado and about 1,450 is in Wyoming. The average area irrigated per well was about 35 acres in Colorado and about 76 acres in Wyoming. The largest yields were produced by wells that penetrate the alluvium and terrace deposits in the vicinities of Carpenter and Hereford; generally, wells drilled into the unconsolidated materials elsewhere in the area or into the bedrock formations were not so productive.

POTENTIAL DEVELOPMENT FOR IRRIGATION

The alluvium and terrace deposits probably are the only aquifers in the report area from which additional large supplies of ground water could be developed. Although the potential yield of some of the terrace deposits possibly could be increased by artificial recharge, the only part of the area where these materials could be expected to yield large quantities is in the valley of Crow Creek in the Carpenter-Hereford-Grover area. From available information, it is impossible to predict the quantity of water that could be safely withdrawn from these materials year after year without depleting the ground-water reservoir. Furthermore, the areal extent of these deposits, except for a small part of them in the vicinity of Carpenter, has not been mapped.

Wells capable of producing sufficient water for small-scale irrigation could be developed from the Fox Hills and Laramie formations in favorable locations in the southern part of the report area and from the Ogallala formation in some places west of Cheyenne. However, because much of the upland west of Cheyenne has been developed by the city for municipal water supplies, any withdrawal of ground water for irrigation in this part of the area would compete with present and anticipated future development of ground water for municipal supplies. The Ogallala formation east of Cheyenne yields sufficient water for domestic use and stock needs, but it will not yield sufficient water for irrigation because only the lowermost part of the formation is saturated. The Ogallala formation is relatively permeable in this part of the area; therefore it is possible that moderate to large quantities of ground water could be pumped from wells if the thickness of the saturated zone could be increased considerably by artifical recharge.

CHEMICAL QUALITY OF THE WATER

By L. R. Kister

Chemical analyses were made of water samples from the Fox Hills sandstone, the Brule and Ogallala formations, the terrace deposits, and the alluvium. In addition, chemical analyses were made of samples collected from Crow and Lone Tree Creeks during low-flow periods.

The analyses of water from five wells (12–62–9cb, 13–61–29ad, 13–61–30cb, 13–62–28ad, and 13–62–32bc) were taken from a report

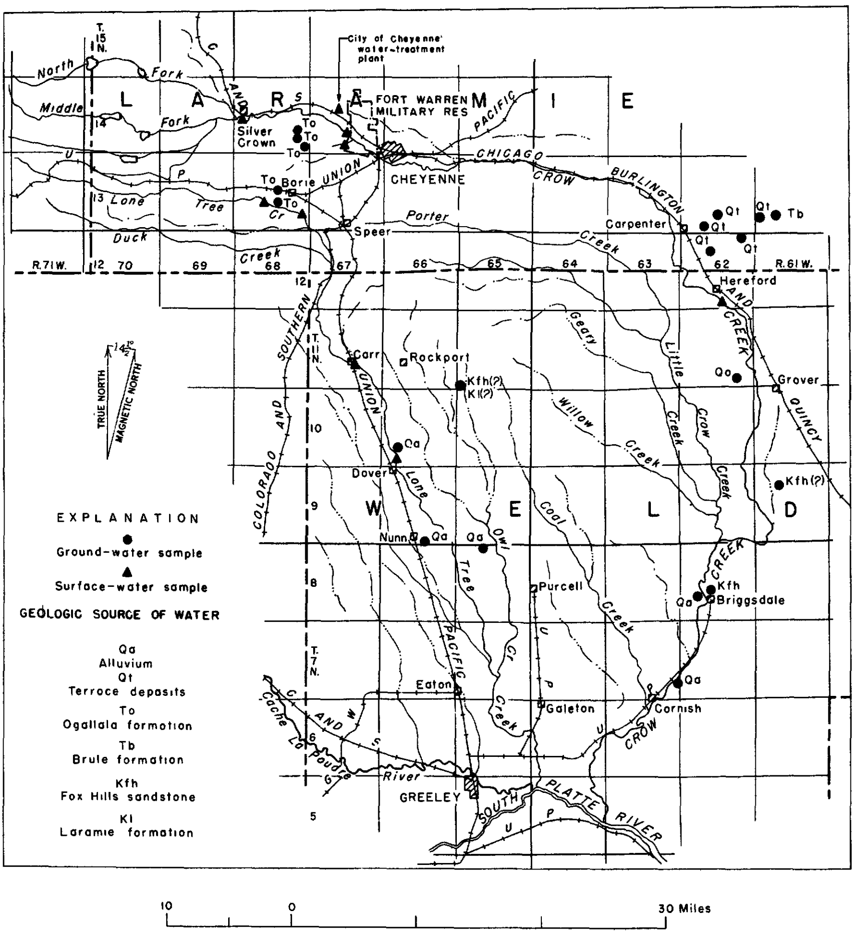

Figure 8.—Location of quality-of-water sampling points.

Table 2.—*Mineral constituents and related physical measurements of ground*

[Geologic source: Kfh, Fox Hills sandstone; Kl, Laramie formation; Tb, Brule formation; To, except as

Location	Depth (feet)	Geologic source	Date of collection	Temperature (°F)	Silica (SiO_2)	Total iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
										Ground
7-63-25db1	28	Qa	4-15-53	....	....	....	108	11	86	....
8-62-21dc..	265	Kfh	1-26-53	58	10	0.82	4.2	.2	158	1.4
29ab2	23	Qa	1-23-53	48	39	.64	180	42	206	12
65- 4cb3	27	Qa	1-22-53	54	23	.02	65	14	40	5.8
9-61- 8dd..	190	Kfh(?)	4-15-53	....	....	....	8.5	2.2	85	....
66-34dc1	26	Qa	1-27-53	48	23	.32	68	16	43	4.8
10-66-29cc..	....	Qa	4-14-53	48	....	....	51	16	33	....
11-62-35bc..	60	Qa	1-26-53	51	37	.14	69	12	33	6.8
65-31dc..	260	Kfh(?)-Kl(?)	4-14-53	....	....	....	51	8.3	27	....
12-62- 2bc..	104	Qt	10- 7-47	52	46	.02	48	8.0	11	4.0
9cb..	145	Qt	11-20-48	51	42	....	50	8.5	10	4.0
13-61-29ab..	85	Tb	10- 7-48	52	53	.02	39	12	18	
30cb..	83	Qt	9-26-47	53	47	.02	45	11	10	
62-28ad..	80	Qt	10- 7-47	52	51	....	68	13	16	
32bc..	65	Qt	10- 7-47	52	55	....	50	13	10	
68-15cd[1].	118	To	4- 4-43	....	....	....	71	9.2	10	
22bd[1].	260	To	4- 4-43	52	....	....	45	5.7	9.8	
14-68-23dd[1].	250	To	5- 7-43	....	....	....	44	8.3	2.5	
26cb[1].	220	To	4- 2-43	....	....	....	43	8.3	3.2	
36bc[1].	214	To	5- 7-43	....	....	....	40	6.6	6.0	
										Surface
Crow Creek										
Crow Creek reservoirs........			10-22-51	44	13	....	26	4.4	4.8	1.9
At Silver Crown, Wyo.[1].....			4- 2-43	....	....	....	39	6.3	8.8	
At W. boundary Ft. Warren, Wyo.[1]........................			4- 2-43	....	....	....	46	7.4	14	
Unnamed tributary near Ft. Warren, Wyo.[1].............			4- 2-43	....	....	....	78	14	27	
½ mile SE of Hereford, Colo.			1-26-53	49	40	....	61	8.8	16	4.4
Lone Tree Creek										
2½miles SW of Borie, Wyo.[1]			4- 4-43	....	....	....	....	....	3.9	
2 miles SE of Borie, Wyo.[1].			4- 4-43	....	....	....	38	4.6	9.0	
At Carr, Colo..................			4-14-53	47	....	....	68	17	37	
1 mile N. of Dover, Colo...			4-14-53	....	....	....	66	18	44	

[1]Analysis from U. S. Geol. Survey, Albuquerque, N. Mex.

and surface water in the Crow Creek and Lone Tree Creek drainage basins

Ogallala formation; **Qt, terrace deposits; Qa, alluvium.** Analytical results in parts per million indicated]

Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Water												
359	0	201	32	...	...	...	...	314	20	37	1,050	7.6
268	7	55	46	0.8	1.2	0.13	417	12	0	96	688	8.5
477	0	605	55	.9	.7	.15	1,410	620	229	41	1,860	7.6
223	0	84	16	.5	29	.13	390	219	36	28	596	7.9
198	2	40	9.5	...	...	...	...	30	0	86	425	8.4
228	0	73	38	.6	23	.09	409	237	50	28	639	7.7
221	6	51	21	...	...	...	...	191	0	27	514	8.3
250	0	51	20	1.0	19	.09	375	221	15	24	571	7.8
231	0	22	7.0	...	...	...	...	161	0	27	426	7.7
187	0	14	4.0	.7	12	.33	266	182	29	13	380	8.1
170	0	12	18	1.2	3.2	.01	234	160	21	12	342	7.7
176	0	30	4.0	.8	2.1	...	238	147	3	21	335	7.7
163	0	29	9.0	.8	2.2	...	234	158	24	13	335	8.0
202	0	42	16	.6	30	...	358	223	57	13	486	7.8
186	0	29	6.0	.8	8.0	...	266	178	25	11	387	7.9
182	0	24	22	0	40	.2	...	215	66	9	434	...
174	0	4	3	.8	5.0	<.1	...	136	0	13	276	...
162	0	6	2	0	9.0	0	...	144	11	3	273	...
165	0	2	3	.4	7.1	<.1	...	141	6	4	275	...
156	0	5	2	.2	4.2	0	...	127	0	9	256	...
Water												
100	0	6.0	2.5	1.0	0.7	...	122	83	1	...	189	7.6
149	0	12	3	1.3	.2	0.1	...	123	1	13	256	...
165	6.9	18	4	1.3	<.2	<.1	...	145	0	16	296	...
312	20	8	7	1.2	.2	.2	...	252	0	19	498	...
228	0	20	12	.7	7.2	.06	289	188	1	15	429	8.1
71	0	10	3	1.4	.5	.2	...	68	10	11	145	...
142	0	8	3	1.0	2.2	.2	...	114	0	15	239	...
284	6	54	17	...	...	...	...	241	0	25	583	8.3
305	0	55	20	...	...	...	...	239	0	29	598	7.9

by Rapp, Warner, and Morgan (1953, p. 36), and some of the data on the chemical quality of water in Crow and Lone Tree Creeks were taken from unpublished analyses in the files of the Albuquerque offices of the U. S. Geological Survey. The analysis of a composite water sample from the Crow Creek reservoirs (collected at a water-treatment plant 3 miles northwest of Cheyenne) was taken from a report by Lohr and Love (1954, p. 449).

The location of all sampling points, except the Crow Creek reservoirs, and the geologic source of the ground-water samples are shown in figure 8. The mineral constituents and related physical measurements of the samples are shown in table 2.

CHEMICAL PROPERTIES OF THE GROUND WATER IN RELATION TO GEOLOGIC SOURCE

Analyses of the ground-water samples collected in the report area indicate fairly wide differences in the chemical quality of the water from the various aquifers. The samples differed not only in total concentration of mineral constituents but also in chemical type. The chemical quality of water from at least one of the water-bearing formations (the Fox Hills sandstone) was sufficiently distinctive to be considered characteristic of that formation alone.

The analyses of representative samples from the four aquifers in the report area are shown as bar diagrams in figure 9. The

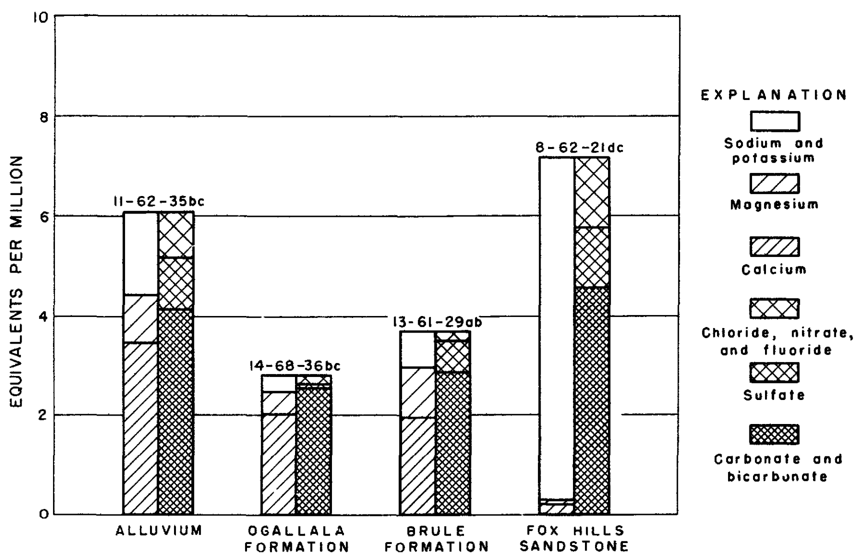

Figure 9.—Graphic representation of chemical composition of ground water from various geologic sources.

height of the bar represents half the dissolved-mineral concentration (excluding silica) in equivalents per million. The left half of the bar represents the combining power of the positive ions, or cations, and the right half represents the combining power of the negative ions, or anions. The chemical characteristics of the ground-water samples from the various aquifers varied widely, as shown in the table below.

Range in chemical characteristics

Geologic source	Number of samples	Depth of wells (feet)	Bicarbonate (parts per million)	Hardness as $CaCO_3$ (parts per million)	Percent sodium	Specific conductance (micromhos at 25°C)
Alluvium or terrace deposits	11	23-145	163-477	158-620	11-41	335-1,860
Ogallala formation	5	118-260	156-182	127-215	3-13	256- 434
Brule formation	1	85	176	147	21	335
Fox Hills sandstone or Fox Hills (?) sandstone	2	190; 265	198; 268	12; 30	86; 96	425; 688
Fox Hills (?) sandstone and Laramie (?) formation	1	260	231	161	27	426

FOX HILLS SANDSTONE

Samples of water were collected from one irrigation well that is known to tap the Fox Hills sandstone and from two other wells that are reported to tap that formation. The sample from the first (8–62–21dc) and one of the others (9–61–8dd) indicate that the water is of the sodium bicarbonate type and that it has a low hardness. These characteristics conform with previous observations[1] of the quality of water in the Fox Hills sandstone. The sample of water from the third well (11–65–31dc) was of the calcium bicarbonate type, which suggests either that most of the water comes from another aquifer (Laramie(?) formation) or that the quality of the water within the Fox Hills sandstone differs appreciably from place to place.

BRULE FORMATION

A sample of water from the Brule formation was collected from well 13–61–29ab. The water was low in mineral concentration (specific conductance, 335 micromhos), and the percentage of equivalents per million of calcium and magnesium was about 80.

[1]Letter from S. W. Lohman to R. F. Brown, Mar. 17, 1953.

As these analytical results are similar to those obtained from samples of water collected from the Brule formation in northeast Colorado, the sample collected for this investigation is believed to be typical of water in the formation. Water from the Brule formation is similar in chemical quality to that from the Ogallala formation, which overlies and recharges the Brule formation throughout most of the Wyoming part of the report area.

OGALLALA FORMATION

Analyses of five samples of water collected in 1943 from wells in the vicinity of Cheyenne showed that water in the Ogallala formation was of the calcium and magnesium bicarbonate type. The calcium and magnesium hardness ranged from 127 to 215 parts per million (ppm).

TERRACE DEPOSITS AND ALLUVIUM

A wide range in mineral concentration characterized the samples of water collected from wells that tap terrace deposits or alluvium. Although the specific conductance ranged from 335 to 1,860 micromhos, it was less than 650 micromhos for 9 of the 11 samples. Because the two samples that had a high specific conductance (1,050 and 1,860 micromhos for wells 7–63–25db1 and 8–62–29ab2, respectively) were characterized also by relatively high concentrations of sodium and sulfate, the samples possibly represented a mixture of water in the alluvium with water from the underlying Laramie formation. Available information[2] on the chemical character of the water in the Laramie formation indicates that the water is of a mixed type because it contains principally calcium and sodium sulfates.

RELATION OF CHEMICAL QUALITY OF GROUND WATER TO USE

IRRIGATION

When water is evaluated for irrigation, the main chemical-quality factors that should be considered are: (1) total concentration (expressed as dissolved solids, as specific conductance, or as total equivalents of cations or anions); (2) percent sodium; (3) amount of boron; and (4), under some conditions, bicarbonate content. It is not possible, however, to classify water as either suitable or unsuitable for irrigation from a chemical analysis alone, because other factors such as expected reactions in the

[2]Letter from S. W. Lohman to R. F. Brown, dated Mar. 17, 1950.

soil solution, permeability and drainage of the soil to be irrigated, quantity of water to be applied, and boron and salt tolerances of the crops to be grown must be considered.

A widely used method of classifying water for irrigation is that of Wilcox (1948). In this method, consideration is given to percent sodium and specific conductance of irrigation water that is applied to well-drained, permeable soil. Except for two samples from wells that penetrate (or are thought to penetrate) the Fox Hills sandstone, all the ground-water samples rated either "excellent to good" or "good to permissible," according to Wilcox's classification. (See fig. 10.) Without exception, the samples of surface water rated "excellent to good."

Eaton (1950) states:

The replacement by sodium of the exchange calcium and magnesium of the soil brings about progressive destruction of particle aggregates and, with particle dispersion, impermeability, provided the soil solution is not very saline. A sodium soil may be permeable to saline water and yet be extremely impermeable to rain.

In recent years, much attention has been given not only to the chemical characteristics of the applied water but also to the changes in the character of the water that may occur in the soil. For example, Eaton points out the effect of the relationship of calcium and magnesium to carbonate and bicarbonate in the formation of black-alkali soils. As evaporation and transpiration draw water from the soil solution, the salts in the applied water are concentrated, and sparingly soluble calcium and magnesium carbonate may precipitate. After the calcium and magnesium salts have precipitated, the remaining carbonate combines with the sodium to form "residual sodium carbonate," which may cause the formation of black-alkali soil. The possibility of "residual sodium carbonate" in the water samples is shown by figure 11.

All points on the "baseline," which has a slope of 1:1, indicate that the concentration of calcium and magnesium was equal to the concentration of carbonate and bicarbonate. Those points above the "baseline" indicate that the samples contained more calcium and magnesium than carbonate and bicarbonate; therefore, after plant intake and evaporation have resulted in precipitation of calcium and magnesium carbonate, no carbonate would be left in solution to combine with the sodium. The points lying below the "baseline" indicate an excess of carbonate and bicarbonate. The formation of black-alkali soil depends in part on drainage conditions and in part on the amount of water applied to the soil. If enough water is applied and drained away, the calcium and magnesium are not precipitated out of the soil solution. Values of "residual sodium carbonate" were about 2.7 and 4.3 equivalents per million (epm) in 2 samples of water derived (or thought to be derived) from the Fox Hills sandstone. (See fig. 11.) These were the same samples shown as

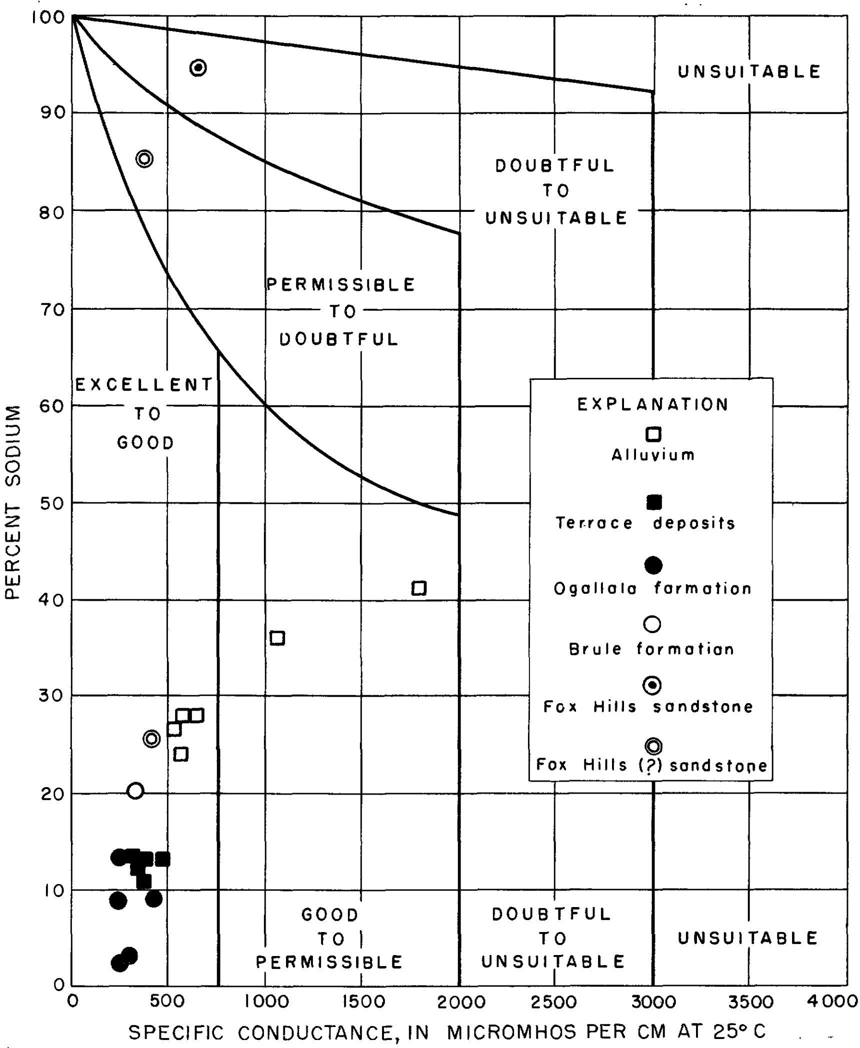

Figure 10.—Classification of ground water for irrigation use (after Wilcox, 1948).

"permissible to doubtful" and "doubtful to unsuitable" in figure 10. Staff members of the U. S. Salinity Laboratory (1954) concluded that water having more than 2.5 epm of "residual sodium carbonate" is not suitable for irrigation.

Small quantities of boron in the soil solution are essential to plant growth, but excessive amounts in irrigation water are injurious to most plants; the limit of boron in water applied to semitolerant crops is 2 ppm (Wilcox, 1948). None of the samples collected in the report area contained more than 0.4 ppm of boron.

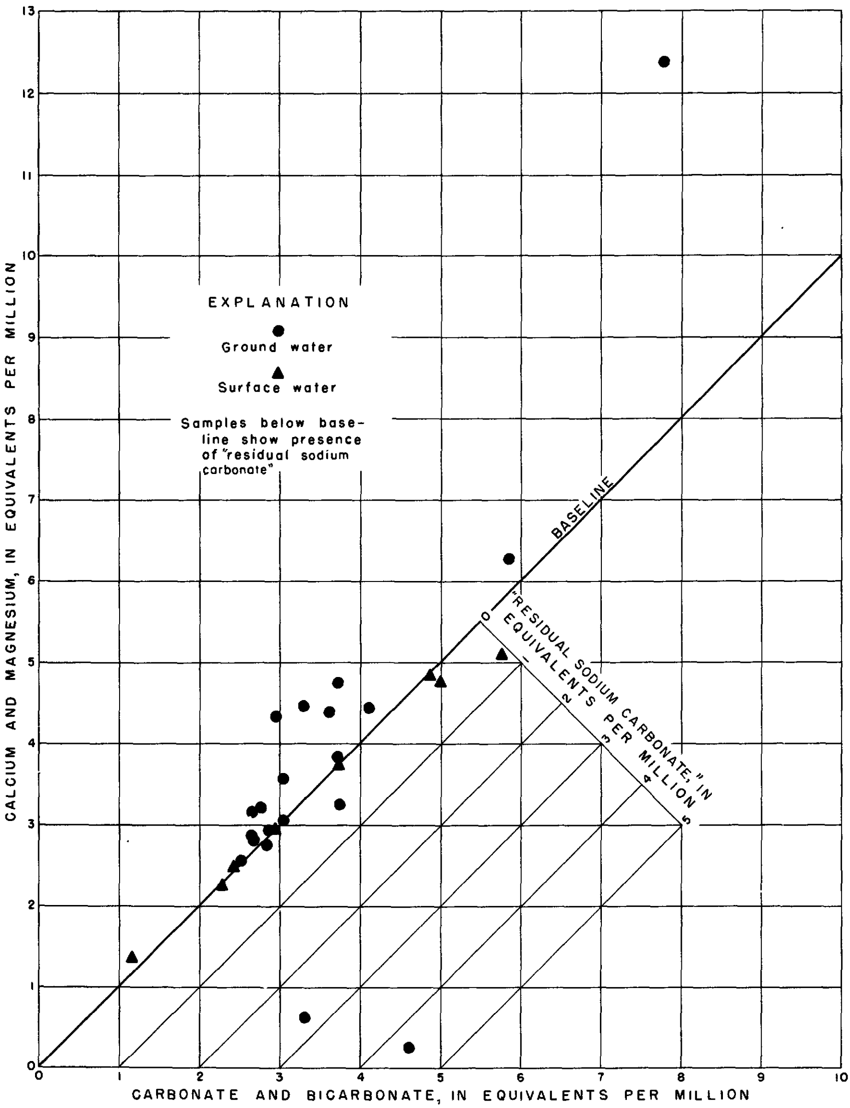

Figure 11.—Relation of calcium and magnesium to carbonate and bicarbonate showing "residual sodium carbonate" in water.

DOMESTIC USE

Certain chemical substances that may be present in natural or treated water used on interstate carriers, according to standards established by the U. S. Public Health Service (1946), should not exceed the following limits:

Constituent	Maximum parts per million
Iron and manganese (together)	0.3
Magnesium	125
Sulfate	250
Chloride	250
Fluoride	1.5
Dissolved solids	[a]500

[a]1,000 ppm permitted, if no other water is available.

None of the sampled domestic supplies contained objectionable amounts of dissolved salts. Although the mineral concentration, expressed as specific conductance, was relatively low (276–486 micromhos), the calcium and magnesium hardness was comparatively high (136–223 ppm).

About 25 percent of the municipal water supply of Cheyenne is obtained from 14 wells tapping the Ogallala formation, and about 75 percent is obtained from five reservoirs—Granite Springs, Crystal Lake, Old North Crow, New North Crow, and South Crow—all of which are on branches of Crow Creek. Samples of the water from three of the wells (14–68–23dd, 26cb, 36bc) were analyzed in 1943, and one sample (representing a composite of the water in all the reservoirs) was analyzed in 1951 (Lohr and Love, 1954, p. 449). (See table 2.) The mineral constituents in none of these samples exceeded the U. S. Public Health Service limits.

SURFACE WATER

Crow and Lone Tree Creeks were sampled in 1943 at places in Wyoming and in 1953 at places in Colorado. Because the samples were collected in effluent (gaining) sections of the streams, the analytical results are considered to be indicative of the general chemical quality of the ground water discharged into the streams by adjacent formations. When Lone Tree Creek was sampled 2 miles southeast of Borie, Wyo., at least part of the water was snowmelt. Analyses of the samples from both Crow and Lone Tree Creeks show that the water is of the calcium bicarbonate type and that the dissolved-salts content increases downstream.

The mineral concentration in the individual samples, expressed in equivalents per million, is represented diagrammatically in figure 12. In this figure, the positive ions (cations) are plotted to the left of a vertical line at zero, and the negative ions (anions) are plotted to the right; the horizontal distance of the plots from the zero line represents the equivalents per million.

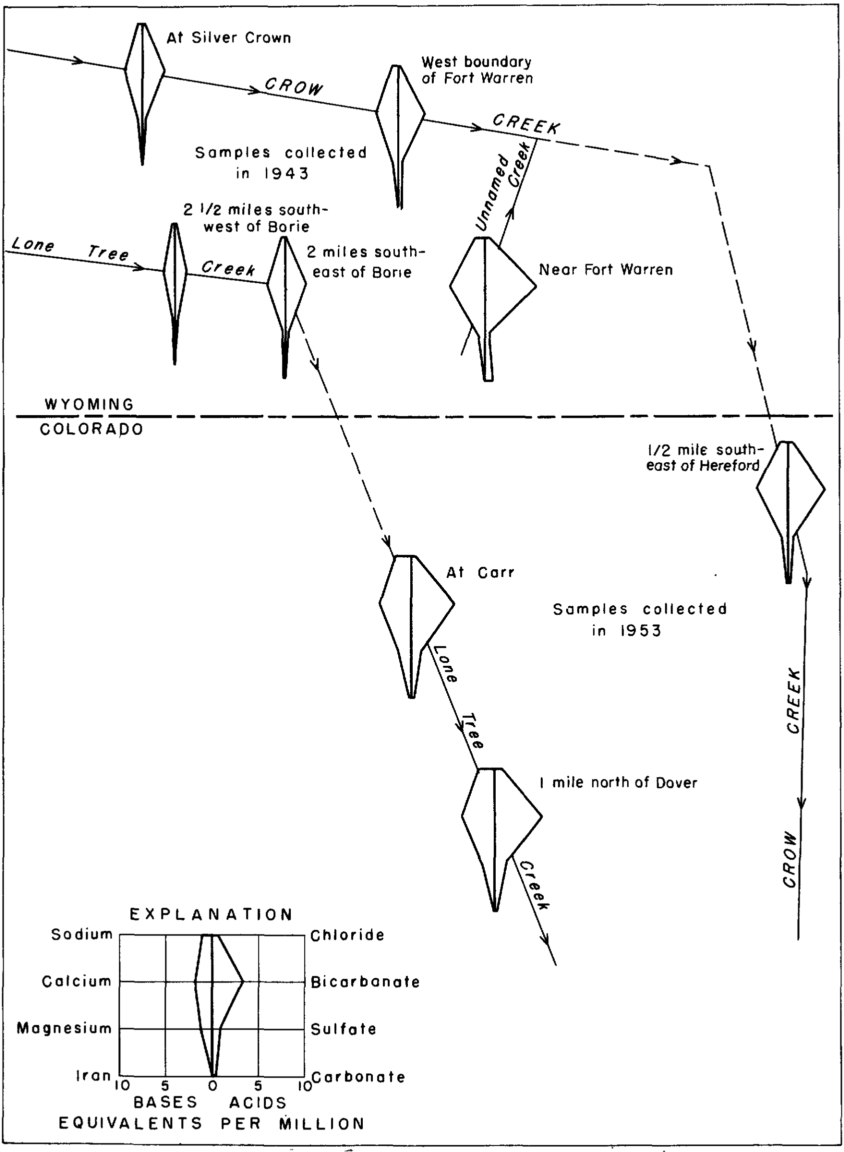

Figure 12.—Pattern analysis of surface-water samples.

As shown in the following table, the samples from Crow Creek indicate a slight decrease downstream in the percentage of equivalents for calcium plus magnesium and for carbonate plus bicarbonate and, of course, a complementary increase in the percentage of equivalents of the other constituents. On the other hand, the samples from Lone Tree Creek indicate a more pronounced decrease downstream in the percentage of equivalents for calcium

Percentage composition of anions and cations in samples from Crow and Lone Tree Creeks

Sampling point	Percentage of equivalents per million			
	Cations		Anions	
	Ca + Mg	Na + K	CO_3 + HCO_3	SO_4 + Cl + F + NO_3
Crow Creek				
At Silver Crown, Wyo	87	13	86	14
At west boundary of Fort Warren, Wyo	84	16	84	16
Unnamed tributary near Fort Warren, Wyo	81	19	93	7
½ mile southeast of Hereford, Colo	82	18	80	20
Lone Tree Creek				
2½ miles southwest of Borie, Wyo	89	11	76	24
2 miles southeast of Borie, Wyo	85	15	87	13
At Carr, Colo	75	25	75	25
1 mile north of Dover, Colo	71	29	75	25

plus magnesium but no perceptible change downstream in the percentage of equivalents for carbonate plus bicarbonate.

CONCLUSIONS

An appreciable number of wells of large discharge tapping the alluvium and terrace deposits could be developed in the Carpenter-Hereford-Grover area, and wells of moderately large to large discharge tapping the Fox Hills sandstone and the Laramie, Brule, and Ogallala formations probably could be developed in other parts of the report area. The only place where the Ogallala formation might yield moderate to large quantities of water is in the area west of Cheyenne, but inasmuch as the ground-water reservoir in this area is being developed by the city for municipal supplies, sufficient ground water probably is not available to supply water to irrigation wells in addition to that which is needed by the city.

A detailed ground-water investigation would be required to determine the perennial yield of the alluvium and terrace deposits in the Carpenter-Hereford-Grover area. The investigation should include: (1) preparation of a geologic map, a water-table contour map, and a map showing the saturated thicknesses of the aquifers; (2) determination of the transmissibility and storage coefficients of the aquifers; (3) determination of the effect of pumping on streamflow; (4) periodic measurement and interpretation of water-level fluctuations; and (5) drilling of test holes to obtain additional information on subsurface conditions.

Analyses of water samples collected for this investigation indicate that water in the Fox Hills sandstone is of the sodium bicarbonate type, and that water in the Brule and Ogallala formations in the terrace deposits and alluvium, and from Crow and Lone Tree Creeks at low flow is of the calcium and magnesium bicarbonate type. Except for water in the Fox Hills sandstone, the sampled supplies of water are of satisfactory chemical quality for either irrigation or domestic use.

LOGS OF WELLS AND TEST HOLES

Logs of wells and test holes obtained from drillers and well owners are listed in the following table. It was not possible to verify the logs by examination of the drill cuttings; consequently, the logs are presented in the terminology of the drillers. It is believed that the logs are reasonably accurate and that they give a fairly good description of the materials penetrated. Some of the logs are of test holes that were drilled to determine favorable locations for irrigation wells.

Table 3.—*Drillers' logs of wells and test holes*

Material	Thickness (feet)	Depth (feet)
Weld County, Colo.		
7-63-35da		
Soil	5	5
Clay	15	20
Gravel	8	28
Sandstone	62	90
Shale	3	93
Sandstone	32	125
9-61-8dd		
Soil and sand	24	24
Shale, brown	25.5	49.5
Sand	1.5	51
Shale, cream-colored	9	60
Shale, gray	2	62
Gravel, cemented	1	63
Shale, yellow	3	66
Shale	34	100
Sandstone (water)	40	140
Sandstone, fine	50	190
9-66-29cd1		
Soil	3	3
Soil and gravel	17	20
Sand and gravel	12	32
Gravel, coarse	9	41
Clay	1	42
Gravel, coarse	6	48
Shale	5	53
10-62-1ab1		
Soil	2	2
Gravel	12	14
Clay	2	16
Gravel	15	31
Sand, fine	1	32
Soapstone (probably volcanic ash)	2	34
11-62-35bc		
Soil	3	3
Gravel	11	14
Clay	1.5	15.5
Gravel	22.5	38
Sand, fine	11	49
Gravel, fine	6	55
Shale	5	60
12-61-19ab. Log of test hole at site of irrigation well.		
Clay and gravel	19	19
Clay	4	23
Sand and gravel	3	26
Clay	4	30
Sand and gravel	13	43
Clay	10	53
Sand, fine	17	70

Table 3.—*Drillers' logs of wells and test holes*—Continued

Material	Thickness (feet)	Depth (feet)
12-61-19ab—Continued		
Clay, sandy	16	86
Sand and gravel	25	111
Clay	6	117
Sand	3	120
Clay	7	127
Siltstone	25	152
12-62-24bc. Log of test hole at site of irrigation well.		
Soil	3	3
Gravel	10	13
Clay	3	16
Gravel	6	22
Gravel and clay	4	26
Clay	6	32
Gravel and clay	8	40
Gravel, fine	5	45
Clay and sand	5	50
Clay	5	55
Sand, fine	3	58
Clay	17	75
Gravel	1	76
Clay	4	80
Clay and gravel	20	100
Sandstone and clay	45	145
Gravel	8	153
Clay, brown	7	160
12-62-26bb. Log of test hole at site of irrigation well.		
Soil	4	4
Gravel	30	34
Siltstone, fractured	52	86
Sand and coarse gravel	10	96
Siltstone	39	135
Laramie County, Wyo.		
12-61-19bb. Log of test hole at site of irrigation well.		
Soil, clay and gravel	32	32
Sand, fine	7	39
Sand, fine, and clay	20	59
Clay, white	8	67
Sand, fine	6	73
Gravel	5	78
Clay and sand	4	82
Clay	10	92
Clay and sand	10	102
Gravel	14	116
Clay	5	121
Clay and gravel	7	128
Clay	3	131
Siltstone	21	152
12-62-1ab		
Soil	4	4
Gravel	56	60
Gravel; contains thin beds of clay	16	76
Gravel	24	100
Sandstone and siltstone	14	114

Table 3.—*Drillers' logs of wells and test holes*—Continued

Material	Thickness (feet)	Depth (feet)
12-62-10da		
Sand and gravel	27	27
Clay	13	40
Sand, dirty	9	49
Gravel	3	52
Sand, dirty	5	57
Gravel	12	69
Clay	10	79
Sand; contains thin clay beds	12	91
Gravel	3	94
Clay	2	96
Gravel	13	109
Clay	2	111
12-62-22ab2. Log of test hole at site of irrigation well.		
Soil and clay; contains some gravel	36	36
Gravel	15	51
Clay	4	55
Gravel	4	59
Clay	8	67
Gravel and clay	6	73
Clay	13	86
Gravel	8	94
Clay	9	103
Clay and gravel	10	113
Gravel	13	126
Clay, red	18	144
13-62-25ba		
Soil	5	5
Gravel, coarse	8	13
Clay, brown; contains beds of coarse gravel	23	36
Gravel	5	41
Clay, white; contains some gravel	6	47
Gravel; contains thin beds of clay	5	52
Clay, sandy, brown	4	56
Gravel, very coarse to coarse; contains thin beds of clay	25	81
Clay, white; contains beds of gravel	16	97
13-68-3bb		
Soil	10	10
Clay, sandy	10	20
Clay	60	80
Clay, sandy	20	100
Gravel	45	145
Sandstone, hard	5	150
Gravel	25	175
Clay	12	187
13-68-4ac		
Clay, yellow	55	55
Sandstone	30	85
Clay, sandy	10	95
Sandstone	15	110
Clay and gravel	20	130
Sandstone	5	135
Clay, sandy, hard	15	150
Sand, fine	15	165

Table 3.—*Drillers' logs of wells and test holes*—Continued

Material	Thickness (feet)	Depth (feet)
13-68-4ac—Continued		
Clay and sand	15	180
Clay	20	200
Sandstone	5	205
Gravel	3	208
Sand	2	210
Clay	40	250
Gravel and clay	5	255
13-68-4dc		
Soil	5	5
Soil and gravel	5	10
Gravel, cemented	100	110
Gravel	75	185
Clay and gravel	10	195
Clay	5	200
13-68-14bb		
Soil, black	10	10
Clay, yellow	85	95
Gravel	5	100
Clay	15	115
Sandstone	40	155
Gravel	5	160
Clay	5	165
Gravel	57	222
13-68-14cb		
Clay	25	25
Gravel, cemented	25	50
Clay, yellow	60	110
Sandstone	5	115
Gravel	10	125
Clay	10	135
Sandstone	5	140
Gravel	60	200
Gravel, cemented	10	210
13-69-24dd		
Gravel, cemented	206	206
Gravel, cemented; contains clay streaks	65	271
Clay	5	276
Clay; contains beds of gravel	34	310
13-69-34dd		
Gravel, cemented	230	230
Gravel, containing thin beds of sand	21	251
Clay, yellow; contains gravel	19	270
Siltstone	298	568

14-66-28cd. Log of test well drilled at Veterans Facility, Cheyenne, Wyo. Log is based on examination of drill cuttings. From report by Cady (1935, p. 7)

Arikaree sandstone (?):		
Sand, medium-coarse to coarse, poorly sorted, light-grayish-brown; contains grains of unaltered feldspar	18	18

Table 3.—*Drillers' logs of wells and test holes*—Continued

Material	Thickness (feet)	Depth (feet)
14-66-28cd—Continued		
Brule formation:		
Clay, impure, limy, silty, light-buff or cream; contains medium-coarse grains of quartz and feldspar	41	59
Clay, sandy, limy, less silty than above, light-pearl-gray mottled with white; associated with an easily drilled shalelike rock, called soapstone by the driller	3	62
Clay, sandy, limy, mostly light-cement-gray with some mottlings of brick-red; contains irregular quantities of gravel and nodules of hard noncalcareous clay or shale. Water at 99 feet rose to 82 feet; was not pumped before it was cased off	66	128
Sandstone, hard, medium-grained, calcareous, dirty, light-cement-gray	7	135
Clay, sandy, light-gray to drab or buff; interbedded with gray calcareous sandstone and gravel; contains nodules of gray pure clay or shale and a few concretions of lime	172	307
Chadron formation:		
Sandstone, very muddy, medium-grained near top and grading to finer toward bottom, buff to cream but more grayish near top. Water from 418 to 438, bailed dry at rate of 21 gpm in 105 minutes—drawdown of 250 feet	200	507
Clay, drab; contains heterogeneous arkosic sand and gravel	3	510
Clay, cement-gray to cream; contains uniformly fine grains of feldspar	18	528
Clay, drab; contains heterogeneous arkosic sand and gravel	12	540
Note: All materials above this point are calcareous; all below are noncalcareous.		
Fox Hills sandstone:		
Clay, hard, sandy, cement-gray to light-buff	18	558
Sandstone, fine-grained, muddy, cement-gray to buff; contains coarse angular grains of feldspar	38	596
Shale, sandy, straw-yellow to mustard-yellow	12	608
Shale, cement-gray to buff; contains fine grains of sand	70	678
Shale, cement-gray to buff	20	698
Sandstone, fine-grained, argillaceous, cement-gray to buff	67	765
Pierre shale:		
Shale, soft, light-drab-gray; contains fine sand	13	778
Shale, soft, light-lead-gray; contains medium-fine sand	50	828
Sandstone, fine-grained, shaly, light-lead-gray	10	838
Shale, light-lead-gray; contains small amount of fine sand	19	857
Shale, sandy, light-lead-gray	11	868
Sandstone, fine-grained, muddy, light-lead-gray; contains abundant dark minerals	10	878
Shale, sandy, light-lead-gray	4	882
Shale, light-lead-gray; contains small amount of fine sand	28	910
Sandstone, fine-grained, muddy, light-lead-gray	18	928
Shale, light-lead-gray; contains fine sand	28	956
Sandstone, fine- to medium-grained, light-lead-gray; interbedded with thick layers of shale. Water	82	1,038
Shale, light-lead-gray; contains fine sand	39	1,077
14-68-26ac		
Gravel	40	40
Sandstone, white	20	60
Clay, yellow	103	163
Gravel, cemented	2	165
Shale, hard	1	166
Gravel, coarse	3	169
Shale, limy, hard	8	177
Clay	38	215

Table 3.—*Drillers' logs of wells and test holes*—Continued

Material	Thickness (feet)	Depth (feet)
14-68-27dc		
Sand, clay and gravel	48	48
Gravel, cemented	62	110
Clay, light-colored	20	130
Gravel	37	167
Clay, brown	5	172
Gravel	47	219
Clay, brown	7	226
Gravel	17	243
Clay	7	250
14-68-33dc		
Clay	15	15
Clay, sandy	140	155
Gravel, dirty	10	165
Clay	5	170
Gravel	10	180
Clay	10	190
Gravel	35	225
14-68-34aa		
Gravel; contains thin beds of clay	40	40
Gravel, cemented	65	105
Clay, light-colored	30	135
Sand and gravel	8	143
Clay, light-colored	17	160
Gravel, cemented	12	172
Clay, brown	13	185
Gravel, cemented	12	197
Clay, brown	2	199
Gravel, cemented	3	202
Clay, brown	3	205
Gravel	5	210
Sand and gravel; contains some clay	25	235
14-68-20ba		
Soil	6	6
Gravel, loose	3	9
Clay, yellow	21	30
Gravel	6	36
Clay, yellow	14	50
Clay, hard, brown	120	170
Gravel, dirty	9	179
Clay, hard, pebbly	46	225
Clay, green with yellow streaks	51	276
Sand, coarse	29	305
Clay, sandy, green	41	346
Sand, coarse	39	385
Clay, sandy, white	55	440
Sand, hard, limy	23	463
Clay, sticky, black	44	507
Clay, yellow	4	511
Clay, black with gray streaks	119	630
Shale, gray; contains thin beds of sandstone	53	683
Sandstone, yellow; contains thin beds of gray clay	36	719
Sandstone, hard	6	725
Sandstone, fine	55	780
Sandstone	70	850

Table 3.—*Drillers' logs of wells and test holes*—Continued

Material	Thickness (feet)	Depth (feet)
14-68-23dd		
Gravel and clay	85	85
Gravel, coarse	25	110
Clay, sticky, brown	37	147
Gravel, coarse	5	152
Clay, brown	54	206
Sandstone, coarse	6	212
Clay, hard, brown	4	216
Sandstone, moderately hard	15	231
Sandstone, fine	5	236
Siltstone	14	250
14-68-24dd		
Dirt and gravel	40	40
Clay	215	255
Clay, sand and gravel	21	276
Gravel	10	286
14-68-35ca		
Soil, black	10	10
Gravel and clay	25	35
Sandstone	55	90
Gravel and clay	60	150
Gravel	75	225
Clay and gravel	10	235
14-68-36ac		
Clay, hard, and gravel	12	12
Clay, hard, yellow	22	34
Sand, brown	14	48
Gravel	6	54
Clay, sand, and gravel	41	95
Limestone	4	99
Sand and clay, hard	36	135
Sand and clay	15	150
Sandstone	2	152
Gravel, with some clay	10	162
Gravel	6	168
Rock	1	169
Gravel and sand	6	175
Clay and gravel	1	176
Sand, fine	4	180
Gravel, cemented	1	181
Sand, fine	3	184
Rock, white	4	188

Table 4.—*Records of wells in the Crow Creek and Lone Tree Creek drainage basins*

Well no.: See text for description of well-numbering system.
Type of well: Dr, drilled; Du, dug.
Depth of well: Measured depths are given in feet and tenths below measuring point; reported depths are given in feet below land-stratum datum.
Type of casing: C, concrete, brick, or tile pipe; N, none, P, iron or steel pipe.
Character of material: G, gravel; S, sand; Sls, siltstone; Ss, sandstone.
Geologic source: Kfh, Fox Hills sandstone; Kl, Laramie formation; Tb, Brule formation; Ta, Arikaree formation; To, Ogallala formation; Qt, terrace deposits; Qa, alluvium.
Type of pump: C, cylinder; Cf, centrifugal; N, none; T, turbine.
Type of power: E, electric motor; F, natural flow; G, gasoline or diesel engine; H, hand-operated; N, none; W, windmill.
Use of water: D, domestic; I, irrigation; In, industrial or railroad; N, none; P, public; S, stock.
Measuring point: Bpb, bottom of pump base; Hpb, hole in pump base; Idp, invert of discharge pipe; Ls, land surface; Tc, top of casing; Tpb, top of pump base; Tvp, top of vent pipe; Twc, top of well cover.
Depth to water: Measured depths to water level are given in feet, tenths, and hundredths; reported depths are given in feet.
Remarks: Bw2, battery of 2 wells (or number given); Ca, sample collected for chemical analysis; D, discharge in gallons per minute (M, measured; R, reported); DD, drawdown in feet while discharging at preceding rate (measured drawdowns are given in feet and tenths; reported and estimated drawdowns are given in feet); L, log of well or nearby test hole is shown in table 4; T, temperature in degrees Fahrenheit.

Well no.	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Principal water-bearing bed		Type of pump	Type of power	Use of water	Measuring point		Depth to water level below measuring point (feet)	Date of measurement	Remarks
						Character of material	Geologic source				Description	Distance above or below (-) land surface (feet)			
							Weld County, Colo.								
7-63-25db1	Fred Johnson	Du, Dr	28	30	P	S, G	Qa	Cf	E	I	Tc	1.5	24.29	12-10-52	D75R;DD11;Bw4;Ca
25db2	do	Dr	39	24	P	S, G	Qa	T	E	I	Tc	1.5	23.64	12-10-52	D75R;DD11
25dc1	do	Dr	40	42	P	S, G	Qa	T	E	I	Twc	.5	20.03	12-10-52	D325R;DD17
25dc2	do	Dr	41	24	P	S, G	Qa	T	E	I	Ls	——	22	10-15-52	
35aa	L. E. Kime	Dr	32	20	P	S, G	Qa	N	N	N	Tc	2.0	17.31	10-13-52	D150R;DD10;Bw3

Table 4.—*Records of wells in the Crow Creek and Lone Tree Creek drainage basins*— Continued

Well no.	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks
							Weld County, Colo.—Continued								
7-63-35ad	L. E. Kime	Dr	32	42	P	S,G	Qa	T	E	I	Tc	1.5	23.33	10-10-52	D300R;DD9;Bw4
35da	do	Dr	125	42	P	Ss	Kfh	T	E	I	Ls	----	22	10-10-52	D300R;DD90;L
8-62- 9ba1	Harold Magnuson	Dr	25	20	P	S,G	Qa	T	E	I	Tc	1.3	12.96	10-15-52	D100R;DD12
9ba2	do	Dr	25	20	P	S,G	Qa	T	E	I	Tc	1.0	12.77	10-15-52	D100R;DD12
9ba3	do	Dr	25	20	P	S,G	Qa	N	N	N	Tc	-1.5	13.01	10-15-52	
20da	U. S. Dept. of Agriculture	Du	----	44	P	S,G	Qa	T	G	I	Tc	2.0	13.56	10-10-52	Bw4
21dc	Carl Mays	Dr	265	6	P	Ss	Kfh	C	E	D	----	----	----	----	T58;Ca
29ab1	F. R. Donovan	Du	23	44	C	S,G	Qa	Cf	G	I	Tc	.5	13.28	10-10-52	D180R;DD7
29ab2	do	Du	23	48	C	S,G	Qa	Cf	G	I	Tc	.5	14.87	10-10-52	T48;D200R;DD7;Ca
65- 4bc	M. McFarlin	Du	28	48	P	S,G	Qa	Cf	E	I	Twc	.3	19.66	1-22-53	
4cb1	A. R. Snodderly	Dr	27	48	P	S,G	Qa	T	E	I	Tc	.5	20.43	1-21-53	D100R;DD7
4cb2	do	Du	26	108	C	S,G	Qa	Cf	E	I	Tc	0	18.93	1-21-53	D40R;DD7
4cb3	do	Dr	27	48	P	S,G	Qa	Cf	E	I	Ls	----	18	1-21-53	T54;D40R;DD7;Ca
4cb4	do	Dr	24	48	P	S,G	Qa	T	E	I	Tc	1.0	17.48	1-21-53	D75R;DD7
4cb5	do	Du	24	108	C	S,G	Qa	T	E	I	Bpb	.5	16.70	1-21-53	D100R;DD7
4cb6	do	Dr	26	48	P	S,G	Qa	T	E	I	Tc	1.5	18.81	1-21-53	D75R;DD7
8bb	D. W. Rush	Du	37	120	C	S,G	Qa	T	E	I	Twc	.3	24.12	1-22-53	D100R;DD13;Bw3
66- 1ba	H. Atkins	Du	----	48	P	S,G	Qa	Cf	G	I	Tc	1.5	21.24	1-22-53	

9-61- 8dd	D. P. Gillette	Dr	190	16	P	Ss	Kfh?	T	G	I	Tc	0	33.27	12-10-52	D350R;DD65;L;Ca
65-22bc	Harland Macy	Du	10	36	P	Ss	Kl	N	F	S					
29cb	A. D. Macy	Du	28	108	C	S,G	Qa	N	N	N	Tc	.5	26.84	1-21-53	D300R;DD9
32cc	W. G. Wickwar	Du	28	108	C	S,G	Qa	T	E	I	Tc	0	22.42	1-21-53	
66- 9bc	Newton Edwards	Du	25			S,G	Qa	Cf	G	I	Twc	0	5.75	1-22-53	D300R
27ca1	V. J. Turner	Dr	36	30	P	S,G	Qa	T	E	I	Tc	2.0	32.23	1-22-53	D150R;DD8
27ca2	do	Du, Dr	35	22	P	S,G	Qa	T	E	I	Bpb	1.5	31.18	1-22-53	D100R;DD8
27db1	do	Du, Dr	35	22	P	S,G	Qa	T	E	I	Tc	.5	28.98	1-22-53	D200R;DD8
27db2	do	Du	38	22	P	S,G	Qa	T	E	I	Tc	.5	29.85	1-22-53	D100R;DD9
29ca	L. I. Hart	Dr	42.3	18	P	S,G	Qa	T	E	I	Ls	0	31.30	10- 2-52	
29cd1	do	Dr	53	18	P	S,G	Qa	T	E	I	Ls		32	10- 2-52	D275R;L
29cd2	do	Dr	41	18	P	S,G	Qa	T	E	I	Ls		16	10- 2-52	D75R
33ca1	City of Nunn	Du	37	48	P	S,G	Qa	T	E	P	Ls		20	10- 2-52	D100R
33ca2	do	Dr	55		P	S,G	Qa, Kl	T	E	P					
34dc1	G. L. Lemonds	Du	26	120	C	S,G	Qa	Cf	G	I	Twc	.5	16.27	1-27-53	T48;D240R;DD8;Ca
34dc2	do	Du	24	48	P	S,G	Qa	Cf	G	I	Ls		17	1-27-53	D30R;DD2
67- 1bc	Lorin Balmer	Du	33	96	C	S,G	Qa	T	E	I	Tc	0	19.66	1-20-53	D300R;DD11
10-61- 5aa	C. B. and Q. R.R. Co	Dr	40.0	144	C	Sls	Tb	C	W	In	Twc	-6.0	19.70	12-10-52	
5ad	City of Grover	Dr	250		P	Ss	Kfh?	T	E	P	Ls		20	12-10-52	
6ba	Robert Warren	Du			C	S,G	Qa	N	N	N	Tc	1.0	9.25	10-17-52	
11dd	C. C. Borger	Dr	44.0	12	P	Sls	Tb	C	H	S	Tc	1.5	35.69	12- 9-52	
14aa	Thomas Fry	Dr	50	18	P	Sls	Tb	T	G	I	Ls		30	12- 9-52	D550R
62- 1ab1	W. Tenney	Dr	34	18	P	S,G	Qa	T	E	I	Tc	3.0	11.49	10-17-52	D225R;DD20;L
1ab2	do	Du	14		C	S,G	Qa	Cf	G	I	Ls		7	10-16-52	D300R;DD6
2ba1	A. Werner	Dr	35.5	18	P	S,G	Qa	T	G	I	Tc	.5	5.60	12- 3-52	
2ba2	do	Dr	23.5	18	P	S,G	Qa	T	E	I	Tc	2.0	6.49	12- 3-52	
6ba	W. H. Bailey	Dr	54	12	P	Sls	Tb	T	E	I	Ls		32	12- 4-52	D200R;DD13
66-19db	M. Rohwer	Du				S,G	Qa	Cf	G	I	Bpb	-1.5	1.95	1-20-53	
29cc	F. Sidwell	Du				S,G	Qa	T	E	I	Bpb	2.5	5.95	1-20-53	Ca
67-11cc	James Morrison	Dr	42.5	6	P	S,G	Qa	N	N	N	Tc	1.0	24.89	1-17-53	
15ad	E. O. Crispe	Du	14			S,G	Qa	Cf	G	I	Bpb	.8	4.55	1-20-53	D300R
22da	L. Chadwick	Du	14			S,G	Qa	Cf	G	I	Ls	0	5.00	1-16-53	D200R;DD5
22db	do	Du	14			S,G	Qa	Cf	G	I	Ls	0	6.00	1-16-53	
11-61-15cd	John Bauman	Dr	80	20	P	Sls	Tb	T	G	I	Hpb	1.0	42.15	12- 5-52	D600R
62-27aa	W. Lawrence	Du, Dr	32	120	P	S,G	Qa	T	E	I	Tc	0	8.59	12- 5-52	
35bc	W. Tenny	Dr	60	18	P	S,G	Qa	T	G	I	Tc	2.0	8.83	12- 3-52	T51;D1,025R;DD23;L;Ca

Table 4.—*Records of wells in the Crow Creek and Lone Tree Creek drainage basins*—Continued

Well no.	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks
	Weld County, Colo.—Continued														
11-65-31dc	Henry Prange	Dr	260	12	P	Ss	Kfh?-Kl?	T	G	I	Tc	1.0	21.42	1-14-53	D300R;DD75;Ca
67-22dc	U. P. R. R. Co	Dr	300	----	P	Ss	Kfh?	T	G	In	Ls	----	2	10- 2-52	
12-61-19ab	Bauman Bros	Dr	113	18	P	S, G	Qt	T	E	I	Hpb	0	17.06	12- 3-52	D1,020R;DD54;L
32bb	W. J. Peters	Dr	100	18	P	S, G	Qt	T	G	I	Hpb	.5	35.35	12- 4-52	
62-20bb	G. Hodgell	Dr	234	18	P	Sls	Tb	T	E	I	Ls	----	18	12- 8-52	D200R;DD90
20dd1	do	Dr	100	18	P	S, G, Sls	Qa, Tb	T	E	I	Ls	----	16	12- 8-52	D580R;DD24
20dd2	do	Dr	100	16	P	S, G, Sls	Qa, Tb	N	N	N	Tc	.5	16.78	12- 8-52	D350R
24bc	E. Lesh	Dr	157	18	P	S, G	Qt	T	E	I	Ls	----	30	10-14-52	D1,100R;L
26bb	R. W. Baskett	Dr	96	18	P	S, G	Qt	T	E	I	Hpb	.5	33.60	12- 2-52	D900R;DD35;L
26bc	do	Dr	110	18	P	S, G	Qt	T	E	I	Hpb	.5	36.73	12- 2-52	D1,100R;DD50
27ba1	L. Lambert	Dr	110	18	P	S, G	Qt	T	E	I	Tc	0	39.38	12- 2-52	D1,000R;DD50
27ba2	do	Dr	110	18	P	S, G	Qt	T	E	I	Hpb	1.2	40.84	12- 2-52	D1,000R;DD50
28ac	G. Hodgell	Dr	29	12	P	S, G	Qa	T	G	I	Tc	1.0	5.20	12- 8-52	D300R;DD20
34ab1	F. J. Mason	Dr	60	12	P	S, G	Qa	T	E	I	Tc	.5	19.21	12- 5-52	D350R
34ab2	do	Dr	60	18	P	S, G	Qa	T	E	I	Hpb	1.0	19.79	12- 5-52	D400R

34ab3	do	Dr	60	18	P	S,G	Qa	T	E	I	Ls		6	12- 5-52	D400R
34ba	do	Dr	60	18	P	S,G	Qa	T	E	I	Tc	2.0	7.67	12- 5-52	D1,250R
35ca	do	Dr	54	18	P	S,G	Qa	T	E	I	Hpb	2.0	21.02	12- 4-52	D800R
64-26bb	M. T. Cox	Dr	25	24	P	Sls	Tb	T	G	I	Tc	0	3.20	1-13-53	Bw3
26db	do	Du	25			Sls	Tb	T	G	I	Bpb	5.0	5.50	1-13-53	D300R;DD20

Laramie County, Wyo.

12-61- 3ab	H. E. Anderson	Dr	110	24	P	S,G	Qt	T	E	I	Hpb	0.3	32.9	9-15-47	D400R
7bb	G. Thompson	Dr	50	4	P	S,G	Qt	T	E	D,S	Ls		35	6-10-47	
18bd	J. Bauman	Dr	95	16	P	S,G	Qt	T	G	I	Ls		24	6- 1-40	D500R
18ca	do	Dr	140	18	P	S,G	Qt	T	E	I	Hpb	.5	24.49	12- 3-52	D1,200R
18cb	do	Dr	152	18	P	S,G	Qt	T	E	I	Hpb	.5	23.98	12- 3-52	D1,050R;DD28
18dd	do	Dr	150	20	P	S,G	Qt	T	G	I	Ls		24	10- 8-47	D1,700R;DD38
19ba	do	Dr	137.0	18	P	S,G	Qt	T	E	I	Hpb	.5	21.15	12- 3-52	D900R;DD40
19bb	do	Dr	128	18	P	S,G	Qt	T	E	I	Hpb	.5	24.76	12- 3-52	D1,020R;DD43;L
62- 1ab	C. Jennings	Dr	114	18	P	S,G	Qt	T	E	I	Ls		54	12-15-47	D1,400R;L
2bc	G. Phillips	Dr	104	36	P	S,G	Qt	T	E	I	Hpb	1.7	61.08	3-15-46	T52;D970R;Ca
2bd	G. Boars	Dr	85	32	P	S,G	Qt	T	G	I	Idp	7.4	60.48	3-15-46	D800R
3bb	C. G. DeMuth	Dr	92	18	P	S,G	Qt	T	E	I	Idp	9.5	64.46	10- 6-47	D700R
5ad	R. True	Dr				S,G	Qt	C	W	S	Tc	1.0	65.87	10- 6-47	
6aa	W. Flamme	Dr	78.0	3	P	S,G	Qt	C	W	S	Tc	.1	58.59	4-25-45	
9cb	P. M. Ragland	Dr	145	60	P	S,G	Qt	T	E	I	Idp	9.4	57.11	3-15-46	D1,350R;Ca
10da	C. Jennings	Dr	111			S,G	Qt	T	E	I					D2,000R,DD33;L
11bb	do	Dr	113.0	18	P	S,G	Qt	T	E	I	Hpb	.9	54.43	3-11-46	D1,050M;DD14.5
22ab1	J. Sharrah	Dr	125	18	P	S,G	Qt	T	E	I	Hpb	.5	36.32	12- 2-52	D350R
22ab2	do	Dr	125	18	P	S,G	Qt	T	E	I	Hpb	.5	36.06	12- 2-52	D1,100R;DD44;L
63- 3ba	R. L. Gasurant	Du	49.0	96	N	Sls	Tb	N	N	N	Twc	.4	48.32	8-28-42	
7db	F. E. Bollan	Dr	75.0	24	P	Sls	Tb	N	N	N	Tc	0	1.25	6-28-42	
64- 4bb	Wyoming Hereford Ranch	Dr	179	5	P	Sls	Tb?	C	W	S	Hpb	1.0	153.14	8-28-42	
65- 6ab		Dr	267.0	5	P	Sls	Tb?	C	W	S	Twc	.8	260.63	10-10-41	
67- 5dd	Warren Livestock Co	Dr		6	P	S,G	To	C	W	S	Tc	9.5	36.09	2-20-50	
11ba	do	Dr		6	P	Sls	Tb	C	W	S	Tc	2.8	295.8	2-16-50	
68- 1dc	do	Dr		8	P			C	W	S	Tc	.6	20.45	2-20-50	
69- 7cc	do	Dr		6	P	S,G	To	C	W	S	Tc	1.9	225.0	2-20-50	T50
13-61-29ab	P. Chamberlain	Dr	85	6	P	Sls	Tb	C	W	S	Tc	.6	60.14	10- 8-47	Ca
30cb	C. E. Hardy	Dr	83	5	P	S,G	Qt	C	W	D,S	Ls		65	9-26-47	Ca
31da	O. M. Young	Dr	85	20	P	S,G	Qt	T	E	I	Ls		50	9-26-47	D800R

Table 4.— *Records of wells in the Crow Creek and Lone Tree Creek drainage basins*— Continued

Well no.	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks
	Laramie County, Wyo.—Continued														
13-62-15db	R. Kent	Dr	75	6	P	S,G	Qt	C	W	S	Tc	0.8	60.40	10- 7-47	
20cc	E. Jacobson	Dr	75	6	P	S,G	Qt	T	E	D	Ls	----	60	10- 6-47	
25ba	H. Vaughan	Dr	97	18	P	S,G	Qt	T	E	I	Ls	----	70	1-15-48	D600R;L
25bb	do	Dr	102	18	P	S,G	Qt	T	G	I	Idp	20.0	92.69	10- 8-47	D500R
28ad	E. Cloyd	Dr	60.0	5	P	S,G	Qt	C	W	D, S	Tc	.2	52.48	9- 1-42	Ca
32bc	R. E. Kane	Dr	65	6	P	S,G	Qt	C	W	D, S	Ls	----	33	10- 7-47	Ca
63- 4cb	J. L. Bailey	Dr	113.0	5	P	S,G	Qt	C	W	S	Bpb	.5	85.79	9- 1-42	
14dc	R. V. Kent	Dr	49	4	P	S,G	Qt	N	N	N	Tc	0	38.28	3-21-42	
20aa	C. E. Montgomery	Dr	54	6	P	S,G	Qt	C	W	D, S	Ls	----	50	10-10-47	
26ca	E. Oline	Dr	57.0	5	P	Sls	Tb	C	W	S	Tc	.8	50.59	11- 1-48	
30aa	W. Evans	Dr	125	6	P	Ss	Ta	C	W	S	Ls	----	90	10-10-47	
33cb	D. A. Bunnell	Dr	131.0	24	P	Sls	Tb	N	N	N	Twc	1.0	49.75	8-21-42	
64-28cc	L. A. Foster	Dr	155	6	P	Sls	Tb?	N	N	N	Tc	.8	145.34	8-28-42	
30cb	W. Sevope	Dr	183	5	P	Sls	Tb?	N	N	N	Tc	1.3	179.13	9- 1-42	
35ad	T. G. Wilcox	Dr	128	3	P	S,G	To?	C	W	S	Tc	.5	108.38	8-21-42	
65- 8bb	Wyoming Hereford Ranch	Dr	400	----	P	Sls	Tb	N	N	N	----	----	----	----	
24ad	C. H. Senior	Dr	150	3	P	Sls	Tb?	C	W	S	----	.1	140.19	8-28-42	

66- 1dd	Wyoming Hereford Ranch	Dr	100	----	----	----	----	N	N	N	----	----	----	----	
7ad	U. S. Bureau of Reclamation	Dr	150	6	P	Ss	To	C	E	In	----	-6.7	59.89	5-23-50	
18ab1	Orchard Valley Water Co	Dr	205	8	P	S, G	To	T	E	P	----	----	----	----	
18ab2	do	Dr	194	8	P	S, G	To	T	E	P	Tc	.5	12.62	4- 2-42	
18ad	do	Dr	182	5	P	S, G	To	N	N	N	Tc	.6	9.04	4- 2-42	
32ca	W. J. Merna	Dr	81	5	P	S, G	To	N	N	N	Tc	-1.5	50.39	2-16-50	
67- 6ad	A. L. King	Dr	19.8	6	P	S, G	To	N	----	N	Tc	-5.3	7.82	9- 3-41	
12bb	F. James	Dr	34	4	P	S, G	To	N	----	N	Tc	-4.5	3.97	2-24-50	
16ab	Warren Livestock Co	Dr	380	10	P	S, Sls	To, Tb	T	E	S	Tc	2.8	8.25	2-24-50	T49
33ac	U. P. R. R. Co	Dr	235	15	P	S, Sls	To, Tb	T	E	D, In	Tc	-5.3	58.65	2-25-50	
68- 3bb	City of Cheyenne	Dr	187	10	P	S, G	To	T	E	P	Tvp	2.2	93.46	12-31-52	D530M;DD52;L
4ac	do	Dr	255	10	P	S, G	To	T	E	P	Tvp	1.8	114.99	1- 6-53	D230M;DD46.6;L
4cb	do	Dr	230	10	P	S, G	To	T	E	P	Tvp	1.6	181.10	1- 6-53	D250R
4dc	do	Dr	200	10	P	S, G	To	T	E	P	Tvp	1.8	132.98	1- 6-53	D480M;L
13cb	A. King	Dr	123	7	P	S, G	To	N	----	N	Tc	1.1	64.68	2-27-53	
14bb	City of Cheyenne	Dr	222	6	P	S, G	To	T	E	P	Tc	.9	83.80	10-29-49	D430M;DD80;L
14cb	do	Dr	210	10	P	S, G	To	T	E	P	Tvp	1.8	51.40	12-31-52	D495M;DD116;L
15cd	W. E. Boyce	Dr	118	5	P	S, G	To	C	W	D	Twc	1.0	83.75	11-14-42	Ca
16da	City of Cheyenne	Dr	300	10	P	S, G	To	T	E	P	Tvp	1.0	114.91	12-31-52	
22bd	Warren Livestock Co	Dr	260	8	P	S, G	To	N	F	S	----	----	----	----	T52;Ca
24aa	City of Cheyenne	Dr	270	10	P	S, G	To	T	E, F	P	----	----	----	----	
34ca	Warren Livestock Co	Dr	----	8	P	S, G	To	N	F	S	----	----	----	----	D11.6M
69-11ab	B. McGee	Dr	400	6	P	S, G	To	C	W	S	Tc	2.9	111.62	2-20-50	
24dd	Warren Livestock Co	Dr	310	6	P	S, G	To	C	W	S	Tc	3.3	245.08	2-20-50	L
34dd	do	Dr	568	8	P	S, G	To	C	W	S	Tc	3.3	230.32	8-15-41	L
14-66-28cd	Veterans' Adm	Dr	1,077	8	P	----	----	N	N	N	Tc	.3	42.50	11-29-33	L
31bd	State of Wyoming	Dr	258	12	P	S, G	To	N	N	N	Tc	0	12.14	12-31-52	
67-10cc	----	Dr	77	5	P	S, G	To	N	N	N	Tc	.3	14.49	2-27-50	
13dd	U. A. L. Housing Assn	Dr	350	8	P	S, G	To	N	N	N	Tc	1.9	44.83	2-18-50	
31bb	M. T. Cox	Dr	69.4	4	P	S, G	To	N	F	S	----	----	----	----	D0.6M
36cc	C. Vaughn	Dr	104	6	P	S, G	To	C	G	D	Tc	1.5	56.22	2-22-50	
68- 2dd	F. Kaster	Dr	----	4	P	S, G	To	C	W	D, S	Tc	.5	211.22	5-15-42	
20ba	City of Cheyenne	Dr	850	12	P	S, G, Sls	Qa, Tb	T	E	P	Tc	-5.4	17.14	7-24-41	L
20bb1	do	Dr	843	15	P	S, G, Sls	Qa, Tb	T	E	P	Tc	-5.7	8.74	7-18-41	

Table 4.— *Records of wells in the Crow Creek and Lone Tree Creek drainage basins*— Continued

Well no.	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below(-) land surface (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks
							Laramie County, Wyo. —Continued								
14-68-20bb2	City of Cheyenne	Dr	947	12	P	S, G, Sls	Qa, Tb	T	E	P	Tpb	1.9	24.77	7-18-41	
23dd	do	Dr	250	10	P	S, G	To	T	E	P	Tvp	1.3	67.60	1- 6-53	D378M;DD61;Ca;L
24dd	do	Dr	286	10	P	S, G	To	T	E	P	Tpb	.6	17.39	1- 6-53	D413M;DD130;L
25bc	do	Dr	334	10	P	S, G	To	T	E	P	Tvp	0	24.37	2-27-50	D224M;DD86
25dd	do	Dr	368	12	P	S, G	To	T	E	P	Tvp	1.0	41.50	12-31-52	D200M;DD114
26ac	do	Dr	215	15	P	S, G	To	T	E	P	Tvp	2.6	6.12	4-30-47	D403M;DD144;L
26cb	do	Dr	220	10	P	S, G	To	T	E	P	Tvp	.7	41.49	12-31-52	D450M;DD60;Ca
27dc	do	Dr	250	10	P	S, G	To	T	E	P	Tvp	1.1	59.69	12-31-52	D400M;DD53;L
32dd	do	Dr	300	10	P	S, G	To	T	E	P	Tvp	1.3	160.86	1- 6-53	
33ab	do	Dr	230	10	P	S, G	To	T	E	P	Tvp	1.6	135.53	12-31-52	D400R
33dc	do	Dr	225	10	P	S, G	To	T	E	P	Tvp	1.3	157.19	1- 6-53	D427M;DD42;L
34aa	do	Dr	235	10	P	S, G	To	T	E	P	Tvp	1.0	48.21	12-31-52	D400M;DD65;L
34db	do	Dr	190	10	P	S, G	To	T	E	P	Tc	-.5	71.91	2-16-50	D330R;DD20
34dd	do	Dr	230	10	P	S, G	To	T	E	P	Tvp	1.2	99.05	12-31-52	D300R;DD25
35ca	do	Dr	235	10	P	S, G	To	T	E	P	Tvp	1.2	87.26	12-31-52	D375M;DD67;L
36ac	do	Dr	188	10	P	S, G	To	T	E	P	Tvp	1.5	37.54	12-31-52	D238M;DD30;L

36ad	----do----------------	Dr	152	12	P	S, G	To	T	E	P	Tvp	1.4	33.54	12-31-52	D276M;DD32
36bc	----do----------------	Dr	214	12	P	S, G	To	T	E	P	Tvp	1.2	38.83	12-31-52	D200M;DD92;Ca
69-26bc	S. Cole----------------	Dr	300	4	P	Sls	Tb	N	N	N	Ls	----	245	8- 5-41	
15-69-21ab	City of Cheyenne----------	Dr	205	10	P	S, Sls	Tb	N	N	N	Tc	0	55.90	11-30-42	D50R

LITERATURE CITED

[See also under Previous Investigations, p. 3]

Eaton, F. M., 1950, Significance of carbonate in irrigation waters: Soil Science, v. 69, no. 2, p. 123–133.

United States Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U. S. Dept. Agriculture, Agriculture Handb. 60, p. 81.

United States Public Health Service, 1946, Drinking-water standards: Public Health Repts., v. 61, no. 11, p. 371–384.

Wilcox, L. V., 1948, The quality of water for irrigation use: U. S. Dept. Agriculture Tech. Bull. 962.

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