Geology and Ground-Water Resources of the Gallatin Valley Gallatin County Montana

By O. M. HACKETT, F. N. VISHER, R. G. McMURTREY, *and* W. L. STEINHILBER

With a section on SURFACE-WATER RESOURCES

By FRANK STERMITZ *and* F. C. BONER

And a section on CHEMICAL QUALITY OF THE WATER

By R. A. KRIEGER

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By O. M. HACKETT, F. N. VISHER, R. G. McMURTREY and W. L. STEINHILBER

ABSTRACT

The Gallatin Valley, an intermontane basin in southwestern Montana, has an area of about 540 square miles and is drained by the Gallatin River and its tributaries. Although much of the valley is semiarid, annual precipitation may average more than 20 inches near the Bridger and Gallatin Ranges, which border the valley on the east and south. Agriculture is the leading occupation. Much of the central part of the valley is irrigated, but most of the higher land along the margins of the valley is dry farmed. The extent to which the agricultural economy of the valley ultimately may be developed depends on the degree to which the valley's water resources are utilized.

The Three Forks structural basin, in which the Gallatin Valley is located, was formed as the result of crustal movements in early Tertiary time. Subsequently, the basin was filled to a depth of 4,000 feet or more with volcanic ash and with sand, silt, and clay eroded from the surrounding highlands. As the result of renewed crustal unrest in late Tertiary or early Quaternary time, the Tertiary strata were tilted eastward; where exposed in the Camp Creek Hills, in the western part of the Gallatin Valley, they form a homocline that dips 1° to 5° to the east. A major east-trending fold in the Tertiary strata in the northern part of the Camp Creek Hills is believed by the authors to mark a subjacent fault, referred to in the present report as the Central Park fault.

The Tertiary strata are divisible into three units, of which the lowest is known only from subsurface data. The subsurface unit probably is of early Oligocene age and is inferred by the authors to be at least 2,400 feet thick. From test drilling, it is known to consist, in part, of blue-green sandstone, claystone, and siltstone, and to contain a few beds of bentonite(?) and lignite. The lower of the exposed units, unit 1, probably includes strata of late Oligocene and early Miocene age and is about 900 feet thick in the Camp Creek Hills. Predominantly of lacustrine origin, this unit is composed largely of well-stratified volcanic ash, tuffaceous marl, siltstone, and sandstone and contains a few beds of limestone. Unit 2, probably of late Miocene and Pliocene age, is predominantly of fluvial and colluvial origin and is a little more than 400 feet thick in most places in the Camp Creek Hills. It consists of poorly stratified to massive, buff to tan, variously consolidated tuffaceous siltstone, claystone, sandstone, and conglomerate, and contains a few beds of gray ash. Whether the strata of Tertiary age that skirt the mountain ranges on the east and south sides of the Gallatin Valley are equivalent in age to, or younger than, those of the Camp Creek Hills could not be determined by the authors.

Post-Tertiary crustal movement, probably along the postulated Central Park fault, created a deep east-trending trough in the Tertiary strata between the Camp Creek Hills and the Bridger Range. Alluvium deposited by the Gallatin River and its tributaries during Quaternary time not only filled this trough but mantled the Tertiary strata throughout the lower part of the Gallatin Valley. Also, broad fans of alluvium were deposited on the lower slopes of the Bridger and Gallatin Ranges by streams heading in the mountains. The alluvium consists of cobbles and gravel intermixed with sand, silt, and clay.

The Gallatin River is the source of irrigation water for about three-fourths of the irrigated land in the valley. During the 2 periods of record (1889-92 and 1930-52) the annual flow into the Gallatin Valley, as measured near Gallatin Gateway, averaged 536,000 acre-feet. During the 1952 water year (October 1, 1951, through September 30, 1952) the discharge of the Gallatin River at Gallatin Gateway was 715,000 acre-feet, or about 73 percent of the total surface-water inflow to the valley (976,000 acre-feet). In the 1953 water year the discharge of the Gallatin River at Gallatin Gateway was 518,000 acre-feet, or about 70 percent of the total inflow to the valley (744,000 acre-feet). Nearly all the other inflow to the valley was contributed by streams draining the Gallatin and Bridger Ranges.

Although much ground water is available in the Gallatin Valley, this resource is largely undeveloped. The principal aquifer is the alluvium beneath the valley floor. This aquifer is characterized by generally high coefficients of transmissibility—100,000 to 300,000 gpd (gallons per day) per foot—and in many places would yield ample water for irrigation. The adjacent alluvial fans generally yield sufficient water for only stock and domestic use, but the more extensive fans probably would yield supplies sufficient for some irrigation. Low to moderate coefficients of transmissibility (7,000 to 65,000 gpd per foot) characterize the alluvial fans. The Tertiary strata have relatively low coefficients of transmissibility (generally less than 6,000 gpd per foot) and yield sufficient water for only stock and domestic use.

The ground-water reservoir is recharged principally by infiltrating irrigation water. Influent seepage from streams, particularly during the period of high runoff in the spring, is another important means of recharge. Ground water is discharged by seepage to the streams at the lower end of the valley and by evapotranspiration. The discharge of ground water as surface flow from the valley is estimated to be about 240,000 acre-feet per year. Recharge to the ground-water reservoir exceeds this amount by the unknown volume of ground water consumed through evapotranspiration.

Along the valley sides, ground water moves toward the valley floor, and in the Bozeman fan and beneath the valley floor it moves generally northward. In most of the area between the Gallatin and East Gallatin Rivers the water table is within 30 feet of the land surface throughout the year, and within much of this area it is within 10 feet of the surface.

Data indicate an increase of ground water in storage during the late spring and early summer months, and a decrease in storage during the rest of the year. Using a computed value of 15 percent for the specific yield, the writers calculated that ground-water storage increased by about 150,000 acre-feet during the period March through July in the 1952 water year and that it decreased by about 132,000 acre-feet during the other months of that year. In the 1953 water year, ground-water storage increased by 149,000

acre-feet during the period April through July and decreased by 167,000 acre-feet during the other months.

An inventory of the water resources in the Gallatin Valley shows that during the 1952 water year a total of 1,484,000 acre-feet of water entered the valley (976,000 acre-feet as surface water and 508,000 acre-feet as precipitation). Of the total, a net of 17,500 acre-feet was added to ground-water storage. During the same period, 437,000 acre-feet was used consumptively, and 1,030,000 acre-feet of water left the valley as surface flow. In the 1953 water year 1,103,000 acre-feet of water entered the valley (744,000 acre-feet as surface water and 359,000 acre-feet as precipitation). During the same period, 405,000 acre-feet was used consumptively, and 716,000 acre-feet left the valley as surface water. Of the total (1,121,000 acre-feet), 17,900 acre-feet was withdrawn from ground-water storage.

In this report the Gallatin Valley is subdivided into areas and subareas according to geologic and hydrologic characteristics. Each area and subarea is discussed in regard to its potential for development of ground water for large-scale use.

Theoretically, about 20,000 acre-feet of ground water per year could be pumped in the Gateway subarea and at least 100,000 acre-feet per year could be pumped in the Belgrade subarea without reducing the amount of ground water in storage. Ground water from the Belgrade subarea could be conveyed by ditches to the Manhattan subarea for irrigation.

In some places on the Bozeman fan, a supplemental supply of water for irrigation could be obtained from underground sources, but elsewhere on the fan the supply of ground water is sufficient only for domestic and stock needs.

Ground water for irrigation is not available in the Camp Creek Hills nor in the Dry Creek, South Bridger, Fort Ellis, and South Gallatin subareas. Available data indicate that the Upper East Gallatin and the Spring Hill subareas do not have large ground-water supplies, but additional information would be necessary before an accurate evaluation could be made.

If ground water were used to increase irrigation in the valley, the reduction in outflow from the valley would approximate the volume of water used consumptively. Maximum irrigation would involve (a) use of surface water for irrigation from the beginning of the irrigation season to the period of surface-water shortage; (b) artificial recharge of the ground-water reservoir in the Gateway and Belgrade subareas by spreading surplus surface water before and during the irrigation season; (c) use of ground water during the period of surface-water shortage for irrigation in the Gateway, Belgrade, Central Park, and Manhattan subareas, and the use of surface water in the remaining irrigated parts of the Gallatin Valley.

Calcium and bicarbonate are the principal dissolved constituents in ground water from deposits of Quaternary age in the Gallatin Valley. Generally, the water has a mineralization of about 150 to 400 ppm of dissolved solids, is hard, and contains iron in excess of 0.3 ppm. The chemical quality of water from the alluvium underlying the valley floor does not vary from place to place nor with depth; it resembles the quality of water from Quaternary deposits in the Bozeman fan and the valley-fringe area. However, water from the Tertiary strata does vary in quality from place to place as well as with depth. Sodium is a principal dissolved constituent in some water from Tertiary strata. In the northern part of the valley floor, water that entered a deep test hole from Tertiary strata and Precambrian rocks was of the

sodium chloride bicarbonate type and was more highly mineralized than water from wells tapping deposits of Quaternary or Tertiary age.

Water in streams in the lower Gallatin River drainage basin also is of the calcium bicarbonate type. At Logan, the only outlet for water from the basin, the maximum concentration of dissolved solids in the Gallatin River was 258 ppm in water samples collected at intervals throughout the 1952 water year.

Ground water in the Quaternary deposits and surface water are rated as excellent for irrigation because salinity, percent sodium, residual sodium carbonate, and boron are low. Most of the water from the Tertiary strata also is rated as excellent for irrigation, though salinity, percent sodium, residual sodium carbonate, and boron generally are greater than in water from the Quaternary deposits.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

Through the Montana State College, the U.S. Soil Conservation Service, and local organizations, such as the Gallatin Valley Water Users' Association, the residents of the Gallatin Valley urged that a detailed study be made of the water resources of their valley. Plans for such a study materialized in the fall of 1950 when, at the request of the U.S. Bureau of Reclamation, the U.S. Geological Survey agreed to evaluate the total water resources of the Gallatin Valley. The study was begun in April 1951 and completed in June 1954.

In making this study it was necessary to ascertain (a) the amount of water entering and leaving the valley; (b) the occurrence and availability of ground water; (c) the source, rate, and quantity of ground-water recharge; (d) the manner, rate, and quantity of ground-water discharge; (e) the seasonal, annual, and long-term changes in ground-water storage; (f) the direction of ground-water movement; (g) the chemical quality and the variations in quality of the water; and (h) the location of those parts of the valley where ground water could be utilized as a source of irrigation supply.

PERSONNEL AND ACKNOWLEDGMENTS

The investigation was under the direct supervision of F. A. Swenson, district geologist of the Ground Water Branch of the Geological Survey. Frank Stermitz, district engineer of the Surface Water Branch, supervised the collection of streamflow data. P. C. Benedict, regional engineer of the Quality of Water Branch, supervised the chemical-quality phase of the investigation.

In addition to the authors, several others of the Geological Survey participated in the study. M. D. Allison, geologist, and A. J. Rosier, hydraulic engineer, assisted with the fieldwork, and E. R. Jochens, chemist, initiated the quality-of-water studies. C. E. Erdmann, of the Conservation Division, and G. D. Robinson, of the Geologic Division, were especially helpful in the geologic phases of the investigation. The names "Camp Creek Hills" and "Salesville fault" were suggested by P. F. Fix.

An experimental geophysical investigation was made for the Geological Survey by Dart Wantland, Roxy Root, and R. D. Casey, of the Geophysical Section of the Engineering Geology Branch, U.S. Bureau of Reclamation.

The cooperation and assistance of the following agencies and organizations contributed to the progress of the investigation: U.S. Weather Bureau, U.S. Bureau of Reclamation, U.S. Soil Conservation Service, Montana State College at Bozeman, State Engineer's Office, Gallatin Valley Water Users' Association, Gallatin County Agent's Office, Gallatin County Commissioners, and officials of the city of Bozeman and the villages of Belgrade and Manhattan.

The writers are particularly indebted to the residents of the valley who gave information, permitted access to land and use of wells, and acted as observers at precipitation and stream-gaging stations. Valuable information was furnished by Harry and Bert VanDyken and P. T. Marsh, well drillers, and by the Montana Power Co. and the Gallatin Gateway Oil Co.

Unpublished maps of adjacent areas were made available by E. S. Perry, of the Montana School of Mines, and W. J. McMannis. Dr. McMannis, who had prepared his map in partial fulfillment of the requirements for the degree of doctor of philosophy at Princeton University, gave his permission for the inclusion of his representation of bedrock relationships along the west flank of the Bridger Range on the geologic map prepared for this report.

Special thanks are due O. W. Monson, of the Agricultural Engineering Department at Montana State College, for his counsel and active assistance throughout the investigation. Others who assisted are C. C. Bradley and E. R. Dodge, of the Montana State College staff, and A. R. Codd, of the U.S. Soil Conservation Service. During the 1953 field season, several valuable field consultations were held with Peter Verrall, who then was mapping the geology of the Horseshoe Hills in partial fulfillment of the requirements for the degree of doctor of philosophy at Princeton University.

PREVIOUS GEOLOGIC AND HYDROLOGIC INVESTIGATIONS

Peale (1896) mapped and described the general geology of the 60-minute Three Forks quadrangle, which includes the Gallatin Valley. He was the first geologist to describe the Tertiary strata of this area, naming them the Bozeman lake beds.

Iddings and Weed (1894) described the general geology of an area adjoining the Gallatin Valley on the east.

Douglass[1] discussed the relationships and extent of the Tertiary lake basins in western Montana. He included a generalized stratigraphic description of the Tertiary strata in the Madison Valley, which is adjacent to the Gallatin Valley, and dated these strata as Oligocene and Miocene on the basis of vertebrate fossils. Douglass (1903, 1909) also published additional descriptions of vertebrate fossils from the Tertiary strata in several western Montana lake basins, including the Three Forks basin of which the Gallatin Valley is a part.

Later, the age and stratigraphic relationships of the Tertiary strata in the Three Forks basin were determined more accurately by other investigators. Reports by Wood (1933, 1938), Wood and others (1941), Schultz and Falkenbach (1940, 1941, 1949), and Dorr (1956) are especially significant.

Pardee (1925) published a comprehensive review of the literature pertaining to the Tertiary geology of western Montana. Later (1950) he summarized the results of many years of study in a general account of the geology and Cenozoic history of western Montana. His discussion of the stratigraphy, history, and structure of the Tertiary strata is of particular interest.

A description of physiographic features in the Gallatin Valley and adjacent areas is included in a comprehensive report by Alden (1953) on the physiography and glacial geology of western Montana. Detailed investigations of areas adjacent to, or including parts of, the Gallatin Valley have been made by Berry (1943), Skeels (1939), Klemme,[2] and McMannis (1955). Each of the reports on these studies contains a geologic map and a detailed description of the stratigraphy and structural geology. Fix[3] described the geologic structure of the Gallatin Valley with particular regard to regional structural relationships.

Several papers that deal with the regional stratigraphy of Montana include extensive reference to the Paleozoic section in the

[1] Douglass, Earl, 1899, The Neocene lake beds of western Montana and description of some new vertebrates from the Loup Fork: Unpublished master of science thesis, Univ. Montana, 27 p.

[2] Klemme, H. D., 1949, Geology of the Sixteen Mile Creek area, Montana: Unpublished doctor of philosophy dissertation, Princeton Univ., 197 p.

[3] Fix, P. F., 1940, Structure of Gallatin Valley, Montana: Unpublished doctor of philosophy dissertation, Univ. Colorado, 68 p.

Horseshoe Hills along the north margin of the Gallatin Valley. Notable among these are papers on the Cambrian section by Deiss (1936), Berry (1943), Lochman (1950), and Hanson (1952) and on the Devonian section by Sloss and Laird (1946). The Precambrian rocks near Gallatin Gateway at the southern end of the valley are described in detail by Clabaugh (1952), with special reference to the occurrence of corundum.

Reed (1951) briefly described the mines and mineral resources of Gallatin County.

Murdock (1926) described irrigation and drainage in the Gallatin Valley as they existed before 1922. He discussed methods of relieving water shortages in the valley and the drainage of wet areas and also called attention to excessive water loss by seepage and evaporation. Murdock suggested that use of ground water for irrigation not only would provide additional water where needed but also would assist in the drainage of waterlogged land. His paper includes some data on ground-water levels in the valley.

A report by the U.S. Soil Conservation Service (1948) contains preliminary hydrologic information on the Gallatin Valley; it also proposes a program for a future hydrologic investigation. In a later report for the Soil Conservation Service, Long (1950) presented the results of a drainage investigation in the Central Park subarea at the north end of the valley. In addition to water-level data, logs of observation wells, and a water-table contour map, Long's report contains recommendations concerning drainage procedure.

Debler and Robertson (1937), in a report prepared for the Bureau of Reclamation, described reservoir sites on streams that enter the Gallatin Valley. The report includes preliminary designs and estimated costs of dams, an economic survey of the valley, and a partial land classification.

The Montana State Engineer's Office (1953a, b) published two reports on the water resources of Gallatin County. The first report presented the history of land and water use in irrigated areas and the second, detailed maps showing irrigated areas and sources of water supply.

In 1952 and 1953 the Bureau of Reclamation measured all water diverted by canals in the valley and the return surface flow from irrigation. The results were not yet available as of 1954. The Bureau also classified the land and made estimates of water shortages in the valley.

The soils of the Gallatin Valley were mapped and described by DeYoung and Smith (1936). The history of the Gallatin Valley, its settlements and institutions, is described in a publication by the Montana Institute of the Arts (1951).

METHODS OF INVESTIGATION

A rather comprehensive stream-gaging program was conducted by personnel of the Surface Water Branch of the Geological Survey to determine, within reasonable limits, the surface-water flow into, and out of, the valley during the time of the study. (See pl. 1.) The Gallatin River was gaged where it enters and leaves the valley and at three intermediate points. Gaging stations were maintained also on the 10 principal tributaries. Five of the gaging stations were among those regularly maintained by the Geological Survey; the others were established for this study. To serve as a basis for estimating the discharge of the numerous other streams having a fairly sustained flow of 1 cfs (cubic foot per second) or more, monthly discharge measurements and some miscellaneous gage readings were obtained. All streams contributing an appreciable amount of water to the valley were measured at least twice. Also, monthly measurements were made of the large spring-fed streams that rise within the valley.

To obtain a record of the distribution of precipitation in the valley, 14 rain gages were installed in addition to the 4 permanent gages maintained by the Weather Bureau. (See pl. 1.) These additional stations were established with the cooperation and assistance of the Weather Bureau and were operated throughout 1952 and 1953. Eleven of the stations were serviced daily by volunteer observers from among the ranchers of the valley, and 3 accumulation gages were serviced monthly by personnel of the Geological Survey. The daily maximum and minimum temperatures also were recorded at three of the stations.

More than two-thirds of the wells and springs in the Gallatin Valley were inventoried and all available pertinent data were compiled (table 36). The well locations are shown on plate 1. Measurement of the water level in 123 wells was made monthly (table 34), and water-stage recorders were installed in 12 wells in order to record water-level fluctuations in detail (table 35).

Reconnaissance mapping of the principal geologic units exposed in the valley proper was begun in 1952 and completed the following year. The mapping was done on aerial photographs and adjusted to Geological Survey 15-minute topographic quadrangles by means of a sketchmaster. The final geologic map (pl. 2), which was compiled from these sheets, includes not only the valley proper but also a marginal belt which was mapped to show the relationship of the valley fill to the consolidated rocks of the mountain flanks. The geology along the east margin of the valley was taken from a map of the Bridger Range by McMannis (1955).

Twenty test holes, ranging in depth from 25 to 1,000 feet and totaling 5,966 feet, were drilled under contract during the period 1951–53; their locations are shown on plate 1. Test drilling was the primary source of subsurface geologic data and provided much valuable information on the occurrence of ground water.

During the planning of the investigation, subsurface exploration by geophysical methods was proposed. It was thought that the seismic (refraction) method would locate the contact between the valley fill and the consolidated rocks of the basement complex and that resistivity surveying would determine the boundaries of the permeable water-bearing beds within the valley fill. Experiments using both methods were made in the summer and fall of 1951 (Wantland, 1951a, b). The seismic work proved to be of little value, however, partly because adequate control was lacking and partly because the method was poorly suited for depth determinations of the order needed. The resistivity work likewise proved to be of little value, probably because the geologic setting was so complicated. If adequate control had been available for verification of the results, geophysical methods of exploration probably would have proved worth while.

The hydrologic properties of water-bearing materials were determined by means of "single-well" pumping tests. Because this type of test can be made with ease, economy, and speed, it was possible to make about 100 such tests. In addition, "multiple-well" pumping tests were made at 4 sites. These latter tests served as a check on the results obtained from the single-well tests.

One hundred and three samples of water for chemical analysis were collected from selected wells, springs, test holes, and streams in all parts of the valley. The analytical results were used in rating the suitability of the water for irrigation and other uses, in correlating water quality with geologic source of the water, and in determining more fully the relationship between surface water and ground water.

WELL-NUMBERING SYSTEM

All wells referred to in this report were assigned numbers indicating their location within the system of land subdivision of the U.S. Bureau of Land Management. (See fig. 1.) The first letter (capital) of the number indicates the quadrant of the principal meridian and base-line system in which the well is located; the letters begin with A in the northeast quadrant and proceed counterclockwise. The first numeral of the number denotes the township; the second, the range; and the third, the section in which the well is situated. Lowercased letters following the section number indicate, respectively, the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section. These subdivisions of the section are designated a, b, c, and d and are assigned in counterclockwise direction, beginning

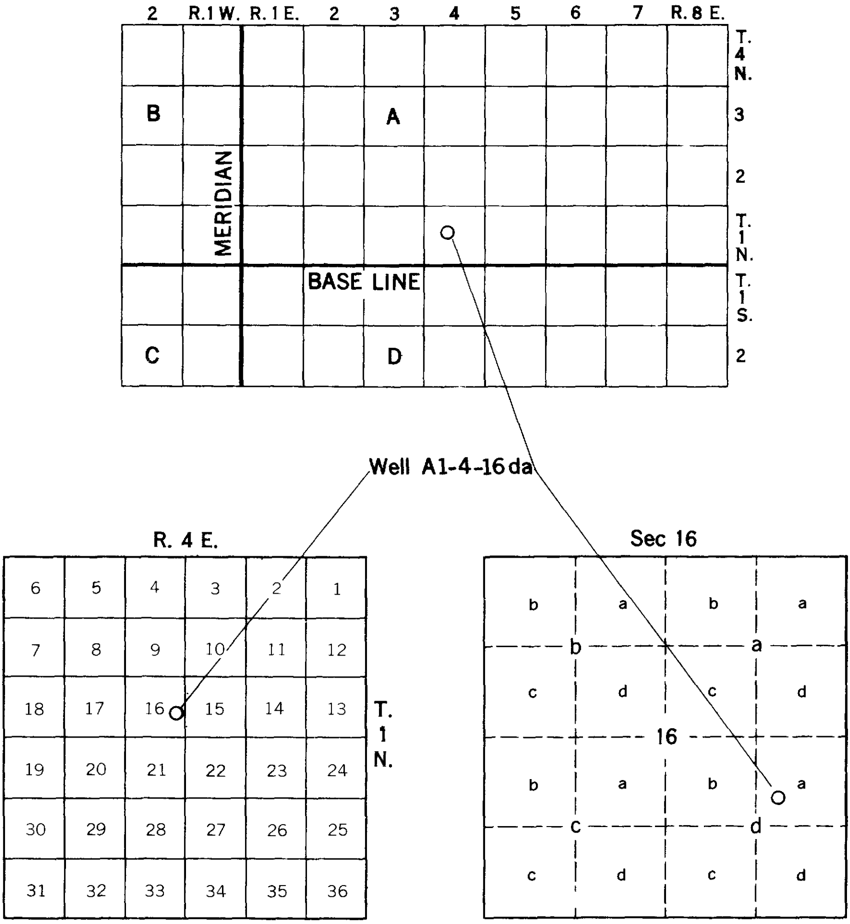

FIGURE 1.—Well-numbering system.

in the northeast quarter. If two or more wells are situated in the same tract, they are distinguished by numerals following the lowercased letters.

Springs, test holes, and precipitation stations also were assigned numbers according to the same system.

GEOGRAPHY

LOCATION AND EXTENT OF THE AREA

The Gallatin Valley is an intermontane basin in the Rocky Mountains of southwestern Montana. (See fig. 2.) It lies almost entirely within Gallatin County, is about 25 miles long and 20 miles wide, and has an area of about 540 square miles. A large

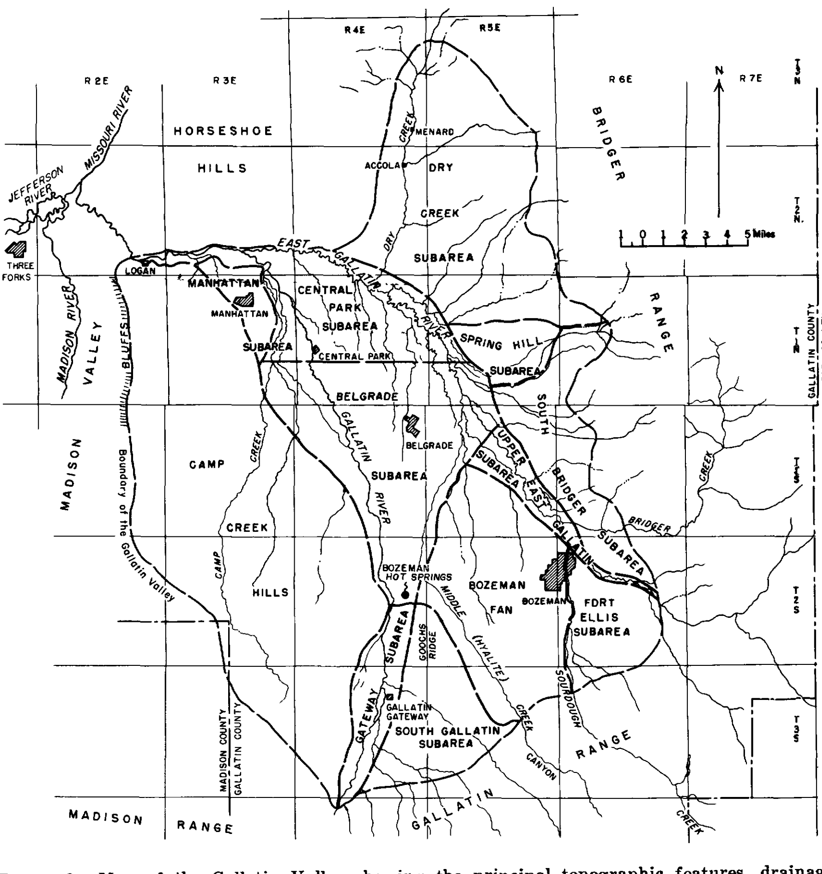

FIGURE 2.—Map of the Gallatin Valley showing the principal topographic features, drainage, and hydrologic subdivisions.

tributary valley, that of Dry Creek, projects to the northeast from the main valley. The Bridger and Gallatin Ranges flank the valley on the east and south, the Horseshoe Hills form the northern boundary, and the topographic divide between the Gallatin and Madison Rivers bounds the valley on the west.

TOPOGRAPHY AND DRAINAGE

Gallatin Canyon, at the upper end of the valley, is the principal inlet for surface water to the valley, and a gorge at Logan, at the lower end, is the only outlet.

The principal part of the Gallatin Valley is bounded on the west by the Gallatin River and on the north and east by the East Gallatin River, Bozeman Creek, and Sourdough Creek.[4] It is shaped, in plan view, like a giant powderhorn having for its large end the southern border of the valley and for its apex the northwestern end of the valley. The land surface gradient of this part of the valley ranges from about 100 feet per mile at the extreme southern, or upper, end to less than 40 feet per mile near the northwestern, or lower, end. From a centrally located axis, this part of the valley slopes toward the Gallatin and East Gallatin Rivers at either side. Its surface is comparatively smooth, and it has little relief except for Goochs Ridge, which extends northward into the valley between Middle (Hyalite)[5] and South Cottonwood Creeks. The altitude ranges from about 5,400 feet at the upper end of the valley to about 4,100 feet at the lower end.

Adjacent to the floor of the valley on the west are the Camp Creek Hills, remnants of a relatively high partly dissected surface or group of surfaces that sloped northeastward from the top of the bluffs along the Madison River toward the valley floor. The Camp Creek Hills taper from a maximum width of about 10 miles in their central part to a width of about 2 miles at their northern end. In the southern part of the valley their boundary with the valley floor is marked by a sharp east-facing escarpment; in the northern part of the valley the escarpment is replaced by a colluvial slope that grades into the Manhattan terrace. The western and southern parts of the Camp Creek Hills area are flat to rolling, but the eastern and northern parts are broken by many draws and small canyons.

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[4] According to a decision by the Board on Geographic Names dated Sept. 5, 1957, Bozeman Creek is formed by the junction of Sourdough and Spring Creeks and flows northward to the East Gallatin River. Sourdough Creek heads in Mystic Lake and flows northwesterly about 10 miles to join Spring Creek and form Bozeman Creek. Locally, however, the names "Sourdough Creek" and "Bozeman Creek" are applied to the entire stretch from Mystic Lake to the East Gallatin River. In this report, therefore, the entire stretch will be referred to as Sourdough (Bozeman) Creek.

[5] According to a decision of the Board on Geographic Names dated Nov. 7, 1928, "Hyalite" is the official name of this creek, but, locally, it is also known as Middle Creek. In this report, it is referrred to as Middle (Hyalite) Creek.

The south and east sides of the Gallatin Valley are bordered by coalescing alluvial fans that slope rather steeply from the Gallatin and Bridger Ranges. The Gallatin Range averages about 9,000 to 10,000 feet in crest altitude. Between Middle (Hyalite) and Sourdough (Bozeman) Creeks a broad alluvial fan, the "Bozeman fan," extends out from this range and merges with the valley floor. The Bridger Range is linear and its crest trends north at an average altitude of 8,500 to 9,000 feet. The fans extending from the base of this range either terminate in an escarpment along the East Gallatin River or merge with the river alluvium.

On the north side of the valley is a sharp cliff cut by the Gallatin and East Gallatin Rivers where they impinge on the Horseshoe Hills, a series of northeast-trending ridges that rise about 1,000 feet above the valley floor.

An extension of the valley, the Dry Creek subarea, lies between the Horseshoe Hills and the Bridger Range. This subarea is rolling and cut by draws; it is continuous with, but somewhat wider than, the slopes bounding the southern part of the valley floor (fig. 2), and is considerably higher than the valley floor. Alluvial fans from the Bridger Range extend into the eastern part of the Dry Creek subarea.

The Fort Ellis subarea extends southeastward from Bozeman. Its surface, which also stands above the valley floor, is rolling and somewhat dissected. Alluvial fans from the Gallatin Range border this subarea on the south.

The Gallatin Valley is drained and watered by the Gallatin River and its tributaries. The Gallatin River rises in the northwest corner of Yellowstone National Park and flows northward through the Gallatin Canyon between the Gallatin and Madison Ranges. About 80 miles below its source the river enters the Gallatin Valley at a point known as the Gateway. It then arcs gently north-northwestward through the valley for a distance of about 28 miles. At Logan it passes through a small gorge and leaves the valley. Three miles downstream it joins the Madison and Jefferson Rivers to form the Missouri River. The few intermittent streams that head in the Camp Creek Hills drain directly into the Gallatin River.

The East Gallatin River is the main tributary of the Gallatin River. It rises about 10 miles east of Bozeman near Bozeman Pass, enters the valley about 5 miles east of Bozeman, and arcs northwestward to its confluence with the Gallatin River north of Manhattan. The entire east side of the valley, most of the south and north sides, and most of the valley floor are drained by tributaries of the East Gallatin River. Therefore, despite its short length, the East Gallatin River becomes a major stream before it joins the Gallatin River.

Numerous short perennial streams of high gradient enter the valley from the Gallatin and Bridger Ranges. A relatively few small intermittent streams form in the Camp Creek Hills or enter the valley from the Horseshoe Hills. Several small spring-fed streams rise within the valley; most of these discharge into the East Gallatin River.

CLIMATE

The climate of the Gallatin Valley is characterized by long cold winters and short cool summers. Much of the valley is semiarid.

Extreme daily and seasonal fluctuations in temperature are common. The mean annual temperature at Bozeman is 42.0°F, the highest recorded temperature is 112°F, and the lowest recorded is 53°F below zero. The growing season at Bozeman is about 119 days; that in the lower part of the valley is shorter by several days to a few weeks, probably owing to downvalley movement of cool air. The average date of the last killing frost at Bozeman is May 22, and that of the first killing frost is September 18. Departures from this average are common, killing frosts having been recorded in all months of the growing season. The maximum and minimum daily temperatures recorded at three stations—near Manhattan, near Menard, and at Anceney—during the period May 1952 through January 1954 are given in table 1.

Precipitation in the Gallatin Valley is unevenly distributed. (See fig. 3.) The northern, central, and western parts of the valley receive much less precipitation than do the parts of the valley near the Bridger and Gallatin Ranges.

The average annual precipitation at Bozeman during the entire period of record, 1869-1953, is 18.16 inches. However, because the record before 1895 is fragmentary, the average of 17.81 inches for the period 1895-1953 probably is more nearly representative. (See fig. 4.) As shown by the graph of average monthly precipitation, nearly two-thirds of the precipitation at Bozeman falls during the period April to September. The precipitation in May and June amounts to about one-third of the annual precipitation. A secondary maximum, much less than that in the spring, usually occurs in September. The amount of precipitation from year to year, however, is characterized by

TABLE 1.—*Daily temperatures at three stations in the Gallatin Valley, May 1952 through January 1954*

[H, high; L, low]

Station A2–3–34bd (near Manhattan)

Day	1952 May H	1952 May L	June H	June L	July H	July L	Aug. H	Aug. L	Sept. H	Sept. L	Oct. H	Oct. L	Nov. H	Nov. L	Dec. H	Dec. L
1	70	...	71	...	72	39	86	51	69	29	76	25	56	26	25	-11
2	72	...	79	...	72	40	87	55	84	28	83	25	47	12	39	-5
3	65	...	81	...	86	37	85	53	90	33	68	33	50	5	44	12
4	71	...	79	42	86	40	82	46	87	44	61	24	66	8	35	3
5	68	...	87	42	86	40	87	41	81	44	64	24	52	19	36	8
6	...	...	86	52	77	40	88	48	84	36	70	19	50	17	42	7
7	64	..	78	45	76	31	89	52	84	39	79	16	58	12	44	7
8	64	...	77	44	86	34	82	44	84	38	80	22	46	24	38	7
9	66	32	86	39	90	40	86	48	89	32	88	19	48	22	37	8
10	66	...	76	54	91	41	74	50	72	35	70	31	53	4	44	13
11	75	41	82	33	86	54	75	47	76	46	74	23	60	17	41	13
12	74	...	76	54	66	52	84	40	72	34	73	32	51	11	39	24
13	67	45	72	29	72	49	89	41	61	39	60	23	51	14	43	24
14	62	...	85	36	79	38	86	40	70	19	54	18	44	10	37	15
15	59	...	81	52	87	39	87	38	83	23	65	14	44	29	38	8
16	61	...	73	46	85	41	84	35	86	26	65	32	36	28	41	14
17	64	...	74	34	81	37	85	35	87	32	68	18	38	26	30	10
18	69	...	80	33	79	36	89	35	85	33	67	18	40	20	30	11
19	59	...	74	44	73	49	86	39	72	37	72	21	43	19	29	16
20	64	...	77	39	82	42	85	38	74	31	71	17	40	11	31	7
21	48	35	71	44	71	55	89	36	73	30	67	19	34	11	30	13
22	60	40	69	34	75	37	96	37	80	24	70	23	28	-1	31	-1
23	71	34	76	27	90	38	94	45	82	25	73	17	30	19	27	9
24	77	35	65	50	85	53	97	41	86	28	70	20	26	18	16	5
25	73	44	59	45	88	35	89	48	85	26	65	17	24	-7	11	-20
26	63	43	64	42	84	39	82	36	89	25	62	15	20	-4	15	-21
27	74	...	68	48	88	44	77	37	81	32	60	14	20	-4	15	-14
28	78	...	82	39	88	47	84	33	76	32	65	12	17	-19	34	-14
29	70	...	84	42	87	37	76	30	85	28	68	11	12	-19	41	-16
30	65	...	75	41	93	39	64	39	77	29	62	41	8	-17	32	5
31	72	...			90	39	64	30			57	18			33	16

Day	1953 Jan. H	1953 Jan. L	Feb. H	Feb. L	Mar. H	Mar. L	Apr. H	Apr. L	May H	May L	June H	June L	July H	July L	Aug. H	Aug. L	Sept. H	Sept. L	Oct. H	Oct. L	Nov. H	Nov. L	Dec. H	Dec. L	1954 Jan. H	1954 Jan. L
1	...	...	52	35	24	10	42	15	51	31	76	37	78	55	89	46	88	42	77	36	64	29	42	27	44	31
2	...	...	48	43	27	-2	46	7	51	34	75	45	84	35	83	49	66	41	58	34	58	39	39	14	41	17
3	47	12	62	32	34	-14	58	8	60	18	48	43	86	39	85	43	64	35	64	16	53	10	37	5	41	25
4	40	25	53	33	45	27	50	23	68	20	59	41	88	37	88	45	72	29	69	20	57	11	38	12	48	12
5	34	16	42	17	47	30	48	32	78	22	60	38	84	42	85	39	82	31	72	19	61	26	42	20	57	39
6	18	-9	43	28	45	18	45	33	83	25	67	41	87	36	92	42	87	31	81	24	56	23	45	28	52	22
7	40	10	55	23	52	19	42	32	77	31	65	47	86	39	96	44	88	33	79	23	54	16	33	0	56	28
8	48	20	34	30	51	19	38	16	55	24	64	40	90	42	89	43	84	31	82	23	58	11	32	2	46	23
9	55	49	35	18	56	19	42	19	52	35	75	34	92	45	84	41	85	44	84	28	55	14	47	22	38	20
10	52	38	38	2	64	23	42	20	48	31	83	49	96	42	75	52	87	31	85	25	57	16	43	20	46	1
11	57	24	33	3	53	32	44	14	40	24	88	41	95	46	80	37	89	31	72	29	68	23	37	6	31	1
12	60	49	39	21	52	27	45	23	41	22	75	40	98	47	94	36	92	31	71	24	67	25	49	25	30	3
13	50	34	35	9	44	29	48	24	48	27	79	35	100	49	91	59	87	33	77	29	62	24	44	21	30	10
14	38	19	38	6	40	27	41	22	58	23	74	48	99	50	87	49	84	32	75	21	58	20	33	10	39	17
15	38	28	38	21	51	17	52	27	66	24	74	42	90	51	93	41	88	29	71	26	67	26	45	20	20	-17
16	45	40	38	15	54	22	46	29	70	25	80	45	80	37	91	40	88	39	70	25	63	34	35	10	2	-18
17	42	7	39	15	41	16	40	27	66	34	80	35	90	34	90	44	76	41	74	24	57	30	44	9	11	-6
18	41	25	32	21	46	16	48	13	72	35	76	39	94	38	92	40	75	30	75	27	33	22	39	8	34	-22
19	48	29	28	4	58	27	62	14	66	47	69	43	92	40	95	40	81	41	71	32	28	0	47	20	28	-21
20	50	33	29	4	48	26	70	32	58	38	64	42	83	42	98	41	77	26	61	18	26	2	50	32	-3	-44
21	45	37	35	3	44	21	73	33	61	33	77	30	84	33	88	41	79	24	51	31	39	20	36	27	5	-34
22	48	32	41	8	44	23	75	28	57	32	81	38	92	34	90	43	84	37	50	26	43	25	33	20	44	28
23	52	22	32	7	45	23	58	35	66	28	80	37	93	42	90	42	76	32	49	16	47	27	32	5	40	1
24	60	23	29	-6	66	17	57	31	60	39	65	36	89	38	90	41	68	34	52	18	49	31	34	3	11	-11
25	55	34	38	3	59	25	67	23	59	38	66	28	80	42	81	29	78	21	56	25	46	26	35	11	13	-19
26	38	17	50	3	54	17	78	32	65	37	73	29	90	42	88	30	80	24	49	20	50	32	42	6	30	-13
27	38	17	49	31	68	26	72	46	70	37	78	34	93	46	84	36	79	32	66	21	48	20	36	18	38	10
28	45	17	41	23	72	26	62	41	64	50	81	40	97	42	74	44	78	31	70	19	44	22	50	22	46	35
29	48	34			59	35	46	33	57	46	84	39	93	47	79	36	80	21	72	22	45	25	45	12	43	35
30	47	32			57	15	53	28	65	42	90	39	97	44	87	35	85	26	62	29	43	22	52	9	42	...
31	62	37			54	29			76	35			92	47	87	37			67	37			50	16	...	...

TABLE 1.—*Daily temperatures at three stations in the Gallatin Valley, May 1952 through January 1954*—Continued

Station A3-5-18da (near Menard)

Day	1952 May H	May L	June H	June L	July H	July L	Aug. H	Aug. L	Sept. H	Sept. L	Oct. H	Oct. L	Nov. H	Nov. L	Dec. H	Dec. L
1	...	...	72	44	68	38	82	54	64	32	...	...	43	26	36	2
2	...	...	77	40	72	39	81	59	74	34	70	36	41	17	35	15
3	70	54	77	46	82	44	80	51	85	45	76	32	43	19	36	18
4	62	37	76	47	87	57	83	44	84	44	64	34	58	28	38	14
5	64	33	86	45	82	50	87	51	77	48	57	27	52	27	41	12
6	62	35	82	49	62	46	78	51	82	42	68	32	47	23	40	22
7	60	35	74	46	73	33	79	46	81	41	75	28	52	21	38	14
8	54	40	76	44	84	53	82	46	80	40	76	30	45	21	33	22
9	54	33	82	54	88	56	68	47	83	38	79	29	45	4	33	13
10	64	28	75	55	86	54	71	47	70	40	67	35	52	18	36	16
11	69	51	82	34	77	51	78	43	76	48	69	31	54	29	36	11
12	70	40	77	30	66	48	84	44	68	38	68	30	53	25	42	28
13	64	47	82	42	68	46	83	46	80	36	44	28	47	22	42	32
14	62	36	67	46	74	40	79	40	66	27	57	...	45	26	43	22
15	48	32	...	...	84	48	80	39	79	32	56	...	59	33	45	20
16	52	35	68	40	80	46	81	41	76	34	54	...	33	25	45	26
17	58	32	70	35	76	42	84	42	78	35	62	25	33	25	33	18
18	59	37	75	39	76	43	81	44	78	43	72	28	35	24	26	22
19	64	42	73	49	68	49	...	...	68	49	70	31	39	28	28	14
20	62	38	73	38	75	46	86	46	69	32	65	34	40	16	36	14
21	47	32	68	48	64	52	91	48	76	32	61	33	34	7	32	19
22	56	35	58	39	73	36	90	48	78	34	67	27	24	1	34	8
23	67	34	71	33	88	45	92	47	79	38	68	29	24	16	25	9
24	73	36	58	41	83	41	84	52	80	36	68	28	24	4	18	−6
25	69	43	59	39	83	39	80	40	81	37	60	25	21	2	19	−8
26	65	36	61	41	78	45	73	43	83	39	63	24	17	−5	21	−7
27	73	37	63	46	83	50	79	42	83	37	63	23	18	−7	35	−3
28	60	44	80	43	82	43	...	...	71	36	64	22	18	-11	33	14
29	60	29	82	54	84	46	75	37	79	36	58	24	25	−8	37	10
30	72	35	71	44	87	43	66	40	81	39	56	39	29	−2	39	10
31	...	...			89	49	57	36			49	31			35	7

Day	1953 Jan. H	Jan. L	Feb. H	Feb. L	Mar. H	Mar. L	Apr. H	Apr. L	May H	May L	June H	June L
1	33	9	50	35	20	8	37	20	47	34	74	40
2	30	4	48	36	22	8	40	3	48	33	72	44
3	42	28	52	36	20	2	51	28	62	28	45	40
4	38	19	48	28	27	−4	50	30	75	30	55	38
5	34	14	36	22	42	24	43	33	79	32	55	39
6	27	−13	40	28	40	26	37	31	71	37	56	42
7	36	26	45	15	41	18	35	28	50	29	60	41
8	41	23	37	25	45	23	34	24	48	33	58	43
9	50	35	29	23	50	18	33	20	42	28	72	35
10	49	31	29	5	46	19	31	18	38	28	85	48
11	51	38	29	12	54	18	37	20	39	20	83	45
12	44	35	34	19	44	30	38	28	48	25	80	45
13	40	19	38	15	43	25	42	28	57	26	76	45
14	...	...	37	8	...	...	37	31	61	28	72	37
15	...	...	35	19	...	...	47	32	65	28	70	42
16	40	30	32	20	45	8	43	32	63	33	79	43
17	38	32	31	18	33	18	36	24	...	...	76	45
18	40	31	28	15	38	4	45	20	67	36	73	38
19	41	31	24	2	46	28	58	21	58	45	70	44
20	42	30	22	0	41	31	69	30	53	37	59	37
21	41	29	26	3	39	19	65	34	56	31	73	29
22	36	17	35	8	36	19	70	36	51	30	78	38
23	46	30	30	10	37	25	55	37	62	30	76	41
24	47	32	28	−7	57	20	52	37	55	36	59	33
25	45	30	32	10	53	30	51	37	55	33	63	28
26	42	19	46	22	46	21	71	37	64	43	69	30
27	31	14	43	24	60	23	67	43	70	42	72	34
28	41	21	27	18	63	36	53	34	66	42	76	42
29	43	24			52	29	42	31	67	41	83	38
30	40	26			51	23	48	31	61	39	86	45
31	53	35			44	33			70	37		

Day	1953 July H	July L	Aug. H	Aug. L	Sept. H	Sept. L	Oct. H	Oct. L	Nov. H	Nov. L	Dec. H	Dec. L	1954 Jan. H	Jan. L
1	76	38	84	49	84	44	72	42	65	31	45	28	...	...
2	80	36	72	52	68	40	52	31	54	20	33	15	...	...
3	76	41	80	41	59	31	58	16	52	12	32	15	...	...
4	...	...	75	48	67	27	69	24	57	14	34	17	43	10
5	...	...	79	40	77	31	72	23	57	27	35	12	47	32
6	...	...	86	42	83	33	71	31	...	...	38	26	49	32
7	83	64	93	46	86	37	74	28	45	18	28	3	49	22
8	88	43	88	49	62	39	78	30	57	16	25	4	40	28
9	88	46	82	41	82	36	79	40	57	19	43	14	30	14
10	89	45	67	48	83	36	80	34	59	20	37	22	31	8
11	89	48	78	34	87	42	70	37	63	27	32	6	24	2
12	95	50	89	42	84	43	69	28	63	29	34	10	24	0
13	96	54	90	43	80	38	74	29	51	28	32	10	24	5
14	94	64	86	52	85	...	72	33	53	29	41	19	35	5
15	84	54	88	44	85	33	70	33	...	...	40	10	15	−15
16	82	39	88	44	82	47	64	37	...	...	36	9	0	−14
17	85	36	85	43	69	43	69	33	54	26	43	15	28	−7
18	88	41	89	43	71	30	70	30	29	20	42	11	30	−12
19	91	43	89	42	76	42	60	36	24	−2	43	21	22	−12
20	78	45	93	53	64	28	58	20	26	10	43	32	28	−36
21	80	40	85	46	79	31	44	30	35	20	34	22	30	−27
22	90	37	85	44	79	40	45	27	39	32	23	15	42	14
23	...	...	86	36	69	36	...	...	42	30	30	6	39	10
24	93	39	81	29	62	39	...	...	39	24	31	6	13	−12
25	78	51	85	36	73	27	...	...	45	22	33	12	18	−18
26	87	41	81	38	74	26	48	22	43	29	39	13	26	10
27	93	45	73	39	77	38	59	30	42	28	32	13	35	12
28	89	43	...	...	75	34	67	25	42	20	42	25	44	31
29	90	48	75	36	63	25	67	29	43	31	32	14	38	32
30	91	47	84	36	80	34	54	24	47	26	32	12	46	21
31	89	48	...	...			...	41			43	26	41	20

Station D2-3-21ad (at Anceney)

1.....	...	...	69	...	70	...	...	...	69	30	73	32	46	24	35	-3	34	5	...	35	...	...	38	20	48	34	70	37	76	47	84	47	83	43	...	...	60	30	34	26	40	31
2.....	...	...	74	35	71	38	...	...	82	31	79	28	43	10	36	16	26	2	...	34	...	-5	49	11	49	32	69	45	79	36	72	54	65	43	...	...	56	37	35	22	38	21
3.....	...	...	79	39	81	41	...	...	88	39	66	34	53	10	37	12	42	18	...	38	...	-5	56	16	55	23	47	41	82	40	81	43	63	...	...	...	49	13	36	20	41	22
4.....	...	...	80	...	88	55	...	...	84	48	63	26	67	14	29	10	44	27	...	27	45	29	53	32	...	26	53	40	84	39	75	48	69	29	...	...	55	15	33	27	44	21
5.....	...	...	86	55	83	50	85	42	78	42	61	23	58	22	38	11	...	...	...	15	42	30	48	37	76	29	53	42	84	41	80	39	76	34	...	...	55	31	40	21	52	40
6.....	...	...	82	51	65	...	84	...	79	39	70	22	48	20	39	30	15	-10	...	26	42	18	41	33	81	32	63	37	85	40	85	42	80	33	...	...	46	32	41	36	53	30
7.....	...	...	77	62	75	31	78	62	79	45	80	24	56	17	43	29	39	11	...	28	50	22	38	27	75	45	62	48	82	...	92	56	84	38	...	...	50	21	29	6	51	31
9.....	...	...	76	55	84	...	80	43	81	43	76	26	48	21	39	26	49	26	...	24	55	22	33	22	55	33	60	36	85	50	90	50	79	40	...	...	56	17	30	8	37	31
9.....	...	...	81	44	88	44	85	...	88	38	75	26	49	6	32	17	54	38	...	6	55	22	35	22	47	34	70	35	89	56	80	...	82	37	...	...	50	18	46	23	34	20
10.....	...	...	77	56	86	44	68	...	80	42	65	35	54	10	40	18	51	38	...	-8	56	30	30	15	45	30	81	46	90	46	68	49	82	37	...	...	55	22	50	15	32	6
11.....	...	...	79	56	77	65	72	48	70	45	74	29	57	23	35	14	60	35	...	4	50	34	38	10	40	25	85	43	94	64	77	35	84	35	...	...	63	29	34	6	26	5
12.....	...	...	73	...	67	...	80	44	70	38	71	31	49	16	43	23	55	47	...	11	48	30	39	28	37	21	82	45	94	58	93	39	89	38	...	...	64	33	43	27	27	6
13.....	...	...	68	30	68	57	82	45	63	...	41	24	49	29	...	...	50	35	...	10	42	28	42	28	51	26	78	58	96	51	92	64	84	47	...	...	51	25	43	15	23	7
14.....	...	...	85	41	77	39	...	...	67	24	50	20	54	21	...	...	38	13	...	3	38	15	39	21	55	25	74	35	97	55	86	49	78	40	...	...	66	26	48	17	38	20
15.....	...	...	85	...	84	39	85	39	78	28	65	18	38	31	...	...	34	5	...	19	47	18	49	23	61	31	70	46	85	54	90	44	86	33	...	...	59	49	41	22	0	-13
16.....	...	...	76	35	84	62	83	40	79	32	65	...	35	27	...	...	43	32	...	13	50	27	48	31	65	30	75	45	76	39	87	44	82	46	...	...	64	33	33	13	-3	-15
17.....	...	...	73	51	80	40	83	40	83	33	67	21	37	22	...	15	41	31	...	28	46	27	35	24	63	36	78	45	84	37	85	44	...	45	...	...	53	31	44	14	17	-2
18.....	...	...	77	37	75	44	88	42	82	56	66	26	36	12	30	...	45	18	...	20	44	21	43	15	70	36	77	39	87	42	90	44	73	31	...	...	29	22	40	15	33	-9
19.....	...	...	70	55	68	49	83	43	76	47	69	32	41	16	26	8	44	31	...	-3	51	32	57	18	56	47	68	50	89	45	87	44	79	39	...	...	24	-6	48	25	28	-12
20.....	...	...	73	39	79	44	82	46	70	40	69	30	43	8	31	10	52	38	...	-4	43	33	67	24	54	38	60	39	80	43	95	44	62	24	...	...	24	0	49	32	-2	-32
21.....	46	...	64	41	70	44	87	41	69	34	63	30	31	...	30	20	...	30	...	-4	38	22	70	40	53	36	73	31	78	35	89	46	74	26	...	...	35	17	34	28	18	-21
22.....	58	38	66	41	71	54	94	43	79	28	67	23	25	-4	33	6	38	23	...	3	42	26	71	32	55	36	77	37	89	39	88	45	80	45	...	...	40	23	33	11	46	18
23.....	69	47	73	30	91	41	93	49	83	30	73	26	29	16	26	5	54	31	...	2	46	23	67	40	62	30	73	40	91	44	88	45	70	38	...	...	40	30	31	6	43	4
24.....	73	34	68	...	87	...	93	45	83	35	67	29	27	15	20	-5	58	26	...	-8	64	22	54	30	55	45	65	35	85	41	85	41	64	...	...	...	43	29	37	5	16	-14
25.....	70	41	58	...	87	38	85	43	81	35	64	21	25	-1	19	-13	...	33	...	2	63	34	64	24	55	39	63	30	78	47	76	30	74	27	...	...	49	28	29	12	16	-13
26.....	61	39	61	...	75	44	82	40	87	34	65	23	17	-10	22	-14	...	23	...	14	50	23	73	34	60	42	66	32	85	52	85	35	76	27	...	...	47	30	37	12	27	-6
27.....	66	34	67	48	85	...	74	37	83	...	57	21	...	-4	31	-8	...	17	...	31	64	24	68	43	66	36	71	32	93	44	82	41	78	34	...	...	49	24	33	20	36	11
28.....	71	36	79	40	...	...	84	47	74	38	62	16	18	-14	34	17	...	32	...	24	70	35	59	36	62	50	80	40	86	43	69	42	78	40	...	...	43	25	41	23	46	35
29.....	66	42	82	50	...	...	83	...	82	32	66	20	21	-12	39	19	...	34			57	33	45	31	57	41	80	39	86	46	75	37	65	26	...	...	48	33	35	22	40	28
30.....	62	26	74	62	...	...	75	37	76	32	64	41	27	-7	38	12	...	30			54	21	48	27	60	44	87	14	88	46	81	35	82	29	...	...	49	28	38	9	47	20
31.....	71	38			90	41	60	35			52	29			34	17	...	40			47	33			70	36			89	48	85	40			...	...			45	33	39	20

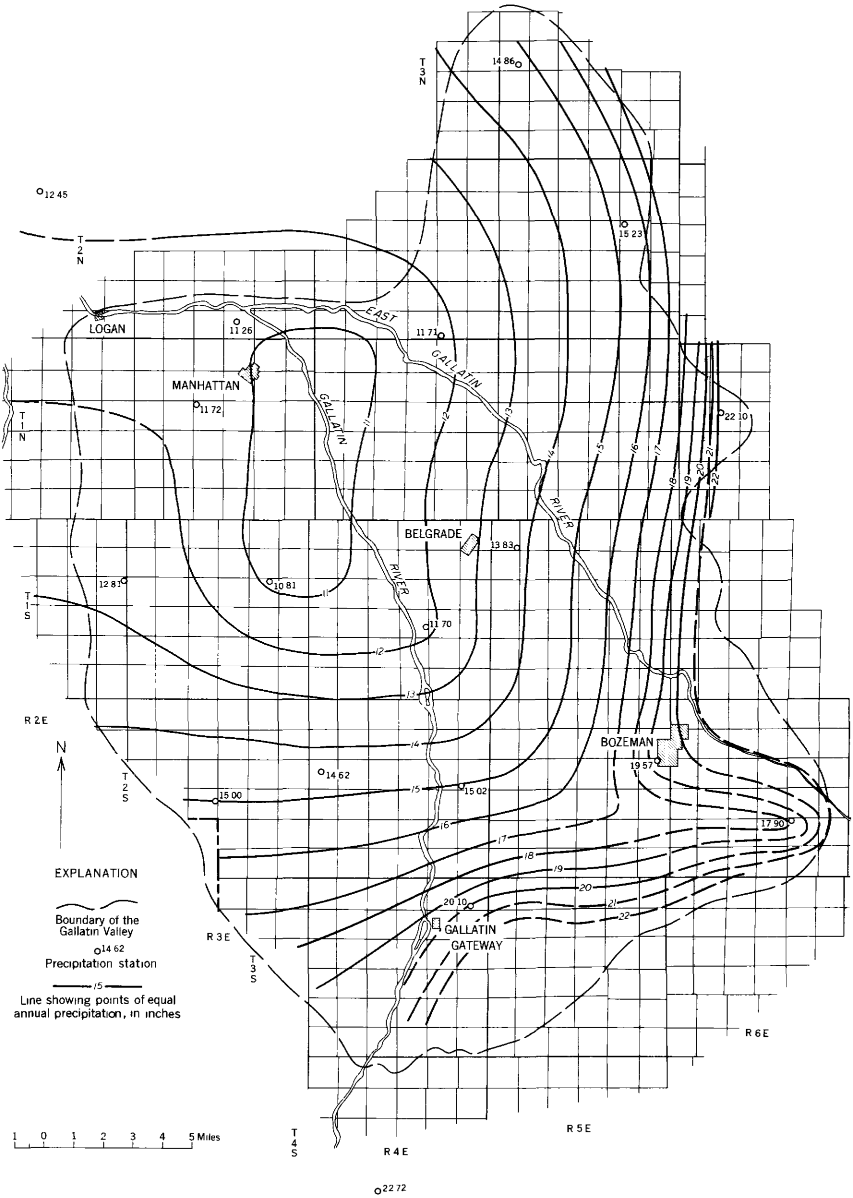


FIGURE 3.—Map of the Gallatin Valley showing the location of precipitation stations and the distribution of precipitation in 1952.

many departures from average. The precipitation trends during the period 1895-1953 are indicated by the graph showing the cumulative departure from average; above-average precipita-

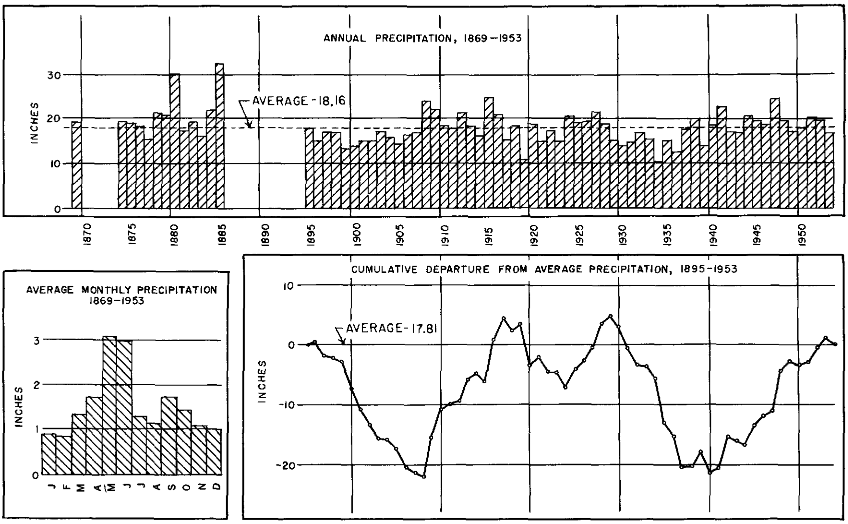


FIGURE 4.—Precipitation at Bozeman. From records of the U.S. Weather Bureau.

tion is represented by a rising line and below-average precipitation by a falling line.

The annual precipitation for the period of record at Bozeman and at Belgrade is given in tables 2 and 3, respectively; the monthly precipitation during the period 1952-53 for all stations is given in table 4.

The monthly volume of precipitation on the Gallatin Valley, excluding the Dry Creek subarea, during water years 1952 and

TABLE 2.—*Annual precipitation at Bozeman, 1869–1953*

[From records of the U.S. Weather Bureau]

Year	Inches	Year	Inches	Year	Inches	Year	Inches
1869	19.54	1891	....	1912	21.65	1933	15.89
1870	....	1892	....	1913	18.67	1934	10.54
1871	....	1893	....	1914	16.46	1935	15.46
1872	....	1894	....	1915	25.00	1936	12.78
1873	....	1895	18.16	1916	21.19	1937	17.99
1874	19.74	1896	15.47	1917	15.68	1938	20.35
1875	19.41	1897	17.42	1918	18.89	1939	14.03
1876	18.58	1898	17.20	1919	11.02	1940	18.63
1877	15.66	1899	13.44	1920	19.25	1941	22.87
1878	21.50	1900	14.18	1921	15.19	1942	17.24
1879	21.08	1901	15.49	1922	17.74	1943	17.18
1880	30.16	1902	15.46	1923	15.27	1944	20.93
1881	17.55	1903	17.64	1924	20.94	1945	19.53
1882	19.68	1904	16.19	1925	19.40	1946	18.58
1883	16.48	1905	14.73	1926	19.82	1947	24.54
1884	22.02	1906	16.88	1927	21.84	1948	19.50
1885	32.63	1907	17.23	1928	19.18	1949	17.11
1886	....	1908	24.47	1929	15.77	1950	18.19
1887	....	1909	22.34	1930	14.17	1951	20.20
1888	....	1910	18.74	1931	15.29	1952	19.57
1889	....	1911	18.14	1932	17.34	1953	16.40
1890	....						

TABLE 3.—*Annual precipitation at Belgrade, 1941–53*
[From records of the U.S. Weather Bureau]

Year	Inches	Year	Inches	Year	Inches	Year	Inches
1941	17.10	1945	12.65	1948	19.70	1951	13.81
1942	12.38	1946	12.12	1949	13.57	1952	13.83
1943	13.50	1947	18.35	1950	15.11	1953	12.04
1944	14.89						

1953 was computed by multiplying the monthly precipitation at each station by an area that was determined by the Theissen method of weighting (Theissen, 1911, p. 1082-1084) and then totaling the products thus obtained. (See table 5.) Because several of the stations were not in operation during the period October through December 1951, estimates of precipitation at these stations were made on the basis of measured precipitation at other stations in the valley.

HISTORY

The Lewis and Clark expedition visited the Gallatin Valley in 1805. The settlement of the valley was not begun, however, until the mining communities, established as a result of the discovery of gold in the early 1860's, created a demand for agricultural products. The first irrigation ditch was dug in 1864, and the arrival of the Northern Pacific Railway in 1883 gave added impetus to the settlement of the valley.

The population of Gallatin County in 1950 was 21,902, and most of the people lived in the valley. In addition to being the leading trading center, Bozeman is the county seat and the site of the Montana State College. Its population in 1950 was 11,325. Belgrade and Manhattan also are important trading centers.

AGRICULTURE AND INDUSTRY

Farming and livestock raising are the principal occupations in the Gallatin Valley. Most of the cropland on the valley floor, the Bozeman fan, and the Manhattan terrace is irrigated, as are about one-third of the Camp Creek Hills and scattered tracts in the eastern and northern parts of the valley. (See fig. 5.) According to data compiled by the Montana State Engineer's office (1953a, p. 27-30), 107,261 acres was irrigated in 1952. Irrigation water is diverted from the Gallatin River, the East Gallatin River, and their tributaries. Because the growing season is short, only small grains, forage crops, and vegetables such as peas and potatoes are grown. Most of the remaining area is dry farmed, wheat being the main crop. In general, individual dry farms are

TABLE 4.—*Monthly precipitation at 18 stations in the Gallatin Valley, 1952-53*

Station and observer	Altitude (feet)	Year	Precipitation, in inches												
			Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
A1-3-16bb, Paul Biering	4,310	1952	0.37	0.38	1.05	0.78	3.87	1.44	1.74	0.86	0.13	Trace	0.84	0.26	11.72
		1953	.49	.86	.28	1.20	2.01	2.07	.09	.33	.28	.40	.54	[1] .18	8.73
A1-6-16bd, C. W. Cramer	5,040	1952	1.32	1.53	2.14	1.20	6.21	2.85	2.26	1.02	.90	.37	1.41	.89	22.10
		1953	.81	1.77	.73	2.41	5.70	4.99	.30	.90	1.27	.69	.99	.93	21.49
A2-2-9aa, U.S. Weather Bureau, Trident	4,036	1952	.43	.32	.97	.77	4.22	2.17	1.87	.63	.23	.01	.69	.14	12.45
		1953	.48	.73	.37	1.23	2.23	2.38	.10	.91	.27	.38	.50	.22	9.80
A2-3-34bd, Lyle Backlin	4,167	1952	[1] .48	.34	1.13	.53	4.04	1.32	1.88	.46	.21	Trace	.63	.24	11.26
		1953	.63	.80	.43	1.30	2.26	2.56	.15	.37	.45	.39	.46	.23	10.03
A2-4-35cc, N. J. Irvine	4,305	1952	.58	.40	1.15	.52	3.95	.35	1.86	1.01	.44	.13	.92	.40	11.71
		1953	.70	1.02	.32	1.22	2.54	2.82	.17	.79	.50	.58	.43	.41	11.50
A2-5-14bb, U.S. Geol. Survey	5,600	1952	.84	.58	1.04	.93	4.99	1.37	1.98	1.29	.52	.24	1.01	.44	15.23
		1953	.62	1.51	.59	1.83	3.63	3.93	.27	1.05	.65	.40	.61	.70	15.79
A3-5-18da, Delmer Moore	5,053	1952	.90	.80	1.20	.50	5.14	1.58	2.61	.54	.38	.04	.77	.40	14.86
		1953	.73	1.30	.38	1.28	2.77	2.92	.39	.88	.41	.39	.60	.58	12.63
D1-2-13aa, U.S. Geol. Survey	4,840	1952	[1] .51	.36	.76	.85	4.59	1.61	1.77	.83	.45	.07	.65	.36	12.81
		1953	.35	.89	.39	1.93	2.43	2.69	.13	.83	.51	.36	.46	.16	11.13
D1-3-14ab, H. I. Visser	4,470	1952	.41	[1] .28	.50	.56	3.91	1.42	1.84	.52	.37	.00	.60	.40	10.81
		1953	.78	.74	.40	1.56	2.47	2.40	.17	.72	.55	.47	.31	.05	10.62
D1-4-22da, George Nutter	4,550	1952	.94	.66	.86	.85	4.25	1.04	1.30	.26	.54	.05	.52	.43	11.70
		1953	.45	.78	.69	1.89	1.60	2.11	.39	.21	.44	.52	.40	.11	9.59
D1-5-6cd, U.S. Weather Bureau, Belgrade	4,450	1952	.92	.65	1.08	.80	4.47	1.65	2.14	.50	.36	.12	.70	.44	13.83
		1953	.55	1.00	.67	1.63	2.46	2.95	.23	.32	.72	.54	.65	.32	12.04
D2-3-21ad, Nick Danhof	4,755	1952	.62	.44	.83	1.21	5.38	1.93	1.86	1.02	.61	.05	.77	.28	15.00
		1953	.28	1.24	.53	1.73	2.28	2.18	.46	.44	.58	.56	.89	.19	11.36
D2-4-13cc, L. B. Clary	4,735	1952	.93	.90	1.13	1.43	4.96	1.61	[1] 1.50	.83	.48	.10	.83	.32	15.02
		1953	.36	1.05	1.11	1.71	2.31	2.98	.59	Trace	.68	.74	.81	.51	12.85
18ac, Mrs. Harold Todd	4,910	1952	.68	.63	.94	1.44	4.53	1.97	1.42	1.23	.59	.07	.84	.28	14.62
		1953	.38	.90	.83	1.74	2.20	2.39	.37	.22	.66	.47	.55	.29	11.00

TABLE 4.—*Monthly precipitation at 18 stations in the Gallatin Valley, 1952-53*—Continued

Station and observer	Altitude (feet)	Year	Precipitation, in inches												
			Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
D2-5-13ab, U.S. Weather Bureau, Bozeman	4,856	1952	1.24	1.19	1.59	1.99	6.63	2.02	1.28	1.16	.56	.21	1.29	.41	19.57
		1953	.65	1.05	1.04	2.05	3.23	3.13	.63	.42	1.00	1.39	1.13	.68	16.40
D2-6-26bb, Williams Bros.	5,090	1952	1.10	1.15	1.54	1.80	5.73	1.78	1.25	1.12	.42	.26	1.29	.46	17.90
		1953	.90	1.28	1.33	1.82	3.33	3.88	.51	.84	1.37	.83	1.05	1.12	18.26
D3-4-1cd, Donald Hart	5,015	1952	2.01	1.15	1.28	2.44	6.23	2.12	1.45	1.32	.66	.16	1.02	.26	20.10
		1953	.27	1.21	1.20	2.41	2.42	2.84	.72	.08	.78	1.04	.80	.51	14.28
D4-4-28, U.S. Weather Bureau, Gallatin Gateway	5,425	1952	1.44	1.17	1.81	2.52	6.55	2.03	2.29	1.86	.79	.54	1.20	.52	22.72
		1953	.60	1.82	1.29	1.48	2.62	3.84	.62	.64	1.48	.41	1.49	1.30	17.59

[1]Estimated.

TABLE 5.—*Monthly volume of precipitation on the Gallatin Valley in water years 1952 and 1953, in thousands of acre-feet*

Month	Water year	
	1952	1953
October	77.0	3.5
November	11.2	25.7
December	33.6	11.1
January	26.3	15.5
February	20.9	30.3
March	33.3	20.8
April	35.3	50.5
May	135.2	76.0
June	46.8	82.3
July	48.8	10.5
August	26.1	13.1
September	13.8	20.1
Total	508.3	359.4

much larger than irrigated farms, but their total area in the valley is smaller.

Throughout most of the valley, livestock is raised in conjunction with the growing of crops. Many of the cattle are sold for beef, but dairy herds also are important sources of income, and some sheep, hogs, and horses are raised.

Industry has a minor but important place in the development of the valley. Logging, an important activity in earlier years, has been resumed recently in the adjacent mountainous regions, and the new sawmill at Belgrade is the largest single industrial plant in the valley. Flour mills, livestock-commission yards, apiaries, a seed company, and a cheese factory are the other chief industrial enterprises. The headquarters for the Gallatin National Forest are at Bozeman, and a federally owned fish hatchery is situated at the mouth of Bridger Canyon, about 3 miles northeast of Bozeman. During the summer the tourist trade is important; many dude ranches are near the valley, and Yellowstone National Park is only a few hours' drive from Bozeman.

TRANSPORTATION

The Gallatin Valley is served by the main line of the Northern Pacific Railway and by a branch line of the Chicago, Milwaukee, St. Paul and Pacific Railroad. A transcontinental highway, U.S. 10, passes through Bozeman, Belgrade, Manhattan, and Logan; U.S. 191 connects Bozeman with points to the south. An adequate system of secondary roads covers the area. Gallatin Field,

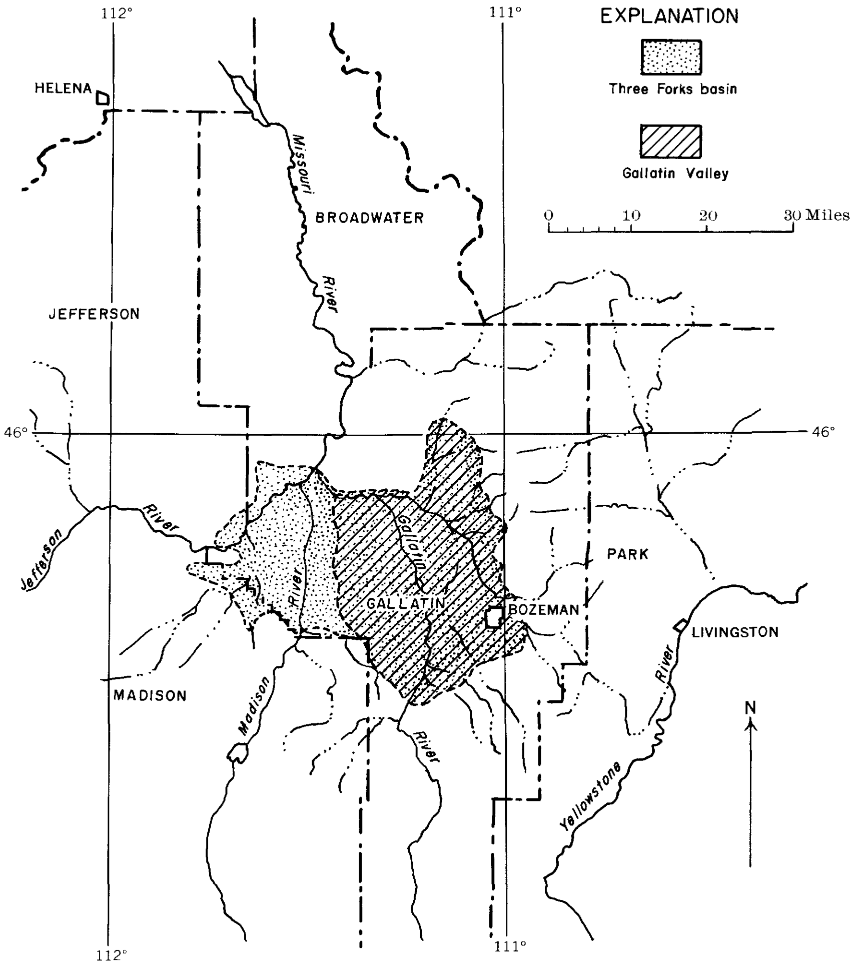


FIGURE 6.—Map showing the relation of the Gallatin Valley to the Three Forks basin.

peripheral mountains. In summarizing the age, lithology, thickness, and relationships of the Precambrian, Paleozoic, and Mesozoic rocks, the writers have drawn freely on reports by Peale (1896), Berry (1943), Deiss (1936), Gardner and others (1945), Sloss and Laird (1946), Lochman (1950), Sloss and Moritz (1951), Hanson (1952), and McMannis (1955).

PRECAMBRIAN ROCKS

Precambrian metamorphic and sedimentary rocks are the oldest rocks exposed in the valley. The metamorphic rocks, called

Archean gneiss by Peale (1896, p. 3), are principally varieties of gneiss, though schist, quartzite, and, locally, marble also are present. Outcrops of metamorphic rocks at the south end of the Camp Creek Hills are thought by Clabaugh (1952, p. 61) to belong to the Pony series (Tansley and Schafer, 1933) of pre-Beltian age. Gneissic rocks are exposed along the base of the southern part of the Bridger Range, along much of the base of the Gallatin Range, and in the southern and southwestern parts of the Camp Creek Hills. Test holes D2-4-9bc and D1-3-36bc, drilled north of the Precambrian outcrop in the Camp Creek Hills, penetrated the Tertiary strata; the former was bottomed in Precambrian gneiss and the latter in what was thought to be weathered Precambrian gneiss. (See table 33.) Possibly the gneissic rocks underlie the Tertiary strata in most places in the southern part of the valley.

The Precambrian sedimentary rocks belong to the Belt series, which has not been subdivided into formations in the Gallatin Valley area. They consist mostly of arkosic sandstone and conglomerate, graywacke conglomerate, and slate; most of these rocks are dark colored, but some in the vicinity of Dry Creek are bright colored. The Belt series is exposed along the base of the Horseshoe Hills, along Dry Creek, and along the base of the northern part of the Bridger Range. The maximum exposed thickness is about 6,000 feet. Within the valley proper these rocks crop out along the south side of the Gallatin River in the stretch 1½ to 3 miles east of Logan. Test hole A2–3–33da was bottomed in strata of the Belt series. (See table 33.) The Belt series is believed by the authors to underlie the Tertiary strata in the northern part of the valley.

The Precambrian rocks in the valley are not considered a potential source of ground water; generally they are too far below the surface to be economically accessible to wells. The two test holes drilled to the gneissic rocks yielded small quantities of water, some of which may have been derived from weathered bedrock. Small quantities of water also may be present in fractures in the gneiss and in rocks of the Belt series.

ROCKS OF PALEOZOIC AGE

Marine rocks of Cambrian, Devonian, Mississippian, Pennsylvanian, and possibly Permian age are present in the Gallatin Valley and vicinity. These Paleozoic rocks crop out along the flanks of the Horseshoe Hills and the Gallatin and Bridger Ranges. They also locally underlie Tertiary and Quaternary deposits in the vicinity of Logan and in the Camp Creek Hills west of Gallatin Gateway.

No wells within the valley derive water from the Paleozoic rocks.

CAMBRIAN SYSTEM

The Cambrian system is represented by the Flathead quartzite, Wolsey shale, Meagher limestone, and Park shale, all of Middle Cambrian age, and the Pilgrim limestone and Snowy Range formation of Late Cambrian age. An unconformity separates the Cambrian rocks from the underlying Precambrian rocks, and there is a disconformity between the Cambrian rocks and the overlying Devonian system. Within the Cambrian system the contacts between formations are conformable and gradational.

The Flathead quartzite is a resistant, ridge-forming formation composed principally of pink and reddish-brown quartzite and sandstone. The average thickness of the Flathead is about 130 feet; however, in the Gallatin Range the Flathead thins to less than 100 feet.

The Wolsey shale, which overlies the Flathead quartzite, is a greenish-gray, black, and purple micaceous shale, interbedded in its lower part with quartzite and sandstone and in its upper part with limestone. Worm casts in the sandy layers characterize the basal part. The Wolsey weathers readily, and, where steeply dipping, usually forms a troughlike depression between outcrops of the Flathead quartzite and the Meagher limestone. The thickness of the Wolsey shale differs considerably from place to place but averages about 200 feet.

The Meagher limestone is a massive-appearing cliff-forming gray to brown limestone, interbedded with shale near its base. Parts of this formation are mottled. The Meagher limestone has a relatively uniform thickness of about 350 feet.

The Park shale is mostly green, brown, and maroon fissile shale, containing limestone layers in its basal part. Like the Wolsey shale, it weathers more readily than the immediately underlying and overlying formations. Its average thickness is about 200 feet.

The Pilgrim limestone is similar in general appearance to the Meagher limestone. It is a massive-appearing cliff-forming gray to brown limestone containing many layers of dark, mottled oolite and limestone conglomerate. It is about 400 feet thick. The term Maurice limestone also has been applied to this formation in the vicinity of the Gallatin Valley (Lochman, 1950, p. 2205).

Overlying the Pilgrim limestone is a mappable unit consisting, in its lower part, of strata of Late Cambrian age and, in its upper part, of strata of Devonian age. Sloss and Laird (1946) were the first to recognize the age of these strata and the presence of an erosional surface at the top of the Cambrian. Lochman (1950, p. 2212-2213) applied the term Snowy Range formation to the Late Cambrian strata, and Emmons and Calkins (1913) applied the term Maywood formation to the Devonian. Lochman described the Snowy Range formation as follows:

> Within the Snowy Range formation two members can be recognized: the lower Dry Creek shale member of interbedded shales and calcareous sandstone * * * and the upper Sage pebble-conglomerate member of intercalated shales and limestone pebble conglomerates with a dense columnar limestone near the base * * *

The thickness of the Snowy Range formation was not ascertained, but it is known to vary considerably because the Sage pebble-conglomerate member was subjected to deep erosion before the overlying Maywood formation was deposited. However, the combined thickness of the Snowy Range and Maywood formations ranges from a little less than 100 to slightly more than 250 feet. Hanson (1952, p. 17-18) identified Lochman's Snowy Range formation as the Red Lion formation of Emmons and Calkins (1913).

DEVONIAN, MISSISSIPPIAN, AND PENNSYLVANIAN SYSTEMS

The Maywood formation of Devonian age consists of red shale and gray to yellow silty dolomite and limestone. Because it was deposited on the eroded surface of the Sage pebble-conglomerate member (Lochman, 1950, p. 2212) of the Snowy Range formation, it varies considerably in thickness but, combined with the Snowy Range formation, is nowhere much more than 250 feet thick.

The Jefferson limestone, also of Devonian age, rests conformably on the Maywood formation. It consists of gray and dark-brown limestone and dolomite and is characterized by a petroliferous odor when freshly broken. It forms massive-appearing cliffs which are distinguishable by their dark color from the other limestone cliffs within the area. The thickness of the formation averages about 550 feet.

The Three Forks shale of Late Devonian and Mississippian age conformably overlies the Jefferson limestone and, in general, is divisible into three units—a basal unit of varicolored shale and limestone capped with ledge-forming gray and yellow limestone; a central unit of green and purple shale; and an upper unit of gray limestone, yellow sandy limestone, and calcareous sandstone. Berry (1943, p. 14-15) applied the term Sappington sandstone to the sandy limestone of the upper unit and considered it to be of Mississippian age. Sloss and Laird (1946) believed the Sappington to be of Devonian age and designated it as a local member of the Three Forks shale. The age of the Sappington is now considered to be Late Devonian and Mississippian. The average thickness of the Three Forks as a whole is about 200 feet.

The Madison group of Mississippian age lies unconformably on the Three Forks shale and includes the Lodgepole limestone, which is a well-laminated gray and yellow to brown limestone, and the Mission Canyon limestone, which is a massive light-gray limestone. The Madison group was not differentiated in this study. The thickness of the Madison in the vicinity of Gallatin Valley ranges from about 1,200 to 1,500 feet or more.

The Big Snowy group, which overlies the Madison group and underlies the Amsden formation in the Bridger Range (McMannis, 1955) was not recognized in the area mapped for this report.

The Amsden formation, in part of Mississippian age and in part of Pennsylvanian age, rests disconformably on the Madison group. The Amsden consists of a lower unit of red siltstone and limestone, which weathers readily, and an upper unit of light-yellow to gray dolomite which is interlayered with quartzite near the contact with the overlying Quadrant quartzite. The Amsden formation is about 400 feet thick in the Horseshoe Hills and about 200 feet thick in the Gallatin Range southeast of Bozeman.

The Quadrant quartzite of Pennsylvanian age is conformable to, and gradational with, the Amsden formation and consists almost wholly of white and pink to light-yellow massive quartzite or quartzitic sandstone. Dolomite, similar to that of the Amsden formation, generally is present at the base of the Quadrant, and in some places layers of brown chert are in the upper part. This formation is a prominent cliff former. It ranges in thickness from about 75 to 150 feet.

PERMIAN SYSTEM

Although the Phosphoria formation was not recognized among the Paleozoic rocks exposed in the area, it may be represented by layers of chert and quartzite on top of the Quadrant quartzite in the Dry Creek subarea. The Phosphoria is present in the Horseshoe Hills west of the Dry Creek subarea.

ROCKS OF MESOZOIC AGE

Rocks of Jurassic and Cretaceous age crop out along the northwest margin of the Dry Creek subarea and east and southeast of the Fort Ellis subarea. They are not a source of ground water in the Gallatin Valley.

JURASSIC SYSTEM

The Jurassic system is represented by the marine Ellis group of Middle and Late Jurassic age and the continental Morrison formation of Late Jurassic age.

The Ellis group comprises the Sawtooth, Rierdon, and Swift formations but was mapped as a unit in this study. From a thickness of more than 300 feet southeast of Bozeman, the Ellis group thins northward to a thickness of about 20 feet near Menard. The Sawtooth formation rests disconformably on the Quadrant and is predominantly a gray to brown shale and limestone. It is the least conspicuous formation of the Ellis group in the Gallatin Valley. The Rierdon formation, conformable to the Sawtooth, is composed of distinctive brown oolitic limestone interbedded with shale. The Swift formation, separated by a disconformity from the Rierdon, is a glauconitic and calcareous brown sandstone and generally is conglomeratic at its base. This formation was not recognized in the vicinity of Menard, but where present elsewhere in the area it forms prominent cliffs.

The Morrison formation rests conformably on the Ellis group. It consists of varicolored red, brown, purple, and gray siltstone and shale interbedded with brown to yellow sandstone. In some places a few feet of coal and carbonaceous shale are present in the upper part of the unit. Because the Morrison weathers rapidly where exposed, its presence generally is marked by a red soil-covered slope below the more resistant basal unit of the overlying Kootenai formation. The thickness of the Morrison ranges from about 100 to 400 feet.

CRETACEOUS SYSTEM

The Cretaceous system is represented by the continental Kootenai formation, the marine Colorado shale, and the continental Livingston formation.

The Kootenai formation consists of three units. The basal unit is resistant quartzitic sandstone that generally is conglomeratic in its lower part. The middle unit is nonresistant red to purple shale, siltstone, and claystone; it includes also a bed of massive pinkish-gray limestone in the area southeast of the Fort Ellis subarea. The upper unit is a resistant, locally quartzitic sandstone; in the vicinity of Menard and in the Fort Ellis subarea, this unit contains a thin notably fossiliferous limestone bed near its top. The thickness of the Kootenai formation ranges from about 400 to 700 feet. At least locally, the contact of the Kootenai with the underlying Morrison formation is a disconformity.

Only the lower part of the Colorado shale is exposed in the area. In the vicinity of Menard it consists only of black and gray shale and thin beds of rusty-colored sandstone, but in the area southeast of the Fort Ellis subarea it also contains massive greenish-gray sandstone.

ROCKS OF MESOZOIC AND CENOZOIC AGE

CRETACEOUS AND TERTIARY SYSTEMS

The Livingston formation of Late Cretaceous and Paleozoic age crops out at the extreme north end of the Dry Creek subarea and also southeast of Bridger Canyon. It consists principally of andesitic tuff and volcanic conglomerate.

ROCKS OF CENOZOIC AGE

The Cenozoic rocks constitute the valley fill and are the primary source of ground water in the Gallatin Valley.

TERTIARY SYSTEM

Continental deposits of Tertiary age in the Three Forks structural basin were named Bozeman lake beds by Peale (1896, p. 3). However, the term "lake beds" now is considered to be a misnomer, because only part of the Tertiary section is of lacustrine origin. In this report, therefore, the deposits are referred to simply as Tertiary strata.

The Tertiary strata crop out in the Camp Creek Hills, the Dry Creek subarea, the Fort Ellis subarea, and along Goochs Ridge; except locally, they underlie the alluvium and alluvial fans throughout the valley. Where exposed along the margins of the Gallatin Valley, most of the strata of Tertiary age are moderately well cemented fanglomerate, consisting of poorly sorted locally derived rock fragments in a matrix of clay or calcareous silt and sand. Toward the center of the basin the Tertiary strata are finer grained and consist principally of tuffaceous siltstone and fine-grained tuffaceous sandstone, which in places are interbedded with marl, pure ash, crossbedded sandstone, and conglomerate. Most of the Tertiary strata are poorly consolidated, but some are well consolidated.

The complete thickness of the Tertiary strata is not exposed in the basin. Test holes A2–3–33da, D1–3–36bc, and D2–4–9bc, which bottomed in Precambrian rock, were drilled through 245, 836, and 515 feet of Tertiary strata, respectively. Other evidence, however, indicates that the Tertiary strata are much thicker in the deepest part of the structural basin. Peale (1896, p. 3) estimated the maximum thickness of the Tertiary in the Gallatin Valley to be between 2,000 and 2,500 feet by assuming that the beds exposed in the bluffs overlooking the Madison River are older than the beds east of Bozeman and that the gentle eastward dip of the beds is not disturbed by faulting. A test hole drilled by the Montana Power Co. in the Madison Valley penetrated 1,182 feet of Tertiary strata older than the 1,300 feet of Tertiary strata exposed in the bluffs overlooking the Madison River; also, an oil test (Tom Tice 1, drilled by Ben Ryan) in the Madison Valley reportedly penetrated claystone and siltstone, probably of Tertiary age, at a depth of 2,000 feet. This additional subsurface information increases the estimated maximum thickness of the Tertiary strata in the Gallatin Valley to at least 4,000 feet.

Available subsurface information and exposures near Anceney indicate that the Tertiary strata rest on a surface of moderate relief. This surface probably was produced by erosion and modified by Tertiary and post-Tertiary faulting.

Peale (1896, p. 3) assigned a Neocene age to his Bozeman lake beds. Subsequently, Douglass (1903, p. 146-155) correlated the beds in the lower part of the bluffs on the east side of the Madison River with the White River formation of Oligocene age, and the beds in the upper part, which he called the Madison Valley beds, with the Loup Fork beds of late Miocene age. The term Loup Fork beds has long since been discarded as having "vague significance" (Wood and others, 1941, p. 24), and the age assigned by Douglass to the Tertiary strata has been corrected and more closely defined by later investigators. Schultz and Falkenbach (1949, p. 80-83), who have studied oreodonts collected from Douglass' upper unit in the Madison Valley, consider this unit to include strata of both late Miocene and Pliocene ages. On the basis of a collection of vertebrate fossils from the same unit in the vicinity of Anceney, Dorr (1956, p. 73), considers the upper unit to be mostly of latest Miocene age. The age of Douglass' lower unit is less well established. The strata underlying the Madison Valley beds of Douglass (1903) at the base of the bluffs east of the Madison River have been termed the *Leuciscus turneri* beds and assigned a late Miocene age by Wood (1938, p. 291-292). On the other hand, the Tertiary strata in the bluffs west of the Madison River, in the Three Forks quadrangle, are reported by G. D. Robinson (written communication,

1956) to be of early Oligocene age, and, as the eastward dip of these beds carries them below the strata east of the river, possibly the lowermost beds exposed east of the river also are of early Oligocene age. However, since fossil evidence is lacking, it cannot be stated definitely that deposits of unquestionable late Oligocene and early Miocene age are present.

The Tertiary strata of the Gallatin Valley are here divided into three units, of which the lowest is present only in the subsurface. The other two crop out at the surface. The lower of the exposed units, unit 1, is predominantly lacustrine and corresponds lithologically to Douglass' White River beds. The upper, unit 2, is predominantly fluvial and colluvial and corresponds lithologically to Douglass' Madison Valley beds. In the Horseshoe Hills north of the Gallatin River, units 1 and 2 cannot be distinguished from each other and are referred to as undifferentiated Tertiary strata.

Many wells, particularly in the Camp Creek Hills and near the margins of the Gallatin Valley, derive water from strata of Tertiary age. Most of these wells tap predominantly fine-grained material that yields water slowly. A few, however, tap lenses of well-sorted sand and gravel that yield water freely. A large spring near Manhattan (A2–3–32db) derives water, at least in part, from fractures in the Tertiary strata.

SUBSURFACE UNIT

Test hole A1–2–29adc, drilled by the Montana Power Co., penetrated mainly gray sandstone, green and gray-green claystone, and siltstone in the lower half of the hole. The claystone is interbedded with a few thin beds of lignite. As cores from test hole A1–2–29adc indicated that the coarse sandstone grades upward into claystone, which is in sharp contact with the sandstone in a similar succession above, these deposits seem to be cyclic, at least in part. In the upper half of the hole, mainly sandstone containing some clayey layers and thin beds of bentonite(?) was penetrated. (See table 33 for log of test hole A1–2–29adc.) The authors believe that the uppermost bed penetrated by the test hole is stratigraphically 140 to 150 feet lower than the lowermost bed of unit 1, which is exposed in the bluffs on the east side of the Madison River in sec. 28, T. 1 N, R. 4 E. This interval may include the bentonitic beds that crop out west of the Madison River.

In the midthirties an oil test near test hole A1–2–29adc was drilled to a depth of a little more than 2,600 feet. The rocks that were penetrated between the depths of 2,000 and 2,400 feet were reported to consist principally of conglomerate and varicolored shale, and a few coal layers were present between depths of 2,000 and 2,100 feet. From this it seems likely that the oil test was still in Tertiary strata at 2,400 feet.

The rocks penetrated by these deep test holes are stratigraphically lower than the rocks exposed in the bluffs along the Madison River and may be equivalent, in part, to beds of early Oligocene age that crop out in the Three Forks quadrangle west of the river. If the subsurface Tertiary strata extend into the Gallatin Valley and dip eastward, as do the exposed Tertiary strata in the Camp Creek Hills, they have not been reached by any of the test holes drilled in the central part of the Gallatin Valley.

UNIT 1

The full thickness of unit 1 crops out 5 to 6 miles south of Logan, in the basal part of the bluffs along the Madison River. Southward, the lower part of the unit is below river level, but the uppermost part crops out in the gullies that are cut into the covered slope at the base of the bluffs. Northward, only the upper part of the unit is exposed near the base of the bluffs. A part of unit 1 crops out for a distance of about 2 miles south of U.S. Highway 10 near Logan. Elsewhere in the valley the upper part of unit 1 is exposed along the upper reaches of Godfrey Creek, along Camp Creek north of Anceney, and in the Dry Creek subarea west of Menard.

Unit 1 is composed principally of well-stratified volcanic ash, tuffaceous marl and siltstone, tuffaceous fine- to medium-grained sandstone, and a few beds of limestone that stand out as resistant ledges where exposed to erosion. In some places conglomerate and poorly sorted crossbedded sandstone also are present. Unit 1 is predominantly white, cream, and light gray. Ripplemarks on the sandstone, the presence of limestone layers, the even stratification of the beds, and the presence of ostracodes throughout the unit indicate that unit 1 was deposited in a lacustrine environment. Several of the limestone beds contain gastropods—of those seen by the writers, the best preserved were those north of the old McCrea ranch, about 2½ miles west of Menard. Douglass (1903) reported finding fish fossils in beds which are considered by the writers to be the upper part of unit 1 and which probably correspond to the *Leuciscus turneri* beds of Wood.

The base of unit 1 has been set arbitrarily at the base of the lowest bed exposed where the Madison River has cut through an anticline in the Tertiary strata, about 5 to 6 miles south of Logan. The contact between units 1 and 2 is marked by a local unconformity which is discernible in the bluffs along the Madison River. (See fig. 7.) Near the margins of the Three Forks basin,

FIGURE 7.—Local unconformity between units 1 and 2 of the Tertiary strata in the bluffs along the Madison River in the SE¼NE¼ sec. 3, T. 1 S., R. 2 E. Photograph taken at same place as that taken by Douglass (1903, p. 200) who considered the unconformity to be the contact of the White River beds with the Loup Fork beds.

unit 1 contains a larger proportion of detrital material and is less well stratified than in the central part of the basin; its contact with unit 2 is gradational. For mapping, the contact in the marginal areas of the basin was placed at the top of the uppermost ostracode-bearing bed.

Near the south end of the bluffs along the Madison River and in the vicinity of Anceney, unit 1 rests on Precambrian gneissic rock. In the Horseshoe Hills, west of Menard, unit 1 rests on Paleozoic and Mesozoic rocks and contains a much larger proportion of limestone than elsewhere.

Section of unit 1, measured in the bluffs along the Madison River

[Beds 1 through 5 measured on the north slope of a prominent bluff in the SE¼NW¼ sec. 34, T. 1 N., R. 2 E., beginning at unconformity at top of unit 1; beds 6 through 16 measured in the NW¼NE¼ sec. 27, T. 1 N., R. 2 E. Bed 5 is common to both exposures]

Bed	Description	Thickness (feet)
1.	Ash, sandy, silty, gray; interbedded with prominent thin white marl beds containing many ostracodes and with layers, 3 to 12 in. thick, of fine-grained loosely cemented tuffaceous sandstone; ash contains numerous dark minerals	199
2.	Sandstone, very coarse grained and pebbly, crossbedded, ferruginous; contains abundant dark minerals	3
3.	Siltstone, gray-white, tuffaceous in places; interbedded with numerous thin layers of white ash and several beds of light-gray fine-grained calcareous sandstone averaging 1 in. in thickness; sandstone beds stand out as resistant bands on the weathered slope	177
4.	Ash, thinbedded, gray-white; interbedded with a few thin beds of siltstone; ash contains ostracodes	21
5.	Limestone, argillaceous, gray; weathers to chocolate-brown; forms a hard, resistant ledge that is useful as a marker horizon	10
6.	Ash, calcareous, sandy, massive, gray; weathers to brown; interbedded with layers of white to gray pure ash that are as much as 4 in. thick	59
7.	Sandstone, medium-grained, calcareous, light-brown	14½
8.	Siltstone, calcareous, brown	½
9.	Sandstone, pebbly, poorly sorted, calcareous, massive, dark-brown; partly crossbedded; contains a few lenses of conglomerate	18
10.	Siltstone, tuffaceous, calcareous, thinbedded; contains a few thin lenses of sandstone	12
11.	Sandstone, poorly sorted, ferruginous, massive, loosely consolidated, light gray-brown	4
12.	Marl, tuffaceous, white; interbedded with calcareous white ash; marl contains ostracodes	11
13.	Limestone, coquinalike, conglomeratic, massive, gray-white; weathers to grayish brown; contains thin beds of white ash	2½
14.	Siltstone, tuffaceous, cream-colored; interbedded with fine-grained loosely cemented massive light-gray sandstone	78
15.	Covered. Probably tuffaceous siltstone interbedded with pure ash	250(?)
16.	Grit, pebbly, poorly sorted, blocky, well-cemented, light-brown to gray; consists principally of quartz, feldspar, mica, and fragments of volcanic and gneissic rock	62
	Total	921½

UNIT 2

Unit 2 is exposed throughout the Camp Creek Hills, in much of the Dry Creek subarea, in draws cutting the alluvial fans along the Bridger Range north of Bozeman, on the north and south sides of the East Gallatin River east of Bozeman, and along Goochs Ridge.

Unit 2 is highly variable in composition but consists principally of poorly stratified massive buff to tan partly calcareous variously consolidated tuffaceous siltstone, claystone, sandstone, and conglomerate; it contains a few beds of gray pure ash and small lenses of marl and limestone. Although it is predominantly of fluvial and colluvial origin, the beds of marl and limestone indicate that some of the deposition occurred in ponds or small lakes. A bed of conglomerate and buff siltstone at the base of unit 2 projects as a ledge from the bluffs along the Madison River. About 100 feet above the base of unit 2 a distinctive bed of conglomerate, locally well cemented, is present in the northern part of the Camp Creek Hills. West of Manhattan, where erosion has removed the overlying material from this bed, it forms a continuous northeastward slope from the bluffs along the Madison River to the floor of the Gallatin Valley. Along the east and southeast margins of the valley, unit 2 grades into, and interfingers with, fanglomerates which extend out from the adjacent highlands. Vertebrate fossils collected from this unit have been described by Douglass (1903), Schultz and Falkenbach (1940, 1941), and Dorr (1956).

Section of unit 2, measured in the bluffs along the Madison River

[Beds 1 through 7 measured at head of large draw in the SW¼NW¼ sec. 2, T. 1 S., R. 2 E., beginning at base of a 32-ft layer of boulders, cobbles, and coarse gravel, which caps the bluffs; beds 8 through 15 measured on south-facing escarpment in the NE¼NW¼ sec. 26, T. 1 N., R. 2 E. Bed 8 is common to both exposures]

Bed	*Description*	*Thickness (feet)*
1.	Siltstone, sandy, tuffaceous, calcareous, cream to buff; interbedded with several beds of gray ash, 1 to 2 ft thick, and a few beds of massive buff claystone	66
2.	Covered. Probably tuffaceous siltstone	43
3.	Claystone and siltstone, massive, buff; interbedded with several very thin layers of gray ash	29
4.	Siltstone interbedded with claystone, cream-colored; contains a few sand-size particles	27
5.	Sandstone, tuffaceous, very loosely cemented, green-gray; composed of fine to medium quartz grains, glass shards, and very fine grains of magnetite	1½
6.	Sandstone, very fine grained, tuffaceous, layer of ash one-fourth inch thick at base; grades downward into tuffaceous siltstone interbedded with claystone	13

Section of unit 2 measured in the bluffs along the Madison River—Continued

Bed	*Description*	*Thickness (feet)*
7.	Covered. Probably tuffaceous sandstone interbedded with layers of gray ash	12
8.	Conglomerate, sandy, calcareous, gray; interfingers with coarse, pebbly sandstone. Angular to rounded cobbles and pebbles of the conglomerate are composed of gneiss, volcanic rocks, and quartz; the fine-grained constituents of the conglomerate are predominantly quartz, dark minerals, and garnet	32
9.	Siltstone, sandy, tuffaceous, calcareous, buff; grades downward into fine-grained tuffaceous sandstone	29
10.	Sandstone, coarse-grained, tan; contains well-rounded pebbles near top; interbedded with, and grading into, fine-grained tan sandstone	44
11.	Siltstone, buff; grades downward into sandy siltstone	9
12.	Sandstone, whitish-tan; grades downward from coarse- to fine-grained sandstone	13
13.	Ash, massive, gray-white; contains coarse shards	10
14.	Conglomerate and coarse sandstone, tan	4½
15.	Conglomerate of subrounded gravel in calcareous silt matrix; interfingers with brown siltstone and sandstone; forms a prominent persistent vertical ledge which is useful as a marker horizon; numerous bone fragments near basal part. (Probably same bed from which Douglass collected vertebrate fossils.)	40
	Unconformity at top of unit 1.	
	Total	373

UNDIFFERENTIATED TERTIARY STRATA

Tertiary strata, which could not be differentiated into units 1 and 2, are exposed in the Horseshoe Hills as small outliers of lime-cemented fanglomerate resting unconformably on Precambrian and Paleozoic rocks. The fanglomerate consists of fragments of locally derived Paleozoic limestone. West of Nixon Gulch the fanglomerate grades upward into cliff-forming cream-colored limestone containing gastropod fossils. From a distance this limestone resembles limestone of Paleozoic age. The fanglomerate either is horizontal or dips very slightly southward toward the valley. The stratigraphic position of these Tertiary strata relative to units 1 and 2 is unknown.

TERTIARY AND QUATERNARY SYSTEMS

OLDER ALLUVIUM

A high benchlike fringe of alluvial-fan and stream-channel deposits skirts the Bridger and Gallatin Ranges. In the Dry Creek and Fort Ellis subareas the surface of these deposits slopes toward, and merges with, the surface of older Tertiary strata, but elsewhere the sloping surface of these deposits terminates in an escarpment. In places, these deposits are deeply eroded.

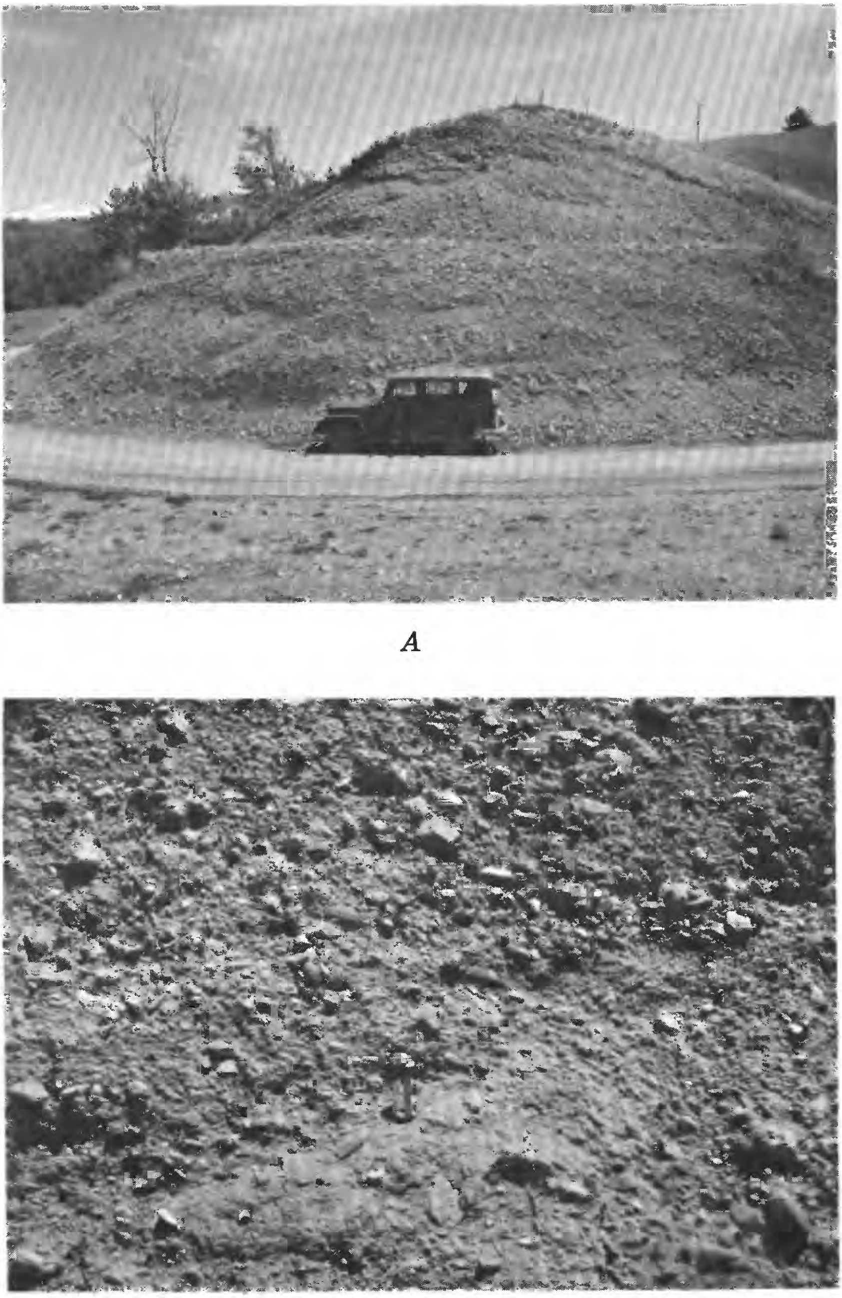
The alluvial fans of this unit are composed of locally derived poorly sorted rock fragments in a matrix of sand, silt, and clay. Some of these deposits, which are lime cemented and variously consolidated, are referred to as fanglomerate. The rock fragments forming the fans that skirt the Gallatin Range generally are more rounded than those in the fans skirting the Bridger Range. The gneissic fragments in the fans are deeply weathered. Fanglomerate does not crop out along the Gallatin Range, but the overall thickness (possibly as much as 150 feet) of unconsolidated material there is so much greater than it is next to the Bridger Range as to suggest that fanglomerate may be present but is mantled by later deposits. The stream-channel alluvium consists of rounded cobbles. The contrast between stream-channel and alluvial-fan deposits is illustrated in figure 8.

As no fossils were found in any of these deposits, it was not possible to determine their age from paleontologic evidence. However, from their physiographic relationship to the deposits that underlie the floor of the Gallatin Valley, they are believed by the writers to be of either late Tertiary or early Pleistocene age, or both. It seems more likely that deposition of rock debris along the mountain front probably was more or less continuous from Tertiary into Quaternary time. Both the Bridger and Gallatin Ranges were glaciated, and it is likely that the coarse materials in these deposits were derived from the glaciers.

The fanglomerate along the front of the Bridger Range in the Pass Creek area of the Dry Creek subarea is tilted, but the undifferentiated Tertiary and Quaternary deposits elsewhere retain their valleyward primary dip.

The Tertiary strata exposed in the bluffs overlooking the Madison River are mantled by a veneer, 10 to 30 feet thick, of moderately well sorted well-rounded cobbles predominantly of quartzite. Pardee (1950, p. 403) suggested that these deposits represent deposition during the same cycle of erosion that formed the Flaxville plain of Alden (1932). If this is correct, these deposits may be of Pliocene or early Pleistocene age. These deposits were not mapped for this study.

Sufficient water for stock and domestic use generally can be obtained from the older alluvium.



A

B

FIGURE 8.—Older alluvium in the Gallatin Valley. *A*. Stream-channel deposits in the SE cor. of the SW¼NE¼ sec. 18, T. 3 S., R. 5 E. *B*. Alluvial-fan deposits in the NE cor. of the NW¼SE¼ sec. 14, T. 1 S., R. 5 E.

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QUATERNARY SYSTEM

YOUNGER ALLUVIUM

Terrace gravels in the Camp Creek Hills

Deposits of probable Pleistocene age, derived from the destruction of higher lying gravel deposits and fanglomerate, are present at the surface in parts of the Camp Creek Hills. These deposits range in thickness from 10 to 40 feet, but they were not mapped for this study.

Remnants of a terrace formed by the Gallatin River are present along the east margin of the Camp Creek Hills. In the SE cor. of sec. 10, T. 2 S., R. 4 E., west of Sheds Bridge, the terrace is about 140 feet above river level, and in sec. 16, T. 1 N., R. 3 E., southwest of Manhattan, the terrace is about 140 to 160 feet above river level. The unconsolidated deposits underlying the terrace remnants are similar in composition to the alluvium along the Gallatin River. The entire thickness of the terrace deposits is not exposed, but west of Sheds Bridge it is at least 15 feet. These deposits were not mapped during this investigation.

Alluvial-fan deposits

Alluvial fans, probably of late Pleistocene age, extend into the Gallatin Valley from the foot of the slopes of the bordering Gallatin and Bridger Ranges. The most extensive of these, the Bozeman and Spring Hill fans, were deposited by streams that cut into fans of older alluvium higher on the slope. Along the Bridger Range, north of the Spring Hill fan, several younger fans have been deposited on pediments previously formed on older fans.

The younger alluvial fans are composed of a heterogeneous mixture of coarse- and fine-grained sediments. The proportion of gravel, cobbles, and scattered boulders to the silt and clay is not uniform in each fan; in general, however, the coarser material is predominant near the head of the fan and the finer material near the margins. Scattered throughout the alluvial fans are stringers of moderately clean sand and gravel which were deposited by the distributaries that built the fan; lenses of clay and gravel also are scattered throughout the alluvial fans. Each fan is composed of locally derived rock.

The alluvial-fan deposits thin in a downslope direction. Well D2–5–22ccd, on the Bozeman fan, was drilled through 165 feet of fan alluvium before entering strata of probable Tertiary age. Well D1–5–34cc2, 4 miles downslope from well D2–5–22ccd, was drilled through 131 feet of alluvial-fan deposits before entering Tertiary strata.

According to the degree of sorting and the amount of silt and clay present, the younger alluvial-fan deposits yield small to moderate quantities of water to wells. The stringers and lenses of gravel and sand are the source of most of the water.

Stream-channel deposits

The alluvium along the Gallatin River and under the extensive alluvial plain between the Gallatin and East Gallatin Rivers consists of cobbles and gravel intermixed with sand, clay, and silt. The upper 20 feet, as seen in gravel pits, is composed of clean and moderately well sorted cobbles and gravel. In the Central Park subarea, however, the upper 20 feet contains a higher proportion of silt and clay. Test drilling indicates that below a depth of 20 feet the alluvium consists predominantly of cobbles and pebbles, but that varying proportions of sand, silt, and clay are mixed with the coarse material, and lenses of sand, silt, and clay are present. Most of the cobbles, pebbles, and sand grains are fragments of gneiss and dark volcanic rocks derived from the Gallatin and Madison Ranges. In general, the ratio of fine- to coarse-grained material increases in a downstream direction. The character of the alluvium in the Belgrade area is shown in figure 9.

Available evidence indicates that the alluvium of the Gallatin River rests on Tertiary strata except where the river enters and leaves the valley. Test drilling between Gallatin Gateway and Sheds Bridge (SE¼ sec. 10, T. 2 S., R. 4 E.) indicates that the alluvium is 70 to 80 feet thick. Northward from Sheds Bridge the alluvium thickens. The log of test hole A1–4–25dc, in the vicinity of Belgrade, indicates that the alluvium is at least 400 feet thick, and it is reported that an oil test (State well 1), a quarter of a mile north of Belgrade, was drilled through more than 800 feet of alluvium. Toward the north end of the valley, however, the alluvium is thinner. Test hole A1–4–15da2, about 4 miles north of Belgrade, penetrated 215 feet of alluvium before entering the underlying Tertiary strata. At the extreme north edge of the valley, test hole A1–4–5da penetrated 31 feet of material known to be alluvium and 104 feet of material of questionable Tertiary age before entering strata of known Tertiary age.

Except where silt and clay fills the voids between the coarse particles of sand and gravel, the alluvium yields copious amounts of water to wells. In the vicinity of Belgrade, at depths ranging from about 15 to 50 feet below the land surface, there is a layer of lime-cemented gravel which is a semiconfining layer for water in the underlying material.

FIGURE 9.—Younger alluvium in the Gallatin Valley. Stream-channel deposits in the SW¼SE¼ sec. 7, T. 1 S., R. 5 E.

The alluvium along the tributary streams entering the valley from the Bridger and Gallatin Ranges generally is composed of sand, gravel, and cobbles. The alluvium along the streams that head in the Bridger Range consists of fragments of Precambrian gneiss and arkose and of Paleozoic limestone and quartzite, but the alluvium along the streams that head in the Gallatin Range is similar in composition to the alluvium underlying the plain between the Gallatin and East Gallatin Rivers. The alluvium along these minor streams is probably no more than 20 or 30 feet thick, but in most places it yields water freely to wells.

Compared to the generally coarse alluvium of the Gallatin River and its tributaries from the mountains, the alluvium along the streams in the Camp Creek Hills, and to some extent along Dry Creek, is much finer grained because it was derived largely from fine-textured Tertiary strata. The yield of water from this material is low.

The alluvium directly underlying the plain between the Gallatin and East Gallatin Rivers is thought to be of late Pleistocene age, whereas that along the present stream courses is of Recent age. The Gallatin River appears to be at grade in its course through the valley and, therefore, is no longer aggrading the alluvial plain. The character, extent, and thickness of the alluvium underlying the plain between the rivers indicate that the alluvium was deposited concurrently with the glaciation of the Gallatin and Madison Ranges.

LOESS

Buff calcareous silt, probably of eolian origin, mantles hills and slopes in many places in the Gallatin Valley. In some places it rests directly on Tertiary strata and in others on the terrace deposits or on the older or younger alluvial fans. Particle-size analyses show that 60 to 80 percent of the material is silt, 10 to 30 percent clay, and 3 to 15 percent sand. The few samples examined under the microscope were composed mostly of quartz grains, some mica, very little calcite and magnetite, and scattered glass shards. The loess is massive and vertically jointed; where cut through, it stands in vertical walls. (See fig. 10.) Generally, it is thicker on hilltops than on slopes.

The eolian origin of these deposits is indicated by their composition and distribution. The glass shards indicate that the loess

FIGURE 10.—Loess mantling upper Tertiary or Pleistocene gravel in the SW¼SW¼ sec. 26, T. 1 S., R. 3 E.

was derived at least in part from the Tertiary strata. Deposition probably began in late Pleistocene time and is still in progress in the Camp Creek Hills. The areal extent of the loess was not mapped during this study.

COLLUVIUM

Colluvium is the gravity-transported debris deposited at the foot of an escarpment or steep slope; as used in this report, the term also includes slope wash. The composition of colluvium depends upon the composition of the type of material exposed in the escarpment or slope from which the colluvium is derived.

The largest deposit of colluvium in the Gallatin Valley borders the Camp Creek Hills near Manhattan. Much of this deposit is silt and clay intermixed with a small amount of sand and gravel; south of Manhattan, waterlogging has resulted where the water table intersects the surface of the colluvium. Most of the other deposits of colluvium consist of coarse material overlying the upper margin of alluvial fans. All the colluvial deposits in the Gallatin Valley are considered to be of Recent age. Their areal extent was not mapped for this study.

IGNEOUS ROCKS

Thick sills are intruded into the rocks of Cambrian age in many places in the Gallatin Valley area. One, described as syenitic rock by Peale (1896, p. 4), is in the middle unit of the Flathead quartzite in the Horseshoe Hills west of Nixon Gulch, but traced eastward its position gradually changes in the section until it is near the base of the Wolsey shale in the vicinity of Dry Creek. Another thick sill lies near the contact of the Wolsey shale with the overlying Meagher limestone in the infaulted block of Paleozoic rock west of Gallatin Gateway. Clabaugh (1952, p. 67) described it as hornblende andesite porphyry. A sill whose petrologic classification was not determined is present in the Kootenai formation west of Menard. As the sills are broken by several transverse faults, intrusion must have occurred before the faulting took place.

A small body of basalt, considered by Peale to be of Miocene age, crops out in sec. 7, T. 3 S., R. 4 E., west of Gallatin Gateway.

STRUCTURE

The Gallatin Valley and the peripheral highland areas are characterized by diverse structural trends. Because the basement complex of the valley is buried beneath thick deposits of

Cenozoic age, valley structure must be considered in relation to that of the surrounding highland areas.

HORSESHOE HILLS

The low Horseshoe Hills bound the floor of the Gallatin Valley on the north and the Dry Creek subarea on the west. The exposed strata range in age from Precambrian to Tertiary, except that strata of known Ordovician, Silurian, and Triassic ages are not represented. Outliers of Tertiary deposits unconformably overlie many of the older rocks.

The Horseshoe Hills are for the most part a group of tight northeast-trending folds, which are overturned slightly to the southeast. The strata that form the north margin of the floor of the Gallatin Valley are part of the southeastern limb of a syncline that is the southernmost fold in the group.

The rocks adjacent to the valley floor form a group of northeast-plunging minor folds. Differential erosion of these folds has formed a series of zigzag ridges, the most prominent of which is underlain by the Madison group. This area has no extensive faults, though several small normal faults offset the Flathead quartzite, particularly in the troughs and at the crests of the minor folds.

At the west margin of the Dry Creek subarea, the older rocks are buried beneath Tertiary strata which fill the basin between the Horseshoe Hills and the Bridger Range. The rocks are tightly folded and extensively faulted. The principal faults appear to be normal, but south of Accola a small thrust cuts the Meagher limestone. Many of the minor normal faults and bedding-plane thrusts were not mapped for this study. The structural complexity in this part of the Horseshoe Hills probably is due to the intersection of the major structural trends of the Horseshoe Hills and the Bridger Range.

The rocks in the southern part of the Horseshoe Hills are in contact with the alluvium of the Gallatin and East Gallatin Rivers. Some of the pre-Tertiary rocks are exposed on the south side of the Gallatin River between sec. 33, T. 2 N., R. 3 E., and sec. 35, T. 2 N., R. 2 E. The river, in this locality, has cut a narrow channel across Precambrian and Paleozoic strata. The depth of this channel was determined by drilling two test holes (A2–2–35abl and A2–2–35ab2) in the narrow gorge near Logan. These test holes entered bedrock at depths of 22 and 23 feet, respectively.

Atwood (1916, p. 706) considered that the present course of the river at Logan was predetermined by its course during a previous cycle of erosion. Tertiary outliers in the Horseshoe Hills strengthen the theory that the Tertiary deposits overlapped the frontal slopes of the Horseshoe Hills and that the Gallatin River was superimposed from its course over the Tertiary strata to its present position.

BRIDGER RANGE

The Bridger Range, a high linear mountain range which bounds the Gallatin Valley on the east, extends from Bridger Creek to the head of Dry Creek. The mountains are composed of rocks that range in age from Precambrian to Cretaceous, but strata of Ordovician, Silurian, Permian, and Triassic ages are not known to be present. The Paleozoic rocks overlie Precambrian metamorphic rocks in the southern part of the Bridger Range and Precambrian rocks of the Belt series in the northern part (McMannis, 1955, p. 1393, 1416). The Paleozoic and Mesozoic rocks strike north-northwest, parallel to the axis of the range. They dip steeply to the east and in places are overturned to the east.

Several high-angle thrust faults transect the Bridger Range. Most of them have an eastward trend with local deviations to the southeast. McMannis (1955, p. 1416-1426) has shown the movement on these faults to be related to two phases of Laramide compression—strike-slip movement by east-west compression and underthrusting by later south-southwest north-northeast compression.

One of these faults, the Pass fault, is of particular significance. The western segment of the fault is believed by McMannis (1955, p. 1391, 1421) to be the contact between the Precambrian gneiss on the south and the Precambrian Belt series on the north. The coarse arkosic nature of the Belt rocks near the fault led him to conclude that deposition of the Belt series in this locality was fault controlled—that is, coarse arkosic material from the rising Archean block to the south was shed onto the subsiding northern block. He believed that later Laramide compression first caused strike-slip movement on this old fault, which was followed by underthrusting of the block of Archean-type rocks on the south.

Berry (1943, p. 7, 25) postulates a similar origin for the Belt series in the Jefferson River valley. According to Berry, the Belt rocks were deposited on the north side of a line of weakness along which thrust faulting (the Jefferson Canyon fault) later took place.

Peale (1893), Berry (1943), and McMannis (1955) are in essential agreement that the shoreline during Belt time trended eastward across the Gallatin Valley, and both Berry and McMannis postulated that the shoreline marks either a fault or a zone of weakness in the basement complex.

Normal faulting along the west side of the Bridger Range is believed to have elevated the range with respect to the valley. Pardee (1950, p. 380) and McMannis (1955, p. 1427, 1428) presented evidence for normal faulting. Pardee believed the minimum relative downthrow along the fault system—called the Bridger frontal fault system—to be 3,000 feet.

GALLATIN AND MADISON RANGES

The Gallatin River canyon separates the Madison Range on the west from the Gallatin Range on the east. Structurally, however, the two ranges are segments of the same mountain unit. This unit bounds the Gallatin Valley on the south.

The mountains are composed of Precambrian gneiss and some infaulted blocks of Paleozoic and Mesozoic rocks. About 150 square miles are covered by andesitic lavas and breccias of probable late Eocene or early Oligocene age (Horberg, 1940, p. 283). The thickness of these extrusive rocks has been estimated by Peale (1896, p. 4) to be about 2,000 feet. Several porphyritic intrusives cut the Mesozoic rocks in the southern part of the mountains.

The Precambrian rocks are dominantly hornblende gneiss and garnetiferous feldspar-rich gneiss. These are cut by numerous pegmatites, quartz stringers, and quartz veins. The rocks are tightly folded and severely crumpled in places, yet a general east-west trend is recognizable.

Of three principal faults cutting across the mountains, only the northernmost, the Salesville fault, is in the Gallatin Valley. This fault, striking N. 50°-55° W., can be traced from sec. 10, T. 3 S., R. 3 E., to sec. 20, T. 3 S., R. 4 E., where it disappears beneath the Tertiary strata. Precambrian gneiss is in contact with Cambrian and Devonian strata along the fault line. Peale (1896, p. 5) believes this fault to be the same one that appears east of the Gallatin River in the foothills of the Gallatin Range, where Carboniferous strata are in contact with Precambrian gneiss. It is a high-angle fault; the exact dip of the fault plane is undetermined.

A clear-cut boundary does not exist between the Madison Range and Gallatin Valley because the foothills of the mountain range grade into the floor of the valley and there is no evidence of faulting between the foothills and the valley. The elevation of the surface of the gneiss in test holes D1–3–36bc and D2–4–9bc is consistent with the projected slope on the gneissic surface in the Madison Range foothills. The Tertiary beds probably were deposited on a normal erosional surface developed on the gneiss.

Faulting may or may not be present along the front of the Gallatin Range. The available subsurface information is not sufficient for a determination.

GALLATIN VALLEY

The Tertiary strata in the Gallatin Valley form a homocline that dips from 1° to 5° in a generally eastward direction toward the Bridger Range. Local deviations are numerous. In the northern Camp Creek Hills the beds dip northeastward. Near the contact of the Precambrian rocks and the Tertiary strata in the southern Camp Creek Hills, the dip of the Tertiary strata reflects the slope of the underlying bedrock surface.

Several of the faults that transect those parts of the Bridger and Gallatin Ranges adjacent to the valley undoubtedly also cross the valley, and the basement complex is probably broken into blocks, especially near the Bridger frontal fault zone. Several linear features in the valley, such as the east escarpment of Goochs Ridge and a similar escarpment about a mile west of Sheds Bridge, suggest the possibility of structural control by post-Tertiary faulting; however, no definite evidence to support this hypothesis was found.

Hot water issuing from the Bozeman Hot Springs and that found during the drilling of test holes D2–4–9bc and D1–3–36bc, as well as the warm water produced by several wells in the southern Camp Creek Hills, indicate deep circulation of water, possibly along faults in the basement complex.

Small normal faults in the Tertiary strata are seen throughout the valley. Most of the observed faults are parallel to the general northward trend of the Bridger frontal fault system. The displacement along these faults generally is less than 1 foot; however, displacements of more than 20 feet have been noted and it seems likely that faults of even greater displacement are present. Figure 11 shows small faults in the Tertiary strata on the east side of South Church Street near the city limits of Bozeman. In the Camp Creek Hills, a gravel deposit is downfaulted against fine-grained Tertiary beds in the SW¼SW¼ sec. 26, T. 1 S., R. 3 E., along the south bank of the Lowline Canal. In an exposure along the Dry Creek road south of Menard, faults in the Tertiary strata are marked by layered clastic dikes. These small normal faults cut unit 2 and probably

FIGURE 11.—Small normal faults in the Tertiary strata in the SW¼SE¼ sec. 7, T. 2 S., R. 6 E.

are due to post-Miocene readjustment of the Tertiary strata to the faulting along the Bridger frontal fault zone.

The only major structural element which is transverse to the Bridger frontal fault system and for which direct evidence was found in the Tertiary strata is an east-trending monoclinal fold crossing the northern part of the valley. This fold, involving both units 1 and 2 of the Tertiary strata, is believed by the authors to reflect a subjacent fault (shown on pl. 2 as the Central Park fault) in the basement complex. The surface of the escarpment above the bluffs along the Madison River is capped with gravel at this location. The gravel cap north of the fold (N½ sec. 35, T. 1 S., R. 2 E.) has been elevated about 200 feet relative to the gravel cap south of the fold. The relationship of the gravel cap and the Tertiary strata is best seen on the north side of the flexure. The Tertiary strata here are truncated and the gravel bed is nonconformable, which indicates that some folding and erosion had taken place before deposition of the gravel. The fact that the gravel bed also is folded indicates reoccurring movement along this structure. As the flexure is traced eastward across the Camp Creek Hills the crest of the fold has

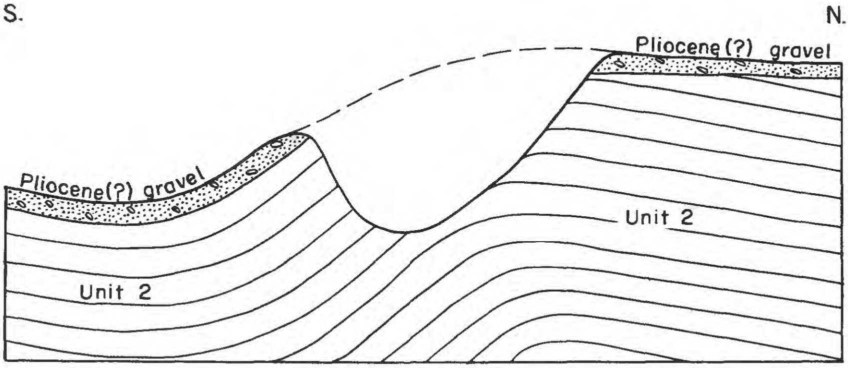

FIGURE 12.—Diagramatic section showing vestiges of the monoclinal fold in Tertiary strata in the Camp Creek Hills.

been eroded, and all that remains is a discontinuous ridge of south-dipping lime-cemented gravel. (See fig. 12.) This ridge arcs east-northeastward from the bluffs along the Madison River toward Central Park, but east of the Gallatin River the fold is concealed by alluvium.

Where covered by alluvium, the location of the fold has been determined from subsurface data. The drilling of test hole A1–4–19cb was terminated in alluvium at a depth of 301 feet. Well A1–3–14dd, 1 mile northwest of A1–4–19cb, entered Tertiary strata at a depth of 30 feet. The fold therefore must pass between test hole A1–4–19cb and well A1–3–14dd. To the east, test hole A1–4–15da2 is believed to be approximately on the fold; this test hole entered Tertiary strata at 215 feet. South of test hole A1–4–15da2 the Tertiary strata are at a much greater depth, and north of the test hole they are at a much shallower depth. East of this test hole the fold cannot be traced. It may coincide, however, with the south edge of unit 2 of the Tertiary strata at, and eastward from, the East Gallatin Cemetery (secs. 15–17, T. 1 N., R. 5 E.) and probably intersects the Bridger frontal fault zone in the vicinity of Spring Hill.

The postulated Central Park fault in the basement complex of the valley coincides approximately with the shoreline of the Belt sea, which shoreline was considered by Berry (1943) and McMannis (1955) to be fault controlled. If the high gravel-capped surface in the bluffs along the Madison River is of Pliocene or early Pleistocene age, as suggested by Pardee (1950, p. 403), then the folding of the Tertiary strata that accompanied movement along the Central Park fault must have occurred at least as recently as late Pliocene time, and perhaps as recently as Pleistocene time. The south side of the Central Park fault is the downthrown side, though during deposition of the Belt series the north side was the downthrown side, a reversal of movement along the fault apparently having taken place. McMannis presented evidence of a similar reversal in the Bridger Range along what probably is a part of the same fault zone.

Elsewhere, also, the Pliocene(?) surface is broken by faulting. A west-northwest-trending escarpment west of the point at which Elk Creek enters the Madison River (about 9 miles west of Anceney) marks a fault; the gravel-capped surface south of the escarpment is about 160 feet lower than the surface north of the escarpment, and the Tertiary strata exposed in the bluffs facing the Madison River are deformed where the fault line intersects the bluffs. This break in the Pliocene(?) surface probably resulted from movement along the westward extension of the Salesville fault and would be another indication of relatively late movement along preexisting faults in the older rocks of the Three Forks basin.

Pleistocene sedimentation in the Belgrade subarea apparently was controlled by renewed movement along the Central Park fault. The relative downward movement of the Tertiary strata south of the fault has formed, in effect, a trough in which the coarse alluvium from the Gallatin River has been deposited. Whether actual ponding in this trough ever took place or whether the rate of deposition approximated the rate of subsidence is unknown. So far as could be determined from the test-hole samples, none of the test holes penetrated obviously layered sediments.

The anomalous position and extent of the Spring Hill fan in relation to contemporaneous fans that flank the Bridger Range at higher levels to the north and south suggest that deposition of this fan also may have been controlled by the Central Park fault.

On the basis of the available test-hole data, the surface of the Tertiary beds below the Bozeman fan does not seem to slope northward at a sufficient angle to account for the great thickness of gravel, in excess of 400 feet, penetrated by test hole A1–4–25dc north of Belgrade. Either the Tertiary strata are warped gently downward (fig. 13*A*) toward the Central Park fault, or a fault near the south margin of the Belgrade plain has dropped the Tertiary strata north of the fault so as to form, with the Central Park fault, a graben (fig. 13*B*). As no geologic evidence was found to support the presence of such a fault south

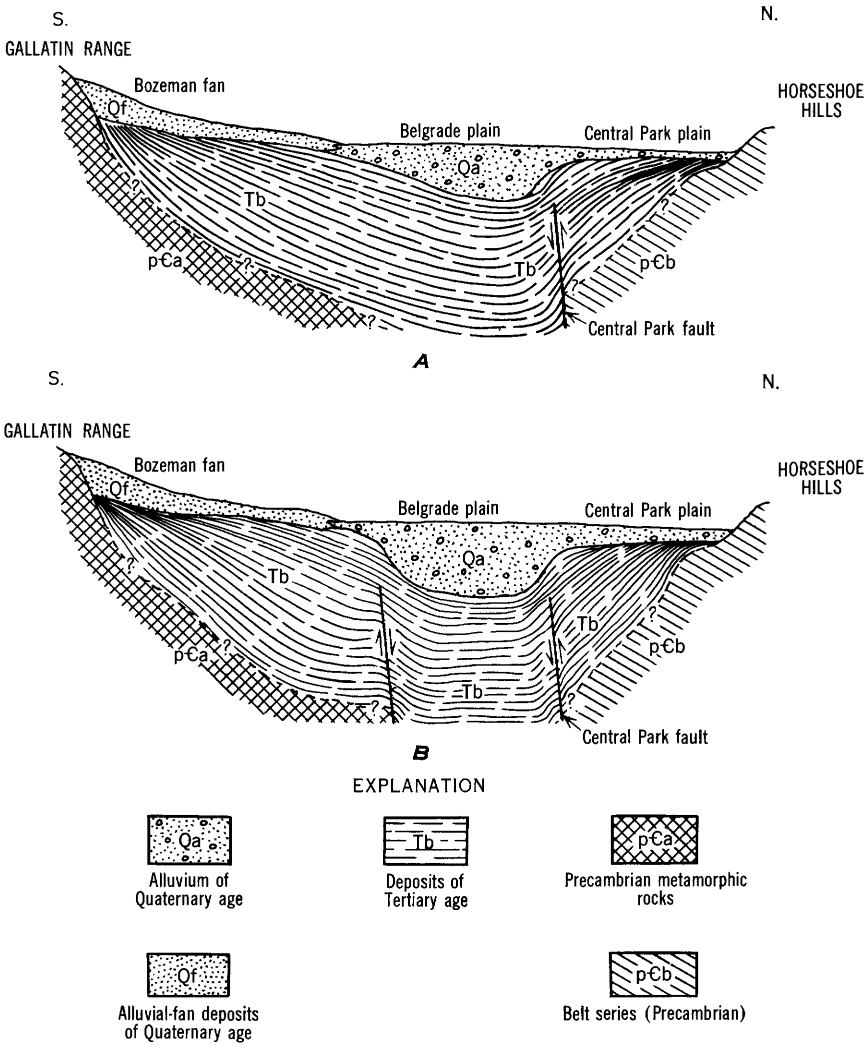

FIGURE 13.—Diagram showing alternative hypotheses for the formation of the Belgrade trough. *A*. By downwarping of the Tertiary strata northward toward the Central Park fault. *B*. By down dropping of block between the Central Park fault and a fault south of Belgrade.

of Belgrade, it seems more likely that the Tertiary strata south of the Central Park fault are merely downwarped.

There is no evidence of a post-Tertiary channel leaving the valley other than that at Logan. Bedrock underlies the alluvium at Logan at a depth of about 20 feet. The fact that the altitude of this bedrock threshold at the valley outlet is considerably higher than the altitude of the base of the alluvium in the Belgrade trough is considered by the writers to be conclusive evidence that the Belgrade trough is a structural feature.

EFFECT OF FAULTS ON THE FLOW OF WATER INTO AND OUT OF THE GALLATIN VALLEY

Although some water probably enters and leaves the valley through faults in the pre-Tertiary rocks, there is no evidence that any of these faults is a conduit for a significant amount of water in relation to the total inflow to, and outflow from, the valley. Locally, however, streams that enter the valley are known to gain a large part of their flow from fault zones.

Ross Creek in the Bridger Range and South Cottonwood Creek in the Gallatin Range are two streams known to gain part of their flow from fault zones. Ross Creek rises where a major fault zone transects limestone of the Madison group, and it picks up most of its flow from springs along the fault zone. Several years ago the Montana State College abandoned its snow-measurement course across the crest of the Bridger Range from Ross Creek because the measurements could not be correlated with streamflow east of the Bridger Range. Much of the snow along the crest and on the east side of the range in the vicinity of Ross Peak undoubtedly percolates into the porous Paleozoic rocks, especially the fractured limestones, and is discharged into Ross Creek on the west side of the range. This accounts for the very high runoff (161 inches in 1952 and 178 inches in 1953) from the Ross Creek drainage basin, an area of 1.29 square miles.

A major fault crosses South Cottonwood Creek just above the site of the gaging station established for this study. Precambrian metamorphic rock on the north side of the fault is in juxtaposition with limestone of the Madison group on the south side. In early October 1952, a discharge of 18.05 cfs was measured at the gaging station and a discharge of only 6.41 cfs was measured above the fault, 2¾ miles upstream from the station. Therefore, at that time, the amount of water entering the stream from the fault was nearly 12 cfs, or about two-thirds of the volume passing the gaging station.

Undoubtedly, other streams from the Bridger and Gallatin Ranges also gain flow from fault zones. For example, McMannis (1955, p. 1423) mentioned that Lyman Creek, which furnishes part of the water supply for Bozeman, is fed by a spring at the junction of two faults.

SUMMARY OF CENOZOIC HISTORY

The Cenozoic history of the Gallatin Valley accords, in general, with the regional history as described by Pardee (1950) and McMannis (1955).

After the deposition of Cretaceous sediments, tectonic activity related to the Laramide orogeny began. There seem to have been several phases of folding and faulting in the area, which culminated in late Paleocene time with major mountain building. Then followed a long period of erosion, during which sediments derived from surrounding mountain ranges and from contemporary vulcanism began to accumulate in basins which were probably formed by tectonic movements. Deposition continued into Oligocene time, and a few thousand feet of Tertiary sediments accumulated in the gradually sinking basins. At that time the area must have been characterized by gently sloping lowlands separated by moderately low mountains. From middle Oligocene to late Miocene time, in the vicinity of the Gallatin Valley at least, the drainage was exterior and erosion prevailed over deposition.

Renewed crustal movement and volcanic activity in late Miocene time again interrupted the through drainage, and additional sediments were deposited in the basin. Faulting (along the Bridger frontal fault), beginning at this time and continuing intermittently through Pliocene and Pleistocene time, dropped the basin floor with respect to the Bridger Range, and tilted the Tertiary strata eastward.

During a period of relative stability an extensive erosion surface was developed, and the gravel cap at the top of the bluffs along the Madison River was formed. The truncation of eastward-dipping Tertiary strata by the surface upon which the gravel was deposited (p. 51) is evidence that the tilting of these strata began before the surface was formed. As the uppermost part of the Tertiary section exposed along the bluffs includes deposits of early Pliocene age, the terrace surface may be of middle or late Pliocene or earliest Pleistocene age.

In early and middle Pleistocene time, the Madison River cut a deep valley across the middle of the Three Forks basin, and the Gallatin River was superimposed at Logan. The present size and the large-scale structural features of the Gallatin Valley thus were determined. Also in early or middle Pleistocene time, renewed movement along the Central Park fault raised the strata north of the fault with respect to those south of the fault. In the Belgrade area, the downthrown block formed a trough in which the alluvium of the Gallatin River began to accumulate. Concurrently, extensive alluvial fans were formed along the flanks of the Bridger and Gallatin Ranges, and the Camp Creek Hills were eroded and terraced.

During late Pleistocene time the then-existing alluvial fans were dissected and new fans were deposited; the Bozeman fan is one of these younger fans. Alluvium continued to accumulate in the Belgrade trough to a thickness of at least 400 feet.

Intermittent crustal movement in the Gallatin Valley area has continued to the present.

WATER RESOURCES

Ground water and surface water are components of a complex dynamic system termed the hydrologic cycle. Therefore, if they are to be evaluated, they must be considered not only in relation to each other but also in relation to the other components of the system.

Meinzer (1942, p. 1) described the hydrologic cycle as

> the circulation of the water from the sea, through the atmosphere, to the land; and thence, with numerous delays, back to the sea by overland and subterranean routes, and in part, by way of the atmosphere * * *

The principal components of the hydrologic cycle are illustrated in figure 14. The cycle is very complex and the components are closely related. Surface water may seep into the underlying rock and become ground water, just as ground water

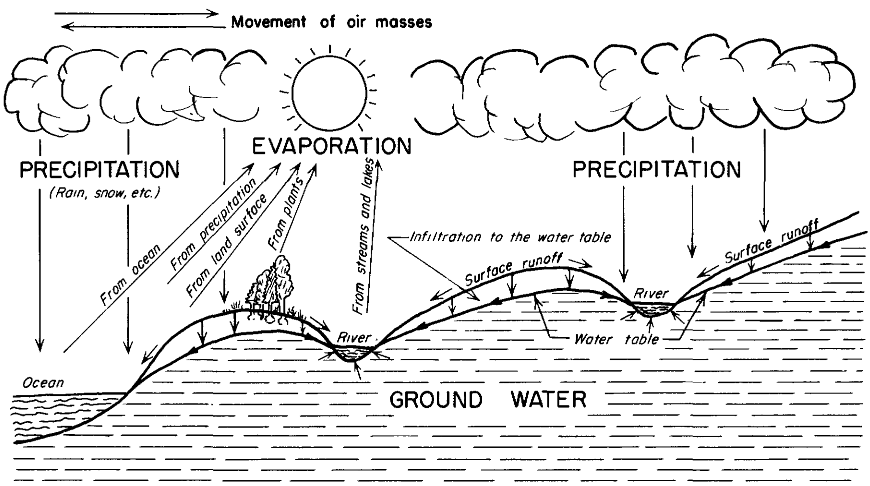

FIGURE 14.—Hydrologic cycle. Modified from U.S. Geological Survey Circular 114, figure 1a.

may return to the earth's surface through springs and effluent seepage to become surface water. Transpiration and evaporation may take place at any point in the cycle where water is exposed to the air or available to plants. Water that is stored temporarily as soil moisture may move downward to the water table and become ground water; also, ground water may move upward into the soil horizon when soil moisture becomes depleted.

The following sections describe the principal phases of the hydrologic cycle with which this report is concerned.

SURFACE WATER

By FRANK STERMITZ and F. C. BONER

At the time the study of the water resources of the Gallatin Valley was begun, permanent stream-gaging stations already were in operation on the Gallatin River near Gallatin Gateway and at Logan, and also on the East Gallatin River and on Bridger and Middle (Hyalite) Creeks. Beginning in May 1951, as part of the Gallatin Valley study, a number of additional gaging stations were established so as to obtain more complete information on the flow of surface water into the valley and on the movement of surface water within the valley. Pertinent data for all the stream-gaging stations are given in table 6; the station locations are shown both in figure 15 and on plate 1. Runoff records for these stations are given in table 7. In addition, occasional measurements were made at various other sites in the valley. These measurements, together with descriptions of the sites, are given in table 8, and the locations of the sites are shown on plate 1.

The general pattern of runoff in the Gallatin Valley is typical of that throughout the Rocky Mountain region, where precipitation varies greatly with altitude and topography, and where the rapidity of snowmelt varies widely with exposure, cover, and altitude. Extensive diversion of surface water for irrigation and the resultant return flow affect all streams in their course across the valley. However, the year-to-year variation of surface outflow from the Gallatin Valley at Logan is not great. During the period August 1928 to September 1953, the highest annual runoff was 1,077,000 acre-feet in water year 1948 and the lowest was an estimated 328,200 acre-feet in water year 1934.

STREAMS

GALLATIN RIVER

In the 80-mile reach of the Gallatin River above the gaging station near Gallatin Gateway, the average gradient is about 40

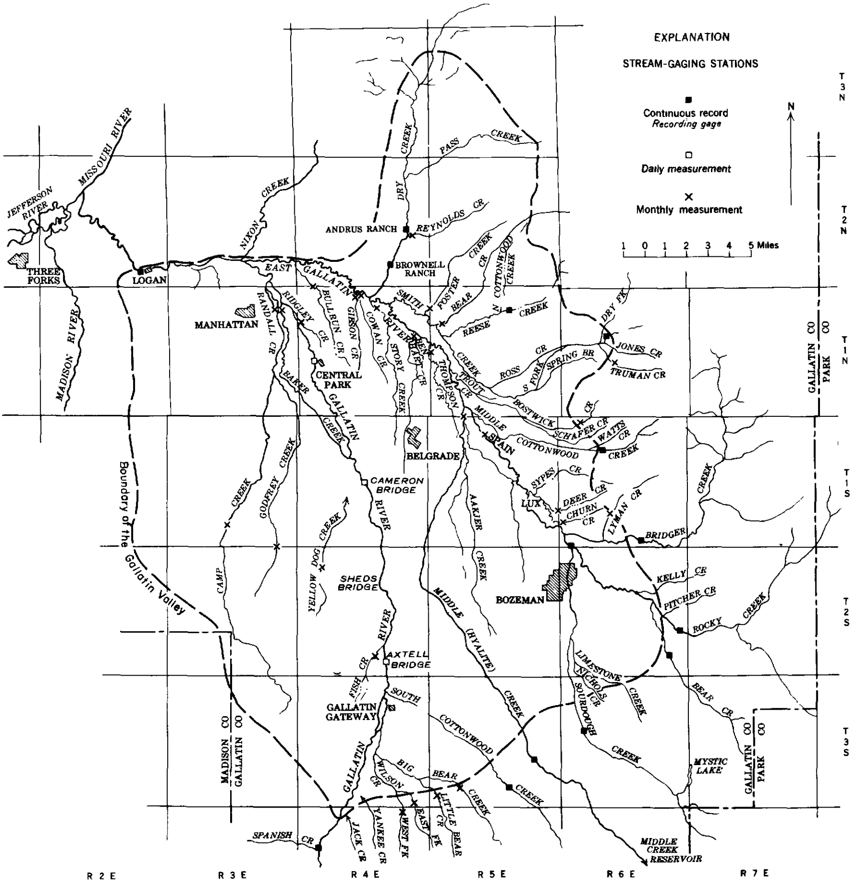

FIGURE 15.—Map of the Gallatin Valley showing location of stream-gaging stations.

feet per mile, the width of the valley is generally less than 1 mile, and only a few tributary streams are longer than 15 miles. Irrigation, which is confined to scattered hay meadows in the tributary valleys, has no appreciable effect on the regimen of the river.

Above the gaging station near Gallatin Gateway, the Gallatin River drains an area of 828 square miles. The inflow to the Gallatin Valley at this station was gaged for the first time in August 1889, and, except for July 1893, gaging was continued through June 1894. Although the Gallatin River was gaged for several subsequent years, the point of gaging was downstream from points where two large diversions were made, and hence, the measurements did not represent the total flow of the river into

TABLE 6.—*Descriptions of stream-gaging stations in the Gallatin Valley*

[Gaging station: P, permanent; T, temporary. Type of gage: R, recording; S, staff; W, wire weight]

Gaging station	Location			Drainage area (square miles)	Gage		Maximum discharge			Minimum discharge			Remarks
	Description	Latitude	Longitude		Type	Altitude of datum (feet)	Date	Cubic feet per second	Gage height (feet)	Date	Cubic feet per second	Gage height (feet)	
Gallatin River near Gallatin Gateway (P).	NE¼ sec. 18, T. 4 S., R. 4 E. On left bank, 0.25 mile below mouth of Spanish Creek and 8 miles southwest of Gallatin Gateway.	45°30′	111°16′	828	R	[1] 5,167.7	June 6, 1952	6,910	5.71	Jan. 19, 1935	117	0.68	
Wilson (East Fork) Creek near Gallatin Gateway.	SW¼ sec. 36, T. 3 S., R. 4 E. 1 mile above confluence with West Fork and 4.5 miles south of Gallatin Gateway.	45°31′25″	111°10′20″	5.33	......	....	....	......	......	....	......	......	Monthly runoff derived from measurements at about monthly intervals and comparison of hydrographs. Measurements prior to continuous record: Aug. 2, 1951, 3.4 cfs; Sept. 12, 1951, 2.6 cfs.
West Fork of Wilson Creek, near Gallatin Gateway.	NE¼ sec. 2, T. 4 S., R. 4 E. 1 mile above confluence with East Fork and 4.5 miles south of Gallatin Gateway.	45°31′05″	111°11′35″	3.81	......	....	....	......	......	....	......	......	Monthly runoff derived from measurements at about monthly intervals and comparison of hydrographs. Measurements prior to continuous record: Aug. 2, 1951, 2.1 cfs; Sept. 12, 1951, 2.0 cfs.
Big Bear Creek near Gallatin Gateway.	SW¼ sec. 29, T. 3 S., R. 5 E. Above main diversion canal, 2 miles above confluence with Little Bear Creek and 4.5 miles southeast of Gallatin Gateway.	45°32′35″	111°08′25″	13.2	S [2]	....	....	......	......	....	......	......	Monthly runoff derived from measurements at about monthly intervals and comparison of hydrographs, supplemented by weekly or daily gage readings. Measurements prior to continuous record: Aug. 2, 1951, 7.9 cfs; Sept. 12, 1951, 6.1 cfs.

Little Bear Creek near Gallatin Gateway.	NW¼ sec. 31, T. 3 S., R. 5 E. 1.5 miles above mouth and 4.5 miles southeast of Gallatin Gateway.	45°32′20″	111°09′45″	3.87	S [3]	....	....	......	......	....	......	......	Monthly runoff derived from measurements at about monthly intervals and comparison of hydrographs, supplemented by weekly or daily gage readings. Measurements prior to continuous record: Aug. 2, 1951, 2.1 cfs; Sept. 12, 1951, 1.6 cfs.
South Cottonwood Creek near Gallatin Gateway (T).	NE¼ sec. 34, T. 3 S., R. 5 E. On left bank, 15 ft below Wortman ranch bridge and 6.5 miles southeast of Gallatin Gateway.	45°32′20″	111°05′15″	22.5	R	[1] 5,689.5	June 5, 1952	283	2.52	Mar. 22, 26, 1952	9.2	.73	
Gallatin River at Axtell Bridge near Gallatin Gateway (T).	NW¼ sec. 35, T. 2 S., R. 4 E. Near center of span on downstream side of bridge, 2 miles north of Gallatin Gateway and 20 miles above confluence with East Gallatin River.	45°37′	111°12′	....	W	[1] 4,815.7	June 7, 1952	6,530	6.90	Jan. 24, 26, 1952	220	......	
Fish Creek near Gallatin Gateway.	Center of north line, sec. 34, T. 2 S., R. 4 E. About 0.5 mile above mouth and 2.5 miles north of Gallatin Gateway.	45°37′40″	111°13′00″	....	S	....	....	......	......	....	......	......	Monthly runoff derived from measurements at monthly intervals and comparison of hydrographs, supplemented by weekly or daily gage readings.
Yellow Dog Creek near Belgrade.	SW¼ sec. 5, T. 2 S., R. 4 E. 200 ft below confluence of 2 forks and 7.5 miles southwest of Belgrade.	45°42′10″	111°15′50″	6.85	S	....	....	......	......	....	......	......	Do.
Godfrey Creek near Belgrade.	NW¼ sec. 24, T. 1 S., R. 3 E. At county road bridge, 25 ft above irrigation canal, 0.5 mile south of Church Hill, and 6.5 miles southwest of Belgrade.	45°45′	111°18′	....	......	....	....	......	......	....	......	......	

See footnotes at end of table.

TABLE 6.—*Descriptions of stream-gaging stations in the Gallatin Valley*—Continued

Gaging station	Location			Drainage area (square miles)	Gage		Maximum discharge			Minimum discharge			Remarks
	Description	Latitude	Longitude		Type	Altitude of datum (feet)	Date	Cubic feet per second	Gage height (feet)	Date	Cubic feet per second	Gage height (feet)	
Godfrey Creek near Belgrade—Continued.	After June 10, 1952: SW¼ sec. 36, T. 1 S., R. 3 E. At county road bridge, 1 mile north of Little Holland School and 8.5 miles southwest of Belgrade.	45°42′05″	111°18′30″	6.32	S [4]	....	....	......	......	....	......	......	Monthly runoff derived from measurements at monthly intervals and comparison of hydrographs, supplemented by weekly or daily gage readings.
Baker Creek near Manhattan	NW¼ sec. 12, T. 1 N., R. 3 E. At county road bridge, 0.3 mile above mouth and 1.5 miles east of Manhattan.	45°51′35″	111°17′55″	....	S [5]	....	....	......	......	....	......	......	Do.
Gallatin River at Cameron Bridge near Belgrade (T).	NW¼ sec. 22, T. 1 S., R. 4 E. Near center of span on downstream side of bridge, 3 miles southwest of Belgrade and 12 miles above confluence with East Gallatin River.	45°45′	111°13′	....	W	[6] 4,496.1	June 14, 1953	9,110	7.00	Oct. 8, 1953	27	1.87	
Gallatin River at Central Park near Manhattan (T).	NE¼ sec. 19, T. 1 N., R. 4 E. Near right bank on downstream side of railroad bridge, 3 miles southeast of Manhattan and 5 miles above confluence with East Gallatin River.	45°49′	111°16′	....	S	[6] 4,291.4	June 18, 1953	4,970	5.22	Aug. 2, 1951	4.8	.92	
Ridgley Creek near Manhattan.	SW¼ sec. 7, T. 1 N., R. 4 E. At county road bridge above mouth and 2 miles east of Manhattan.	45°51′00″	111°16′55″	....	S [4]	....	....	......	......	....	......	......	Do.

Camp Creek near Belgrade.	SE¼ sec. 28, T. 1 S., R. 3 E. At county road bridge at Arnold railroad siding, 9.5 miles southwest of Belgrade and 10 miles above mouth.	45°42′55″	111°21′15″	34.5	S [7]	....	....	......	......	....	......	......	Do.
Randall Creek near Manhattan.	SE¼ sec. 2, T. 1 N., R. 3 E. At county road bridge, 1 mile east of Manhattan and 1.5 miles above mouth.	45°51′40″	111°18′15″	....	S [8]	....	....	......	......	....	......	......	Do.
Rocky Creek (East Gallatin River) near Bozeman (T).	SE¼ sec. 24, T. 2 S., R. 6 E. On right bank, 0.3 mile downstream from highway bridge and 6 miles southeast of Bozeman.	45°38′35″	110°55′35″	49.5	R	[6] 5,044.1	June 3, 1953	608	4.65	Nov. 7, 1952	7.9	......	Measurement prior to continuous record: Sept. 11, 1951, 15.1 cfs; Sept. 21, 1951, 14.0 cfs.
Bear Creek near Bozeman (T).	NW¼ sec. 36, T. 2 S., R. 6 E. On left bank, 3 miles above mouth and 6 miles southeast of Bozeman.	45°37′35″	110°55′45″	17.6	R	[6] 5,183.4	....do..	450	3.40	Feb. 9, 10, 19-25, 1953; Mar. 3, 4, 1953	1.1	......	Measurements prior to continuous record: Sept. 11, 1951, 3.6 cfs.
Sourdough (Bozeman) Creek near Bozeman (T).	SW¼ sec. 17, T. 3 S., R. 6 E. On left bank, 0.25 mile above Bozeman settling basin and 7 miles south of Bozeman.	45°34′40″	111°01′15″	28.0	R	[1] 5,351.0	June 4, 1953	348	2.41	Feb. 23, 24, 1953	5	......	
East Gallatin River at Bozeman (P).	SE¼ sec. 31, T. 1 S., R. 6 E. On left bank, 100 ft above highway bridge, 500 ft below mouth of Sourdough Creek, 0.5 mile above mouth of Bridger Creek and 0.5 mile north of Bozeman.	45°42′05″	111°01′40″	149	R	[6] 4,701.6	...do...	1,240	6.09	Dec. 9, 1944	12	1.88	
Bridger Creek near Bozeman (P).	NE¼SE¼ sec. 34, T. 1 S., R. 6 E. On right bank, 3 miles above mouth and 3 miles northeast of Bozeman.	45°42′30″	110°58′00″	62.2	R	....	June 3, 1953	902	4.90	Mar. 23, 1953	.9	.31	

See footnotes at end of table.

TABLE 6.—*Descriptions of stream-gaging stations in the Gallatin Valley*—Continued

Gaging station	Location			Drainage area (square miles)	Gage		Maximum discharge			Minimum discharge			Remarks
	Description	Latitude	Longitude		Type	Altitude of datum (feet)	Date	Cubic feet per second	Gage height (feet)	Date	Cubic feet per second	Gage height (feet)	
Lyman Creek near Bozeman.	NW¼ sec. 28, T. 1 S., R. 6 E. About 0.25 mile above city of Bozeman diversion and about 1.5 miles above mouth.	45°43′30″	110°59′30″	175	......	....	....	......	......	....	......	......	Monthly runoff derived from measurements at monthly intervals and comparison of hydrographs.
Churn Creek near Bozeman.	SW¼ sec. 30, T. 1 S., R. 6 E. About 2 miles above mouth and 2 miles north of Bozeman.	....	....	....	......	....	....	......	......	....	......	......	Monthly runoff derived from measurements at monthly intervals and comparison of hydrographs. Measurements prior to continuous record: Sept. 13, 1951, 0.5 cfs; Aug. 27, 1952, 0.6 cfs.
Deer Creek near Bozeman.	NW¼ sec. 30, T. 1 S., R. 6 E. At county road, 1 mile above mouth and 3 miles north of Bozeman.	....	....	....	......	....	....	......	......	....	......	......	Monthly runoff derived from measurements at monthly intervals and comparison of hydrographs.
East Gallatin River near Belgrade.	SE¼ sec. 4, T. 1 S., R. 5 E. At Spain railroad siding and 3 miles east of Belgrade.	....	....	....	S [5]	....	....	......	......	....	......	......	Monthly runoff derived from measurements at monthly intervals and comparison of hydrographs, supplemented by weekly or daily gage readings. Measurements prior to continuous record: July 12, 1951, 75.0 cfs; Aug. 3, 1951, 25.2 cfs; Sept. 5, 1951, 52.4 cfs.
Middle Cottonwood Creek	SW¼ sec. 9, T. 1 S., R. 6 E. On left bank,	45°45′50″	110°59′50″	4.35	R	[6] 5,286.5	June 4, 1953	120	2.32	....	......	......	

near Bozeman (T).	100 ft from Forest Service trail, 0.8 mile from end of county road, and 5.5 miles northeast of Bozeman.											
Middle (Hyalite) Creek at Hyalite ranger station near Bozeman (P).	SE¼ sec. 23, T. 3 S., R. 5 E. On right bank, 7.5 miles south of Bozeman and 20 miles above mouth.	45°34′	111°03′	48.4	R	[1]5,539.6	June 14, 1898	956	[9]2.10	Feb. 2, 1939	.4	[9]1.16	Flow regulated by Middle Creek Reservoir since March 1951.
Middle (Hyalite) Creek near Belgrade.	SE¼ sec. 32, T. 1 N., R. 5 E. At railroad bridge, 0.5 mile above mouth and 2.5 miles northeast of Belgrade.	45°47′15″	111°07′40″	....	.....	....	....	......	......	....	......	......	Monthly runoff derived from measurements at monthly intervals and comparison of hydrographs. Measurement prior to continuous record: Oct. 8, 1952, 53.5 cfs.
Bostwick Creek near Belgrade.	NE¼ sec. 6, T. 1 S., R. 6 E. 0.25 mile above diversion dam and 7 miles east of Belgrade.	45°47′00″	111°01′10″	5.04	S [8]	....	....	......	......	....	......	......	Monthly runoff derived from measurements at monthly intervals and comparison of hydrographs, supplemented by weekly or daily gage readings. Measurement prior to continuous record: Sept. 14, 1951, 1.7 cfs.
Thompson Creek near Belgrade.	SE¼ sec. 13, T. 1 N., R. 4 E. 0.5 mile above mouth and 4 miles north of Belgrade.	45°49′55″	111°09′35″	....	S	....	....	......	......	....	......	......	Monthly runoff derived from measurements at monthly intervals and comparison of hydrographs, supplemented by weekly or daily gage readings.
Ben Hart Creek near Belgrade.	SE¼ sec. 11, T. 1 N., R. 4 E. 0.5 mile above mouth and 5 miles north of Belgrade.	45°51′00″	111°11′05″	....	S [4]	....	....	......	......	....	......	......	Do.
Ross Creek near Belgrade (T).	NW¼ sec. 16, T. 1 N., R. 6 E. On left bank, 5 ft above county road bridge and 10 miles northeast of Belgrade.	45°50′30″	110°59′25″	1.29	R	[6]5,194.9	June 3, 1953; July 5, 6, 1953	34	1.86	Mar. 21–25, 1952	9.2	......	

See footnotes at end of table.

TABLE 6.—*Descriptions of stream-gaging stations in the Gallatin Valley*—Continued

Gaging station	Location			Drainage area (square miles)	Gage		Maximum discharge			Minimum discharge			Remarks
	Description	Latitude	Longitude		Type	Altitude of datum (feet)	Date	Cubic feet per second	Gage height (feet)	Date	Cubic feet per second	Gage height (feet)	
Truman Creek near Belgrade.	SW¼ sec. 21, T. 1 N., R. 6 E. 100 ft above abandoned diversion ditch and 9.5 miles northeast of Belgrade.	45°49′25″	110°59′10″	2.94	......	....	....	......	......	....	......	......	Monthly runoff dervied from measurements at monthly intervals and comparison of hydrographs. Measurement prior to continuous record: Sept. 14, 1951, 1.1 cfs.
Reese Creek near Belgrade (T).	NE¼ sec. 10, T. 1 N., R. 5 E. On left upstream abutment of county bridge, 7 miles northeast of Belgrade.	45°51′35″	111°04′50″	22.0	R	[6]4,505.2	June 3, 1953	175	3.55	July 31, 1951	4.0	1.93	
Bear Creek near Belgrade.	SE¼ sec. 7, T. 1 N., R. 5 E. At county road bridge, 300 ft above mouth and 5 miles north of Belgrade.	45°51′00″	111°08′55″	4.30	S [10]	....	....	......	......	....	......	......	Monthly runoff derived from measurements at monthly intervals and comparison of hydrographs, supplemented by weekly or daily gage readings. Measurement prior to continuous record: Sept. 14, 1951, 2.7 cfs.
Foster Creek near Belgrade.	NE¼ sec. 12, T. 1 N., R. 4 E. At county road bridge, 5.5 miles north of Belgrade.	....	....	....	......	....	....	......	......	....	......	......	Monthly runoff derived from measurements at about monthly intervals and comparison of hydrographs.
Dry Creek at Andrus ranch near Manhattan (T).	SE¼ sec. 23, T. 2 N., R. 4 E. On right downstream abutment of county bridge, 0.25 mile above mouth of Reynolds Creek and 8 miles northeast of Manhattan.	45°54′35″	111°10′55″	96.4	R	[6]4,445.0	Apr. 7, 1952	309	4.03	....	......	......	

Reynolds Creek near Manhattan.	SE¼ sec. 23, T. 2 N., R. 4 E. 0.1 mile above mouth and 8 miles northeast of Manhattan.	....	....	....	.....	....	....	.....	.....	....	.....	.....	Do.
Dry Creek at Brownell ranch near Manhattan (T).	SW¼ sec. 26, T. 2 N., R. 4 E. On right downstream abutment of county road bridge, about 1 mile below mouth of Reynolds Creek and 7 miles northeast of Manhattan.	45°53′25″	111°11′45″	....	R	....	May 24, 1951	33	2.44	Aug. 18, 1951	4.7	1.84	Replaced by station at Andrus ranch.
Story Creek near Manhattan.	SE¼ sec. 3, T. 1 N., R. 4 E. 0.25 mile above mouth and 6 miles east of Manhattan.	45°51′40″	111°12′25″	....	S [4]	....	....	.....	.....	....	.....	.....	Monthly runoff derived from measurements at about monthly intervals and comparison of hydrographs, supplemented by weekly or daily gage readings.
Cowan Creek near Mantan.	NE¼ sec. 4, T. 1 N., R. 4 E. 100 ft above county road bridge, 300 ft above mouth and 5 miles east of Manhattan.	45°52′10″	111°13′40″	....	S [11]	....	....	.....	.....	....	.....	.....	Do.
Gibson Creek near Manhattan.	NE¼ sec. 4, T. 1 N., R. 4 E. 300 ft above mouth, 500 ft above county road bridge and 5 miles east of Manhattan.	45°52′15″	111°13′50″	....	S [11]	....	....	.....	.....	....	.....	.....	Monthly runoff derived from measurements at about monthly intervals and comparison of hydrographs, supplemented by weekly or daily gage readings. Measurement prior to continuous record: Sept. 20, 1951, 17.3 cfs.
Bullrun Creek near Manhattan.	SE¼ sec. 31, T. 2 N., R. 4 E. At county road bridge, 1.5 miles above mouth and 3.5 miles northeast of Manhattan.	45°52′30″	111°16′10″	....	S [11]	....	....	.....	.....	....	.....	.....	Monthly runoff derived from measurements at about monthly intervals and comparison of hydrographs, supplemented by weekly or daily gage readings.

See footnotes at end of table.

TABLE 6.—*Descriptions of stream-gaging stations in the Gallatin Valley*—Continued

Gaging station	Location			Drainage area (square miles)	Gage		Maximum discharge			Minimum discharge			Remarks
	Description	Latitude	Longitude		Type	Altitude of datum (feet)	Date	Cubic feet per second	Gage height (feet)	Date	Cubic feet per second	Gage height (feet)	
Gallatin River at Logan (P).	NE¼ sec. 35, T. 2 N., R. 2 E. On right bank at bridge, 0.5 mile west of Logan and 5 miles above confluence with Jefferson and Madison Rivers.	45°53′	111°26′	1,805	R	[1]4,082.3	June 5, 1948	7,870	8.40	July 19, 1939	130	2.04	

1 Datum of 1929, supplementary adjustment of 1940.
2 After Apr. 8, 1952.
3 After Mar. 31, 1952.
4 After June 9, 1952.
5 After Apr. 16, 1952.
6 Datum of 1929, unadjusted.
7 After Apr. 5, 1952.
8 After June 10, 1952.
9 Site and datum then in use.
10 After Apr. 1, 1952.
11 After Apr. 30, 1952.

TABLE 7.—*Monthly and annual runoff, in acre-feet, of streams in the Gallatin Valley*

[Annual runoff values rounded according to standard practice of U.S. Geological Survey. Values in italics were used in computing measured tributary inflow (table 23)]

Water year [1]	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Gallatin River near Gallatin Gateway													
1889	....	....	....	....	....	....	....	....	....	....	26,200	26,800	....
1890	24,700	23,800	24,600	19,700	17,800	19,700	27,400	129,000	157,000	85,400	46,800	36,100	612,000
1891	36,300	30,100	25,000	24,600	22,200	27,700	29,800	117,000	150,000	94,300	46,800	34,700	638,000
1892	36,100	29,800	26,700	26,400	24,700	24,600	26,800	91,500	264,000	156,000	58,900	43,700	809,000
1893	45,700	35,000	33,800	28,800	23,900	23,100	27,500	87,000	232,000	[2] 79,900	38,200	34,900	[2] 690,000
1894	35,400	27,300	24,600	20,300	18,900	19,100	33,600	180,000	239,000	[2] 85,400	[2] 46,800	[2] 36,100	[2] 766,000
1930	....	....	....	....	....	....	....	....	125,000	59,300	38,800	26,500	....
1931	31,700	20,800	18,400	12,300	17,700	20,300	29,900	89,800	105,000	29,200	18,200	13,900	407,000
1932	14,600	18,300	17,900	16,700	15,900	16,300	20,900	117,000	227,000	71,300	30,600	24,500	591,000
1933	22,600	19,300	16,400	17,500	14,700	15,900	22,700	55,300	181,000	51,100	29,000	24,300	470,000
1934	19,370	17,850	17,830	18,200	15,790	18,150	34,160	62,820	38,290	21,200	16,570	15,370	295,600
1935	16,350	14,800	13,180	13,380	12,240	12,640	18,720	54,990	158,000	59,320	26,240	20,260	420,100
1936	18,560	16,060	14,800	14,360	12,960	13,820	34,810	127,000	90,260	31,890	24,520	19,010	418,000
1937	18,050	14,690	14,060	14,630	13,190	13,430	15,660	92,360	107,700	45,190	23,090	18,110	390,200
1938	17,890	15,900	14,740	14,350	12,680	13,960	22,170	84,430	187,600	75,810	32,910	23,090	515,500
1939	25,970	19,780	17,080	17,120	14,980	19,410	33,770	125,200	89,970	50,690	26,660	21,440	462,100
1940	20,560	16,350	14,380	14,000	13,040	14,490	22,750	121,000	134,500	45,000	26,040	22,050	464,200
1941	21,710	16,450	15,880	15,250	13,390	15,290	18,710	82,360	91,260	37,010	26,210	32,300	385,800
1942	32,540	23,610	19,460	16,780	15,330	16,210	40,080	86,170	177,000	91,610	33,020	24,120	575,900
1943	21,920	20,280	17,320	16,240	14,780	17,230	44,640	106,200	238,600	124,400	41,210	27,290	690,100
1944	25,870	22,180	19,110	17,860	16,490	16,860	21,080	92,190	160,600	76,250	33,670	28,180	530,300
1945	24,500	20,040	16,840	17,750	15,310	16,460	17,820	67,110	155,300	96,370	37,280	28,430	513,200
1946	27,410	21,740	16,740	17,410	15,920	18,400	47,540	106,700	158,800	69,600	30,830	26,290	557,400
1947	24,940	19,400	17,630	15,340	13,100	16,170	24,740	154,900	193,600	113,100	42,630	32,070	667,600
1948	32,370	24,130	22,560	21,480	19,470	17,760	26,520	153,000	224,300	78,010	44,260	30,160	694,000
1949	28,910	23,040	19,540	18,490	15,680	17,260	35,980	135,000	120,400	48,840	28,140	24,600	515,900
1950	24,290	21,000	17,060	14,540	14,510	17,000	24,830	60,220	179,900	112,600	45,150	31,170	562,300
1951	28,690	24,580	19,890	15,280	15,440	17,310	26,100	116,000	120,200	70,620	39,170	26,910	520,200
1952	27,750	22,550	18,020	17,400	15,550	17,300	44,310	186,800	207,700	85,420	42,540	29,210	714,600
1953	24,690	19,460	19,000	18,590	15,180	17,120	20,370	53,680	183,600	87,770	33,890	24,310	517,700
1954	21,220	17,910	16,330	....	....	....	....	....	....	....	....	....	....

See footnotes at end of table.

TABLE 7.—*Monthly and annual runoff, in acre-feet, of streams in the Gallatin Valley*—Continued

Water year [1]	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Wilson (East Fork) Creek near Gallatin Gateway													
1952	160	134	128	117	101	101	206	1,070	2,080	480	238	163	4,980
1953	148	113	107	115	83	130	117	209	1,050	437	182	146	2,840
West Fork of Wilson Creek near Gallatin Gateway													
1952	99	101	103	93	77	75	160	767	1,010	301	184	125	3,100
1953	123	101	92	98	72	105	95	165	659	283	123	95	2,010
Big Bear Creek near Gallatin Gateway													
1952	292	280	264	228	184	160	686	3,930	4,900	1,240	514	357	13,040
1953	291	253	230	226	163	172	241	871	3,330	1,130	476	340	7,720
1954	497	548	407	....	....	....	....	....	....	....	....	....	....
Little Bear Creek near Gallatin Gateway													
1952	99	81	73	69	58	56	194	867	799	397	196	135	3,020
1953	107	85	78	73	61	59	60	173	586	262	125	116	1,780
1954	107	105	86	....	....	....	....	....	....	....	....	....	....
South Cottonwood Creek near Gallatin Gateway													
1951	....	....	....	....	....	....	....	....	4,520	3,100	1,550	1,210	....
1952	1,130	914	819	772	682	642	1,340	6,290	9,120	3,270	1,700	1,220	27,900
1953	1,100	891	865	750	662	706	736	1,580	7,860	4,300	1,520	1,080	22,050
Gallatin River at Axtell Bridge, near Gallatin Gateway													
1950	....	....	....	....	....	....	....	....	171,000	84,170	32,330	26,750	....
1951	....	....	....	....	....	....	....	....	95,130	55,060	37,680	26,700	....

1952	26,380	24,310	19,440	19,580	16,660	18,370	48,910	215,700	197,700	74,990	34,240	24,250	720,500
1953	21,530	21,600	21,270	20,650	17,140	18,700	22,120	48,450	196,700	77,410	29,990	19,500	515,100
1954	18,840	20,690	22,150	...	...	...	...	...	...	...	...	...	...
Fish Creek near Gallatin Gateway													
1952	...	...	...	...	...	...	...	...	853	1,040	879	674	...
1953	586	574	522	479	440	494	472	571	725	639	695	669	6,870
1954	551	616	527	...	...	...	...	...	...	...	...	...	...
Yellow Dog Creek near Belgrade													
1952	...	...	...	...	...	...	1,470	419	383	474	347	333	...
1953	402	269	209	174	134	153	131	240	445	382	186	192	2,920
1954	228	280	231	...	...	...	...	...	...	...	...	...	...
Godfrey Creek near Belgrade													
1952	393	250	214	218	222	258	2,060	676	516	591	456	419	6,270
1953	391	408	311	298	233	254	259	341	527	570	360	309	4,260
1954	386	334	218	...	...	...	...	...	...	...	...	...	...
Baker Creek near Manhattan													
1952	...	...	7,240	5,530	4,720	5,220	12,180	37,240	33,720	4,960	3,520	5,810	...
1953	5,150	6,530	6,070	5,960	4,820	5,850	5,260	3,810	23,340	4,580	3,370	4,950	79,690
1954	4,380	5,450	6,010	...	...	...	...	...	...	...	...	...	...
Gallatin River at Cameron Bridge, near Belgrade													
1950	...	...	...	...	...	...	...	...	127,600	44,040	9,440	15,160	...
1951	...	...	...	...	...	...	...	...	63,640	14,420	16,100	16,850	...
1952	20,120	25,120	19,950	20,750	17,710	18,460	45,860	213,200	201,500	38,040	11,890	12,230	644,800
1953	7,580	17,190	23,660	22,500	18,580	19,790	20,550	28,600	164,700	35,830	8,980	6,770	374,700
1954	7,880	14,040	20,810	...	...	...	...	...	...	...	...	...	...

See footnotes at end of table.

TABLE 7.—*Monthly and annual runoff, in acre-feet, of streams in the Gallatin Valley*—Continued

Water year [1]	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Gallatin River at Central Park, near Manhattan													
1950	...	...	...	...	...	...	...	...	111,100	41,990	1,220	4,170	...
1951	...	...	...	...	...	...	...	...	43,810	2,490	6,830	10,710	...
1952	13,740	19,930	16,070	15,750	14,750	16,370	46,100	166,400	121,200	29,340	3,480	7,100	470,200
1953	4,920	14,420	20,560	20,240	15,700	17,760	18,290	18,640	140,100	35,920	1,530	2,510	310,600
1954	5,580	10,890	17,910	...	...	...	...	...	...	...	...	...	...
Ridgley Creek near Manhattan													
1952	413	393	393	313	276	307	385	325	119	258	115	301	3,598
1953	237	276	234	262	239	274	240	236	84	145	79	79	2,390
1954	113	154	195	...	...	...	...	...	...	...	...	...	...
Camp Creek near Belgrade													
1952	296	149	87	67	58	65	3,130	361	311	317	200	323	5,364
1953	271	189	103	116	107	145	171	158	363	310	147	83	2,160
1954	74	71	74	...	...	...	...	...	...	...	...	...	...
Randall Creek near Manhattan													
1952	...	...	397	234	234	484	1,050	639	1,380	65	353	492	...
1953	169	84	46	41	34	36	139	117	104	89	165	95	1,120
1954	153	117	119	...	...	...	...	...	...	...	...	...	...
Rocky Creek (East Gallatin River) near Bozeman													
1952	*754*	*750*	*690*	*608*	*574*	*654*	*8,140*	*9,990*	*3,230*	*1,470*	*867*	*742*	*28,470*
1953	*710*	*600*	*592*	*593*	*555*	*848*	*2,010*	*5,990*	*8,270*	*1,550*	*912*	*785*	*23,420*

Bear Creek near Bozeman													
1952	*137*	*173*	*117*	*99*	*89*	*119*	*1,720*	*3,720*	*1,020*	*371*	*228*	*154*	*7,950*
1953	*115*	*107*	*91*	*106*	*71*	*114*	*341*	*1,840*	*3,030*	*319*	*169*	*118*	*6,420*
Sourdough (Bozeman) Creek near Bozeman													
1951	....	....	....	....	....	....	....	5,170	2,240	1,740	1,060	1,050	....
1952	*835*	*662*	*575*	*521*	*461*	*430*	*3,160*	*7,150*	*4,370*	*1,410*	*1,320*	*1,430*	*22,320*
1953	*766*	*680*	*633*	*538*	*405*	*464*	*848*	*2,550*	*6,040*	*2,510*	*1,550*	*1,010*	*17,990*
East Gallatin River at Bozeman													
1939	....	....	....	....	....	....	....	....	....	....	....	1,890	....
1940	1,830	1,840	1,730	1,500	1,670	3,150	8,710	11,420	7,570	2,500	1,790	2,050	45,760
1941	2,570	2,020	1,930	1,860	1,640	3,380	4,920	5,860	5,760	2,090	1,940	3,750	37,720
1942	5,310	4,440	4,600	2,980	2,460	3,130	16,270	15,220	11,530	3,890	2,060	2,720	74,610
1943	2,870	2,970	2,860	2,240	2,640	4,560	11,550	15,140	15,780	4,040	2,970	3,010	70,630
1944	3,020	3,120	2,910	2,240	2,210	3,370	5,800	6,080	13,370	6,360	2,470	3,050	54,000
1945	3,400	2,790	2,410	2,420	2,660	3,150	4,180	11,040	11,030	4,810	2,890	2,840	53,620
1946	3,140	3,160	2,490	2,540	2,420	4,980	11,750	11,740	5,690	2,610	1,840	2,510	54,870
1947	3,610	3,810	3,190	2,570	2,700	6,190	13,100	19,010	18,000	5,070	3,800	4,930	85,980
1948	4,450	4,310	4,140	3,960	2,580	3,400	19,580	32,540	20,370	8,220	5,910	3,560	113,000
1949	3,500	3,480	2,850	2,420	3,040	3,480	9,610	8,720	5,910	2,610	1,790	2,380	49,790
1950	3,070	2,600	2,380	2,080	3,080	3,780	8,520	13,170	8,960	4,170	3,600	3,220	58,630
1951	3,560	3,040	2,950	2,510	2,860	3,190	10,330	20,850	7,760	3,590	2,760	3,140	66,540
1952	3,710	3,310	3,020	2,410	2,460	2,660	19,460	27,170	9,920	4,520	3,540	3,530	85,710
1953	3,160	2,960	2,870	2,790	2,510	3,390	5,230	12,340	20,420	3,750	2,880	2,790	65,090
1954	2,910	2,790	2,720	....	....	....	....	....	....	....	....	....	....
Bridger Creek near Bozeman													
1946	430	417	307	303	349	1,110	5,530	5,980	3,120	970	506	398	19,420
1947	657	736	637	447	560	1,550	4,170	12,420	6,950	2,200	1,090	1,380	32,800
1948	1,050	888	962	940	579	688	7,690	18,490	10,110	3,500	1,690	904	47,490
1949	686	564	464	336	371	494	3,570	4,450	2,300	1,130	326	324	15,020
1950	474	458	278	183	422	460	2,450	7,230	5,790	1,950	1,060	623	21,380
1951	720	791	749	495	445	635	3,090	9,860	3,680	1,240	754	585	23,040
1952	*653*	*595*	*382*	*256*	*254*	*341*	*7,190*	*13,510*	*4,490*	*1,740*	*747*	*510*	*30,670*
1953	*486*	*378*	*323*	*419*	*346*	*540*	*1,580*	*7,710*	*14,290*	*2,420*	*875*	*550*	*29,920*
1954	471	399	331	....	....	....	....	....	....	....	....	....	....

See *footnotes at end of table.*

TABLE 7.—*Monthly and annual runoff, in acre-feet, of streams in the Gallatin Valley*—Continued

Water year [1]	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Lyman Creek near Bozeman													
1952	234	196	184	173	149	179	349	627	714	545	397	274	4,020
1953	246	208	184	166	150	172	149	248	762	479	394	345	3,500
Churn Creek near Bozeman													
1953	....	....	....	....	....	....	....	94	326	57	68	24	....
Deer Creek near Bozeman													
1953	....	....	....	....	....	....	....	45	109	14	6	6	....
East Gallatin River near Belgrade													
1952	4,280	3,780	3,530	2,640	2,970	3,110	22,530	42,800	17,120	7,200	3,690	3,490	117,100
1953	2,640	2,520	2,590	2,780	2,040	3,270	5,770	16,630	33,450	5,160	2,520	2,450	81,820
1954	2,350	2,520	2,570	....	....	....	....	....	....	....	....	....	....
Middle Cottonwood Creek near Bozeman													
1951	....	....	....	....	....	....	....	....	353	134	83	71	....
1952	79	69	63	55	52	70	939	1,460	368	137	79	54	3,420
1953	44	45	40	40	28	52	241	973	1,550	182	70	42	3,310
Middle (Hyalite) Creek at Hyalite Ranger Station, near Bozeman													
1895	....	....	....	....	....	....	....	....	....	....	3,566	2,975	....
1896	3,136	2,737	[2] 2,460	[2] 1,845	[2] 1,438	[2] 1,537	1,964	5,903	17,256	10,084	2,705	2,380	[2] 53,445
1897	2,337	....	....	....	....	....	....	....	....	....	....	....	....

1898	...	...	...	...	...	...	[2]4,844	10,883	24,159	13,589	4,562	4,457	...
1899	[2]4,544	[2]3,868	[2]3,689	[2]3,074	[2]3,055	[2]4,612	[2]5,355	[2]9,285	29,982	20,559	6,383	3,414	[2]97,820
1900	2,987	...	...	...	...	...	...	...	[2]16,066	5,472	3,382	2,856	...
1901	[2]2,951	...	...	...	...	...	...						...
1902	...	...	...	...	...	...	...	[2]9,039	15,055	7,133	4,564	2,499	...
1903	...	...	...	...	...	...	...	...	...	...	...	...	...
1904	...	...	...	...	...	...	...	...	...	...	...	[2]2,380	...
1905	2,580	2,320	[2]1,840	...	...	...	...	...	...	...	...	...	...
1934	...	...	...	...	...	...	...	...	...	...	...	[2]964	...
1935	1,170	1,010	708	599	637	764	1,100	6,590	13,910	7,230	2,520	1,470	37,710
1936	1,310	1,100	1,060	837	690	906	3,900	7,270	5,280	1,880	1,530	1,260	27,020
1937	1,300	1,130	1,030	891	696	873	1,240	8,460	9,430	3,280	1,570	1,430	31,330
1938	1,350	1,040	861	899	742	980	2,100	8,170	10,980	3,980	2,260	1,520	34,880
1939	1,780	1,460	1,350	1,170	833	1,070	2,570	8,590	7,770	4,710	2,080	1,650	35,030
1940	1,470	1,110	1,020	1,120	750	841	1,870	10,440	12,020	4,160	2,070	1,680	38,550
1941	1,610	1,170	1,070	1,270	1,060	1,220	1,900	6,790	7,370	2,780	1,820	3,430	31,490
1942	3,260	2,070	1,900	1,510	1,010	1,230	4,050	7,340	10,830	8,040	2,740	1,960	45,940
1943	1,830	1,590	1,270	1,200	1,160	1,060	4,050	7,770	14,190	8,260	2,820	1,860	47,060
1944	1,830	1,740	1,260	1,120	1,100	1,060	1,300	8,060	13,970	7,630	2,750	2,670	44,490
1945	2,300	1,500	1,170	1,100	1,100	1,020	1,280	8,330	11,990	9,250	2,780	2,180	44,000
1946	2,080	1,790	1,610	1,410	1,410	1,480	4,680	6,920	9,200	5,610	2,950	2,290	41,430
1947	2,060	1,900	1,370	1,040	916	994	2,280	12,640	14,280	9,860	3,760	3,310	54,410
1948	2,780	1,940	1,860	1,810	1,060	1,480	7,290	17,860	15,830	6,390	4,590	3,030	65,920
1949	2,510	2,230	1,840	1,210	1,250	920	3,120	8,710	9,830	4,180	2,130	2,170	40,100
1950	2,030	1,510	1,390	1,120	1,160	1,160	1,810	6,090	12,170	7,680	3,380	2,330	41,830
1951	2,060	1,810	1,740	1,500	992	653	1,360	6,880	7,330	6,120	4,070	1,980	[3]36,500
1952	*2,190*	*1,610*	*1,370*	*1,090*	*1,060*	*1,150*	*3,240*	*11,280*	*13,340*	*6,360*	*4,000*	*2,770*	[3]*49,460*
1953	*1,750*	*881*	*700*	*815*	*845*	*1,030*	*1,480*	*5,450*	*13,740*	*8,540*	*5,360*	*2,330*	[3]*42,920*
1954	1,760	1,080	863	...	...	...	...	...	...	...	...	...	...

Middle (Hyalite) Creek near Belgrade

1952	...	...	974	339	258	688	7,160	15,300	8,090	7,360	4,680	4,760	...

Bostwick Creek near Belgrade

1952	*95*	*95*	*89*	*79*	*69*	*83*	*464*	*930*	*704*	*315*	*165*	*107*	*3,200*
1953	*85*	*77*	*41*	*66*	*50*	*65*	*128*	*686*	*1,660*	*424*	*137*	*101*	*3,520*
1954	86	57	26	...	...	...	...	...	...	...	...	...	...

See footnotes at end of table.

TABLE 7.—*Monthly and annual runoff, in acre-feet, of streams in the Gallatin Valley*—Continued

Water year [1]	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Thompson Creek near Belgrade													
1952	2,400	2,140	1,840	1,660	1,380	1,450	2,830	2,300	1,960	2,140	2,320	2,420	24,840
1953	2,340	2,060	1,700	1,600	1,250	1,300	1,150	1,420	2,010	2,100	2,380	2,280	21,590
1954	2,280	2,080	1,910	....	....	....	....	....	....	....	....	....	....
Ben Hart Creek near Belgrade													
1952	2,220	2,080	1,890	1,740	1,550	1,570	1,960	2,340	1,700	1,920	1,950	1,960	22,880
1953	2,050	2,030	1,910	2,060	1,650	1,730	1,670	1,890	2,210	1,890	1,840	1,660	22,590
1954	1,780	1,790	1,840	....	....	....	....	....	....	....	....	....	....
Ross Creek near Belgrade													
1951	....	....	....	....	....	....	....	....	1,030	1,030	994	901	....
1952	*885*	*776*	*821*	*734*	*591*	*581*	*701*	*1,110*	*1,300*	*1,370*	*1,150*	*1,100*	*11,120*
1953	*978*	*841*	*744*	*684*	*544*	*640*	*588*	*825*	*1,510*	*1,920*	*1,580*	*1,380*	*12,230*
Truman Creek near Belgrade													
1952	*56*	*44*	*40*	*38*	*28*	*32*	*258*	*502*	*250*	*135*	*89*	*63*	*1,540*
1953	*52*	*44*	*25*	*37*	*28*	*35*	*55*	*222*	*734*	*197*	*113*	*80*	*1,620*
Reese Creek near Belgrade													
1951	....	....	....	....	....	....	....	....	997	442	355	394	....
1952	*449*	*417*	*405*	*363*	*311*	*361*	*1,220*	*2,730*	*1,730*	*842*	*457*	*415*	*9,700*
1953	*420*	*422*	*404*	*455*	*379*	*489*	*433*	*994*	*4,590*	*1,130*	571	450	*10,740*

Bear Creek near Belgrade													
1952	*188*	*186*	*152*	*196*	*166*	*184*	*432*	*212*	*186*	*224*	*200*	*182*	*2,510*
1953	*189*	*163*	*167*	*246*	*210*	*245*	*230*	*163*	*204*	*117*	*161*	*162*	*2,260*
1954	181	195	193	...	...	...	...	...	...	...	...	...	...
Foster Creek near Belgrade													
1953	...	...	...	...	...	...	...	23	32	16	15	12	...
Dry Creek at Andrus ranch, near Manhattan													
1952	*1,180*	*1,100*	*1,070*	*1,050*	*980*	*996*	*4,560*	*2,030*	*1,350*	*1,220*	*956*	*1,090*	*17,580*
1953	*1,250*	*1,180*	*1,230*	*1,270*	*942*	*1,300*	*1,140*	*1,240*	*2,260*	*1,460*	*1,290*	*1,290*	*15,850*
Reynolds Creek near Manhattan													
1953	*68*	*65*	*74*	*89*	*67*	*77*	*60*	*76*	*127*	*92*	*92*	*95*	*982*
Dry Creek at Brownell ranch, near Manhattan													
1951	...	...	...	...	...	...	...	...	508	402	332	458	...
Story Creek near Manhattan													
1952	1,480	1,290	1,290	1,070	805	831	1,330	1,700	674	984	1,060	1,290	13,800
1953	1,120	1,180	1,110	1,060	797	936	845	776	900	664	1,070	1,180	11,640
1954	1,000	922	778	...	...	...	...	...	...	...	...	...	...
Cowan Creek near Manhattan													
1952	541	512	415	430	442	480	662	635	409	309	403	476	5,714
1953	581	526	500	586	477	491	499	342	650	584	200	419	5,860
1954	562	568	555	...	...	...	...	...	...	...	...	...	...

See footnotes at end of table.

TABLE 7.—*Monthly and annual runoff, in acre-feet, of streams in the Gallatin Valley*—Continued

Water year [1]	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Gibson Creek near Manhattan													
1952	1,080	952	1,020	795	575	659	942	946	833	758	1,080	1,050	10,690
1953	1,110	1,130	1,110	1,110	910	1,010	889	1,090	1,050	753	845	1,020	12,030
1954	1,050	1,110	1,040	......	......	......	......	......	......	......	......	......	......
Bullrun Creek near Manhattan													
1952	829	873	922	954	827	805	1,850	2,230	833	1,060	208	686	12,080
1953	534	637	741	746	706	869	807	631	926	286	369	367	7,620
1954	532	936	1,080	......	......	......	......	......	......	......	......	......	......
Gallatin River at Logan													
1893	......	......	......	......	......	......	......	......	......	......	......	[2] 23,800	......
1894	[2] 36,900	[2] 29,800	[2] 27,700	[2] 24,600	[2] 25,000	[2] 35,000	[2] 49,300	[2] 176,000	[2] 256,000	[2] 67,600	[2] 27,700	[2] 31,500	[2] 787,000
1895	[2] 43,000	[2] 44,600	[2] 49,200	49,200	44,400	48,800	69,100	148,000	151,000	64,600	29,500	43,000	[2] 784,000
1896	43,200	42,400	37,500	41,800	38,100	43,000	42,400	67,500	268,000	75,000	42,900	40,600	782,000
1897	41,800	40,500	43,300	43,000	36,100	40,000	58,900	232,000	173,000	42,700	27,500	30,800	810,000
1898	37,900	40,100	39,700	43,000	38,900	42,800	61,200	133,000	296,000	57,400	22,800	43,900	857,000
1899	51,300	42,100	49,200	[2] 43,000	[2] 33,300	[2] 39,200	[2] 76,300	[2] 121,000	[2] 325,000	[2] 105,000	[2] 41,900	[2] 30,300	[2] 958,000
1900	[2] 34,900	[2] 42,800	[2] 49,200	55,300	55,500	61,500	67,900	192,000	134,000	20,200	21,000	28,800	[2] 763,000
1901	37,300	41,700	38,900	[2] 36,900	[2] 33,300	[2] 36,900	[2] 46,100	[2] 289,000	[2] 122,000	[2] 17,600	[2] 11,600	[2] 24,000	[2] 735,000
1902	33,400	33,800	36,900	32,600	30,600	41,700	36,600	133,000	165,000	53,400	25,200	23,700	646,000
1903	36,300	40,400	36,900	43,000	44,400	48,500	51,900	93,200	210,000	72,600	22,600	24,800	725,000
1904	43,800	41,700	36,900	28,400	30,100	29,400	69,600	170,000	232,000	79,300	22,000	32,400	816,000
1905	45,400	44,000	50,700	45,600	36,100	35,700	32,900	58,700	132,000	31,700	13,800	16,600	543,000
1906	30,700	36,700	[2] 36,900	......	......	......	......	......	......	......	......	......	......
1928	......	......	......	......	......	......	......	......	......	......	[2] 29,500	41,300	......
1929	54,700	52,800	44,900	40,300	28,900	48,900	53,110	101,000	168,000	46,700	19,500	29,700	688,000
1930	41,600	44,400	45,100	33,200	43,000	42,700	63,700	76,900	57,700	22,100	32,100	36,200	539,000
1931	55,200	44,600	40,100	38,100	30,000	47,500	51,700	71,900	88,100	11,600	14,400	18,000	511,000
1932	24,900	32,700	34,400	25,800	31,100	40,600	44,300	117,000	159,000	37,800	18,400	26,700	593,000

1933	39,000	49,000	37,500	38,700	25,800	39,600	42,300	76,900	137,000	[2] 14,800	[2] 16,600	[2] 27,400	[2] 545,000
1934	[2] 39,970	[2] 45,820	[2] 40,580	[2] 39,970	35,570	38,950	25,530	[2] 10,760	16,660	9,960	10,290	14,190	[2] 328,200
1935	20,490	19,500	28,540	27,670	27,540	34,020	37,490	43,960	103,200	19,190	14,350	19,690	395,600
1936	25,180	36,510	36,520	33,830	22,140	46,670	59,250	124,400	41,150	10,480	13,750	19,360	469,200
1937	23,140	28,920	30,680	25,190	36,370	35,140	47,340	80,440	84,030	19,750	15,940	20,980	447,900
1938	24,480	26,630	34,590	33,540	31,050	34,620	46,520	116,300	163,000	58,300	19,840	20,900	609,800
1939	40,500	50,620	45,180	40,140	24,490	53,080	58,790	97,350	80,630	24,340	18,340	25,810	559,300
1940	34,900	35,600	39,860	33,990	34,210	45,200	57,980	132,400	117,600	18,650	20,090	26,380	596,400
1941	33,450	35,760	39,990	38,010	33,510	43,360	42,740	65,010	58,400	20,220	21,960	48,290	480,700
1942	60,580	53,340	52,490	40,270	38,780	46,500	96,970	128,500	193,300	51,680	21,470	36,310	820,200
1943	43,280	49,100	42,690	41,010	40,650	64,960	82,470	131 600	252,000	81,700	32,350	37,730	899,500
1944	41,950	49,940	49,700	41,000	36,080	46,960	48,140	69,020	184,600	79,640	23,160	40,910	711,100
1945	49,130	46,930	44,380	46,930	40,500	42,680	39,660	75,830	148,500	70,960	25,570	36,080	667,200
1946	49,010	49,560	45,720	43,170	39,420	55,430	81,770	122,600	114,300	38,030	26,790	43,650	709,400
1947	51,540	53,710	48,480	44,450	40,950	51,170	67,220	166,200	228,500	84,740	33,620	57,560	928,100
1948	65,400	61,760	55,960	54,020	51,250	54,120	90,870	226,700	262,900	65,460	47,670	40,600	1,077,000
1949	51,960	56,230	51,210	44,050	35,790	53,090	77,900	144,000	103,500	32,610	23,860	38,120	712,300
1950	49,360	49,240	42,410	35,780	40,800	47,910	57,560	75,700	151,000	75,280	40,570	44,010	709,600
1951	58,680	54,420	51,370	39,610	44,710	53,270	62,490	155,300	78,090	28,580	38,420	49,670	714,600
1952	55,520	55,900	47,660	42,620	39,180	43,630	118,600	279,100	197,200	70,220	35,830	44,460	1,030,000
1953	37,840	47,900	49,990	50,260	40,940	47,560	47,870	63,290	211,700	55,870	29,570	33,410	716,200
1954	35,990	43,030	48,030	....	....	....	....	....	....	....	....	....	....

[1] Year ending September 30 of the date shown.
[2] Estimated.
[3] Does not include 2,660 acre-ft stored in Middle Creek Reservoir (completed in late 1950).
[4] Does not include 280 acre-ft stored in Middle Creek Reservoir.
[5] Includes 1,790 acre-ft released from storage in Middle Creek Reservoir.

TABLE 8.—*Occasional measurements of the discharge of streams, ditches, and springs in the Gallatin Valley*

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)

Jack Creek, tributary of Gallatin River
[Measured in SE¼ sec. 9, T. 4 S., R. 4 E., about 1.75 miles above mouth and 6.5 miles south of Gallatin Gateway]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Aug. 26, 1952	0.2	45	Aug. 28, 1953	0.2	...

Yankee Creek, tributary of Gallatin River
[Measured in SW¼ sec. 3, T. 4 S., R. 4 E., about 2 miles above mouth and 5.5 miles south of Gallatin Gateway]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Aug. 26, 1952	0.5	48	Aug. 28, 1953	0.2	...

Wilson Creek, tributary of Gallatin River
[Measured in NW¼ sec. 35, T. 3 S., R. 4 E., about 0.25 mile below mouth of West Fork and 3.5 miles south of Gallatin Gateway]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
June 3, 1952	55.6	...	Feb. 24, 1953	3.8	32
June 12, 1952	48.8	45	Mar. 18, 1953	4.8	33
July 16, 1952	7.0	56	Apr. 15, 1953	3.9	40
Aug. 12, 1952	3.2	58	May 25, 1953	5.9	44
Sept. 10, 1952	2.3	53	June 18, 1953	29.3	47
Oct. 14, 1952	2.8	42	July 21, 1953	4.6	54
Nov. 11, 1952	4.6	37	Aug. 10, 1953	1.8	58
Dec. 17, 1952	3.9	32	Sept. 17, 1953	2.3	51
Jan. 20, 1953	4.0	35			

Big Bear Creek, tributary of Wilson Creek
[Measured in SE¼ sec. 32, T. 3 S., R. 5 E., about 1 mile above gaging station and 5.5 miles southeast of Gallatin Gateway]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Oct. 3, 1952	5.2	42			

Big Bear Creek, tributary of Wilson Creek
[Measured in NE¼ sec. 32, T. 3 S., R. 5 E., about 0.5 mile above gaging station and 5 miles southeast of Gallatin Gateway]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Oct. 3, 1952	3.6	42			

South Cottonwood Creek, tributary of Gallatin River
[Measured in NE¼ sec. 12, T. 4 S., R. 5 E., 2.75 miles above gaging station and 9.5 miles southeast of Gallatin Gateway]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Oct. 3, 1952	6.4	41			

Spain-Ferris ditch 4, diversion from Spain-Ferris ditch 5
[Measured in SW¼NW¼ sec. 7, T. 1 S., R. 5 E., at U.S. Highway 10 and 0.85 mile southeast of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
July 7, 1953	7.4	...	Sept. 1, 1953	3.7	...
Aug. 5, 1953	7.5	...	Sept. 28, 1953	3.2	...

Spain-Ferris ditch 5, diversion from Spain-Ferris ditch 1
[Measured in NW¼NW¼ sec. 7, T. 1 S., R. 5 E., at U.S. Highway 10 and 0.8 mile southeast of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
July 7, 1953	5.6	...	Sept. 1, 1953	0.4	...
Aug. 5, 1953	1.0	...	Sept. 28, 1953	.1	...

TABLE 8.—*Occasional measurements of the discharge of streams, ditches, and springs in the Gallatin Valley*—Continued

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Spain-Ferris ditch 3, diversion from Spain-Ferris ditch 1 [Measured in SW¼SW¼ sec. 5, T. 1 S., R. 5 E., 1.6 miles east of Belgrade]					
Aug. 5, 1953	2.1	....	Sept. 1, 1953	0.4	....
Spain-Ferris ditch 2, diversion from Spain-Ferris ditch 1 [Measured in SE¼SW¼ sec. 5, T. 1 S., R. 5 E., 2 miles east of Belgrade]					
July 7, 1953	0.4	....	Sept. 1, 1953	0.1	....
Aug. 5, 1953	.3	....			
Spain-Ferris ditch 1, diversion from Gallatin River in NW¼ sec. 14, T. 2 S., R. 4 E. [Measured in SW¼SE¼ sec. 5, T. 1 S., R. 5 E., 2.1 miles east of Belgrade]					
July 7, 1953	5.0	....	Sept. 1, 1953	8.6	....
Aug. 5, 1953	4.2	....	Sept. 28, 1953	6.5	....
Gallatin River [Measured in SE¼ sec. 10, T. 2 S., R. 4 E., 250 ft below Sheds Bridge and 7.5 miles west of Bozeman]					
Apr. 2, 1952	305	....			
Mammoth ditch, diversion from Gallatin River [Measured in NW¼SW¼ sec. 1, T. 1 S., R. 4 E., at U.S. Highway 10 and 0.4 mile northwest of Belgrade]					
July 7, 1953	10.3	....	Sept. 1, 1953	2.2	....
Aug. 5, 1953	10.3	....	Sept. 28, 1953	.9	....
J. S. Hoffman ditch 2, diversion from J. S. Hoffman ditch 1 [Measured in NE¼NE¼ sec. 33, T. 1 N., R. 4 E., at U.S. Highway 10 and 2.9 miles northwest of Belgrade]					
July 7, 1953	3.9	....	Sept. 1, 1953	1.7	....
Aug. 5, 1953	2.1	....	Sept. 28, 1953	1.0	....
J. S. Hoffman ditch 1, diversion from J. B. Weaver ditch 1 in NE¼ sec. 22, T. 1 S., R. 4 E. [Measured in NE¼SE¼ sec. 34, T. 1 N., R. 4 E., at U.S. Highway 10 and 1.7 miles northwest of Belgrade]					
July 7, 1953	6.5	....	Sept. 1, 1953	1.9	....
Aug. 5, 1953	3.8	....	Sept. 28, 1953	1.5	....
J. B. Weaver ditch 2, diversion from J. B. Weaver ditch 1 [Measured in SE¼SE¼ sec. 34, T. 1 N., R. 4 E., at U.S. Highway 10 and 1.65 miles northwest of Belgrade]					
July 7, 1953	2.5	....	Sept. 1, 1953	0.2	....
Aug. 5, 1953	4.3	....	Sept. 28, 1953	1.2	....

TABLE 8.—*Occasional measurements of the discharge of streams, ditches, and springs in the Gallatin Valley*—Continued

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
J. B. Weaver ditch 1, diversion from Gallatin River in NE¼ sec. 22, T. 1 S., R. 4 E. [Measured in NW¼NE¼ sec. 2, T. 1 S., R. 4 E., at U.S. Highway 10 and 0.9 mile northwest of Belgrade]					
July 7, 1953	22.0	....	Sept. 1, 1953	6.4	....
Aug. 5, 1953	16.8	....	Sept. 28, 1953	3.6	....
Stone-Weaver ditch 2, diversion from Stone-Weaver ditch 1 [Measured in SE¼NW¼ sec. 34, T. 1 N., R. 4 E., at U.S. Highway 10 and 2.3 miles northwest of Belgrade]					
Sept. 1, 1953	0.2	....	Sept. 28, 1953	0.3	....
Stone-Weaver ditch 1, diversion from Gallatin River in NW¼ sec. 22, T. 1 S., R. 4 E. [Measured in SE¼NW¼ sec. 34, T. 1 N., R. 4 E., at U.S. Highway 10 and 2.4 miles northwest of Belgrade]					
July 7, 1953	4.6	....	Sept. 1, 1953	1.6	....
Aug. 5, 1953	2.1	....	Sept. 28, 1953	1.3	....
Barnes ditch, diversion from D. N. Hoffman ditch in SW¼ sec. 28, T. 1 N., R. 4 E. [Measured in SE¼SW¼ sec. 28, T. 1 N., R. 4 E., at U.S. Highway 10 and 3.3 miles northwest of Belgrade]					
July 7, 1953	4.8	....	Sept. 1, 1953	0.7	....
Aug. 5, 1953	2.6	....	Sept. 28, 1953	.4	....
Gallatin River [Measured in SW¼ sec. 4, T. 1 S., R. 4 E., 200 ft below county road bridge and 3 miles west of Belgrade]					
Apr. 2, 1952	276	....			
Smith drain (continuation of Upper Creamery ditch), diversion from Gallatin River in SW¼ sec. 4, T. 1 S., R. 4 E. [Measured in SW¼SW¼ sec. 20, T. 1 N., R. 4 E., at U.S. Highway 10 and 4.9 miles northwest of Belgrade]					
July 7, 1953	5.1	....	Sept. 1, 1953	6.7	....
Aug. 5, 1953	5.9	....	Sept. 28, 1953	6.5	....
Lower Creamery ditch, diversion from Gallatin River in SW¼SE¼ sec. 19, T. 1 N., R. 4 E. [Measured in NE¼SE¼ sec. 19, T. 1 N., R. 4 E., at U.S. Highway 10 and 5.4 miles northwest of Belgrade]					
July 7, 1953	17.6	....	Sept. 1, 1953	2.1	....
Aug. 5, 1953	14.0	....	Sept. 28, 1953	3.5	....
Gallatin River [Measured in SE¼ sec. 1, T. 1 N., R. 3 E., 50 ft below county road bridge and 1.75 miles east of Manhattan]					
Sept. 20, 1951	182	51			

TABLE 8.—*Occasional measurements of the discharge of streams, ditches, and springs in the Gallatin Valley*—Continued

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Camp Creek, tributary of Gallatin River [Measured in NE¼ sec. 4, T. 2 S., R. 3 E., at Vincent School, 50 ft below county road bridge and 10.5 miles northwest of Gallatin Gateway]					
Sept. 20, 1951	0.5	49			
Camp Creek, tributary of Gallatin River [Measured in NW¼ sec. 2, T. 1 S., R. 3 E., at Buell railroad siding, 50 ft above county road bridge and 4.75 miles south of Manhattan]					
Sept. 20, 1951	16.3	51			
Gallatin River [Measured in NW¼ sec. 1, T. 1 N., R. 3 E., 300 ft above railroad bridge and 1.5 miles northeast of Manhattan]					
Apr. 2, 1952	425	....			
Pitcher Creek, tributary of Rocky Creek (East Gallatin River) [Measured in SW¼ sec. 13, T. 2 S., R. 6 E., 0.4 mile above mouth and 5 miles east of Bozeman]					
Sept. 13, 1951	0.2	45	Aug. 26, 1953	0.3	....
Aug. 27, 1952	.3	49			
Kelly Creek, tributary of East Gallatin River [Measured in SE¼ sec. 11, T. 2 S., R. 6 E., 1.25 miles above mouth and 4.5 miles east of Bozeman]					
Sept. 13, 1951	0.4	43	Aug. 26, 1953	0.6	....
Aug. 27, 1952	.8	49			
Limestone Creek, tributary of Sourdough (Bozeman) Creek [Measured in NE¼ sec. 4, T. 3 S., R. 6 E., at abandoned farm 2.25 miles above mouth and 5.5 miles southeast of Bozeman]					
Sept. 12, 1951	0.7	41	Aug. 26, 1953	0.5	....
Aug. 26, 1952	.7	52			
Nichols Creek, tributary of Limestone Creek [Measured in SE¼ sec. 5, T. 3 S., R. 6 E., 1.5 miles above mouth and 5.5 miles south of Bozeman]					
Sept. 12, 1951	0.2	41	Aug. 26, 1953	0.2	....
Aug. 26, 1952	.2	51			
East Gallatin River, tributary of Gallatin River [Measured in NE¼ sec. 36, T. 1 S., R. 5 E., 10 feet below county road bridge and 2 miles north of Bozeman]					
Apr. 3, 1952	73.5	....			

TABLE 8.—*Occasional measurements of the discharge of streams, ditches, and springs in the Gallatin Valley*—Continued

East Gallatin River, tributary of Gallatin River
[Measured in NW¼ sec. 23, T. 1 S., R. 5 E., 4.0 miles northwest of Bozeman]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Apr. 3, 1952	79.2	....			

Deer Creek, tributary of East Gallatin River
[Measured in SW¼ sec. 20, T. 1 S., R. 6 E., 1.5 miles above mouth and 3 miles northeast of Bozeman]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Aug. 27, 1952	0.1	....			

Sypes Creek, tributary of East Gallatin River
[Measured in SE¼ sec. 17, T. 1 S., R. 6 E., 3.5 miles above mouth and 4.5 miles northeast of Bozeman]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Sept. 13, 1951	0.5	46	Aug. 26, 1953	0.1	....
Aug. 27, 1952	.1	51			

West branch of East Gallatin River, diversion from East Gallatin River in SW¼ sec. 14, T. 1 S., R. 5 E., and tributary of East Gallatin River in SW¼ sec. 32, T. 1 N., R. 5 E.
[Measured in SW¼SW¼ sec. 4, T. 1 S., R. 5 E., 2.6 miles east of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
July 7, 1953	16.2	....	Sept. 1, 1953	7.6	....
Aug. 5, 1953	7.8	....	Sept. 28, 1953	4.0	....

Arnold-Toohey ditch, diversion from East Gallatin River in SW¼ sec. 10, T. 1 S., R. 5 E.
[Measured in SE¼SW¼ sec. 4, T. 1 S., R. 5 E., 3.1 miles east of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
July 7, 1953	1.4	....	Sept. 1, 1953	2.0	....
Aug. 5, 1953	3.9	....			

Middle Cottonwood Creek, tributary of East Gallatin River
[Measured in NW¼ sec. 10, T. 1 S., R. 6 E., 1.1 miles above gaging station and 6 miles northeast of Bozeman]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Oct. 2, 1952	0.6	48			

Middle Cottonwood Creek, tributary of East Gallatin River
[Measured in SE¼ sec. 9, T. 1 S., R. 6 E., 0.5 mile above gaging station and 6 miles northeast of Bozeman]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Oct. 2, 1952	0.8	48			

Watts Creek, tributary of Middle Cottonwood Creek
[Measured in NE¼NW¼ sec. 9, T. 1 S., R. 6 E., 1 mile above mouth and 6 miles northeast of Bozeman]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Oct. 2, 1952	0.04	46			

TABLE 8.—*Occasional measurements of the discharge of streams, ditches, and springs in the Gallatin Valley*—Continued

Watts Creek, tributary of Middle Cottonwood Creek
[Measured in NW¼NW¼ sec. 9, T. 1 S., R. 6 E., 0.75 mile above mouth and 6 miles northeast of Bozeman]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Aug. 27, 1952	0.1	46	Aug. 26, 1953	0.1	....
Oct. 2, 1952	.1	46			

Middle (Hyalite) Creek, tributary of East Gallatin River
[Measured in NE¼ sec. 17, T. 1 S., R. 5 E., at U.S. Highway 10 and 2.5 miles southeast of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Nov. 25, 1952	4.9	....	Dec. 5, 1952	0.6	....

Aakjer Creek, tributary of Middle (Hyalite) Creek
[Measured in SE¼ sec. 17, T. 1 S., R. 5 E., at U.S. Highway 10 and 3 miles southeast of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Sept. 20, 1951	17.7	48.5	Dec. 5, 1952	0.5	....
Nov. 25, 1952	3.1	....			

Middle (Hyalite) Creek, tributary of East Gallatin River
[Measured in SW¼SE¼ sec. 5, T. 1 S., R. 5 E., 0.5 mile above mouth of West Branch of East Gallatin River and 2.4 miles east of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
July 7, 1953	46.9	....	Sept. 1, 1953	48.2	....
Aug. 5, 1953	27.5	....	Sept. 28, 1953	45.7	....

Schafer Creek, tributary of Bostwick Creek
[Measured in SE¼ sec. 5, T. 1 S., R. 6 E., 3 miles above mouth and 6 miles northeast of Bozeman]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Sept. 14, 1951	0.2	45	Aug. 26, 1953	0.1	....
Aug. 27, 1952	.1	53			

East Gallatin River, tributary of Gallatin River
[Measured in NE¼ sec. 19, T. 1 N., R. 5 E., 250 ft below county road bridge and 3.5 miles northeast of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Apr. 3, 1952	141	....			

East Gallatin River, tributary of Gallatin River
[Measured in SW¼ sec. 2, T. 1 N., R. 4 E., 300 ft above county road bridge and mouth of Smith Creek and 6 miles north of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Apr. 3, 1952	221	....			

Jones Creek, tributary of Ross Creek
[Measured in NE¼ sec. 21, T. 1 N., R. 6 E., 1.5 miles above mouth and 10 miles northeast of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Aug. 28, 1952	0.2	41	Aug. 28, 1953	0.1	....

TABLE 8.—*Occasional measurements of the discharge of streams, ditches, and springs in the Gallatin Valley*—Continued

Dry Fork Creek, tributary of Ross Creek
[Measured in SE¼ sec. 4, T. 1 N., R. 6 E., 2 miles above mouth and 11 miles northeast of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Oct. 2, 1952	0.3	41			

Dry Fork Creek, tributary of Ross Creek
[Measured in NW¼ sec. 9, T. 1 N., R. 6 E., 1.5 miles above mouth and 10.5 miles northeast of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Oct. 2, 1952	0.6	41			

Dry Fork Creek, tributary of Ross Creek
[Measured in SW¼ sec. 9, T. 1 N., R. 6 E., 1 mile above mouth and 10 miles northeast of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Sept. 14, 1951	0.2	45	Oct. 2, 1952	0.1	41
Aug. 28, 1952	.4	45	Aug. 28, 1953	.8	...

North Cottonwood Creek, tributary of Reese Creek
[Measured in NE¼ sec. 18, T. 2 N., R. 6 E., 7 miles above mouth and 12.5 miles northeast of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Oct. 1, 1952	0.8	40			

North Cottonwood Creek, tributary of Reese Creek
[Measured in NW¼ sec. 18, T. 2 N., R. 6 E., 6 miles above mouth and 12 miles northeast of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Oct. 1, 1952	1.5	40			

North Cottonwood Creek, tributary of Reese Creek
[Measured in SW¼ sec. 13, T. 2 N., R. 5 E., 5 miles above mouth and 11.5 miles northeast of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Oct. 25, 1951	0.8	35	Oct. 1, 1952	0.4	40
Aug. 28, 1952	1.3	45	Aug. 28, 1953	1.5	...

Bright ditch, diversion from Reese Creek in SW¼ sec. 8, T. 1 N., R. 5 E.
[Measured in SE¼ sec. 7, T. 1 N., R. 5 E., 0.1 mile above mouth and 5.5 miles north of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Apr. 30, 1953	0.9	49	Aug. 11, 1953	2.3	58
June 23, 1953	.4	62	Sept. 4, 1953	1.6	...
July 22, 1953	2.9	...	Sept. 30, 1953	.3	...

Reese Creek, tributary of Smith Creek
[Measured in NE¼ sec. 18, T. 1 N., R. 5 E., 0.25 mile above mouth, 0.5 mile below Bright ditch diversion, 3.25 miles below gaging station and 4.5 miles north of Belgrade]

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Apr. 30, 1953	14.0	51	Aug. 11, 1953	11.8	55
June 23, 1953	95.4	55	Sept. 4, 1953	9.6	...
July 22, 1953	12.2	64	Sept. 30, 1953	14.0	...

TABLE 8.—*Occasional measurements of the discharge of streams, ditches, and springs in the Gallatin Valley*—Continued

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
Foster Creek, tributary of Smith Creek [Measured in NE¼ sec. 29, T. 2 N., R. 5 E., at county road bridge and 8.5 miles north of Belgrade]					
Oct. 25, 1951	0.6	40	Aug. 28, 1952	0.4	53
Spring 4, tributary of Dry Creek [Measured in NW¼NW¼ sec. 14, T. 3 N., R. 4 E., 12.5 miles northeast of Manhattan]					
Aug. 27, 1953	0.004	....			
Spring 6, tributary of Dry Creek [Measured in NW¼NE¼ sec. 22, T. 3 N., R. 4 E., 11.5 miles northeast of Manhattan]					
Aug. 27, 1953	0.04	....			
Spring 5, tributary of Dry Creek [Measured in NE¼SW¼ sec. 15, T. 3 N., R. 4 E., 12 miles northeast of Manhattan]					
Aug. 27, 1953	0.02	....			
Spring 7, tributary of Dry Creek [Measured in NW¼NE¼ sec. 21, T. 3 N., R. 4 E., 11 miles northeast of Manhattan]					
Aug. 27, 1953	0.04	....			
Spring 8, tributary to Dry Creek [Measured in SW¼SE¼ sec. 28, T. 3 N., R. 4 E., 9.5 miles northeast of Manhattan]					
Aug. 27, 1953	0.1	....			
Spring 9, tributary to Dry Creek [Measured in NE¼SE¼ sec. 34, T. 3 N., R. 4 E., 9.5 miles northeast of Manhattan]					
Aug. 27, 1953	0.02	....			
Dry Creek, tributary of East Gallatin River [Measured in NE¼ sec. 3, T. 1 N., R. 4 E., 100 ft below county road bridge and 6 miles east of Manhattan]					
Dec. 4, 1952	17.0	....			
East Gallatin River, tributary of Gallatin River [Measured in SE¼ sec. 32, T. 2 N., R. 4 E., 100 ft below county road bridge and 4 miles northeast of Manhattan]					
Sept. 20, 1951	351	50	Apr. 3, 1952	393	....

TABLE 8.—*Occasional measurements of the discharge of streams, ditches, and springs in the Gallatin Valley*—Continued

Date	Discharge (cfs)	Temperature (°F)	Date	Discharge (cfs)	Temperature (°F)
East Gallatin River, tributary of Gallatin River [Measured in NE¼ sec. 36, T. 2 N., R. 3 E., 200 ft below mouth of Bullrun Creek and 3 miles northeast of Manhattan]					
Nov. 25, 1952	314	....	Dec. 4, 1952	301	....
Gallatin River [Measured in SE¼ sec. 27, T. 2 N., R 3 E., 500 ft below county road bridge and 2.5 miles north of Manhattan]					
Mar. 27, 1952	755	....			
Spring 1, tributary of Gallatin River [Measured in NW¼ sec. 33, T. 2 N., R. 3 E., 2.5 miles northwest of Manhattan]					
Aug. 29, 1952	10.7	54	Apr. 24, 1953	0.00	....
Mar. 5, 1953	.06	33			
Spring 2, tributary of Gallatin River [Measured in NE¼ sec. 32, T. 2 N., R. 3 E., 2.75 miles northwest of Manhattan]					
Aug. 29, 1952	22.6	53	Apr. 24, 1953	8.3	55
Mar. 5, 1953	9.0	53	Aug. 12, 1953	18.6	....
Spring 3, tributary of Gallatin River [Measured in NE¼ sec. 32, T. 2 N., R. 3 E., at abandoned fish hatchery 2.75 miles northwest of Manhattan]					
July 22, 1952	8.3	....	Apr. 24, 1953	3.7	52
Aug. 29, 1952	14.5	52	Aug. 12, 1953	11.7	....
Mar. 5, 1953	4.9	52			

the Gallatin Valley. Gaging at the Gallatin Gateway station was resumed in June 1930. The average discharge for the 25 water years of complete record during the period 1889 to 1952 was 758 cfs and the median, 725 cfs. The mean discharge of 1,116 cfs in water year 1892 was the highest during the period of record, and 984 cfs during water year 1952 was the second highest. The lowest was in water year 1934, when the mean discharge was 409 cfs.

The general pattern of inflow at the Gallatin Gateway gaging station is fairly well illustrated by the hydrographs for water years 1952 and 1953. (See fig. 16.) From the beginning of the water year through March the gradual recession of streamflow is affected occasionally by rain, severe cold, or minor snowmelt. A rising trend beginning in April and culminating in a peak in

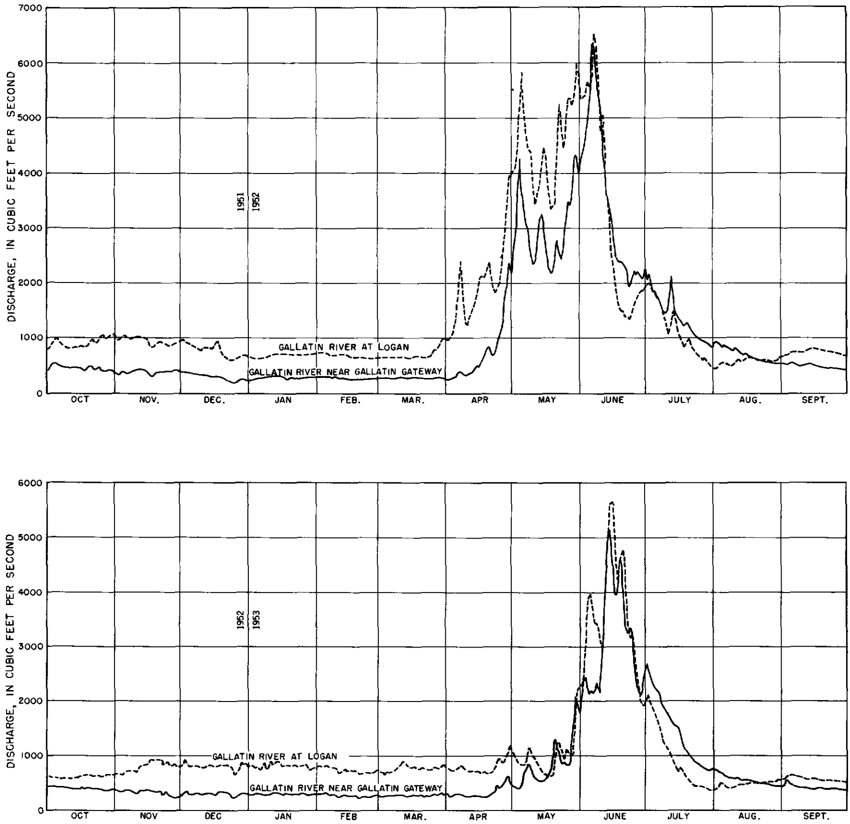

FIGURE 16.—Hydrographs of the discharge of the Gallatin River near Gallatin Gateway and at Logan, water years 1952 and 1953.

late May or early June is caused by concurrent precipitation and snowmelt. The pronounced recession that follows is affected slightly by occasional rains. The rise to a secondary peak on May 4, 1952, was somewhat unusual.

In the reach of the Gallatin River from the gaging station near Gallatin Gateway to the gaging station at Logan, the pattern of flow is modified by extensive diversions for irrigation; losses to, and gains from, the ground-water reservoir; and, to a lesser extent, runoff from within the valley. Comparison of the flow at the several gaging stations on the Gallatin River during water years 1952 and 1953 illustrates the usual downstream depletion during the irrigation season and other losses. (See table 9.) A rather consistent loss between the gaging stations at Cameron Bridge and Central Park is accounted for, at least in part, by discharge into Baker Creek and other distributary channels of the river originating between these two stations. In years of

TABLE 9.—*Differences in monthly and annual runoff at gaging stations on the Gallatin River, in thousands of acre-feet, during water years 1952 and 1953*

Gaging station	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Water year 1952													
Near Gallatin Gateway	27.75	22.55	18.02	17.40	15.55	17.30	44.31	186.80	207.70	85.42	42.54	29.21	714.55
At Axtell Bridge	26.38	24.31	19.44	19.58	16.66	18.37	48.91	215.70	197.70	74.99	34.24	24.25	720.53
Gain (+) or loss (−) in flow	−1.37	+1.76	+1.42	+2.18	+1.11	+1.07	+4.60	+28.90	−10.00	−10.43	−8.30	−4.96	+5.98
At Axtell Bridge	26.38	24.31	19.44	19.58	16.66	18.37	48.91	215.70	197.70	74.99	34.24	24.25	720.53
At Cameron Bridge	20.12	25.12	19.95	20.75	17.71	18.46	45.86	213.20	201.50	38.04	11.89	12.23	644.83
Gain (+) or loss (−) in flow	−6.26	+.81	+.51	+1.17	+1.05	+.09	−3.05	−2.50	+3.80	−36.95	−22.35	−12.02	−75.70
At Cameron Bridge	20.12	25.12	19.95	20.75	17.71	18.46	45.86	213.20	201.50	38.04	11.89	12.23	644.83
At Central Park	13.74	19.93	16.07	15.75	14.75	16.37	46.10	166.40	121.20	29.34	3.48	7.10	470.23
Gain (+) or loss (−) in flow	−6.38	−5.19	−3.88	−5.00	−2.96	−2.09	+.24	−46.80	−80.30	−8.70	−8.41	−5.13	−174.60
At Central Park	13.74	19.93	16.07	15.75	14.75	16.37	46.10	166.40	121.20	29.34	3.48	7.10	470.23
At Logan	55.52	55.90	47.66	42.62	39.18	43.63	118.60	279.10	197.20	70.22	35.83	44.46	1,029.92
Gain (+) or loss (−) in flow	+41.78	+35.97	+31.59	+26.87	+24.43	+27.26	+72.50	+112.70	+76.00	+40.88	+32.35	+37.36	+559.69
Total gain (+) or loss (−) in flow between Gallatin Gateway and Logan	+27.77	+33.35	+29.64	+25.22	+23.63	+26.33	+74.29	+92.30	−10.50	−15.20	−6.71	+15.25	+315.37
Gain in flow due to tributary inflow	10.19	8.77	7.87	7.01	6.32	6.66	37.49	73.10	54.64	23.41	14.45	11.67	261.58
Net gain (+) or loss (−) in flow due to changes in total water storage within the Gallatin Valley	+17.58	+24.58	+21.77	+18.21	+17.31	+19.67	+36.80	+19.20	−65.14	−38.61	−21.16	+3.58	+53.79
Water year 1953													
Near Gallatin Gateway	24.69	19.46	19.00	18.59	15.18	17.12	20.37	53.68	183.60	87.77	33.89	24.31	517.66
At Axtell Bridge	21.53	21.60	21.27	20.65	17.14	18.70	22.12	48.45	196.70	77.41	29.99	19.50	515.06
Gain (+) or loss (−) in flow	−3.16	+2.14	+2.27	+2.06	+1.96	+1.58	+1.75	−5.23	+13.10	−10.36	−3.90	−4.81	−2.60
At Axtell Bridge	21.53	21.60	21.27	20.65	17.14	18.70	22.12	48.45	196.70	77.41	29.99	19.50	515.06
At Cameron Bridge	7.58	17.19	23.66	22.50	18.58	19.79	20.55	28.60	164.70	35.83	8.98	6.77	374.73
Gain (+) or loss (−) in flow	−13.95	−4.41	+2.39	+1.85	+1.44	+1.09	−1.57	−19.85	−32.00	−41.58	−21.01	−12.73	−140.33
At Cameron Bridge	7.58	17.19	23.66	22.50	18.58	19.79	20.55	28.60	164.70	35.83	8.98	6.77	374.73
At Central Park	4.92	14.42	20.56	20.24	15.70	17.76	18.29	18.64	140.10	35.92	1.53	2.51	310.59
Gain (+) or loss (−) in flow	−2.66	−2.77	−3.10	−2.26	−2.88	−2.03	−2.26	−9.96	−24.60	+.09	−7.45	−4.26	− 64.14

At Central Park	4.92	14.42	20.56	20.24	15.70	17.76	18.29	18.64	140.10	35.92	1.53	2.51	310.59
At Logan	37.84	47.90	49.99	50.26	40.94	47.56	47.87	63.29	211.70	55.87	29.57	33.41	716.20
Gain (+) or loss (−) in flow	+32.92	+33.48	+29.43	+30.02	+25.24	+29.80	+29.58	+44.65	+71.60	+19.95	+28.04	+30.90	+405.61
Total gain (+) or loss (−) in flow between Gallatin Gateway and Logan	+13.15	+28.44	+30.99	+31.67	+25.76	+30.44	+27.50	+9.61	+28.10	−31.90	−4.32	+9.10	+198.54
Gain in flow due to tributary inflow	9.58	7.66	7.11	7.29	6.08	7.78	11.31	34.32	77.59	29.80	16.86	11.30	226.68
Net gain (+) or loss (−) in flow due to changes in total water storage within the Gallatin Valley	+3.57	+20.78	+23.88	+24.38	+19.68	+22.66	+16.19	−24.71	−49.49	−61.70	−21.18	−2.20	−28.14

low runoff the streambed at a few points between Cameron Bridge and Central Park is dry during much of the latter half of the irrigation season. The greater diversion for irrigation from the reach of river between the Axtell and the Cameron Bridges does not fully account for the apparent loss between these points. The loss is particularly evident in the 1953 water year and throughout the period of record, June through September, in the 1950 and 1951 water years.

The discharge of the Gallatin River at Logan for water years 1952 and 1953 (fig. 16) is typical of the outflow from the valley. Flow generally increases during October and continues to increase until the weather becomes severely cold. Flow during the winter usually decreases until snowmelt from the valley and foothills produces a rise in March or early April. A brief recession in flow generally precedes a rise in flow that results from snowmelt at higher elevations. Peak flow occurs in May or June concurrently with the peak flow at Gallatin Gateway, but often is somewhat lower in spite of the nearly synchronized peak flows of intervening tributaries. The discharge at Logan then decreases rapidly to a low in late July or early August. The rise in late August, which continues into the next water year, probably is the result of increasing ground-water discharge and decreasing evapotranspiration.

The average discharge of the Gallatin River at Logan for the years of complete record is 957 cfs. The median yearly discharge is 984 cfs.

Comparison of the hydrographs of the discharge of the Gallatin River near Gallatin Gateway and at Logan shows the relation of the monthly (fig. 17) and annual (fig. 18) runoff at these points. It is interesting to note the divergence between the two hydrographs after the drought years of the 1930's.

EAST GALLATIN RIVER

The East Gallatin River is a relatively short stream, but, because of its many tributaries, its flow increases rapidly in its course through the valley. Its tributaries include most of the streams from the Gallatin and Bridger Ranges and many spring-fed streams rising within the valley. Some of the streams that rise in the mountainous areas either sink into their alluvial fans or are diverted before reaching the East Gallatin River, but they contribute to the flow of the river through some of the shorter spring-fed streams that rise on the lower slopes of the fans.

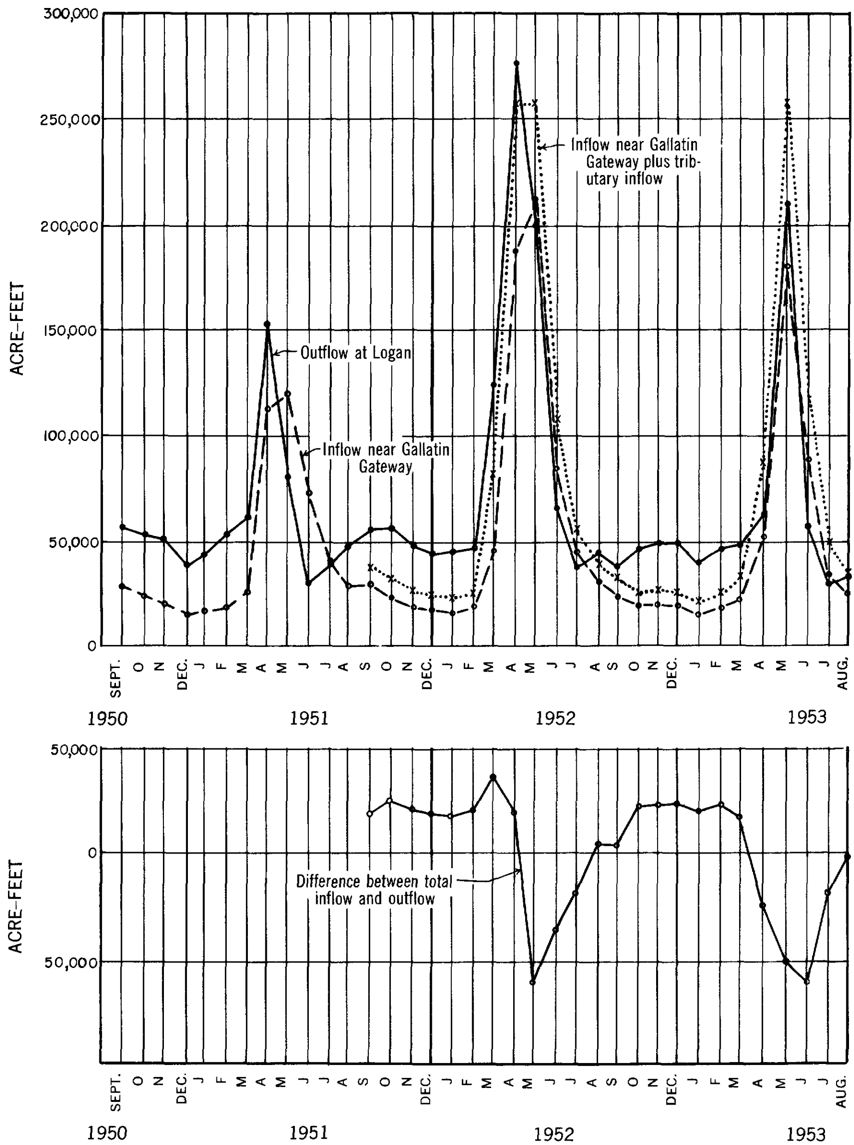

FIGURE 17.—Hydrographs of monthly surface-water inflow to, and outflow from, the Gallatin Valley, water years 1951–53.

STREAMS FROM THE GALLATIN RANGE

The principal streams that rise in the Gallatin Range and that make a major contribution to the water supply of the valley are Wilson, Big Bear, South Cottonwood, Middle (Hyalite), Sourdough (Bozeman), and Bear Creeks. Their yield per square mile of drainage area is high, averaging approximately the same as

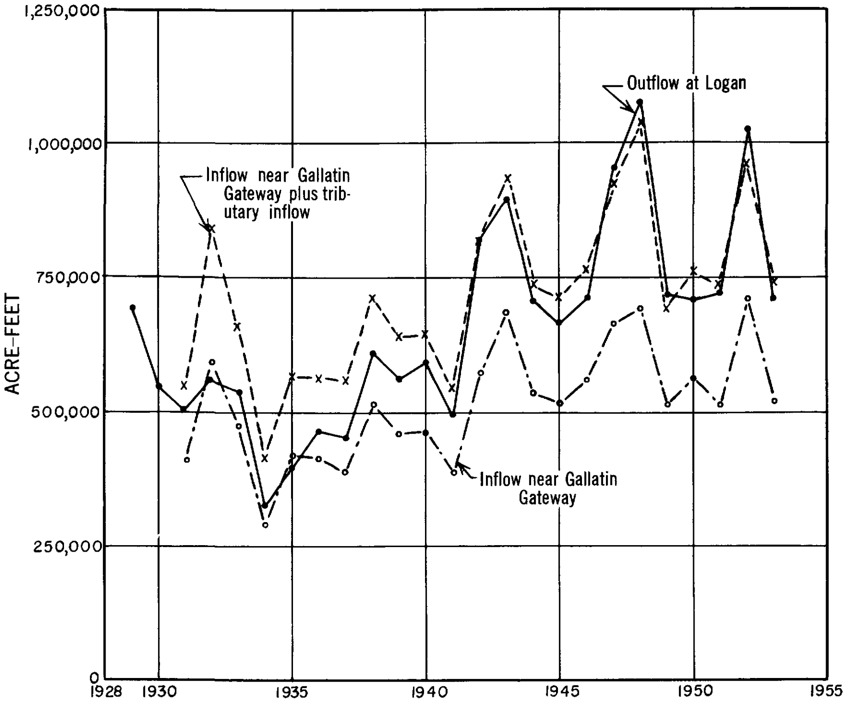

FIGURE 18.—Hydrographs of annual surface-water inflow to, and outflow from, the Gallatin Valley; estimated for period 1931–51, measured for period 1952–53.

that of the Gallatin River above Gallatin Gateway. Their combined flow during water year 1952 was nearly 132,000 acre-feet, or about half the measured tributary inflow to the Gallatin River within the valley.

STREAMS FROM THE BRIDGER RANGE

Bridger Creek, which drains a considerable part of the east slope as well as the narrow south edge of the Bridger Range, is a principal tributary of the East Gallatin River. Some water for irrigation is diverted from it before it enters the Gallatin Valley. Streams draining the west slope of the Bridger Range are fairly short and are characterized by more rapid snow runoff than are the streams draining the Gallatin Range. Ross Creek evidently receives a large part of its flow from outside its surface drainage area, presumably from an underground source. Although the surficial drainage area above the gaging station is only 1.29 square miles, the runoff was 161 inches in water year 1952 and 178 inches in water year 1953. Furthermore, the runoff pattern lags behind the precipitation pattern. The other principal streams entering the Gallatin Valley from the Bridger Range are Reese, Middle Cottonwood, and Bear Creeks. The discharge of Middle Cottonwood Creek near Bozeman (fig. 19) is typical of runoff from the Bridger Range.

Insofar as their contribution to the surface-water supply of the valley is concerned, the streams draining the west slope of the Bridger Range are relatively unimportant because the flow of most of them either sinks into their alluvial fans or is diverted completely before reaching the East Gallatin River. These streams are important locally, however, as they are the only source of irrigation supply for some of the higher lying cropland.

Dry Creek, although it rises in the Bridger Range, is similar in its flow characteristics to streams rising in the foothills. (See pl. 3.) During water year 1952 the high flow occurred in early April and was followed by a lesser peak in late May. Thereafter the flow receded rapidly to a low point in mid-August. The slight rise to a firm flow of 17 to 19 cfs probably reflects inflow from springs or return flow from upstream irrigation.

OTHER STREAMS

The few streams rising in the Horseshoe Hills are intermittent and contribute little to the water supply of the Gallatin Valley. Streams rising in the Camp Creek Hills, which rim the west side of the Gallatin Valley, are similar in their flow characteristics to those rising in the Horseshoe Hills. Heavy rains or rapid snowmelt in the early spring produces appreciable runoff for a short time, but at other times the flow is negligible in the upper reaches of these streams. Many of them are perennial in their lower courses, however, because they receive return flow from irrigation. Ridgley, Bullrun, Gibson, Ben Hart, and Thompson Creeks are typical of streams rising in the lower part of the Gallatin Valley. The flow of these streams is derived largely from ground-water discharge and, in many places, is diverted for irrigation.

A complex system of diversion for irrigation has greatly modified the natural drainage pattern. Long-continued diversion during all seasons of the year has given many canals the appearance of natural stream channels, and many of the old channels have lost their identity as stream courses. A multiplicity and confusion of stream names has resulted. Stream names in this report are those commonly used in the area, though they may differ from the names used in water-right filings.

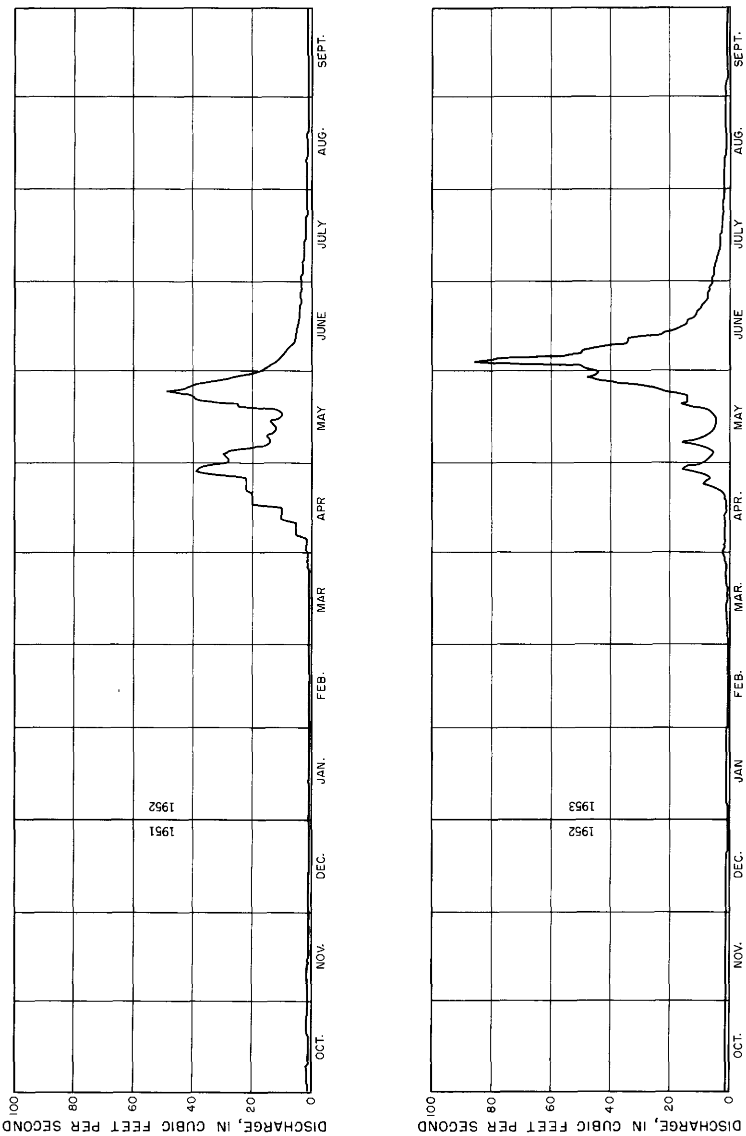

FIGURE 19.—Hydrograph of the discharge of Middle Cottonwood Creek near Bozeman, water years 1952 and 1953.

ESTIMATES OF SURFACE-WATER INFLOW TO GALLATIN VALLEY

Except for the runoff from a total of 44 square miles in water year 1952 and 39 square miles in water year 1953, all the runoff from the 1,265-square-mile area draining into the Gallatin Valley was gaged with reasonable completeness during the 2 years this study was in progress. The ungaged area consisted of scattered small wedge-shaped tracts along the east and northeast margins of the valley; the runoff from this ungaged area was estimated to be 400 acre-feet per square mile, or 17,600 acre-feet in water year 1952 and 15,600 acre-feet in water year 1953. Miscellaneous measurements and occasional gage readings that were made in water year 1953 on a few small streams and springs indicated that this estimated runoff was approximately correct.

For use in computing annual ground-water discharge during the period 1934-51, estimates of annual tributary inflow to the Gallatin Valley were made for the 21-year period preceding this study (table 10); estimates were also made of the monthly tributary inflow for the months November through February of each water year during the same period (table 11). Both the annual and monthly estimates of tributary inflow were based primarily on the relationship of the flow of individual streams or groups of streams to the total tributary inflow during water years 1952 and 1953. The discharge of the Gallatin River near Gallatin

TABLE 10.—*Estimated annual inflow to the Gallatin Valley, in thousands of acre-feet, during water years 1931 through 1951*

Water year	Gaged inflow near Gallatin Gateway	Estimated tributary inflow	Estimated total inflow
1931	407	160	567
1932	591	200	791
1933	470	190	660
1934	296	120	416
1935	420	150	570
1936	418	150	568
1937	390	170	560
1938	516	200	716
1939	462	180	642
1940	464	180	644
1941	386	160	546
1942	576	240	816
1943	690	240	930
1944	530	200	730
1945	513	200	713
1946	557	200	757
1947	668	280	948
1948	694	350	1,044
1949	516	180	696
1950	562	200	762
1951	520	210	730

TABLE 11.—*Estimated monthly inflow to the Gallatin Valley, exclusive of the Gallatin River, during period November through February of water years 1931 through 1951, in thousands of acre-feet*

Water year	November	December	January	February
1931	8	7	5	7
1932	7	7	7	6
1933	8	7	7	6
1934	7	7	7	6
1935	6	5	4	4
1936	6	6	5	5
1937	6	6	5	5
1938	6	5	5	5
1939	8	7	5	4
1940	5	5	5	4
1941	6	5	6	4
1942	12	12	8	6
1943	8	7	6	6
1944	9	7	6	5
1945	8	6	6	6
1946	10	8	7	6
1947	11	9	7	6
1948	12	12	11	6
1949	10	8	7	7
1950	8	7	6	7
1951	9	9	8	7

Gateway, precipitation records, and the results of snow surveys in the Middle (Hyalite) Creek basin also were used in making the estimates. The general uniformity of the numerical relationships of the individual months and those for the water year, particularly for water years 1940 through 1951, made the results seem reasonable.

The accuracy of the estimates of tributary inflow to the Gallatin Valley varies inversely with the extent of the ungaged area. The estimates for water years 1931 through 1934, when records for the Gallatin River near Gallatin Gateway and precipitation records were the only basis, are considered to be accurate within 30 percent. The estimates for water years 1935 through 1939, when the flow of Middle (Hyalite) Creek also was measured, are considered to be accurate within 25 percent. Establishment of a gaging station on the East Gallatin River at Bozeman in September 1939 again decreased the area from which runoff was not measured, and the estimates for water years 1940 through 1945 are considered to be accurate within about 20 percent. The collection of records on Bridger Creek near Bozeman, beginning in January 1946, may have improved further the accuracy of these estimates of tributary inflow for the water years 1946 through 1951.

The estimates of tributary inflow for individual months November through February (table 11) are considered to be accurate within the following percentages: For water years 1931 through 1939, 40 percent; water years 1940 through 1945, 30 percent; water years 1946 through 1951, 25 percent. However, the estimates of total tributary inflow during the period November through February of each water year may be accurate within about 20 percent.

Values for total surface-water inflow to the Gallatin Valley during water years 1931 through 1951 are shown in table 10 and figure 18. Because gaged discharges generally are considered to be accurate within 15 percent for individual months and within 10 percent for annual values, the values for total annual surface-water inflow (gaged plus estimated) probably are reliable within 15 percent.

UTILIZATION

Surface water is the principal source of irrigation supply in the Gallatin Valley. According to data collected by the Montana State Engineer (1953a, p. 27-30), 107,261 acres was under irrigation in 1952. A total of 72,433 acres received water from the Gallatin River, and 10,594 acres received water from tributaries of the Gallatin River, exclusive of the East Gallatin. A total of 3,424 acres received water from the East Gallatin, and 20,810 acres received water from its tributaries. Water shortages during the last half of the irrigation season are reported in nearly all years for farms having the later water rights. These shortages are aggravated during extremely dry years. The only existing storage facilities, except for municipal storage, are Middle Creek Reservoir, which can store about 8,000 acre-feet, and Mystic Lake, which can store about 1,100 acre-feet.

The city of Bozeman is supplied with water from Sourdough (Bozeman) Creek, which rises in the Gallatin Range, and from Lyman Creek, a short, partly spring-fed stream, which rises in the Bridger Range. Storage facilities are provided by Mystic Lake near the head of Sourdough (Bozeman) Creek, and by two reservoirs, one on Sourdough (Bozeman) Creek and one on Lyman Creek.

Sportsmen consider the streams of the Gallatin Valley to be excellent for trout fishing. The spring-fed streams in the north end of the valley provide a nesting place for ducks; also, because these streams remain relatively free of ice, many ducks winter in the area.

GROUND WATER

DEFINITION OF TERMS

Below a certain level within the earth the porous rocks generally are saturated with water under hydrostatic pressure. This water is known as ground water, and the water-bearing rocks (formations, groups of formations, or parts of formations) that will yield sufficient water to be a source of supply are referred to as aquifers. Aquifers are recharged chiefly by the infiltration of precipitation and by influent (losing) streams, and they discharge mostly through seeps and springs into effluent (gaining) streams. In some places water is withdrawn from the aquifers by pumping from wells and, where the water table is shallow, by vegetation having roots that penetrate to the zone of saturation or to the capillary fringe that extends above it.

Where ground water is unconfined, its upper surface is referred to as the water table and the water is said to occur under water-table conditions. Meinzer (1923b, p. 22, 32) defined the water table as the upper surface of a zone of saturation except where that surface is formed by an impermeable body. In general, the water table is not a level surface, but conforms, in subdued relief, to the irregularities of the overlying land surface; also, it fluctuates in response to changes in the ratio of ground-water recharge to discharge.

Where a zone of saturation is bounded above by a bed of relatively impermeable material and the water is confined under sufficient hydrostatic pressure to rise above the base of that confining bed, the aquifer is termed "artesian" and the confining bed is referred to as an aquiclude. The imaginary plane to which artesian water will rise in nonpumped wells is called a pressure-head-indicating surface, or piezometric surface, and may be either below or above the land surface. Like the water table, the piezometric surface is not a level surface, but, unlike the water table, it fluctuates not only with changes in the ratio of recharge to discharge but also with changes in pressure conditions within the aquifer.

Meinzer (1942, p. 390) stated:

> The two properties of a rock material that most largely determine the behavior of its contained water and its productiveness as a water-bearing formation are its specific yield and its permeability. Both of these properties are determined by the character of the interstices and the resultant effects of molecular attraction. The specific yield relates to the storage capacity of the rocks; the permeability relates to their capacity to transmit water.

The specific yield of a water-bearing formation, as defined by Meinzer (1923b, p. 28), is the ratio of (1) the volume of water that a saturated aquifer will yield by gravity to (2) the volume of the aquifer. It is, therefore, a measure of the quantity of water that a saturated aquifer will yield when drained by gravity. Under water-table conditions, the specific yield is practically equal to the coefficient of storage, which is a property of the aquifer that may be determined by making pumping tests. Unlike the term "specific yield," however, the coefficient of storage applies to both water-table and artesian aquifers and is defined as the volume of water (measured outside the aquifer) that an aquifer releases from, or takes into, storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. For a water-table aquifer, the water released from storage is attributed largely to gravity drainage or refilling of the zone through which the water table moves and only in small part to compressibility of the water and aquifer material in the saturated zone. For an artesian aquifer, however, the water released from storage is attributed solely to compressibility of the water and aquifer material in the saturated zone.

The standard coefficient of permeability of a water-bearing formation, as used by the Geological Survey, is the rate of flow of water at 60°F, in gallons per day, through a cross section of 1 square foot, under a hydraulic gradient of 100 percent (1 foot per foot). A related coefficient, which has been called the field coefficient of permeability, was defined by Meinzer (1942, p. 452) as

> the rate of flow of water, in gallons a day, under prevailing conditions, through each foot of thickness of a given aquifer in a width of 1 mile, for each foot per mile of hydraulic gradient.

The capacity of an aquifer to transmit water is termed "transmissibility." The coefficient of transmissibility, which for many purposes is a more useful unit than the field coefficient of permeability, was defined by Theis (1935, p. 520) and commonly is expressed by the Geological Survey as the number of gallons of water per day, at the prevailing water temperature, that is transmitted through each mile strip extending the full saturated thickness of the aquifer under a hydraulic gradient of 1 foot per mile.

The specific capacity of a well is its rate of discharge per unit of drawdown. The term is applied only to wells in which the drawdown varies approximately as the discharge. In such wells the specific capacity can be determined by dividing the discharge of the well, generally in gallons per minute (gpm) by the water-level drawdown, generally measured in feet.

DETERMINATIONS OF AQUIFER PROPERTIES

An aquifer test, or so-called "pumping test," is a field method whereby the main hydrologic properties of an aquifer can be determined. The coefficient of transmissibility of an aquifer can be computed from a test using a single pumped well ("single-well" test), whereas the coefficients of both transmissibility and storage can be computed from a test using a single pumped well and one or more observation wells ("multiple-well" test). If, in addition to the coefficient of transmissibility, the saturated thickness of the aquifer is known, the average coefficient of permeability of the water-bearing material can be computed.

Because a single-well test can be made without installing observation wells, this type of test was the principal method used in the determination of transmissibility coefficients in the Gallatin Valley. Altogether, about 100 such tests were made and the coefficient of transmissibility at 37 sites was computed (more than one test was made at several of the sites). As a check on the values thus obtained, tests involving the use of 3 or 4 observation wells in addition to the pumped well were made at 4 sites. These multiple-well tests served also as a random sampling of the coefficients of storage. The results of both types of tests are summarized in table 12.

The coefficient of transmissibility of known Tertiary strata was determined at six scattered points within the valley. Five of the values ranged from 300 to 6,000 gpd per foot but one was 17,000 gpd per foot. The results of two other tests indicated inconclusively that lenses of unconsolidated sand and gravel within the Tertiary strata may have considerably higher coefficients of transmissibility. One of these, a test on well A1–3–33dd, gave a value of 26,000 gpd per foot, but it was not known whether all or only part of the water was withdrawn from Tertiary strata. The other, a test of a sand layer between the depths of 249 and 260 feet in test hole A1–4–15da2, indicated a coefficient of transmissibility between 30,000 and 40,000 gpd per foot, but a more exact computation could not be made. Examination of exposed Tertiary strata and computations of the coefficient of permeability for the tests at sites D1–3–36bc, D1–4–25aa2, and D2–4–9bc have led to the conclusion that the Tertiary strata generally would yield sufficient water for domestic use and the watering of livestock but not for irrigation or other large-scale uses.

The coefficient of transmissibility of the Bozeman alluvial fan was determined at 6 sites and that of the Spring Hill fan at 2 sites. The wide range in values, 7,000 to 65,000 gpd per foot, indicates that the alluvial-fan deposits generally will yield ample water for domestic and livestock use but that only locally will it yield sufficient water for irrigation or other large-scale uses.

The coefficient of transmissibility of the alluvium of the Gallatin and East Gallatin Rivers was determined at 24 sites; it ranges from 38,000 to 670,000 gpd per foot and averages about 200,000 gpd per foot. A test made on a well (A1–5–10ba) tapping both the alluvium along Reese Creek and the underlying Tertiary strata yielded a transmissibility value of 24,000 gpd per foot.

AQUIFER PROPERTIES AS THEY AFFECT THE SPECIFIC CAPACITY OF A WELL

The specific capacity of a well depends not only on the water-yielding properties of the aquifer but also on the type and construction of the well. Theoretically, therefore, if a well has been designed and constructed perfectly (an "ideal" well), its specific capacity can be determined from known aquifer properties.

To illustrate this point, a graph has been prepared to show the theoretical drawdown in an ideal well that taps an aquifer of known characteristics. (See fig. 20.) In this graph, the coefficient of transmissibility (T) is plotted along the abscissa and the drawdown (s), for a pumping period (t) of 12 hours, is plotted along the ordinate. Three lines representing different values for the coefficient of storage (S) are plotted on the graph, each for a well having a radius (r) of 1 foot and yielding at a rate (Q) of 500 gpm. Thus, for example, at the end of a 12-hour pumping period an ideal well yielding 500 gpm and tapping an aquifer having $T = 100{,}000$ gpd per foot would have a drawdown of about 7.1 feet if $S = 0.05$, a drawdown of about 8.4 feet if $S = 0.005$, and a drawdown of about 9.7 feet if $S = 0.0005$. Similarly, after a 12-hour pumping period an ideal well yielding 500 gpm and tapping an aquifer having $T = 50{,}000$ gpd per foot would have a drawdown of about 13.5 feet if $S = 0.05$, about 16 feet if $S = 0.005$, and about 18.5 feet if $S = 0.0005$.

In reality, actual drawdown exceeds theoretical drawdown even in the best designed and constructed wells and may be several times the theoretical drawdown in poorly designed and constructed wells.

The 4 multiple-well tests gave values ranging from 0.001 to 0.06 for the storage coefficient of the alluvial deposits in the Gallatin Valley. The smaller values (0.001 and 0.006) indicate that in at least a part of the areas "sampled" by the tests the water is confined. It is believed that the average coefficient of storage of

TABLE 12.—*Summary of aquifer-test data*

Well or test hole	Aquifer	Depth of well at time of test (feet)	Yield (gpm)	Length of test (minutes)	Coefficient of transmissibility (T) (gpd per foot)	Coefficient of storage (S)	Thickness of aquifer (feet)	Field coefficient of permeability (P_f) (gpd per square foot)	Remarks
Gateway subarea									
D2-4-26dc	Alluvium	25.9	64	60	380,000	...	...	...	
D3-4-11bdb	do	18.5	71	100	170,000	...	[1] 85	[1] 2,000	
Belgrade subarea									
A1-4-28da3	Alluvium	24	74	100	280,000	...	...	...	
5-28db2	do	118	265	10	58,000	...	...	...	
D1-4-1cb	do	110	224	200	670,000	...	...	...	
1dc	do	107	520	250	240,000	...	...	...	
2dd	do	178	62	13	130,000	...	...	...	
9cb	do	30	250	30	140,000	...	...	...	
15ab	do	30.5	220	60	94,000	...	...	...	
25aa2	Tertiary strata	225	[2] 125	8,760	17,000	...	74	230	Flow test of aquifer between depths of 149 and 223 ft.
D1-5-5ad	Alluvium	25.6	24	30	130,000	...	...	...	
9cd	do	25	68	30	50,000	...	11	4,500	
30cb	do	12.5	260	60	290,000	...	...	...	
D2-4-11dc	do	65	280	100	270,000	...	58	4,500	
14ada2	do	50	48	30	260,000	...	...	...	
14bb	do	11.1	28	75	70,000	...	...	...	
Central Park subarea									
A1-4-5da	Alluvium	35	240	30	100,000	0.006	26	4,000	Obervation wells at 25, 50, and 100 ft from pumped well.
	Tertiary strata	207	16	40	3,700	...	...	...	
5dd	Alluvium	18	32	100	110,000	...	[1] 25	[1] 4,000	
6bc	do	39.3	55	60	38,000	...	[1] 25	[1] 1,500	
19cb	do	81	310	10	480,000	...	89	5,500	
		180	...	...	180,000	...	63	2,900	Flow test of aquifer between depths of 117 and 180 ft.
22dc4	do	27	220	200	480,000	.05	...	...	Observation wells at 200, 270, and 300 ft from pumped well.

Manhattan subarea									
A1-3-4da	Alluvium	77	78	300	140,000	...	18	7,800	
10bd	do	11	76	60	140,000	0.001	...	...	Observation wells at 42, 85, and 154 ft from pumped well.
10ca	do	27.6	240	100	130,000	...	...	...	
22da2	do	15	66	60	120,000	...	...	...	
Bozeman fan									
D1-5-26da	Alluvium	28.2	14	10	64,000	...	...	...	
34cc2	Tertiary strata	255	2.5	30	300	...	...	...	
D2-5-11dcc	Alluvium	33.2	51	30	4,500	...	...	...	
14ac	do	110	93	1,440	36,000	0.06	63	600	Observation wells at 20, 40, 80, and 150 ft from pumped well.
14ac	Tertiary strata	200	13.5	30	2,700	...	...	...	
15aal	Alluvium	16.4	14.5	98	26.000	...	...	...	
27cc	do	19	18	180	50,000	...	...	...	
35dc	do	155	224	115	65,000	...	...	...	
Camp Creek Hills									
A1-3-33dd	Tertiary(?) strata	99	25	30	26,000	...	...	...	
D1-3-36bc	Tertiary strata	113	46	70	6,000	...	84	70	
D2-4-9bc	do	600	75	20	1,200	...	111	10	
Dry Creek subarea									
A1-5-10ba	Alluvium and Tertiary strata.	25	7	16	24,000	...	...	...	
Spring Hill subarea									
A1-5-21bc4	Alluvium	11.6	16	30	7.000	...	...	...	
26cd	do	25	12	30	30,000	...	...	...	

1 Estimated.

2 Average for test.

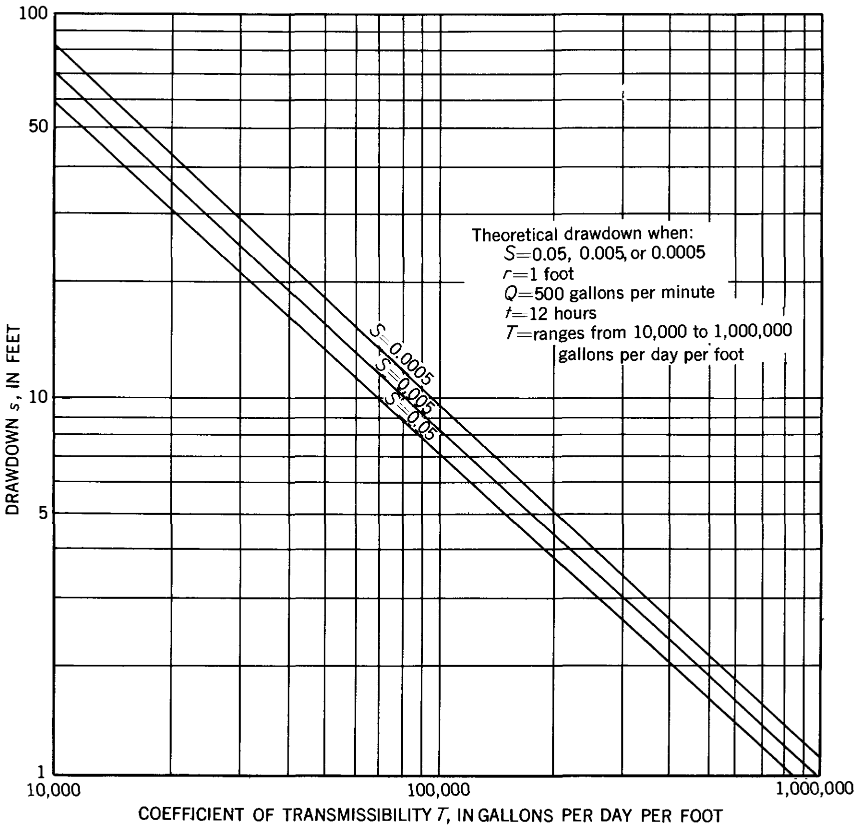

FIGURE 20.—Graph showing theoretical drawdown in an "ideal" pumped well.

the alluvium in the Gallatin Valley would be about 0.05 after 12 hours of pumping and at the end of many weeks of pumping it would be much larger.

When it is considered that the maximum saturated thickness of the alluvial-fan deposits is 80 to 100 feet, that the coefficient of transmissibility ranges from 7,000 to 65,000 gpd per foot, and that the coefficient of storage is about 0.05, or higher, it can readily be seen that the drawdown in wells pumped at a high rate would be great except where the coefficient of transmissibility is relatively high. However, the drawdown in wells tapping the alluvium of the Gallatin and East Gallatin Rivers would rarely be excessive, even if the actual drawdown were two or three times the theoretical drawdown, because the coefficient of transmissibility of that aquifer generally is greater than 100,000 gpd per foot.

RECHARGE

The ground-water reservoir underlying the Gallatin Valley is recharged principally by infiltrating stream and irrigation water and only in small part by direct infiltration of precipitation and snowmelt.

In at least part of their course across the valley, Middle (Hyalite) Creek and the Gallatin and East Gallatin Rivers are influent during part or all of the year and are a source of considerable recharge to the underlying and adjacent alluvium. The monthly loss from the Gallatin River between gaging stations at Cameron Bridge, near Belgrade, and Central Park, near Manhattan, for example, is estimated to have averaged at least 3,000 acre-feet per month during the 1953 water year. Smaller streams, where they emerge from the Bridger and Gallatin Ranges, lose much, if not all, of their flow by seepage into their alluvial fans.

In the irrigated parts of the valley, seepage from the many irrigation canals and laterals is the chief source of recharge to the ground-water reservoir. Infiltration of applied irrigation water, another source of recharge, is appreciable where the soil is highly permeable. The effect of application of irrigation water is illustrated by the hydrograph of the water level in well A2–3–33da, which was drilled into the alluvium near the outer edge of the Manhattan terrace. (See fig. 21.) Irrigation of fields upgradient from the well caused a rapid and substantial rise of the water level; when water was no longer applied, the water level in the well fell rapidly. Of the surface water that entered the valley during the 1952 and 1953 irrigation seasons, between 300,000 and 400,000 acre-feet is estimated to have been diverted for irrigation each season. Probably at least half this amount infiltrated to the water table.

The amount of recharge from precipitation depends on the volume, duration, intensity, and seasonal distribution of the precipitation, the slope of the land surface, the permeability and moisture-holding capacity of the soil, the consumptive use through evapotranspiration, and the capacity of the ground-water reservoir to store additional water.

Parts of the Gallatin Valley receive a substantial amount of recharge from direct precipitation and snowmelt during the spring. Recharge from infiltrating snowmelt and from increased streamflow due to snowmelt is illustrated by the hydrograph of the water level in well D2–5–16aa1, which is on the Bozeman fan. (See fig. 22.) Daytime rises in temperature caused melting of

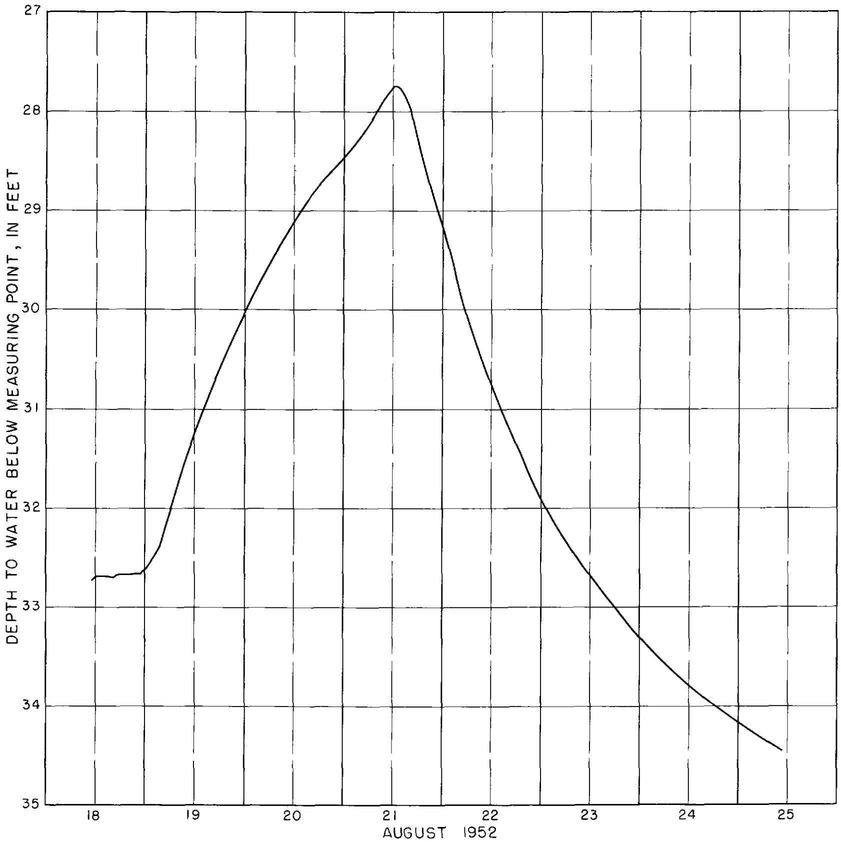

FIGURE 21.—Hydrograph of the water level in well A2–3–33da showing the effect of recharge from infiltrating irrigation water.

snow and consequent increases in streamflow, and nighttime cooler temperatures either slowed or stopped the snowmelt and reduced the streamflow. The highest daily water level lagged about 4 to 5 hours behind the highest daily temperature. In the higher part of the Bozeman fan, in particular, the water level in wells rises in response to precipitation. Recharge from direct infiltration of precipitation and to increased streamflow due to precipitation is illustrated by figure 23, which is a hydrograph of well D2–5–16aal during a period of substantial rainfall. Recharge from precipitation is greater in this part of the valley than elsewhere because of a combination of favorable factors: the volume of precipitation is greater than in the lower part of the valley, moisture requirements are less than in nonirrigated

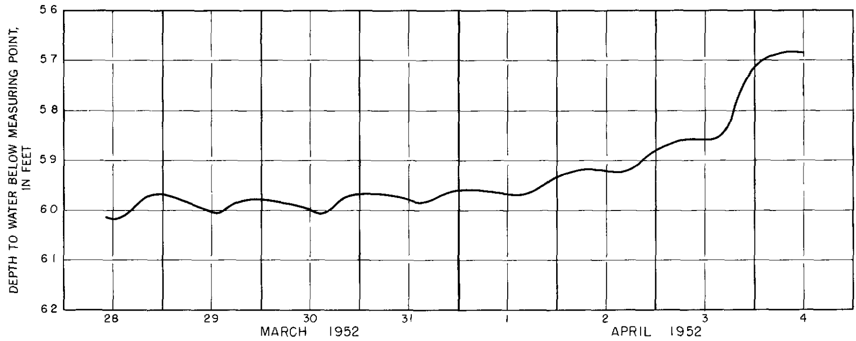

FIGURE 22.—Hydrograph of the water level in well D2-5-16aa1 showing the effect of recharge from infiltrating snowmelt and streamflow.

parts of the valley, spring snowmelt immediately precedes or coincides with the period of heaviest rainfall, and the soil generally is highly permeable.

DISCHARGE

Ground water is discharged by wells, springs, evaporation, transpiration, and effluent seepage into streams and drains.

Almost all the ground water pumped from wells in the Gallatin Valley is used for watering livestock and for domestic supply.

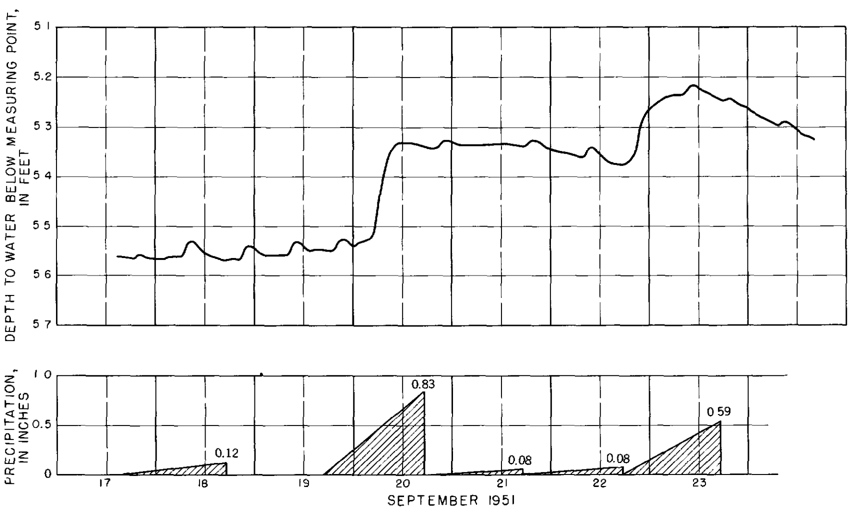

FIGURE 23.—Hydrograph of the water level in well D2-5-16aa1 showing the effect of recharge from infiltrating precipitation and streamflow.

Only one municipal supply, that for the town of Belgrade, is provided by wells. Total pumpage in the valley is minute compared to the total volume of ground water and, therefore, is relatively unimportant as a discharge factor. However, if irrigation or industrial use of ground water is increased materially in the future, discharge by pumping from wells then would become an important factor.

Evaporation of ground water occurs wherever the water table is near the land surface. Transpiration of ground water by phreatophytes (plants whose roots penetrate to the capillary fringe or to the zone of saturation) is another method of discharge. Evapotranspiration (evaporation plus transpiration) is large along stream courses and in poorly drained areas. In the Gallatin Valley the principal areas of ground-water discharge by evapotranspiration, aside from land bordering the stream courses, are an extensive waterlogged area north of Central Park between the Gallatin and East Gallatin Rivers, a small area just south of Manhattan along the road to Amsterdam, and the shallow drainageways on the Bozeman fan.

An attempt was made in the fall of 1952 and during the 1953 growing season to determine the amount of ground water discharged by evapotranspiration from a large part of the Central Park plain. Inflow to, and outflow from, a part of the plain were measured (table 13) and ground-water inflow was estimated. However, other variables were such that a reliable determination could not be made.

The amount of ground water consumed during the 1953 growing season by a typical grove of cottonwood trees 175 feet long and 150 feet wide (fig. 24) was measured by a method devised by White (1932, p. 61).

This method is based on the formula

$$q = y\ (24r \pm s)$$

in which

q = the quantity of ground water withdrawn by transpiration and evaporation during a 24-hour period, in inches;

y = the specific yield of the material in which the water table fluctuated during the same 24-hour period;

r = the hourly rate of water-table rise during a 4-hour period of darkness when ground-water withdrawals by transpiration and evaporation were negligible, in inches;

and

s = the net fall or rise of the water table during the same 24-hour period, in inches.

Well A1–4–22dcl, which is 9.1 feet deep and 36 inches in diameter, is near the middle of the cottonwood grove. A Stevens type–F weekly recording gage with a 12-inch float was installed

TABLE 13.—*Inflow to, and outflow from, the Central Park subarea*

[Asterisk (*) indicates preliminary data supplied by U.S. Bureau of Reclamation]

Stream or irrigation diversion	Amount of flow (cubic feet per second)				
	Fall 1952	July 7, 1953	Aug. 5, 1953	Sept. 1, 1953	Sept. 28, 1953
Inflow to area					
Spain-Ferris ditches:					
No. 4	....	7.4	7.5	3.7	3.2
No. 5	....	5.6	1.0	.4	.1
No. 3	....	....	2.1	.4	....
No. 2	....	.4	.3	.1	....
No. 1	....	5.0	4.2	8.6	6.5
Mammoth ditch	....	10.3	10.3	2.2	.9
J. S. Hoffman ditches:					
No. 2	....	3.9	2.1	1.7	1.0
No. 1	....	6.5	3.8	1.9	1.5
J. B. Weaver ditches:					
No. 2	....	2.5	4.3	.2	1.2
No. 1	....	22.0	16.8	6.4	3.6
Stone-Weaver ditches:					
No. 2	....	....	....	.2	.3
No. 1	....	4.6	2.1	1.6	1.3
Barnes ditch, diversion from D. N. Hoffman ditch	....	4.8	2.6	.7	.4
West branch of East Gallatin River	....	16.2	7.8	7.6	4.0
Arnold-Toohey ditch	....	1.4	3.9	2.0	....
Middle (Hyalite) Creek	....	46.9	27.5	48.2	45.7
East Gallatin River near Belgrade	....	*115.0	*52.0	*36.0	*38.0
East Gallatin River at Penwell Bridge	*54.3	....	....	....	....
Reese Creek	....	*36.0	*12.0	*11.0	*11.0
Foster Creek	....	*.4	*.2	*.2	*.2
Bear Creek	....	*1.1	*2.3	*2.6	*2.8
Dry Creek	*17.0	*26.0	*18.0	*21.0	*22.0
Spring Branch Creek	*.7	*.6	*.5	*.6	*1.0
Trout Creek	*10.0	*12.0	*7.7	*8.8	*10.9
Smith Creek near East Gallatin School	....	*27.7	*10.9	*18.8	*20.0
Smith Creek at mouth	*41.9	....	....	....	....
Total	123.9	356.3	199.9	184.9	175.6
Outflow from area					
East Gallatin River below mouth of Bullrun Creek	301	*414.1	*271.2	*352.0	*345.6
Difference					
Outflow minus inflow	177.1	57.8	71.3	167.1	170.0

FIGURE 24.—Cottonwood grove in the SW¼SE¼ sec. 22, T. 1 N., R. 4 E.

on this well to obtain smooth records of diurnal water-level fluctuations. (See fig. 25.) The values of r and s in the formula were determined from these records, and an aquifer test made on test hole A1–4–22dc4, also in the grove, gave a value of 0.05 for the storage coefficient used as y in the formula. The daily

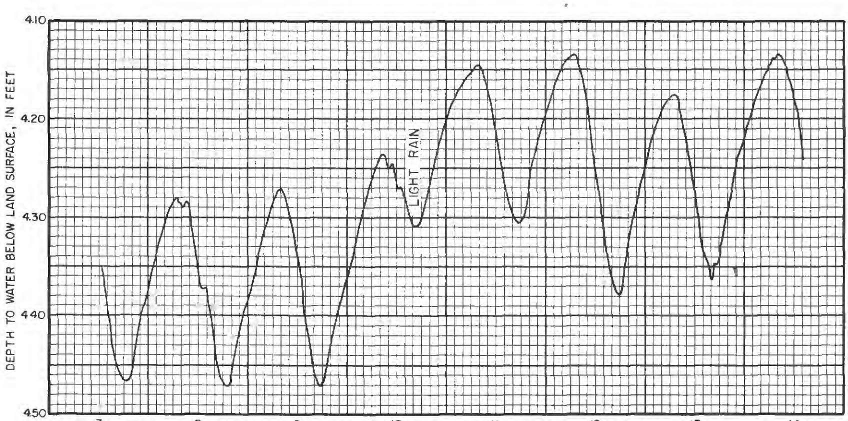

FIGURE 25.—Specimen hydrograph of the water level in well A1–4–22dc1.

consumption of ground water by the cottonwood grove (transpiration), as computed from the formula, is given in table 14 and shown graphically on plate 4. Consumption for the season totaled about 2 feet. The consumption would be greater if, as may be true, the storage coefficient is higher than the 0.05 indicated by the test.

TABLE 14.—*Daily consumption of ground water, in inches, by cottonwood grove*

Day	1953				
	June	July	August	September	October
1	(1)	(1)	0.28	0.22	0.11
2	(1)	(1)	.03	.08	.01
3	(1)	0.16	.19	(1)	.04
4	(1)	.20	.19	.13	.07
5	(1)	.21	.24	.16	.06
6	(1)	.21	.25	.15	.10
7	(1)	.20	.25	.17	.07
8	(1)	.19	.25	.18	.06
9	0.04	.25	.25	.19	.07
10	.12	.25	.10	(1)	.06
11	.10	.25	.19	.16	.06
12	.04	.25	.27	.13	.03
13	.12	.25	.20	.18	.06
14	.15	.25	(1)	.15	.05
15	.06	(1)	.24	.14	.05
16	.14	(1)	.20	.14	.04
17	.16	.29	.25	.14	.09
18	.12	.25	.17	.18	.03
19	.10	.24	.24	.21	.07
20	.01	.28	.23	.11	.07
21	.07	.23	(1)	.09	(1)
22	.11	.25	(1)	.08	(1)
23	.11	.26	(1)	.08	(1)
24	.06	.27	(1)	.13	(1)
25	.06	.28	(1)	.17	(1)
26	.12	.25	(1)	.13	(1)
27	.12	.31	(1)	.15	(1)
28	.12	.28	(1)	.14	(1)
29	.16	.28	.14	.08	(1)
30	(1)	.25	.16	.18	(1)
31		.21	.23		(1)

[1] Not determined.

Precipitation, relative humidity, temperature, wind velocity, evaporation, and hours of sunshine are factors that affect the transpiration rate of vegetation. Records of all but the hours of sunshine were kept at, or near, the cottonwood grove during most of the 1953 growing season and are shown graphically on plate 4. The total length of daylight (that is, the theoretical number of hours of sunshine rather than the actual hours of sunshine) is shown also.

Precipitation was measured by a recording rain gage near the grove (table 15). The CAA station, about 4 miles southeast of the grove, measured the relative humidity and both the maximum and minimum temperatures. An anemometer near the grove was used in measuring wind velocity (table 16) and a class–A evaporation pan was used in measuring evaporation (table 17). Both the anemometer and evaporation pan were read daily by Mr. Holdiman, a local resident.

Temperature, more than any other factor, seems to have had the greatest effect on the withdrawal of ground water by the cottonwood grove. A high relative humidity, however, significantly decreased the transpiration rate of the trees. If the wind velocity had been recorded for the daylight hours only, rather than for the entire day, possibly a better correlation between it and ground-water withdrawals would have been apparent. When precipitation was sufficient to wet the leaves of the trees,

TABLE 15.—*Daily precipitation, in inches, near cottonwood grove*

Day	1953				
	June	July	August	September	October
1	(1)	0.00	0.00	0.00	0.00
2	(1)	.00	.08	.50	.20
3	(1)	.00	.00	.00	.00
4	(1)	.00	.07	.00	.00
5	(1)	.00	.00	.00	.00
6	(1)	.00	.00	.00	.00
7	0.07	.00	.00	.00	.00
8	.02	.00	.00	.00	.00
9	.00	.00	.04	.00	.00
10	.03	.00	.04	.00	.00
11	.04	.00	.00	.00	.00
12	.21	.00	.00	.00	.00
13	.00	.00	.00	.00	.00
14	.06	.00	.00	.00	.00
15	.00	.14	.00	.00	.00
16	.00	.00	.00	.00	.00
17	.02	.00	.00	.00	.00
18	.02	.00	.00	.00	.00
19	.10	.00	.00	.00	.00
20	.40	.00	.00	.00	.10
21	.00	.00	.00	.00	.30
22	.00	.00	.00	.08	.00
23	.18	.00	.00	.00	.00
24	.00	.00	.00	.00	.00
25	.09	.00	.00	.00	.00
26	.00	.00	.00	.00	.00
27	.00	.00	.00	.00	.00
28	.00	.00	.00	.00	.00
29	.00	.00	.00	.00	.00
30	.00	.00	.00	.00	.00
31		.00	.00		.00

[1] Not measured.

TABLE 16.—*Wind velocity, in miles per day, near cottonwood grove*

Day	1953					
	May	June	July	August	September	October
1	(1)	41.5	100.0	29.3	40.5	54.7
2	(1)	130.4	49.5	69.7	145.9	98.9
3	(1)	107.6	64.7	50.0	45.0	95.0
4	(1)	22.8	55.1	83.7	28.6	(1)
5	(1)	142.4	57.1	28.9	48.9	26.7
6	(1)	39.0	46.5	47.3	42.0	44.4
7	79.6	69.3	40.0	60.8	50.3	40.3
8	191.9	80.3	51.8	115.7	84.8	42.3
9	95.3	43.2	47.7	82.2	24.8	44.7
10	163.0	61.0	48.0	88.2	39.6	51.6
11	155.4	62.6	42.5	35.0	22.0	47.0
12	230.8	50.1	45.2	77.0	41.9	37.0
13	73.8	116.4	72.1	43.6	50.2	17.3
14	73.9	89.5	92.3	53.7	31.0	79.0
15	55.8	35.8	63.4	64.2	31.6	15.8
16	56.9	84.5	18.4	62.5	74.4	26.9
17	67.2	69.1	45.1	38.0	82.7	43.8
18	113.5	102.2	47.8	38.3	117.2	112.8
19	55.4	58.5	44.0	49.5	194.3	(1)
20	117.2	130.8	92.1	51.9	19.1	104.8
21	69.9	113.5	71.5	47.4	37.0	118.5
22	149.3	225.5	38.6	53.6	70.5	19.3
23	136.5	80.3	48.5	64.6	67.2	20.1
24	163.2	(1)	61.1	149.1	56.0	27.5
25	136.3	(1)	100.0	41.8	150.0	34.1
26	100.8	(1)	58.4	79.4	96.7	23.0
27	71.7	112.6	73.7	36.1	55.4	21.1
28	95.1	12.5	56.1	71.7	106.9	39.3
29	122.4	63.3	85.4	37.7	41.4	53.2
30	67.7	69.6	88.0	29.3	126.4	60.4
31	73.9		56.2	44.5		45.1

1 Not recorded.

ground-water withdrawals virtually ceased. This is illustrated by the fact that during a light rain the water level in the well began to rise earlier in the day than usual, and rose at the same rate as at night. (See fig. 25.)

A reconnaissance of the Gallatin Valley indicated that a total of about 15,000 acres of land is covered by cottonwoods and willows. If the consumptive use of ground water by this type of vegetation is about 2 feet of water per year, as was computed for the typical stand of cottonwoods (fig. 24), then the total consumptive use of ground water by such vegetation in the Gallatin Valley is about 30,000 acre-feet per year. However, if the specific yield determination used in the computation for the typical grove is low by a factor of as much as 2 or 3, the real order of magnitude of evapotranspiration may be more nearly 60,000 or 90,000 acre-feet per year.

TABLE 17.—*Daily evaporation, in inches, from a class-A pan near cottonwood grove*

Day	1953					
	May	June	July	August	September	October
1	(1)	(1)	0.24	0.26	0.14	0.03
2	(1)	(1)	.26	.10	.05	.12
3	(1)	(1)	.21	.16	.06	.03
4	(1)	(1)	(1)	.26	.15	.0
5	(1)	(1)	(1)	.12	.12	.05
6	(1)	(1)	(1)	.24	.16	.08
7	0.25	(1)	(1)	.24	.07	.03
8	.11	(1)	(1)	.29	.14	.03
9	(1)	(1)	(1)	.16	.16	.02
10	(1)	(1)	(1)	.16	.18	.12
11	(1)	(1)	.28	.22	.13	.0
12	(1)	(1)	.19	.22	.13	.03
13	(1)	(1)	.22	.18	.11	.03
14	(1)	(1)	.38	.18	.09	.02
15	(1)	(1)	.28	.29	.21	.06
16	(1)	(1)	.16	.15	.11	.04
17	(1)	(1)	.18	.07	.12	.08
18	(1)	0.24	.22	.22	.19	.0
19	(1)	.08	.22	.20	.11	.08
20	(1)	.17	(1)	.21	.07	(1)
21	(1)	.21	(1)	.12	.11	(1)
22	(1)	.35	(1)	.22	.13	(1)
23	(1)	.24	(1)	.17	.08	(1)
24	(1)	(1)	(1)	.25	.04	(1)
25	(1)	(1)	.30	.06	.15	(1)
26	(1)	(1)	.24	.15	.10	(1)
27	(1)	.10	.28	.17	.09	(1)
28	(1)	(1)	.28	.15	.12	(1)
29	(1)	.26	.21	.09	.005	(1)
30	(1)	.29	.31	.12	.15	(1)
31	(1)		.11	.15		(1)

1 Not measured.

Ground water is discharged wherever the water table intersects the land surface. In the Gallatin Valley, discharge by both spring flow and effluent seepage occurs where alluvial-fan deposits thin above relatively impermeable underlying material or where drains and stream courses intersect the water table. Much of the ground-water discharge occurs in the Central Park subarea, north of an east-west line drawn through Central Park. The Gallatin and East Gallatin Rivers are effluent north of this line, and many streams rise in the area.

Estimates were made of the annual discharge of ground water as surface water during the period March 1934 through February 1953. (See table 18.) These estimates are based on an analysis of records of streamflow in the Gallatin Valley.

Because nearly all the inflow to the valley during July and August is diverted for irrigation and very little of the diverted

TABLE 18.—*Estimated ground-water discharge, in thousands of acre-feet, from the Gallatin Valley*

Year (March through February)	Measured discharge of Gallatin River at Logan during August	Estimated average monthly ground-water discharge during summer	Average difference between monthly inflow and outflow during period November through February	Estimated average monthly ground-water discharge		Estimated annual ground-water discharge
				During winter	For the year	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1934–35......	10	10	8	11	10	120
1935–36......	14	14	12	15	14	170
1936–37......	14	10	11	11	10	120
1937–38......	16	16	12	15	16	190
1938–39......	20	20	17	20	20	240
1939–40......	18	18	17	18	18	220
1940–41......	20	19	16	18	18	220
1941–42......	22	20	18	18	19	230
1942–43......	21	21	19	19	20	240
1943–44......	32	24	16	19	22	260
1944–45......	23	23	21	21	22	260
1945–46......	26	25	19	19	22	260
1946–47......	27	25	22	22	24	290
1947–48......	34	31	24	23	27	320
1948–49......	48	27	20	20	24	290
1949–50......	24	24	18	18	21	250
1950–51......	41	28	20	21	25	300
1951–52......	38	28	[1] 20.5	[1] 20.5	24	290
1952–53......	36	32	[1] 22.2	[1] 22.2	27	320

[1] Measured.

water returns as waste surface water to the valley streams, the outflow from the valley during these months largely represents ground-water discharge. If, however, the records of streamflow and precipitation indicated that not all surface-water inflow was diverted or that precipitation within the valley or return of waste water contributed substantially to the outflow, the measured flow of the Gallatin River at Logan during August (column 2) was adjusted accordingly in estimating the average monthly ground-water discharge during the summer (column 3). The estimates of ground-water discharge probably err on the low side.

During the cold-weather months, November through February, when precipitation contributes little or no runoff and evapotranspiration is of minor importance, the difference between inflow to, and outflow from, the valley consists largely of ground-water discharge. Differences between the inflow and outflow during the winter months were averaged (column 4) and then adjusted (column 5) on the basis of temperature and precipitation records.

The average of the monthly summer and winter ground-water discharges (column 6) was considered to represent the average monthly ground-water discharge for the year, and when multiplied by 12, was considered to represent the annual ground-water discharge (column 7). The estimates of annual ground-water discharge range from 120,000 to 320,000 acre-feet and average about 240,000 acre-feet.

A different method of estimating ground-water discharge was used for the years March 1951 through February 1952 and March 1952 through February 1953. This method was based on a graph showing cumulative departure from the amount of ground water in storage on June 30, 1952. (See fig. 26.) The slope of the graph during the fall and winter months, when evapotranspiration is at a minimum, was used to determine the average monthly rate of ground-water discharge as surface flow. By this method, the amount of ground water discharged from the valley for those years was computed to be about 280,000 and 300,000 acre-feet, respectively. These values compare well with the values obtained for the same years by the streamflow method.

CONFIGURATION OF THE WATER TABLE

The water table is an irregular sloping surface that conforms roughly to the topography of the land surface. The configuration of the water table beneath a large part of the Gallatin Valley at the approximate low and high positions during 1953 (about April 1 and August 1, respectively) is shown by contour lines on plate 5. The configuration of the water table beneath the rest of the valley could not be shown because of the lack of sufficient data and because much of the ground water is confined.

Ground water moves in the direction of the hydraulic gradient, that is, at a right angle to the water-table contour lines. Along the sides of the Gallatin Valley, ground-water movement is toward the valley floor, and within the valley it is in a general northward direction. The rate of movement is proportional to the slope (hydraulic gradient) and to the permeability of the material.

The depths to water (about April 1, 1953) in wells in the Gallatin Valley are shown on plate 6 by numbers adjacent to the well symbols. As shown by the pattern on the same plate, the depth to water is less than 10 feet throughout most of the valley floor and the lower part of the Bozeman fan. However, in some places in these parts of the valley, the depth to water is as much as 50 feet. In the Camp Creek Hills the depth to water ranges from about 1 foot to as much as 600 feet. Along the south and east fringes of the valley and in the Dry Creek subarea it ranges from a few feet to 170 feet.

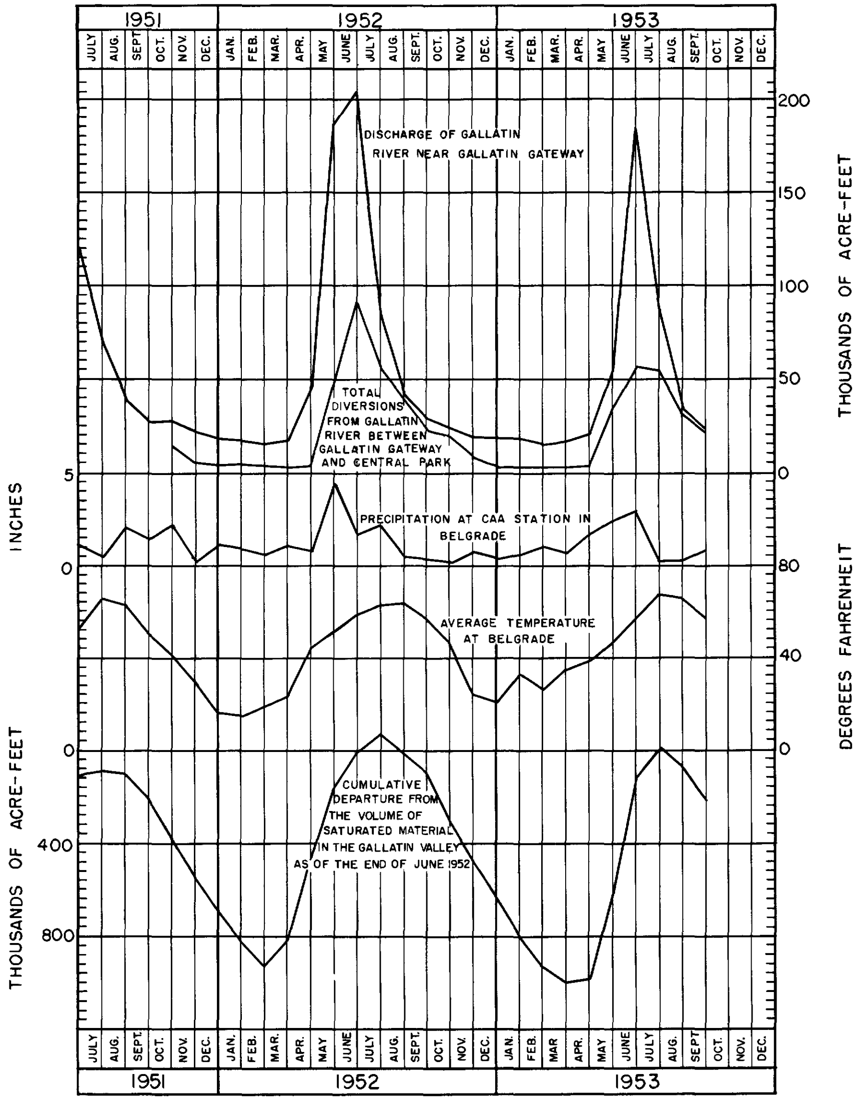

FIGURE 26.—Graphs for period July 1951 through September 1953, showing discharge of Gallatin River near Gallatin Gateway, total diversions from Gallatin River between Gallatin Gateway and Central Park, total monthly precipitation and average monthly temperature at Belgrade, and monthly cumulative departure from the volume of saturated material as of the end of June 1952.

CHANGES IN STORAGE

The water table rises when recharge exceeds discharge and falls when discharge exceeds recharge. Changes in ground-water storage within the valley are reflected by fluctuations of the water level in wells. The difference between any two measurements of the water level in a well is a measure of the net amount of material that was saturated or drained in the vicinity of the well during the period between the measurements.

In estimating changes in ground-water storage for the valley as a whole, the valley was divided into hydrologic units (fig. 2), each having distinctive characteristics; the units were subdivided into polygonal areas, each having an observation well within it. The boundaries of the polygonal areas were determined by the Theissen method (Theissen, 1911, p. 1082-1084). The change in water level in each well, multiplied by the area of the polygon in which the well was situated, was considered to be the volume of material saturated or drained within the polygon during the period for which computed. The sum of the volumes for all the polygonal areas in a hydrologic unit was considered to be the total volume of material saturated or drained within the unit. In some instances, where observation wells were widely scattered and the polygonal areas were correspondingly large, the measured changes in water level were adjusted to conform more nearly to water-level changes in areas having similar hydrologic characteristics and for which more adequate information was available. Fortunately, observation-well coverage was adequate throughout the valley floor, where most of the change in storage takes place. The nonirrigated part of the Camp Creek Hills was not included in the computation because so little recharge is available to this area that the annual change in ground-water storage is insignificant.

The monthly changes in the volume of saturated material in the Gallatin Valley (excluding the Dry Creek subarea) for the period July 1951 through September 1953 are given in table 19, and the cumulative monthly departures from the volume of saturated material as of the end of June 1952 are given in table 20. A graph of the monthly cumulative departure from the volume of saturated material as of the end of June 1952 in the Gallatin Valley is shown in figure 26, together with graphs of the discharge of the Gallatin River at Gallatin Gateway, total diversions of water from the Gallatin River between Gallatin Gateway and Central Park, and precipitation and average temperature at Belgrade. The changes in the volume of ground water in storage (table 21) were computed by multiplying the changes in volume of saturated material by the average specific yield of the material (0.15).

TABLE 19.—*Monthly changes in volume of saturated material in the Gallatin Valley (exclusive of Dry Creek subarea), in thousands of acre-feet*

[Ia, Gateway subarea; Ib, Belgrade subarea; Ic, Central Park subarea; Id, Manhattan subarea; Ie, Upper East Gallatin subarea; II, Bozeman fan; R, remainder of Gallatin Valley]

Area or subarea	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Water year 1951												
Ia, Ib, Ic, Ie	......	......	......	......	......	......	......	......	......	+11.0	−15.4	−44.1
Id	......	......	......	......	......	......	......	......	......	+1.5	−4.0	−6.9
II	......	......	......	......	......	......	......	......	......	−13.6	+2.0	−15.9
R	......	......	......	......	......	......	......	......	......	+18.9	−7.0	−35.3
Total	......	......	......	......	......	......	......	......	......	+17.8	−24.4	−102.2
Water year 1952												
Ia	......	......	......	......	......	......	......	......	......	−6.6	−13.4	−11.9
Ib	......	......	......	......	......	......	......	......	......	+31.5	−22.9	−34.8
Ic	......	......	......	......	......	......	......	......	......	−.2	−4.5	−6.9
Ie	......	......	......	......	......	......	......	......	......	−2.5	−.9	−3.7
Ia, Ib, Ic, Ie	−106.2	−90.5	−102.9	−71.3	−54.7	+32.3	+138.0	+213.5	+113.7	......	......	......
Id	−7.1	−6.2	−8.0	−7.0	−6.3	+.6	−4.6	+27.2	+17.5	+.5	+.5	−4.0
II	−10.4	−36.9	−11.0	−22.5	−24.4	+57.1	+49.5	+26.5	+29.1	+11.5	+23.6	−20.0
R	−40.0	−31.6	−24.6	−19.9	−31.3	+20.0	+156.4	+45.5	−.7	+42.5	−16.1	−6.6
Total	−163.9	−165.2	−146.5	−120.7	−116.7	+110.2	+339.3	+312.7	+159.6	+76.7	−80.9	−87.9
Water year 1953												
Ia	−14.4	−13.4	−10.7	−8.4	−3.8	−3.0	−3.2	+26.6	+55.8	−10.9	−9.4	−5.0
Ib	−72.8	−77.5	−56.6	−100.0	−52.1	−44.4	+9.5	+144.7	+231.6	+72.3	−17.8	−67.5
Ic	−6.7	−3.4	−7.5	−2.2	−3.0	+1.3	+.6	+24.5	+7.0	−1.9	−2.2	−5.5
Id	−3.9	−9.3	−6.7	−7.7	−4.2	−3.4	+.1	+29.0	+7.9	+10.6	−8.6	−5.0
Ie	−2.9	−2.1	−2.9	−2.9	−4.2	−4.3	+1.7	+31.4	−16.8	+4.9	−2.6	−2.6
II	−27.8	−26.7	−25.6	−23.1	−18.6	−6.5	−1.4	+17.1	+117.3	+12.4	−4.6	−27.8
R	−75.1	−47.3	−34.2	−32.7	−39.9	−6.1	+3.0	+96.8	+93.3	+28.2	−27.3	−29.1
Total	−203.6	−179.7	−144.2	−177.0	−125.8	−66.4	+10.3	+370.1	+496.1	+115.6	−72.5	−142.5

TABLE 20.—*Cumulative monthly departures from volume of saturated material in the Gallatin Valley (exclusive of Dry Creek subarea) as of the end of June 1952, in thousands of acre-feet*

[Ia, Gateway subarea; Ib, Belgrade subarea; Ic, Central Park subarea; Id, Manhattan subarea; Ie, Upper East Gallatin subarea; II, Bozeman fan; R, remainder of Gallatin Valley]

Area or subarea	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Water year 1951												
Ia, Ib, Ic, Ie	....	....	....	....	....	....	....	....	....	−23.4	−12.4	−27.8
Id	....	....	....	....	....	....	....	....	....	+3.3	+4.8	+.8
II	....	....	....	....	....	....	....	....	....	−29.5	−43.1	−41.1
R	....	....	....	....	....	....	....	....	....	−50.4	−31.5	−38.5
Total	....	....	....	....	....	....	....	....	....	−100.0	−82.2	−106.6
Water year 1952												
Ia	....	....	....	....	....	....	....	....	....	−6.6	−20.0	−31.9
Ib	....	....	....	....	....	....	....	....	....	+31.5	+8.6	−26.2
Ic	....	....	....	....	....	....	....	....	....	−.2	−4.7	−11.6
Ie	....	....	....	....	....	....	....	....	....	−2.5	−3.4	−7.1
Ia, Ib, Ic, Ie	−71.9	−178.1	−268.6	−371.5	−442.8	−497.5	−465.2	−327.2	−113.7	....	....	....
Id	−6.1	−13.2	−19.4	−27.4	−34.4	−40.7	−40.1	−44.7	−17.5	+.5	+1.0	−3.0
II	−57.0	−67.4	−104.3	−115.3	−137.8	−162.2	−105.1	−55.6	−29.1	+11.5	−12.1	−32.1
R	−73.8	−114.0	−145.6	−170.2	−190.1	−221.4	−201.2	−44.8	+.7	+42.5	+26.4	+19.9
Total	−208.8	−372.7	−537.9	−684.4	−805.1	−921.8	−811.6	−472.3	−159.6	+76.7	−4.2	−92.0
Water year 1953												
Ia	−46.3	−59.7	−70.4	−78.8	−82.6	−85.6	−88.8	−62.2	−6.4	−17.3	−26.7	−31.7
Ib	−99.0	−176.5	−233.1	−333.1	−385.2	−429.6	−420.1	−275.4	−43.8	+28.5	+10.7	−56.8
Ic	−18.3	−21.7	−29.2	−31.4	−34.4	−33.1	−32.5	−8.0	−1.0	−2.9	−5.1	−10.6
Id	−6.9	−16.2	−22.9	−30.6	−34.8	−38.2	−38.1	−9.1	−1.2	+9.4	+.8	−4.2
Ie	−10.0	−12.1	−15.0	−17.9	−22.1	−26.4	−24.7	+6.7	−10.1	−5.2	−7.8	−10.4
II	−59.9	−86.6	−112.2	−135.3	−153.9	−160.4	−161.8	−144.7	−27.4	−15.0	−19.6	−47.4
R	−55.2	−102.5	−136.7	−169.4	−209.3	−215.4	−212.4	−115.6	−22.3	+5.9	−21.4	−50.5
Total	−295.6	−475.3	−619.5	−796.5	−922.3	−988.7	−978.4	−608.3	−112.2	+3.4	−69.1	−211.6

TABLE 21.—*Monthly changes in volume of ground water stored in the Gallatin Valley, in thousands of acre-feet*

Month	Water year		
	1951	1952	1953
October	....	−24.58	−30.57
November	....	−24.78	−26.98
December	....	−21.97	−21.58
January	....	−18.11	−26.48
February	....	−17.51	−18.88
March	....	+16.53	−9.96
April	....	+50.90	+1.61
May	....	+46.90	+55.51
June	....	+23.94	+74.49
July	+2.67	+11.51	+17.30
August	−3.67	−12.14	−10.92
September	−15.33	−13.18	−21.40

This value for specific yield is the average ratio of net gain in surface flow to net loss in volume of saturated material during a period when all precipitation was stored as snow and no ground water was used consumptively. During such a period, the net gain in surface flow was due wholly to discharge of ground water. Figure 27 is the graph used in computing the average specific yield of the ground-water reservoir in the Gallatin Valley.

The average monthly water-level fluctuations in the Gallatin Valley are illustrated by the same graph that shows monthly cumulative departure from the volume of saturated material as of the end of June 1952. (See fig. 26.) Under the existing water regimen in the valley, the pattern of fluctuation is unlikely to change from year to year, though the magnitude of seasonal changes will vary with the volume and duration of recharge. The difference between the water level on about April 1 and August 1, 1953 (the average lowest and highest positions, respectively, during that year) is shown on plate 7. It may readily be seen that the maximum change in water level occurs in the central part of the Belgrade subarea, that significant changes occur in the Gateway subarea, at the upper end of the Bozeman fan, and in the Manhattan subarea, but that elsewhere in the valley the change is relatively insignificant.

A long-term record of water-level fluctuations is important because a progressive decline or rise of the water table over a period of several years could have a pronounced effect on water use and the agricultural economy of the Gallatin Valley. No measurements of water-level fluctuations in the Gallatin Valley were made before the period of this investigation. However, the trend

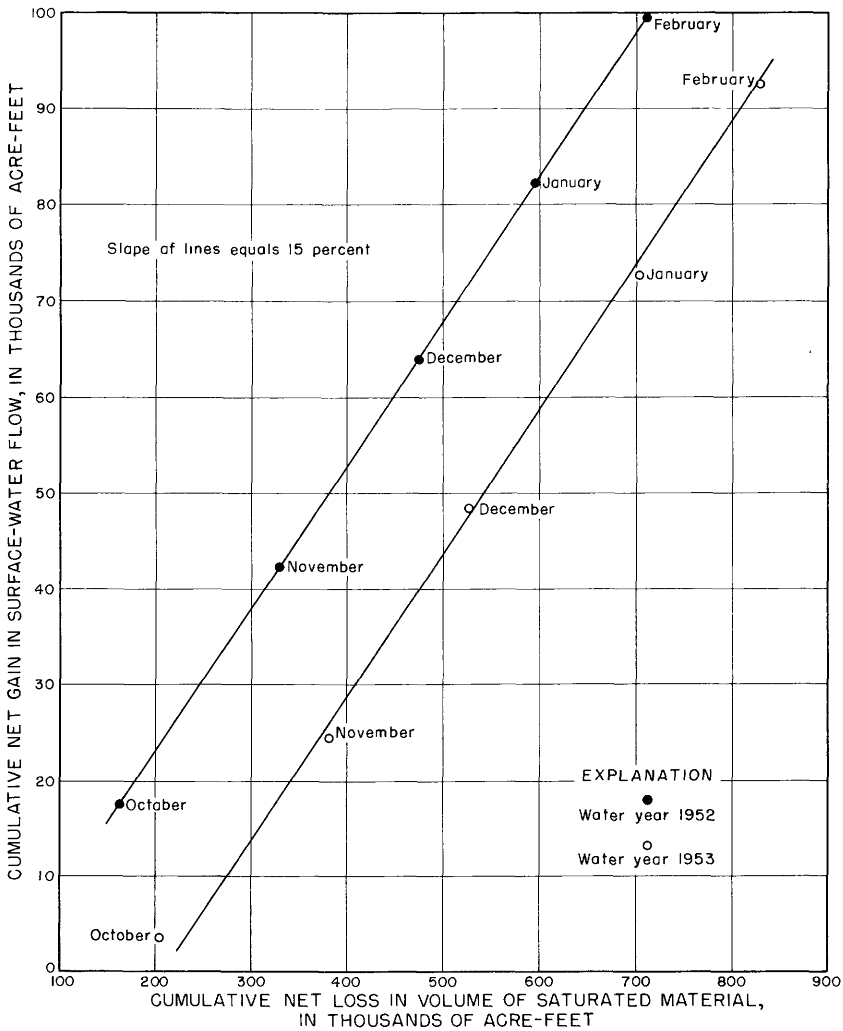

FIGURE 27.—Graph used in computing average specific yield of the ground-water reservoir in the Gallatin Valley.

and magnitude of the annual water-level fluctuations during the 17-year period preceding this investigation were inferred by estimating the cumulative departure (at the beginning of August and at the end of December in each year of the period) from the volume of saturated material as of the end of June 1952. (See table 22 and fig. 28.)

The estimates for the end of December (column 2, table 22) were obtained by using the estimates of average winter ground-water discharge (column 5, table 18) and a rating curve based

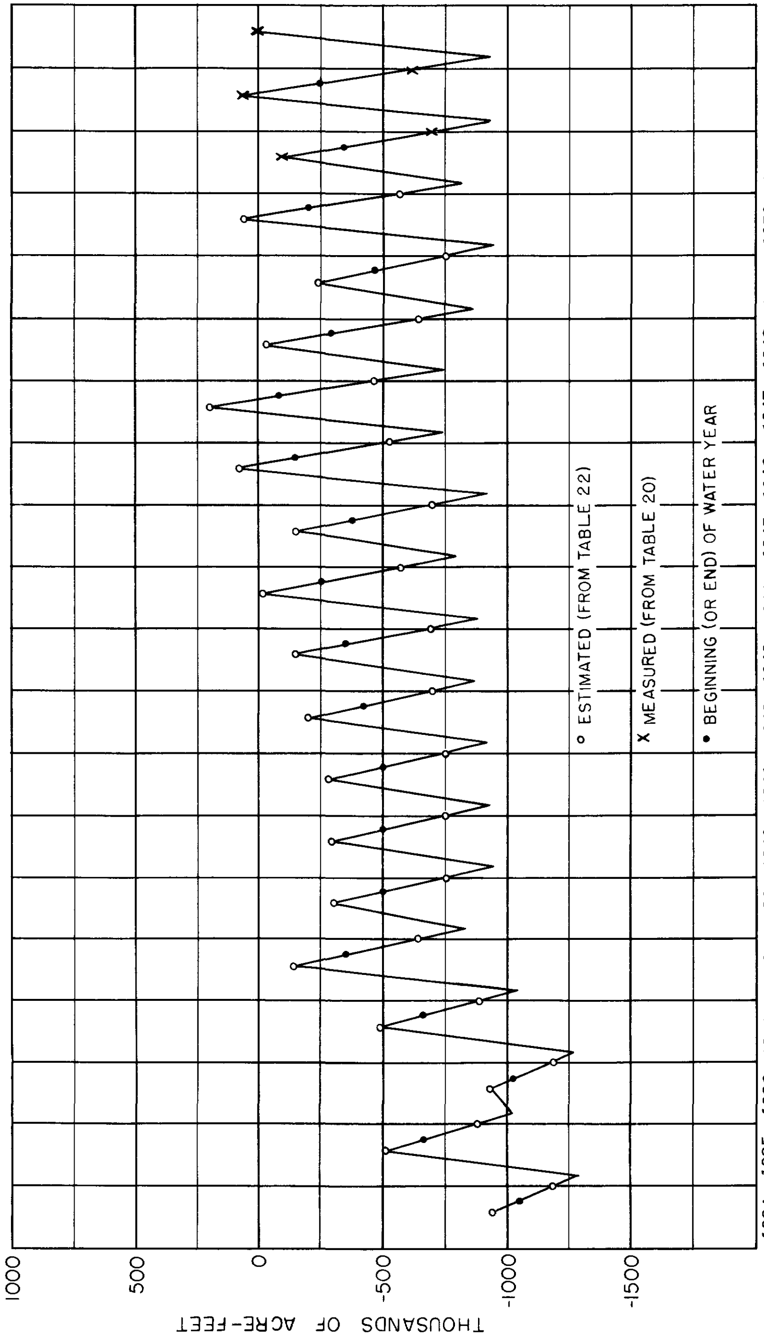

FIGURE 28.—Graph showing estimated cumulative departure, 1934–53, from the volume of saturated material as of the end of June 1952.

TABLE 22.—*Estimated cumulative departures from volume of saturated material as of the end of June 1952, in thousands of acre-feet*

Year (March through February)	Estimated cumulative departure, at end of December, from the volume of saturated material as of the end of June 1952	Estimated change in volume of saturated material, August through December	Estimated cumulative departure, at beginning of August, from volume of saturated material as of the end of June 1952
(1)	(2)	(3)	(4)
1934–35......	−1,180	−250	−930
1935–36......	−880	−360	−520
1936–37......	−1,180	−250	−930
1937–38......	−880	−400	−480
1938–39......	−640	−500	−140
1939–40......	−760	−460	−300
1940–41......	−760	−460	−300
1941–42......	−760	−480	−280
1942–43......	−700	−500	−200
1943–44......	−700	−550	−150
1944–45......	−570	−550	−20
1945–46......	−700	−550	−150
1946–47......	−530	−610	+80
1947–48......	−470	−670	+200
1948–49......	−640	−610	−30
1949–40......	−760	−530	−230
1950–51......	−570	−630	+60

on the ratio of monthly ground-water discharge to the corresponding cumulative departures from volume of saturated material during the period November 1951 through February 1952 (fig. 29). The estimates for the beginning of August (column 4, table 22) were obtained by subtracting the estimated change in volume of saturated material, August through December (column 3, table 22), from the estimated cumulative departure at the end of December (column 2, table 22). The estimated change in volume of saturated material, August through December, was obtained by multiplying the estimated annual ground-water discharge (column 7, table 18) by the ratio (2.1) of the volume of material drained during the period August through December 1951 (602,200 acre-feet) to the volume of ground water discharged during the year March 1951 to February 1952 (290,000 acre-feet). The cumulative departure in volume of saturated material at the beginning of March (fig. 28) was approximated by extending the line that connects the August and December departures.

Figure 28 indicates that the lowest water level in the period 1934-53 was in 1935. The fluctuation in 1952 was the greatest annual fluctuation during the 19-year period and was about two-thirds of the difference between the lowest and highest water

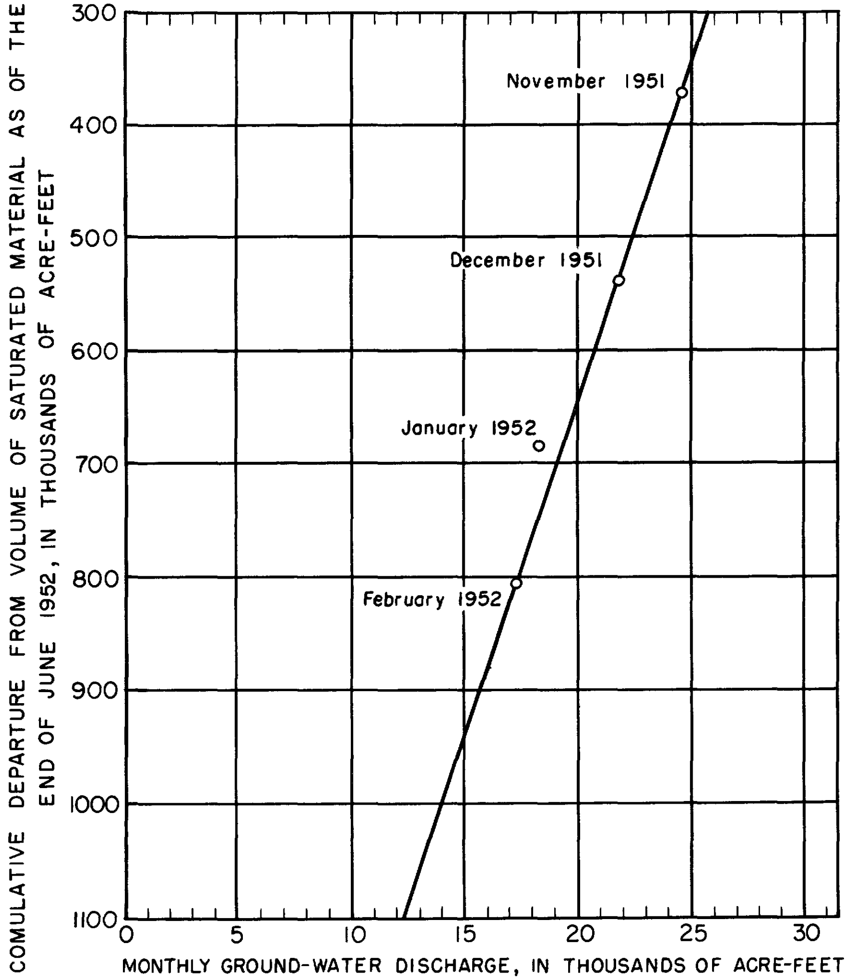

FIGURE 29.—Rating curve used in estimating midwinter cumulative departures from volume of saturated material as of the end of June 1952.

level during the period. The period 1929-36 was one of deficient precipitation, and near the end of this period, as illustrated by figure 28, the water table was low. As the water level in August 1934 was about the same as that in March 1953, the water level in August, after several years of deficient precipitation, probably would not be lower than the water level recorded in March 1953.

The effect on the water table of a period of deficient precipitation is especially important with regard to potential ground-water development because of the decrease in ground-water storage and the increase in depth to water that may result.

WATER-LEVEL FLUCTUATIONS CAUSED BY EARTHQUAKES AND OTHER DISTURBANCES

During this investigation several earthquakes caused fluctuations of the water level in wells A1–4–25dc and D2–4–9bc, each of which was equipped with a water-level recording gage. The effect of two earthquakes, one in Siberia and the other in Mexico, are illustrated by hydrographs of the water level in well A1–4–25dc. (See fig. 30.) The water level in this well was affected also by the passing of trains on the freight line of the Northern Pacific Railway, about 150 feet from the well. Minor water-level fluctuations caused by the passing of automobiles and trucks were recorded by the gage on well A1–4–5da, located about 20 feet from the county road.

WATER-RESOURCES INVENTORY, WATER YEARS 1952 AND 1953

EVALUATION

The hydrologic data collected in the Gallatin Valley during the 1952 and 1953 water years were used in making a monthly inventory of the total water resources of the valley. The Dry Creek subarea was not included in the inventory, however, because too few data on changes in ground-water storage were collected in that part of the valley. The results of the inventory are given in table 23 and are shown graphically on plate 8.

The Gallatin Valley is well suited for an inventory of this type because nearly all the components of the inventory could be measured with reasonable accuracy. Surface-water inflow to the valley was measured at gaging stations situated around the margin of the valley; precipitation was measured at stations scattered throughout the valley; the net discharge from, and recharge to, the ground-water reservoir underlying the valley were computed from measurements of the water level in numerous wells; and surface-water outflow was measured at Logan, the valley's only outlet.

Because the accretions to the surface-water supply of the valley must balance the depletions, the difference between the measured accretions (surface-water inflow, precipitation, and net ground-water discharge) and the measured depletions (net ground-water recharge and surface-water outflow) is equal to the net difference between the unmeasured accretions and unmeasured depletions. The unmeasured accretions consist of subsurface inflow and snowmelt; the unmeasured depletions consist

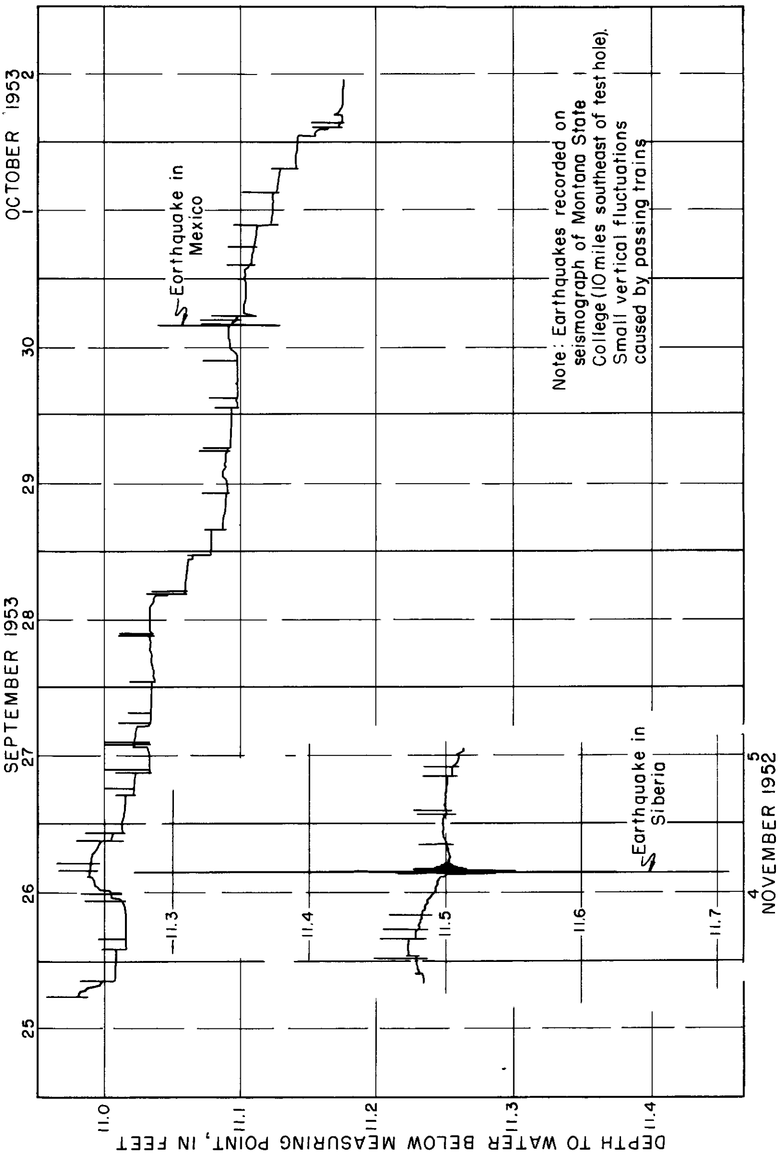

FIGURE 30.—Hydrographs of the water level in well A1-4-25dc showing the effect of earthquakes and passing trains.

TABLE 23.—*Monthly and annual changes in surface-water supply of the Gallatin Valley, water years 1952 and 1953, in thousands of acre-feet*

Month	Surface-water inflow to Gallatin Valley				Measured surface-water outflow from Gallatin Valley (Gallatin River at Logan)	Net gain (+) or loss (−) in surface flow	Accretions occurring within Gallatin Valley				Depletions occurring within Gallatin Valley			Net gain (+) or loss (−) occurring within Gallatin Valley	Total accretions to surface-water supply of Gallatin Valley (total surface-water inflow plus total accretions within valley)	Total depletions of surface-water supply of Gallatin Valley (total depletions within valley plus surface-water outflow)
	Measured															
	Gallatin River near Gallatin Gateway	Tributaries of Gallatin River [1]	Unmeasured tributaries of Gallatin River (estimated)	Total			Precipitation	Net gains from ground-water reservoir (ground-water discharge)	Snowmelt minus evapotranspiration and net increase in soil moisture	Total	Evapotranspiration and net increases in soil moisture and snow storage	Net loss to ground-water reservoir (ground-water recharge)	Total			
Water year 1952																
October	27.75	9.51	0.68	37.94	55.52	+17.58	77.00	24.58	....	101.58	84.00	....	84.00	+17.58	139.52	139.52
November	22.55	8.18	.59	31.32	55.90	+24.58	11.20	24.78	....	35.98	11.40	....	11.40	+24.58	67.30	67.30
December	18.02	7.34	.53	25.89	47.66	+21.77	33.60	21.97	....	55.57	33.80	....	33.80	+21.77	81.46	81.46
January	17.40	6.54	.47	24.41	42.62	+18.21	26.30	18.11	....	44.41	26.20	....	26.20	+18.21	68.82	68.82
February	15.55	5.89	.43	21.87	39.18	+17.31	20.90	17.51	....	38.41	21.10	....	21.10	+17.31	60.28	60.28
March	17.30	6.21	.45	23.96	43.63	+19.67	33.30	....	2.90	36.20	....	16.53	16.53	+19.67	60.16	60.16
April	44.31	34.96	2.53	81.80	118.60	+36.80	35.30	....	52.40	87.70	....	50.90	50.90	+36.80	169.50	169.50
May	186.80	68.18	4.92	259.10	279.10	+19.20	135.20	....	....	135.20	69.10	46.90	116.00	+19.20	395.10	395.10
June	207.70	50.96	3.68	262.34	197.20	−65.14	46.80	....	....	46.80	88.00	23.94	111.94	−65.14	309.14	309.14
July	85.42	21.83	1.58	108.83	70.22	−38.61	48.80	....	....	48.80	75.90	11.51	87.41	−38.61	157.63	157.63
August	42.54	13.49	.96	56.99	35.83	−21.16	26.10	12.14	....	38.24	59.40	....	59.40	−21.16	95.23	95.23
September	29.21	10.89	.78	40.88	44.46	+3.58	13.80	13.18	....	26.98	23.40	....	23.40	+3.58	67.86	67.86
Total	714.55	243.98	17.60	976.13	1,029.92	+53.79	508.30	132.27	55.30	695.87	492.30	149.78	642.08	+53.79	1,672.00	1,672.00
Water year 1953																
October	24.69	8.93	0.65	34.27	37.84	+3.57	3.50	30.57	....	34.07	30.50	....	30.50	+3.57	68.34	68.34
November	19.46	7.13	.53	27.12	47.90	+20.78	25.70	26.98	....	52.68	31.90	....	31.90	+20.78	79.80	79.80
December	19.00	6.62	.49	26.11	49.99	+23.88	11.10	21.58	....	32.68	8.80	....	8.80	+23.88	58.79	58.79
January	18.59	6.79	.50	25.88	50.26	+24.38	15.50	26.48	....	41.98	17.60	....	17.60	+24.38	67.86	67.86
February	15.18	5.66	.42	21.26	40.94	+19.68	30.30	18.88	....	49.18	29.50	....	29.50	+19.68	70.44	70.44
March	17.12	7.24	.54	24.90	47.56	+22.66	20.80	9.96	....	30.76	8.10	....	8.10	+22.66	55.66	55.66
April	20.37	10.53	.78	31.68	47.87	+16.19	50.50	....	....	50.50	32.70	1.61	34.31	+16.19	82.18	82.18
May	53.68	31.96	2.36	88.00	63.29	−24.71	76.00	....	....	76.00	45.20	55.51	100.71	−24.71	164.00	164.00
June	183.60	72.25	5.34	261.19	211.70	−49.49	82.30	....	....	82.30	57.30	74.49	131.79	−49.49	343.49	343.49
July	87.77	27.75	2.05	117.57	55.87	−61.70	10.50	....	....	10.50	54.90	17.30	72.20	−61.70	128.07	128.07
August	33.89	15.70	1.16	50.75	29.57	−21.18	13.10	10.92	....	24.02	45.20	....	45.20	−21.18	74.77	74.77
September	24.31	10.52	.78	35.61	33.41	−2.20	20.10	21.40	....	41.50	43.70	....	43.70	−2.20	77.11	77.11
Total	517.66	211.08	15.60	744.34	716.20	−28.14	359.40	166.77	....	526.17	405.40	148.91	554.31	−28.14	1,270.51	1,270.51

[1] Does not include partial record for Churn, Deer, and Foster Creeks in the 1953 water year.

of subsurface outflow, evaporation, transpiration, storage as snow, and net increases in soil moisture. The inventory shows that the unmeasured accretions exceeded the unmeasured depletions in only 2 months (March and April 1952) of the 2-year period.

Subsurface inflow and outflow are believed to be negligible. The only subsurface materials that conceivably might transmit a significant volume of water to, or from, the valley are the Tertiary strata that separate the Gallatin and Madison Valleys, the alluvium beneath the floor of the inlet and outlet canyons of the valley, and fractured rocks in the basement complex.

As the water table in the Camp Creek Hills stands above the water table in both the Madison and Gallatin Valleys, ground water cannot move out of the Gallatin Valley into the Madison Valley, nor can ground water move from the Madison Valley into the Gallatin Valley.

The thickness of the alluvium at the inlet gaging station is not definitely known but probably is about 40 feet. This thickness is based on evidence that the alluvium probably is less than 20 feet thick at other places in the canyon and that it is about 80 feet thick at Gallatin Gateway, about 8 miles downstream from the gaging station. The width of the alluvial surface at the gaging station is about 0.1 mile, and the gradient of the stream is about 30 feet per mile. Therefore, if it is assumed that the coefficient of permeability is 10,000 gpd per square foot, the maximum underflow at the inlet gaging station would be only 1,300 acre-feet per year.

Two wells, A2–2–35abl and –35ab2, were drilled near the outlet gaging station and penetrated, respectively, 22 and 23 feet of alluvium before entering limestone bedrock. (See fig. 31.) As

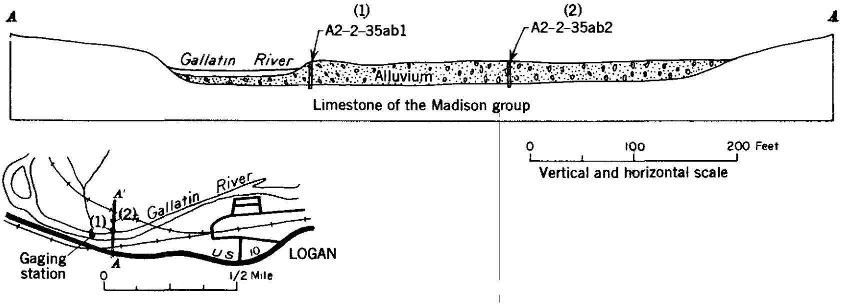

FIGURE 31.—Geologic section near Logan.

these wells, drilled in September 1952, reached no water, apparently all underflow at that time was restricted to the alluvium underlying the riverbed. At the time of spring runoff, however, more of the alluvium probably transmits underflow. Although the river crosses several limestone formations at Logan, the formations are not known to be very cavernous in that vicinity, and loss of water into them is believed to be small. Underflow through the alluvium plus loss to the limestone formations is considered to be well within the error of measurements at the Logan gaging station.

Thermal water issuing from springs and flowing wells in the valley suggests that the basement rocks may be broken in places by joints or faults. Although water conceivably enters or leaves the valley through such conduits, no evidence indicates that any large amounts of water are conveyed by them. The difference between amounts of water entering and those leaving the valley through openings in the basement rocks probably is so small as to be of no importance.

In the cold-weather months the unmeasured depletions consist largely of snow storage and evaporation of snowmelt, and in the warm-weather months largely of evapotranspiration and increases in the moisture content of the soil. Unmeasured accretions consist largely of snowmelt that results in increased runoff.

ANALYSIS

During the period October 1951 through February 1952 ground-water recharge was slight, and, as ground-water discharge continued, there was a decrease in the volume of saturated material within the valley and a gain in surface-water flow. Most of the precipitation occurred as snow, much of which was discharged from the valley by evaporation. Surface-water outflow from the valley during this period consisted largely of water that entered the valley as surface-water inflow and of water discharged from the ground-water reservoir.

During March and April 1952 soil moisture was replenished and the ground-water reservoir received considerable recharge from melting snow and precipitation. Surface-water outflow from the valley still exceeded surface-water inflow, however, because precipitation and snowmelt added to the runoff.

In May 1952 the ground-water reservoir was replenished further, in part by the infiltration of surface water diverted for irrigation and in part by precipitation. Much water was consumed by evapotranspiration. It was the month of greatest accretion to the total water supply of the valley and also the month of greatest surface-water outflow from the valley.

During June and July 1952, ground-water storage continued to increase in spite of withdrawals by evapotranspiration and discharge as surface flow. Much of the surface-water inflow to the valley was diverted for irrigation, and part of the diverted water infiltrated to the zone of saturation. Nearly all the precipitation either evaporated or replenished soil moisture; little or none infiltrated to the water table and little or none left the valley as surface-water outflow. For the first time in the 2-year period, surface-water outflow was less than surface-water inflow.

In August 1952, despite continued recharge to the ground-water reservoir, discharge of ground water exceeded recharge. As surface-water inflow to the valley was entirely consumed within the valley, surface-water outflow from the valley consisted wholly of pickup from the ground-water reservoir and continued to be less than surface-water inflow.

During the period September 1952 to March 1953 ground-water discharge exceeded recharge. Replenishment of soil moisture and evapotranspiration exceeded precipitation, the difference being largely accounted for by discharge from the ground-water reservoir. Surface-water outflow from the valley was greater than surface-water inflow throughout this period, the increase consisting almost wholly of ground-water discharge.

Beginning in April 1953 and continuing through the next July, the ground-water reservoir was filled to a level only slightly below that of July 1952. Apparently most of the recharge resulted from the infiltration of rainfall and applied irrigation water. In contrast to the previous spring, direct recharge from melting snow was insignificant. Except during April, surface-water outflow from the valley was less than surface-water inflow.

In August and September 1953, discharge of ground water again exceeded recharge. Most of the precipitation and surface-water inflow to the valley were disposed of by evapotranspiration and the replenishment of soil moisture; surface-water outflow from the valley consisted almost wholly of ground water discharged from storage.

Despite the constantly varying ratio of ground-water recharge to discharge, the volume of ground water in storage in the Gallatin Valley at the end of the 2-year period almost exactly equaled the volume in storage at the beginning. Although precipitation, particularly as snowmelt, sometimes is significant as a source of recharge to the ground-water reservoir, surface-water inflow to the valley, diverted for irrigation, is by far the principal source of recharge. Even though surface-water inflow was insufficient for existing irrigation requirements, surface-water outflow from the valley during the 2-year period was slightly greater than surface-water inflow.

WATER-RESOURCES INVENTORY, WATER YEARS 1935 THROUGH 1951

Estimates of the annual changes in the surface-water supply of the valley for the 17 water years preceding the 2-year period of the monthly inventory are given in table 24. In this table, the estimates of surface-water inflow to the valley are those given in table 10, and the values for surface-water outflow are the measurements of the flow of the Gallatin River at Logan, as given in table 7.

The estimated values for precipitation were derived as follows: The ratio was determined between (a) total precipitation on the valley as measured in water years 1952 and 1953 (table 5) and (b) precipitation during those same years at the Bozeman and Belgrade stations of the U. S. Weather Bureau (tables 2 and 3). The annual precipitation by water years at the Bozeman station during the period 1934-40 and the averaged annual precipitation by water years at the Bozeman and Belgrade stations for the period 1940-51 were multiplied by this ratio. The results probably are accurate within about 20 percent.

The values for the net gains from, or losses to the ground-water reservoir are the differences between successive October 1 points on the graph in figure 29 multiplied by 0.15 (the specific yield for the valley as a whole). Net depletions, excluding net loss to the ground-water reservoir, were computed by subtracting (a) surface-water outflow from the valley plus net losses of surface water to the ground-water reservoir from (b) surface-water inflow to the valley plus precipitation on the valley plus net gains in surface-water flow derived from the ground-water reservoir. As pointed out on page 132, depletions other than losses to the ground-water reservoir consist largely of evapotranspiration, increase in soil moisture, and storage as snow. The magnitude of evapotranspiration, the largest of these depletions, is affected by such factors as volume of water available, temperature, wind velocity, relative humidity, hours of sunshine, and length of the growing season. Although an attempt was made to establish a constant relationship between the magnitude of evapotranspiration and the factors affecting it, none was found.

TABLE 24.—*Estimated annual changes in surface-water supply of the Gallatin Valley, water years 1935 through 1951, in thousands of acre-feet*

Water year	Surface-water inflow to Gallatin Valley	Surface-water outflow from Gallatin Valley (Gallatin River at Logan)	Net gain (+) or loss (−) in surface-water flow	Accretions occurring within Gallatin Valley			Depletions occurring within Gallatin Valley			Net gain (+) or loss (−) occurring within Gallatin Valley	Total accretions to surface-water supply of Gallatin Valley (total surface-water inflow plus total accretions within valley)	Total depletions of surface-water supply of Gallatin Valley (total depletions within valley plus surface-water outflow)
				Precipitation	Net gain from ground-water reservoir (ground-water discharge)	Total	Net depletions, excluding loss to ground-water reservoir	Net loss to ground-water reservoir (ground-water recharge)	Total			
1935	570	396	−174	330	.....	330	447	57	504	−174	900	900
1936	568	469	−99	300	54	354	453	.....	453	−99	922	922
1937	560	448	−112	410	.....	410	469	53	522	−112	970	970
1938	716	610	−106	380	.....	380	436	50	486	−106	1,096	1,096
1939	642	559	−83	380	23	403	486	.....	486	−83	1,045	1,045
1940	644	596	−48	390	0	390	438	0	438	−48	1,034	1,034
1941	546	481	−65	460	.....	460	520	5	525	−65	1,006	1,006
1942	816	820	+4	430	.....	430	415	11	426	+4	1,246	1,246
1943	930	900	−30	560	.....	560	585	5	590	−30	1,490	1,490
1944	730	711	−19	470	.....	470	471	18	489	−19	1,200	1,200
1945	713	667	−46	370	20	390	436	.....	436	−46	1,103	1,103
1946	757	709	−48	410	.....	410	423	35	458	−48	1,167	1,167
1947	948	928	−20	520	.....	520	530	10	540	−20	1,468	1,468
1948	1,044	1,077	+33	570	32	602	569	.....	569	+33	1,646	1,646
1949	696	712	+16	420	27	447	431	.....	431	+16	1,143	1,143
1950	762	710	−52	420	.....	420	432	40	472	−52	1,182	1,182
1951	730	715	−15	370	23	393	408	.....	408	−15	1,123	1,123

It is probable, therefore, that the relationship is complex and not easily resolved.

HYDROLOGIC UNITS WITHIN THE GALLATIN VALLEY

VALLEY FLOOR

The floor of the Gallatin Valley is underlain by alluvium deposited by the Gallatin and East Gallatin Rivers. In this report, the valley floor has been subdivided arbitrarily into five subareas—the Gateway, Belgrade, Central Park, Manhattan, and Upper East Gallatin (fig. 2).

GATEWAY SUBAREA

The Gateway subarea extends northward from the inlet at the south end of the valley to the vicinity of Bozeman Hot Springs, a distance of about 10 miles, and comprises an area of about 16 square miles. Most wells in this subarea are 10 to 40 feet deep, though near the margins some of the wells are considerably deeper.

The alluvium of the Gallatin River in this subarea ranges in width from about 1½ miles to 2 miles and is bordered along its east margin by a narrow terracelike belt of stream deposits and colluvium derived from Goochs Ridge. The alluvium was deposited in a trench cut by the Gallatin River into relatively impermeable Tertiary strata. The subsurface configuration of the trench is not known, but in cross section probably appears as represented by one of the sketches in figure 32. A well (D3–4–3ca) near Gallatin Gateway was drilled through 80 feet of alluvium before entering Tertiary strata, and test hole D2–4–11dc, 1 mile north of the downstream boundary of the subarea, penetrated 68 feet of alluvium before entering Tertiary strata. The average thickness of the alluvium in the subarea, however, is estimated to be about 55 feet. No evidence indicates that the alluvium is other than uniformly coarse and permeable. The coefficient of transmissibility, as determined by aquifer tests, was 380,000 gpd per foot at well D2–4–26dc and 170,000 gpd per foot at well D3–4–11bdb. A similar test made at well D2–4–11dc, just north of the subarea but in the same aquifer, gave a coefficient of transmissibility of 270,000 gpd per foot.

The main sources of recharge are the irrigation canals that cross the subarea and the streams that enter it from the highlands on either side. During years of heavy snowfall, if the soil is not frozen, spring snowmelt also is an important source of recharge. The ground water moves downvalley and toward the

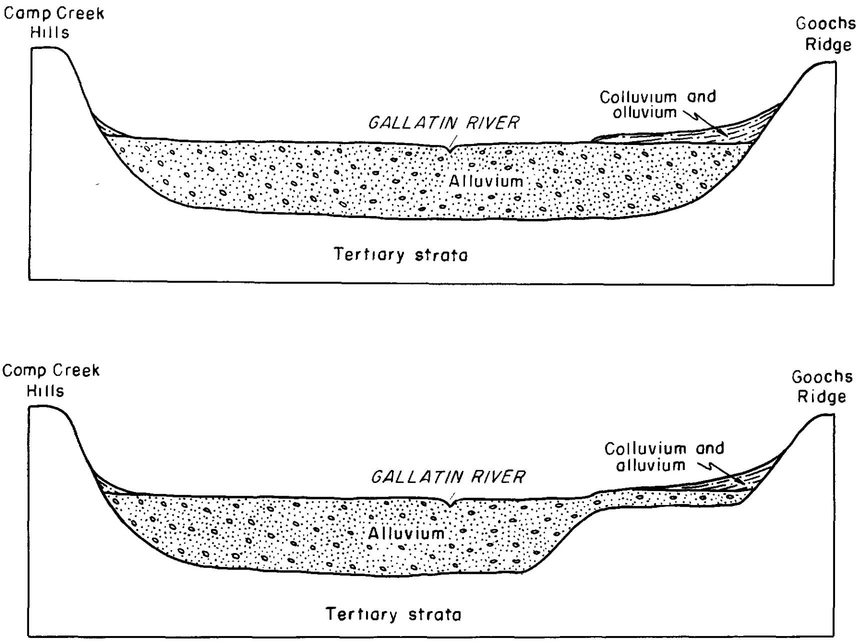

FIGURE 32.—Diagrammatic sections of the Gateway subarea showing two possible interpretations of subsurface geologic relationships.

Gallatin River. Most of it either discharges into the Gallatin River or leaves the subarea as underflow to the adjoining Belgrade subarea; a small amount discharges into a few small streams, principally Fish Creek, on the alluvial plain southwest of Axtell Bridge; and the remainder is discharged by evapotranspiration, especially along the Gallatin River.

At present the water table is between 10 and 15 feet below the land surface throughout much of the Gateway subarea. During a period of dry years, however, the ground-water level undoubtedly would decline. For example, if annual recharge over a period of years were only half the present rate, decline of the water table east of the Gallatin River probably would average about 10 feet, and at the extreme east margin of the subarea it would be as much as 20 feet. West of the river the decline probably would not be as great. However, as the flow of the Gallatin River where it enters this subarea is dependably large and as several major irrigation canals either cross or skirt the area, it is unlikely that recharge would be deficient for a succession of years.

A graph showing the cumulative departure from the volume of saturated material as of the end of June 1952 in the Gateway subarea (fig. 33) indicates that ground-water discharge exceeded ground-water recharge during all the months of water year 1953 except May and June, when recharge exceeded discharge. From the spring of 1952 to the spring of 1953, ground-water discharge from the Gateway subarea as surface water is estimated to have

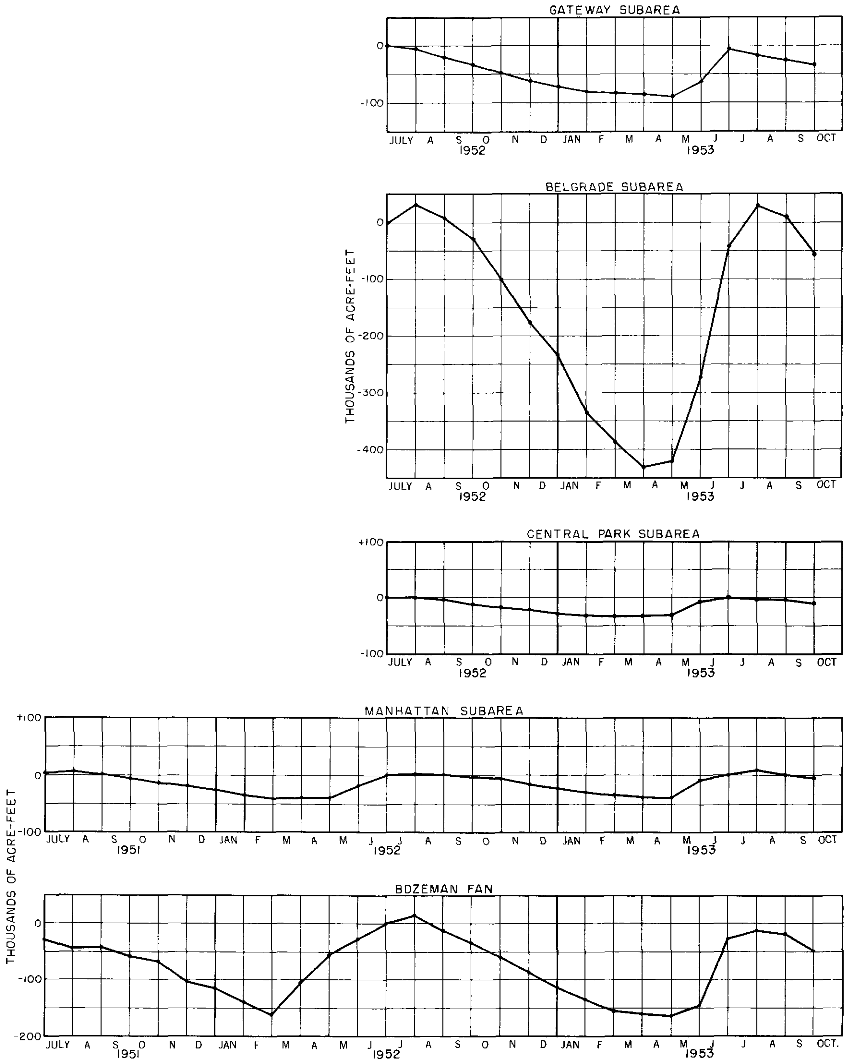

FIGURE 33.—Graphs showing the cumulative departure from the volume of saturated material as of the end of June 1952 in the Gateway, Belgrade, Central Park, and Manhattan subareas and in the Bozeman fan.

been at least 25,000 acre-feet. This estimate is based on the gain in flow of the Gallatin River between the Gallatin Gateway and Axtell Bridge gaging stations during November and December 1952 and January and February 1953 (table 9), which were months of negligible gain from surface runoff and months in which no diversions were made. However, because ground-water discharge from the Gallatin Valley as a whole during that year was somewhat above average for the preceding 18-year period (table 18), it is assumed that the volume of ground water discharged as surface water from the Gateway subarea that year was above average in about the same ratio as was that from the valley as a whole. Therefore, the average annual dicharge of ground water from the Gateway subarea as surface water is estimated to be about 20,000 acre-feet. Because, in general, average annual recharge equals average annual discharge, the average annual recharge to the Gateway subarea is at least 20,000 acre-feet plus the volume of ground water discharged by evapotranspiration within the subarea and by underflow downvalley to the Belgrade subarea.

Thus, the average annual volume of ground water theoretically available for additional consumptive use in the Gateway subarea is at least 20,000 acre-feet. If this or a lesser amount were consumptively used, the annual flow of surface water across the north boundary of the subarea would be reduced by an equivalent amount but would not be less than the annual flow of surface water into the subarea. If much more than 20,000 acre-feet were pumped each year and no part of the pumped water returned to the zone of saturation, the water table eventually would be lowered to a level below that of the river. Recharge from the river would result, and surface-water outflow from the subarea would be less than inflow.

Pumping of ground water on a large scale in the Gateway subarea would lower the water table, of course, and thereby tend to relieve waterlogging in poorly drained places. The hypothetical effect on the water-table position that would result from increased consumptive use of ground water is illustrated in figure 34. In an aquifer that discharges principally by seepage into a stream, such as the alluvium in the Gateway subarea, the lowering of the water level in wells tapping the aquifer would be in proportion to the initial height of the water level in the well above the level of the surface of the stream. In reality, however, the position of the water table would be affected by factors other than the volume of withdrawals. Some recharge may now be rejected,

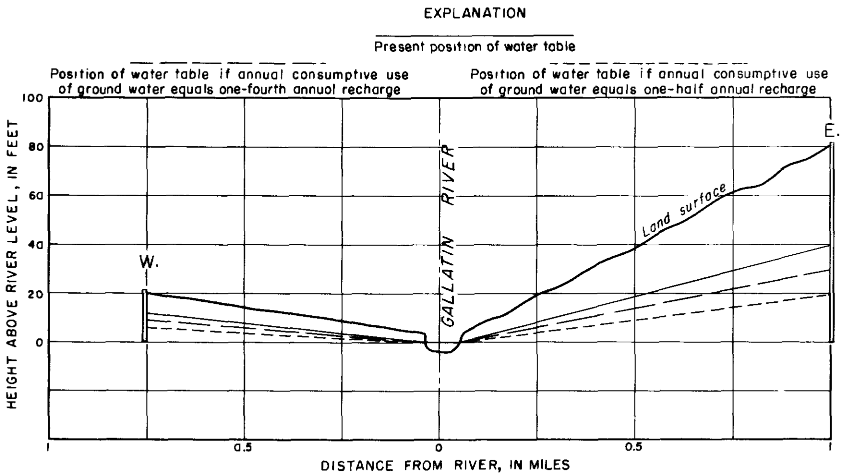

FIGURE 34.—Diagrammatic section of the Gateway subarea showing the theoretical changes in position of the water table that would result from increased consumptive use of ground water.

and additional pumping might salvage some of it, so that the decline would not be so great as might otherwise be expected.

BELGRADE SUBAREA

Northward from Bozeman Hot Springs, the surface of the alluvium of the Gallatin River broadens into an extensive plain that merges on the southeast with the alluvium of Middle (Hyalite) Creek and on the east with the alluvium of the East Gallatin River. (See pl. 2.) The Belgrade subarea comprises about 67 square miles. Its northern boundary is the east-west county road half a mile south of Central Park.

The alluvium underlying the Belgrade subarea is the principal ground-water reservoir in the Gallatin Valley. Most of this alluvium was deposited by the Gallatin River and consists of cobbles and coarse gravel, intermixed with varying amounts of sand, silt, and clay.

The alluvium thickens to the north. In test hole D2–4–11dc, near the south boundary of the subarea, it was 68 feet thick, and in test hole D1–4–25aa2, about 4 miles north, it was 137 feet thick. Test hole A1–4–25dc, about 5 miles farther north, was drilled in alluvium to a depth of 400 feet without penetrating strata of Tertiary age. Although, locally, layers of clay and silt reduce its permeability, the alluvium generally is rather permeable and fairly homogeneous. The coefficient of transmissibility of the alluvium in this subarea was determined by aquifer tests at 13 sites. The values obtained at 9 of the sites were between 94,000 and 290,000 gpd per foot and averaged 200,000 gpd per foot. At 3 of the sites it was less than 70,000 gpd per foot and at 1 it was 670,000 gpd per foot.

One of the smaller values, 58,000 gpd per foot, was obtained at test hole A1–5–28db2, which was drilled into the alluvium of the East Gallatin River. This value confirms the inference, based on examination of test-hole samples, that the alluvium of the East Gallatin River is less permeable than that of the Gallatin River. Another of the smaller values was obtained from test hole D1–5–9cd, which was drilled into alluvium deposited by either or both the East Gallatin River and Middle (Hyalite) Creek. The coefficient of transmissibility obtained at this site was 50,000 gpd per foot, but it represented only 11 feet of saturated material. The coefficient of permeability, therefore, was about 4,500 gpd per square foot, which is the same as the coefficient of permeability computed for the 58-foot thickness of saturated material in test hole D2–4–11dc. Underlying the 11-foot water-bearing zone in test hole D1–5–9cd was an impermeable layer, possibly lime-cemented silt. The alluvium beneath the impermeable layer also yielded water, but no satisfactory test of its hydrologic properties was made; thus, although the coefficient of transmissibility of the entire saturated section is not known, it probably is considerably more than that for the 11-foot zone. A value of 70,000 gpd per foot for the coefficient of transmissibility was obtained from well D2–4–14bb, which was only 11.1 feet deep. This coefficient of transmissibility probably is representative of only part of the alluvium, especially in view of the much larger value, 270,000 gpd per foot, obtained from nearby test hole D2–4–11dc.

The largest coefficient of transmissibility, 670,000 gpd per foot, was obtained at well D1–4–1cb and was more than double that obtained from any other test in this subarea. The flatness of the water table in the vicinity of the well (pl. 5) also indicates a high transmissibility. As no description of the water-bearing material was available for study, the reason for the high transmissibility could not be determined. The gravel penetrated in the drilling of the somewhat deeper well D1–4–2dd, only half a mile south of well D1–4–1cb, was very silty and when tested was found to have a coefficient of transmissibility of 130,000 gpd per foot. As no geologic evidence indicates that the saturated thickness of the alluvium changes substantially between these wells, it seems likely that the higher coefficient of transmissibility at well D1–

4–1cb is due to greater permeability of the water-bearing material. In general, it is probable that the coefficient of transmissibility is greatest in the north-central part of this subarea where the alluvium is thickest. However, as no well in the Belgrade subarea north of well D1–4–25aa2 is known to have been drilled through the entire thickness of the alluvium, transmissibility values from tests in that part of the subarea would not necessarily represent the transmissibility of the full thickness of the alluvium.

The coefficient of transmissibility of the part of the Tertiary section tested at test hole D1–4–25aa2 was 17,000 gpd per foot, which is much lower than any of the values for the alluvium.

Seepage from irrigation canals and applied irrigation water, influent seepage from the Gallatin River, and ground-water underflow from upgradient areas are the principal sources of recharge to the alluvium of the Belgrade subarea, though influent seepage from the East Gallatin River also is significant. Recharge by precipitation is of minor importance. Water in the zone of saturation moves in a generally northward direction and is discharged by underflow to the adjoining Central Park subarea. Some, however, is discharged into the Gallatin and East Gallatin Rivers and into Middle (Hyalite) Creek, and some is discharged by evapotranspiration where the water table is close to the surface.

Recharge to the Belgrade subarea during water year 1953 began to exceed discharge in April and continued to do so through July; discharge exceeded recharge in all the other months of the year. (See fig. 33.) From the spring of 1952 to the spring of 1953 about 135,000 acre-feet of ground water was discharged from the Belgrade subarea as surface-water flow and as ground-water underflow to downgradient subareas. This estimate is based on the average monthly rate of decrease in ground-water storage in the Belgrade subarea during the period November 1952 through February 1953 (fig. 33), when recharge to the subarea consisted only of underflow from the adjacent upgradient subareas and when discharge of ground water by evapotranspiration was negligible. Because ground-water discharge as surface-water flow was above normal that year, the average annual discharge by this means plus that by underflow is estimated to be at least 100,000 acre-feet. Therefore, average annual recharge within the subarea is at least 100,000 acre-feet plus an amount equal to the volume of ground water discharged by evapotranspiration.

The Gallatin River is influent in the reach from Cameron Bridge (sec. 22, T. 1 S., R. 4 E.) northward to a mile beyond Irving Bridge (sec. 4, T. 1 S., R. 4 E.). Streamflow loss in this reach during the period November 1952 through April 1953, when the only significant diversion was into Baker Creek, was about 12,700 acre-feet. (See table 25.) If the ratio (0.10) between total streamflow losses (12,700 acre-feet) and the flow at Cameron Bridge for the same period (122,400 acre-feet) was applied to the flow at Cameron Bridge for 1952 (628,000 acre-feet) and for 1953 (369,000 acre-feet), recharge to the ground water by influent seepage from the Gallatin River was about 63,000 acre-feet in 1952 and about 37,000 acre-feet in 1953.

TABLE 25.—*Monthly losses in flow of the Gallatin River between Cameron Bridge and Central Park, in acre-feet*

Month	Cameron Bridge (Gallatin River near Belgrade)	Baker Creek	Irving Bridge [1]	Central Park (Gallatin River near Manhattan)	Gain (+) or loss (−) between Cameron and Irving Bridges	Gain (+) or loss (−) between Irving Bridge and Central Park	Total loss
	1	2	3	4	1 −(2+3)	3 −4	
1952							
November	17,200	1,390	15,700	14,400	−100	−1,300	1,400
December	23,700	1,110	20,700	20,600	−1,900	−100	2,000
1953							
January	22,500	790	19,000	20,200	−2,700	+1,200	2,700
February	18,600	670	15,800	15,700	−2,100	−100	2,200
March	19,800	650	16,500	17,800	−2,600	+1,300	2,600
April	20,600	770	20,100	18,300	+300	−1,800	1,800
Total	122,400	5,380	107,800	107,000	....	....	12,700

[1] Preliminary data from U.S. Bureau of Reclamation.

The East Gallatin River between Lux Siding (sec. 23, T. 1 S., R. 5 E.) and Penwell Bridge (sec. 29, T. 1 N., R. 5 E.) also is influent during part of the year. (See table 26.) Middle (Hyalite) Creek (measured in sec. 32, T. 1 N., R. 5 E.) and Churn Creek drain (measured in sec. 23, T. 1 S., R. 5 E.) are tributaries of the East Gallatin. During the period December 1952 through June 1953, the East Gallatin River in that reach lost about 9,500 acre-feet by influent seepage and during the remainder of 1953 it gained in flow.

In this subarea the water table generally is highest near the end of July or in early August (fig. 33), at which time the water table is less than 20 feet below the land surface in most of the

TABLE 26.—*Monthly gains and losses in flow of the East Gallatin River between Lux Siding and Penwell Bridge, in acre-feet*

[Preliminary data from U.S. Bureau of Reclamation]

Month	East Gallatin River near Lux Siding	Churn Creek drain	Middle (Hyalite) Creek	East Gallatin River at Penwell Bridge	Gain (+) or loss (−)
	1	2	3	4	4− (1+2+3)
1952					
November	3,800	111	485	4,890	+490
December	4,120	69	28	3,650	−570
1953					
January	4,130	128	103	3,900	−460
February	2,580	160	378	2,660	−460
March	4,100	236	928	4,910	−350
April	7,170	252	1,460	7,560	−1,300
May	21,300	325	4,120	22,600	−3,100
June	36,200	726	7,400	[1] 31,000	[1] −3,300
July	7,150	24	2,030	9,380	+180
August	4,220	40	2,230	6,810	+320
September	3,840	39	2,460	7,180	+840
October	3,680	45	2,320	6,530	+480
November	3,700	54	1,570	5,680	+360

[1] Estimated.

area. The depth to the water table is somewhat greater in the vicinity of Belgrade than elsewhere; even at its highest position during the year, it may be as much as 40 feet below the land surface. The difference between the highest and lowest positions of the water table ranges from about 10 feet or less along the margins of the area to more than 40 feet in the vicinity of Belgrade. (See pl. 7.) Water-level fluctuations in selected wells are illustrated on plate 9. Near the margins of the Belgrade subarea most of the wells are 20 to 60 feet deep, whereas in the vicinity of Belgrade wells are 60 to 200 feet deep.

In this subarea some of the ground water occurs under water-table conditions and the remainder under artesian conditions. It is thought, however, that confinement of water is only local in extent. Water-level data suggest the presence, in part of the area, of a relatively impermeable layer that retards infiltrating recharge and creates, thereby, a temporarily perched zone of saturation. Test drilling, together with additional information on water-level fluctuations, is needed to determine the exact nature and extent of the indicated condition.

In drilling test hole D1–4–25aa2, artesian water was encountered in the Tertiary strata at a depth of 149 to 223 feet. The water was under about 13 feet of head at the land surface. Available evidence, however, indicates that the Tertiary strata would not yield sufficient water for irrigation.

Consumptive use of part or all of the 100,000 acre-feet per year of ground water estimated to be theoretically available for use in the Belgrade subarea would cause a lowering of the water table and a corresponding decrease in the volume of natural ground-water discharge from the subarea. If it is assumed that 100,000 acre-feet of the ground water added to storage within the subarea is discharged annually along the northern boundary of the subarea, consumptive use of 25,000 acre-feet of ground water within the subarea theoretically would cause a 9-foot lowering of the water level in a well 2 miles south of the northern boundary and an 18-foot lowering in a well 3.5 miles south of the northern boundary. (See fig. 35.) Correspondingly larger declines of the water level would occur if annual consumptive use of ground water were greater. If net withdrawals became great enough, the point at which the Gallatin River becomes influent would migrate southward, and the East Gallatin River, instead of gaining in flow, would become a losing stream. Discharge of ground water by evapotranspiration and by springs

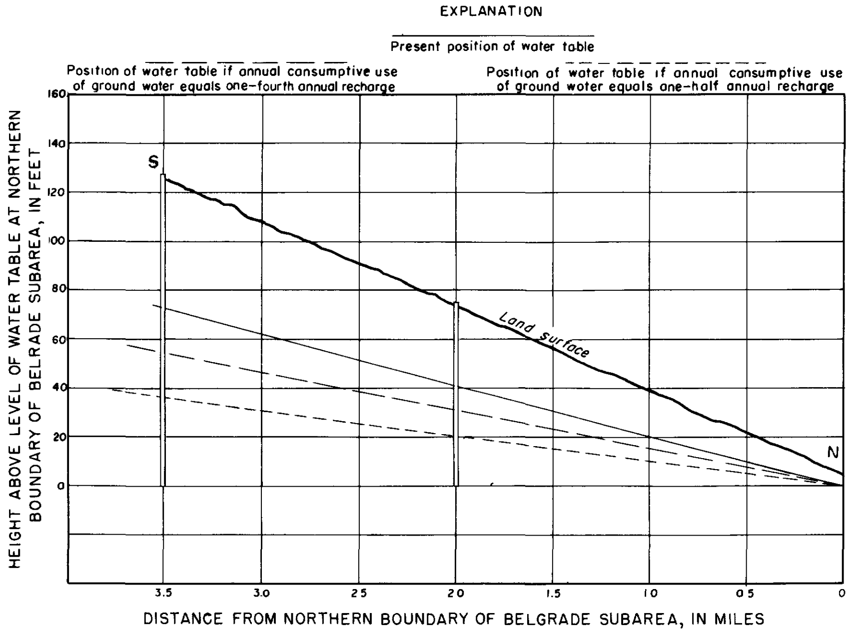

FIGURE 35.—Diagrammatic section of the northern part of the Belgrade subarea showing changes in position of the water table that would result from increased consumptive use of ground water.

and effluent streams in the Central Park subarea also would be reduced if withdrawals of ground water in the Belgrade subarea resulted in a reduction of underflow into the Central Park subarea.

A succession of dry years would lessen recharge and have similar effects on the position of the water table and the amount of ground-water discharge from the subarea. However, as a result of reduction in recharge alone, the summertime position of the water table probably would not drop lower than the wintertime low reached in the early months of 1952 and 1953.

CENTRAL PARK SUBAREA

The Central Park subarea is that part of the valley floor extending northward from the Belgrade subarea. It has an area of about 40 square miles. It is characterized by a high water table, and much of it is swampy throughout the year.

Compared with the alluvium of the Belgrade subarea, that of the Central Park subarea is finer grained and better sorted. Test drilling indicates that the alluvium north of the postulated east trending Central Park fault, near the south margin of the subarea, is much thinner than that south of the fault. Test hole A1–4–19cb, about a fourth of a mile south of the fault, was drilled to a depth of 301 feet without completely penetrating the alluvium, and test hole A1–4–15da2, almost on the fault, entered Tertiary strata at a depth of 215 feet. In contrast, test hole A1–4–5da, about 2 miles north of the fault, penetrated only 31 feet of alluvium before entering material thought to be of Tertiary age.

The coefficient of transmissibility of the alluvium was determined at five sites. At test hole A1–4–22dc the coefficient was 480,000 gpd per foot, and at test hole A1–4–19cb it was 480,000 gpd per foot for the material between depths of 5 and 94 feet and 180,000 gpd per foot for the material between depths of 117 and 180 feet; these coefficients assume that the 2 zones are effectively separated at least so far as the duration of the tests is concerned. The coefficient of permeability of the 2 water-bearing zones in test hole A1–4–19cb was 5,500 and 2,900 gpd per square foot, respectively. Three values for the coefficient of transmissibility of the alluvium north of the Central Park fault were 38,000, 100,000, and 110,000 gpd per foot, and computed coefficients of permeability were 1,500, 4,000, and 4,000 gpd per square foot, respectively. The thinning of the alluvium northward from the Central Park fault is reflected by the lower transmissibility. The coefficient of transmissibility of Tertiary strata penetrated by test hole A1–4–15da2 was 3,700 gpd per foot.

The Central Park subarea contains the largest tract of poorly drained land in the Gallatin Valley. Throughout nearly all the subarea the water table is less than 5 feet below the land surface, and most wells are less than 25 feet deep. Typical hydrographs of the water-level fluctuations in wells are shown in figure 36.

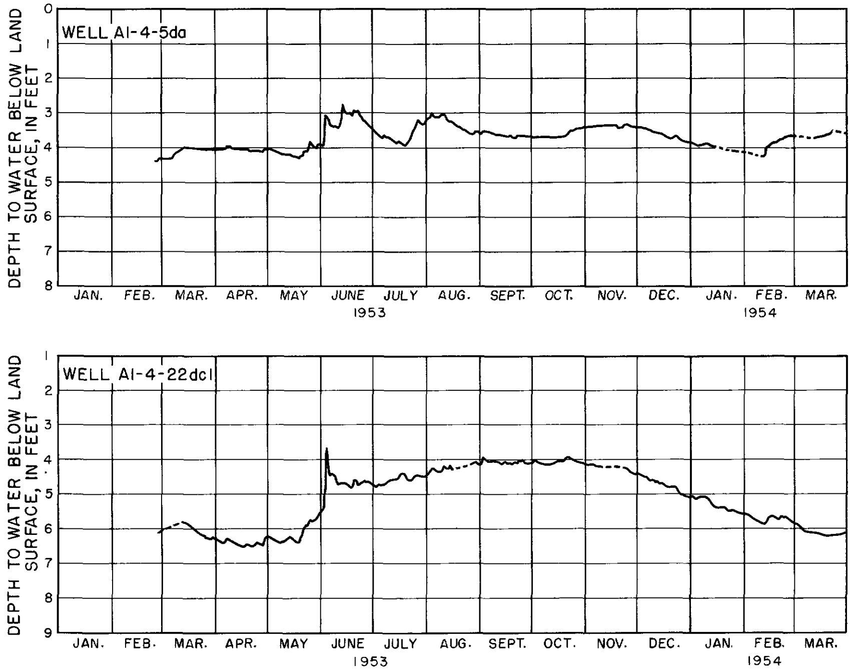

FIGURE 36.—Hydrographs of the water level in wells A1–4–5da and A1–4–22dc1.

The ground-water reservoir in the part of the subarea between the Gallatin and East Gallatin Rivers is recharged principally by underflow from the Belgrade plain. The bottom land west of the Gallatin River is recharged mainly by underflow from that part of the Belgrade subarea west of the Gallatin River, the Camp Creek Hills, and the Manhattan terrace; the bottom land east of the East Gallatin River is recharged by underflow from the Dry Creek subarea and the Spring Hill fan.

In the Central Park subarea, more ground water is discharged at the surface than in any other part of the Gallatin Valley. Because the alluvium north of the Central Park fault cannot transmit all the water entering the subarea by underflow (estimated to be 300,000 acre-feet per year), some of the ground water is forced to the surface, where it is discharged by spring flow and effluent seepage into streams and by evapotranspiration. It is estimated that 70,000 acre-feet of water is discharged annually to the principal spring-fed streams that rise in this subarea. (See fig. 37; table 7, p. 69.) Because Thompson Creek is least affected by extraneous influences, the hydrograph of its flow illustrates best the seasonal streamflow pattern of the spring-fed

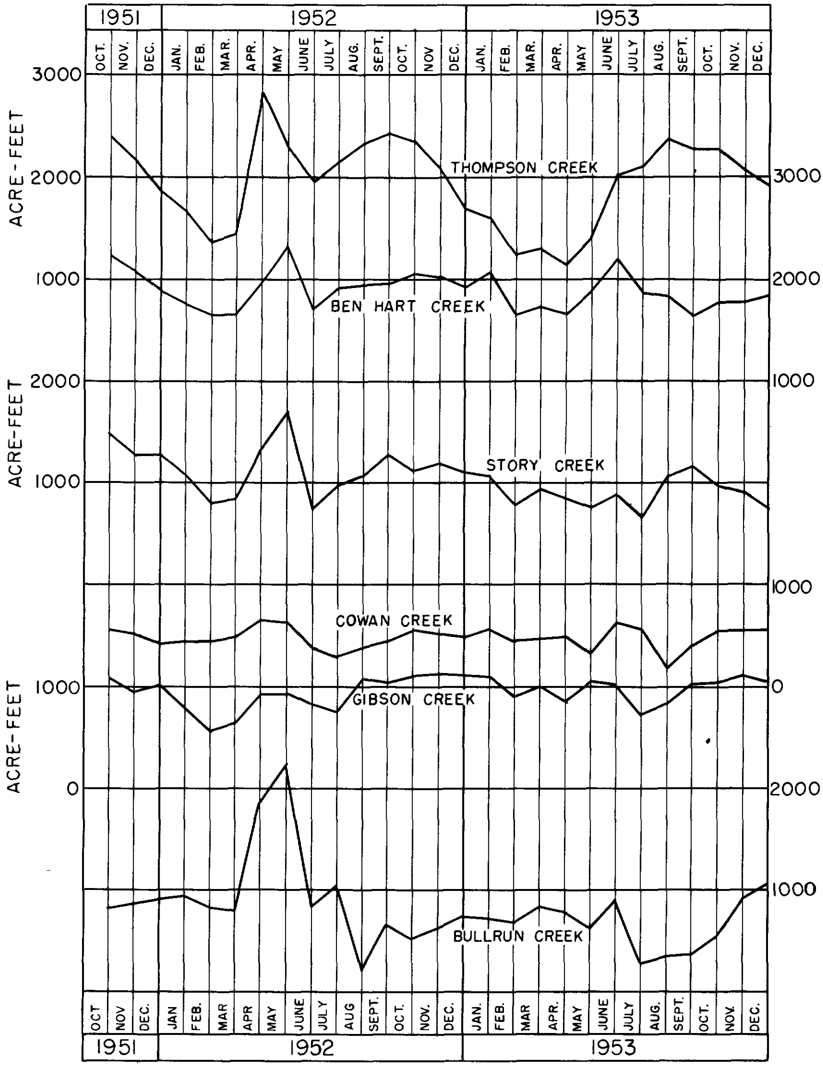

FIGURE 37.—Hydrographs of the flow of the principal streams rising in the Central Park subarea.

streams. Except for the comparatively minute amount of ground water that leaves by underflow through the outlet of the Gallatin Valley at Logan, all the ground water that is transmitted by the alluvium in this subarea is discharged eventually by seepage into the Gallatin or East Gallatin Rivers.

The graph showing cumulative departure from the volume of saturated material as of the end of June 1952 (fig. 33) indicates that net recharge characterized the period March through June and that net discharge characterized the other months of the year. The magnitude of the changes in volume of saturated material is far less than in the Belgrade subarea.

Although increased consumptive use of ground water in upgradient parts of the Gallatin Valley would result in some reduction of ground-water underflow into the Central Park subarea, it is unlikely that the water table would be lowered significantly in more than the extreme southern part of the subarea.

Even though underflow into the subarea were considerably less, the alluvium north of the Central Park fault probably still would be incapable of transmitting all of it. Therefore, lowering of the water table north of the fault can be effected only by artificially increasing discharge. Pumping of ground water for the express purpose of lowering the water table is not considered feasible because so many wells would be needed. Surface drains probably would be much more effective and would cost less than wells. Two types of drainage measures may be practicable—one, the construction of interception drains, as recommended by the U.S. Soil Conservation Service (Long, 1950, p. 11), and the other, the deepening and straightening of existing streams and construction of new drains parallel to the present streams. Some drains of the interception type have been constructed. Under the existing pattern of water use, deepening of present streambeds would lower the water table about as much as the amount of deepening.

No foreseeable increase in consumptive use of ground water in the Central Park subarea would lower the water table appreciably, nor would a succession of dry years.

MANHATTAN SUBAREA

The Manhattan terrace is separated from the alluvial plain of the Gallatin River by a low north- and east-facing escarpment along its outer edge and from the higher Camp Creek Hills by a colluvial slope along its southwestern border. It comprises about 8 square miles.

Only a few feet of gravel overlies Precambrian bedrock in the face of the escarpment at the northwest corner of the subarea, but the gravel apparently thickens eastward to a point north of Manhattan. Test hole A2–3–33da penetrated 55 feet of alluvium before entering fanglomerate of Tertiary(?) age, and well A1–3–4da, about two-thirds of a mile northwest of Manhattan, was drilled through 38 feet of alluvium before entering material of Tertiary(?) age. Southeast of Manhattan, near the terrace escarpment, a 30-foot thickness of alluvium was penetrated in the drilling of well A1–3–14dd. This range in thickness indicates probable channeling of the Tertiary strata before the alluvium was deposited. The average thickness of the alluvium is estimated to be between 30 and 45 feet. The coefficient of transmissibility of the alluvium was determined at 4 sites and ranged from 120,000 to 140,000 gpd per foot. As the saturated alluvium is known to be thin, these values indicate that the alluvium is highly permeable.

The fanglomerate penetrated by test hole A2–3–33da crops out in draws along the north-facing part of the terrace escarpment. Fractures in this material yield water to spring A2–3–32ac and supply water to nearby wells.

Artesian water was found between the depths of 215 and 300 feet in test hole A2–3–33da. The water, which rose to within 12 feet of the land surface, was derived from Tertiary strata that immediately overlie rocks of the Belt series. Unfortunately the water contained too much hydrogen sulfide and sodium salts to be fit even for irrigation.

The graph showing cumulative departure from the volume of saturated material as of the end of June 1952 in the Manhattan subarea (fig. 33) indicates that in both 1952 and 1953 net recharge to the alluvium began in May and continued through July and that discharge exceeded recharge the remainder of the year.

The ground-water reservoir in the subarea is recharged almost wholly by seepage from irrigation canals that skirt the inner edge of the terrace, and from applied irrigation water. The water used for irrigation, though diverted from surface streams, is largely return flow from irrigation in the Belgrade subarea and in the Camp Creek Hills, and, therefore, is a dependable source of supply. Discharge is mainly by underflow to the bottom land adjacent to the terrace escarpment, where it is picked up by the Gallatin River and tributary drains. Water is discharged also by evapotranspiration, mostly from a small waterlogged area south of Manhattan, and through a series of springs in the draws along the north-facing part of the terrace escarpment. Discharge of ground water from the Manhattan subarea, exclusive of that discharged by evapotranspiration, is estimated to have been 14,000 acre-feet between the spring of 1952 and the spring of 1953; the average annual discharge probably is about 10,000 acre-feet. The average annual recharge exceeds this average annual discharge by the amount discharged by evapotranspiration.

Fluctuations in the discharge of springs A2–3–32ac, –32ad, and –33ba reflect the changes in volume of saturated material, and, thus, the dependence of the flow on recharge from irrigation water. Discharge from springs A2–3–32ad and –32ac, the 2 largest springs, fluctuated from 22.6 and 14.5 cfs, respectively, in August 1952, to 8.3 and 3.9 cfs, respectively, in April 1953.

During the summer the water table in much of the area is within 10 to 20 feet of the land surface. Wells range from 10 to 105 feet in depth. The water-level fluctuations in well A2–3–33da (fig. 38) are somewhat greater than in most other wells in this subarea because of the proximity of the well to the terrace escarpment.

Waterlogging in the area south of Manhattan is caused by excessive recharge. Lining the Moreland Canal in the reach adjacent to the area would reduce recharge, and a ditch in the waterlogged area would help drain ground water. Additional investigation would be necessary to determine the feasibility and relative effectiveness of these measures, singly or in combination.

The alluvium underlying the Manhattan subarea is sufficiently permeable to yield water freely, but in most of the subarea is too thin to supply sufficient water for irrigation. At the peak of the irrigation season, when water shortages are sometimes acute in other parts of the valley, return flow from irrigation in the Belgrade subarea supplies much of the irrigation water used in the Manhattan subarea. This supply could be supplemented by pumping ground water into the existing canals where they traverse the Belgrade subarea.

UPPER EAST GALLATIN SUBAREA

The Upper East Gallatin subarea consists of the flood plain of the East Gallatin River from the river's point of entry into the valley northwestward for about 11 miles. The subarea is about a quarter of a mile wide at its upper end and broadens to about 2½ miles at its lower end where it adjoins the Belgrade subarea. It comprises abut 10 square miles.

Well D2–6–10dc, near the upper end of the subarea, is reported to have been drilled through 29 feet of alluvium before entering

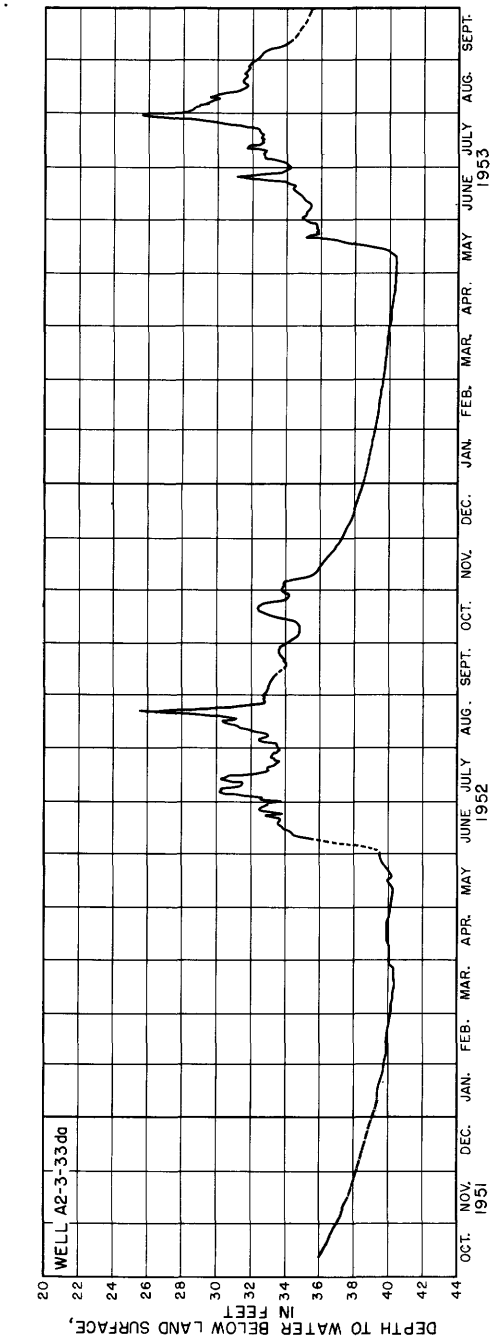

FIGURE 38.—Hydrograph of the water level in well A2–3–33da.

red clay of probable Tertiary age. Test hole D1–5–9cd, near the lower end, was drilled to a depth of 162 feet in the alluvium without reaching the underlying Tertiary strata. In this test hole the alluvium is poorly sorted and contains more silt and clay than the alluvium of the Gallatin River. Because Bear and Bridger Creeks, tributaries to the East Gallatin River in its upper reach, drain areas partly underlain by relatively fine grained easily eroded formations of Cretaceous age, they probably transported to the East Gallatin River much of the fine-grained material in the alluvium.

Although several aquifer tests were made in this subarea, the coefficient of transmissibility could not be determined from the data obtained.

The alluvium is recharged by infiltrating precipitation, by underflow from adjacent areas, and, in the upper reach of the subarea, by seepage from the East Gallatin River and its tributaries. Ground water is discharged by evapotranspiration, seepage into the East Gallatin River in the lower reach of the subarea, and underflow to the Belgrade subarea.

The water table is within 10 feet of the land surface during most of the year. Most wells are less than 30 feet deep, and the range of water-level fluctuations is small.

Although existing data indicate that the alluvium will not yield large quantities of water to wells, additional data should be gathered in order to evaluate accurately the ground-water resources of this subarea.

BOZEMAN FAN

An alluvial fan composed of material derived from the Gallatin Range slopes northward from the mouth of Hyalite Canyon where Middle (Hyalite) Creek enters the Gallatin Valley (sec. 14, T. 3 S., R. 5 E). The fan is bounded on the southwest by Goochs Ridge and on the east by Sourdough (Bozeman) Creek; along its northwest margin it merges with the floor of the valley and on its northeast margin with the flood plain of the East Gallatin River. The area of the fan is about 56 square miles.

The alluvium composing the fan is the principal aquifer in this area. The logs of test holes D1–5–34cc2, D2–4–14ac, and –22cd indicate that the alluvial-fan deposits thin from nearly 200 feet near the head of the fan to a hundred feet or less near the toe of the fan where it grades into, or interfingers with, the alluvium of the Gallatin and East Gallatin Rivers. The coefficient of transmissibility of the alluvial-fan deposits, determined at 6 sites, ranged from 26,000 to 65,000 gpd per foot and averaged

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about 48,000 gpd per foot. The range in values reflects variations in permeability and thickness of the saturated material.

Even where they are drilled into the more permeable, thicker sections of water-bearing alluvial-fan deposits, wells yielding more than 500 gpm should not be expected. Alluvial deposits filling the channels of former distributaries that built the fan are the most likely sources of ground-water supplies. These deposits cross the fan from head to toe and can be located by careful test drilling. Most of the wells on the Bozeman fan are less than 35 feet deep (many are dug wells) and few are more than 75 feet deep. However, when wells D2–6–19cb1 and –19cb2 were drilled about 1 mile south of Bozeman, sufficient water for domestic use reportedly was not obtained until the wells reached depths of 80 and 155 feet, respectively. It is probable that the upper part of the alluvial-fan deposits is not water bearing in the vicinity of these wells because of the draining effect of nearby Sourdough (Bozeman) Creek.

Test hole D2–5–22ccd was drilled through 165 feet of alluvial-fan deposits and 835 feet into the underlying Tertiary strata, and test hole D1–5–34cc2 was drilled through 127 feet of alluvial-fan deposits and 123 feet into Tertiary strata. The Tertiary strata penetrated by both test holes were relatively impermeable. Well D2–6–7ac, drilled in 1936 for the city of Bozeman to augment its water supply, penetrated clay, sand, and gravel to a depth of 304 feet. Although this material, probably mostly of Tertiary age, initially yielded 450 to 500 gpm, the sustained yield, which was much less, was insufficient and the well was abandoned. All available evidence, therefore, indicates that the Tertiary strata underlying the Bozeman fan would not yield sufficient water for irrigation.

Streamflow, irrigation water, and precipitation are the principal sources of recharge on the Bozeman fan. Sourdough (Bozeman) and Middle (Hyalite) Creeks, near where they enter the valley, are sources of recharge, particularly during the months of high streamflow and low ground-water level in the spring. Seepage from the numerous irrigation ditches crossing the surface of the fan, and infiltrating irrigation water applied to the fields, are generally the main sources of recharge during most of the summer. In some years when irrigation water is in short supply, however, the recharge from these sources is correspondingly less.

In this part of the Gallatin Valley precipitation is somewhat greater than elsewhere. Generally much of the winter precipitation is stored as snow; snowmelt and relatively high rainfall in the spring produce appreciable recharge. This was especially true in the 1952 water year. In October 1951 heavy snowfall mantled the Bozeman fan before the soil was frozen. During the succeeding months the average temperature was lower than usual and the abnormally heavy precipitation, nearly twice the average, accumulated as snow on the unfrozen ground. Higher temperatures in March and April caused the snow to melt, but there was little runoff because most of the water infiltrated to the water table. The resultant rise in the water level is shown in figure 33 by the graph for the Bozeman fan. By May, before any significant recharge from streamflow and irrigation water occurred, the increase in saturated material already was 65 percent of the total for the year. During the same period, the volume of saturated material beneath the floor of the Gallatin Valley increased only 32 percent of the total increase for the year.

Precipitation was a much less important source of recharge in the 1953 water year. During the period October 1952 through February 1953, precipitation was only 72 percent of average. There was no snow cover on the Bozeman fan and the soil was frozen. In consequence, recharge by snowmelt was insignificant and net recharge did not begin until May, when streamflow and irrigation water became effective recharge factors. Recharge followed a somewhat similar pattern throughout the remainder of the valley. The great difference in the amount of recharge from precipitation and snowmelt in the 2 water years indicates that this type of recharge cannot be depended upon to occur in any particular year.

Discharge of ground water from the Bozeman fan is by effluent seepage to streams, by underflow to adjacent areas downvalley, and by evapotranspiration. Middle (Hyalite) and Sourdough (Bozeman) Creeks, the only streams that completely cross the Bozeman fan, are effluent in the lower parts of their courses across the fan. Several small streams rise about 3 miles north of the head of the fan and drain northward into either Middle (Hyalite) Creek or the East Gallatin River. During the irrigation season most of the water in the streams draining the Bozeman fan is diverted for irrigation. Evapotranspiration is greatest along the streams and drains. Underflow from the Bozeman fan enters the alluvium underlying the Belgrade plain and the flood plain of the East Gallatin River.

At the head of the fan, where the land is steeply sloping, and at the toe of the fan, where the surface is dissected and drainage is adequate, the water table is more than 30 feet below the land surface. Elsewhere on the fan, the water table is less than 10 feet below the land surface and in many places is less than 5 feet. Near the head of the fan, the water level in wells fluctuates as much as 25 feet, but throughout the remainder of the fan the fluctuations are less than 10 feet. (See fig. 39.)

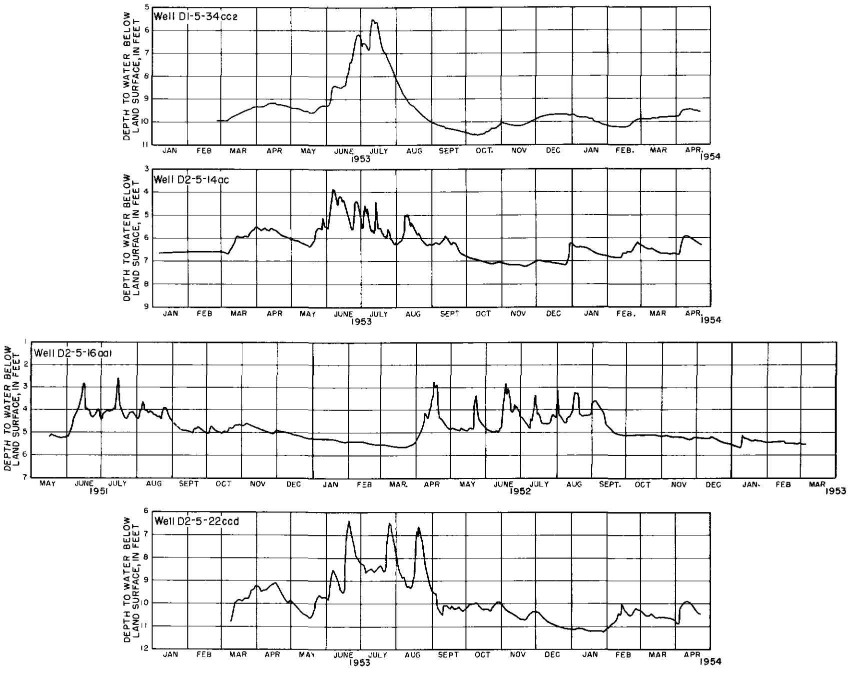

FIGURE 39.—Hydrographs of the water level in wells D1–5–34cc2, D2–5–14ac, –16aa1, and –22ccd.

At best, the aquifer underlying the Bozeman fan would yield only sufficient water for irrigating gardens or for supplemental irrigation of larger fields. If the ground-water resources of the Bozeman fan were to be developed to the extent that the flow of streams draining the fan was reduced significantly, less water would be available for irrigation by diversion from these streams. Such an eventuality should be given careful thought if large withdrawals of ground water on the Bozeman fan are planned. Underflow from the Bozeman fan to the Belgrade subarea also would be reduced if consumptive use were increased considerably.

CAMP CREEK HILLS

The area of the Camp Creek Hills is about 160 square miles. Tertiary strata are exposed throughout the area except at the south end, where Precambrian gneissic rocks crop out; near Logan, where Paleozoic and Precambrian rocks crop out; and in the places where the Tertiary strata are overlain by a thin mantle of terrace gravel, alluvium, colluvium, or loess. The thickness of the Tertiary strata, where penetrated by test holes D1–3–36bc and D2–4–9bc, is 836 and 515 feet, respectively. The alluvium, which overlies the Tertiary strata along the east-central margins of the Camp Creek Hills, probably is no more than about 20 feet thick. Most wells on the higher surfaces in the Camp Creek Hills are between 200 and 600 feet deep, whereas those on the lower surfaces and along the draws are correspondingly shallow.

Although the Tertiary strata as a whole are relatively impermeable, they form the principal aquifer in the area, and wells drilled into the more pervious layers yield sufficient water for stock and domestic use. The coefficient of transmissibility as determined by tests at test holes D1–3–36bc and D2–4–9bc, was 6,000 and 1,200 gpd per foot, respectively. Another aquifer test, at well A1–3–33dd, gave a coefficient of transmissibility of 26,000 gpd per foot, but it is probable that the water-yielding beds consisted in part of alluvium.

In the Camp Creek Hills, ground water occurs under both water-table and artesian conditions. Because insufficient water-level data were available, maps showing the contour of the water table or piezometric surfaces in this area were not prepared. It is probable, however, that ground water in the Camp Creek Hills moves eastward and northeastward toward the valley floor—that is, in the direction of the dip of the Tertiary strata.

As precipitation on the Camp Creek Hills generally is less than that required to satisfy the evapotranspiration requirements, only a small amount infiltrates to the zone of saturation. In the lower, irrigated part of the area, seepage from irrigation canals and irrigated fields is a significant source of recharge, but, because the many draws and shallow canyons effect good drainage, the water table has not risen appreciably. If much additional water were used for irrigation in this part of the Camp Creek Hills, however, the low-lying land along the east margin of the irrigated area might become waterlogged.

Available evidence indicates that the Tertiary strata in the Camp Creek Hills are incapable of yielding more than enough water for domestic and stock supply.

VALLEY FRINGE

Bordering the valley floor on the northeast and east are the Dry Creek, Spring Hill, and South Bridger subareas, and bordering the Bozeman fan on the east is the Fort Ellis subarea and on the southwest the South Gallatin subarea. These five subareas are referred to collectively as the valley fringe.

DRY CREEK SUBAREA

Most of the Dry Creek subarea, an area of about 89 square miles, is underlain by Tertiary strata. Along the stream courses the Tertiary strata are mantled by alluvium; along the east margin of the area they are mantled by alluvial fans from the Bridger Range. The entire area has been dissected by Dry Creek, its tributaries, and other tributaries of the East Gallatin River.

Insofar as can be determined from a reconnaissance of this subarea, the hydrologic properties of the Tertiary strata seem to be similar to those of Tertiary strata in other parts of the valley. The stream alluvium and alluvial fans seem to consist of coarse and moderately permeable material, but because the latter are dissected by draws and small canyons, they probably are well drained and contain little ground water.

Although a few wells tap the Tertiary strata, most wells in the Dry Creek subarea tap either alluvium along the stream courses or alluvial-fan deposits. Springs along the mountain front are a source of water on several ranches. Ground water moves toward Dry Creek except at the south end of the subarea, where the direction of movement is southwestward toward the valley floor.

Streamflow from the Bridger Range and precipitation along the east margin of the subarea are the chief sources of recharge. Ground water discharges principally as streamflow, but along several of the streams, such as Bear and Reese Creeks, extensive bottom-land areas are waterlogged.

Because the Tertiary strata are relatively impermeable and the alluvial fans contain little water, it is probable that large yields of ground water cannot be obtained in the Dry Creek subarea.

SPRING HILL SUBAREA

The Spring Hill subarea is an alluvial fan having an area of about 11 square miles. This fan is of later origin than the other fans in the valley fringe, and its surface is smooth and undissected. The lower end of the fan merges with the flood plain of the East Gallatin River. As no test holes were drilled into the alluvial fan, little is known of its thickness and subsurface characteristics. The coefficient of transmissibility, as determined at wells A1–5–21bc4 and –26cd, was 7,000 and 30,000 gpd per foot, respectively. These values, however, may not be representative of the full thickness of alluvial-fan deposits because the wells used in making the tests were very shallow.

Runoff from the Bridger Range and precipitation near the mountain front are the principal sources of recharge. The ground water moves toward the valley floor, and that not lost by evapotranspiration either discharges into Smith Creek or percolates into the alluvium of the East Gallatin River.

Additional information is needed before the ground-water supply in the Spring Hill subarea can be evaluated accurately.

SOUTH BRIDGER SUBAREA

The South Bridger subarea consists of remnants of a rather high dissected surface that fringes the Bridger Range between the Spring Hill fan and the valley of the East Gallatin River. North of Bridger Creek alluvial-fan deposits are the surficial material, whereas, south of Bridger Creek, Tertiary strata are at the surface. Both parts of the subarea are well drained and it is likely that supplies of water sufficient for irrigation cannot be developed. The subarea comprises about 33 square miles.

FORT ELLIS SUBAREA

In general, the geologic and hydrologic characteristics of the Fort Ellis subarea are similar to those of the Dry Creek subarea. It is probable, on the basis of available evidence, that the ground-water reservoir would not yield more than enough water for stock and domestic supply. The Fort Ellis subarea is about 18 square miles in extent.

SOUTH GALLATIN SUBAREA

The South Gallatin subarea comprises about 29 square miles and consists of remnants of high-lying alluvial fans that rest on Tertiary strata. A prominent fingerlike ridge, Goochs Ridge, extends northward into the valley. The alluvial-fan deposits are so well drained that they contain little or no water, and the Tertiary strata, as in other parts of the valley, yield water sufficient only for stock and domestic use.

CHEMICAL QUALITY OF THE WATER

By R. A. KRIEGER

The chemical quality of the water in the Gallatin Valley was determined from the analyses of 58 samples of ground water and 45 of surface water. The ground-water samples were collected between July 1951 and September 1953 from wells, test holes, and springs. Surface-water samples were collected from May 1949 to September 1952 from the Gallatin River and most of its important tributaries.

The locations of the sampling points for both ground and surface waters are shown on plates 10 and 11. In addition, the chemical characteristics of the water are shown by means of patterns as devised by Stiff (1951). The chemical analyses the ground- and surface-water samples are given in tables 27 and 28, respectively.

GEOLOGIC SOURCE AND SIGNIFICANCE OF THE IONS

The water samples were analyzed chemically to determine the concentration of the mineral constituents that affect the usability of the water. Characteristics of the water, such as pH and specific conductance, also were determined. The importance of the principal ions and some of the characteristics is discussed below.

Calcium is dissolved principally from limestone, dolomite, gypsum, and gypsiferous shales; magnesium is dissolved mainly from dolomite. Water that has leached these rocks may contain as much as several hundred parts per million of calcium and magnesium, whereas water that has leached granitic or other highly siliceous rocks may contain less than 10 ppm of calcium and magnesium. Calcium and magnesium cause hardness in water and scale in hot-water pipes and boilers. However, if present in suitable proportion, they are desirable in irrigation water because they counteract the harmful effects of sodium on the soil.

Sodium and potassium are dissolved from nearly all rocks. If ground water is connate or from rocks of marine origin, it may contain several thousand parts per million of sodium and can be classed as a brine. Sodium often is the predominant cation of surface waters in arid regions. Although sodium in water generally is of little importance to domestic users, it is of major importance to irrigationists because, if sodium constitutes a major part of the cations in an irrigation water, the soil may be damaged and become impervious to water. The relation between sodium and other cations is expressed as the percent sodium, which is computed by dividing the concentration of sodium in equivalents per million by the sum of the equivalents of the four principal cations—sodium, potassium, calcium, and magnesium—and multiplying the quotient by 100. Because potassium usually is present in low concentrations in natural water, it is of little significance.

Carbonate and bicarbonate are dissolved from limestone, dolomite, and other carbonate rocks. Carbon dioxide in water aids in the solution of calcium and magnesium carbonates from rocks and soils. Carbonate, if present at all, is generally low in concentration. Water from hard, insoluble rocks, such as granite, may contain only a small amount of bicarbonate, but water from limestone may contain several hundred parts per million. Carbonate and bicarbonate are important in irrigation water because of the possible effect of residual sodium carbonate on the soil.

Sulfate is dissolved mainly from gypsum and gypsiferous deposits. Also, it is derived from deposits of sodium sulfate and from the oxidation of sulfides. In combination with calcium, sulfate forms a hard scale in hot-water pipes and boilers.

Chloride is dissolved from nearly all rocks and soils; however, except when present in large amounts, it generally does not affect the use of the water. A high chloride concentration in water indicates the presence of brines, marine-deposited minerals, or pollution of the water from animal or industrial wastes. Drainage from irrigated land in arid regions often contains a high concentration of chloride.

Although fluoride is present in many rocks, the concentration in natural water usually is much less than that of chloride. Fluoride in drinking water may affect the teeth of children. There is evidence that children's teeth decay less when the fluoride concentration in the water supply is about 1.0 ppm; however, mottling of the tooth enamel may result if, during the period of formation of the permanent teeth, the drinking water has a fluoride concentration exceeding about 1.5 ppm (Am. Water Works Assoc., 1950, p. 381).

Nitrate in natural water usually is not dissolved from rock materials as are most of the other constituents. Rather, nitrate is the end product of the aerobic stabilization of nitrogenous organic matter, and high concentrations of nitrate may indicate contamination of the water from sewage or from plant and animal wastes. If fed to babies, water containing more than about

TABLE 27.—*Chemical analyses of ground water in the Gallatin Valley*

[Geologic source: P, Precambrian rocks; T, strata of Tertiary age; and Q, deposits of Quaternary age. Results in parts per million]

Location	Geologic source	Depth at sampling time (feet)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Calculated	Dissolved solids: Residue on evaporation at 180°C	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Valley floor																								
A1-4-5da....	T........	207....	Dec. 29, 1952	48	25	....	64	17	13	4.6	277	0	31	3.0	0.5	1.5	0.03	......	313	229	2	11	503	7.9
			Sept. 21, 1951	56	29	0.38	82	26	13	6.1	332	0	64	6.0	.2	1.7	.03	......	398	312	40	8	620	7.5
5dd...	Q........	18.0..	Sept. 9, 1952	56	23	.29	61	19	9.4	5.0	264	0	34	2.0	.2	3.8	.03	......	288	229	13	8	464	7.7
			Aug. 28, 1953	61	30	.58	69	21	11	5.9	304	0	39	2.5	.3	.3	.03	330	......	260	11	8	523	7.5
15da2..	T........	315....	Apr. 18, 1953	59	30	2.1	35	6.0	6.7	3.6	151	0	1.0	2.0	.1	.5	.13	......	162	112	0	11	242	8.1
		87....	Aug. 31, 1953	....	21	.91	62	14	5.2	2.8	219	0	36	6.5	.1	2.9	.03	......	278	212	32	5	415	7.9
19cb...	Q........	123....	July 23, 1953	46	19	2.6	65	19	5.3	3.2	243	0	40	8.0	.1	3.6	.03	286	......	239	40	5	460	7.5
		301....	Aug. 25, 1953	46	17	.18	65	18	5.8	2.3	239	0	39	9.0	.1	3.1	.02	......	287	235	39	5	467	7.3
25dc...	Q........	102....	Nov. 30, 1951	52	24	....	42	13	5.7	2.9	178	0	25	2.5	.3	4.4	.08	......	210	159	13	7	332	8.2
		400....	Nov. 26, 1951	49	....	....	....	....	5.6	....	....	....	....	....	....	....	....	......	......	172	....	7	354	...
A1-5-28db2.	Q........	170....	Aug. 31, 1953	46	12	....	52	14	5.2	1.6	227	0	13	3.5	.1	5.4	.01	219	......	189	3	6	380	7.7
	Q........	55....	Aug. 28, 1951	57	38	....	60	19	20	8.1	264	0	48	8.5	.5	3.5	.15	336	......	229	13	15	503	7.9
A2-3-33da...	T........	190....	Sept. 5, 1951	55	31	....	22	13	187	9.6	340	0	33	178	4.0	4.4	5.7	655	......	159	0	70	1,100	7.9
	T........	250....	Sept. 8, 1951	56	11	....	5.2	8.4	400	13	416	39	13	330	16	8.0	12	1,060	......	48	0	94	1,820	8.5
	T and P..	450....	Sept. 20, 1951	53	14	....	14	3.6	421	8.0	456	33	16	336	18	10	12	1,110	......	49	0	94	1,900	8.5
D1-4-1cb...	Q........	110....	Sept. 9, 1952	51	22	.02	56	12	5.9	2.8	212	0	24	2.0	.1	2.2	.01	......	238	187	13	6	378	7.8
1dc...	Q........	107....	Sept. 10, 1952	51	25	.03	53	12	5.6	3.3	204	0	24	2.5	.1	3.9	.01	......	234	182	15	6	371	7.5
6ddcl..	Q........	22.4..	Sept. 22, 1951	51	21	.23	47	20	15	3.7	242	0	28	4.5	.2	3.4	.03	......	264	200	2	14	434	7.8
13bb..	Q........	65....	Sept. 23, 1951	57	22	.08	57	16	5.6	3.1	241	0	21	2.0	.1	2.9	.01	......	262	209	11	5	414	7.6
25aa2.	Q........	158....	Jan. 28, 1953	49	24	.84	35	6.4	3.6	2.4	148	0	.0	1.0	.0	.7	.01	......	154	114	0	6	227	8.1
		32....	Sept. 9, 1953	47	19	1.0	77	20	19	3.7	331	0	26	5.5	.1	16	.03	350	......	273	2	13	570	7.7
D1-5-9cd...	Q........	156....	Sept. 15, 1953	....	24	....	71	18	18	4.2	311	0	23	6.0	.1	8.0	.01	......	323	253	0	13	532	7.3
		156....	Sept. 16, 1953	52	5.8	1.4	65	19	16	4.2	291	0	24	3.5	.1	11	.01	......	308	241	2	12	505	7.6
D2-4-11dc...	Q........	68....	Sept. 8, 1953	51	22	.38	57	13	6.5	3.3	235	0	18	1.0	.1	.8	.00	......	245	196	3	7	389	7.5
	T........	145....	Sept. 4, 1953	49	23	.45	58	14	7.4	3.1	246	0	17	2.5	.0	1.2	.06	248	......	202	0	7	407	7.6
14dac2	....	Spring.	Sept. 22, 1951	140	60	.02	3.5	.4	135	3.3	107	8	115	51	10	.2	.21	......	464	10	0	95	679	8.7
			...do........	....	18	.06	46	12	4.9	3.0	170	0	33	2.0	.2	1.6	.01	......	212	165	26	6	337	7.6
D3-4-3ab1..	Q........	11....	Sept. 9, 1952	....	17	....	....	....	4.7	....	....	....	....	....	....	....	....	......	......	172	....	5	345	...
			Aug. 28, 1953	....	16	.03	48	13	4.9	2.6	175	0	37	2.5	.2	1.6	.01	......	216	172	28	6	349	7.3
3ca....	T(?).....	435....	Sept. 23, 1952	50	39	4.2	32	8.0	9.3	7.8	135	0	26	2.5	.0	.4	.06	......	198	113	2	14	272	8.2

Bozeman fan

D1-5-22cd..	Q........	30.1..	Sept. 23, 1951	....	29	....	69	22	18	6.1	334	0	27	2.0	0.1	0.9	0.02	......	343	261	0	13	552	7.3
			Sept. 9, 1952	....	28	....	....	....	18	5.5	....	....	....	....	....	....	....	......	......	257	....	13	548	...
			Sept. 11, 1953	....	28	....	72	19	19	5.9	334	0	20	2.0	.1	4.0	.02	335	......	258	0	14	546	7.4
34cc2..	T........	250....	Oct. 15, 1952	47	34	1.2	67	17	26	5.2	337	0	17	2.0	.1	1.9	.33	......	338	235	0	19	523	8.0
D2-5-14ac...	Q........	265	Nov. 6, 1952	48	23	....	44	11	8.8	4.3	209	0	1.0	1.5	.4	2.7	.02	......	202	154	0	11	338	8.1
15aa1.	Q........	16.4..	Sept. 22, 1951	52	28	.64	69	13	8.1	5.4	301	0	3.0	1.0	.1	1.4	.01	......	290	227	0	7	470	7.5
22ccd..	Q........	145....	Jan. 9, 1952	44	28	....	45	14	6.9	3.9	219	0	1.0	1.5	.3	3.6	.01	......	214	170	0	8	353	8.0
	T or Q...	510....	Feb. 25, 1952	47	18	....	28	5.4	10	6.0	138	0	1.0	2.5	.3	.6	.09	......	140	92	0	18	234	8.0
D3-5-3da...	Q........	32.1..	Sept. 22, 1951	45	25	1.5	35	8.9	4.4	2.7	159	0	5.0	.5	.1	1.6	.01	......	172	124	0	7	266	7.6
			Sept. 9, 1952	53	26	....	....	....	3.8	....	....	...	....	....	....	....	....	......	......	128	....	6	263	...
			Aug. 28, 1953	50	25	2.7	35	7.4	5.4	3.3	157	0	2.0	.5	.2	.2	.02	......	157	118	0	9	251	7.6

Camp Creek Hills

A1-3-22da1..	T or Q...	28.3..	Sept. 22, 1951	49	32	2.1	53	20	20	5.3	213	0	47	26	0.2	7.2	0.08	......	318	215	40	16	512	7.7
29aa...	T........	310....	...do........	....	54	....	28	13	34	9.5	199	0	31	4.0	1.1	4.7	.10	......	280	123	0	35	398	7.5
A2-3-32ac...	....	Spring..	Sept. 9, 1952	53	50	.08	63	19	34	9.5	301	0	54	13	.3	5.0	.10	......	400	235	0	23	599	7.5
D1-3-16aa..	T........	280....	Sept. 22, 1951	....	61	.10	31	8.4	57	14	198	0	65	12	1.0	4.2	.12	......	368	112	0	49	498	7.7
36bc..	T or Q...	32.5..	June 24, 1952	51	47	.33	60	28	61	11	172	0	83	75	.3	110	.19	......	597	266	125	32	857	8.1
	T........	820....	Aug. 15, 1952	115	7.0	....	6.6	.1	119	1.4	104	4	116	31	11	1.1	.30	......	364	17	0	93	615	8.6
D2-3-11aa...	T........	170....	Sept. 22, 1951	....	21	....	93	18	35	13	316	0	77	25	.3	24	.10	......	506	305	46	19	741	7.5
	T........	120....	July 11, 1951	51	42	....	17	23	76	6.6	325	0	34	3.5	.8	2.7	.21	366	......	138	0	53	538	8.1
D2-4-9bc...	T........	465....	July 27, 1951	52	32	.28	41	4.6	19	8.3	177	0	18	6.0	.5	1.4	.24	218	......	124	0	24	309	7.8
	T and (or)P....	595....	Aug. 22, 1951	62	26	3.7	38	3.2	23	8.4	169	0	20	4.5	.8	1.2	.09	212	......	109	0	30	306	7.7
22da..	....	Spring..	Sept. 8, 1952	56	36	....	45	31	14	4.3	205	0	65	26	.4	1.2	.05	......	330	239	71	11	519	8.1

Valley-fringe area

A1-5-23cc...	Q(?).....	55....	Sept. 23, 1951	....	12	....	56	20	5.7	1.9	269	0	2.0	0.5	0.1	4.8	0.01	......	246	221	0	5	426	7.5
A1-6-18cb1..	Q(?).....	72....	Sept. 21, 1951	....	9.5	0.05	69	17	2.9	1.3	282	0	9.0	1.5	.1	3.1	.01	......	261	241	10	3	451	7.5
18cb2.	Q........	26....	...do........	....	9.4	.02	62	15	2.1	1.5	258	0	2.0	.5	.1	2.8	.01	......	238	218	6	2	412	7.5
A3-5-28dd...	Q(?).....	70.8..	...do........	46	4.6	2.6	45	14	4.0	1.0	201	0	8.0	2.0	.1	2.1	.02	......	182	172	7	5	339	7.6
D1-5-12ad..	T(?).....	225....	Sept. 23, 1951	52	10	1.4	47	15	4.0	2.1	217	0	1.0	1.5	.0	4.4	.01	......	212	180	2	4	354	7.6
D2-6-22cb...	T(?).....	6.....	Sept. 22, 1951	54	23	.07	61	16	15	.9	258	0	2.0	10	.4	20	.01	......	286	217	5	13	468	7.5

TABLE 28.—*Chemical analyses of surface water in the Gallatin Valley*

[Results in parts per million]

No. on pl. 11	Location	Discharge (cfs)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	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 $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
1	Gallatin River at Yellowstone Park boundary	....	6-24-49	..	17	0.05	27	7.8	0.7		110	0	8.0	1.0	0.1	0.5	0.09	124	100	10	1	196	6.9
	Do	....	8-18-49	..	19	.07	36	9.8	.7		127	0	26	.0	.1	.4	....	159	131	27	1	240	8.0
	Do	....	10-30-49	36	22	.06	38	8.6	6.2		140	0	24	1.8	.1	1.6	....	172	131	16	9	275	7.3
2	Gallatin River, Red Cliff Camp	....	8-18-49	56	15	.06	39	11	1.8		123	8	31	.0	.2	.2	....	171	143	29	3	272	8.2
3	Gallatin River at Squaw Creek Bridge	....	6-24-49	..	14	.05	21	7.1	3.9		84	0	19	.0	.1	.5	.05	108	82	13	9	172	7.0
4	Gallatin River at Spanish Creek	....	8-20-49	61	15	.04	38	11	5.3		115	5	46	.5	.2	.5	....	181	141	38	8	281	8.2
	Do	328	9-20-51	45	14	.04	34	7.1	3.4	1.2	110	0	32	1.0	.2	.4	.04	160	114	24	6	239	8.2
5	Gallatin River below Spanish Creek	....	6-24-49	..	13	.05	19	7.1	.5		74	0	15	.0	.1	1.1	.07	96	77	16	1	150	6.6
	Do	....	10-30-49	..	9.1	.04	31	8.6	13		118	0	39	1.2	.2	1.9	....	186	113	16	20	265	7.3
6	Gallatin River in sec. 8, T. 4 S., R. 4 E	....	5-27-49	..	14	.10	20	5.5	.7		74	0	12	.0	.1	.8	.08	92	73	12	2	148	6.6
7	Goose Creek in NE¼NW¼ sec. 16, T. 3 S., R. 4 E	....	9- 8-52	59	17	.04	49	20	7.4	2.6	234	7	8.0	7.0	.2	2.2	.02	236	204	1	7	407	8.4
8	Lowline Canal 2½ miles west of Buell in SW¼SW¼ sec. 33, T. 1 N., R. 3 E	....	9-20-51	51	16	.04	42	9.2	4.5	2.3	145	0	35	1.5	.3	.8	.06	186	143	24	6	298	7.7
9	Gallatin River at Sheds Bridge in SE¼SE¼ sec. 10, T. 2 S., R. 4 E	....	6-25-49	..	14	.05	23	6.5	5.3		92	0	18	.0	.1	.8	.04	116	84	9	12	183	7.3
	Do	....	8-19-49	64	18	.05	42	11	4.4		147	0	35	1.5	.2	.7	....	188	151	30	6	294	8.1
10	Gallatin River at Cameron Bridge in NW¼NW¼ sec. 22, T. 1 S., R. 4 E	298	9-23-51	47	15	.04	41	8.6	4.2	2.1	142	0	34	1.0	.2	.2	.03	188	138	22	6	284	7.8
11	Gallatin River at Central Park RR. Bridge in SW¼NE¼ sec. 19, T. 1 N., R. 4 E	....	5-27-49	..	14	.05	20	6.5	9.0		90	0	18	1.0	.2	1.5	.12	114	77	3	20	175	6.6
	Do	....	6-25-49	..	15	.05	27	7.9	7.8		112	0	20	2.0	.1	.6	.08	132	100	8	15	214	7.2
	Do	....	8-19-49	60	20	.07	50	16	7.6		212	0	30	1.0	.2	.9	....	227	191	17	8	373	7.9
	Do	....	10-30-49	39	16	.04	37	12	12		130	10	39	2.0	.2	2.6	....	192	142	19	16	302	8.4
12	Gallatin River east of Manhattan in SE¼NE¼ sec 12, T. 1 N., R. 3 E	182	9-20-51	51	17	.04	42	10	4.6	1.6	142	6	34	1.5	.2	.7	.10	200	148	22	6	300	8.5
13	Camp Creek at Vincent School in SW¼NE¼ sec. 4, T. 2 S., R. 3 E	.5	...do...	49	21	.04	46	10	9.4	4.1	170	0	33	10	.3	1.1	.06	228	158	19	11	351	8.1
14	Camp Creek at Buell in SE¼SW¼ sec. 35, T. 1 N., R. 3 E	16.3	...do...	51	21	.02	48	13	12	4.0	189	0	39	7.5	.3	3.0	.14	262	173	18	13	384	8.2
15	Rocky Creek (East Gallatin River) at Fort Ellis in SW¼SE¼ sec. 24, T. 2 S., R. 6 E	14.0	9-21-51	..	10	.04	53	18	7.4	2.0	199	7	46	1.5	.3	.6	.04	250	204	29	7	401	8.5
16	Sourdough (Bozeman) Creek near Bozeman in NW¼SE¼ sec. 30, T. 2 S., R. 6 E	....	9-22-51	45	20	.02	27	7.9	3.1	1.7	121	0	8.0	.5	.1	1.0	.04	132	100	1	6	208	7.5

17	East Gallatin River at Bozeman in SW¼SE¼ sec. 31, T. 1 S., R. 6 E	25	9-21-51	46	16	.04	51	14	8.9	2.5	214	0	28	3.0	.2	2.0	.02	236	184	9	9	377	7.2
18	Bridger Creek at mouth of Bridger Canyon in SE¼NW¼ sec. 34, T. 1 S., R. 6 E	11	...do...	44	9.0	.04	57	9.2	11	.8	231	0	15	2.0	.2	.5	.03	236	180	0	12	379	7.5
19	Lyman Creek near Bozeman in NW¼ sec. 28, T. 1 S., R. 6 E	....	9-22-51	53	9.0	.02	40	16	.5	.4	170	6	18	1.0	.1	1.1	.05	178	166	17	1	306	8.4
20	Middle (Hyalite) Creek in Hyalite Canyon in SE¼SE¼ sec. 23, T. 3 S., R. 5 E	38	9-20-51	42	20	.04	18	4.4	2.4	1.9	82	0	2.0	.5	.1	.4	.05	96	63	0	7	140	8.2
21	Bostwick Creek north of Walker School in NW¼SE¼ sec. 6, T. 1 S., R. 6 E	....	9-23-51	41	8.5	.06	32	7.1	1.6	1.8	130	0	6.0	1.0	.1	.2	.01	140	109	2	3	218	7.5
22	Ross Creek near Springhill in NW¼ sec. 16, T. 1 N., R. 6 E	15	9-21-51	46	5.4	.04	35	12	.2	.4	157	0	5.0	.5	.1	.7	.00	152	136	7	0	256	7.6
23	Bear Creek 1½ miles west of Reese Creek School in SE¼SW¼ sec. 33, T. 2 N., R. 5 E	....	...do...	..	12	.06	46	7.1	2.5	.5	177	0	1.0	1.0	.1	1.1	.04	176	144	0	4	280	7.7
24	Dry Creek at Partnell farm in SE¼SE¼ sec. 34, T. 2 N., R. 4 E	9.3	...do...	..	12	.04	53	15	4.9	1.2	232	0	6.0	2.5	.2	1.8	.07	224	194	4	5	374	8.0
25	Gibson Creek in NE¼ sec. 4, T. 1 N., R. 4 E	17.3	9-20-51	50	22	.04	57	16	9.3	3.0	246	0	24	2.5	.3	.9	.07	258	208	6	9	417	8.0
26	East Gallatin River in SE¼SW¼ sec. 33, T. 2 N., R. 4 E	351	...do...	50	19	.04	46	14	7.3	2.3	196	4	21	3.5	.1	2.2	.08	222	173	6	8	353	8.4
27	Gallatin River at Logan	749	...do...	51	24	.04	50	14	10	2.8	193	9	30	4.5	.1	1.7	.22	258	183	10	10	383	8.5
	Do	890	12-3-51	37	19	.04	50	13	12		196	0	34	4.5	.3	2.5	.09	233	180	19	12	381	7.5
	Do	[1] 700	1-28-52	..	21	.04	50	13	11		192	0	35	4.0	.2	3.2	.03	233	178	21	12	374	8.0
	Do	[1] 660	2-18-52	..	19	.04	52	13	11		201	0	33	4.0	.2	2.3	.05	235	184	19	11	387	7.9
	Do	[1] 650	3-3-52	32	19	.04	52	14	10		202	0	35	4.0	.2	2.3	.04	241	188	22	10	393	8.0
	Do	960	4-2-52	45	18	.04	49	14	12		198	0	34	4.5	.3	2.8	.06	242	182	20	12	390	7.7
	Do	4,260	5-7-52	46	14	.13	31	7.9	5.1		122	0	16	1.5	.2	2.3	.00	155	110	10	9	229	7.8
	Do	4,950	6-3-52	51	14	.06	30	7.3	5.1		119	0	15	1.0	.1	1.3	.02	138	105	7	9	219	7.6
	Do	1,610	7-4-52	..	14	.04	40	10	7.8		157	0	22	4.0	.1	1.8	.00	180	142	13	11	301	7.5
	Do	566	8-5-52	67	21	.04	50	15	14		210	3	29	5.0	.1	1.5	.02	242	186	9	14	393	8.3
	Do	792	9-18-52	55	20	.05	52	14	16		213	5	30	4.0	.2	2.2	.04	250	188	5	15	398	8.3

[1] Mean daily discharge.

45 ppm of nitrate may cause cyanosis (Comly, 1945, p. 112-116).

Boron is important in determining the suitability of water for irrigation. It is one of the essential elements for plant growth, but its beneficial concentration is very low. Toxic effects may be noticed on some plants if the irrigation water has more than about 0.3 ppm of boron.

Specific conductance is a measure of the ability of a solution to conduct an electrical current. As the concentration of dissolved material increases, the electrical resistance of the water decreases and the specific conductance of the water increases. Thus, specific conductance is an approximate measure of the total amount of dissolved mineral matter in a water.

CONCENTRATION AND NATURE OF DISSOLVED CONSTITUENTS

The shallow wells and test holes in the Gallatin Valley produce water from stream alluvium and alluvial-fan deposits of Quaternary age or from strata of Tertiary age. Most of the deeper wells and test holes derive water from the Tertiary strata, but a few springs and test holes may derive some water from Precambrian rocks. Because the chemical compositions of the water from Bozeman Hot Spring (D2–4–14dac2) and the test holes that tap Precambrian rocks are different, a wide field is provided for speculation as to the source of the ions in solution in those waters. (See table 27.)

Wells drilled in the valley floor derive water from either the Quaternary deposits or Tertiary strata, or both. The chemical characteristics of most samples are shown on plate 10*A*. Water from the Quaternary deposits was relatively low in dissolved solids and was of the calcium bicarbonate type. The concentration of dissolved solids ranged from 154 to 398 ppm. The magnesium and sulfate percentages of the anhydrous residue of water from wells near Manhattan are slightly higher than those of water from wells in the upstream part of the area. Analyses of water from test holes D1–5–9cd, A1–4–19cb, and –25dc, which penetrate thick alluvial deposits, show that the mineralization of the water is uniform with depth. Wells A1–4–5da, –15da2, D2–4–11dc, and D3–4–3ca, tapping strata of Tertiary age, produce water that is very similar in quality to water from wells in Quaternary deposits. However, the water from Tertiary strata in test hole A2–3–33da increases in mineralization with depth and is of the sodium chloride bicarbonate type.

In the Bozeman fan, most of the samples were from wells tapping Quaternary deposits. (See pl. 10*B*.) Dissolved solids ranged from 157 to 343 ppm, and calcium and bicarbonate were the major constituents. The concentration of dissolved minerals is independent of well depth but increases downslope. (See table 29.) The increase in mineralization may be attributed to recharge to the aquifer by infiltrating irrigation water and to longer contact of the ground water with the aquifer in the downslope areas.

TABLE 29.—*Changes in water quality in a downslope direction in the Bozeman fan*

Location of well or test hole	Sampling date	Depth (feet)	Dissolved solids (ppm)	Percent sodium
D3–5–3da	Sept. 22, 1951	32.1	172	7
	Aug. 28, 1953	32.1	157	9
D2–5–22ccd	Jan. 9, 1952	145	214	8
-14ac	Nov. 6, 1952	265	202	11
-15aal	Sept. 22, 1951	16.4	290	7
D1–5–22cd	Sept. 23, 1951	30.1	343	13
	Sept. 9, 1952	30.1	257	13

In the Camp Creek Hills ground water in the Tertiary strata varies in quality not only from place to place but also vertically in the same well. (See pl. 10*C*.) Correlation of chemical quality with geology would require detailed information on the mineral composition and stratigraphy of the Tertiary strata. However, the variation in quality is relatively unimportant because the water from most of the wells was relatively low in dissolved solids and was suitable for many uses.

Ground water in the valley-fringe area was very similar in chemical type and in concentration of dissolved solids to water from the Quaternary deposits in other parts of the Gallatin Valley. (See pl. 10*D*.)

CHEMICAL QUALITY IN RELATION TO HYDROLOGY

The quality of surface water is closely related to that of the ground water because infiltration of surface water is a principal source of ground-water recharge in the upper part of the valley, and because seepage into streams is a major source of surface water in the lower part of the valley. (See pls. 10, 11.) Surface water in the valley is of the calcium bicarbonate type. In the lower part of the valley, where streams are effluent, the total mineralization of the surface water is but slightly greater than in the upstream part of the valley, where the streams are influent.

The quality of surface water in September 1951, during a period of low flow, is shown by patterns on plate 11.

Four shallow wells in the alluvium were sampled annually in the period 1951-53 to ascertain changes in water quality. Total mineralization of water from three of the wells changed only slightly. (See table 30.) Specific conductance of the water from well A1–4–5dd ranged from 464 to 620 micromhos. In the spring when runoff is high the surface water contains a little less dissolved material than in late summer and fall when streamflow is low. Although there is no analytical proof, the mineralization of the ground water in places where water levels are directly affected by streamflow probably varies somewhat in response to the salinity of the surface water.

TABLE 30.—*Annual changes in total mineralization of ground water from shallow wells*

Well	Depth (feet)	Date	Specific conductance (micromhos at 25°C)
D3-4-3abl	11	Sept. 22, 1951	337
		Sept. 9, 1952	345
		Aug. 28, 1953	349
A1-4-5dd	18.0	Sept. 21, 1951	620
		Sept. 9, 1952	464
		Aug. 28, 1953	523
D3-5-3da	32.1	Sept. 22, 1951	266
		Sept. 9, 1952	263
		Aug. 28, 1953	251
D1-5-22cd	30.1	Sept. 23, 1951	552
		Sept. 9, 1952	548
		Sept. 11, 1953	546

SUITABILITY OF THE WATER FOR IRRIGATION

The suitability of any water for irrigation depends on the amount and kind of dissolved minerals or "salts" in the water in relation to certain other factors. (See tables 31, 32.) The dissolved salts affect the ability of the plant to take in water and nutrients. The normal osmotic gradient between the soil solution and the root cells is reversed if the soil solution is highly saline; thus, a plant may wilt from lack of moisture even though soil moisture seems to be adequate. A plant may be more easily injured by saline water during germination and early seedling stage than when older. Irrigation water of high salinity adds to the soluble salts in the soil and should be avoided; however, such water can be used if the texture of the soil is coarse, internal drainage is good, and salt-tolerant crops are planted. If the only water available is saline, more water than is necessary for plant use should be applied to flush the salts from the soil and to prevent their accumulation. Generally, water having a specific conductance of less than 750 micromhos can be used safely on all soils. As salinity increases, the water becomes less suitable for irrigation; and when the specific conductance is greater than about 5,000 micromhos, the water generally is unsuitable for irrigation (Thorne and Thorne, 1951, p. 11).

Sodium has a detrimental effect on the soil because it deflocculates soil colloids. The deflocculating effect of sodium is controlled by the ratio of the concentrations of calcium and magnesium to sodium. Therefore, the percent sodium is important for determining the suitability of water for irrigation.

Wilcox (1948, p. 5-6) proposed a diagram for rating the suitability of irrigation water on the basis of specific conductance and percent sodium. This diagram, as revised by Thorne and Thorne (1951, p. 9-12), was used in rating the water of the Gallatin Valley. (See fig. 40.) The following interpretation of the revised diagram is adapted from Thorne and Thorne:

Class	*Rating*
1	Water can be used safely on all soils.
2	Water can be expected to cause salt problems where drainage is poor and leaching of residual salts from previous irrigation is not consistently practiced.
3	Water can be used on crops of medium to high salt tolerance, on soils of good permeability, and with irrigation practices that provide some leaching.
4	Water can be used successfully only if applied to crops of high salt tolerance, on permeable and well-drained soils, and with carefully devised and conducted irrigation and soil-management practices.
5	Water is generally unsuitable and should be used for irrigation only in special situations.

Group	*Rating*
A	There should be no difficulty from sodium accumulation in soils.
B	Where soils are of fine texture and do not contain gypsum or lime, where drainage is poor, and where small quantities of water are applied with each irrigation, there may be some evidence of sodium accumulation but usually not enough to injure soils or crops seriously. Serious sodium accumulation may occur in waters high in carbonate or bicarbonate.
C	Serious alkali formation should not occur in permeable soils (sands to silt loams), unless poor drainage, residual carbonate in water, or limited water use are problems. Fine-textured soils must be managed with care.
D	Some alkali formation should be expected in all soils irrigated with group D water. Sandy or permeable soils high in gypsum might be irrigated with such water without highly injurious sodium accumulations. Loams or finer textured soils irrigated for some time with 3D or 4D water and then irrigated with water of low salt content would probably puddle and require gypsum for reclamation.
E	Generally unsatisfactory for irrigation.

NOTE.—1C, 1D, and 1E waters often can be improved in quality by treating with gypsum to reduce the percent sodium.

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TABLE 31.—*Chemical properties relating to suitability of ground water for irrigation in the Gallatin Valley*

[Geologic source: P, Precambrian rocks; T, strata of Tertiary age; and Q, deposits of Quaternary age]

Location	Geologic source	Depth at sampling time (feet)	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B) (ppm)	Percent sodium	Residual sodium carbonate (epm)	Specific conductance (micromhos at 25°C)
				Equivalents per million											
Valley floor															
A1-4-5da	T	207	Dec. 29, 1952	3.19	1.39	0.57	0.12	4.54	0.00	0.65	0.08	0.03	11	0.00	503
			Sept. 21, 1951	4.09	2.15	.57	.16	5.44	.00	1.33	.17	.03	8	.00	620
5dd	Q	18.0	Sept. 9, 1952	3.04	1.54	.41	.13	4.33	.00	.71	.06	.03	8	.00	464
			Aug. 28, 1953	3.44	1.76	.48	.15	4.98	.00	.81	.07	.03	8	.00	523
15da2	T	315	Apr. 18, 1953	1.75	.49	.29	.09	2.47	.00	.02	.06	.13	11	.23	242
		87	Aug. 31, 1953	3.09	1.15	.23	.07	3.59	.00	.75	.18	.03	5	.00	415
19cb	Q	123	July 23, 1953	3.24	1.54	.23	.08	3.98	.00	.83	.23	.03	5	.00	460
		301	Aug. 25, 1953	3.24	1.46	.25	.06	3.92	.00	.81	.25	.02	5	.00	467
25dc	Q	102	Nov. 30, 1951	2.10	1.08	.25	.07	2.92	.00	.52	.07	.08	7	.00	332
		400	Nov. 26, 1951	.....	.....	.24	.....	.....	.....	.....	.....	.....	7	.....	354
A1-5-28db2	Q	170	Aug. 31, 1953	2.59	1.19	.23	.04	3.72	.00	.27	.10	.01	6	.00	380
	Q	55	Aug. 28, 1951	2.99	1.59	.87	.21	4.33	.00	1.00	.24	.15	15	.00	503
A2-3-33da	T	190	Sept. 5, 1951	2.07	1.11	8.13	.25	5.57	.00	.69	5.02	5.7	70	2.39	1,100
	T	250	Sept. 8, 1951	.26	.69	17.39	.33	6.82	1.30	.27	9.31	12	94	7.17	1,820
	T and P	450	Sept. 20, 1951	.68	.30	18.31	.20	7.47	1.10	.33	9.48	12	94	7.59	1,900
D1-4-1cb	Q	110	Sept. 9, 1952	2.79	.95	.26	.07	3.47	.00	.50	.06	.01	6	.00	378
1dc	Q	107	Sept. 10, 1952	2.64	1.00	.24	.08	3.34	.00	.50	.07	.01	6	.00	371
6ddc1	Q	22.4	Sept. 22, 1951	2.35	1.65	.65	.09	3.97	.00	.58	.13	.03	14	.00	434
13bb	Q	65	Sept. 23, 1951	2.84	1.34	.24	.08	3.95	.00	.44	.06	.01	5	.00	414
25aa2	Q	158	Jan. 28, 1953	1.75	.53	.16	.06	2.43	.00	.00	.03	.01	6	.15	227
		32	Sept. 9, 1953	3.84	1.62	.83	.09	5.42	.00	.54	.16	.03	13	.00	570
D1-5-9cd	Q	156	Sept. 15, 1953	3.54	1.52	.78	.11	5.10	.00	.48	.17	.01	13	.04	532
		156	Sept. 16, 1953	3.24	1.58	.70	.11	4.77	.00	.50	.10	.01	12	.00	505
D2-4-11dc	Q	68	Sept. 8, 1953	2.84	1.08	.28	.08	3.85	.00	.37	.03	.00	7	.00	389
	T	145	Sept. 4, 1953	2.89	1.15	.32	.08	4.03	.00	.35	.07	.06	7	.00	407
14dac2	....	Spring	Sept. 22, 1951	.17	.03	5.87	.08	1.75	.27	2.39	1.44	.21	95	1.82	679
			..do	2.30	1.00	.21	.08	2.79	.00	.69	.06	.01	6	.00	337
D3-4-3ab1	Q	11	Sept. 9, 1952	.....	.....	.20	.....	.....	.....	.....	.....	.....	5	.....	345
			Aug. 28, 1953	2.40	1.04	.21	.07	2.87	.00	.77	.07	.01	6	.00	349
3ca	T(?)	435	Sept. 23, 1952	1.60	.66	.40	.20	2.21	.00	.54	.07	.06	14	.00	272

Bozeman fan

			Sept. 23, 1951	3.44	1.78	0.78	0.16	5.47	0.00	0.56	0.06	0.02	13	0.25	552
D1-5-22cd	Q	30.1	Sept. 9, 1952	......	......	.78	.14	......	......	......	......	......	13	......	548
			Sept. 11, 1953	3.59	1.57	.83	.15	5.47	.00	.42	.06	.02	14	.31	546
34cc2	T	250	Oct. 15, 1952	3.34	1.36	1.13	.13	5.52	.00	.35	.06	.33	19	.82	523
D2-5-14ac	Q	265	Nov. 6, 1952	2.20	.88	.38	.11	3.43	.00	.02	.04	.02	11	.35	338
15aa1	Q	16.4	Sept. 22, 1951	3.44	1.10	.35	.14	4.93	.00	.06	.03	.C1	7	.39	470
22ccd	Q	145	Jan. 9, 1952	2.25	1.15	.30	.10	3.59	.00	.02	.04	.01	8	.19	353
	T or Q	510	Feb. 25, 1952	1.40	.44	.43	.15	2.26	.00	.02	.07	.09	18	.42	234
			Sept. 22, 1951	1.75	.73	.19	.07	2.61	.00	.10	.01	.01	7	.13	266
D3-5-3da	Q	32.1	Sept. 9, 1952	......	......	.17	......	......	......	......	......	......	6	......	263
			Aug. 28, 1953	1.75	.61	.23	.08	2.57	.00	.04	.01	.02	9	.21	251

Camp Creek Hills

A1-3-22da1	T or Q	28.3	Sept. 22, 1951	2.64	1.66	0.87	0.14	3.49	0.00	0.98	0.73	0.08	16	0.00	512
29aa	T	310	...do	1.40	1.06	1.48	.24	3.26	.00	.65	.11	.10	35	.80	398
A2-3-32ac		Spring	Sept. 9, 1952	3.14	1.56	1.48	.24	4.93	.00	1.12	.37	.10	23	.23	599
D1-3-16aa	T	280	Sept. 22, 1951	1.55	.69	2.48	.36	3.24	.00	1.35	.34	.12	49	1.00	498
36bc	T or Q	32.5	June 24, 1952	2.99	2.33	2.65	.28	2.82	.00	1.73	2.12	.19	32	.00	857
	T	820	Aug. 15, 1952	.33	.01	5.17	.04	1.70	.13	2.42	.87	.30	93	1.49	615
D2-3-11aa	T	170	Sept. 22, 1951	4.64	1.46	1.52	.33	5.18	.00	1.60	.71	.10	19	.00	741
	T	120	July 11, 1951	.84	1.91	3.30	.17	5.33	.00	.71	.10	.21	53	2.58	538
D2-4-9bc	T	465	July 27, 1951	2.07	.38	.83	.21	2.90	.00	.37	.17	.24	24	.45	309
	T and (or) P	595	Aug. 22, 1951	1.91	.26	1.00	.21	2.77	.00	.42	.13	.09	30	.60	306
22da		Spring	Sept. 8, 1952	2.25	2.53	.61	.11	3.36	.00	1.35	.73	.05	11	.00	519

Valley-fringe area

A1-5-23cc	Q(?)	55	Sept. 23, 1951	2.79	1.63	0.25	0.05	4.41	0.00	0.04	0.01	0.01	5	0.00	426
A1-6-18cb1	Q(?)	72	Sept. 21, 1951	3.44	1.38	.13	.03	4.62	.00	.19	.04	.01	3	.00	451
18cb2	Q	26	...do	3.09	1.27	.09	.04	4.23	.00	.04	.01	.01	2	.00	412
A3-5-28dd	Q(?)	70.8	...do	2.25	1.19	.17	.03	3.29	.00	.17	.06	.02	5	.00	339
D1-5-12ad	T(?)	225	Sept. 23, 1951	2.35	1.25	.17	.05	3.56	.00	.02	.04	.01	4	.00	354
D2-6-22cb	T(?)	60	Sept. 22, 1951	3.04	1.30	.65	.02	4.23	.00	.04	.28	.01	13	.00	468

TABLE 32.—*Chemical properties relating to suitability of surface water for irrigation in the Gallatin Valley*

No. on pl. 11	Location	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B) (ppm)	Percent sodium	Residual sodium carbonate (epm)	Specific conductance (micromhos at 25°C)
			Equivalents per million											
1	Gallatin River at Yellowstone Park boundary	June 24, 1949	1.35	0.64	0.03		1.80	0.00	0.17	0.03	0.09	1	0.00	196
	Do	Aug. 18, 1949	1.80	.81	.03		2.08	.00	.54	.00	......	1	.00	240
	Do	Oct. 30, 1949	1.90	.71	.27		2.29	.00	.50	.05	......	9	.00	275
2	Gallatin River, Red Cliff Camp	Aug. 18, 1949	1.95	.91	.08		2.02	.26	.65	.00	......	3	.00	272
3	Gallatin River at Squaw Creek Bridge	June 24, 1949	1.05	.58	.17		1.38	.00	.40	.00	.05	9	.00	172
4	Gallatin River at Spanish Creek	Aug. 20, 1949	1.90	.91	.23		1.89	.16	.96	.01	......	8	.00	281
	Do	Sept. 20, 1951	1.70	.58	0.15	0.03	1.80	.00	.67	.03	.04	6	.00	239
5	Gallatin River below Spanish Creek	June 24, 1949	.95	.58	.02		1.21	.00	.31	.00	.07	1	.00	150
	Do	Oct. 30, 1949	1.55	.71	.55		1.93	.00	.81	.03	......	20	.00	265
6	Gallatin River in sec. 8, T. 4 S., R. 4 E.	May 27, 1949	1.00	.45	.03		1.21	.00	.25	.00	.08	2	.00	148
7	Goose Creek in NE¼NW¼ sec. 16, T. 3 S., R. 4 E.	Sept. 8, 1952	2.45	1.63	.32	.07	3.83	.23	.17	.20	.02	7	.00	407
8	Lowline Canal 2½ miles west of Buell in SW¼SW¼ sec. 33, T. 1 N., R. 3 E.	Sept. 20, 1951	2.10	.76	.20	.06	2.38	.00	.73	.04	.06	6	.00	298
9	Gallatin River at Sheds Bridge in SE¼SE¼ sec. 10, T. 2 S., R. 4 E.	June 25, 1949	1.15	.53	.23		1.51	.00	.38	.00	.04	12	.00	183
	Do	Aug. 19, 1949	2.10	.91	.19		2.41	.00	.73	.04	......	6	.00	294
10	Gallatin River at Cameron Bridge in NW¼NW¼ sec. 22, T. 1 S., R. 4 E.	Sept. 23, 1951	2.05	.71	.18	.05	2.33	.00	.71	.03	.03	6	.00	284
11	Gallatin River at Central Park RR. Bridge in SW¼NE¼ sec. 19, T. 1 N., R. 4 E.	May 27, 1949	1.00	.53	.39		1.48	.00	.38	.03	.12	20	.00	175
	Do	June 25, 1949	1.35	.65	.34		1.84	.00	.42	.06	.08	15	.00	214
	Do	Aug. 19, 1949	2.50	1.32	.33		3.47	.00	.63	.03	......	8	.00	373
	Do	Oct. 30, 1949	1.85	.99	.54		2.13	.33	.81	.06	......	16	.00	302
12	Gallatin River east of Manhattan in SE¼NE¼ sec. 12, T. 1 N., R. 3 E.	Sept. 20, 1951	2.10	.86	.20	.04	2.33	.20	.71	.04	.10	6	.00	300
13	Camp Creek at Vincent School in SW¼NE¼ sec. 4, T. 2 S., R. 3 E.	...do	2.30	.86	.41	.10	2.79	.00	.69	.28	.06	11	.00	351
14	Camp Creek at Buell in SE¼SW¼ sec. 35, T. 1 N., R. 3 E.	...do	2.40	1.06	.52	.10	3.10	.00	.81	.21	.14	13	.00	384
15	Rocky Creek (East Gallatin River) at Fort Ellis in SW¼SE¼ sec. 24, T. 2 S., R. 6 E.	Sept. 21, 1951	2.64	1.44	.32	.05	3.26	.23	.96	.04	.04	7	.00	401
16	Sourdough (Bozeman) Creek near Bozeman in NW¼SE¼ sec. 30, T. 2 S., R. 6 E.	Sept. 22, 1951	1.35	.65	.14	.04	1.98	.00	.17	.01	.04	6	......	208
17	East Gallatin River at Bozeman in SW¼SE¼ sec. 31, T. 1 S., R. 6 E.	Sept. 21, 1951	2.54	1.14	.39	.06	3.51	.00	.58	.08	.02	9	.00	377
18	Bridger Creek at mouth of Bridger Canyon in SE¼NW¼ sec. 34, T. 1 S., R. 6 E.	...do	2.84	.76	.48	.02	3.79	.00	.31	.06	.03	12	.17	379
19	Lyman Creek near Bozeman in NW¼ sec. 28, T. 1 S., R. 6 E.	Sept. 22, 1951	2.00	1.32	.02	.01	2.79	.20	.38	.03	.05	1	......	306

20	Middle (Hyalite) Creek in Hyalite Canyon in SE¼SE¼ sec. 23, T. 3 S., R. 5 E.	Sept. 20, 1951	.90	.36	.10	.05	1.34	.00	.04	.01	.05	7	.08	140
21	Bostwick Creek north of Walker School in NW¼ SE¼ sec. 6, T. 1 S., R. 6 E.	Sept. 23, 1951	1.60	.58	.07	.05	2.13	.00	.12	.03	.01	3	.00	218
22	Ross Creek near Springhill in NW¼ sec. 16, T. 1 N., R. 6 E.	Sept. 21, 1951	1.75	.97	.01	.01	2.57	.00	.10	.01	.00	0	.00	256
23	Bear Creek 1½ miles west of Reese Creek School in SE¼SW¼ sec. 33, T. 2 N., R. 5 E.	...do.	2.30	.58	.11	.01	2.90	.00	.02	.03	.04	4	.02	280
24	Dry Creek at Partnell farm in SE¼SE¼ sec. 34, T. 2 N., R. 4 E.	...do.	2.64	1.24	.21	.03	3.80	.00	.12	.07	.07	5	.00	374
25	Gibson Creek in NE¼ sec. 4., T. 1 N., R. 4 E.	Sept. 20, 1951	2.84	1.32	.40	.08	4.03	.00	.50	.07	.07	9	.00	417
26	East Gallatin River in SE¼SW¼ sec. 33, T. 2 N., R. 4 E.	...do.	2.30	1.16	.32	.06	3.21	.13	.44	.10	.08	8	.00	353
27	Gallatin River at Logan.	...do.	2.50	1.16	.43	.07	3.16	.30	.62	.13	.22	10	.00	383
	Do.	Dec. 3, 1951	2.50	1.10	.51		3.21	.00	.71	.13	.09	12	.00	381
	Do.	Jan. 28, 1952	2.50	1.06	.49		3.15	.00	.73	.11	.03	12	.00	374
	Do.	Feb. 18, 1952	2.59	1.09	.46		3.29	.00	.69	.11	.05	11	.00	387
	Do.	Mar. 3, 1952	2.59	1.17	.44		3.31	.00	.73	.11	.04	10	.00	393
	Do.	Apr. 2, 1952	2.45	1.19	.51		3.24	.00	.71	.13	.06	12	.00	390
	Do.	May 7, 1952	1.55	.65	.22		2.00	.00	.33	.04	.00	9	.00	229
	Do.	June 3, 1952	1.50	.60	.22		1.95	.00	.31	.03	.02	9	.00	219
	Do.	July 4, 1952	2.00	.84	.34		2.57	.00	.46	.11	.00	11	.00	301
	Do.	Aug. 5, 1952	2.50	1.22	.59		3.44	.10	.60	.14	.02	14	.00	393
	Do.	Sept. 18, 1952	2.59	1.17	.68		3.49	.17	.62	.11	.04	15	.00	398

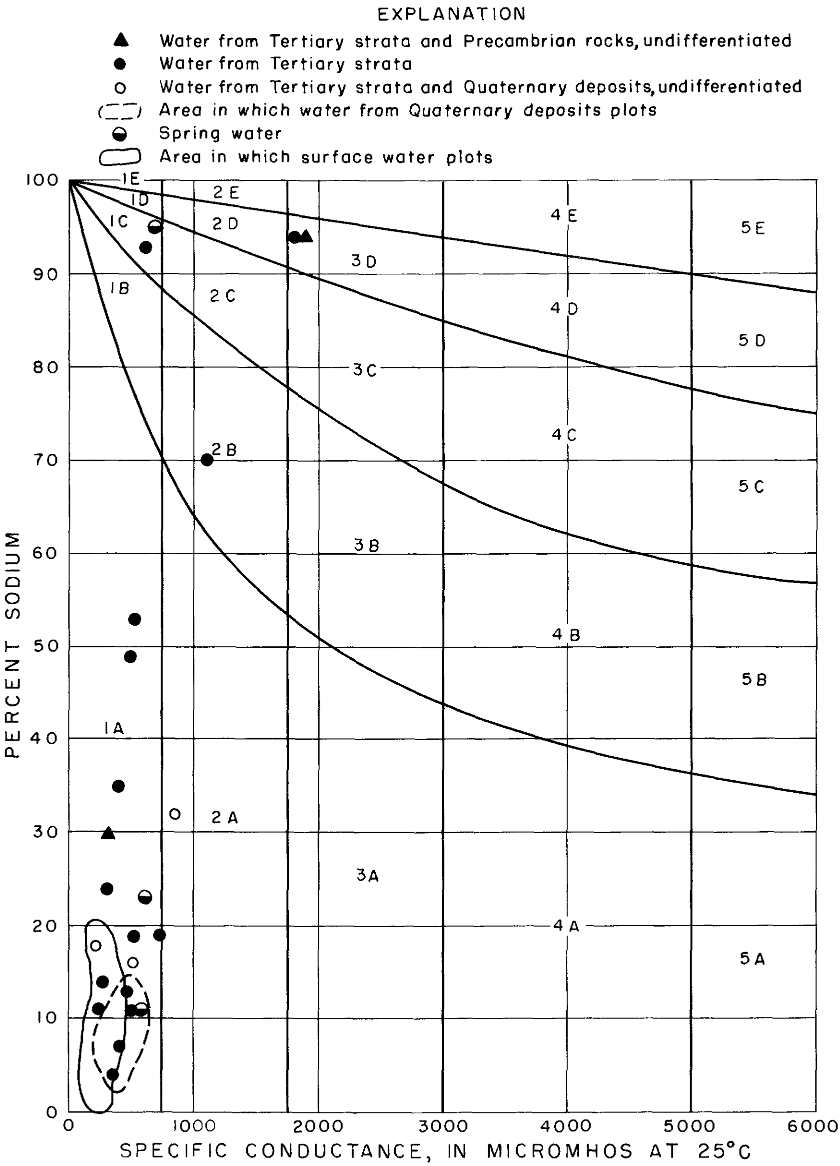

FIGURE 40.—Graph showing classification of ground and surface waters of the Gallatin Valley for irrigation. After Thorne and Thorne, 1951.

As irrigation water high in bicarbonate and carbonate is concentrated by evapotranspiration, calcium and magnesium may precipitate as carbonates, and an increase in percent sodium may result. The carbonate and bicarbonate content of the water in excess of the calcium and magnesium content, expressed in equivalents per million, is "residual sodium carbonate" (Eaton, 1950, p. 123-133). Water containing residual sodium carbonate raises the pH of the soil and dissolves organic matter, perhaps to the extent that the soil condition known as "black alkali" may develop. Wilcox, Blair, and Bower (1954, p. 259-266) found that waters containing less than 1.25 epm (equivalents per million) of residual sodium carbonate are probably safe for irrigation, those containing from 1.25 to 2.50 epm are marginal, and those containing more than 2.50 epm are not suitable. These limits are tentative and may be modified by the degree of leaching of the soil and by other factors. Ground water from Quaternary deposits and surface water had little or no residual sodium carbonate; however, water from Tertiary strata had significant amounts. (See tables 31, 32.)

Boron is an essential minor element for plant growth; however, its beneficial effects are limited to a narrow range in concentration (Scofield, 1936, p. 275-287).

Permissible limits for concentration of boron in several classes of water for irrigation

Class of water	Limits for concentration of boron (ppm)		
	Sensitive plants	Semitolerant plants	Tolerant plants
Excellent	<0.33	<0.67	<1.00
Good	0.33– .67	.67–1.33	1.00–2.00
Permissible	.67–1.00	1.33–2.00	2.00–3.00
Doubtful	1.00–1.25	2.00–2.50	3.00–3.75
Unsuitable	>1.25	>2.50	>3.75

The most sensitive plants include nut, citrus, and deciduous trees; semitolerant plants include most truck crops, cereals, and cotton; tolerant plants include lettuce, alfalfa, beets, asparagus, and date palms.

Water from all sources in the valley had less than 0.34 ppm of boron except water from test hole A2–3–33da, which contained 5.7, 12, and 12 ppm at depths of 190, 250, and 450 feet, respectively.

SUITABILITY OF THE WATER FOR DOMESTIC USE

Concentration limits of important chemical constituents in drinking water for use on carriers subject to Federal quarantine regulations have been established by the U. S. Public Health Service (1946). The American Water Works Association by resolution adopted the standards for public water supplies. Some of the chemical constituents, the concentration of which preferably should not exceed those shown below, are as follows:

Constituent	*Concentration (ppm)*
Fluoride	1.5
Iron and manganese together	.3
Magnesium	125
Chloride	250
Sulfate	250
Dissolved solids	[1]500

[1] 1,000 ppm permitted if water of better quality is not available.

The concentration of 1.5 ppm for fluoride was exceeded in water from only 3 ground-water sources. (See table 27.) Although manganese was not determined, concentrations of iron exceeded 0.3 ppm in most of the ground-water samples. Excessive concentrations of iron will stain fixtures, utensils, and laundry. Magnesium and sulfate concentration limits were not exceeded in any of the ground-water samples, but water from well A2–3–33da contained more than 250 ppm of chloride. Dissolved solids exceeded 1,000 ppm in water from only the deeper part of test hole A2–3–33da. Concentrations of none of the constituents in surface-water samples exceeded those shown above. (See table 28.)

A sample from the shallow part of test hole D1–3–36bc contained 110 ppm of nitrate; this test hole was near a barn and the water may have been contaminated by animal wastes.

Hardness of water can be detected in the domestic use of water by the scum or curd formed by soap. Hard water wastes soap and detergent and forms deposits on textiles, utensils, and heating equipment. Generally, water having a hardness of less than 120 ppm (as $CaCO_3$) need not be softened, that between 120 and 200 ppm may require softening, and that exceeding 200 ppm requires softening for most uses. Hardness of ground water in the Gallatin Valley ranged from 10 to 312 ppm; most of the water would need to be softened to be entirely satisfactory. Hardness of surface waters ranged from 63 to 208 ppm.

CONCLUSION

Throughout the Gallatin Valley, water for domestic and livestock use is obtained from ground-water sources. Although ground water is pumped in a few places for municipal and small-scale industrial use, large withdrawals are not made anywhere in the valley. If integrated with full use of the surface-water resources of the valley, full development of the ground-water resources would not only overcome, in large measure, the existing shortages of surface water but also would make possible the extension of irrigation to some lands now dry farmed. In parts of the valley, the supply of ground water is sufficient to fill the demands of large-scale industries.

Theoretically, the amount of ground water that could be pumped annually in the Gallatin Valley and used consumptively is equal to the average annual recharge to the ground-water reservoir. If less than this amount is pumped and used consumptively, natural discharge from the ground-water reservoir would be reduced by an amount equal to the net use, but, if the full amount is pumped and used consumptively, natural discharge eventually would cease. Under present conditions some of the surface water available for recharge to the ground-water reservoir in Gallatin Valley at times of high runoff is rejected. Thus, a large volume of water leaves the valley each spring without any use having been made of it. Development of the ground-water resources of the valley would increase the amount of space available for storage of additional water within the reservoir and thereby would increase the capacity of the reservoir to store a greater part of the available recharge. Within limits, therefore, the greater the withdrawal from the reservoir, the greater the recharge to it.

In the Gallatin Valley under natural conditions there was an approximate balance between recharge to, and discharge from, the ground-water reservoir. Development of agriculture was accompanied by an increased and, eventually, full use of the available supply of surface water during the growing season. The artificial recharge to the ground-water reservoir resulting from the use of surface water so altered the water regimen that a new state of equilibrium was reached. If, in the future, the ground-water resources of the valley are developed, the regimen again will be affected.

The average annual discharge of ground water from the Gallatin Valley, exclusive of that discharged by evapotranspiration, is about 240,000 acre-feet.

Increase in the consumptive use of ground water within the valley would reduce natural discharge from the valley by an amount equal to the volume used. Because the principal areas of ground-water discharge by evapotranspiration would be the last to be affected by withdrawals of ground water, nearly all the ground-water use would be reflected by a corresponding reduction in surface-water outflow from the valley. The reduction would be caused in part by a diminution of ground-water discharge into streams and in part by loss of surplus surface water to ground-water storage, and would occur principally during the latter part of the irrigation season.

If, in making plans for further development of the ground-water resources of the Gallatin Valley, plans were made also for augmenting the recharge to the ground-water reservoir, the volume of ground water that could be used consumptively each year without exhausting the supply would be increased. A sound basis for "managing" the ground-water reservoir by water spreading would be afforded by the annual forecasts of runoff in the drainage basin of the Gallatin River and periodic measurements of water levels in selected wells. The many borrow pits, gravel pits, and irrigation installations are means by which the ground-water reservoir could be filled when surface water is available for artificial recharge.

If, instead of developing the ground-water resources of the valley, surface-water reservoirs are constructed as a means of storing additional water for irrigation, the added recharge to the ground-water reservoir from the increased spreading of surface water would cause an increase in the amount of waterlogged land in the valley. Much of the land now waterlogged could be drained by open ditches if they were cut into the gravel that underlies the waterlogged soil. Other measures that would help to relieve waterlogging would be consolidation of irrigation canals and the lining of reaches of canals where leakage occurs.

Maximum use of the water resources of the Gallatin Valley would involve, in general terms, use of surface water for irrigation from the beginning of the irrigation season until the supply becomes short. Then, in those parts of the valley where the ground-water supply is adequate, use of ground water would supplant that of surface water, and the remaining available supply of surface water would be sufficient for continued irrigation in other parts of the valley. During the part of the year when the surface-water supply exceeded the demand, the ground-water reservoir should be recharged artificially by surface water that otherwise would be lost from the valley.

A factor, not mentioned previously, in determining the feasibility of developing ground water for irrigation is the initial cost of the wells and the subsequent maintenance and pumping costs. The factors involved in computing pumping costs, together with other factors of interest to the individual water user, are discussed by Wood (1950). Furthermore, the generally close interrelationship of ground water and surface water emphasizes the need for clarification of the legal status of each in relation to the other, in order that existing rights can be protected and that full development of the water resources will not be impeded.

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BASIC DATA

Table 33.—*Logs of wells and test holes*

[Interpretative information supplied by authors is enclosed in brackets]

	Thickness (feet)	Depth (feet)
A1–2–29adc [Drilled by Montana Power Co. (Rice No. 1). Logged by U. S. Geological Survey]		
No record	95	95
Tertiary:		
Sand, very fine to medium, angular to subangular; composed of quartz, feldspar, garnet, gneiss, obsidian, dark volcanics, and pale-green clayey siltstone	5	100
Sand, very fine to medium; contains some coarser grains and a few siltstone fragments	25	125
Sand, poorly sorted; contains pebbles and some light-green claystone and siltstone fragments	25	150
Siltstone, light-green; contains some claystone	5	155
Sand, very fine to very coarse, subangular to subrounded; contains few fragments of light-green claystone and siltstone	10	165
Sand, poorly sorted, subangular; composed of quartz, feldspar, obsidian, and red and black volcanic rocks	15	180
Sand, poorly sorted, greenish due to green quartz grains; contains pebbles and green siltstone fragments[1]	20	200
Sand, poorly sorted, interbedded with green siltstone	30	230
Siltstone interbedded with green claystone	8	238
Sand and gravel, poorly sorted, greenish	15	253
Bentonite(?), light-green; swells and slakes rapidly in water	2	255
Claystone interbedded with green siltstone	5	260
Sand and gravel, poorly sorted	12	272
Siltstone, sandy, green	4	276
Bentonite(?)	3	279
Sand and gravel, poorly sorted	3	282
Siltstone, sandy, green; interbedded with thin layers of sand	14	296
Sand, poorly sorted; contains pebbles	6	302
Claystone, green	6	308
Sand, fine to medium, angular, greenish	2	310
Claystone, green	1	311
Sand, poorly sorted	7	318
Siltstone interbedded with sand	16	334
Sand, angular, poorly sorted	16	350
Siltstone, clayey, green	22	372
Sand; contains some gravel	3	375
Siltstone, green	2	377
Sand; contains some gravel	7	384
Siltstone, pale-green streaked with light-brown	8	392
Sand, poorly sorted, angular; contains pebbles	6	398
Claystone, cream with pale-green tinge, tuffaceous(?)	2	400
Sand, angular, poorly sorted, light-green	4	404
Claystone, tuffaceous, cream-colored	5	409
Sand, fine to medium, poorly sorted, gray; contains some well-developed quartz crystals	29	438
Claystone interbedded with siltstone	5	443
Sand, fine to medium, poorly sorted, gray	4	447
Claystone, green	8	455
Sand, fine to medium, poorly sorted, gray	4	459
Siltstone, green	4	463
Sand, fine to medium, poorly sorted, gray	5	468
Siltstone, sandy, pale-green	12	480
Sand, fine, gray	8	488
Claystone interbedded with siltstone	13	501

The remainder of the log has been adjusted to an electric log, which begins at this point.

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
A1-2-29adc—Continued		
Tertiary—Continued		
Sand, poorly sorted, angular, gray; composed of quartz, feldspar, gneiss, and some dark volcanic grains	4	505
Siltstone, light-green	5	510
Sand, poorly sorted, angular, gray	3	513
Siltstone, sandy; interbedded with gray-green claystone	8	521
Sand, poorly sorted, angular, gray	4	525
Siltstone, gray-green	6	531
Sand, poorly sorted, angular, gray	4	535
Sand, silty, interbedded with siltstone	17	552
Claystone interbedded with bentonite(?) and siltstone	12	564
Sand, poorly sorted, angular, gray	2	566
Claystone interbedded with gray-green siltstone	7	573
Sand, medium-grained, angular, poorly sorted	5	578
Siltstone, claystone, and pale-green sandy siltstone	22	600
Sand, fine to medium, subangular, light-gray; composed of quartz, feldspar, gneiss, and muscovite; this is the deepest sand containing dark volcanic rocks	4	604
Claystone interbedded with silty fine sand, pale-green	9	613
Sand, fine to medium, subangular, light-gray	7	620
Claystone interbedded with siltstone, pale-green	13	633
Sand, fine to medium, subangular, light-gray	2	635
Siltstone interbedded with claystone and thin layers of sand, pale-green	47	682
Sand, fine to medium, subangular, light-gray	3	685
Siltstone, clayey, light-green	5	690
Claystone, silty, micaceous, gray-green; grades downward to gray, medium, friable sandstone composed of quartz, feldspar, and biotite	6	696
Claystone, greenish-gray	1	697
Sandstone, coarse-grained, porous, gray	.5	697.5
Claystone, greenish-gray; grades downward to green, clayey and sandy siltstone	13.5	711
Sandstone, porous, poorly sorted, angular, gray; contains pebbles	5	716
Claystone, green; grades downward to fine-grained sandstone	10	726
Sandstone, coarse-grained, calcareous, hard, gray; contains pebbles	2	728
Sandstone, coarse-grained, porous, friable, gray	14	742
Siltstone, green	4	746
Claystone, gray-green	8	754
Sandstone, poorly sorted, silty, clayey, gray	6	760
Sandstone, fine-grained, gray; grades downward to medium-grained sandstone	6	766
Sandstone, medium-grained, gray; grades downward to fine-grained sandstone	2	768
Sandstone, fine-grained, gray	4	772
Claystone, green; grades downward to fine-grained sandstone	4	776
Sandstone, fine-grained, gray	3	779
Sandstone, coarse-grained, porous, gray	3	782
Sandstone, coarse-grained, porous, gray, interbedded with thin layers of claystone	6	788
Conglomerate; composed of well-rounded pebbles of quartz and muscovite-quartz gneiss; green	.3	788.3
Siltstone, sandy, micaceous	9.7	798
Sandstone, medium-grained, calcareous, micaceous (the mica flakes are arranged in layers)	3	801
Sandstone, coarse-grained, porous, gray	10	811
Claystone, green	2	813
Siltstone, sandy; grades downward to coarse-grained sandstone	7	820

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Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
A1-2-29adc—Continued		
Tertiary—Continued		
Siltstone, green	5	825
Mudstone, carbonaceous, dark-gray; contains thin coal seams	3	828
Sandstone, coarse-grained, porous, gray	4	832
Sandstone, medium-grained, hard, calcareous, gray	4	836
Claystone, green	6	842
Sandstone, silty, poorly sorted, gray	5	847
Siltstone interbedded with claystone, gray; contains coal seam at 850 ft	9	856
Sandstone, gray	3	859
Claystone, silty, green	12	871
Sandstone, poorly sorted, gray	9	880
Siltstone, clayey and sandy, gray-green	15	895
Sandstone alternating with sandy siltstone and claystone. Each bed averages about 2–5 ft in thickness	157	1,052
Siltstone, green, maroon-streaked	6	1,058
Sandstone, coarse-grained, porous, gray; composed of quartz, feldspar, muscovite and biotite	4	1,062
Claystone, green, maroon-streaked	2	1,064
Sandstone, coarse-grained, porous, friable, gray	7	1,071
Siltstone, green	5	1,076
Sandstone, coarse-grained, gray	4	1,080
Claystone, green	4	1,084
Sandstone, silty, poorly sorted	5	1,089
Siltstone, micaceous, green; contains sand	11	1,100
Sandstone, gray	6	1,106
Siltstone, sandy, green, maroon-streaked	6	1,112
Sandstone, coarse-grained, gray	4	1,116
Claystone interbedded with siltstone, green	9	1,125
Siltstone interbedded with fine-grained sandstone; contains an 8-in. coal seam at 1,126 ft	5	1,130
Sandstone, coarse-grained, micaceous, gray	2	1,132
Claystone, gray	2	1,134
Sandstone, coarse- to medium-grained, porous, friable, gray; composed of quartz, feldspar, and mica	2	1,136
Claystone, gray; grades downward to sandy siltstone	8	1,144
Sandstone, predominantly coarse-grained, porous, friable, gray; composed of quartz, feldspar, and mica	10	1,154
Siltstone, clayey, gray	6	1,160
Sandstone, medium-grained, gray; grades downward to a gray claystone	5	1,165
Siltstone interbedded with claystone, gray-green	17	1,182
A1-3-4da [Drilled by commercial driller]		
Soil [alluvium]	3	3
Gravel	4	7
Clay (no water)	13	20
Gravel	18	38
Hardpan and clay [Tertiary?]	42	80
A1-3-14dd [Drilled by commercial driller]		
Gravel	30	30
Hardpan [calcareous, siltstone; Tertiary]	30	60
Siltstone, harder than above	7	67
Siltstone	2	69
Hardpan	1	70
Sandstone, fine-grained	5	75

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
A1-3-29aa		
[Drilled by commerical driller]		
Dirt	15	15
Gravel	78	93
Sandrock, soft	6	99
Sandrock, hard	1	100
Clay, soft, yellow	150	250
Quicksand	18	268
Clay, soft	12	280
Sand, fine; pumped dry in 2½ hr	7	287
Clay	12	299
Sand	7	306
Clay	4	310
A1-4-5da		
[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zone, 5–31 ft. Depth to water December 1952, 4 ft]		
Quaternary (alluvium):		
Loam, silty	5	5
Gravel, calcareous (comprised largely of dark-colored volcanic and metamorphic rocks; also contains a few fragments of dolomite and quartzite)	10	15
Gravel, silty, calcareous	3	18
Sand and gravel, silty, calcareous, tuffaceous(?); contains limestone fragments	13	31
Tertiary(?):		
Silt and clay, sandy, calcareous, tuffaceous(?), light-tan; contains pebbles	4	35
Sand, medium, silty, calcareous, light-tan; contains pebbles	10	45
Silt, sandy, calcareous, light-tan; contains pebbles and a few marly fragments. Pebbles and sand are comprised of volcanic rock fragments, quartz, limestone, and magnetite	32	77
Sand, silty, calcareous, light-tan; contains pebbles	30	107
Silt, sandy, calcareous, light-tan; contains scattered pebbles and siltstone fragments	16	123
Sand, silty, fine, calcareous, light-tan; contains pebbles	12	135
Tertiary:		
Siltstone, sandy, calcareous, tuffaceous, buff; contains a small amount of sand and gravel	22	157
Sandstone, medium-grained, silty, calcareous, gray; contains pebbles. Sand grains are subrounded	11	168
Sandstone interbedded with calcareous conglomerate, grayish-brown. Sand grains and pebbles are subangular to subrounded	39	207
A1-4-15da2		
[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zones, 4–80 ft and 249–260 ft. Depth to water for upper zone, 4 ft; for lower zone only, 3 ft]		
Quaternary (alluvium):		
Soil, silty	1	1
Gravel, fine, and coarse to very coarse sand; some dark-brown silt	22	23
Gravel, poorly sorted	5	28
Sand, very fine to fine, silty, light-brown; some coarse sand and gravel	7	35
Gravel and coarse sand	5	40
Sand, very fine to fine, silty, light-brown; little fine gravel and some cobbles	5	45

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
A1-4-15da2—Continued		
Quaternary (alluvium)—Continued		
Gravel, fine, and coarse sand; some very fine sand and brown silt	4	49
Sand, very fine to coarse, silty, brown	6	55
Gravel, fine, and coarse sand; some brown silt	20	75
Gravel, cobbles, and coarse sand	5	80
Sand, medium to coarse; contains pebbles and brown silt	14	94
Sand and gravel, poorly sorted; some brown silt and clay	9	103
Sand, medium to very fine, silty, brown	9	112
Gravel and sand, poorly sorted; large amount of very fine sand and silt	12	124
Sand, medium to very coarse, silty	6	130
Silt and clay, light-brown; some sand	6	136
Sand and gravel; small amount of silt	7	143
Sand, fine, silty, light-brown; some coarse sand and gravel	10	153
Gravel and sand, poorly sorted; some dark-brown silt	30	183
Sand, poorly sorted; small amount of dark-brown silt and clay	22	205
Sand, coarse, clean, dark-colored; some Tertiary rock fragments	10	215
Tertiary:		
Clay, slightly silty, buff; contains mica	15	230
Claystone, buff; some white marl; very small amount of calcareous tuffaceous siltstone	5	235
Claystone, buff; interbedded with calcareous tuffaceous siltstone	9	244
Gravel, sandy, silty	2	246
Siltstone, calcareous, tuffaceous, buff	3	249
Sand, poorly sorted, coarser grains predominant; some silt	11	260
Siltstone, slightly sandy, tuffaceous, calcareous, buff; interbedded with buff claystone	45	305
Claystone, silty, calcareous, buff	10	315

A1-4-19cb

[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zones, 5–94 ft and 117-180 ft. Depth to water for upper zone, 5 ft. Water level for lower zone, 3 ft above land surface]

	Thickness (feet)	Depth (feet)
Quaternary (alluvium):		
Soil	1	1
Gravel, sandy, poorly sorted, dark-colored	14	15
Sand, medium to very coarse, poorly sorted	15	30
Sand and gravel, poorly sorted; some brown silt	5	35
Sand and gravel, poorly sorted, dark-colored	20	55
Sand, medium to very coarse, dark-colored	5	60
Sand, poorly sorted; contains pebbles	10	70
Gravel and sand, poorly sorted, clean	24	94
Clay, calcareous, light-brown to cream; fragments of very slightly tuffaceous calcareous siltstone; some marl fragments	13	107
Sand and gravel, poorly sorted, dark-colored	16	123
Sand, medium to very coarse	2	125
Sand and gravel, poorly sorted	5	130
Sand and gravel, poorly sorted, silty, brown	5	135
Sand, poorly sorted, very clean	5	140
Sand and gravel, poorly sorted, clean; contains a few large pebbles and cobbles	45	185
Sand, silty; contains pebbles	10	195

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
A1-4-19cb—Continued		
Quaternary (alluvium)—Continued		
Sand, medium to coarse; fragments of light-brown calcareous bentonitic(?) claystone	5	200
Silt and clay, sandy, greenish-gray; contains fragments of kaolinite(?) and some small glass shards	10	210
Sand and gravel, poorly sorted	10	220
Sand, very fine to very coarse; some silt	5	225
Sand and gravel, poorly sorted; some silt	45	270
Silt, sandy, clayey, brown	10	280
Sand and gravel, silty, brown	5	285
Sand, poorly sorted; very little brown silt	7	292
Sand, poorly sorted; contains a few pebbles, some silt, and a little clay	9	301
A1-4-22dc4		
[Drilled by contractor for the U. S. Geological Survey. Depth to water, 3 ft]		
Quaternary (alluvium):		
Soil, silty	4	4
Gravel and coarse sand; some brown calcareous silt	11	15
Gravel, coarse, sandy; very little brown calcareous silt	5	20
Sand, coarse; contains pebbles, brown silt, and fine sand	15	35
Sand, medium to coarse; some silt	8	43
A1-4-25dc		
[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zone, 10–55 ft; saturated from 60–400 ft. Depth to water, 10 ft]		
Gravel, sandy, silty, calcareous; contains cobbles; composed of volcanic and metamorphic rocks	50	50
Gravel; contains sand lenses	40	90
Gravel, sandy	120	210
Sand, medium to coarse; contains pebbles	30	240
Gravel, sandy	35	275
Gravel, sandy, silty	25	300
Gravel, sandy	78	378
Sand, medium, silty	6	384
Gravel, sandy	16	400
A1-5-9bb		
[Drilled by commercial driller]		
Topsoil	2	2
Gravel [alluvium]. Water at 25 ft	23	25
Clay, sandy, yellow [Tertiary(?)]. A little water at 85 ft	60	85
Clay, sandy, yellow. More water	22	107
A1-5-28db2		
[Drilled by contractor for the U. S. Geological Survey. Depth to water, 3 ft]		
Quaternary (alluvium):		
Soil	6	6
Silt and clay, calcareous, brown-gray; fine gravel and coarse sand. Gravel and sand composed of fragments of gneiss and Paleozoic limestone. Numerous terrestrial gastropod shells (Recent?) in a calcareous matrix	4	10

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
A1-5-28db2—Continued		
Quaternary (alluvium)—Continued		
Silt and clay, calcareous, gray; coarse gravel	5	15
Silt and clay, calcareous, yellow-buff; coarse sand and fine gravel. Sand and gravel composed of fragments of Tertiary beds, Paleozoic limestone and gneiss	10	25
Gravel and yellow-buff calcareous silt and clay	10	35
Silt, yellow-buff, and poorly sorted sand	10	45
Sand, gravel, and buff calcareous silt	5	50
Silt, calcareous, buff; some sand and gravel	9	59
Sand, gravel, and buff calcareous silt	26	85
Sand, medium, well-sorted; some buff calcareous silt	5	90
Sand and silt, calcareous, buff; some fine gravel; small amount of clay	25	115
Gravel and sand; buff silt	35	150
Silt and clay, calcareous, buff; some gravel and sand	5	155
Sand, coarse, and fine gravel; silt	5	160
Silt and clay, calcareous, buff; sand and gravel	10	170
Sand and fine gravel; calcareous silt	25	195
Gravel, coarse; sand and silt	6	201
Sand, very fine to coarse; silt	3	204
Gravel, coarse; sand; brown calcareous silt	6	210
A1-6-18cb1 [Drilled by commercial driller]		
Soil	5	5
Gravel, tight	15	20
Water sand	5	25
Clay, sandy	45	70
Sand and boulders	3	73
A2-2-35ab1 [Drilled by contractor for the U. S. Geological Survey]		
Quaternary (alluvium):		
Soil	2	2
Gravel and cobbles	20	22
Mississippian (Madison group): Limestone, brown	4	26
A2-2-35ab2 [Drilled by contractor for the U. S. Geological Survey]		
Quaternary (alluvium):		
Soil	2	2
Gravel and cobbles	19	21
Gravel, clayey, and cobbles	2	23
Mississippian (Madison group): Limestone, brown	4	27
A2-2-35ad1 [Drilled by commercial driller]		
[Quaternary (colluvium)]: Gravel	30	30
[Tertiary(?)]: Soapstone, ivory-colored [probably claystone]	30	60
[Mississippian (Madison group?)]: Solid rock	50	110

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
A2-2-35ad2		
[Drilled by commercial driller]		
Unconsolidated deposits	28	28
Solid rock, dark-colored	64	92
A2-2-36bb		
[Drilled by commercial driller]		
[Quaternary (alluvium)]: Gravel	15	15
[Devonian (Jefferson limestone?)]: Solid rock, very dark colored; hard to drill	122	137
A2-2-36bc		
[Drilled by commercial driller]		
[Quaternary (alluvium)]: Gravel	17	17
[Mississippian and Devonian (Threeforks shale or Jefferson limestone?)]: Red hardpan, fairly soft rock	62	79
A2-3-23cb		
[Drilled by commercial driller]		
Topsoil	9	9
[Cambrian (Wolsey shale)]:		
Shale; very little water at 24 ft	31	40
Red rock	25	65
Shale, blue-gray	45	110
Sandstone, gray	32	142
Soapstone, light-gray	8	150
Sandstone, light-colored (almost white); water rose to 80 ft	2	152
[Cambrian (Flathead quartzite?)]:		
Hard rock	6	152.6
A2-3-33da		
[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zones, 32–73 ft and 215–300 ft. Depth to water for upper zone, 32 ft; for lower zone only, 12 ft]		
Quaternary (alluvium):		
Silt	1	1
Gravel, sandy and silty; contains cobbles. Composed predominantly of volcanic rock fragments; also contains some metamorphic rock fragments	14	15
Sand, medium to coarse, and fine gravel. Composed predominantly of volcanic rock fragments; contains some gneiss and a few limestone pebbles	25	40
Gravel, sandy, fine	10	50
Gravel, sandy and silty, fine	5	55
Tertiary (fanglomerate?):		
Gravel, sandy, calcareous; contains cobbles of limestone and quartzite	18	73
Tertiary:		
Volcanic ash, pure, cream-gray	2	75
Siltstone, calcareous, tuffaceous, buff	3	78
Volcanic ash, pure, cream-gray	2	80
Marl, tuffaceous; interbedded with tuffaceous claystone and volcanic ash	60	140
Tertiary (fanglomerate):		
Gravel and cobbles, angular, in a matrix of greenish silt and clay; contains several clay lenses. Gravel composed predominantly of dark-colored (black, gray, and brown) limestone and chert; also contains some quartzite	75	215

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
A2-3-33da—Continued		
Tertiary (fanglomerate):—Continued		
Sand, medium, angular to subangular, dark-brown. Composed predominantly of limestone; also contains some chert, a few crystal-quartz grains, and pyrite cubes and octahedra	20	235
Gravel and cobbles (similar to that between 140 and 215 ft.	5	240
Sand, medium to coarse, dark-brown. Composed of limestone, chert, and quartz containing a little pyrite	20	260
Sand and gravel, intermixed	40	300
Precambrian (Belt series, undifferentiated):		
Siltstone, in shades of buff, yellow, gray, and green; some clay either as a matrix or in thin layers; some calcite and tarry residue on bedding planes and seams. Possibly a weathered zone	20	320
Siltstone interbedded with mudstone, calcareous, dolomitic, variegated (salmon, buff, gray, green, and blue); predominantly grayish-brown to reddish-brown. Tarry residue and calcite on seams	87	407
Limestone, dolomitic, and dolomite, dark-gray to brownish-gray	15	422
Siltstone, dolomitic, calcareous, variegated; interbedded with dolomitic limestone and dolomite; dark-gray to brownish-gray	28	450
A2-3-34ca [Drilled by commercial driller]		
Gravel	25	25
Clay	10	35
Gravel	17	52
D1-3-13bb [Drilled by commercial driller]		
Topsoil	17	17
Gravel	44	61
Hardpan	13	74
Gravel	37	111
D1-3-13bc [Drilled by commercial driller]		
Dirt and clay	14	14
Gravel, tightly packed, dry	112	126
Sand and gravel; small amount of water	5	131
Clay, sandy, dirty; little water	12	143
Sand, dirty (quicksand)	12	155
Quicksand	15	170
Sand, coarse, clean, saturated	5	175
Sand, dirty	60	235
D1-3-13ca2 [Drilled by commercial driller]		
Topsoil	24	24
Gravel	3	27
Clay and gravel	8	35
Gravel and sand	67	102
D1-3-13cb2 [Drilled by commercial driller]		
Topsoil and clay	17	17
Gravel and silt intermixed	147	164

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
D1-3-24ba		
[Drilled by commerical driller]		
Topsoil	5	5
Gravel	18	23
Clay	22	45
Quicksand	13	58
Sand and clay	92	150
(?)	22	172
D1-3-36bc		
[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zone, 16–100 ft. Depth to water, 16 ft]		
Quaternary (colluvium):		
Silt, sandy, calcareous, tuffaceous, buff; contains pebbles	23	23
Tertiary (unit T_2?):		
Gravel, sandy, silty. Gravel is composed of pebbles derived from Tertiary beds and volcanic rocks	9	32
Silt, sandy, calcareous, buff; contains pebbles	33	65
Gravel, silty. Gravel is composed of volcanic and metamorphic rocks and fragments of Tertiary beds	20	85
Sand, silty, poorly sorted, calcareous	7	92
Gravel, sandy; contains fragments of buff claystone	8	100
Tertiary (unit T_2):		
Silt, sandy, calcareous, tuffaceous, buff; contains fragments of marl	25	125
Clay, calcareous, tuffaceous, light-brown; contains fragments of siltstone	30	155
Silt, sandy, clayey, calcareous. tuffaceous, buff	19	174
Gravel, sandy, calcareous, tuffaceous	6	180
Silt, sandy, clayey, tuffaceous, buff	45	225
Sand, silty, poorly sorted	7	232
Silt, sandy, calcareous, tuffaceous, buff	16	248
Gravel, sandy	4	252
Siltstone, sandy, calcareous, tuffaceous, buff	28	280
Volcanic ash, gray	4	284
Gravel, sandy and silty	21	305
Sand and silt, calcareous; contains numerous dark minerals	18	323
Tertiary (unit T_1?):		
Siltstone, sandy, calcareous, tuffaceous, buff; interbedded with tan laminated claystone	31	354
Sand, poorly sorted; contains pebbles	9	363
Siltstone, clayey, calcareous, tuffaceous, buff	22	385
Sand, poorly sorted	43	428
Claystone, silty, slightly calcareous, buff	30	458
Tertiary (unit T_1):		
Volcanic ash, calcareous	3	461
Clay and claystone, silty, calcareous, tuffaceous, tan	42	503
Clay and claystone, silty, calcareous, light-green	55	558
Claystone, silty, pyritic, bluish-green	32	590
Clay and claystone, pyritic, dark-blue; fossiliferous (ostracodes at 715 ft)	135	725
Sand, poorly sorted, composed chiefly of quartz, garnet, dark minerals, calcite, and pyrite grains	24	749
Clay, silty, dark-blue; contains gypsum fragments, which probably occur in thin layers	44	793
Clay and claystone, dark-blue, fossiliferous (ostracodes at 820 and 835 ft); contains siltstone fragments	66	859

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
D1-3-36bc—Continued		
Precambrian(?):		
Sand, angular, bluish; contains pebbles. Sand is composed chiefly of quartz, feldspar, and gneiss fragments. This material is probably derived from weathered Precambrian gneiss	23	882

D1-4-1cd

[Drilled by commercial driller]

	Thickness (feet)	Depth (feet)
Soil	2	2
Gravel, loose. Water at 28 ft	26	28
Sand, water-bearing	4	32
Gravel, tight; contains some sand. Struck second water at 54 ft and it raised to 47.4 ft from the surface	88	120
Sand, clean. More water	4	124
Gravel, tight; contains some sand	66	190
Sand, clean. More water	6	196
Gravel, tight	4	200

D1-4-2dd

[Drilled by commercial driller. Samples examined by U. S. Geological Survey personnel]

	Thickness (feet)	Depth (feet)
Gravel and sand; some calcareous silt	12	12
Sand and gravel; little light-gray calcareous silt	22	34
Gravel and sand; some light-brown silt	44	78
Silt, light-brown; some gravel and sand	17	95
Gravel and sand; varying amounts of light-brown silt	83	178

D1-4-6ddc2

[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zones, 14–65 ft and 150–240 ft. Depth to water for upper zone, 15 ft; for lower zone only, 28 ft]

	Thickness (feet)	Depth (feet)
Quaternary (alluvium):		
Silt, calcareous, light-gray; some clay and sand	5	5
Silt, calcareous, light-gray; some fine sand	10	15
Silt, calcareous, light-gray; some sand and gravel	5	20
Silt, calcareous, gray; some medium sand	5	25
Sand, silty, slightly calcareous, gray; some fine gravel	8	33
Gravel and sand; some gray silt	7	40
Sand, coarse; some gray silt	5	45
Sand, very fine to fine; some gray silt	5	50
Gravel, brown sand and silt	10	60
Sand, coarse, and fine gravel; some light-brown silt	26	86
Sand, fine to medium, silty, light-brown	6	92
Gravel and sand; light-brown silt and clay	6	98
Sand, coarse, and gravel; light-brown silt	5	103
Sand, well sorted, medium, gray-brown	15	118
Sand and gravel; some light-brown silt	28	146
Silt, light-brown; very fine to fine sand; some gravel	5	151
Sand, medium to very coarse, and fine gravel; some light-brown silt	10	161
Sand, coarse, and gravel; very fine sand in silt matrix, light-brown	25	186
Sand, very fine, and light-brown silt; some gravel and clay	32	218

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
D1-4-6ddc2—Continued		
Quaternary (alluvium):—Continued		
Sand, well-sorted, fine to medium; contains numerous grains of magnetite	4	222
Silt, clayey, light-brown; some coarse sand and gravel	18	240
Gravel, fine, and medium to coarse sand; light-brown silt	6	246
Gravel, medium to coarse, and sand; silt and clay matrix	9	255
Note: Fragments of metamorphic and volcanic rocks and quartz are the predominant constituents of the sand and gravel.		

D1-4-9ba1

[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zones, 12–45 ft and 50–97 ft. Depth to water for upper zone 11 ft; for lower zone only, 23 ft]

	Thickness (feet)	Depth (feet)
Quaternary (alluvium):		
Sand, coarse to fine; contains pebbles and some cobbles	20	20
Sand, very coarse to coarse; contains pebbles, very fine sand, and some brown silt	15	35
Gravel, fine, and coarse sand	3	38
Gravel, medium to fine, sandy; some brown silt	7	45
Clay, sandy, light-brown	2	47
Sand, coarse to fine; contains pebbles and some silt	14	61
Gravel and sand, poorly sorted; some brown silt and clay	25	86
Sand and gravel, poorly sorted, angular to subrounded; some brown silt	11.5	97.5
Note: Fragments of metamorphic rocks and some of volcanic rocks are the principal constituents of the sand and gravel.		

D1-4-25aa2

[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zones, 5–50 ft and 149–223 ft. Depth to water for upper zone, 5 ft; water level for lower zone only, 13 ft above land surface]

	Thickness (feet)	Depth (feet)
Quaternary (alluvium):		
Soil	3	3
Gravel and cobbles of limestone, and metamorphic and volcanic rocks; contains some gray-brown calcareous silt	13	16
Gravel and sand, poorly sorted, dark-gray; some gray-brown calcareous silt	14	30
Sand, very fine to medium, dark	13	43
Gravel, fine; some sand and silt	3	46
Sand, very fine to medium, dark	3	49
Quaternary (fan alluvium?):		
Gravel, sandy, silty, tan to brown; contains several thin lenses of sand and silt. Gravel composed of volcanic and metamorphic rocks	52	101
Silt and very fine sand, light-brown	3	104
Sand, silty, poorly sorted, very fine to very coarse, tan; contains pebbles	33	137
Tertiary:		
Silt, clayey, tan; contains fragments of claystone and tan calcareous tuffaceous siltstone; some gray ash fragments	12	149
Sand, poorly sorted, calcareous, tan; some fragments of calcareous cemented sandstone	8	157
Sand, fine to very fine, and silt	6	163

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
D1-4-25aa2—Continued		
Tertiary:—Continued		
Gravel, poorly sorted, rounded, sandy; little light-brown silt	15	178
Sand, poorly sorted, fine to coarse, gray; some tan silt in places; fragments of calcareous tuffaceous siltstone and claystone	43	221
Sand, gray, and fragments of calcareous cemented sandstone	2	223
Siltstone, tuffaceous, calcareous, tan; interbedded with buff claystone	57	280

D1-4-25aa3

[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zone, 5–50 ft. Depth to water, 5 ft]

	Thickness (feet)	Depth (feet)
Quaternary:		
Soil	5.5	5.5
Gravel, dark; some large pebbles and cobbles	9.5	15
Sand and gravel, dark	13	28
Sand and gravel; some brown silt	6	34
Sand and some gravel, clean	16	50
Sand, silty, brown	.5	50.5

D1-4-34bd

[Drilled by commercial driller]

	Thickness (feet)	Depth (feet)
Quaternary: Sand and gravel	16	16
[Tertiary(?)]: Clay, yellow and brown	22	38

D1-5-9cd

[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zone, 14–70 ft. Depth to water, 14 ft]

	Thickness (feet)	Depth (feet)
Quaternary (alluvium):		
Gravel, poorly sorted; composed of red and black volcanic rocks, gneiss, and brown and gray limestone; some light-brown calcareous silt and fine sand	10	10
Gravel, fine, moderately sorted; very little silt	5	15
Gravel, poorly sorted, sandy, dark; some brown calcareous silt	15	30
Sand, poorly sorted, clean, calcareous, dark	5	35
Gravel, sandy, poorly sorted; some brown calcareous silt	15	50
Gravel, sandy, and some brown slightly calcareous silt. Gravel is composed chiefly of dark volcanic rocks and gneiss; also contains a few fragments of limestone	10	60
Sand, poorly sorted, in matrix of brown silt; contains pebbles. Sand is composed of fragments of volcanic rocks and gneiss	5	65
Gravel, sandy, poorly sorted; some brown silt	45	110
Sand and gravel, poorly sorted, silty	45	155
Sand, poorly sorted, clean; contains pebbles	7	162

D1-5-18cc

[Drilled by commercial driller]

	Thickness (feet)	Depth (feet)
Sand and gravel	49	49
Hardpan	.5	49.5
Gravel	.5	50

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
D1-5-32ca		
[Drilled by commercial driller]		
Clay	5	5
Gravel	18	23
Clay and hardpan	19	42
Hardpan. Water	10	52
D1-5-34cc2		
[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zones, 10–39 ft, 60–83 ft, and 103–120 ft. Depth to water for top zone, 10 ft]		
Quaternary (fan alluvium):		
Silt, buff	9	9
Gravel, silty, sandy; composed chiefly of volcanic and metamorphic rocks	30	39
Clay, sandy, silty, buff	23	62
Sand, poorly sorted; contains pebbles. The sand is composed chiefly of quartz with some biotite	21	83
Silt, clayey, buff	20	103
Gravel, silty; contains pebbles	12	115
Sand, medium to fine, silty; contains pebbles	12	127
Tertiary:		
Volcanic ash, gray	4	131
Siltstone, sandy, calcareous, tuffaceous, buff	9	140
Sand, medium to coarse, silty; contains pebbles	14	154
Siltstone, sandy, calcareous, tuffaceous, buff	90	244
Gravel; composed of volcanic and metamorphic rocks	3	247
Silt, buff; contains pebbles	3	250
D1-5-36ddc		
[Drilled by commercial driller]		
Topsoil and dirt	20	20
Gravel, sand, boulders. Water at 30 ft	73	93
D2-4-4aa		
[Drilled by commercial driller]		
Soil	7	7
Gravel	27	34
D2-4-9bc		
[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zones: 85–100 ft, 185–200 ft, 433–459 ft, 497–542 ft, and 555–595 ft. Depth to water for top zone, 85 ft]		
Quaternary (loess?): Silt, clayey, calcareous, buff to gray	18	18
Quaternary (terrace deposits?):		
Silt, sandy, calcareous, tan; contains pebbles	12	30
Gravel and sand in matrix of tuffaceous silt, tan; composed of metamorphic and volcanic rocks	30	60
Tertiary (unit T_2 ?):		
Silt, sandy, tan	10	70
Gravel, sandy; contains well-rounded cobbles	11	81
Sand and gravel, coarse; some silicified wood fragments	19	100
Tertiary (unit T_2):		
Sand; contains fragments of tan tuffaceous siltstone	25	125
Silt, sandy, tuffaceous, buff-tan	15	140
Siltstone, sandy, calcareous, tuffaceous, buff; contains silicified wood at 170 ft and bone fragments at 180 ft	45	185

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
D2-4-9bc—Continued		
Tertiary (unit T_2)—Continued		
Sand, silty, calcareous, gray	6	191
Silt, sandy, tuffaceous, buff to gray; contains pebbles	9	200
Siltstone, sandy, calcareous, tuffaceous, buff	19	219
Volcanic ash, gray	4	223
Siltstone, slightly sandy, calcareous, tuffaceous, buff	76	299
Volcanic ash, buff to gray	2	301
Siltstone, sandy, calcareous, tuffaceous, buff; interbedded with light-brown laminated claystone; contains some scattered fragments of gray volcanic ash	87	388
Sandstone, moderately cemented, fine, gray	4	392
Tertiary (unit T_1?):		
Bentonite, greenish-cream; contains some fragments of clayey siltstone	10	402
Claystone, sandy, silty, calcareous, tan; interbedded with thin layers of volcanic ash	31	433
Sand, poorly sorted, dark; contains pebbles. Sand is composed of quartz, hornblende, feldspar, garnet, magnetite, mica, and a few rounded grains of volcanic rock	26	459
Clay, silty, light-blue	11	470
Silt, clayey, bluish-gray	10	480
Clay, silty, light-blue	17	497
Sand, medium, gray; composed of quartz, feldspar, garnet, biotite, and hornblende	19	516
Sand interbedded with clay, pyritic, blue	26	542
Silt, clayey, pyritic, bluish-gray	13	555
Sand, poorly sorted, angular, bluish-green	20	575
Precambrian (Archean? type):		
Sand and clay, bluish-green (probably weathered gneiss). Sand is composed of angular grains of quartz, garnet, feldspar (microcline), biotite, and hornblende	20	595
Precambrian (Archean type): Gneiss, coarsely crystalline, greenish	5	600

D2-4-11dc

[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zone, 10–68 ft. Depth to water, 10 ft]

	Thickness (feet)	Depth (feet)
Quaternary (alluvium):		
Gravel, poorly sorted, sandy, in a matrix of gray calcareous micaceous silt. Gravel is composed of fragments of dark volcanic rocks, gneiss, and some limestone	5	5
Sand and gravel; contains some gray calcareous silt. Composition of sand and gravel is similar to that of the gravel from 0–5 ft; contains varying amounts of limestone fragments	49	54
Gravel, sandy, in a silt matrix	6	60
Sand, poorly sorted, gray; contains gray silt	8	68
Tertiary (unit T_2?):		
Claystone interbedded with siltstone, calcareous, light-brown	5	73
Sand, poorly sorted, dark; contains pebbles	5	78
Claystone, light-brown, and calcareous clayey siltstone; contains some bentonite(?)	22	100
Siltstone, slightly calcareous, light-brown; contains some marl and claystone	5	105
Siltstone, light-brown; contains a few thin lenses of sand	40	145
Sand, silty, slightly calcareous, light-brown; composed chiefly of well-sorted frosted quartz grains	5	150

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
D2-4-15da		
[Drilled by commercial driller]		
Gravel	19	19
Clay, yellow. A little water	28	47
Clay	63	110
Sandrock	10	120
D2-5-1dd2		
[Drilled by commercial driller]		
Gravel	14	14
Clay	42	56
Gravel. Some water	1.5	57.5
Clay and some gravel. Water at 64 ft	6.5	64
D2-5-2aa		
[Drilled by commercial driller]		
Topsoil	8	8
Sand and gravel, dirty. Some water	47	55
Clay	10	65
Sand and gravel, dirty. Some water	3	68
Clay, sandy	6	74
Sand and gravel. Water	4	78
D2-5-14ac		
[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zone, 6.5–115 ft. Depth to water, 6.5 ft]		
Quaternary (fan alluvium):		
Loam	4	4
Gravel, sandy, calcareous; gravel is composed of subangular to subrounded fragments of gneiss and volcanic rocks	6	10
Gravel, sandy and silty, calcareous	15	25
Sand; contains pebbles	2	27
Gravel, medium, sandy	28	55
Sand; contains pebbles	2	57
Gravel, medium, sandy	10	67
Clay, light-brown	.5	67.5
Gravel, medium, sandy	27.5	95
Gravel, sandy and slightly silty	20	115
Gravel, sandy, silty, and clayey. The amount of clay increases downward	30	145
Sand, fine, silty, interbedded with brown clay	10	155
Tertiary(?):		
Sand, silty, clayey; contains pebbles	30	185
Silt, clayey; interbedded with silty clay	25	210
Sand, silty; contains pebbles	4	214
Gravel, sandy; contains cobbles	2	216
Sand; contains pebbles	8	224
Silt and clay, buff; contains magnetite from 250–265 ft	41	265
D2-5-22ccd		
[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zones, 7–25 ft and 90–165 ft. Depth to water, 7 ft]		
Quaternary (fan alluvium):		
Loam, silty, light brownish-gray	3	3
Gravel, sandy, calcareous; composed of subrounded metamorphic and volcanic rocks	22	25

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
D2-5-22ccd—Continued		
Quaternary (fan alluvium)—Continued		
Gravel, sandy, silty	25	50
Gravel, silt, and sand; contains some cobbles	15	65
Sand, silty, brown; contains pebbles	9	74
Gravel, medium, sandy, silty	16	90
Sand, silty, brown; contains pebbles	5	95
Gravel, sandy, silty	30	125
Note: Fragments of volcanic rocks are more numerous than those of metamorphic rocks from 3 to 125 ft.		
Gravel, silty, interbedded with sandy gravel; basal 5 ft are notably micaceous; gravel is composed chiefly of fragments of metamorphic rocks, but contains some fragments of volcanic rocks	40	165
Tertiary(?):		
Silt, sand, and clay, buff-gray. Sand contains well-rounded quartz grains	33	198
Gravel, sandy, silty	4	202
Sand, very fine to fine, silty	13	215
Clay and silt, buff to gray; contains rounded pebbles	15	230
Gravel, fine, silty, sandy	5	235
Silt and sand; contains cobbles	22	257
Gravel, silty; contains cobbles	8	265
Sand, fine, interbedded with sandy gravel	30	295
Silt, sandy at top, clayey near base, light-brown	38	333
Sand, silty, fine; contains lenses of clay. Sand is composed of spherical quartz grains and a large amount of magnetite	25	358
Sand, very fine to medium, calcareous, dark-brown; contains magnetite and well-rounded quartz grains	12	370
Tertiary:		
Silt, sandy, calcareous; interbedded with clay light-brown; contains some fragments of light-brown calcareous tuffaceous siltstone, also silicified wood fragments at 377 ft	55	425
Silt, sandy; interbedded with cream-colored marl; contains some tuffaceous siltstone	30	455
Siltstone, sandy, calcareous, tuffaceous, buff	22	477
Clay, light-brown; contains silicified bone fragments	5	482
Siltstone, sandy, calcareous, tuffaceous, buff; interbedded with light-brown clay	30	512
Silt, tuffaceous; intermixed with clay	14	526
Siltstone, sandy, calcareous, tuffaceous, buff; contains some pebbles of red and black volcanic rocks	70	596
Bentonite(?), tan to light-brown	2	598
Silt, tan; interbedded with thin layers of marl	7	605
Silt, slightly tuffaceous, tan	30	635
Silt, slightly tuffaceous, tan; interbedded with thin layers of clay	5	640
Silt, slightly tuffaceous, tan	30	670
Siltstone, sandy, calcareous, tuffaceous, buff	19	689
Sandstone, poorly sorted, calcareous	3	692
Volcanic ash, pure, grayish-buff	1	693
Sandstone, calcareous; contains pebbles	7	700
Siltstone, sandy, calcareous, tuffaceous, buff	20	720
Siltstone, sandy, calcareous, tuffaceous, buff; interbedded with thin layers of clay	35	755
Siltstone, calcareous, tuffaceous, buff; contains pebbles	44	799
Sand, silty, poorly sorted, subangular; contains pebbles and much magnetite	4	803
Siltstone, sandy, calcareous, tuffaceous, buff	7	810
Siltstone, clayey, calcareous, tuffaceous, buff	55	865

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
D2-5-22ccd—Continued		
Tertiary—Continued		
Tuff, silicified, grayish	2	867
Volcanic ash, light-gray	2	869
Sand, fine to coarse, poorly sorted, silty, calcareous, dark-brown	19	888
Siltstone	2	890
Volcanic ash, pure	1	891
Claystone	1	892
Sand, poorly sorted, silty, calcareous, dark-brown; contains pebbles	8	900
Silt and clay, sandy, tan; contains pebbles	45	945
Sand and gravel, subangular; composed chiefly of fragments of volcanic rocks	13	958
Silt and clay, sandy, tan, slightly tuffaceous; contains pebbles	42	1,000
D2-5-35dc [Drilled by commercial driller]		
Gravel, loose	30	30
Gravel and some sand	10	40
Gravel	20	60
Gravel and sand	30	90
Sand	10	100
Hardpan, clay, and sand streaks	40	140
Sand and silt, yellow	8	148
Clay	4	152
Sand	3	155
D2-6-7-ac [Drilled by commercial driller]		
Soil	7	7
Boulders	14	21
Clay, yellow	3	24
Boulders	6	30
Clay	3	33
Gravel	2	35
Clay	3	38
Gravel	4	42
Clay	7	49
Gravel	1	50
Shale	11	61
Gravel	5	66
Clay	9	75
Gravel	15	90
Clay	34	124
Sandstone, hard	11	135
Shale	40	175
Boulders and conglomerate	19	194
Shale, tough	8	202
Conglomerate	10	212
Shale, tough	13	225
Boulders and conglomerate	21	246
Shale, tough	14	260
Conglomerate	38	298
Shale	4	302
Conglomerate	2	304

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
D2-6-7da		
[Drilled by commercial driller]		
Clay	25	25
Gravel	15	40
Clay and some sand. Water	48	88
Gravel. Water	9	97
Clay	7	104
Gravel. Little water	?	104+
D2-6-10dc		
[Drilled by commercial driller]		
Soil, black	9	9
Sand and gravel	12	21
Sand, gravel, and silt	8	29
Red material [clay(?)]. No water	3	32
D2-6-18db		
[Drilled by commercial driller]		
Gravel	13	13
Clay. No water	19	32
Gravel. No water	6	38
Hardpan. Some water	17	55
D2-6-19aa1		
[Drilled by commercial driller]		
Clay, sandy	51	51
Sand	7	58
D2-6-19aa2		
[Drilled by commercial driller]		
[Tertiary(?)]:		
Silt	19.5	19.5
Gravel	10.5	30
Silt, brown; some sand and gravel	70	100
D2-6-19cb1		
[Drilled by commercial driller]		
Topsoil	7	7
Gravel	5	12
Sand, soft, yellow	68	80
D2-6-19cb2		
[Drilled by commercial driller. Samples examined by U. S. Geological Survey personnel]		
[Quaternary (alluvium)]:		
Clay	11	11
Gravel	10	21
Silt and fine sand, light-brown; some clay. Little water	104	125
[Tertiary(?)]:		
Silt, calcareous, tan; some sand and fragments of claystone. No water	11	136
Silt and clay, calcareous, buff; contains some sand and a few fragments of marl and buff claystone. Little water	18	154
Sand, silty, buff; contains pebbles	1	155

Table 33.—*Logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)
D3-4-26ba2		
[Drilled by commercial driller]		
Gravel and boulders. No water	17	17
Clay, soft, pinkish. No water	32	49
Clay, hard. No water	2	51
Silt and clay, buff ("Lake beds")	94	145
D3-4-34aa		
[Drilled by commercial driller]		
Rock and gravel	41	41
Clay, soft [probably Tertiary]	4	45
Gravel	15	60
D3-6-6dd1		
[Drilled by commercial driller]		
Gravel	20	20
Quicksand, gray	145	165
Sand	3	168

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*

Date	Water level	Date	Water level	Date	Water level
		A1-3-2cdc2			
July 31, 1951	3.81	June 9, 1952	5.19	Apr. 1, 1953	14.31
Aug. 28	4.93	June 27	3.02	May 8	13.86
Sept. 26	5.65	Aug. 5	4.61	June 2	4.46
Nov. 1	5.56	Sept. 1	4.78	July 2	4.00
Dec. 3	6.56	Oct. 3	5.12	Aug. 4	3.61
Jan. 8, 1952	8.73	Nov. 17	6.00	Sept. 1	5.01
Feb. 6	11.80	Dec. 3	7.28	Oct. 2	6.96
Mar. 5	13.98	Jan. 7, 1953	8.66	Nov. 5	6.20
Apr. 4	13.86	Feb. 4	12.13	Dec. 1	7.42
May 5	15.07	Mar. 4	13.43	Jan. 5, 1954	10.74
		A1-3-4da			
May 21, 1951	32.85	June 9, 1952	21.46	June 2, 1953	18.56
May 31	30.94	June 26	14.21	July 2	12.38
July 5	11.05	July 31	13.27	Aug. 3	7.63
Aug. 2	8.66	Sept. 3	11.07	Sept. 2	11.06
Aug. 28	9.59	Oct. 1	13.16	Oct. 1	13.93
Sept. 26	14.36	Nov. 17	19.09	Nov. 5	18.07
Nov. 2	20.61	Dec. 2	21.54	Dec. 1	21.48
Jan. 7, 1952	28.01	Jan. 3, 1953	25.82	Jan. 5, 1954	25.29
Feb. 6	29.59	Feb. 2	28.66	Feb. 3	27.70
Mar. 5	32.03	Mar. 4	30.59	Mar. 3	29.77
Apr. 4	31.30	Apr. 1	31.82	Apr. 1	31.23
May 5	32.40	May 8	30.98		
		A1-3-9bbb			
Apr. 24, 1951	64.71	Mar. 5, 1952	58.21	May 8, 1953	62.80
May 31	65.31	May 5	65.84	June 2	58.10
July 5	54.79	June 9	62.71	July 2	51.02
Aug. 2	44.85	June 28	54.08	Aug. 3	45.18
Aug. 28	44.44	Aug. 1	46.08	Sept. 2	43.41
Sept. 26	48.09	Sept. 3	47.21	Oct. 1	44.50
Nov. 2	53.61	Oct. 1	45.42	Nov. 5	48.84
Dec. 3	56.82	Feb. 2, 1953	60.48	Dec. 1	51.72
Jan. 7, 1952	57.41	Mar. 4	62.24	Jan. 5, 1954	55.72
Feb. 6	57.22	Apr. 1	63.68		
		A1-3-10bd			
Sept. 24, 1952	2.81	June 1, 1953	4.75	Oct. 1, 1953	2.58
Feb. 2, 1953	6.21	July 2	2.98	Nov. 5	3.42
Mar. 4	6.98	Aug. 3	2.63	Dec. 1	3.95
Apr. 1	7.38	Sept. 1	3.05	Jan. 5, 1954	5.17
May 1	8.05				
		A1-3-12aa			
Aug. 26, 1952	3.56	Feb. 4, 1953	2.75	Aug. 4, 1953	3.27
Sept. 1	3.24	Mar. 5	2.66	Sept. 4	3.21
Oct. 1	3.32	Apr. 3	2.64	Oct. 2	3.42
Nov. 1	3.14	May 8	2.58	Nov. 4	3.03
Nov. 25	2.74	June 1	1.96	Dec. 1	2.61
Jan. 7, 1953	2.62	July 2	1.64	Jan. 4, 1954	3.70

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
		A1-3-23bb			
Aug. 2, 1951	0.40	May 5, 1952	0.41	May 1, 1953	0.60
Aug. 28	.30	June 9	1.28	June 2	.74
Sept. 26	.17	June 28	1.43	July 2	.59
Nov. 2	Frozen	Aug. 1	.63	Aug. 3	.94
Dec. 3	Frozen	Sept. 3	.61	Sept. 2	.66
Jan. 7, 1952	Frozen	Oct. 1	.75	Oct. 1	.65
Feb. 1	Frozen	Feb. 2, 1953	.72	Nov. 5	.51
Mar. 5	Frozen	Mar. 4	.65	Dec. 2	.46
Apr. 4	.39	Apr. 1	.62	Jan. 5, 1954	.58
		A1-3-26cd1			
June 27, 1951	5.76	May 5, 1952	6.03	Apr. 1, 1953	6.63
July 5	5.78	June 9	5.96	May 1	6.68
Aug. 2	5.73	June 28	7.94	June 2	6.15
Aug. 28	5.65	Aug. 1	6.04	July 2	5.82
Sept. 26	5.54	Sept. 3	6.20	Aug. 3	5.98
Nov. 2	5.66	Oct. 1	6.22	Sept. 2	5.95
Dec. 3	6.02	Nov. 17	6.48	Oct. 1	6.38
Jan. 7, 1952	6.46	Dec. 3	6.51	Nov. 5	6.32
Feb. 4	6.54	Jan. 2, 1953	6.67	Dec. 2	6.35
Mar. 5	6.64	Feb. 2	6.50	Jan. 5, 1954	6.43
Apr. 4	5.74	Mar. 4	6.73		
		A1-4-3bb			
Apr. 24, 1951	19.45	Apr. 4, 1952	19.60	Mar. 5, 1953	19.10
May 31	19.77	May 6	17.74	Apr. 2	20.02
July 5	12.61	June 9	15.73	May 8	20.90
Aug. 2	10.54	June 28	9.68	June 1	20.34
Aug. 28	10.67	Aug. 5	8.19	July 2	9.64
Sept. 26	15.49	Sept. 1	8.63	Aug. 4	10.59
Nov. 3	17.26	Oct. 3	12.54	Sept. 1	8.69
Dec. 3	18.26	Nov. 17	16.51	Oct. 2	8.59
Jan. 8, 1952	18.63	Dec. 3	16.85	Nov. 4	13.05
Feb. 6	19.25	Jan. 7, 1953	17.92	Dec. 1	16.04
Mar. 5	19.95	Feb. 4	18.91	Jan. 4, 1954	17.94
		A1-4-5ad			
May 31, 1951	3.36	May 6, 1952	3.23	Apr. 2, 1953	3.56
July 5	3.27	June 9	3.19	May 8	3.52
Aug. 2	2.65	June 26	2.68	June 1	3.48
Aug. 28	3.08	Aug. 5	2.81	July 2	3.09
Sept. 26	2.85	Sept. 1	3.40	Aug. 1	2.79
Nov. 3	2.69	Oct. 3	3.48	Sept. 4	3.05
Dec. 3	2.70	Nov. 17	3.55	Oct. 2	3.31
Jan. 8, 1952	2.81	Dec. 3	3.63	Nov. 4	2.95
Feb. 6	3.39	Jan. 7, 1953	Frozen	Dec. 1	2.97
Mar. 5	3.58	Feb. 4	3.43	Jan. 4, 1954	3.39
Apr. 7	2.45	Mar. 5	3.64		
		A1-4-5ba			
July 5, 1951	2.99	Aug. 28, 1951	3.68	Sept. 26, 1951	3.03
Aug. 2	3.71				

A1-4-5da

[No measurements by tape; for measurements from recorder chart, see table 35]

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
		A1-4-6ab			
May 31, 1951	5.90	May 6, 1952	4.63	Apr. 3, 1953	5.21
July 5	4.67	June 9	4.67	May 8	5.16
Aug. 2	5.07	June 27	4.48	June 1	5.37
Aug. 28	4.66	Aug. 5	3.12	July 2	4.49
Sept. 26	4.22	Sept. 3	4.07	Aug. 4	3.82
Nov. 3	4.40	Oct. 3	3.45	Sept. 4	3.88
Dec. 3	4.94	Nov. 17	3.74	Oct. 2	4.75
Jan. 8, 1952	5.12	Dec. 3	4.61	Nov. 4	5.38
Feb. 6	5.17	Jan. 7, 1953	5.86	Dec. 1	5.84
Mar. 5	5.26	Feb. 4	5.40	Jan. 4, 1954	5.90
Apr. 4	5.18	Mar. 5	5.82		
		A1-4-6bc			
Aug. 9, 1951	5.97	June 9, 1952	8.83	May 8, 1953	10.28
Aug. 28	7.73	Aug. 5	4.82	June 1	10.07
Sept. 26	9.41	Sept. 3	7.82	July 2	2.01
Nov. 2	10.00	Oct. 3	9.57	Aug. 4	4.57
Dec. 3	10.16	Nov. 17	10.37	Sept. 4	7.02
Jan. 8, 1952	10.21	Dec. 3	10.32	Oct. 2	8.81
Feb. 6	10.43	Jan. 7, 1953	10.48	Nov. 4	9.83
Mar. 5	10.51	Feb. 4	10.38	Dec. 1	10.24
Apr. 3	9.74	Mar. 5	10.55	Jan. 4, 1954	10.42
May 6	9.88	Apr. 3	10.37		
		A1-4-7aa			
May 31, 1951	2.02	May 6, 1952	4.40	Apr. 2, 1953	4.60
July 5	3.54	June 9	4.30	May 8	4.40
Aug. 2	3.42	June 26	1.10	June 1	.59
Aug. 28	2.52	Aug. 5	3.02	July 2	4.41
Sept. 26	3.51	Sept. 1	1.85	Aug. 1	1.73
Nov. 2	3.78	Oct. 3	3.23	Sept. 4	4.87
Dec. 3	4.25	Nov. 17	2.75	Oct. 2	4.31
Jan. 8, 1952	4.29	Dec. 3	4.32	Nov. 4	4.14
Feb. 6	Frozen	Jan. 7, 1953	4.95	Dec. 1	3.80
Mar. 5	Frozen	Feb. 4	4.74	Jan. 4, 1954	4.80
Apr. 7	3.97	Mar. 5	4.98		
		A1-4-8ba			
May 31, 1951	0.64	Nov. 2, 1951	Frozen	Apr. 7, 1952	0.46
July 5	.18	Dec. 3	Frozen	May 6	2.16
Aug. 2	2.72	Jan. 8, 1952	Frozen	June 9	2.42
Aug. 28	.39	Feb. 6	Frozen	Oct. 3	2.28
Sept. 26	.21	Mar. 5	Frozen		
		A1-4-10aa			
July 6, 1951	3.32	June 6, 1952	2.72	Apr. 3, 1953	3.24
Aug. 2	3.30	June 27	3.24	May 8	3.18
Aug. 28	3.02	Aug. 5	3.50	June 1	1.87
Sept. 26	2.96	Sept. 3	3.32	July 2	3.22
Nov. 1	3.72	Oct. 3	3.49	Aug. 4	3.38
Dec. 3	2.70	Nov. 17	3.61	Sept. 4	3.22
Jan. 7, 1952	3.18	Dec. 3	3.22	Oct. 5	3.36
Feb. 6	3.07	Jan. 7, 1953	3.31	Nov. 4	3.05
Mar 5	3.27	Feb. 4	3.08	Dec. 1	2.99
Apr. 7	2.91	Mar. 5	3.27	Jan. 4, 1954	3.12
May 6	2.31				

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
A1-4-13ad					
May 31, 1951	2.50	May 6, 1952	1.02	Apr. 1, 1953	3.56
July 6	3.79	June 6	1.32	May 8	3.36
Aug. 2	3.94	June 27	2.93	June 4	1.10
Aug. 29	3.29	Aug. 4	3.56	July 2	3.04
Sept. 26	3.32	Sept. 2	3.39	Aug. 5	3.64
Nov. 1	3.43	Oct. 3	3.46	Sept. 4	3.43
Dec. 3	3.39	Nov. 17	3.49	Oct. 2	3.51
Jan. 8, 1952	3.68	Dec. 3	3.40	Nov. 4	3.37
Feb. 6	3.76	Jan. 5, 1953	3.64	Dec. 2	3.37
Mar. 5	3.82	Feb. 4	3.53	Jan. 4, 1954	3.59
Apr. 2	3.32	Mar. 5	3.64		
A1-4-15ba					
July 6, 1951	5.43	June 6, 1952	4.46	Apr. 2, 1953	4.26
Aug. 2	5.35	June 27	4.91	May 8	4.09
Aug. 28	5.34	Aug. 5	5.08	June 4	3.61
Sept. 26	4.95	Sept. 3	5.22	July 2	5.07
Nov. 1	4.56	Oct. 2	5.08	Aug. 4	5.24
Dec. 4	4.48	Nov. 17	5.00	Sept. 4	5.20
Jan. 7, 1952	Plugged	Dec. 3	4.69	Oct. 5	5.12
Feb. 6	4.44	Jan. 7, 1953	4.57	Nov. 4	4.89
Mar. 5	4.61	Feb. 4	4.23	Dec. 2	4.74
Apr. 7	3.70	Mar. 5	4.42	Jan. 4, 1954	4.79
May 6	4.28				
A1-4-15da1					
July 6, 1951	3.81	June 27, 1952	3.15	May 8, 1953	3.26
Aug. 2	3.57	Aug. 5	3.49	June 4	2.28
Aug. 28	3.12	Sept. 3	3.20	July 2	2.58
Sept. 26	2.90	Oct. 2	3.11	Aug. 4	3.51
Nov. 1	2.74	Nov. 17	3.28	Sept. 4	3.23
Dec. 3	2.74	Dec. 3	3.00	Oct. 5	3.17
Jan. 7, 1952	2.93	Jan. 7, 1953	3.15	Nov. 4	3.04
Apr. 7	2.26	Feb. 4	3.04	Dec. 2	3.09
May 6	3.30	Mar. 5	3.24	Jan. 4, 1954	3.23
June 6	3.38	Apr. 2	3.31		
A1-4-15da2					
May 20, 1953	4.64	Aug. 4, 1953	3.74	Nov. 4, 1953	3.31
June 4	2.60	Sept. 4	3.51	Dec. 2	3.33
July 2	3.08	Oct. 5	3.42	Jan. 4, 1954	3.48
A1-4-16bb					
July 6, 1951	3.40	May 6, 1952	2.99	Apr. 2, 1953	3.42
Aug. 2	3.45	June 27	3.66	May 8	3.38
Aug. 28	3.12	Aug. 5	3.69	June 4	2.47
Sept. 26	3.24	Sept. 3	3.23	July 2	3.45
Nov. 1	3.11	Oct. 2	3.05	Aug. 4	3.11
Dec. 4	3.08	Nov. 17	3.38	Sept. 4	3.06
Jan. 8, 1952	3.78	Dec. 2	2.41	Oct. 5	4.00
Feb. 6	3.90	Jan. 7, 1953	2.96	Nov. 4	3.78
Mar. 5	4.01	Feb. 4	3.06	Dec. 2	3.96
Apr. 7	2.11	Mar. 5	3.84	Jan. 4, 1954	4.02

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

A1-4-21dc

Date	Water level	Date	Water level	Date	Water level
July 6, 1951	0.82	Sept. 26, 1951	1.88	Oct. 2, 1952	1.18
Aug. 2	.80	Nov. 1	.51	Aug. 6, 1953	1.62
Aug. 28	.64	Aug. 5, 1952	1.13		

A1-4-22dc1

[Depth to water Aug. 7, 1951, 3.98 ft. No other measurements by tape; for measurements from recorder chart, see table 35]

A1-4-22dd

Date	Water level	Date	Water level	Date	Water level
July 6, 1951	4.53	June 6, 1952	5.19	Apr. 2, 1953	7.39
Aug. 2	4.08	June 27	4.49	May 8	7.13
Aug. 28	3.63	Aug. 5	4.08	June 4	4.47
Sept. 26	3.74	Sept. 3	3.89	July 2	4.89
Nov. 1	4.37	Oct. 2	3.99	Aug. 4	4.24
Dec. 3	5.13	Nov. 17	4.31	Sept. 4	4.12
Jan. 8, 1952	6.42	Dec. 3	4.67	Oct. 5	4.25
Feb. 6	6.58	Jan. 7, 1953	5.75	Nov. 4	4.37
Apr. 7	5.97	Feb. 4	6.26	Dec. 2	4.84
May 6	6.76	Mar. 5	7.03	Jan. 4, 1954	5.72

A1-4-24dc

Date	Water level	Date	Water level	Date	Water level
July 6, 1951	3.94	Sept. 26, 1951	3.16	Dec. 3, 1951	3.74
Aug. 2	3.69	Nov. 1	3.34	Mar. 5, 1952	5.41
Aug. 29	3.19				

A1-4-25bd

Date	Water level	Date	Water level	Date	Water level
July 6, 1951	3.19	June 2, 1952	5.68	Apr. 1, 1953	7.54
Aug. 2	2.66	June 27	2.99	May 8	7.40
Aug. 29	2.34	Aug. 1	2.29	June 4	3.68
Sept. 26	2.49	Sept. 3	2.72	July 2	3.26
Nov. 3	2.93	Oct. 3	2.99	Aug. 5	2.43
Dec. 3	4.13	Nov. 17	3.31	Sept. 4	2.63
Jan. 8, 1952	5.41	Dec. 3	3.89	Oct. 2	2.98
Feb. 6	6.79	Jan. 2, 1953	5.16	Nov. 4	2.91
Mar. 5	7.61	Feb. 4	6.17	Dec. 1	3.46
Apr. 1	7.43	Mar. 5	7.26	Jan. 4, 1954	5.07
May 2	6.92				

A1-4-25dc

[No measurements by tape; for measurements from recorder chart, see table 35]

A1-4-29ab

Date	Water level	Date	Water level	Date	Water level
July 6, 1951	3.28	June 10, 1952	4.55	Apr. 3, 1953	5.41
Aug. 2	2.98	June 26	4.74	May 1	5.41
Aug. 28	2.28	Aug. 5	4.61	June 4	4.32
Sept. 26	2.59	Sept. 3	4.64	July 2	4.43
Nov. 1	2.92	Oct. 2	4.43	Aug. 6	4.21
Dec. 3	3.31	Nov. 17	4.58	Sept. 4	4.09
Jan. 8, 1952	3.97	Dec. 2	4.67	Oct. 5	4.07
Feb. 6	4.16	Jan. 7, 1953	5.01	Nov. 5	4.09
Apr. 3	4.16	Feb. 3	5.19	Dec. 2	4.54
May 5	4.16	Mar. 4	5.40	Jan. 4, 1954	4.63

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
		A1-4-36dc			
June 27, 1952......	29.64	Sept. 2, 1952....	26.42	Nov. 12, 1952...	28.11
Aug. 4.............	26.47	Sept. 29...........	26.31	Dec. 3..........	29.65
		A1-5-5da			
May 28, 1951......	6.16	Nov. 2, 1951....	8.08	June 29, 1952...	6.74
July 6.............	6.64	Dec. 4...........	8.36	Aug. 1..........	7.54
Aug. 2.............	7.10	Jan. 11, 1952....	8.52	Aug. 27..........	8.00
Aug. 28.............	7.17	May 6...........	5.74	Oct. 3..........	8.10
Sept. 29.............	7.84	June 2...........	5.76		
		A1-5-6bd			
May 14, 1951......	33.78	Nov. 1, 1951....	34.94	May 6, 1952...	30.44
May 31.............	33.67	Dec. 3...........	34.42	June 6..........	30.54
July 6.............	33.29	Jan. 7, 1952....	34.72	June 29..........	31.19
Aug. 2.............	32.96	Feb. 6...........	34.91	Aug. 4..........	31.78
Aug. 29.............	33.64	Mar. 6...........	35.63	Sept. 1..........	32.90
Sept. 26.............	34.34	Apr. 7...........	34.60	Oct. 3..........	33.41
		A1-5-6cc			
May 15, 1951......	22.22	Apr. 7, 1952....	22.80	Mar. 3, 1953...	21.88
May 31.............	21.90	May 6...........	21.54	Apr. 1..........	21.73
July 6.............	22.10	June 6...........	20.90	May 8..........	21.68
Aug. 2.............	22.56	June 29...........	21.09	June 4..........	21.06
Aug. 29.............	21.96	Aug. 4...........	20.59	July 2..........	22.15
Sept. 26.............	23.00	Sept. 1...........	20.80	Aug. 5..........	21.19
Nov. 1.............	22.92	Oct. 3...........	21.92	Sept. 4..........	21.62
Dec. 3.............	22.61	Nov. 17...........	22.14	Oct. 5..........	21.91
Jan. 11, 1952......	22.73	Dec. 3...........	22.30	Nov. 5..........	21.77
Feb. 6.............	22.92	Jan. 5, 1953....	21.00	Dec. 2..........	21.83
Mar. 6.............	23.21	Feb. 2...........	21.07	Jan. 4, 1954...	21.02
		A1-5-8ad			
May 29, 1952......	9.19	Apr. 3, 1953....	10.47	Sept. 4, 1953...	10.21
June 29.............	9.75	May 8...........	10.45	Oct. 1..........	10.94
Aug. 1.............	10.17	June 4...........	10.20	Nov. 5..........	10.14
Oct. 3.............	10.40	July 2...........	9.97	Dec. 3..........	10.64
Feb. 2, 1953......	10.41	Aug. 5...........	10.00	Jan. 4, 1954...	10.71
Mar. 3.............	10.50				
		A1-5-16bc1			
Aug. 2, 1951......	12.89	Oct. 3, 1952....	11.10	June 4, 1953...	13.68
Aug. 28.............	14.29	Nov. 17...........	12.72	July 2..........	13.20
Apr. 1, 1952......	15.61	Dec. 3...........	13.10	Aug. 5..........	12.74
May 1.............	11.18	Jan. 2, 1953....	12.98	Sept. 4..........	12.93
June 2.............	9.75	Feb. 2...........	13.11	Oct. 1..........	12.93
June 29.............	9.81	Mar. 5...........	14.08	Nov. 5..........	13.56
Aug. 1.............	9.30	Apr. 3...........	14.25	Dec. 3..........	13.81
Sept. 3.............	10.03	May 8...........	13.98	Jan. 4, 1954...	14.06

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
		A1-5-19bc			
July 6, 1951	2.84	June 6, 1952	2.64	Apr. 1, 1953	2.75
Aug. 2	2.63	June 27	2.63	May 8	2.70
Aug. 29	2.14	Aug. 4	2.53	June 4	2.40
Sept. 26	1.93	Sept. 2	2.28	July 2	2.58
Nov. 1	1.92	Oct. 3	2.18	Aug. 5	2.41
Dec. 3	2.29	Nov. 17	2.23	Sept. 4	2.14
Jan. 8, 1952	2.58	Dec. 3	2.17	Oct. 2	2.08
Feb. 6	2.77	Jan. 5, 1953	2.71	Nov. 4	2.00
Mar. 5	2.86	Feb. 4	2.67	Dec. 2	2.20
Apr. 2	2.63	Mar. 5	2.76	Jan. 4, 1954	2.55
May 2	2.54				
		A1-5-21bc4			
Dec. 4, 1951	7.75	June 2, 1952	3.94	Sept. 3, 1952	5.11
Apr. 1, 1952	8.42	June 29	4.53	Oct. 3	5.49
May 1	5.39	Aug. 1	4.98		
		A1-5-26cd			
Sept. 28, 1951	6.52	Mar. 5, 1952	6.61	June 29, 1952	6.49
Dec. 3	6.36	Apr. 1	6.55	Aug. 1	6.76
Jan. 8, 1952	6.52	May 1	6.14	Sept. 2	6.56
Feb. 6	6.53	June 2	6.16	Sept. 29	6.62
		A1-5-30dd			
July 7, 1951	2.68	June 6, 1952	2.16	Apr. 2, 1953	2.94
Aug. 2	2.65	June 27	2.40	May 8	2.86
Aug. 29	2.29	Aug. 1	2.43	June 4	1.43
Sept. 26	2.15	Sept. 2	2.17	July 2	2.52
Nov. 3	2.14	Oct. 3	2.13	Aug. 4	2.56
Dec. 3	2.29	Nov. 10	2.03	Sept. 4	2.29
Jan. 8, 1952	2.48	Dec. 3	2.18	Oct. 2	2.35
Feb. 6	2.78	Jan. 2, 1953	2.63	Nov. 4	2.28
Mar. 5	3.19	Feb. 4	2.70	Dec. 2	2.41
Apr. 1	2.81	Mar. 5	3.08	Jan. 4, 1954	2.70
May 6	2.21				
		A1-5-35aa			
Sept. 28, 1951	12.45	May 1, 1952	8.22	Aug. 1, 1952	10.82
Dec. 3	11.33	June 2	8.07	Sept. 2	10.54
Jan. 8, 1952	11.54	June 29	10.03	Sept. 29	10.05
		A1-5-35ca			
May 28, 1951	8.39	June 2, 1952	5.78	Apr. 1, 1953	8.19
Aug. 28	11.49	June 29	7.60	May 1	8.38
Sept. 26	11.59	Aug. 1	8.40	June 1	7.28
Nov. 11	11.31	Sept. 2	8.51	July 1	7.74
Dec. 3	11.68	Sept. 29	8.23	Aug. 1	8.76
Jan. 8, 1952	11.91	Nov. 11	8.09	Sept. 1	9.23
Feb. 6	12.25	Dec. 1	8.20	Oct. 1	9.25
Mar. 5	12.52	Jan. 2, 1953	8.43	Nov. 5	9.15
Apr. 1	12.63	Feb. 2	8.38	Dec. 1	9.24
May 1	4.47	Mar. 3	8.74	Jan. 4, 1954	9.37

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

A2-3-33da

[No measurements by tape; for measurements from recorder chart, see table 35]

A2-3-36ac

Date	Water level	Date	Water level	Date	Water level
Aug. 9, 1951	7.38	June 27, 1952	7.54	May 8, 1953	7.99
Aug. 29	7.51	Aug. 5	7.80	June 1	7.82
Sept. 26	8.00	Sept. 3	8.06	July 2	7.63
Nov. 2	8.52	Oct. 3	8.18	Aug. 4	7.70
Apr. 3, 1952	6.87	Feb. 4, 1953	8.06	Sept. 4	7.82
May 6	7.30	Mar. 5	8.25	Nov. 4	8.06
June 9	7.06	Apr. 3	8.08		

A2-4-2dd

Date	Water level	Date	Water level	Date	Water level
May 28, 1951	10.96	Jan. 11, 1952	11.16	Aug. 4, 1952	11.12
July 5	11.01	Feb. 6	11.22	Sept. 2	11.08
Aug. 2	11.01	Mar. 6	11.26	Oct. 1	11.11
Aug. 29	10.81	Apr. 2	10.56	Nov. 10	11.17
Sept. 29	11.05	May 2	10.26	Dec. 1	11.28
Nov. 2	10.98	June 9	10.68	Jan. 5, 1953	11.20
Dec. 4	11.27	June 28	10.64		

A2-4-12cc

Date	Water level	Date	Water level	Date	Water level
May 15, 1951	6.47	Dec. 4, 1951	6.38	June 28, 1952	5.97
May 31	6.82	Jan. 11, 1952	6.43	Aug. 4	6.37
July 5	7.11	Feb. 6	6.78	Sept. 2	5.87
Aug. 2	7.30	Mar. 6	6.82	Oct. 1	6.15
Aug. 29	7.27	Apr. 2	6.15	Nov. 10	5.91
Sept. 29	7.06	May 2	5.21	Dec. 1	5.58
Nov. 3	6.79	June 9	5.68	Jan. 5, 1953	6.09

A2-4-23da

Date	Water level	Date	Water level	Date	Water level
May 14, 1951	13.58	Apr. 2, 1952	14.39	Mar. 3, 1953	14.85
May 31	14.00	May 2	13.10	Apr. 1	14.58
July 5	14.41	June 9	13.60	May 2	14.49
Aug. 2	14.80	June 28	13.87	June 1	13.55
Aug. 29	14.77	Aug. 4	14.44	July 2	13.87
Sept. 29	14.54	Sept. 22	15.04	Aug. 1	14.70
Nov. 3	14.60	Oct. 1	14.79	Sept. 1	15.00
Dec. 4	14.88	Nov. 10	14.46	Oct. 1	14.87
Jan. 11, 1952	14.53	Dec. 1	13.92	Nov. 4	15.06
Feb. 6	15.12	Jan. 5, 1953	14.66	Dec. 1	15.05
Mar. 6	15.33	Feb. 2	14.64	Jan. 4, 1954	15.03

A2-4-24bb

Date	Water level	Date	Water level	Date	Water level
May 15, 1951	36.17	Sept. 29, 1951	36.85	Feb. 6, 1952	34.41
May 31	33.37	Nov. 3	32.00	Mar. 6	36.31
July 5	32.86	Dec. 4	29.88	Apr. 2	36.76
Aug. 2	29.22	Jan. 11, 1952	30.73	May 2	35.15
Aug. 29	31.65				

A2-4-26ba1

Date	Water level	Date	Water level	Date	Water level
May 14, 1951	20.23	Aug. 2, 1951	18.84	Nov. 3, 1951	19.97
May 31	20.60	Aug. 29	18.04	Dec. 3	20.41
July 5	18.06	Sept. 29	19.41	Jan. 11, 1952	19.73

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

A2-4-26ba1—Continued

Date	Water level	Date	Water level	Date	Water level
Feb. 6, 1952	20.29	Oct. 1, 1952	20.07	June 1, 1953	19.86
Mar. 6	21.51	Nov. 10	19.80	July 2	18.65
Apr. 2	21.04	Dec. 1	19.40	Aug. 1	18.28
May 2	18.80	Jan. 5, 1953	20.00	Sept. 1	19.31
June 9	19.20	Feb. 2	20.81	Oct. 1	19.58
June 28	19.20	Mar. 3	21.15	Nov. 4	19.86
Aug. 4	18.71	Apr. 1	21.02	Dec. 1	20.33
Sept. 2	19.64	May 2	21.07	Jan. 4, 1954	20.71

A2-4-31cc

Date	Water level	Date	Water level	Date	Water level
May 31, 1951	5.00	Dec. 3, 1951	Dry	June 9, 1952	6.50
July 5	4.69	Jan. 8, 1952	Dry	June 27	2.11
Aug. 2	3.00	Feb. 6	Dry	Aug. 5	3.12
Aug. 28	5.14	Mar. 5	Dry	Sept. 3	5.91
Sept. 26	6.85	Apr. 3	6.44	Aug. 4, 1953	3.19
Nov. 3	6.81	May 6	6.46		

A2-4-36cc

Date	Water level	Date	Water level	Date	Water level
May 15, 1951	12.90	Aug. 29, 1951	12.83	Jan. 7, 1952	12.82
May 31	13.17	Sept. 26	12.87	May 6	12.28
July 6	12.93	Nov. 1	12.81	June 6	12.08
Aug. 2	12.71	Dec. 3	12.84	Oct. 3	12.18

A2-5-6ac1

Date	Water level	Date	Water level	Date	Water level
May 28, 1951	7.10	Nov. 2, 1951	7.13	June 9, 1952	7.13
July 5	7.11	Dec. 4	7.31	June 28	6.77
Aug. 2	7.29	Jan. 11, 1952	7.34	Aug. 4	7.28
Aug. 29	7.19	Mar. 6	7.43	Aug. 27	7.05
Sept. 29	7.23	May 1	7.05	Oct. 3	7.19

A2-5-8bc

Date	Water level	Date	Water level	Date	Water level
May 28, 1951	24.99	Jan. 11, 1952	27.91	Aug. 4, 1952	25.02
July 5	25.99	Feb. 6	28.78	Sept. 2	24.31
Aug. 2	26.59	Mar. 6	29.17	Oct. 3	25.09
Aug. 28	26.31	Apr. 7	28.84	Nov. 10	22.53
Sept. 29	27.55	May 1	22.34	Dec. 3	25.78
Nov. 3	27.55	June 9	23.70	Jan. 5, 1953	26.80
Dec. 4	27.59	June 29	25.34		

A2-5-18ba

Date	Water level	Date	Water level	Date	Water level
May 16, 1951	6.27	Nov. 2, 1951	3.74	May 2, 1952	2.85
May 31	5.40	Dec. 4	5.54	June 9	3.32
July 5	4.88	Jan. 11, 1952	5.73	June 28	1.79
Aug. 2	3.46	Feb. 6	5.82	Aug. 4	4.18
Aug. 28	3.02	Mar. 6	5.91	Sept. 2	3.02
Sept. 29	3.32	Apr. 7	5.80	Oct. 3	4.80

A2-5-18bc

Date	Water level	Date	Water level	Date	Water level
May 16, 1951	8.12	Sept. 29, 1951	8.45	Mar. 6, 1952	8.97
May 31	7.73	Nov. 2	8.81	Apr. 7	8.56
July 5	8.30	Dec. 4	9.09	May 2	7.56
Aug. 2	9.07	Jan. 11, 1952	9.18	June 9	7.91
Aug. 28	8.80	Feb. 6	8.29	June 28	7.13

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
A2-5-18bc—Continued					
Aug. 4, 1952	7.74	Oct. 3, 1952	7.87	Nov. 10, 1952	7.65
Sept. 2	8.30				
A2-5-20ad					
May 28, 1951	27.83	June 29, 1952	25.76	May 2, 1953	29.21
July 5	28.41	Aug. 4	26.39	June 1	29.39
Aug. 2	28.66	Sept. 2	26.97	July 2	28.86
Aug. 28	28.91	Oct. 3	27.21	Aug. 1	26.13
Sept. 29	28.93	Nov. 10	27.62	Sept. 1	26.73
Nov. 2	29.10	Dec. 3	27.93	Oct. 1	26.98
Dec. 4	29.33	Jan. 5, 1953	28.62	Nov. 5	27.45
Jan. 11, 1952	29.47	Feb. 2	28.44	Dec. 1	27.72
May 1	27.63	Mar. 3	29.03	Jan. 4, 1954	28.32
June 9	25.33	Apr. 1	28.98		
A2-5-30bb					
May 15, 1951	76.08	Aug. 28, 1951	75.84	Jan. 11, 1952	75.87
May 31	75.95	Sept. 29	75.98	Apr. 7	75.75
July 5	74.81	Nov. 2	76.04	May 6	75.67
Aug. 2	75.80	Dec. 4	75.74	Oct. 3	75.32
A2-5-33bd					
May 28, 1951	12.71	Sept. 29, 1951	20.06	Feb. 6, 1952	21.53
July 6	16.69	Nov. 2	20.91	Mar. 6	21.78
Aug. 2	18.56	Dec. 4	20.83	Apr. 7	20.30
Aug. 28	20.56	Jan. 11, 1952	20.92		
A2-5-35ba					
May 14, 1951	13.03	Aug. 29, 1951	12.59	Jan. 11, 1952	13.15
May 31	12.47	Sept. 29	12.70	Apr. 4	12.79
July 5	13.13	Nov. 2	12.93	Oct. 1	12.74
Aug. 2	13.48	Dec. 4	13.09		
A3-5-28dd					
May 15, 1951	27.67	Dec. 4, 1951	23.59	June 28, 1952	14.12
May 28	23.02	Jan. 11, 1952	28.46	Aug. 4	19.34
July 5	11.70	Feb. 6	30.14	Sept. 2	20.63
Aug. 2	16.84	Mar. 6	30.71	Oct. 1	22.32
Aug. 28	16.96	Apr. 4	29.80	Nov. 10	19.34
Sept. 29	18.38	May 1	30.68	Dec. 1	22.14
Nov. 2	19.21	June 9	15.31	Jan. 5, 1953	25.33
D1-4-1cb					
July 28, 1952	39.73	Jan. 7, 1953	50.71	Aug. 4, 1953	39.37
Aug. 4	39.52	Feb. 3	54.73	Sept. 4	37.40
Aug. 18	38.54	Mar. 4	58.26	Oct. 2	38.13
Sept. 2	38.07	Apr. 3	61.14	Nov. 5	40.98
Sept. 10	38.12	May 8	60.08	Dec. 3	43.58
Sept. 29	38.59	June 4	55.10	Jan. 5, 1954	49.04
Oct. 7	39.14	July 2	46.35		

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
		D1-4-2ab			
May 8, 1951	50.74	May 2, 1952	50.93	Dec. 2, 1952	38.10
May 31	48.12	June 10	45.38	Jan. 7, 1953	43.85
July 5	37.84	June 27	42.05	Feb. 3	47.45
Aug. 2	33.94	July 9	36.75	Mar. 4	50.41
Aug. 28	30.14	July 18	34.30	Apr. 3	52.73
Sept. 26	31.19	July 28	33.90	May 8	52.11
Nov. 1	35.68	Aug. 5	33.54	June 4	37.88
Dec. 3	40.71	Aug. 18	32.27	July 2	39.85
Jan. 8, 1952	43.16	Aug. 25	32.13	Aug. 4	35.74
Feb. 5	43.63	Sept. 2	32.82	Sept. 4	32.84
Mar. 5	45.41	Sept. 10	32.53	Oct. 2	33.70
Apr. 4	53.98	Sept. 29	32.65	Nov. 5	35.84
Apr. 11	53.05	Oct. 7	33.30	Dec. 3	38.51
Apr. 15	52.47	Nov. 17	36.05	Jan. 5, 1954	43.07
		D1-4-6bb			
May 9, 1951	8.20	Mar. 5, 1952	Dry	Apr. 1, 1953	8.00
May 31	6.64	Apr. 4	Dry	May 8	7.60
July 5	2.74	May 5	Dry	June 3	5.69
Aug. 2	3.43	June 9	1.65	July 2	2.84
Aug. 28	4.81	June 28	3.90	Aug. 6	4.14
Sept. 26	5.88	Aug. 5	3.15	Sept. 4	4.62
Nov. 2	6.09	Sept. 3	4.07	Oct. 5	6.63
Dec. 5	Frozen	Oct. 3	5.10	Nov. 5	7.02
Jan. 7, 1952	Frozen	Feb. 4, 1953	Dry	Dec. 2	7.64
Feb. 6	Dry	Mar. 4	Dry		
		D1-4-6ddc1			
Aug. 9, 1951	5.59	June 9, 1952	3.00	Apr. 1, 1953	18.05
Aug. 28	9.19	June 28	5.49	May 8	18.60
Sept. 26	10.44	Aug. 5	5.60	June 3	15.31
Nov. 1	12.74	Sept. 3	5.87	July 2	5.20
Dec. 3	13.85	Oct. 3	7.88	Aug. 6	7.69
Jan. 7, 1952	17.15	Nov. 17	10.00	Sept. 4	7.95
Feb. 6	17.53	Dec. 3	13.72	Oct. 5	11.44
Mar. 5	19.26	Jan. 2, 1953	14.84	Nov. 5	11.96
Apr. 4	20.51	Feb. 4	15.61	Dec. 2	13.25
May 5	12.59	Mar. 4	16.92	Jan. 4, 1954	15.18

D1-4-6ddc2

[No measurements by tape; for measurements from recorder chart, see table 35]

D1-4-9ba1

[No measurements by tape; for measurements from recorder chart, see table 35]

D1-4-9ba2

Date	Water level	Date	Water level	Date	Water level
Apr. 25, 1953	4.57	July 3, 1953	2.51	Aug. 28, 1953	4.57
May 2	4.68	July 10	3.41	Sept. 4	4.38
May 9	4.55	July 24	3.56	Sept. 11	4.34
May 16	5.23	Aug. 7	3.89	Sept. 18	4.69
May 23	5.03	Aug. 14	4.25	Sept. 25	5.05
June 6	2.46	Aug. 21	4.46	Oct. 2	5.22

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
D1-4-9ba2—Continued					
Oct. 8, 1953	5.24	Dec. 28, 1953	4.41	Feb. 24, 1954	4.69
Oct. 15	4.80	Jan. 4, 1954	4.41	Mar. 3	4.84
Oct. 29	3.60	Jan. 11	4.67	Mar. 10	4.77
Nov. 12	4.24	Jan. 21	4.68	Mar. 24	5.04
Nov. 20	3.81	Jan. 27	4.18	Mar. 31	5.29
Nov. 25	3.89	Feb. 3	4.44	Apr. 7	4.88
Dec. 2	3.97	Feb. 10	4.76	Apr. 13	4.91
Dec. 8	4.10	Feb. 17	4.67	Apr. 22	5.16
Dec. 21	4.39				
D1-4-12bb					
Apr. 24, 1952	66.70	Sept. 3, 1952	28.50	Apr. 9, 1953	67.35
June 10	45.48	Sept. 10	28.71	May 4	65.75
June 27	40.82	Sept. 29	31.01	June 4	62.36
July 9	34.64	Nov. 7	31.87	July 2	34.50
July 18	31.70	Nov. 12	37.33	Aug. 5	24.48
July 28	31.70	Dec. 3	42.52	Sept. 4	23.61
Aug. 5	31.37	Jan. 6, 1953	52.95	Oct. 23	32.72
Aug. 18	29.48	Feb. 3	56.53	Dec. 3	38.55
Aug. 27	28.64	Mar. 5	61.86	Jan. 4, 1954	48.10
D1-4-13ad					
July 28, 1952	11.87	Jan. 7, 1953	36.59	Sept. 9, 1953	13.35
Aug. 5	8.47	Feb. 3	43.70	Oct. 2	16.32
Aug. 18	11.00	Mar. 5	47.80	Nov. 5	21.26
Aug. 27	10.44	Apr. 3	51.80	Dec. 2	26.59
Sept. 2	10.43	May 8	50.31	Jan. 5, 1954	34.57
Sept. 10	10.48	June 4	45.71	Feb. 3	40.70
Sept. 29	11.44	July 9	17.96	Mar. 3	46.32
Oct. 7	13.52	Aug. 4	12.42	Mar. 31	50.60
D1-4-13bb					
July 11, 1951	19.31	Aug. 28, 1951	10.61	Dec. 4, 1951	17.03
Aug. 2	8.52	Nov. 2	16.21		
D1-4-15ab					
Apr. 23, 1952	22.93	Feb. 4, 1953	23.78	Aug. 5, 1953	5.71
June 9	13.33	Mar. 5	24.09	Sept. 4	6.92
June 28	3.74	Apr. 3	23.90	Oct. 2	10.11
Aug. 6	5.02	May 4	26.24	Nov. 6	11.86
Sept. 8	7.27	June 4	20.90	Dec. 2	14.64
Oct. 3	9.06	July 2	5.21	Jan. 6, 1954	18.21
D1-4-15cd					
Apr. 23, 1951	7.22	Nov. 2, 1951	4.41	May 5, 1952	8.01
May 31	4.91	Dec. 4	5.28	June 9	5.17
July 6	3.10	Jan. 7, 1952	5.14	June 28	3.01
Aug. 1	3.46	Feb. 5	5.23	Aug. 6	2.76
Aug. 30	3.68	Mar. 6	5.48	Sept. 8	5.29
Oct. 1	4.12	Apr. 7	4.88	Oct. 10	6.50

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
D1-4-17bb					
July 13, 1951	3.59	June 9, 1952	10.82	Apr. 3, 1953	15.93
Aug. 1	4.03	June 28	3.86	May 4	15.86
Aug. 30	4.07	Aug. 6	5.91	June 3	17.00
Oct. 1	8.09	Sept. 8	4.43	July 2	10.12
Nov. 2	9.10	Oct. 3	7.11	Aug. 6	4.03
Dec. 4	11.78	Nov. 10	9.24	Sept. 4	4.76
Jan. 7, 1952	14.62	Dec. 1	9.79	Oct. 5	7.14
Feb. 5	14.91	Jan. 2, 1953	11.38	Nov. 5	8.20
Mar. 7	15.23	Feb. 4	13.04	Dec. 2	10.24
Apr. 7	15.52	Mar. 4	15.71	Jan. 4, 1954	12.11
May 5	17.90				
D1-4-25aa1					
Apr. 18, 1951	13.00	Apr. 7, 1952	11.36	Mar. 5, 1953	15.45
May 31	11.14	May 5	11.05	Apr. 3	17.16
July 6	3.85	June 4	5.30	May 4	15.46
Aug. 1	4.65	June 27	3.70	June 2	10.91
Aug. 30	7.86	Aug. 6	5.61	July 2	7.63
Oct. 1	8.27	Sept. 4	8.04	Aug. 4	5.09
Nov. 2	8.81	Sept. 30	9.61	Sept. 9	8.53
Dec. 4	11.39	Nov. 10	11.29	Oct. 2	9.54
Jan. 7, 1952	11.52	Dec. 1	12.10	Nov. 4	10.14
Feb. 5	11.74	Jan. 6, 1953	13.11	Dec. 2	11.67
Mar. 6	11.91	Feb. 3	13.48	Jan. 4, 1954	13.34

D1-4-25aa2

[No measurements by tape; for measurements from recorder chart, see table 35]

D1-4-25aa3

[No measurements by tape; for measurements from recorder chart, see table 35]

Date	Water level	Date	Water level	Date	Water level
D1-4-25ba1					
Apr. 19, 1951	12.85	Mar. 6, 1952	9.72	Apr. 3, 1953	15.27
May 31	8.29	Apr. 7	18.50	May 4	13.04
July 6	1.20	May 5	10.40	June 2	10.11
Aug. 1	2.49	June 24	5.69	July 2	2.71
Aug. 30	3.72	June 27	1.61	Aug. 4	2.22
Oct. 1	4.24	Aug. 6	3.12	Sept. 9	4.39
Nov. 2	6.30	Sept. 4	4.18	Oct. 2	4.85
Dec. 4	8.92	Sept. 30	6.08	Nov. 4	6.26
Jan. 7, 1952	9.11	Feb. 3, 1953	13.12	Dec. 2	8.68
Feb. 5	9.51	Mar. 5	14.27	Jan. 4, 1954	11.14
D1-4-26bbb					
Aug. 1, 1951	3.40	Feb. 4, 1952	Dry	June 4, 1952	5.65
Aug. 30	4.86	Mar. 6	Dry	June 27	3.32
Oct. 1	4.98	Apr. 7	Dry	Aug. 6	3.80
Nov. 2	5.13	May 5	Dry	Aug. 5, 1953	3.18
Dec. 4	Dry				

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
		D1-4-27bb			
Apr. 19, 1951	9.52	Apr. 7, 1952	7.25	Mar. 4, 1953	10.58
May 31	8.33	May 5	9.35	Apr. 3	10.40
July 6	8.22	June 9	3.93	May 4	9.98
Aug. 1	8.45	June 28	8.70	June 4	7.90
Aug. 30	9.36	Aug. 6	7.94	July 4	6.46
Oct. 1	10.17	Sept. 8	8.25	Aug. 1	8.15
Nov. 2	10.81	Oct. 3	9.23	Sept. 2	8.72
Dec. 4	10.49	Nov. 10	8.93	Oct. 5	9.39
Jan. 7, 1952	10.44	Dec. 1	9.82	Nov. 6	9.48
Feb. 5	10.53	Jan. 2, 1953	10.46	Dec. 2	10.28
Mar. 7	10.72	Feb. 4	10.40	Jan. 6, 1954	10.40
		D1-5-4db1			
Apr. 24, 1951	15.80	Apr. 4, 1952	17.02	Mar. 4, 1953	14.04
May 31	11.80	May 6	4.13	Apr. 2	15.05
July 5	11.96	June 6	5.14	May 8	14.72
Aug. 1	9.69	June 29	5.60	June 4	6.44
Aug. 28	10.92	Aug. 1	7.10	July 2	7.21
Sept. 26	11.49	Sept. 2	8.07	Aug. 4	6.81
Nov. 1	12.62	Sept. 29	8.44	Sept. 4	7.53
Dec. 3	14.25	Nov. 12	9.61	Oct. 2	8.56
Jan. 8, 1952	14.44	Dec. 3	10.18	Nov. 5	9.21
Feb. 6	15.24	Jan. 5, 1953	10.36	Dec. 3	11.26
Mar. 5	15.86	Feb. 2	12.03	Jan. 5, 1954	12.72
		D1-5-6dc			
May 3, 1951	38.15	June 27, 1952	24.16	Feb. 2, 1953	33.43
May 31	37.11	July 9	22.74	Mar. 4	35.61
July 5	29.71	July 18	22.30	Apr. 2	37.44
Aug. 1	24.82	July 28	21.83	May 8	36.88
Aug. 28	22.34	Aug. 4	21.44	June 4	35.38
Sept. 26	21.07	Sept. 2	20.97	July 2	27.56
Nov. 1	25.54	Sept. 10	21.05	Aug. 4	20.91
Dec. 3	27.29	Sept. 29	21.22	Sept. 4	21.27
Jan. 8, 1952	28.87	Nov. 7	21.26	Oct. 2	22.41
Feb. 6	31.28	Nov. 12	23.69	Nov. 5	23.84
May 6	35.44	Dec. 3	25.22	Dec. 3	26.42
June 6	29.42	Jan. 5, 1953	30.05	Jan. 5, 1954	30.21
		D1-5-8ab			
Aug. 3, 1951	3.96	Jan. 8, 1952	Dry	June 6, 1952	2.73
Aug. 28	3.14	Feb. 6	Dry	June 29	2.11
Sept. 26	3.92	Mar. 5	Dry	Aug. 1	2.63
Nov. 1	4.43	Apr. 4	Dry	Sept. 2	2.59
Dec. 3	Dry	May 6	Dry	Sept. 29	2.79
		D1-5-9ac			
July 16, 1951	18.57	Jan. 8, 1952	17.52	Sept. 29, 1952	12.48
Aug. 1	17.69	May 6	13.78	Nov. 12	14.40
Aug. 28	13.33	June 6	8.41	Dec. 3	14.78
Sept. 26	14.94	June 29	10.27	Jan. 5, 1953	16.46
Nov. 1	16.05	Aug. 1	11.35	Feb. 2	17.77
Dec. 3	17.26	Sept. 2	11.90	Mar. 4	19.72

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
		D1-5-9ac—Continued			
Apr. 2, 1953	22.55	Aug. 4, 1953	13.14	Nov. 5, 1953	14.59
May 8	22.28	Sept. 4	12.70	Dec. 3	16.10
June 4	7.70	Oct. 2	13.61	Jan. 5, 1954	18.18
July 2	14.89				
		D1-5-19cd			
Feb. 3, 1953	9.79	June 2, 1953	10.24	Oct. 2, 1953	8.29
Mar. 5	11.64	July 2	7.12	Nov. 4	8.39
Apr. 3	12.63	Aug. 4	5.30	Feb. 24, 1954	11.74
May 4	12.60	Sept. 9	6.96		
		D1-5-21ddd			
Aug. 2, 1951	6.87	Jan. 8, 1952	Dry	June 4, 1952	5.19
Aug. 29	6.25	Feb. 6	Dry	June 27	5.82
Sept. 26	Dry	Mar. 5	Dry	Aug. 6	5.80
Nov. 2	Dry	Apr. 1	Dry	Sept. 4	6.38
Dec. 4	Dry	May 5	5.33	Aug. 5, 1953	5.61
		D1-5-23db			
May 15, 1951	5.30	Apr. 1, 1952	7.19	Mar. 3, 1953	7.19
May 31	6.10	May 1	2.53	Apr. 1	6.71
July 5	6.38	June 2	4.71	May 2	6.57
Aug. 1	6.61	June 29	6.30	June 1	4.17
Aug. 28	7.07	Aug. 1	6.54	July 2	6.31
Sept. 26	7.47	Sept. 2	7.34	Aug. 1	5.98
Nov. 1	7.24	Sept. 29	7.54	Sept. 1	7.43
Dec. 3	7.28	Nov. 10	7.56	Oct. 1	7.94
Jan. 8, 1952	7.41	Dec. 1	7.33	Nov. 5	7.87
Feb. 5	6.21	Jan. 2, 1953	7.45	Dec. 1	7.75
Mar. 5	7.29	Feb. 2	7.15	Jan. 5, 1954	7.69
		D1-5-26da			
July 17, 1951	11.57	Mar. 5, 1952	12.39	Aug. 1, 1952	11.81
Dec. 3	11.79	Apr. 1	11.25	Sept. 2	11.37
Jan. 8, 1952	11.91	May 1	10.41	Sept. 29	12.41
Feb. 5	12.22	June 2	10.57	Aug. 8, 1953	10.60
		D1-5-27aa			
Aug. 3, 1951	9.50	Feb. 6, 1952	Dry	June 29, 1952	7.94
Aug. 29	9.28	Mar. 5	Dry	Aug. 6	9.61
Sept. 26	10.78	Apr. 1	Dry	Sept. 4	10.01
Nov. 3	11.70	May 5	9.49	Oct. 2	10.32
Dec. 4	Dry	June 4	8.27	Aug. 5, 1953	10.44
Jan. 8, 1952	Dry				
		D1-5-30aa			
Apr. 18, 1951	10.29	Nov. 2, 1951	8.21	Sept. 30, 1952	5.82
May 31	10.74	Dec. 4	8.48	Feb. 3, 1953	9.67
July 6	3.88	Jan. 7, 1952	8.76	Mar. 5	11.27
Aug. 1	3.70	Feb. 5	8.96	Apr. 3	12.01
Aug. 30	6.47	Mar. 6	9.13	May 4	12.73
Oct. 1	7.13	Apr. 7	8.21	June 2	11.78

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

D1-5-30aa—Continued

Date	Water level	Date	Water level	Date	Water level
July 2, 1953	5.70	Oct. 2, 1953	6.31	Dec. 3, 1953	8.98
Aug. 4	3.21	Nov. 4	7.34	Jan. 4, 1954	10.10
Sept. 9	4.17				

D1-5-30cd

Date	Water level	Date	Water level	Date	Water level
May 17, 1951	8.48	Feb. 5, 1952	6.14	Apr. 3, 1953	9.75
May 31	8.92	May 5	4.40	May 4	10.27
July 7	4.70	June 9	4.30	June 2	9.54
Aug. 1	4.26	June 29	3.77	July 4	4.54
Aug. 30	4.13	Aug. 5	4.18	Aug. 4	3.99
Oct. 1	5.36	Sept. 4	4.53	Sept. 9	4.32
Nov. 2	6.08	Sept. 30	5.00	Oct. 2	4.92
Dec. 4	5.72	Feb. 3, 1953	7.29	Nov. 4	5.24
Jan. 7, 1952	5.99	Mar. 5	8.34	Dec. 3	6.04

D1-5-33dd

Date	Water level	Date	Water level	Date	Water level
July 6, 1951	2.80	Apr. 7, 1952	4.14	Feb. 3, 1953	7.72
Aug. 1	7.25	May 2	3.54	Mar. 5	7.66
Aug. 29	7.02	June 4	4.60	Apr. 3	7.01
Oct. 1	7.32	June 29	6.46	May 4	7.07
Nov. 1	6.48	Aug. 5	6.56	June 2	7.10
Dec. 4	7.38	Sept. 4	7.60	July 4	2.91
Jan. 7, 1952	6.81	Sept. 30	7.80	Aug. 4	5.76
Feb. 5	7.36	Dec. 4	Dry	Sept. 9	Dry
Mar. 6	7.42	Jan. 6, 1953	Dry		

D1-5-34cc2

[No measurements by tape; for measurements from recorder chart, see table 35]

D1-5-35ca1

Date	Water level	Date	Water level	Date	Water level
July 7, 1951	5.73	Dec. 4, 1951	6.23	June 29, 1952	4.79
Aug. 1	6.42	Jan. 7, 1952	6.42	Aug. 5	5.11
Aug. 29	6.65	Feb. 4	5.95	Sept. 4	6.19
Oct. 1	6.58	May 2	3.94	Sept. 30	5.94
Nov. 1	6.07	June 4	4.29		

D1-5-35cd1

Date	Water level	Date	Water level	Date	Water level
July 6, 1951	5.44	Oct. 1, 1951	5.23	Jan. 7, 1952	5.10
Aug. 1	5.39	Nov. 1	5.23	Mar. 6	5.14
Aug. 29	5.46	Dec. 4	5.07		

D1-5-35cd2

Date	Water level	Date	Water level	Date	Water level
May 27, 1952	3.93	Dec. 4, 1952	4.41	July 4, 1953	4.42
June 4	4.26	Jan. 6, 1953	4.38	Aug. 4	4.85
June 29	4.38	Feb. 3	4.28	Sept. 9	4.48
Aug. 5	4.73	Mar. 5	4.36	Oct. 2	4.61
Sept. 4	4.77	Apr. 3	4.15	Nov. 4	4.37
Sept. 30	4.70	May 4	4.22	Dec. 3	4.24
Nov. 10	4.45	June 2	4.21	Jan. 4, 1954	4.36

508919 O-60—16

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
		D1-5-36ddd			
July 6, 1951	4.60	June 4, 1952	4.39	Apr. 3, 1953	5.47
Aug. 1	4.31	June 29	4.35	May 4	5.42
Aug. 29	4.27	Aug. 5	4.21	June 3	5.42
Oct. 1	4.41	Sept. 4	4.12	July 4	5.35
Nov. 1	4.50	Sept. 30	4.24	Aug. 4	4.52
Dec. 4	4.60	Nov. 10	4.90	Sept. 4	4.58
Jan. 7, 1952	4.75	Dec. 4	5.21	Oct. 2	4.61
Feb. 5	4.89	Jan. 6, 1953	5.41	Nov. 4	4.74
Mar. 6	5.09	Feb. 3	5.41	Dec. 1	4.92
Apr. 7	4.98	Mar. 5	5.51	Jan. 4, 1954	5.05
May 2	4.81				
		D2-3-4ac			
May 16, 1951	6.37	Apr. 2, 1952	6.45	Mar. 4, 1953	6.64
May 31	6.31	May 1	3.22	Apr. 1	6.50
July 6	4.94	June 2	3.46	May 1	7.12
Aug. 1	4.87	June 30	2.54	June 3	2.55
Aug. 29	6.26	Aug. 1	4.01	July 3	3.50
Oct. 1	6.31	Sept. 3	3.72	Aug. 3	4.69
Nov. 2	6.42	Oct. 1	2.85	Sept. 2	6.11
Dec. 4	7.06	Nov. 5	4.33	Oct. 1	7.27
Jan. 7, 1952	6.89	Dec. 1	4.98	Nov. 6	5.87
Feb. 5	8.73	Jan. 2, 1953	4.70	Dec. 1	6.47
Mar. 7	9.01	Feb. 2	5.36	Jan. 6, 1954	7.53
		D2-4-1bal			
June 29, 1951	3.54	Apr. 7, 1952	Dry	Apr. 3, 1953	Dry
Aug. 1	6.02	May 2	Dry	May 4	Dry
Aug. 29	7.54	June 4	9.58	June 2	Dry
Oct. 1	7.47	June 29	1.83	July 4	5.24
Nov. 1	Dry	Aug. 5	5.46	Aug. 1	4.98
Dec. 4	Dry	Sept. 4	7.84	Sept. 9	8.75
Jan. 7, 1952	Dry	Sept. 30	9.79	Oct. 2	9.96
Feb. 5	Dry	Mar. 5	Dry	Nov. 4	12.50
Mar. 6	Dry				
		D2-4-9bc [For measurements from recorder chart, see table 35]			
June 3, 1953	22.79	Oct. 1, 1953	21.01	Feb. 4, 1954	21.12
July 3	22.21	Nov. 6	20.72	Mar. 3	21.49
Aug. 3	21.42	Dec. 1	20.47	Mar. 31	21.78
Sept. 2	21.22	Jan. 6, 1954	20.72		
		D2-4-10dd			
May 14, 1951	8.18	Feb. 5, 1952	8.64	Nov. 10, 1952	5.08
May 30	6.23	Mar. 7	8.89	Dec. 1	5.96
July 6	2.53	Apr. 7	6.98	Jan. 2, 1953	7.17
Aug. 1	2.48	May 1	6.99	Feb. 2	7.87
Aug. 29	3.62	June 2	5.20	Mar. 4	8.42
Oct. 1	4.11	July 28	2.58	Apr. 1	8.54
Nov. 1	5.76	Aug. 1	2.29	May 1	8.60
Dec. 4	7.20	Sept. 3	3.98	June 3	6.98
Jan. 7, 1952	6.79	Oct. 1	4.98	July 3	3.17

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
		D2-4-10dd—Continued			
Aug. 1, 1953	2.64	Oct. 1, 1953	5.82	Dec. 2, 1953	6.59
Sept. 2	4.67	Nov. 6	6.44	Jan. 6, 1954	7.96
		D2-4-11cd1			
May 14, 1951	6.34	Apr. 7, 1952	5.34	Mar. 4, 1953	6.65
May 30	5.86	May 1	5.77	Apr. 1	6.58
July 6	4.31	June 2	4.55	May 1	6.00
Aug. 1	4.50	June 28	4.67	June 3	4.37
Aug. 29	5.61	Aug. 1	4.21	July 3	3.98
Oct. 1	5.82	Sept. 3	4.79	Aug. 1	4.68
Nov. 1	6.31	Oct. 1	4.83	Sept. 2	5.14
Dec. 2	6.52	Nov. 10	7.23	Oct. 1	6.36
Jan. 7, 1952	5.48	Dec. 1	7.11	Nov. 6	5.95
Feb. 5	6.76	Jan. 2, 1953	6.70	Dec. 2	6.33
Mar. 7	6.97	Feb. 2	6.91	Jan. 6, 1954	6.74
		D2-4-13aa			
June 29, 1951	3.80	Jan. 7, 1952	Dry	June 27, 1952	5.55
Aug. 1	5.81	Feb. 4	Dry	Aug. 1	5.38
Aug. 29	5.95	Mar. 7	Dry	Sept. 3	5.56
Oct. 1	6.49	Apr. 4	Dry	Sept. 29	5.40
Nov. 1	7.13	May 1	5.04	Aug. 1, 1953	6.36
Dec. 4	Dry	June 2	2.52		
		D2-4-13cc			
June 21, 1947	3.30	June 21, 1950	4.68	Mar. 7, 1952	8.53
Sept. 10	3.88	July 27	4.02	Apr. 4	7.74
Oct. 20	6.10	Sept. 28	4.91	May 5	5.41
Dec. 31	7.95	Oct. 31	6.17	June 4	4.92
Feb. 10, 1948	8.50	Jan. 5, 1951	7.77	June 27	2.54
Sept. 1	5.77	Feb. 2	8.20	Aug. 6	4.09
Sept. 23	5.96	Mar. 1	8.48	Sept. 5	4.80
Oct. 27	6.48	Mar. 28	7.06	Sept. 29	5.60
Dec. 1	7.78	May 2	7.04	Nov. 7	6.74
Jan. 4, 1949	7.72	May 26	5.74	Dec. 3	7.26
Mar. 2	8.18	May 30	5.99	Jan. 6, 1953	8.12
Mar. 31	7.58	June 12	6.00	Feb. 3	8.25
Apr. 14	7.46	July 6	4.62	Mar. 3	7.74
May 17	6.65	July 11	3.98	Apr. 2	8.20
June 15	4.34	July 31	3.47	May 4	7.90
July 27	3.83	Aug. 1	3.66	June 2	6.68
Oct. 18	4.83	Aug. 29	3.77	July 3	3.10
Nov. 26	7.27	Sept. 3	3.12	Aug. 3	4.39
Jan. 4, 1950	7.75	Oct. 1	5.98	Sept. 2	5.50
Feb. 14	8.48	Nov. 1	6.38	Oct. 1	4.81
Mar. 8	8.07	Dec. 4	7.35	Nov. 6	6.52
Apr. 12	7.29	Jan. 11, 1952	7.63	Dec. 2	7.22
May 1	7.68	Feb. 4	8.44	Jan. 5, 1954	8.04
June 5	6.45				
		D2-4-17aa			
May 15, 1951	17.94	Aug. 1, 1951	13.84	Nov. 1, 1951	14.54
May 30	18.06	Aug. 29	12.89	Dec. 4	14.73
July 6	14.83	Oct. 1	13.87	Jan. 7, 1952	15.42

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
		D2-4-17aa—Continued			
Feb. 5, 1952	16.75	Oct. 1, 1952	13.82	June 3, 1953	16.99
Mar. 7	17.18	Nov. 5	14.94	July 3	15.14
Apr. 7	16.47	Dec. 1	14.86	Aug. 3	12.20
May 1	16.03	Jan. 2, 1953	15.89	Sept. 2	11.76
June 2	16.32	Feb. 2	16.36	Oct. 1	13.21
June 28	16.12	Mar. 4	17.08	Nov. 6	14.46
Aug. 1	14.61	Apr. 1	17.30	Dec. 1	14.53
Sept. 3	13.29	May 1	17.86	Jan. 6, 1954	15.33
		D2-4-25bd			
May 22, 1951	19.50	June 4, 1952	18.98	June 2, 1953	19.57
May 30	20.12	June 27	17.83	July 3	17.00
July 6	15.94	Aug. 6	18.22	Aug. 3	16.92
Aug. 1	17.66	Sept. 5	17.01	Sept. 2	17.83
Aug. 29	17.11	Oct. 9	17.76	Oct. 5	16.45
Sept. 28	17.73	Feb. 3, 1953	20.68	Nov. 6	18.72
Dec. 4	18.69	Mar. 3	20.26	Dec. 2	19.23
Apr. 4, 1952	20.32	Apr. 2	20.32	Jan. 5, 1954	19.76
May 5	18.72	May 4	20.55		
		D2-5-2dd			
May 15, 1951	12.94	May 5, 1952	8.66	Apr. 1, 1953	15.24
July 6	7.70	June 9	8.09	May 2	14.72
Aug. 2	8.06	June 29	7.16	June 3	11.81
Aug. 29	9.76	Aug. 5	7.47	July 4	7.61
Oct. 1	9.83	Sept. 30	9.57	Aug. 3	7.92
Nov. 1	11.17	Nov. 10	11.32	Sept. 4	7.72
Dec. 3	11.98	Dec. 4	12.84	Oct. 1	9.56
Jan. 7, 1952	12.13	Jan. 6, 1953	14.83	Nov. 5	11.53
Feb. 5	14.05	Feb. 3	15.00	Dec. 1	12.91
Mar. 6	16.24	Mar. 5	15.95	Jan. 4, 1954	14.67
Apr. 7	13.38				
		D2-5-5ba			
July 6, 1951	2.88	June 4, 1952	4.86	Apr. 3, 1953	5.08
Aug. 1	2.84	June 29	4.85	May 4	5.14
Aug. 29	2.95	Aug. 5	4.72	June 2	5.34
Oct. 1	3.11	Sept. 4	4.61	July 4	5.22
Nov. 1	3.27	Sept. 30	4.59	Aug. 4	4.98
Dec. 4	3.49	Nov. 10	4.67	Sept. 9	4.79
Jan. 7, 1952	3.88	Dec. 4	4.72	Oct. 2	4.85
Feb. 5	4.13	Jan. 6, 1953	4.95	Nov. 4	4.88
Mar. 6	4.40	Feb. 3	4.89	Dec. 3	4.94
Apr. 7	5.24	Mar. 5	4.93	Jan. 4, 1954	5.09
May 2	5.09				
		D2-5-9cc1			
Apr. 19, 1951	4.32	Sept. 27, 1951	4.31	May 1, 1952	3.76
May 30	4.45	Nov. 1	3.49	June 2	4.11
July 5	4.04	Dec. 3	3.88	Sept. 29	4.02
Aug. 1	4.10	Jan. 7, 1952	4.01	Aug. 5, 1953	4.54
Aug. 28	3.64	Feb. 4	3.65		

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

D2-5-13bb

Date	Water level	Date	Water level	Date	Water level
June 29, 1951	2.80	Jan. 7, 1952	5.28	June 27, 1952	3.09
Aug. 1	4.98	Feb. 4	5.83	Aug. 1	3.66
Aug. 28	5.07	Mar. 6	6.45	Sept. 3	4.03
Sept. 27	4.94	Apr. 4	5.50	Sept. 29	4.80
Nov. 1	4.89	May 1	4.99	Aug. 3, 1953	3.93
Dec. 3	5.19	June 2	4.91		

D2-5-14ac

[No measurements by tape; for measurements from recorder chart, see table 35]

D2-5-14dd

Date	Water level	Date	Water level	Date	Water level
June 29, 1951	4.41	Jan. 7, 1952	Dry	June 27, 1952	2.56
Aug. 2	4.21	Feb. 4	Dry	Aug. 1	3.02
Aug. 28	3.02	Mar. 6	Dry	Sept. 3	4.93
Sept. 27	5.51	Apr. 4	Dry	Sept. 29	6.28
Nov. 1	Dry	May 1	5.29	Aug. 3, 1953	4.05
Dec. 3	Dry	June 2	4.79		

D2-5-15aa1

Date	Water level	Date	Water level	Date	Water level
Apr. 17, 1951	3.36	Nov. 1, 1951	3.04	June 2, 1952	2.73
May 30	3.38	Dec. 3	4.02	June 27	1.15
July 5	1.38	Jan. 7, 1952	4.22	Aug. 1	2.82
Aug. 1	3.19	Feb. 5	4.31	Sept. 3	3.44
Aug. 28	1.84	May 1	3.06	Sept. 29	3.88
Sept. 27	3.22				

D2-5-16aa1

[For measurements from recorder chart, see table 35]

Date	Water level	Date	Water level	Date	Water level
June 2, 1953	4.75	Sept. 2, 1953	3.95	Dec. 2, 1953	5.13
July 3	3.76	Oct. 5	4.92	Jan. 5, 1954	5.33
Aug. 3	4.68	Nov. 6	5.09		

D2-5-21da

Date	Water level	Date	Water level	Date	Water level
May 22, 1951	5.99	Apr. 7, 1952	5.11	Mar. 3, 1953	6.82
May 30	6.21	May 7	5.69	Apr. 2	6.04
July 5	2.70	June 2	5.23	May 4	6.19
Aug. 1	5.40	June 27	3.07	June 2	6.30
Aug. 28	5.50	Aug. 6	3.88	July 3	3.85
Sept. 28	5.67	Sept. 5	5.64	Aug. 3	5.58
Nov. 2	5.98	Sept. 29	6.12	Sept. 2	5.63
Dec. 3	6.07	Nov. 10	6.34	Oct. 5	6.09
Jan. 7, 1952	8.18	Dec. 2	6.61	Nov. 6	6.31
Feb. 4	7.10	Jan. 6, 1953	6.89	Dec. 2	6.44
Mar. 7	7.25	Feb. 3	6.62	Jan. 5, 1954	6.90

D2-5-22ccd

[No measurements by tape; for measurements from recorder chart, see table 35]

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
		D2-5-25cb1			
May 10, 1951	5.19	May 5, 1952	5.01	Apr. 2, 1953	5.86
May 30	5.51	June 4	5.02	May 4	5.79
July 5	4.88	June 27	4.81	June 2	5.79
Aug. 1	4.96	Aug. 6	4.49	July 3	5.75
Aug. 28	5.54	Sept. 5	5.70	Aug. 3	5.28
Sept. 28	5.41	Sept. 29	5.76	Sept. 2	6.32
Nov. 2	5.24	Nov. 7	5.66	Oct. 5	5.94
Dec. 3	5.16	Dec. 2	5.72	Nov. 6	5.90
Jan. 11, 1952	5.35	Jan. 6, 1953	5.32	Dec. 2	5.89
Feb. 4	5.64	Feb. 3	5.82	Jan. 5, 1954	5.83
Apr. 7	5.07	Mar. 3	6.04		
		D2-5-26cc2			
May 14, 1951	2.00	June 4, 1952	1.73	Sept. 5, 1952	1.80
Apr. 7, 1952	1.58	June 27	1.49	Sept. 29	2.34
May 7	2.06	Aug. 6	1.68	Aug. 3, 1953	1.61
		D2-5-29ac			
Aug. 13, 1951	4.70	Mar. 3, 1953	6.33	Sept. 2, 1953	5.64
Sept. 28	5.09	Apr. 2	5.63	Oct. 5	4.81
Nov. 2	5.22	May 4	5.48	Nov. 6	4.90
Dec. 4	5.95	June 2	5.09	Dec. 2	6.09
Jan. 11, 1952	6.13	July 3	5.00	Jan. 5, 1954	6.10
Feb. 3, 1953	5.87	Aug. 3	5.19		
		D2-5-33db1			
May 14, 1951	8.62	Sept. 29, 1951	9.55	Mar. 7, 1952	11.22
May 30	6.34	Nov. 2	8.73	Apr. 7	9.62
Aug. 1	9.61	Dec. 4	9.91	May 5	7.34
Aug. 29	9.19	Jan. 11, 1952	10.10		
		D2-5-34ba			
May 15, 1951	4.14	Apr. 7, 1952	4.10	Mar. 3, 1953	4.82
May 30	4.68	May 7	3.71	Apr. 2	3.47
July 5	2.00	June 4	3.63	May 4	3.88
Aug. 1	3.40	June 27	2.39	June 2	3.91
Aug. 28	3.62	Aug. 6	2.83	July 3	3.84
Sept. 28	3.29	Sept. 5	4.29	Aug. 3	3.05
Nov. 2	2.89	Sept. 29	4.82	Sept. 2	4.05
Dec. 3	4.29	Nov. 7	3.89	Oct. 5	3.58
Jan. 7, 1952	4.57	Dec. 2	3.97	Nov. 6	3.58
Feb. 4	4.71	Jan. 6, 1953	4.40	Dec. 2	3.28
Mar. 7	5.58	Feb. 3	4.09	Jan. 5, 1954	4.41
		D2-5-34cd			
Apr. 23, 1951	11.37	Nov. 2, 1951	10.07	May 5, 1952	5.10
May 30	8.92	Dec. 4	10.03	June 4	2.48
July 5	2.21	Jan. 11, 1952	Frozen	June 27	1.46
Aug. 1	3.46	Feb. 4	Frozen	Aug. 6	2.68
Aug. 29	5.41	Mar. 7	Frozen	Sept. 5	3.48
Sept. 28	8.09	Apr. 7	Frozen	Sept. 29	4.35

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
D2-5-35dc					
May 14, 1951	35.68	May 5, 1952	31.03	Apr. 2, 1953	37.80
May 30	35.78	June 4	26.79	May 4	39.56
July 5	26.27	June 27	21.52	June 2	39.39
Aug. 1	22.93	Aug. 6	16.15	July 3	28.76
Aug. 28	20.15	Sept. 5	15.31	Aug. 3	21.50
Sept. 28	21.08	Sept. 29	17.29	Sept. 2	17.17
Nov. 2	24.06	Nov. 7	22.11	Oct. 5	20.84
Dec. 3	28.78	Dec. 2	25.27	Nov. 6	22.58
Jan. 11, 1952	29.63	Jan. 6, 1953	28.50	Dec. 2	26.43
Feb. 4	29.92	Feb. 3	32.23	Jan. 5, 1954	28.90
Apr. 7	27.48	Mar. 3	34.99		
D2-6-18cb					
Aug. 3, 1951	2.32	Jan. 7, 1952	2.54	June 4, 1952	1.51
Aug. 28	1.38	Feb. 4	2.93	June 26	1.72
Sept. 27	1.63	Mar. 6	3.12	Aug. 4	2.26
Nov. 2	1.54	Apr. 1	2.39	Sept. 1	1.42
Dec. 4	2.26	May 5	2.26	Oct. 2	2.22
D2-6-20ab					
Aug. 15, 1951	40.35	Oct. 2, 1952	38.61	June 2, 1953	38.88
Aug. 28	40.17	Nov. 10	38.75	July 3	38.80
Sept. 27	40.84	Dec. 3	38.85	Aug. 3	38.87
Nov. 2	41.52	Jan. 5, 1953	38.69	Sept. 4	39.00
May 2, 1952	20.59	Feb. 3	39.90	Oct. 5	39.08
June 4	39.54	Mar. 5	40.68	Nov. 5	38.64
June 27	38.50	Apr. 2	39.74	Dec. 2	38.99
Aug. 4	38.17	May 2	39.41	Jan. 6, 1954	39.10
Sept. 5	38.42				
D2-6-22cb					
Aug. 15, 1951	37.00	Nov. 2, 1951	39.57	Jan. 7, 1952	44.26
Aug. 28	38.52	Dec. 3	43.13	Feb. 4	44.42
Sept. 27	39.24				
D2-6-26cb					
Aug. 6, 1951	30.29	June 4, 1952	24.78	Apr. 2, 1953	26.25
Aug. 28	29.42	June 27	27.54	May 2	26.12
Sept. 27	29.18	Aug. 4	24.27	June 2	26.21
Nov. 2	31.71	Sept. 5	23.28	July 3	25.62
Dec. 3	30.56	Oct. 2	22.92	Aug. 3	26.33
Jan. 7, 1952	31.74	Nov. 10	23.49	Sept. 4	26.49
Feb. 4	31.81	Dec. 3	23.80	Oct. 5	26.68
Mar. 7	32.78	Jan. 6, 1953	24.04	Nov. 5	27.51
Apr. 4	33.44	Feb. 3	25.11	Dec. 2	28.06
May 1	25.71	Mar. 5	26.12	Jan. 6, 1954	28.77
D2-6-27aa					
May 25, 1951	3.50	Aug. 28, 1951	3.94	Jan. 7, 1952	Frozen
May 29	2.53	Sept. 27	3.37	Feb. 4	Frozen
July 5	2.80	Nov. 2	Frozen	Mar. 7	Frozen
Aug. 1	4.21	Dec. 3	2.31	Apr. 4	2.18

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
		D2-6-27aa—Continued			
May 2, 1952	2.16	Dec. 3, 1952	2.25	July 3, 1953	2.49
June 4	2.27	Jan. 6, 1953	Frozen	Aug. 3	3.09
June 27	2.35	Feb. 3	2.07	Sept. 4	3.17
Aug. 4	3.10	Mar. 5	2.28	Oct. 5	2.84
Sept. 5	3.16	Apr. 2	2.40	Nov. 5	2.37
Oct. 2	2.91	May 2	1.96	Dec. 2	2.18
Nov. 10	2.34	June 2	1.99	Jan. 6, 1954	2.32
		D3-4-11bdb			
Aug. 22, 1952	6.17	July 3, 1953	7.74	Dec. 2, 1953	14.65
Feb. 3, 1953	13.94	Aug. 3	8.86	Jan. 5, 1954	14.90
Mar. 3	14.49	Sept. 2	10.20	Feb. 4	15.31
Apr. 2	14.89	Oct. 5	11.12	Mar. 3	14.84
May 4	15.54	Nov. 6	11.70	Apr. 1	15.20
June 2	11.42				
		D3-4-14ba			
May 18, 1951	46.50	May 5, 1952	43.51	June 2, 1953	37.80
May 30	44.39	June 4	39.43	July 3	34.57
July 6	32.40	June 27	32.00	Aug. 3	32.66
Aug. 1	32.20	Aug. 6	31.80	Sept. 2	32.96
Aug. 29	31.71	Sept. 5	31.84	Oct. 5	34.93
Sept. 28	33.93	Sept. 29	33.98	Nov. 6	36.86
Nov. 1	39.92	Feb. 3, 1953	44.62	Dec. 2	42.25
Dec. 4	42.66	Apr. 2	46.00	Jan. 5, 1954	43.18
Jan. 11, 1952	43.03	May 4	46.38		
		D3-4-27ba			
May 18, 1951	21.60	May 5, 1952	12.10	May 4, 1953	23.40
May 30	18.53	June 4	2.25	June 2	22.65
July 6	3.48	June 27	2.15	July 3	5.70
Aug. 1	5.16	Aug. 6	4.92	Aug. 3	5.93
Aug. 29	11.03	Sept. 5	10.19	Sept. 2	6.95
Sept. 28	11.88	Sept. 29	12.92	Oct. 5	9.30
Nov. 1	16.57	Feb. 3, 1953	21.10	Nov. 6	11.82
Dec. 4	20.67	Mar. 3	22.38	Dec. 2	19.61
Jan. 11, 1952	20.84	Apr. 2	23.19	Jan. 5, 1954	20.70
		D3-5-1ac			
May 14, 1951	36.12	Apr. 7, 1952	32.77	Mar. 3, 1953	33.94
May 30	37.93	May 5	30.05	Apr. 2	36.73
July 5	31.20	June 4	26.73	May 4	39.09
Aug. 1	24.99	June 27	20.20	June 2	38.63
Aug. 28	21.55	Aug. 6	15.08	July 3	23.88
Sept. 28	21.73	Sept. 5	15.05	Aug. 3	20.90
Nov. 2	27.01	Sept. 29	16.55	Sept. 2	18.55
Dec. 3	27.62	Nov. 7	21.09	Oct. 5	19.28
Jan. 11, 1952	29.01	Dec. 2	23.88	Nov. 6	21.51
Feb. 4	33.95	Jan. 6, 1953	28.08	Dec. 2	24.63
Mar. 7	37.78	Feb. 3	31.09	Jan. 5, 1954	28.40

Table 34.—*Water-level measurements by tape, in feet below land-surface datum*—Cont.

Date	Water level	Date	Water level	Date	Water level
		D3-5-3bb			
May 15, 1951	12.28	Mar. 7, 1952	Dry	Apr. 2, 1953	15.87
May 25	11.88	Apr. 7	Dry	May 4	11.24
July 5	4.74	May 5	7.60	June 2	11.61
Aug. 1	6.56	June 4	6.28	July 3	3.78
Aug. 29	9.04	June 27	3.01	Aug. 3	5.27
Sept. 28	12.00	Aug. 6	3.26	Sept. 2	5.39
Nov. 2	8.31	Sept. 5	5.84	Oct. 5	9.97
Dec. 3	14.79	Sept. 29	6.84	Nov. 6	13.71
Jan. 11, 1952	Dry	Feb. 3, 1953	15.63	Dec. 2	14.52
Feb. 4	Dry	Mar. 3	16.05	Jan. 5, 1954	15.36
		D3-5-3da			
Apr. 23, 1951	29.20	June 2, 1953	29.43	Oct. 5, 1953	12.26
Feb. 2, 1953	25.36	July 3	5.08	Nov. 6	18.29
Mar. 3	26.10	Aug. 3	6.01	Dec. 2	20.56
Apr. 2	29.76	Sept. 2	8.23	Jan. 5, 1954	22.72
May 4	29.80				
		D3-5-5aa1			
Apr. 23, 1951	4.51	Apr. 7, 1952	5.18	Mar. 3, 1953	5.67
May 30	4.02	May 5	2.52	Apr. 2	4.66
July 6	2.92	June 4	2.71	May 4	4.72
Aug. 1	3.41	June 27	2.54	June 2	3.74
Aug. 29	4.11	Aug. 6	2.98	July 3	3.11
Sept. 28	4.09	Sept. 5	4.66	Aug. 3	3.51
Nov. 2	4.27	Sept. 29	4.40	Sept. 2	4.50
Dec. 4	4.86	Nov. 7	4.76	Oct. 5	4.58
Jan. 11, 1952	5.25	Dec. 2	5.08	Nov. 6	2.84
Feb. 4	5.57	Jan. 6, 1953	5.18	Dec. 2	3.89
Mar. 7	6.13	Feb. 3	5.30	Jan. 5, 1954	5.04
		D3-5-9da			
May 25, 1951	32.90	Apr. 7, 1952	22.67	June 2, 1953	31.02
July 5	18.40	May 5	26.32	July 3	23.82
Aug. 1	20.40	June 4	24.92	Aug. 3	18.59
Aug. 28	16.01	June 27	20.29	Sept. 2	17.69
Sept. 28	18.67	Feb. 3, 1953	24.26	Oct. 5	17.23
Nov. 2	22.26	Mar. 3	26.69	Nov. 6	18.78
Dec. 3	22.66	Apr. 2	28.72	Dec. 2	20.40
Jan. 11, 1952	23.31	May 4	29.26	Jan. 5, 1954	24.15
		D3-5-18ab			
Apr. 19, 1951	18.87	Sept. 30, 1952	17.37	Aug. 3, 1953	15.82
May 30	17.51	Feb. 3, 1953	18.69	Sept. 2	16.99
July 6	14.62	Mar. 3	18.74	Oct. 5	17.18
Aug. 1	15.67	Apr. 2	19.19	Nov. 6	17.42
Aug. 29	16.00	May 4	18.78	Dec. 2	17.37
Sept. 28	16.96	June 2	16.82	Jan. 5, 1954	17.83
Nov. 2	17.23	July 3	13.58		

Date	Water level	Date	Water level	Date	Water level
		D3-6-6ac			
Aug. 13, 1951	15.40	June 4, 1952	10.78	Apr. 2, 1953	15.76
Aug. 28	16.09	June 27	11.55	May 4	14.68
Sept. 28	13.27	Aug. 6	11.60	June 2	14.41
Nov. 1	13.13	Sept. 5	11.75	July 3	13.96
Dec. 3	13.77	Sept. 29	11.40	Aug. 3	13.61
Jan. 11, 1952	13.91	Nov. 7	11.97	Sept. 2	12.79
Feb. 4	14.20	Dec. 2	12.86	Oct. 5	15.68
Mar. 7	15.01	Jan. 6, 1953	13.22	Nov. 6	14.16
Apr. 7	13.38	Feb. 3	14.64	Dec. 2	14.25
May 5	11.46	Mar. 3	15.28	Jan. 5, 1954	14.98

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*

Day	1953												1954		
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
							A1-4-5da								
1	....	....	4.32	4.05	4.04	3.92	3.51	3.16	3.61	3.71	3.40	3.42	3.85	....	3.67
2	....	....	4.32	4.03	4.04	3.93	3.56	3.15	3.55	3.72	3.40	3.43	....	....	3.68
3	....	....	4.32	4.04	4.05	3.04	3.60	3.13	3.54	3.69	3.40	3.44	....	4.15	3.69
4	....	4.21	4.32	4.04	4.08	3.12	3.62	3.00	3.54	3.68	3.39	3.44	....	4.17	....
5	....	....	4.31	4.03	4.10	3.32	3.67	3.10	3.55	3.68	3.38	3.46	3.94	4.18	....
6	....	....	4.30	4.01	4.12	3.38	3.71	3.10	3.57	3.67	3.37	3.46	3.92	....	....
7	4.70	....	4.29	3.97	4.14	3.40	3.65	3.11	3.59	3.67	3.37	....	3.90	....	....
8	....	....	4.18	3.97	4.17	3.38	3.68	3.11	3.60	3.68	3.37	....	3.89	....	....
9	....	....	4.14	3.98	4.19	3.41	3.70	3.08	3.62	3.68	3.37	3.54	3.87	....	....
10	....	....	4.12	3.98	4.21	3.43	3.70	3.06	3.64	3.67	3.36	3.54	3.87	4.25	3.72
11	....	....	4.07	4.01	4.21	3.40	3.74	3.06	....	3.67	3.36	3.55	3.90	4.25	3.71
12	....	....	4.03	4.01	4.21	3.17	3.78	3.14	3.63	3.67	3.36	3.58	3.95	4.23	3.71
13	....	....	4.02	4.02	4.20	2.72	3.81	3.22	3.65	3.69	3.35	3.59	....	4.00	3.71
14	....	....	4.00	4.04	4.21	2.92	3.84	3.24	3.66	....	3.34	3.60	....	3.96	3.70
15	....	....	4.00	4.04	4.23	2.96	3.85	3.24	3.66	3.71	3.35	3.64	....	3.94	3.69
16	....	....	4.00	4.05	4.25	3.01	3.82	3.29	3.68	3.71	3.34	3.65	....	3.89	3.68
17	....	....	4.00	4.06	4.26	3.01	3.85	3.31	3.69	3.72	3.35	3.68	....	3.84	3.66
18	....	....	4.01	4.05	4.28	3.04	3.88	3.37	3.68	3.70	3.34	3.70	....	3.84	3.66
19	....	....	4.01	4.06	4.30	3.10	3.92	3.39	3.73	3.68	3.34	3.72	....	3.83	3.63
20	....	....	4.01	4.07	4.25	2.94	3.94	3.42	3.72	3.65	3.42	3.73	....	3.82	3.62
21	....	....	4.02	4.08	4.23	2.97	3.86	3.47	3.72	3.63	3.42	3.72	....	3.79	3.61
22	....	....	4.03	4.09	4.10	2.91	3.77	3.48	3.67	3.57	3.40	3.67	....	3.76	3.56
23	....	....	4.04	4.09	4.10	3.04	3.68	3.51	3.66	3.51	3.35	3.67	....	3.75	3.51
24	....	....	4.05	4.08	4.12	3.13	3.50	3.53	3.66	3.51	....	3.71	....	3.69	3.52
25	....	....	4.04	4.09	3.81	3.21	3.39	....	3.65	3.49	3.34	3.76	....	3.68	....
26	....	4.38	4.05	4.09	3.89	3.23	3.29	....	3.67	3.47	3.36	3.80	....	3.67	....
27	....	4.37	4.05	4.11	3.94	3.30	3.19	3.62	3.68	3.46	3.37	3.82	4.13	3.68	....
28	....	4.32	4.05	4.12	3.98	3.33	3.26	3.60	3.69	3.45	3.40	3.83	....	3.67	....
29	....		4.05	4.05	4.00	3.39	3.31	3.55	3.69	3.43	3.41	3.83	....		....
30	....		4.04	4.04	3.92	3.44	3.32	3.56	3.69	3.42	3.41	3.83	....		....
31	....		4.05		3.90		3.27	3.58		3.41		3.85	....		3.60

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*—Continued

Day	1952			1953												1954		
	Sept.	Oct.	Nov.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
									A1-4-22dc1									
1	....	3.99	3.90	....	....	....	6.32	6.24	5.47	....	4.43	4.15	4.18	4.12	4.40	5.06	5.57	5.85
2	....	3.96	3.97	....	....	....	6.34	6.27	5.41	....	4.37	3.92	4.00	4.17	4.43	5.09	5.58	5.88
3	3.96	4.00	3.96	....	....	....	6.37	6.30	4.67	4.79	4.30	3.98	4.05	4.15	4.47	5.13	5.62	5.91
4	3.99	3.98	3.99	....	....	....	6.39	6.33	3.98	4.74	4.26	....	4.08	4.14	4.49	5.12	5.66	5.96
5	3.93	3.96	3.97	....	....	....	6.41	6.36	4.34	4.76	4.29	4.06	4.10	4.14	4.53	5.11	5.70	6.00
6	3.96	3.97	3.95	....	....	....	6.36	6.38	4.45	4.74	4.33	4.05	4.12	4.15	4.52	5.09	5.72	6.05
7	3.99	3.97	3.99	5.35	....	....	6.27	6.40	4.43	4.73	4.35	4.05	4.13	4.19	4.57	5.08	5.75	6.08
8	3.93	3.98	4.01	....	....	....	6.29	6.40	4.45	4.69	4.35	....	4.14	4.19	4.62	5.09	5.77	6.09
9	3.92	3.98	4.04	....	....	....	6.33	6.36	4.57	4.65	4.34	....	4.15	4.20	4.61	5.10	5.79	6.10
10	3.91	4.00	4.06	....	....	....	6.37	6.35	4.69	4.61	4.26	....	4.17	4.20	4.61	5.12	5.82	6.10
11	3.91	3.98	4.01	....	....	....	6.42	6.31	4.72	4.60	4.21	4.08	4.12	4.23	4.66	5.20	5.84	6.10
12	3.89	3.99	4.01	....	....	....	6.43	6.25	4.69	4.58	4.25	4.09	4.12	....	4.65	5.29	5.85	6.11
13	3.83	4.01	3.98	....	....	5.78	6.46	6.22	4.69	4.58	4.27	4.12	4.10	....	4.70	5.34	5.76	6.12
14	3.87	3.99	3.99	....	....	5.82	6.48	6.24	4.70	4.58	4.18	4.07	....	....	4.72	5.36	5.67	6.14
15	3.87	3.98	3.97	....	....	5.87	6.49	6.29	4.70	....	4.30	4.06	4.07	....	4.72	5.39	5.66	6.15
16	3.92	4.01	3.92	....	....	5.92	6.51	6.34	4.73	....	4.29	4.12	4.07	....	4.75	5.41	5.63	6.17
17	3.94	4.02	3.91	....	....	5.97	6.51	6.37	4.77	4.41	4.27	4.11	4.07	....	4.80	5.39	5.64	6.19
18	3.99	4.02	3.95	....	....	....	6.45	6.41	4.81	4.43	4.26	4.11	4.06	....	4.83	5.38	5.66	6.22
19	4.03	4.00	3.98	....	....	....	6.45	6.40	4.77	4.50	4.27	4.15	4.07	4.20	4.80	5.38	5.71	6.22
20	4.03	3.99	4.02	....	....	6.07	6.48	6.23	4.60	4.58	....	4.11	4.04	....	4.80	....	5.74	6.21
21	4.04	3.99	4.06	....	....	6.10	6.51	6.11	4.63	4.60	....	4.09	3.92	....	4.80	5.46	5.69	6.19
22	4.00	3.99	4.10	....	....	6.13	6.53	5.94	4.68	4.60	....	4.11	3.93	....	4.79	5.49	5.62	6.20
23	4.01	3.99	....	....	....	6.17	6.49	5.89	4.72	4.60	....	4.03	3.95	....	4.85	5.49	5.66	6.18
24	4.01	3.99	....	....	....	6.20	6.41	5.92	4.67	....	....	4.06	4.03	....	4.94	5.48	5.64	6.19
25	4.00	4.00	4.14	....	....	6.21	6.43	5.75	4.67	4.48	....	4.05	4.06	4.29	5.00	5.49	5.68	....
26	3.99	4.00	....	....	....	6.25	6.46	5.75	4.62	4.46	....	4.10	4.06	4.35	5.02	5.50	5.73	....
27	3.99	4.00	....	....	6.10	6.27	6.48	5.74	4.66	4.48	....	4.11	4.07	4.37	5.04	5.50	5.78	....
28	4.00	3.99	....	....	....	6.29	6.49	5.75	4.64	4.48	....	4.14	4.07	4.40	5.06	5.53	5.80	....
29	3.98	3.98	....	....		6.28	6.30	5.70	4.69	4.49	4.09	4.10	4.10	4.41	5.05	5.54		....
30	3.99	3.96	....	....		6.26	6.22	5.61	4.71	4.49	4.13	4.11	4.12	4.41	5.09	5.55		....
31		3.93		....		6.29		5.53		4.49	4.15		4.14		5.10	5.56		6.10

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*—Continued

Day	1951	1952											
	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A1-4-25dc													
1	....	11.86	13.33	14.34	14.79	13.88	....	7.80	6.84	7.77	8.00	8.49	9.56
2	....	11.92	13.37	14.36	14.70	13.73	11.89	7.70	6.73	7.72	8.02	8.56	9.61
3	....	11.97	13.41	14.41	14.60	13.67	11.95	7.59	6.36	7.71	8.08	8.55	9.67
4	....	12.03	13.45	14.42	14.38	13.63	11.84	....	6.49	7.70	8.14	8.60	9.74
5	....	12.06	13.49	14.44	14.06	13.62	11.70	7.57	6.09	7.72	8.20	....	9.77
6	....	12.09	13.52	14.61	13.35	13.71	11.61	7.62	5.92	7.71	8.23	....	9.83
7	10.57	12.17	13.55	14.65	....	13.77	11.22	7.72	6.43	7.73	8.22	....	9.85
8	....	12.23	13.60	14.66	....	13.82	10.93	7.90	6.76	7.76	8.17	....	9.93
9	....	12.27	13.62	14.67	....	13.85	10.94	7.97	6.97	7.79	8.18	....	10.01
10	....	12.34	13.67	14.73	....	13.86	10.75	8.05	7.05	7.86	8.22	8.67	10.05
11	10.57	12.38	13.70	14.73	12.90	13.84	10.51	8.10	7.00	7.87	8.22	....	10.12
12	10.70	12.42	13.73	14.76	....	13.84	10.27	8.09	7.24	7.88	8.24	....	10.18
13	10.75	12.48	13.77	14.79	....	13.81	....	7.87	7.44	7.93	8.30	....	10.24
14	10.83	12.53	13.81	14.83	....	13.73	....	7.68	7.58	7.97	8.33	....	10.28
15	10.79	12.57	13.85	14.84	13.03	13.60	....	7.58	7.62	7.80	8.33	8.85	10.34
16	10.73	12.61	....	14.88	....	13.45	9.95	7.82	....	7.80	8.37	....	10.40
17	10.66	12.68	....	14.91	....	13.32	9.40	8.10	7.75	7.80	8.41	....	10.45
18	10.61	12.70	....	14.93	....	13.18	9.40	8.13	7.78	7.78	8.44	....	10.50
19	10.54	12.76	....	14.96	....	13.06	9.47	8.22	7.82	7.76	....	....	10.57
20	10.49	12.80	14.04	14.99	....	12.93	9.37	7.86	7.87	7.79	8.47	8.97	10.61
21	10.43	12.85	14.05	15.02	13.48	12.75	9.25	8.02	7.88	7.79	8.49	9.03	10.67
22	10.45	12.88	14.08	15.02	13.54	12.46	9.27	7.99	7.88	7.77	8.51	9.09	10.73
23	10.49	12.94	14.10	15.02	13.62	12.10	9.09	7.94	7.89	7.78	8.53	9.13	10.79
24	10.57	13.00	14.14	15.06	13.68	11.82	9.02	7.94	7.91	7.81	8.54	9.18	10.83
25	10.63	13.03	14.17	15.07	13.79	11.65	8.90	7.99	7.87	7.85	8.52	9.26	10.90
26	....	13.06	14.20	15.11	13.84	11.58	8.72	7.24	7.89	7.87	8.52	9.30	10.95
27	11.60	13.11	14.24	15.11	13.89	11.52	8.41	6.97	7.92	7.90	8.55	9.36	11.01
28	11.66	13.16	14.28	15.10	13.94	11.45	8.05	6.92	7.99	7.94	8.53	9.40	11.06
29	11.68	13.21	14.32	15.07	14.02	11.47	....	6.97	8.03	7.93	8.50	9.47	11.15
30	11.76	13.23		14.96	14.06	11.57	7.90	7.00	7.92	7.96	8.51	....	11.19
31	11.80	13.28		14.82		....		6.92	7.81		8.52		11.25

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*—Continued

Day	1953												1954			
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
A1-4-25dc—Continued																
1	11.31	12.63	13.87	14.73	15.06	11.69	....	....	7.45	8.22	8.41	9.19	11.08	12.64	13.60	14.64
2	11.35	12.68	13.90	14.77	15.05	11.62	....	....	7.57	8.27	8.47	9.22	11.14	12.68	13.65	14.67
3	11.41	12.71	13.93	14.80	15.06	11.41	8.56	....	7.61	8.30	8.37	9.27	11.19	12.72	13.72	14.68
4	11.47	12.75	13.95	14.83	15.07	10.82	....	....	7.59	8.32	8.27	9.35	11.25	12.77	13.77	14.67
5	11.56	12.80	14.02	14.87	15.08	10.32	....	....	7.60	8.33	8.29	9.44	11.30	12.81	13.81	14.65
6	11.61	12.83	14.05	14.90	15.03	10.08	....	....	7.68	8.33	8.19	9.48	11.35	12.86	13.85	14.64
7	11.66	12.87	14.11	14.93	14.91	9.92	....	7.05	7.69	8.36	8.24	9.55	11.38	12.90	13.91	14.63
8	11.70	12.92	14.14	14.96	14.74	9.79	....	6.99	7.71	8.39	8.23	9.64	11.44	12.96	13.94	14.62
9	11.74	13.00	14.09	14.99	14.55	9.67	....	6.75	7.73	8.41	8.21	9.71	11.50	13.00	13.98	14.62
10	11.76	13.03	14.08	15.02	14.41	9.45	8.32	6.72	7.77	8.42	8.18	9.76	11.54	13.04	14.02	14.63
11	11.78	13.07	14.07	15.05	14.31	9.31	8.29	6.83	7.82	8.45	8.17	9.81	11.60	13.09	14.06	14.64
12	11.80	13.14	14.06	15.07	14.27	9.51	7.93	6.64	7.83	8.47	8.15	9.87	....	13.13	14.11	14.66
13	11.75	13.19	14.05	15.10	14.27	9.57	7.72	6.67	7.88	8.49	8.18	9.93	11.62	13.17	14.15	14.67
14	11.76	13.22	14.03	15.12	14.23	9.65	7.40	6.68	7.93	8.50	8.19	9.98	11.68	13.21	14.19	14.69
15	11.84	13.26	14.12	15.14	14.17	9.35	7.37	6.72	7.96	8.48	8.24	10.04	11.74	13.25	14.24	14.70
16	11.88	13.30	14.16	15.16	14.12	9.21	7.46	6.69	7.96	8.50	8.27	10.09	11.80	13.28	14.27	14.72
17	11.93	13.35	14.19	15.19	14.11	9.01	7.88	6.64	7.98	8.49	8.32	10.15	11.85	13.31	14.31	14.73
18	11.99	13.37	14.23	15.20	14.00	8.88	7.94	6.48	7.99	8.47	8.36	10.21	11.89	13.33	14.33	14.61
19	12.03	13.48	14.27	15.22	13.89	8.89	7.83	6.53	8.00	8.50	8.45	10.28	11.94	....	14.37	14.60
20	12.07	13.51	14.30	15.23	13.79	8.84	7.64	6.96	8.06	8.54	8.54	10.35	....	....	14.40	14.59
21	12.13	13.56	14.34	15.23	13.70	8.97	7.48	7.25	8.06	8.55	8.66	10.45	....	....	14.42	....
22	12.18	13.58	14.38	15.24	13.48	8.87	7.44	7.38	8.06	8.43	8.69	10.47	12.16	....	14.45	14.52
23	12.24	13.64	14.42	15.26	13.28	8.62	7.53	7.42	8.09	8.37	8.72	10.52	12.19	....	14.47	....
24	12.26	13.68	14.47	15.27	13.13	8.47	7.59	7.43	8.12	8.35	8.81	....	12.24	13.43	14.49	....
25	12.31	13.73	14.50	15.26	12.99	8.46	7.65	7.53	8.09	8.42	8.89	....	12.29	13.45	14.52	....
26	12.34	13.74	14.53	15.24	12.80	8.47	7.70	7.55	8.10	8.43	8.95	....	12.35	13.47	....	....
27	12.40	13.81	14.57	15.23	12.67	....	7.69	7.61	8.13	8.42	9.01	....	12.39	13.52	....	....
28	12.43	13.83	14.60	15.21	12.52	....	7.44	7.67	8.13	8.39	9.07	10.88	12.43	13.57	....	....
29	12.49		14.64	15.17	12.26	....	....	....	8.19	8.37	9.11	10.91	12.50		....	....
30	12.53		14.68	15.10	12.02	....	....	7.65	8.19	8.41	9.15	10.98	12.54		....	....
31	12.59		14.71		11.83		7.27	....		8.41		10.83	12.60		14.63	

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*—Continued

Day	1951 Sept.	1951 Oct.	1951 Nov.	1951 Dec.	1952 Jan.	1952 Feb.	1952 Mar.	1952 Apr.	1952 May	1952 June	1952 July	1952 Aug.	1952 Sept.	1952 Oct.	1952 Nov.	1952 Dec.
							A2-3-33da									
1	....	....	....	....	....	39.76	40.15	40.03	....	....	32.52	....	32.84	34.28	33.78	37.31
2	....	....	....	....	....	....	40.15	40.03	41.40	39.49	32.67	33.47	32.93	34.42	33.86	37.33
3	....	....	....	....	....	....	40.15	40.03	....	....	31.69	32.93	32.97	34.60	33.90	37.39
4	....	....	....	....	....	....	40.15	40.05	....	....	30.50	32.47	33.00	34.72	33.90	37.46
5	....	....	37.30	....	....	....	40.19	40.05	....	....	30.19	32.45	33.03	34.79	33.90	37.47
6	....	....	37.31	....	....	....	40.19	40.05	....	....	30.29	32.86	33.06	34.83	34.43	37.51
7	....	....	37.34	....	....	....	40.25	40.05	....	....	30.22	32.97	33.11	34.84	35.01	37.56
8	....	....	37.40	....	....	39.88	40.25	40.05	....	....	31.18	32.73	33.19	34.82	35.36	37.63
9	34.43	....	37.43	....	39.39	....	40.25	40.05	40.25	35.37	31.49	32.23	33.24	34.81	35.59	37.70
10	....	....	37.44	....	....	....	40.25	39.99	40.23	34.75	31.50	32.04	33.32	34.84	35.73	37.73
11	....	....	37.48	....	39.38	....	40.25	39.93	40.23	34.45	31.54	31.39	33.45	34.78	35.82	37.78
12	....	36.05	37.51	....	....	....	40.26	39.93	40.20	34.40	30.43	31.13	33.56	34.60	35.88	37.83
13	....	....	37.58	....	....	....	40.28	39.93	40.09	34.23	30.23	31.06	....	34.46	35.96	37.87
14	....	....	37.62	....	....	....	40.32	39.93	40.02	34.05	30.59	30.46	....	34.25	36.01	37.89
15	....	36.23	37.70	....	....	39.92	40.33	39.93	39.96	33.87	31.47	30.32	33.90	33.74	36.09	37.91
16	....	36.26	37.74	....	....	....	40.34	39.94	39.97	33.80	32.28	30.94	34.00	33.26	36.19	37.95
17	....	36.32	....	....	....	....	40.34	39.94	40.18	33.58	32.83	30.90	34.09	32.96	36.27	37.99
18	....	36.39	....	....	....	....	40.35	39.94	....	33.59	32.98	30.49	34.07	32.57	36.36	38.01
19	....	36.43	....	....	....	....	40.32	39.94	40.14	33.65	32.93	29.02	33.96	32.42	36.42	38.04
20	....	36.45	....	....	....	40.02	40.30	39.94	....	33.76	33.13	26.89	33.90	32.35	36.47	38.09
21	....	36.52	....	....	....	40.02	40.31	39.94	....	33.22	33.46	25.57	33.90	32.40	36.58	38.13
22	....	36.58	....	....	....	40.03	40.30	39.95	....	32.75	33.62	28.59	33.77	32.50	36.66	38.16
23	....	36.61	....	....	....	40.04	40.30	39.98	....	33.82	33.36	30.50	33.72	32.91	36.75	38.20
24	....	36.64	....	....	....	40.04	40.31	40.04	....	33.82	33.35	31.59	33.64	33.36	36.83	38.22
25	....	36.71	....	....	39.68	40.06	40.32	40.08	....	32.51	33.32	32.28	33.60	33.72	36.90	38.26
26	....	36.75	....	....	39.68	40.06	40.33	....	39.63	32.44	33.18	32.76	33.62	34.02	36.96	38.29
27	....	36.79	....	....	39.69	40.09	40.13	....	39.60	32.66	33.25	32.85	33.64	34.17	37.05	38.33
28	....	36.82	....	....	39.71	40.09	40.11	....	39.55	32.87	33.47	32.77	33.71	34.21	37.12	38.36
29	....	36.86	....	....	39.72	40.14	40.04	....	....	32.74	33.69	32.74	33.92	34.00	37.20	38.39
30	....	....	....	....	....		40.03	....	....	33.80	....	32.80	34.11	33.83	....	38.42
31		....		....	....		40.03		....		....	32.70		33.76		38.45

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*—Continued

Day	1953												1954
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
	A2-3-33da—Continued												
1	38.48	39.17	39.65	40.07	40.39	34.90	34.12	28.32	32.32	......	......	36.24	......
2	38.52	39.19	39.67	40.09	40.39	35.15	33.96	28.49	32.48	......	......	......	......
3	38.56	39.21	39.69	40.10	40.39	35.24	33.80	28.66	32.55	......	......	......	......
4	38.57	39.22	39.71	40.12	40.40	35.21	33.43	28.88	32.61	......	......	......	......
5	38.59	39.23	39.72	40.13	40.41	35.33	32.85	29.03	32.70	......	35.99	......	38.45
6	38.61	39.25	39.73	40.14	40.41	35.40	32.66	29.52	33.02	......	......	......	......
7	38.64	39.27	39.75	40.14	40.42	35.39	32.66	29.41	33.46	......	......	......	......
8	38.68	39.28	39.75	40.14	40.42	35.43	32.69	29.79	33.76	......	......	......	......
9	38.71	39.30	39.75	40.14	40.39	35.47	32.86	30.15	33.96	......	......	......	......
10	38.73	39.31	39.76	40.14	40.33	35.28	32.57	29.62	......	......	......	......	......
11	38.74	39.32	39.77	40.15	40.22	35.14	31.75	30.01	34.27	......	......	......	......
12	38.76	39.34	39.79	40.16	40.12	35.01	31.84	30.66	......	......	......	......	......
13	38.78	39.35	39.80	40.17	39.95	34.91	32.45	31.11	......	......	......	......	......
14	38.80	39.37	39.81	40.19	39.68	34.87	32.74	31.40	......	......	......	......	......
15	38.83	39.38	39.81	40.21	39.20	34.92	32.72	31.63	......	......	......	......	......
16	38.85	39.40	39.82	40.22	38.55	34.60	32.70	31.82	......	......	......	......	......
17	38.86	39.41	39.83	40.24	38.13	34.48	32.64	31.78	......	......	......	......	......
18	38.88	39.43	39.84	40.26	37.49	34.44	32.71	31.56	......	......	......	......	......
19	38.90	39.46	39.85	40.27	37.09	34.55	32.67	31.46	34.94	......	......	......	......
20	38.92	39.48	39.86	40.28	36.55	34.47	32.48	31.47	35.04	......	......	......	......
21	38.96	39.50	39.87	40.30	35.15	34.15	32.48	31.68	35.07	......	......	......	......
22	38.97	39.52	39.88	40.31	35.39	33.17	32.35	31.71	35.12	......	......	......	......
23	38.99	39.54	39.90	40.34	35.88	32.33	31.85	31.69	35.18	......	......	......	......
24	39.02	39.56	39.91	40.34	35.84	31.08	31.18	31.60	35.23	......	......	......	......
25	39.03	39.58	39.93	40.36	35.93	31.28	30.57	31.68	35.24	......	......	......	......
26	39.05	39.60	39.95	40.37	35.82	32.60	29.79	31.82	35.31	......	......	......	......
27	39.07	39.62	39.97	40.37	35.82	33.70	29.09	31.87	35.34	......	......	......	......
28	39.09	39.64	39.98	40.38	35.78	33.92	28.61	31.84	35.37	......	......	......	......
29	39.12		40.00	40.39	35.54	34.24	27.28	31.88	35.44	......	......	......	......
30	39.15		40.01	40.39	35.26	34.32	25.70	32.12	......	......	......	......	......
31	39.16		40.04	......	35.13		27.40	32.22		......		......	......

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*—Continued

Day	1953										1954		
	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
						D1-4-6ddc2							
1	...	16.66	17.25	14.53	...	6.19	5.54	9.91	11.06	...	13.97	15.84	16.33
2	...	16.67	17.31	14.11	...	6.31	5.48	10.08	11.04	12.28	14.04	15.91	16.37
3	...	16.68	17.39	13.85	4.45	6.36	4.23	10.22	11.00	12.32	14.09	15.99	16.40
4	...	16.71	17.43	13.74	4.61	6.45	5.40	10.34	10.97	12.39	14.14	16.05	16.44
5	...	16.74	17.49	...	4.66	6.58	5.75	10.44	10.92	12.45	14.21	16.10	16.49
6	...	16.77	17.51	12.87	4.65	6.62	5.82	10.62	10.94	12.51	14.25	16.17	16.54
7	...	16.79	17.59	12.67	4.67	6.68	5.92	10.72	10.97	...	14.30	16.22	16.59
8	...	16.68	17.55	12.51	4.65	6.73	5.89	10.81	10.97	12.62	14.35	16.27	16.63
9	...	16.71	17.51	12.37	...	6.74	6.18	10.89	10.98	12.68	14.41	16.31	16.69
10	...	16.75	17.54	12.25	4.50	6.70	6.32	11.00	11.00	12.76	14.46	16.34	16.74
11	...	16.80	17.58	12.13	4.43	6.55	6.62	11.11	11.03	12.83	14.51	16.38	16.79
12	...	16.83	17.64	11.97	4.06	6.31	5.89	11.20	11.05	12.91	14.55	16.39	16.84
13	...	16.89	17.71	11.34	3.76	6.42	6.18	11.28	11.07	12.97	14.57	16.38	16.88
14	...	16.91	17.77	...	3.98	6.52	6.46	11.34	11.09	13.02	14.63	16.27	16.92
15	...	16.95	17.83	...	3.79	6.54	6.72	11.36	11.12	13.08	14.70	16.25	16.97
16	...	17.00	17.88	...	3.48	6.56	6.96	11.38	11.13	13.13	14.76	16.23	17.01
17	17.61	17.10	...	...	3.98	6.51	7.22	11.41	11.18	13.17	14.81	16.21	17.06
18	...	17.12	...	...	4.35	6.40	7.50	11.42	11.21	13.21	14.87	16.20	...
19	...	17.15	...	3.27	4.55	6.36	7.75	11.45	11.27	13.25	14.94	16.21	...
20	...	17.18	17.86	2.72	4.91	6.32	8.00	11.43	11.36	13.30	...	16.21	...
21	...	17.23	17.68	2.27	5.13	6.32	8.20	11.41	11.47	13.37	15.10	16.22	...
22	...	17.29	17.44	2.33	5.02	6.26	8.40	11.43	11.56	13.42	15.15	16.24	...
23	...	17.33	17.23	2.70	4.91	6.20	8.70	11.40	11.63	13.46	15.22	16.25	...
24	16.37	17.35	16.91	2.11	4.64	6.10	...	11.37	11.71	13.51	15.28	16.25	...
25	16.39	17.31	16.65	3.17	4.68	5.97	...	11.39	11.78	13.57	15.36	16.25	...
26	16.44	17.35	...	3.42	4.91	4.99	9.13	11.37	11.88	13.62	15.42	16.25	...
27	16.45	17.36	...	3.70	4.62	5.69	9.28	11.35	11.95	...	15.50	16.27	...
28	16.47	17.32	...	3.80	5.07	5.76	9.44	11.27	12.03	13.74	15.55	16.28	...
29	16.52	17.29	...	...	5.25	5.67	9.62	11.20	12.11	13.80	15.63		...
30	16.57	17.26	15.23	...	5.51	5.56	9.76	11.18	...	13.87	15.70		...
31	16.62		14.90		6.03	5.54		11.12		13.92	15.76		17.65

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*—Continued

Day	1953									1954			
	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
D1-4-9ba1													
1	....	22.51	....	15.54	14.81	17.05	....	16.91	18.06	20.13	21.35	....	23.32
2	....	22.63	....	....	14.72	17.05	....	16.87	18.13	20.19	21.38	....	23.33
3	....	22.68	....	15.35	14.68	16.90	....	16.86	18.23	20.24	21.46	22.29	23.32
4	....	22.71	....	15.38	14.75	16.72	....	16.89	18.33	20.27	21.49	22.35	23.22
5	....	22.72	....	15.40	14.88	16.66	....	16.95	18.41	20.30	21.55	22.40	23.16
6	....	22.73	18.14	15.40	14.98	16.62	....	....	18.48	20.35	21.59	22.46	23.13
7	....	22.65	18.11	15.41	15.11	16.60	....	17.06	....	20.40	21.62	22.50	23.13
8	22.71	22.57	18.05	15.44	15.21	16.57	20.70	17.11	18.65	20.46	21.65	22.49	23.14
9	22.76	22.58	17.98	....	15.37	16.52	20.90	17.33	18.72	20.51	21.67	22.48	23.16
10	22.81	22.63	17.95	15.30	15.53	16.53	21.15	17.50	18.82	20.56	21.72	22.48	23.21
11	22.83	22.71	17.70	15.29	15.64	16.57	21.30	17.63	18.87	20.62	21.73	22.51	23.24
12	22.86	22.82	17.11	15.33	15.73	16.59	....	17.73	18.95	20.68	21.76	22.60	23.26
13	22.90	22.94	....	15.39	....	16.69	....	17.82	19.01	20.72	21.76	22.67	23.26
14	22.93	23.07	....	15.34	16.01	16.76	....	17.89	19.04	20.77	21.76	22.75	23.25
15	22.96	23.15	....	15.32	....	16.82	19.15	17.96	19.13	20.83	21.77	22.79	23.21
16	22.96	23.22	....	15.31	....	16.89	18.87	17.99	19.17	20.87	21.78	22.83	23.21
17	22.97	23.25	....	15.34	....	17.01	18.63	18.02	19.25	20.90	21.61	22.85	23.22
18	22.98	23.23	....	15.45	....	17.13	....	18.12	19.31	20.94	21.83	22.87	23.22
19	22.97	23.17	14.73	15.66	....	17.23	....	18.13	19.37	21.03	21.88	22.89	....
20	22.95	22.83	14.72	15.76	....	17.38	....	18.01	19.41	....	21.93	22.91	....
21	22.90	22.27	14.69	15.75	16.58	17.47	....	17.88	19.48	21.13	21.94	22.94	....
22	22.83	22.01	14.76	15.46	16.62	17.62	17.53	17.70	19.53	21.08	21.94	22.95	23.31
23	22.73	21.88	14.81	15.08	16.66	17.70	17.21	17.44	19.59	20.06	21.95	22.99	....
24	22.64	21.90	14.86	14.92	16.69	17.82	17.15	17.48	19.68	21.08	21.96	23.03	....
25	22.61	21.96	14.86	14.78	16.78	17.94	17.11	17.55	19.74	21.12	21.96	23.06	....
26	22.61	22.00	14.91	14.71	....	....	17.06	17.62	19.78	21.16	21.98	23.07	....
27	22.59	21.86	15.53	14.65	....	....	17.03	17.70	19.82	21.18	22.04	23.06	....
28	22.54	21.43	....	14.84	17.03	....	17.00	17.82	19.86	21.20	22.08	23.07	....
29	22.49	20.62	....	14.70	17.05	....	17.02	17.91	19.96	21.25		23.14	....
30	22.46	20.02	....	14.77	17.04	....	17.06	17.97	20.01	21.28		23.19	....
31		19.74		15.00	17.04		17.00		20.07	21.30		23.25	....

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*—Continued

Day	1953								Day	1953							
	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
								D1-4-25aa2									
1		18.3						18.5	17	15.6		26.2				20.4	
2		18.6				23.9		18.4	18	15.8				24.8		20.3	
3		18.9	25.0					18.4	19	16.1	23.6					20.2	
4		19.3			25.0			18.3	20	16.2						20.1	
5		19.7						18.2	21	16.4			25.5				16.6
6	13.0	20.1					22.0	18.1	22	16.4							
7	14.3	20.5		26.0				18.0	23	16.2							
8	14.9	20.9				23.6		17.9	24	16.4	24.3					20.0	
9	14.9								25	16.5				24.3		19.8	
10	15.0		26.0						26	16.6						19.7	
11	15.1				24.8				27	16.8						18.8	
12	15.2	22.5					21.3		28	17.1			25.5			18.7	15.9
13	15.2								29	17.4					22.5	18.6	
14	15.4			25.5					30	17.7						18.6	
15	15.5							16.9	31	17.9		26.0					
16	15.6						20.6										

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*—Continued

Day	1953										1954			
	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
	D1-4-25aa3													
1	....	17.44	16.15	11.65	8.20	....	8.38	9.79	....	11.91	13.53	15.37	16.44	18.73
2	....	17.48	16.01	....	8.01	....	8.48	9.84	....	11.96	13.57	15.42	16.49	18.81
3	....	17.52	15.86	....	7.87	....	8.51	....	....	12.05	13.64	15.48	16.55	18.89
4	....	17.58	15.77	....	....	....	8.60	....	....	12.10	13.70	15.53	16.61	18.96
5	....	17.60	15.67	....	....	....	8.65	....	10.48	12.15	13.75	15.57	16.67	18.96
6	....	17.67	15.74	11.73	....	....	8.70	10.00	....	12.20	13.80	15.62	16.74	18.70
7	15.97	17.72	15.71	11.00	6.69	6.08	8.72	10.00	....	12.25	13.85	15.65	16.81	18.37
8	15.98	17.76	15.75	10.87	6.50	6.47	8.77	10.00	....	12.31	13.90	15.69	16.87	18.23
9	....	17.81	15.80	10.75	6.30	6.70	8.83	9.95	....	12.36	13.94	15.73	16.93	18.14
10	16.24	17.85	15.84	10.67	6.11	6.79	8.87	9.98	....	12.41	14.00	15.77	16.99	18.05
11	....	17.88	15.88	10.58	6.09	....	8.91	....	....	12.46	14.05	15.81	17.06	17.96
12	16.29	17.91	15.86	10.53	6.12	....	9.01	....	10.78	12.51	14.11	15.85	17.13	17.81
13	16.31	17.96	15.83	10.49	6.11	....	9.05	....	10.82	12.56	14.14	15.89	17.20	17.65
14	16.38	18.00	15.79	10.43	6.12	7.02	9.08	....	10.88	12.61	14.20	15.94	17.27	17.53
15	16.45	18.00	15.73	10.34	6.14	7.12	9.12	10.16	10.94	12.66	14.23	15.97	17.34	17.48
16	16.51	18.00	15.67	10.12	6.08	7.20	9.16	....	10.99	12.67	....	16.01	17.42	17.43
17	16.58	18.01	15.65	9.95	5.63	7.30	9.22	....	11.04	12.72	....	16.05	17.49	17.00
18	16.64	17.98	15.63	9.86	5.05	7.39	9.30	....	11.10	12.76	....	16.09	17.58	17.01
19	16.69	17.94	15.62	9.78	....	7.45	9.34	....	11.16	12.80	....	16.13	17.66	16.98
20	16.71	17.89	15.61	9.70	....	7.51	9.35	....	11.21	12.84	....	16.17	17.75	16.91
21	16.78	17.82	15.54	9.64	....	7.57	9.41	....	11.26	12.88	14.70	16.21	17.84	16.83
22	16.83	17.75	15.52	9.57	....	7.63	9.45	10.24	11.32	12.92	14.73	16.15	17.93	16.75
23	16.89	17.67	15.48	9.45	....	7.67	9.48	....	11.38	12.97	14.79	16.19	17.99	....
24	16.93	17.58	15.36	9.39	4.14	....	....	....	11.45	13.01	14.86	16.22	18.07	....
25	17.01	17.48	15.04	9.31	5.46	....	....	....	11.52	13.06	14.93	16.26	18.15	....
26	17.08	17.13	14.62	9.26	5.65	....	9.58	....	11.59	13.12	15.00	16.31	18.24	....
27	17.11	16.83	14.30	9.16	5.77	....	9.61	....	11.66	13.19	15.07	16.35	18.31	....
28	17.16	16.61	....	....	5.90	....	9.63	....	11.73	13.25	15.13	16.40	18.39	....
29	17.18	16.45	....	....	5.96	8.21	9.66	10.33	11.79	13.35	15.20		18.47	....
30	17.30	16.30	12.75	....	6.01	8.28	9.71	....	11.85	13.41	15.26		18.55	....
31	17.38		12.39		5.96	8.34		....		13.47	15.31		18.64	

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*—Continued

Day	1953											1954			
	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
							D1-5-34cc2								
1	....	....	9.33	9.38	9.30	6.66	8.25	10.03	10.48	10.04	....	9.72	10.20	....	9.79
2	....	....	9.33	9.39	9.29	6.53	8.39	10.06	10.50	10.07	....	9.74	10.20	....	9.79
3	....	....	9.33	9.39	9.26	6.55	8.43	10.09	10.51	10.09	....	9.75	10.21	9.90	9.77
4	....	....	9.33	9.41	8.95	6.60	8.54	10.10	10.52	10.10	9.80	9.78	10.22	9.90	9.61
5	....	9.95	9.33	9.41	8.62	6.69	8.64	10.12	10.53	10.10	9.80	9.81	10.22	9.90	9.56
6	....	....	9.32	9.42	8.47	6.80	8.78	10.14	10.53	10.12	9.78	9.82	10.23	9.90	9.52
7	....	....	9.31	9.43	8.42	6.86	8.84	10.15	10.54	10.14	9.77	9.83	10.23	9.90	9.51
8	....	....	9.27	9.45	8.43	....	8.92	10.17	10.54	10.14	9.77	9.83	10.24	9.89	....
9	....	....	9.27	9.48	8.43	....	8.99	10.18	10.56	10.14	9.74	9.84	10.24	9.87	....
10	....	....	9.25	9.49	8.46	5.50	9.08	10.19	10.56	10.15	....	9.85	10.24	9.86	....
11	....	....	9.23	9.51	8.48	5.53	9.13	10.19	10.57	10.17	....	9.86	10.24	9.85	....
12	....	9.75	9.21	9.53	8.49	5.59	9.20	10.26	10.57	10.18	....	9.85	10.24	9.85	....
13	....	9.72	9.20	9.53	8.51	5.68	9.26	10.27	10.54	10.19	....	9.85	10.24	9.86	....
14	....	....	9.20	9.53	8.50	5.63	9.29	....	10.52	10.19	....	9.86	10.24	9.86	9.49
15	....	....	9.21	9.55	8.46	5.84	9.32	....	10.52	10.19	9.71	9.89	10.25	9.86	9.51
16	....	....	9.20	9.56	8.42	6.13	9.36	....	10.51	10.18	9.70	9.90	10.24	9.85	9.52
17	....	....	9.20	9.58	8.41	6.39	9.42	....	10.49	10.17	9.70	9.91	10.23	9.84	9.52
18	....	....	9.24	9.59	8.10	6.62	9.47	....	....	10.17	9.70	9.93	10.22	9.83	9.53
19	....	9.59	9.24	9.59	7.85	6.81	9.52	....	....	10.15	9.70	9.96	10.22	9.83	9.53
20	....	9.55	9.24	9.59	7.50	6.91	9.57	....	....	10.14	9.70	....	....	9.83	9.56
21	....	9.53	9.24	9.58	7.41	6.95	9.63	....	....	10.14	9.71	10.03	....	9.82	9.57
22	....	9.51	9.26	9.54	7.41	7.05	9.68	....	10.33	10.10	9.71	10.03	....	9.82	....
23	....	9.50	9.28	9.45	7.09	7.22	9.72	....	10.29	10.08	9.69	10.04	....	9.82	....
24	....	9.46	9.30	9.40	6.79	7.30	9.75	....	10.28	10.05	9.70	10.06	9.99	9.82	....
25	....	9.44	9.32	9.38	6.53	7.41	9.80	....	10.28	10.01	9.71	10.09	....	9.82	....
26	9.96	9.43	9.32	9.32	....	7.52	9.83	10.42	10.28	9.99	9.71	10.11	....	9.82	....
27	....	9.43	9.32	9.31	6.21	7.65	9.87	10.43	10.25	....	9.73	10.14	....	9.81	....
28	....	9.37	9.33	9.29	6.16	7.79	9.90	10.44	10.20	....	9.71	10.15	....	9.81	....
29	....	9.37	9.35	9.28	6.22	7.91	9.95	10.46	10.14	....	9.74	10.16		9.81	....
30	....	9.35	9.36	9.29	6.44	8.00	9.98	10.47	10.10	....	9.75	10.19		9.81	....
31	....	9.34		9.29		8.12	10.01		10.06		9.74	10.19		9.80	

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*—Continued

Day	1951 Aug.	1951 Sept.	1951 Oct.	1951 Nov.	1951 Dec.	1952 Jan.	1952 Feb.	1952 Mar.	1952 Apr.	1952 May	1952 June	1952 July	1952 Aug.	1952 Sept.	1952 Oct.	1952 Nov.	1952 Dec.
								D2-4-9bc									
1	...	31.36	...	25.67	...	25.23	25.40	25.72	26.30	26.54	26.25	25.47	24.14	23.49	23.27	22.92	...
2	...	...	26.68	25.59	...	25.29	25.36	25.72	26.28	26.55	26.27	25.45	24.08	23.43	23.22	22.98	...
3	...	...	...	25.59	...	25.29	25.44	25.73	26.33	26.53	26.29	25.40	24.06	23.40	23.24	22.96	22.74
4	...	...	...	25.56	...	25.29	25.45	25.74	26.37	26.56	26.33	25.34	24.02	23.39	23.25	22.90	22.77
5	...	...	...	25.57	...	25.29	25.50	25.77	26.36	26.57	26.32	25.28	24.01	23.38	23.24	22.91	22.69
6	...	...	...	25.57	...	25.27	25.54	25.83	26.36	26.54	26.28	25.31	23.96	23.35	23.23	22.90	22.66
7	...	29.23	...	25.52	25.20	25.20	25.52	25.88	26.34	26.56	26.29	25.30	23.92	23.32	23.21	22.87	22.57
8	...	...	26.48	25.49	...	25.25	25.53	25.87	26.41	26.53	26.33	25.24	23.93	23.30	23.18	22.92	22.70
9	...	...	...	25.47	...	25.34	25.52	25.87	26.46	26.61	26.28	25.16	23.90	23.26	23.16	22.89	22.80
10	...	...	...	25.50	...	25.24	25.55	25.80	26.42	26.61	26.12	25.18	23.87	23.25	23.21	22.88	...
11	...	...	...	25.43	...	25.23	25.54	25.82	26.43	26.57	26.11	25.17	23.82	23.24	23.20	22.86	...
12	...	...	...	25.38	...	25.17	25.53	25.83	26.51	26.59	26.11	25.14	23.80	23.22	23.17	22.80	...
13	...	...	...	25.41	...	25.14	25.59	25.88	26.52	26.58	26.12	25.12	23.78	23.29	23.19	22.78	...
14	...	...	...	25.41	25.23	25.12	25.60	25.95	26.51	26.55	26.07	25.04	23.75	23.30	23.23	22.71	...
15	...	...	26.15	25.48	25.21	25.12	25.60	25.99	26.57	26.54	26.07	24.91	23.72	23.24	23.14	22.69	...
16	...	...	...	25.55	25.19	25.08	...	25.95	26.59	26.63	26.04	24.88	23.72	23.22	23.12	22.73	...
17	...	27.81	...	25.27	25.20	25.11	...	25.96	26.59	...	26.06	24.85	23.72	23.29	23.18	22.76	...
18	...	...	...	25.21	25.11	25.17	...	25.96	26.51	...	26.08	24.80	23.71	23.30	23.17	22.82	...
19	...	...	...	25.17	25.11	25.22	...	25.99	26.48	26.51	26.01	24.75	23.64	23.30	23.13	22.81	...
20	...	...	...	...	25.14	25.20	...	26.07	26.54	26.44	25.97	24.70	23.65	23.31	23.11	22.76	...
21	...	...	...	...	25.17	25.22	...	26.19	26.56	26.37	25.89	24.61	23.64	23.34	23.10	22.80	...
22	...	...	25.86	...	25.15	25.27	25.64	26.20	26.54	26.36	25.86	24.60	23.61	23.31	23.10	...	...
23	...	...	25.81	25.14	25.20	25.27	25.66	26.12	26.54	26.36	25.82	24.63	23.58	23.30	23.06	...	...
24	...	27.13	25.75	25.08	25.20	25.25	25.74	26.12	26.57	26.35	25.77	24.47	23.55	23.31	23.06	...	...
25	...	27.14	25.69	25.10	25.25	25.27	25.77	26.16	26.58	26.31	25.72	24.48	23.53	23.31	23.04	...	...
26	...	...	25.70	25.08	25.30	25.34	25.77	26.19	26.54	26.35	25.68	24.46	23.52	23.27	23.01	22.78	...
27	...	...	25.69	...	25.27	25.41	25.77	26.20	26.53	26.36	25.59	24.36	23.54	23.23	23.06	22.77	...
28	...	...	25.67	...	25.15	25.44	25.76	26.12	26.48	26.32	25.58	24.30	23.51	23.26	23.03	...	...
29	...	...	25.52	...	25.13	25.42	25.76	26.11	26.56	26.26	25.52	24.25	23.44	23.26	22.96	...	...
30	...	...	25.62	25.07	25.12	25.40		26.13	26.56	26.29	25.53	24.19	23.46	23.26	22.96	...	...
31	31.50		25.62		25.15	25.38		26.18		26.25		24.17	23.45		22.91		...

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*—Continued

Day	1952		1953												1954			
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
									D2-5-14ac									
1	....	....	....	....	....	5.52	6.05	5.55	5.51	6.27	6.30	6.81	7.08	6.99	6.32	6.80	6.31	6.72
2	....	....	....	6.58	....	5.58	6.07	5.57	5.53	....	6.24	6.84	7.10	6.98	6.34	6.81	6.35	6.72
3	....	....	....	....	....	5.62	6.08	4.92	4.84	....	6.22	6.85	7.11	6.97	6.37	6.81	6.40	6.72
4	....	6.38	....	....	....	5.68	6.10	....	4.55	....	6.22	6.86	7.11	6.97	6.39	6.83	6.41	6.34
5	....	....	....	....	6.66	5.65	6.11	....	4.90	6.10	6.23	6.87	7.11	6.98	6.41	6.83	6.43	6.14
6	....	....	6.65	....	6.70	5.61	6.12	3.86	4.72	5.90	6.24	6.88	....	7.00	6.41	6.83	6.45	6.01
7	....	....	....	....	....	5.58	6.15	3.89	5.17	5.73	6.29	6.90	7.14	7.03	6.41	6.83	6.47	5.95
8	6.13	....	....	....	....	5.57	6.18	4.03	5.44	5.00	6.18	6.92	7.15	7.03	6.39	6.84	6.48	5.91
9	....	....	....	....	....	5.65	6.21	4.40	5.63	5.04	6.11	6.93	7.15	7.03	6.41	6.84	6.49	5.91
10	....	....	....	....	....	5.67	6.24	4.53	5.71	4.98	6.08	6.94	7.15	7.03	6.42	6.84	6.46	5.93
11	....	....	....	....	....	5.69	6.26	4.24	5.66	5.11	....	6.96	7.16	7.03	6.43	6.85	6.49	5.95
12	....	....	....	....	6.15	5.62	6.28	4.19	5.76	5.36	5.91	6.97	7.16	7.04	6.43	6.86	6.53	5.98
13	....	....	....	....	5.99	5.58	6.29	4.20	4.41	5.49	5.98	6.98	7.16	7.06	6.45	6.74	6.57	6.00
14	....	....	....	....	5.91	5.60	6.31	4.39	5.02	5.33	6.07	7.00	7.17	7.07	6.47	6.63	6.59	6.03
15	....	....	....	....	....	5.64	6.33	4.33	5.55	5.49	6.17	7.01	7.17	7.08	6.48	6.64	6.62	6.08
16	....	....	....	....	....	5.65	6.34	4.55	5.58	5.60	6.20	7.02	7.18	7.09	6.51	6.63	6.63	6.11
17	....	....	....	....	....	5.68	6.36	....	5.57	5.66	6.26	7.03	7.19	7.10	6.55	6.62	6.64	6.13
18	....	....	....	....	....	5.72	6.33	....	5.60	5.77	6.28	7.05	7.20	7.11	6.57	6.58	6.66	6.16
19	....	....	....	....	5.98	5.74	6.22	....	5.78	5.87	6.19	7.06	7.20	7.12	6.60	6.61	6.67	6.20
20	....	....	....	....	5.95	5.78	6.15	....	5.88	5.78	6.22	7.07	7.21	7.12	....	6.62	6.67	6.23
21	....	....	....	....	5.92	5.82	6.10	....	5.94	5.94	6.23	7.08	7.25	7.13	....	6.61	6.65	6.25
22	....	....	....	....	5.90	5.85	5.72	5.62	5.95	6.04	6.32	7.09	7.23	7.13	6.70	6.48	6.65	6.28
23	....	....	....	....	5.91	5.90	5.61	5.62	5.99	6.12	....	7.10	7.18	7.14	6.71	6.43	6.66	....
24	....	....	....	....	5.92	5.92	5.55	5.04	5.62	6.16	....	7.09	7.17	7.15	6.73	6.30	6.67	....
25	....	....	....	6.59	5.80	5.92	5.55	4.48	5.72	6.21	6.65	7.09	7.16	7.16	6.74	6.25	6.70	....
26	....	....	....	6.57	5.72	5.95	5.57	4.37	5.92	6.26	6.68	7.06	7.11	7.17	6.75	6.20	6.70	....
27	....	....	....	....	5.68	5.96	5.61	4.37	6.06	6.30	6.71	7.05	7.08	7.17	6.77	6.26	6.71	....
28	....	....	....	....	5.64	5.99	5.13	4.61	6.17	6.30	6.73	7.05	7.05	....	6.78	6.27	6.69	....
29	....	....	....		5.62	6.01	5.48	....	6.24	6.26	6.76	7.05	7.03	6.31	6.78		6.68	....
30	....	....	....		5.54	6.03	5.49	5.27	6.28	6.27	6.79	7.06	7.01	6.32	6.79		6.68	....
31	....	....	....		5.52		5.54		6.22	6.29		7.07		6.32	6.80		6.70	

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*—Continued

Day	1951									1952												1953		
	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
											D2-5-16aa1													
1	......	......	5.13	4.42	4.52	......	5.05	4.72	4.93	......	5.41	5.54	5.46	4.86	4.85	4.37	3.12	3.66	5.07	5.14	......	......	5.42	5.52
2	......	4.86	5.16	4.37	4.52	......	5.05	......	4.94	......	5.41	5.54	5.42	4.89	4.86	4.32	4.15	3.61	5.07	5.16	......	......	5.43	5.52
3	......	......	5.05	4.12	4.34	......	4.96	......	4.98	......	5.42	5.54	5.36	4.90	4.90	4.44	4.32	3.55	5.09	5.16	5.27	......	5.44	5.53
4	......	......	5.00	4.12	3.99	......	4.70	......	4.97	5.29	5.42	5.55	5.18	4.90	4.93	4.52	4.37	3.71	5.10	5.16	5.27	......	5.44	5.53
5	......	......	4.75	4.04	4.01	......	4.74	4.60	4.99	......	5.42	5.55	4.84	4.92	4.97	4.59	4.39	3.74	5.10	5.17	5.26	......	5.44	5.54
6	......	......	4.52	3.99	3.58	......	4.83	4.64	5.01	......	5.42	5.55	4.51	4.95	5.00	4.73	4.43	3.89	5.06	5.18	5.26	......	5.44	......
7	......	......	4.36	4.01	4.01	4.84	4.88	4.68	5.03	......	5.42	5.59	4.10	4.98	4.99	4.80	4.60	4.02	5.08	5.19	5.26	5.64	5.42	......
8	......	......	4.26	4.04	3.99	4.89	4.91	4.70	......	......	5.43	5.59	4.10	5.01	4.96	4.86	4.62	4.11	5.08	5.20	5.27	5.66	5.42	......
9	......	5.16	4.14	4.00	4.06	4.91	4.93	4.73	......	......	5.43	5.60	4.31	4.78	4.90	4.43	4.46	4.16	5.08	5.21	5.28	5.11	5.44	......
10	......	......	4.10	3.99	4.08	4.90	4.98	4.74	......	......	5.42	5.60	4.43	4.87	5.00	4.46	4.34	4.20	5.08	5.22	5.28	5.17	5.42	......
11	......	......	4.01	4.01	4.10	4.93	5.01	4.76	......	5.28	5.42	5.60	4.45	4.91	4.97	4.28	4.30	4.55	5.07	5.22	5.28	......	5.41	......
12	......	......	3.86	3.91	4.02	4.92	4.99	4.77	......	5.30	5.43	5.60	4.22	4.93	4.95	4.10	4.33	4.67	5.10	5.23	5.28	5.27	5.41	......
13	......	......	3.63	3.98	4.07	4.94	5.04	4.80	......	5.30	5.39	5.60	3.93	4.93	4.78	3.33	4.17	4.73	5.10	5.23	5.24	5.27	5.40	......
14	......	......	3.12	3.39	4.15	4.96	5.06	4.82	5.08	5.31	......	5.61	3.48	4.94	4.71	4.08	4.04	4.79	5.07	5.24	5.22	5.29	5.40	......
15	......	......	2.92	2.96	4.20	5.00	5.00	4.84	5.09	5.31	5.44	5.61	2.69	4.94	4.06	4.24	4.10	4.81	5.04	5.24	5.24	5.33	5.40	......
16	......	5.19	2.81	2.51	4.23	5.03	4.96	4.86	5.10	5.28	5.44	5.61	3.06	4.76	3.50	4.11	3.18	4.85	5.05	5.24	5.26	5.34	5.46	......
17	......	5.17	3.97	3.76	4.23	5.06	4.97	......	5.11	......	5.45	5.61	2.91	4.77	2.78	4.31	3.26	4.88	5.06	5.24	5.31	5.35	5.46	......
18	......	5.05	3.97	3.90	4.29	5.05	5.00	......	5.11	5.32	5.46	5.59	3.85	4.81	3.36	4.59	3.30	4.91	5.07	5.24	5.36	5.36	5.47	......
19	5.42	5.12	3.95	4.09	4.30	5.04	4.99	......	......	5.31	......	5.60	4.13	4.82	3.05	4.63	3.24	4.93	5.07	5.25	5.40	5.37	5.48	......
20	......	5.15	4.02	4.21	4.24	4.83	4.83	......	......	5.33	......	5.61	4.35	4.85	3.30	4.57	4.21	4.97	5.07	5.26	5.43	5.34	5.47	......
21	......	5.17	4.04	4.36	4.35	4.84	4.78	......	5.15	5.34	......	5.62	4.37	3.60	3.92	4.50	4.25	4.99	5.08	5.29	5.45	5.32	5.47	......
22	......	5.16	4.26	4.43	4.50	4.85	4.80	......	5.15	......	5.49	5.62	4.46	3.31	4.09	4.49	4.24	4.98	5.09	5.30	5.46	5.35	5.46	......
23	......	5.19	4.38	4.36	4.27	4.72	4.82	4.96	5.18	......	5.49	5.62	4.53	4.03	4.15	4.57	4.28	5.00	5.08	5.30	5.48	5.37	5.46	......
24	......	5.19	4.30	4.35	3.93	4.81	4.78	4.98	......	......	5.50	5.63	4.60	4.32	4.03	4.61	4.24	5.01	5.11	5.31	5.49	5.37	5.48	......
25	......	5.22	4.24	4.19	3.86	4.87	4.70	5.00	......	5.40	5.51	5.61	4.64	4.47	3.72	4.54	4.18	5.02	5.11	5.32	......	5.37	5.50	......
26	......	5.25	4.25	4.11	3.94	4.91	4.68	5.01	......	5.41	5.52	5.54	4.69	4.40	3.96	4.48	4.23	5.06	5.11	5.29	......	5.39	5.51	......
27	......	5.27	4.14	4.10	4.07	4.95	4.71	5.01	......	5.41	5.53	5.46	4.73	4.51	3.89	4.20	4.20	5.08	5.13	5.28	......	5.41	5.50	......
28	......	5.21	3.93	4.06	4.22	4.98	4.70	5.01	5.26	5.41	5.53	5.51	4.77	4.61	4.02	4.17	4.20	5.08	5.13	......	......	5.42	5.48	......
29	......	5.18	4.02	4.16	4.35	5.00	4.65	4.97	5.26	5.40	5.54	5.50	4.80	4.68	4.10	4.31	4.25	5.09	5.14	......	......	5.42		......
30	......	5.24	4.25	4.26	4.43	5.03	4.68	4.94	5.26	5.40		5.50	4.83	4.75	4.26	4.30	4.21	5.08	5.14	......	......	5.42		......
31	......	5.18		4.33	4.51		4.69		......	5.41		5.48		4.80		4.35	3.87		5.15		5.58	5.43		......

Table 35.—*Water-level measurements from recorder chart, in feet below land-surface datum*—Continued

Day	1953										1954			
	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
	D2-5-22ccd													
1	....	9.24	9.90	9.77	8.29	8.11	9.47	10.17	10.05	10.34	11.11	11.09	10.30	10.83
2	....	9.27	9.96	9.83	8.23	8.38	9.55	10.11	10.12	10.35	11.11	11.04	10.33	10.86
3	....	9.39	10.03	9.44	8.32	8.55	9.56	10.05	10.18	10.39	11.12	10.99	10.36	10.86
4	....	9.47	10.08	....	8.66	8.66	9.57	10.02	10.23	10.46	11.12	10.93	10.40	10.27
5	....	....	10.13	....	8.59	8.80	10.10	10.00	10.27	10.51	11.10	10.89	10.46	10.13
6	....	....	10.18	8.51	8.56	8.88	10.23	10.00	10.31	10.56	11.10	10.84	10.51	10.05
7	....	....	10.22	8.59	8.51	8.85	10.32	10.00	10.35	10.61	11.11	10.82	10.54	9.98
8	....	....	10.28	8.70	8.50	8.98	10.40	10.00	10.39	10.67	11.09	10.77	10.53	9.93
9	10.78	9.38	10.34	8.82	8.49	9.18	10.44	9.97	10.42	10.70	11.10	10.68	10.51	9.93
10	10.51	9.33	10.40	8.96	8.48	9.29	10.49	9.96	10.44	10.74	11.11	10.51	10.42	9.91
11	10.24	9.27	10.44	9.10	8.54	9.26	10.08	10.06	10.47	10.77	11.12	10.43	10.47	9.92
12	9.99	9.23	10.47	9.37	8.63	9.27	10.08	10.14	10.52	10.81	11.16	10.51	10.53	9.94
13	9.93	9.19	10.50	9.43	8.55	9.32	10.10	10.18	10.55	10.84	11.17	10.02	10.58	9.98
14	9.90	9.16	10.51	9.50	8.53	9.25	10.10	10.22	10.57	10.87	11.19	10.07	10.60	9.99
15	9.86	9.15	10.54	9.54	8.46	8.94	10.17	10.24	10.60	10.91	11.19	10.23	10.62	10.07
16	9.84	9.11	10.58	9.45	8.38	8.80	10.21	10.26	10.63	10.92	11.20	10.32	10.61	10.15
17	9.83	9.08	10.62	7.40	8.36	7.58	10.23	10.26	10.67	10.94	11.20	10.39	10.58	10.21
18	9.87	9.17	10.55	6.82	8.31	6.88	10.10	10.24	10.69	10.96	11.20	10.41	10.59	....
19	9.88	....	10.50	6.54	8.46	7.05	10.18	10.23	10.69	10.98	11.22	10.46	10.60	10.35
20	9.80	....	10.36	6.35	8.56	6.65	10.24	10.25	10.70	11.00	....	10.51	10.60	10.41
21	9.76	....	10.21	6.66	8.64	6.89	10.23	10.32	10.71	11.02	....	10.53	10.61	10.43
22	9.77	....	9.88	6.92	8.48	7.16	10.22	10.30	10.69	11.02	11.24	10.46	10.62	10.45
23	9.79	....	9.76	7.16	7.32	7.27	10.22	10.18	10.61	11.03	11.23	10.41	10.62	....
24	9.78	....	9.66	7.44	6.94	7.72	10.15	10.13	10.53	11.05	11.23	10.28	10.63	....
25	9.62	9.76	9.63	7.67	6.46	8.14	10.22	10.08	10.48	11.06	11.23	10.23	10.65	....
26	9.46	9.83	9.65	7.92	6.52	8.44	10.27	10.00	10.43	11.07	11.22	10.20	10.66	....
27	9.41	9.91	9.70	7.98	....	8.68	10.33	9.96	10.37	11.08	11.24	10.26	10.67	....
28	9.40	9.99	9.75	8.07	....	8.91	10.33	9.90	10.35	11.10	11.25	10.26	10.66	....
29	9.36	9.88	9.70	8.18	7.15	9.08	10.28	9.92	10.34	11.10	11.22		10.68	....
30	9.23	9.83	9.72	8.24	7.55	9.24	10.21	9.92	10.35	11.11	11.18		10.71	....
31	9.22		9.71		7.78	9.38		9.98		11.12	11.13		10.75	

Table 36.—*Record of wells and springs*

Well number: See explanation of well-numbering system.
Type of well: B, bored; DD, dug and drilled; Dn, driven; Dr, drilled; Du, dug; Sp, spring.
Depth of well: Measured depths are given in feet and tenths below measuring point; reported depths are given in feet below land surface.
Type of casing: C, concrete; P, iron or steel pipe; T, tile; R, rock; W, wood.
Type of pump: C, centrifugal; Cy, cylinder; N, none; P, pitcher; J, jet; T, turbine.
Type of power: E, electric; F, natural flow; G, gas; H, hand-operated; N, none; W, wind.
Use of water: D, domestic; Ir, irrigation; In, industrial; N, none; O, observation of water-level measurements; P, public supply.
Measuring point: Hh, hole in pump housing; Hp, hole in pump base; Ls, land surface; Pb, pump base; Tc, top of casing; Tp, top of platform.
Depth to water: Measured depths are given in feet and hundredths; reported depths are given in feet.
Remarks: A, aquifer test; Caf, chemical analysis by Federal agency; Cao, chemical analysis by other than Federal agency; Cp, casing perforated or slotted (numeral indicates depth); D, drawdown in feet (r, reported; m, measured); F, filled in (numeral indicates depth); Fc, filled in and covered; Fl, natural flow (numeral indicates depth); L, log; OT, oil test in progress; P, plugged (numeral indicates depth); R, recorder in well; S, screen in well; T, temperature, in degrees Fahrenheit; TH, test hole (numeral indicates original depth); Y, yield (numeral indicates gallons per minute for wells and cubic feet per second for springs; r, reported; m, measured); U, water reported unfit for human consumption; Ww, water reported to be warm.

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
A1-2-10db....	Catherine Martin.........	....	Du	10.3	48	W	Cy	H	D	Tc	0	....	6.90	10-14-52	
22ab....	A. W. Overturf............	....	DD	28.4	30	R	Cy	H	D	Tc	0	....	22.46	.....do.......	
26ab....	Manhattan Co..............	1941	Dr	630	4	P	Cy	G	S	Ls	....	....	600	5-19-41	
29adc...	Montana Power Co........	1952	Dr	1,182.0	....	.....	.....	....	....	Ls	0	4,180	....	....	TH; L
34cb....	Cecelia E. McDonnell....	....	Dr	....	....	P	Cy	G	S	Tc	2.0	....	94.58	10-14-52	
3- 1da....	Dick Muir..................	....	Dr	84	4	P	J	E	D	Tc	0	4,227	5.81	8- 9-51	Y20r; D25r
1dd....	Enoch Sales...............	....	Dr	26	4	P	J	E	D,S	Ls	....	....	5	....	

2ac1...	Henry Oyler.........	1949	Dr	52	6	P	J	E	D	Ls	0	....	15	....	
2ac2...	Ivan Oyler.........	......	Dr	40	6	P	J	E	D	Ls	0	....	15	....	
2cdc1..	Leeta Townsend.........	......	Dr	29	6	P	J	E	D	Ls	0	....	4	....	
2cdc2..	.....do.........	......	Du	18.5	12	T	Cy	H	S,O	Tp	.2	4,239	4.01	7-31-51	
2cdd...	Hattie Tate.........	......	Dr	20	5	P	Cy	H	D	Ls	0	....	4	....	
2dc....	D. Vegter.........	......	Dr	30	5	P	C	E	D,S	Ls	0	....	6	....	
2dd....	Hattie Townsend.........	......	Dr	35	5	P	C	E	D,S	Ls	....	....	15	....	
4bb....	Manhattan Co.........	1950	Dr	105	6	P	Cy	E	S	Ls	....	....	15	11-28-50	Y40r; D < 1r
4cc....	C. Yadon.........	......	Dr	60	4	P	J	E	D,S	Ls	....	....	25	....	
4da....	Manhattan Co.........	......	Dr	76.6	6	P	N	N	O	Tc	1.2	4,225	34.05	5-21-51	L; A; T50
9bba...	James Martin.........	......	Dr	80	6	P	J	E	D	Ls	....	....	40	....	
9bbb...	.....do.........	......	Dr	134	6	P	J	E	D,S,O	Tc	0	4,266	64.71	4-24-51	
10bb....	Bert Poleman.........	......	Dr	30	4	P	Cy	H	D,S	Ls	....	....	15	....	
10bd....	Wm. D. Gover.........	......	Du	10.5	12	T	P	H	D,S,O	Tc	2.0	4,251	4.81	9-24-52	A; T51
10ca....	Herman Vangoorn.........	......	Du	27.6	36 by 36	W	N	N	N	Tc	1.0	....	9.87	2-24-54	A
10cb....	Joe Zelliox.........	1951	Dr	33	6	P	Cy	H	D,S	Ls	....	....	12	....	
11ab....	Guy S. Oman.........	......	Dr	35	6	P	C	E	D,S	Ls	....	....	6	....	
12aa....	U. S. Geol. Survey.........	1952	Du	6.0	12	P	N	N	O	Tc	3.0	4,230	6.56	8-26-52	
14dd....	Jake Brouwer.........	1954	Dr	75	6	P	....	....	D	Tc	-5	4,288	18	3- 7-54	L; Y40r; D30r
21aa....	C. B. Chase.........	......	Dr	185	6	P	Cy	E	D,S	Ls	....	....	60	....	
22ad....	J. F. White, Estate.........	......	Dr	65	4	P	Cy	H	D,S	Ls	....	....	7	....	
22da1..	.....do.........	......	DD	28.3	5	P	Cy	H	D,S	Ls	0	....	12.68	8- 4-53	A; Caf; T49
22da2..	.....do.........	......	Du	15	30	R	N	N	N	Tp	0	....	12.60	.....do......	A; T51
23bb....	U. S. Geol. Survey.........	1951	Dn	9.5	3/4	P	N	N	O	Tc	1.7	4,293	2.10	8- 2-51	
25cb....	Town of Manhattan.........	......	Sp	....	....	....	....	....	P	....	....	....	....	....	T47
26cc....	J. F. White, Estate.........	......	Du	10.4	42	R	Cy	H	S	Tp	1.0	....	5.49	7-30-53	A; T49
26cd1...	U. S. Geol. Survey.........	1951	B	20.3	3/4	P	N	N	O	Tc	3.8	4,331	9.56	6-27-51	
26cd2...	Elizabeth Emmelkamp.........	......	Dr	30	6	P	....	....	D	....	....	....	10	.....do......	
27dc....	Jack White.........	......	Du	15	42	R	Cy	H	D	Tp	.6	4,343	10.95	6-13-51	
29aa....	C. J. Kuipers.........	......	Dr	310	4	P	Cy	W	D	Ls	....	....	260	....	L; Caf
33dd....	Jacob Dykema.........	......	DD	99	6	P	J	E	D,S	Ls	0	4,407	48.60	5-10-51	A; Y45r
35dd....	J. R. Brink.........	......	DD	40	4	P	J	E	D,S	Ls	0	4,357	12.30	5- 9-51	
36dd....	Helen Heeb.........	......	DD	25	4	P	J	E	D	Ls	0	4,357	5.80	5- 8-51	

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
A1-4- 1cb	A. M. Moore	......	Du	25	48	C	C	E	D	Ls	......	......	20	......	
2ad	Zena Duncan	......	Dr	80	6	P	Cy	W	D,S	Ls	......	......	30	......	
3ab	Reid Smith	......	Dr	45	4	P	Cy	H	D,S	Ls	......	......	20	......	
3ac	R. Stucky	......	Dr	40	4	P	Cy	H	D,S	Ls	......	......	12	......	
3bb	Dry Creek School	......	Dr	48.3	4	P	Cy	H	D,O	Tc	0.6	4,270	20.05	4-24-51	
3bc	Lena E. McLeod	......	Dr	35	4	P	Cy	H	D	Ls	......	......	9	......	
4ac	C. G. Jordan	......	Dr	20	4	P	J	E	D,S	Ls	......	......	6	......	
5ad	U S. Soil Conserv. Service 11.	1949	B	8.0	3/4	P	N	N	O	Tc	2.1	4,245	5.46	5-31-51	
5ba	U. S. Soil Conserv. Service 3.	1949	B	8.1	3/4	P	N	N	O	Tc	2.1	4,229	5.09	7- 5-51	
5cc	Bernard Heetderks	......	DD	25	4	P	J	E	D,S	Tc	1.2	4,246	4.66	8-10-51	
5da	U. S. Geol. Survey	1952	Dr	35.0	6	P	N	N	O	Tc	1.0	4,245	5.21	2- 4-53	A; TH207; L; Cp11–35; P42; R; Caf; T48
5dd	Bernard Heetderks	......	Dr	18.0	4	P	Cy	H	D	Tc	0	4,255	6.75	8-10-51	A; Caf; T56
6ab	U. S. Soil Conserv. Service 2.	1949	Du, B	13.7	3½	P	N	N	O	Tp	.8	4,220	6.70	5-31-51	
6bc	Bernard Heetderks	......	Dr	39.3	4	P	Cy	H	O	Tc	.3	4,224	6.27	8- 9-51	A; T49
7aa	U. S. Soil Conserv. Service 13.	1949	B	7.9	3/4	P	N	N	O	Tc	1.6	4,245	3.62	5-31-51	
7ba	Michael J. Aughney	......	Du	12	48	W	Cy	H	D,S	Ls	......	......	7	......	

8ad....	P. Reinhart..................	....	Du	14	36	R	Cy	H	D,S	Ls	....	....	4	....	
8ba....	U. S. Soil Conserv. Service 14.	1949	B	7.0	2	P	N	N	O	Tc	1.7	4,252	2.34	5-31-51	
8bb....	J. H. Evans..................	....	Dr	23	4	P	Cy	H	D,S	Ls	....	....	4	....	
8cd....	P. Miller.....................	....	Dr	30	4	P	J	E	D,S	Ls	....	....	4	....	
9ab....	H. Brainard..................	....	Du	17	18	T	J	E	D,S	Ls	....	....	7	....	
10aa....	U. S. Soil Conserv. Service 50.	1949	B	8.9	1½	P	N	N	O	Tc	.9	4,278	4.22	7- 6-51	
13ad....	U. S. Soil Conserv. Service 43.	1946	B	6.6	1½	P	N	N	O	Tc	.7	4,321	3.20	.....do......	
14bbb..	U. S. Soil Conserv. Service 48.	1946	B	10.2	1½	P	N	N	N	Tc	2.3	4,298	3.43	.....do......	
14bbc..	M. Coil.......................	....	Dr	25	4	P	J	E	D,S	Ls	0	4,300	2.45	8- 7-51	
14cc....	F. F. Wilson..................	....	Du	8	36	R	Cy	H	D	Ls	....	....	3	....	
15ba....	U. S. Soil Conserv. Service 31.	1949	B	8.8	¾	P	N	N	O	Tc	1.0	4,302	6.43	7- 6-51	
15da1...	U. S. Soil Conserv. Service 35.	1949	B	8.4	1½	P	N	N	O	Tc	.4	4,318	4.21	.....do......	
15da2...	U. S. Geol. Survey.........	1953	Dr	300.0	6	P	N	N	O	Tc	.9	4,320	5.54	5-20-53	TH315; L; A; Caf; T59
16bb....	U. S. Soil Conserv. Service 27.	1949	B	8.1	2	P	N	N	O	Tc	1.2	4,289	4.60	7- 6-51	
17ba....	H. P. Smith................	....	Dr	25	4	P	J	E	D,S	Ls	....	....	4	....	
18ab....	Albert Schneiter..........	....	Dr	35	4	P	J	E	D,S	Ls	....	....	8	....	
18bb....	J. Sinnema................	....	Dr	35	4	P	Cy	H	D,S	Ls	....	....	7	....	
18bd....	Walter Schneiter..........	....	Dr	40	4	P	J	E	D,S	Ls	....	....	3	....	
19cb....	U. S. Geol. Survey........	1953	Dr	81.0	6	P	N	N	N	Tc	.8	4,298	5.12	9- 1-53	TH301; L; A; Cp 15-85; P92; Fl 117-180; Caf
21dc....	U. S. Soil Conserv. Service 87.	1949	B	6.3	¾	P	N	N	O	Tc	1.8	4,347	2.62	7- 6-51	
22cc....	T. Cope......................	......	Dr	18	4	P	Cy	H	D	Ls	....	....	2	....	
22dc1...	Julina Hoffman............	....	Du	9.1	60	R	N	N	O	Tp	0	4,349	3.98	8- 7-51	A; R
22dc2..	.....do.......................	....	Du	9.3	30	R	Cy	H	S	Tp	1.2	....	5.60	2-24-54	
22dc3...	.....do.......................	....	Du	8.7	30	R	Cy	H	S	Tc	0	....	5.24	.....do......	

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
A1-4-22dc4	U. S. Geol. Survey	1953	Dr	27.0	6	P	N	N	N	Tc	0.0	4,349	3.13	10- 7-53	TH43; L; A; Cp 3-43; F27
22dd	U. S. Soil Conserv. Service 12B.	1946	B	10.5	$1\frac{1}{2}$	P	N	N	O	Tc	.9	4,354	5.43	7- 6-51	
23bb1	Don Ray	......	Dr	20.0	4	P	Cy	H	D	Ls	0	....	2.60	8- 7-51	
23bb2	U. S. Soil Conserv. Service 32.	1946	B	5.5	$1\frac{1}{2}$	P	N	N	N	Tc	.5	4,333	2.91	8- 4-53	Y30r
24cd	Henry DeHaan	1948	Dr	20	7	P	J	E	D,S	Ls	....	....	5	....	
24dc	U. S. Soil Conserv. Service 8.	1946	B	7.1	$1\frac{1}{2}$	P	N	N	O	Tc	1.0	4,357	4.94	7- 6-51	
25bd	U. S. Soil Conserv. Service 5.	1946	B	9.4	$1\frac{1}{2}$	P	N	N	O	Tc	1.3	4,370	4.49	....do......	
25dc	U. S. Geol. Survey	1951	Dr	101.0	6	P	N	N	O	Tc	1.5	4,387	12.07	12- 7-51	TH400; L; Cp10-329; R; F100; Y140m; D7.1m; Caf; T52
28da1	L. M. Happel	......	Du	17.6	12	T	Cy	H	D,S	Tc	.2	4,370	7.80	8- 3-51	
28da2	....do	......	Dr	60	6	P	Cy	H	D,S	Ls	....	....	8	....	
28da3	....do	1952	Dr	24	6	P	C	E	D,S	Tc	.8	....	7.45	9-25-52	A; T50
29ab	U. S. Soil Conserv. Service 88.	1949	B	7.3	$\frac{3}{4}$	P	N	N	O	Tc	1.0	4,344	4.28	7- 6-51	
29dc	Helen Hutchinson	......	DD	31.5	4	P	Cy	E	D,S	Ls	0	4,357	9.04	5- 9-51	
31ba	L. B. Heeb	......	Sp	....	....	....	N	F	D	......	....	....	....	....	

31ca...	Buell Heeb	......	Dr	23.1	6	P	J	E	D,S	Ls	0	4,350	6.20	5- 9-51	
32ab1..	Louis Reichman	......	Dr	34	5	P	C	E	D	Ls	......	......	7	......	
32ab2..	.....do	......	Dr	30	5	P	J	E	S	Ls	......	......	4	......	
32db....	William Menzel	......	Dr	25	5	P	C	E	D	Ls	......	......	8	......	
33aa....	Roy Brickman	......	Dr	63	6	P	C	E	D,S	Ls	......	......	10	......	
33cc....	E. Gibson	......	Dr	45	4	P	J	E	D,S	Ls	......	......	14	......	
33cd....	R. Harrison	......	Dr	50	4	P	J	E	D,S	Ls	......	......	10	......	
36dc....	C. J. Sanders	......	Dr	33.0	6	P	N	N	O	Tc	1.2	4,424	30.84	6-27-52	
A1-5- 3da....	Vern Sexton	......	Dr	103	6	P	J	E	D	Ls	......	......	12	......	
4dd1..	R. L. Eukes	......	Du	13.5	10	T	Cy	H	......	Tp	.2	4,502	6.01	5-29-52	
4dd2..	.....do	......	Du	13	10	T	J	E	D	Ls	......	......	6	......	
5da....	D. Norman	......	Du	10.6	30	C	N	N	O	Tc	2.0	4,465	8.16	5-28-51	
6bd....	Foster Creek School	......	Dr	80.8	5	P	Cy	H	O	Tc	.2	4,394	33.98	5-14-51	
6cc....	E. Huffine	......	Dr	52.2	4	P	Cy	H	O	Tc	0	4,337	22.22	5-15-51	
8ad....	Grace Saisbury	......	Du	15	40	R	Cy	H	S,O	Pb	.3	4,413	9.49	5-29-52	
9bb....	.....do	1948	Dr	107	7	P	J	E	D	Ls	......	......	20	......	L; Y30r; D30r
10ba....	Pearle E. Cole	......	Dr	25	4	P	Cy	H	S	Tc	1.2	......	7.19	7- 9-53	A
11cb1..	Edwin Seifert	......	Dr	35	4	P	Cy	H	D	Ls	......	......	16	......	
11cb2..	.....do	......	Dr	35	4	P	J	E	Ir	Ls	......	......	13	......	
13ad....	Springhill School	......	Dr	50	5	P	Cy	H	D	Ls	......	......	10	......	
14ab....	Lester Crouse	......	Dr	80	5	P	Cy	H	D	......	......	......	......	......	
15cb1..	Lucy Hamilton	......	Du	10.7	42	R	N	N	N	Ls	0	4,490	6.64	6-19-52	
15cb2..	.....do	......	Du	15	42	R	Cy	E	D	Ls	......	......	7	......	
16bc1..	Albert Seifert	......	Dr	22.4	6	P	Cy	H	S,O	Tc	1.0	4,416	15.29	5-28-51	
16bc2..	.....do	......	Du	15	7	T	N	N	O	Tc	.2	4,413	13.9	12-11-51	
19bc....	U. S. Soil Conserv. Service 22.	1946	B	9.8	$1\frac{1}{2}$	P	N	N	O	Tc	1.4	4,336	4.24	7- 6-51	
20ca....	Goldia White	......	Du	16	12	T	J	E	D	Ls	......	......	8	......	
20db....	East Gallatin School	......	Dr	37.0	4	P	Cy	H	D	Ls	0	......	8.95	6-17-53	A
21bc1..	Percy Reese	......	Du	12	......	......	C	E	D	Ls	......	......	6	......	
21bc2..	Earl Warwood	......	Du	9	12	P	P	H	Ir	Ls	......	......	3	......	
21bc3..	.....do	......	Du	14	12	T	J	E	D	Ls	......	......	3	......	
21bc4..	Percy Reese	......	Du	11.6	18	T	P	H	O	Tp	1.0	4,402	8.75	12- 4-51	A
21ca....	George Gee	......	Du	18	12	T	Cy	H	D	Ls	......	......	10	......	

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
A1-5-22ad	Edwin Seifert	......	Dr	30	4	P	J	E	D	Ls	......	......	15	......	
22cc	Roges Spring	......	Dr	80	6	P	Cy	H	D	......	......	......	......	......	
23cc	Frank Gowin	......	Dr	55	4	P	J	E	D	Ls	......	......	17	......	Caf
24ac	Bertha Carlson	......	Dr	100	6	P	J	E	D	Ls	......	......	70	......	
26cd	Frank Gowin	......	Dr	25	4	P	Cy	H	D,S,O	Tc	0.8	4,515	7.32	9-28-51	A
27cc	West Davis	......	Du	18	10	T	J	E	D,S	Ls	......	......	8	......	
28db1	Wilbur Spring	......	Du	25	36	C	Cy	H	D	Ls	......	......	6	......	
28db2	U. S. Geol. Survey	1953	Dr	118.0	6	P	N	N	N	Tc	1.5	4,418	2.87	9-28-53	TH210; L; A; Cp 11-118; F118; Caf; T46
29ab	Chas. Osborne, Estate	......	Du	10	48	W	J	E	D,S	Ls	......	......	5	......	
29ca1	Thompson Hereford Ranches, Inc.	......	Dr	42	4	P	J	E	D	Ls	......	......	6	......	
29ca2	.....do	......	Du	8	......	......	C	E	D	Ls	......	......	6	......	
29cc	Norman Penwell	......	Dr	50	......	......	J	E	D,S	Ls	......	......	8	......	
29db	Wilbur Spring	......	Dr	35	4	P	J	E	D,S	Ls	......	......	5	......	
30cc1	C. J. Sanders	......	Dr	70	4	P	N	N	N	Tc	......	......	5	......	
30cc2	.....do	......	Dr	70	4	P	C	E	D,S	Tp	0	4,376	3.46	7-31-51	
30dc	A. H. Cloyd	......	Dr	30	5	P	J	E	D,S	Ls	0	4,378	8	.....do	
30dd	U. S. Geol. Survey	1951	B	10.3	$\frac{3}{4}$	P	N	N	O	Tc	3.3	4,383	5.98	7- 7-51	
32cca	Fred Tubb	......	Dr	28	4	P	Cy	G	S	Ls	......	......	8	......	
32ccd1	.....do	......	Dr	33	4	P	Cy	E	S	Ls	......	......	8	......	

32ccd2	....do		Dr	32	4	P	J	E	D	Ls			8		
32dd	E. Spain		Dr	37	6	P	J	E	D,S	Ls			7		
34bd1	H. S. Hecox		Dr	60	4	P	J	E	D	Ls			21		
34bd2	....do		Du	19	6	P	Cy	H	S	Ls			7		
34db	George Stimson		Dr	60	6	P	J	E	D,S	Ls			40		
35aa	Busch School		Dr	18.6	4	P	N	N	O	Tc	.4	4,549	12.85	9-28-51	
35ad	Carrie Roberts		Dr	52	6,4	P	J	E	D,S	Tc	-6.2	4,564	19.03	5- 7-51	
35ca	H. S. Hecox		Du	15.9	20	T	N	N	O	Tp	.3	4,529	8.69	5-28-51	A
36cd	W. M. Lincoln	1950	Dr	140	4	P	Cy	E	D,S				120		
A1-6- 7cc	Charles W. Cramer		Sp				N	F	D						
18cb1	Henry J. Wall		Dr	72	6	P	J	E	D	Ls			7		L; Caf
18cb2	....do		Dr	26	6	P	J	E	S	Ls			6		Caf
30ab	Harold Wright		Sp				N	F	D						T54
A2-2-35ab1	U. S. Geol. Survey	1952	Dr		6	P	N	N	N				Dry		TH26; L; F
35ab2	....do	1952	Dr		6	P	N	N	N				Dry		TH27; L; F
35ad1	F. F. Kessinger	1947	Dr	110	6	P			D	Ls			87		L; Y15r; D20r
35ad2	R. H. Johnston	1948	Dr	92	6	P			D	Ls			60		L; Y10r
35db	Jack Brant		Dr	90	5	P	Cy	G,H	S	Tp	.9		68.19	10-14-52	T48
36ba	Northern Pacific Ry. Co.	1951	Dr	145	6	P	N	N	D	Tc	-6.3	4,094	11.24	5-21-51	
36bb	L. C. Burrell	1950	Dr	137	6	P			D	Ls			40		L; Y15r
36bc	California Co.	1948	Dr	79	7	P			In	Ls			35		L
3-23cb	George Sinton	1948	Dr	152.6	7	P	Cy	H	S	Ls			24		L
31cd	Manhattan Co.		Sp				F	N	S						Y1,400r
32ac	....do		Sp				N	F	S						F3.7-14.5m; Caf; T53
32ad	....do		Sp				N	F	S						F8.3-22.6m; T53
32dd	R. J. Glisan		Dr	80	4	P	J	E	D,S	Ls			30		
33ba	Manhattan Co.		Sp				N	F	S						F0-10m
33da	U. S. Geol. Survey	1951	Dr	61.0	6	P	N	N	O	Tc	1.5	4,204	35.93	9- 9-51	TH450; L; Cp42-64; P62; R; Caf; T52-57
34ca	J. Green	1953	Dr	52	6	P	Cy	E	D	Ls			35		L
34dd	Charles Spaulding		Dr	49.3	4	P	N	N	N	Tp	0	4,218	37.55	5-21-51	

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
A2-3-36ac	Enoch Sales	...	Du	11.5	24	C	P	H	O	Tc	2.3	4,201	9.68	8- 9-51	
4- 2dd	Ralph Biggs	...	Du	13.2	30	C	N	N	O	Tc	.3	4,608	11.26	5-28-51	
12cc	Art Gee	...	Du	9.8	42	C	N	N	O	Tc	.1	4,544	6.57	5-15-51	Y8m; D6m; T50
23da	Orpha G. Boyd	...	Dr	22.2	6	P	Cy	H	D,O	Tc	.8	4,455	14.38	5-14-51	
23db	....do	...	Dr	80	6	P	Cy	W	D,S	Ls	...	...	35	...	
24bb	Dick Vanderby	...	DD	50.1	5	P	Cy	H	O	Tc	- .5	4,519	35.67	5-15-51	
24dd	Orpha G. Boyd	1949	Dr	78	8	P	N	N	D	Ls	...	...	60	...	
26ba1	H. L. Snyder	...	Du	23.2	54	R	Cy	E	S,O	Tp	.4	4,423	20.63	5-14-51	
26ba2	....do	...	Dr	33	5	P	J	E	D	Ls	...	...	20	...	
28cc	R. W. Hespen	...	Dr	28.6	4	P	Cy	H	N	Tc	1.0	4,266	24.82	8-10-51	
29dd	O. McElwee	...	Dr	40	5	P	J	E	D,S	Ls	...	...	25	...	
31cc	U. S. Soil Conserv. Service 1.	1946	B	8.0	$\frac{3}{4}$	P	N	N	O	Tc	1.0	4,212	6.00	5-31-51	
32ab	Pearle E. Cole	...	Dr	40	6	P	Cy	H	D,S	Ls	...	...	10	...	
33bc	Jesse R. Green	...	Du	20	18	T	J	E	D,S	Ls	...	...	8	...	
33ca	L. A. Cowan	...	Du	15	36	R	Cy	H	D	Ls	...	...	5	...	
36cc	Mary Tribble	...	Du	14.6	48	R	Cy	H	O	Tp	.5	4,332	13.40	5-15-51	
5- 6ac1	Ralph Biggs	...	Du	15.0	30	T	N	N	O	Tc	.4	4,822	7.50	5-28-51	
6ac2	....do	...	Du	22	40	C	C	E	D	Ls	...	...	18	...	
8bc	Estelle A. Bacon	...	Dr	72.6	5	P	Cy	H	O	Tc	.3	4,889	25.29	5-28-51	
15ac	Mildred Vadheim	...	Sp	...	...	...	F	N	D	...	...	...	...	...	T55

18ba......	Peter Dyk......	......	DD	39.1	4	P	N	N	O	Tc	1.3	4,743	7.57	5-16-51	
18bc......	.....do......	......	Du	14.7	54	C	N	N	O	Tp	1.8	4,685	9.92	.....do......	
20ad......	Russell Rector......	......	Du	33.8	48	R	Cy	W	O	Tp	0	4,964	27.83	5-28-51	
23cd......	Ralph Armstrong......	......	Sp	......	......	......	N	F	D,S	......	......	......	......	......	T49
27dd......	Zenas Warwood......	......	Sp	......	......	......	N	F	D	......	......	......	......	......	T54
28cd......	W. E. Dean......	......	Du	15	42	C	C	E	D	Ls	......	......	3	......	
30bb......	Delwin Theisen......	......	Dr	100+	5	P	Cy	H	O	Tc	-4.5	4,648	71.58	5-15-51	
33bd......	D. T. Saisbury......	......	Dr	44.2	5	P	Cy	H	O	Tc	0	4,656	12.71	5-28-51	
33ca......	.....do......	......	Du	50	36	C	C	E	D	Ls	......	......	10	......	
34ad......	Rose Warwood......	......	Sp	......	......	......	F	N	D	......	......	......	......	......	
34da......	Louis Warwood......	......	Du	8.5	48	R	Cy	H	N	Tp	0	4,744	2.20	5-15-51	
34ddc......	O. H. Hutchinson......	......	Du	14	12	T	P	H	D	Ls	......	......	3	......	
34ddd......	Robert Snell......	1950	Dr	95	6	P	Cy	E	D	Ls	......	......	27	......	Y40r
35ba......	Lester Warwood......	......	DD	62.9	5	P	N	N	O	Tp	0	4,926	13.03	5-14-51	
A3-4-36bb......	Jim Border......	1948	Dr	64	7	P	......	......	D	......	......	......	......	......	
5-17cc......	Delmer Moore......	......	Sp	......	......	......	N	F	D	......	......	......	......	......	
28dd......	Pass Creek School......	......	Dr	70.8	5	P	Cy	H	O	Tc	.5	5,154	28.17	5-15-51	Caf; T46
D1-2- 2dd......	Willard Harris......	1915	Dr	401	4	P	Cy	W	N	Ls	......	4,812	320	......	
10ac......	Earl G. Smith......	......	Dr	158	$2\frac{1}{2}$	P	N	N	N	Tc	3.5	......	115.51	10-14-52	
12ba......	Zales Ecton......	1915	Dr	500	4	P	Cy	N	N	Ls	......	......	350	......	
13aa......	M. C. Smiley......	......	Dr	600	......	......	Cy	N	N	......	......	......	......	......	Ww
21db......	Dean D. Francis, Trustee.	......	Dr	42.3	6	P	N	N	N	Tp	0	......	35.80	10-14-52	
35da......	Henry DeHaan......	1921	Dr	556	4	P	Cy	W	D	Ls	......	......	485	......	
3- 1ab......	T. Emmelkamp......	......	Dr	40	4	P	J	E	D	Ls	......	......	10	......	
3aa......	N. VanDyk......	......	Dr	90	5	P	Cy	E	D,S	......	......	......	......	......	
3ba......	J. Veltkamp......	......	Dr	95	6,4	P	J	E	D	Ls	......	......	39	......	
3bb......	E. Ypma......	......	Dr	102	$2\frac{1}{2}$-3	P	Cy	E	D,S	Ls	......	......	40	......	
3dd......	John Dykstra......	......	Dr	80	......	P	J	E	D,S	......	......	......	......	......	
4ba......	Harry Droge......	......	Dr	105	3	P	Cy	E	D,S	......	......	......	......	......	
10aaa......	Herman Dykman......	1951	Dr	114	6	P	J	E	D	......	......	......	......	......	
10aab......	Henry Dyk......	......	Dr	120	6	P	J	E	D,S	Ls	......	......	80	......	
10cc......	G. Klompein......	......	Dr	230	6	P	Cy	W	D,S	......	......	......	......	......	
10db......	Peter Klompein......	......	Dr	130	4	P	Cy	W	D,S	Ls	......	......	90	......	

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
D1-3-11aa	Sam Dyk	1912	Dr	75	4	P	Cy	W	D,S	Ls	...	...	40	...	
13bb	A. Dykstrahouse	...	Dr	111	6	P	...	...	D	Ls	...	...	84	...	L; Y12r
13bc	Lena Feddes	1949	Dr	235	6	P	J	E	D	Ls	...	...	105	...	L; S; F175
13bd	Christian Reformed Church.	1910	Dr	187	6	P	Cy	E	D	Ls	...	...	90	...	
13ca1	Henry Santhuisen	1949	Dr	128	6	P	...	...	D	Ls	...	...	88	...	Y30r
13ca2	H. Douma	1952	Dr	102	6	P	...	...	D	Ls	...	...	70	...	L
13cb1	Elizabeth Emmelkamp	...	Dr	153	6	P	...	...	D	Ls	...	...	105	1951	
13cb2	Sam Sinnema	1948	Dr	164	7	P	...	...	D	Ls	...	...	104	...	L; Y16r
13cb3	Pierre Hoekema	1952	Dr	175	6	P	...	...	D	Ls	...	...	100	...	Y12r; D5r
14ba1	M. Flikkema	...	Dr	80	4	P	Cy	E	D	Ls	...	...	30	...	
14ba2	N. Sinnema	1948	Dr	140	...	...	...	...	...	...	...	...	3	...	
14cc	Herman VanDyken	...	Dr	64.4	4	P	J	E	D,S	Tp	0.4	4,477	9.61	8-18-52	
16aa	B. R. Bates	...	Dr	280	6	P	Cy	W	D,S	Ls	...	...	...	...	Caf
18da	Alma Newbury	...	Dr	450	4	P	Cy	W	N	Ls	...	...	365	...	Ww
22dc	J. Lucas	...	Dr	67	6	P	...	...	D	Ls	...	...	4	...	Y12r; D30r
24ba	H. Cok	1949	Dr	172	6	P	...	...	D	Ls	...	...	28	...	L; Y16r; D33r
24cb	Henry Cok	1915	Dr	160	4	P	Cy	E	D,S	Ls	...	...	50	...	
26da	Patten Estate	1915	Dr	180	4	P	Cy	W,E	D	Hh	2.0	4,602	34.07	8-18-52	
27ab	Menko Flikkema	1951	Dr	40	6	P	C	E	D	Ls	...	...	8	...	Y24r; D20r
27ba	....do	1942	Dr	32	5	P	C	E	D,S	Ls	...	...	8	...	
28da	V. E. Willson	...	Dr	43.9	4	P	J	E	D,S	Tc	-5.1	4,545	2.27	8-20-52	

36bc	U. S. Geol. Survey	1952	Dr	113.0	8,6	P	N	N	N	Tc	1.0	4,680	15.20	10-14-52	TH882; L; A; Cp 15-113; P185; F113; Caf; T51-115
4- 1bc	Fred Bessette	1954	Dr	107	6	P	......	......	......	Tc	2.4	......	56.41	4-22-54	
1cb	.....do	1941	Dr	110	8	P	T	E	Ir,O	Ls	0	4,444	50.71	1- 7-53	A; Caf; T51
1cd	Village of Belgrade	1948	Dr	200	13	P	T	E,G	P	Ls	......	4,456	47.40	12- ?-48	L; Y750r
1dc	.....do	......	Du	107	48	W	T	E	P	Tc	0	4,457	31.39	8-29-52	A; Caf
2ab	Frank Clark	......	Dr	57.7	4	P	Cy	H	O	Tc	.7	4,428	51.44	5- 8-51	
2bb	.....do	......	Dr	60-65	4	P	J	E	D,S	Ls	......	......	23	......	
2dd	Northwest Improvement Co.	1953	Dr	178	13	P	J	E	In	Tc	3.0	4,457	42.79	8- 5-53	A; L
4aa	R. Harrison	......	Dr	50	4	P	J	E	D,S	Ls	......	......	10	......	
4cc1	Clifford Barnes	......	Dr	21	6	P	Cy	E	S	Ls	......	......	7	......	
4cc2	.....do	......	Dr	30	6	P	J	E	D	Ls	......	......	7	......	
6bb	W. L. Sales	......	Du	8.4	24	T	N	N	O	Tc	0	4,364	8.20	5- 9-51	
6cd1	Harry Droge	......	Dr	35	4	P	J	E	D,S	Ls	......	......	5	......	
6cd2	.....do	1953	Dr	30	6	P	......	......	D	Ls	......	......	10	......	Y25r
6ddc1	Baker Creek School	......	Dr	22.4	4	P	Cy	H	O	Hp	.2	4,407	5.79	8- 9-51	Caf; T51
6ddc2	U. S. Geol. Survey	1953	Dr	65.0	6	P	N	N	O	Tc	1.0	4,407	18.61	3-17-53	TH255; L; A; Cp 5-65; P140; R; F65
6ddd	Queen Bly	......	Dr	35	4	P	Cy	H	D,S	Ls	......	......	12	......	
7ab	John Wiedenaar	......	Dr	25	4	P	J	E	D,S	Ls	0	......	4.55	8 -6-51	
7bb	John Droge	......	Dr	40	4	P	J	E	D,S	Ls	......	......	6	......	
7da	Robert E. Cline	......	DD	30	4	P	J	E	D,S	Ls	......	......	10	......	
8ab	C. DeBoer	1951	Dr	25	4	P	Cy	E	D	Ls	......	......	8	......	
8bb	Joe T. Droge, and others	......	Dr	21.4	4	P	J	E	D,S	Tp	0	4,413	6.10	8- 6-51	
8da1	Dick Dolezalik, Jr.	......	Dr	28	6	P	J	E	D	Ls	......	......	6	......	
8da2	.....do	......	Dr	40	5	P	Cy	H	S	Ls	......	......	6	......	
9ab	D. H. Brant	......	Dr	34	5,6	P	J	E	D	Tc	-4.0	......	13.61	2-23-53	
9ba1	U. S. Geol. Survey	1953	Dr	97.5	6	P	N	N	O	Tc	1.0	4,429	23.70	4- 8-53	Th; L; R
9ba2	.....do	......	Dn	7.1	3/4	P	N	N	O	Tc	1.0	......	5.57	4-25-53	

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
D1-4- 9bc	N. E. Baker	......	DD	25	4	P	J	E	D,S	Tp	0.6	4,437	8.29	8- 6-51	
9cb	James H. O'Rourke	......	Du	30.0	24	W	J	E	D	Tp	0	....	16.98	2-23-53	A
10ba	Omar Satre	......	Dr	70	5	P	J	E	D,S	Tc	-4.5	4,444	54.56	4-23-52	
10db	H. H. Norwood	......	Dr	95	6	P	Cy	G	D,S	Ls	....	....	20	....	
10dd	J. H. Griswold	......	Dr	54	5,3	P	Cy	E	D,S	Ls	....	....	20	....	
12bb	R. E. Huelster	......	Dr	76	4	P	J	E	D,O	Tc	-4.5	4,461	62.20	4-24-52	
12cb	Roy Surface	......	Dr	75	6	P	J	E	D,S	Ls	....	....	5	....	
12da	Carl Miller	......	Dr	50	6	P	C	E	D,S	Ls	....	....	18	....	
13ad	H. C. Davis	......	Dr	80	5	P	Cy	H	D,O	Hp	.5	4,503	12.37	7-28-52	
13bb	Herman Kujath	......	Dr	65	5	P	Cy	E	D,S,O	Tc	-4.0	4,493	15.31	7-11-51	Caf
13cc	H. B. McCay, Estate	......	Dr	35	6	P	J	E	D,S	Tc	0	4,530	3.09	7-10-51	
13dd	P. S. Antonsen	......	Dr	33	6	P	J	E	D,S	Ls	....	....	4	....	
14aa	Rosabelle V. Frazer	......	Dr	72	5	P	Cy	E	D,S	Ls	....	....	20	....	
14bb	Elmer Jenkins	......	Dr	60	6	P	J	E	D,S	Ls	....	....	20	....	
14ca	.....do	......	Du, Dn	25	42,1	R,P	C	E	D	Ls	....	....	20	....	
14cc	H. J. Finnegan	......	Dr	70	6	P	J	E	D,S	Ls	....	....	25	....	
15ab	John Schaefer	......	Du	30.5	42	R	Cy	H	D,S,O	Tp	1.0	4,486	23.93	4-23-52	A
15ad	.....do	......	Du	30	42	R	J	E	D,S	Ls	....	....	25	....	
15cd	Arts Bros	......	Du	12.5	42	C	Cy	H	D,O	Tp	.5	4,512	7.72	4-23-51	
16bb	Francis A. Brown	......	Dr	38	6	P	J	E	D	Ls	....	....	8	....	

16dc1 ...	C. A. Clark	......	Du	8	15,12	P	C	E	D	Ls	......	......	5	......	
16dc2 ...	F. Hoffman	......	Du	8	15,12	P	C	E	D	Ls	......	......	4	......	
16dd ...	J. H. Jensen	......	Du	16	36	R	C	E	D	Ls	......	......	6	......	
17ad ...	M. L. Hutchinson	......	Dr	43	4	P	J	E	D,S	Ls	......	......	8	......	
17bb ...	Wm. E. Durham	......	Dr	28.1	4	P	Cy	H	O	Tc	0	4,445	3.59	7-13-51	
17da ...	Ernest Hoffman	......	Dr	36	6	P	J	E	D	Ls	......	......	6	......	
17dc ...	Charles Sales	......	Dr	62	6	P	J	E	D,S	Ls	......	......	9	......	
17dd ...	E. L. Staffanson	......	Dr	40	6	P	C	E	D	Ls	......	......	6	......	
18ad ...	Henry A. Feddes	......	Dr	20	6	P	Cy	E	D	Ls	......	......	3	......	
18ba ...	John Weidenaar	......	Dr	50	5	P	J	E	D,S	Ls	......	......	10	......	
18da ...	Henry J. Kimm	......	Dr	82	6	P	Cy	E	D,S	Ls	......	......	30	......	
19bc ...	M. Kimm	1950	Dr	194	6	P	T	E	D, In	Ls	......	......	82	......	
19da ...	Dick Heys	......	Du	80	42	C	J	E	D	Ls	......	......	50	......	
20aa ...	Bernard Benson	......	Dr	42	6	P	C	E	D	Ls	......	......	7	......	
20ba ...	S. Benson	......	Dr	100	6	P	J	E	D	Ls	......	......	25	......	
20cd ...	M. Lee	......	Du	75	8	P	Cy	G	D,S	Ls	......	......	60	......	
21ad ...	O. Sales	......	Dr	56	4	P	C	E	D	Ls	......	......	8	......	
22cd ...	C. W. Francis	......	Dr	25	4,5	P	C	E	D	Ls	......	......	10	......	
22da1 ...	G. Nutter	......	Dr	35	6	P	J	E	D,S	Ls	......	......	23	......	
22da2 ...	.....do	......	Dr	28	6	P	C	E	S	Ls	......	......	18	......	
23aa ...	J. Benepe	......	Dr	30	6	P	Cy	H	D	Ls	......	......	3	......	
23dd ...	.....do	......	Dr	35	4,5	P	Cy	E	D,S	Ls	......	......	15	......	
24bb ...	Rosabelle Fraser	......	DD	27	42,6	C,P	C	E	D,S	Tc	0	4,532	3.18	7-10-51	
24bc ...	Robert Buck	......	Dr	45	4	P	J	E	D	Ls	......	......	3	......	
24cd ...	Art Lenehan	......	Dr	19.8	4	P	C	E	D,S	Tp	.6	4,569	13.41	4-19-51	
24da1 ...	Carl F. Fogh	......	Dr	42	6	P	J	E	D	Ls	......	......	4	......	
24da2 ...	.....do	......	Dr	36	6	P	Cy	H	S	Ls	......	......	4	......	
25aa1 ...	Waterman School	......	Dr	30.2	4	P	N	N	O	Tc	1.0	4,571	14.00	4-18-51	Y24m; D2.8m; T47
25aa2 ...	U. S. Geol. Survey	1953	Dr	225.0	6	P	N	N	O	Tc	1.0	4,570	14.00	5- 6-53	TH280; L; A; Cp 155-223; R; Caf; T49

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point			Distance to water level below measuring point (feet)	Date of measurement	Remarks
										Description	Distance above or below (-) land surface	Height above mean sea level (feet)			
D1-4-25aa3	U. S. Geol. Survey	1953	Dr	50.5	6	P	N	N	O	Tc	0.6	4,570	16.57	3- 7-53	TH50.5; L; Cp32-50; R; Y270m; D2.6m
25ba1	N. Dykstra		Dr	25.5	6	P	Cy	H	O	Tc	.8	4,569	13.65	4-19-51	
25ba2	.....do		Du	25	42	W	C	E	D	Ls			14		
25ba3	.....do		Dr	26	6	P	Cy	G	S	Ls			14		
25cc1	Laurence Noyes		Dr	56	6	P	J	E	D,S	Ls			4		
25cc2	.....do		Du	3.5	30	R	Cy	H	N	Tc	0	4,602	2.78	8- 9-51	
26bba	Bert Ketterrer		Du	24	42	C	Cy	E	D,S	Ls			16		
26bbb	U. S. Geol. Survey	1951	Dn	9.2	3/4	P	N	N	O	Tc	2.2	4,559	5.60	8- 1-51	
26cd	E. Keltz		Du	24	42	R	C	E	D,S	Ls			4		
26da	Helen W. Benepe		Dr	60	5	P	Cy	W,H,E	D,S	Ls			8		
27bb	Cameron School		Dr	32.1	4	P	Cy	H	O	Tc	2.2	4,550	11.72	4-19-51	
28bb	E. Pastoor		Dr	33	4	P	J	E	D	Ls			16		
29aba	H. J. Kamps		Dr	56	6,4	P	Cy	E	D,S	Ls			20		
29abb	.....do		Dr	56	6,4	P	C	E	D	Ls			20		
29dc	N. VanDyk		Du	100	12	T	J	E	D,S	Ls			30		
30aa	D. Heys		Dr	180	6	P	C	E	D,S	Ls			60		
30da	Sam Schaper		Dr	100	6	P	Cy	W	D,S						
31aa	W. J. Hartman		Dr	160	6	P	Cy	E	D,S						

31dd	L. VanDyke	1910	DD	280	4	P	C	E	D,S	Ls			80		
32aa	Mary L. Esgar		Du	35	20	T	Cy	H	D,S	Ls			8		
33aa	James P. Heiskell		Dr	35	4	P	J	E	D,S	Ls			8		
34bd	John Cook	1953	Dr	38	6	P			D	Ls			4		L
34db	do		Du	18.4	36		Cy	H	D	Tp	0	4,610	4.54	8- 6-51	
35ad1	W. J. Cass		Dr	20	4	P	Cy	E	D,S	Ls			6		
35ad2	do		Dr	50	5	P	N	N	N	Ls			6		
35bd1	John Ketterer		Dr	17	4	P	C	E	D	Ls			4		
35bd2	do		Dr	18	4	P	Cy	E	S	Ls			4		
36dd1	George Boilan		Du	19.4	10	T	Cy	H	S	Tc	.6	4,632	2.41	7-17-51	
36dd2	do		Du	15	36	W	Cy	H	S	Ls			4		
36dd3	do		Dr	30	6	P	J	E	D	Ls			4		
5- 1cb	Verne H. Ballantyne		Dr	140	5	P	Cy	E	D						
2dc	Mable Ballantyne		Dr	110	6	P	Cy	E	D	Ls			100		
3cb	Alfred E. Heinrich		Dr	35	6,4	P	Cy	H	S	Ls			15		
3cd	Alvie Behnke		Dr	50	6	P	J	E	D,S	Ls			12		
4bd	C. Toohey		Dr	35	4	P	J	E	D	Ls			11		
4db1	E. B. Tonn		Dr	48.0	4	P	N	N	O	Tc	1.0	4,459	16.80	4-24-51	Y27r; T46
4db2	do		Dr	40	8	P	Cy	H	S	Ls			12		
4dc1	A. G. Kluckhohn		Du	25.8	30 by 60	C	Cy	H	S	Tp	1.0	4,462	18.10	4-24-51	
4dc2	do		Du	18	12	P	Cy	H	D	Ls			12		
5ad	George VanHoorn		Dr	25.6	4	P	C	H	S	Tc	1.0		4.27	6-29-53	A
5cd	Alfred E. Heinrich		Dr	30	4	P	J	E	D,S						
6cd	Gallatin Field	1950	Dr	65	6	P	J	E	P	Ls			33	6- 3-50	Y48m; D8m
6dc	Gallatin Airport		Dr	62.1	6	P	N	N	O	Tc	-5.8	4,450	32.35	5- 3-51	
8ab	U. S. Geol. Survey		Dn	7.7	$\frac{3}{4}$	P	N	N	O	Tc	2.0	4,450	5.96	8- 3-51	
9ac	John Toohey		Dr	28	5	P	Cy	H	O	Tp	.5	4,476	19.07	7-16-51	
9bb	George VanHoorn		Dr	19	8	P	J	E	D,S	Ls	0	4,455	5.46	do	
9cd	U. S. Geol. Survey	1953	Dr	145.0	6	P	N	N	N	Tc	1.0	4,491	16.68	10-26-53	TH162; L; A; Cp 15-145; F139.6; Caf; T47
10ac	R. V. Spain		Dr	25	12	P	J	E	D	Ls			10		
10cc	Fred Schneiter		Dr	50	6	P	J	E	D	Ls			10		

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point			Distance to water level below measuring point (feet)	Date of measurement	Remarks
										Description	Distance above or below (-) land surface	Height above mean sea level (feet)			
D1-5-11bc1	Tom Toohey	....	Dr	75	6	P	Cy	E	D,S	Ls	....	....	55	....	
11bc2	.....do	....	Dr	85	5	P	Cy	E	S	Ls	....	....	65	....	
11cb	.....do	....	Dr	65	6	P	J	E	D,S	Ls	....	....	25	....	
12ad	Jonathan Walker	....	Dr	225	6,4	P	Cy	E	D,S	Ls	....	....	165	....	Caf; T52
12db	Charles Walker	....	Dr	182	6	P	Cy	E	D	Ls	....	....	170	....	
13aa	J. S. Smiley	....	Dr	120	4	P	Cy	.....	N	Tc	1.2	4,828	65.27	8-21-52	
14bd	C. Spain	....	Dr	37	6	P	J	E	D,S	Ls	....	....	25	....	
14db	Esther H. Beck	....	Dr	38	6	P	J	E	D,S	Ls	....	....	23	....	
14dd	Louis Huffine	....	Dr	28	4	P	J	E	D,S	Ls	....	....	24	....	
15ba	E. S. Williams	....	Dr	50	5	P	J	E	D	Ls	....	....	8	....	
15dc	Marie Freese	....	Dr	17	4	P	Cy	H	D	Ls	....	....	9	....	
15dd1	C. T. Kirk	1950	Dr	30	6	P	J	E	D,S	Ls	....	....	13	....	
15dd2	.....do	....	Du	12	42	R	Cy	H	D	Ls	....	....	11	....	
17ac	Andrew Coscik	....	Dr	35	8	P	J	E	D,S	Ls	....	....	15	....	
17ba	.....do	....	Dr	37	6	P	J	E	D,S	Ls	....	....	15	....	
17cc	W. H. LaRue	....	Du	12	36	W	J	E	D	Ls	....	....	6	....	
17db	I. E. Barrick	....	Dr	36	6	P	Cy	H	D,S	Ls	....	....	30	....	
18bb	Theodore Balke	....	Dr	60	5	P	J	E	D	Ls	....	....	16	....	
18cc	Bessie Roth	....	Dr	50	6	P	J	E	D,S	Ls	....	....	18.70	12- 1-53	L
19cb	Carl F. Fogh	....	Dr	40	6	P	Cy	E	D,S	Ls	....	....	5	....	

19cd	John Paugh	....	Dr	27.0	4	P	N	N	O	Tc	0	4,563	9.79	2- 3-53	
20ba	Harvey Carter	....	Dr	40	6	P	J	E	D,S	Ls	....	....	6	....	
21cd	John P. Cloninger	....	Dr	80	6	P	Cy	E	D	Ls	....	....	20	....	
21dda	John Tatarka	....	Dr	90	4	P	J	E	D,S	Ls	....	....	16	....	
21ddd	U. S. Geol. Survey	1951	Dn	9	3/4	P	N	N	O	Tc	2.0	4,586	8.87	8- 2-51	
22bc	William McGinley	....	Dr	75	5	P	J	E	D,S	Ls	....	....	10	....	
22cc	Valley Center School	....	Dr	22.8	5	P	Cy	H	D	Tc	-4.5	4,583	11.98	4-18-51	
22cd	H. C. Rogers	....	Dr	30.1	10	P	J	E	D,S	Tc	.5	4,596	17.07	....do........	Caf
23aa	J. S. Smiley	....	Dr	65	6	P	J	E	D,S	Ls	....	....	31	....	
23ac	R. Hoffman	....	Du	22	36	W	Cy	H	D,S	Ls	....	....	18	....	
23ad1	A. C. Reed	....	Dr	36	4	P	J	E	D,S	Ls	....	....	10	....	
23ad2	.....do	....	Du	17	48	W	Cy	H	S	Ls	....	....	10	....	
23db	Nelson School	....	DD	13.1	12,4	T,P	Cy	H	O	Tc	0	4,596	5.30	5-15-51	A
24bc	A. F. Reed	....	Du	26	12	T	Cy	H	D,S	Ls	....	....	23	....	
25cc	J. J. Walker	....	Dr	74	5	P	J	E	D,S	Ls	....	....	35	....	
26ab1	Mary C. Biggs	1949	Dr	27	6	P	Cy	H	D,S	Ls	....	....	14	....	
26ab2	.....do	1948	Dr	127	6	P	N	N	N	Ls	....	....	17	....	U
26ac	J. S. Smiley	....	Dr	78	6	P	J	E,F	D	....	....	....	....	....	
26cb	L. D. Westlake	1900	Dr	35	4	P	J	E	D,S	Ls	....	....	14	....	
26da	Vesta Anderson	....	Dr	28.2	4	P	C	E	O	Tc	1.0	4,635	12.57	7-17-51	A
26db	Elton L. Bogart	....	Dr	32	6	P	J	E	D,S	Ls	....	....	11	....	
27aa	U. S. Geol. Survey	1951	Dn	13.2	3/4	P	N	N	O	Tc	1.6	4,601	11.10	8- 3-51	
27bb	Emma D. Preston	....	Dr	26.5	6	P	Cy	E	D,S	Tc	.5	4,590	17.54	4-18-51	
27cc	A. McGinley	....	Dr	42	4	P	J	E	D,S	Ls	....	....	20	....	
27da	Lovitt Westlake	....	Dr	55	4	P	J	E	D,S	Tc	-5.5	4,624	9.24	7-17-51	
28ca1	J. L. Rundlett	....	Dr	35	6	P	J	E	D,S	Ls	....	....	8	....	
28ca2	.....do	....	Du	12	36	W	Cy	H	S	Ls	....	....	8	....	
28cd	J. M. Puckett	....	Dr	35	4	P	J	E	D,S	Ls	....	....	10	....	
29cb1	John Paugh	....	Dr	60	4	P	J	E	D	Ls	....	....	25	....	
29cb2	.....do	....	Dr	60	6	P	C	E	S	Ls	....	....	10	....	
30aa	Mary Doane	....	Du	14.9	54	R	Cy	H	D,O	Tp	0	4,558	10.29	4-18-51	
30cb	Mary K. Marx	....	Du	12.5	36	R	Cy	H	S	Tp	.6	....	4.42	7-25-53	A

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
D1-5-30cd	James Paugh	....	Du	14.7	14	T	Cy	H	O	Tp	0.3	4,593	8.78	5-17-51	
30dc	.....do	....	Dr	57	6	P	....	....	D	Ls	....	....	32	....	
31cc	L. Gaffney	....	Du	22	60	R	Cy	H	D	Ls	....	....	4	....	
32ca	John Paugh	1947	Dr	52	6	P	J	E	D,S	Ls	....	....	5	3- ?-47	L
32dc	John Aakjer	....	D	35	6	P	Cy	H	D	Ls	....	....	8	....	
33cc	Peter S. Dyk	....	Du	18	48	P	C	E	D	Ls	....	....	14	....	
33dc	R. G. Baxter	....	Dr	30	6	P	C	E	D	Ls	....	....	12	....	
33dd	U. S. Geol. Survey	1951	Dn	9.5	3/4	P	N	N	O	Tc	1.4	4,712	4.20	7- 6-51	
34cc1	Harper School	....	Du	30	48	P	J	E	D	Ls	....	....	6	....	
34cc2	U. S. Geol. Survey	1952	Dr	157.0	6	P	N	N	O	Tc	1.5	4,713	11.92	10-27-52	TH250; L; A; Cp 15-150; R; Caf; T47-51
35ca1	A. Nickles	......	Du	10.5	48	R	Cy	H	S,O	Tp	.5	4,694	6.23	7-17-51	
35ca2	.....do	....	Du	12	48	R	Cy	H	D	Ls	....	....	6	....	
35ca3	.....do	....	Du	12	48	R	N	N	N	Ls	....	....	6	....	
35cd1	U. S. Geol. Survey	1951	Dn	8.9	3/4	P	N	N	O	Tc	.5	4,721	5.94	7- 6-51	
35cd2	.....do	1952	Dn	9.7	3/4	P	N	N	O	Tc	1.7	4,720	5.63	5-27-52	
35da	H. M. Catron	......	Dr	80	6	P	J	E	D	Ls	....	....	6	....	
36ac	James J. Walker	....	Dr	7.5	6	P	N	N	N	Tc	1.5	4,667	4.44	8- 9-51	
36bb	Albert Evans	....	Dr	95	6	P	Cy	H	D	Ls	....	....	9	....	
36cd	J. M. Mandeville	....	Du	20	48	R	C	E	D	Ls	....	....	10	....	
36ddc	J. H. Newhall	1948	Dr	93	7	P	....	....	D,S	......	....	....	30	9- ?-48	L

36ddd...	U. S. Geol. Survey	1951	Dn	9.5	$\frac{3}{4}$	P	N	N	O	Tc	2.0	4,718	6.60	7- 6-51	
6-31cc.....	E. C. Elliott		Du	7.0	42	C	C	E	S	Tp	0		2.84	7- 2-53	A
31da.....	School District 31	1949	Dr	33	6	P			D	Ls			6		
34bd.....	U. S. Fish and Wildlife Service.		Sp				N	F	In			4,871			Y100-500r; Cao; T47
34ca.....	.....do		Sp				N	F	In						Y100-500r; Cao; T77
D2-2- 1dd.....	Genevieve Moore		Dr	950	4	P	Cy		N				600		U; Ww
3- 1cc.....	John Visser	1952	Dr	80	6	P			D	Ls			35		Y12r; D70r
2da.....	W. Alberda	1953	Dr	95	6	P			D	Ls			14		
2cb.....	Geo. Sinnema	1951	Dr	273	4	P	Cy	G	D,S	Ls			123		
4ac.....	Vincent School		Dr	36.6	5	P	Cy	H	O	Tc	.2	4,591	6.57	5-16-51	Y5r
6da.....	R. Sinnema		Dr	295	3	P	Cy	W	D	Ls			284		
7aa.....	Jake Alberda		Dr	400	3	P	Cy	W	N						
8aa.....	L. M. Cumings	1910	DD	80	36,4	C,P	J	E	D	Ls			65		
10aa.....	H. Viterdyk		DD	400	4	P	Cy	E	D,S	Ls			90		
10bc.....	George Wierda		Dr	85	6	P	Cy	W	D,S	Ls			45		
11aa.....	John Visser		Dr	170	6,4	P	Cy	W	D,S	Ls			50		Caf
12bb.....	Henry Broekema		DD	100	4	P	Cy	G	D,S	Ls			30		
12dd.....	A. Brouwer		Du	40			C	E	D,S	Ls			15		
13cc.....	R. Blanksma		Sp				N	F	D,S						Y10r; T58
14bb.....	H. Westra	1948	Dr	150	7	P	J	E	D,S	Ls			120		Y30r
20ad.....	P. Flikkema	1943	Dr	60	4	P			D	Ls			30		
21ad.....	John T. Kamp, Estate		Dr	35	5	P	C	E	D	Ls			8		Y12r; D4r
21da.....	Northern Pacific Ry	1951	Dr	42	6	P	C	E	S	Ls			20		
34ca.....	Roy C. Hyde		Dr	50+	4	P	Cy	H	N	Tc	0	4,984	26.75	8-21-52	
35ac.....	Henry Broekema		Du	18.3	36	R	N	N	N	Tp	0	5,022	15.04	....do	
4- 1aa1...	Laurence Gaffney		Dr	27	6	P	C	E	D	Ls			5		
1aa2...	.....do		Du	12	48	R	Cy	H	S	Ls			5		
1ba1...	U. S. Geol. Survey	1951	Dn	14.1	$\frac{3}{4}$	P	N	N	O	Tc	2.0	4,641	5.54	6-29-51	
1ba2...	Lawrence W. Barclay		Du	18.8	14	W	Cy	H	N	Tc	0	4,640	4.10	7-17-51	
4aa.....	Hayes Bryan	1949	Dr	34	6	P			D	Ls			15		L; Y40r
4bd.....	.....do	1952	Dr	200	4	P			S	Ls			20		Y20r; D85r

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
D2-4- 9bc	U. S. Geol. Survey	1951	Dr	600.0	6	P	N	N	O	Tc	1.0	4,910	26.53	2- 8-52	TH; L; A; R; Caf; T51-62
9cd	Henry M. Skank	....	Dr	82.2	4	P	Cy	H	N	Tc	1.0	4,850	8.27	5-23-52	
10dd	Rubye Kaemmer	....	Du	10.6	72	R	Cy	H	O	Tp	0	4,697	8.18	5-14-51	A
11cd1	A. D. Pruitt	....	DD	16.1	10,6	T,P	Cy	H	S,O	Tc	1.0	4,697	7.34	....do........	
11cd2	.....do	....	Dr	25	4	P	J	E	D,S	Ls	....	....	5	....	
11dc	U. S. Geol. Survey	1953	Dr	65.0	6	P	N	N	N	Tc	1.0	4,706	10.92	9- 8-53	TH150; L; A; Cp 12-65; P80; Caf; T49
13aa	.....do	1951	Dn	8.5	$\frac{3}{4}$	P	N	N	O	Tc	2.0	4,734	5.80	6-29-51	
13ab	Michel Bros	....	Du	25	12,10	T	J	E	D,S	Ls	....	....	22	....	
13bc	John Kamps	....	Du	20	12	T	J	E	D	Ls	....	....	7	....	
13cbc	Chicago, Milwaukee, St. Paul & Pacific RR.	....	Du	16	36	R	Cy	H	D	Ls	....	....	6	....	
13cbd	R. R. Sigler	....	Dr	50	4	P	J	E	D	Ls	....	....	8	....	
13cc	Hugh Nicely	....	Du	10.4	12	T	Cy	H	O	Tc	.5	4,738	3.80	6-21-47	A; T52
13cd	Lucille B. Sigler	....	Dr	25	4	P	Cy	E	D	Ls	....	....	6	....	
13da	Herbert B. Ross	....	Du	15	10	T	J	E	D	Ls	....	....	3	....	
13dd	P. Dolan	....	Du	12	10	T	Cy	E	D	Ls	....	....	2	....	
14aa	Guy Burrell	....	DD	38	6	P	J	E	D	Ls	....	....	20	....	
14ac	I. M. Maynard	....	Dr	35	8	P	Cy	H	D	Ls	....	....	12	....	
14ada1	Guy Burrell	....	Dr	18	4	P	Cy	H	D	Ls	....	....	6	....	

14ada2	A. H. Doornboss	...	Dr	50	4	P	N	N	D	Tc	-5.0	...	2.85	7-13-53	A
14add	J. W. Devous	...	Du	15	10	T	C	E	D	Ls	...	...	6	...	
14bb	John Kaemmer	...	Dr	11.1	4	P	N	N	N	Tc	.6	...	5.38	10- 7-52	A; T50
14daa	A. E. Randall	...	Dr	50	5	P	C	E	D,In	Ls	...	...	8	...	
14dac1	Bozeman Hot Springs	...	Dr	70	6	P	C	E	D	Ls	...	...	15	...	
14dac2	....do	...	Sp	...	...	...	C	E,F	P	...	...	...	...	...	Y120r; Caf; T140
14dc	N. W. McKenney	...	Dr	23	6	P	J	E	D	Ls	...	...	10	...	
14dd	C. R. Rupp	...	Dr	38	5	P	C	E	D	Ls	...	...	8	...	
15da	Wilbur Story	1945	Dr	120	4	P	...	...	D	Ls	...	...	6	1- ?-45	L
17aa	Pine Butte School	...	DD	68.1	4	P	Cy	H	O	Tc	.5	4,874	18.44	5-15-51	
18ac	Harold Todd	1949	Dr	37	4	P	...	...	D	Ls	...	...	1	12- ?-49	
18ca	H. DeHahn	...	Du	40	8	T	J	E	D	Ls	...	...	25	...	
22da	A. B. Steele	...	Sp	...	...	...	N	F	D,S	...	...	...	...	...	Y50r; Caf; T56
23aa	R. Otto	...	Dr	35	4	P	J	E	D	Ls	...	...	5	...	
23ab	James Todd	...	Du	14	42	R	Cy	H	D	Ls	...	...	5	...	
24dc1	James D. Walker	...	Dr	35	4	P	C	E	D	Ls	...	...	10	...	
24dc2	....do	...	Dr	40	4	P	Cy	E	S	Ls	...	...	10	...	
25bd	Ralph Sime	...	Du	21.5	48	C	Cy	H	O	Tp	.6	4,813	20.10	5-22-51	
26aa	Elk Grove School	...	Du	15	10	T	P	H	D	Ls	...	...	5	...	Y18r
26ac	O. L. Ward	...	Dr	26	4	P	Cy	H	S	Tc	1.0	...	3.87	7-14-53	
26dc	....do	...	Dr	25.9	4	P	N	N	N	Tc	1.6	...	6.53	....do	A
33ab	G. J. Kamps	...	Sp	...	...	...	N	F	D	...	...	...	...	...	Y50r; T58
33da	Rochambeau School	...	Dr	97.8	4,3	P	Cy	H	D	Tp	0	4,918	57.25	5-18-51	
33dd	J. McReynolds	...	Dr	26	4	P	J	E	D,S	Ls	...	...	6	...	
34dd1	W. Olson	...	Dr	12	4	P	J	E	D,S	Ls	...	...	4	...	
34dd2	....do	1952	Dr	20	6	P	P	H	D	Tc	2.0	...	6.45	7-13-53	
5- 1ba	Elers Koch, and others	...	Dr	30	8	P	C	E	D	Ls	...	...	10	...	
1cc	J. Budd	1953	Dr	40	6	P	...	...	D	Ls	...	...	15	...	
1db	Roy Hauser	1950	Dr	96	6	P	J	E	D	Ls	...	...	24	...	Y25r; D11r
1ddb	Scott Potter	1951	Dr	34	6	P	...	...	D	Ls	...	...	17	...	
1dd1	Milam Greenhouse	1949	Dr	30.5	6	P	J	E	In	...	...	...	...	...	Y60r
1dd2	Paul Jones	1948	Dr	64	4	P	...	...	D	Ls	...	...	8	...	L
2aa	Harry Bolinger	1948	Dr	78	7	P	J	E	D	Ls	...	...	8	...	L
2ab	A. Nickles	...	Du	10	6	T	J	E	D	Ls	...	...	6	...	

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
D2-5- 2cd	Wilbur E. Smith	......	Dr	26	6	P	C	E	D	Ls	......	......	12	......	
2dd	....do	......	Du	24.0	72,60	R	Cy	H	O	Tp	0	4,779	12.94	5-15-51	
3ab1	Edna T. White	......	Du	23	48	R	C	E	D	Ls	......	......	6	......	
3ab2	....do	1950	Du	20	48	R	J	E	S	Ls	......	......	10	......	
3cc	R. G. Baxter	......	Dr	34	6	P	Cy	H	D	Ls	......	......	6	......	
3db	Wilbur E. Smith	......	Dr	45	6	P	J	E	D	Ls	......	......	12	......	
4ab	R. G. Baxter	......	Dr	18.5	4	P	N	N	D	Tc	1.1	4,710	4.99	5-22-51	
4bb	....do	......	Dr	38	6	P	Cy	H	D	Tp	.1	4,721	20.88	7-17-51	
4cc	Emma Miller	......	Dr	30	6	P	C	E	D	Ls	......	......	10	......	
4dc	J. A. Stout	......	Dr	30	6	P	C	E	D	Ls	......	......	6	......	
5ba	U. S. Geol. Survey	1951	Dn	9.5	$\frac{3}{4}$	P	N	N	O	Tc	2.0	4,694	4.88	7- 6-51	
5dc	Vernon Lang	......	Du	22	14 by 20	T	Cy	E	D	Ls	......	......	16	......	
6ba	H. A. Martin	......	Du	9	18	P	Cy	H	D,S	Ls	......	......	2	......	
6dc	John Michel	......	Dr	40	6	P	J	E	D	Ls	......	......	10	......	
7aa	John Balkema	......	Dr	30	6	P	C	E	D	Ls	......	......	2	......	
8bc	I. N. Love	......	Dr	30	8	P	Cy	H	D	Ls	......	......	2	......	
8db	J. E. Norton	......	Du	24	8	T	J	E	D,S	Ls	......	......	20	......	
9bc	Fred Happel	......	Dr	32	5	P	C	E	D	Ls	......	......	12	......	
9cc1	J. C. Huffine	......	Du	7.3	18	T	N	N	S,O	Tc	.5	4,822	4.82	4-19-51	
9cc2	....do	1918	Dr	21	8	P	C	E	D	Ls	......	......	7	......	
9dc1	J. E. Norton	......	Du	7.6	36	W	N	N	S	Tc	0	4,832	4.74	4-19-51	

9dc2...	.....do..........	....	Du	9.1	12	T	Cy	H	S	Tc	.5	4,831	5.98	.....do.......	
10cc.....	Lester Covey..........	....	Du	....	....	....	J	E	D	Ls	....	....	3	....	
11ac.....	Paul L. Eneboe..........	1951	Dr	22	6	P	N	N	D,S	Ls	....	....	6	....	
11baa...	Emil Hedrich..........	....	Dr	28	6	P	C	E	D	Ls	....	....	12	....	
11bab...	H. J. Leigh..........	....	Dr	28	6	P	J	E	D	Ls	....	....	12	....	
11bba...	O. F. Christenot..........	1948	Dr	25	6	P	C	E	D	Ls	....	....	12	....	
11bbb...	Lester Gee..........	1950	Dr	21	8	P	C	E	D	Ls	....	....	10	....	
11cd.....	A. I. Poor..........	1945	Dr	45	6	P	J	E	D,S	Ls	....	....	4	....	
11dcc...	O. C. Hodge..........	....	Dr	33.2	4	P	N	N	N	Tc	1.2	....	4.27	10-23-52	A; T54
11dcd...	Alfred Yergey..........	1936	Dr	30	5	P	J	E	D	Tc	-4.0	4,855	1.12	4-17-51	
11ddc...	V. E. Iverson..........	1948	Dr	42	5	P	J	E	D	Ls	....	....	5	....	
11ddd...	K. F. Swingle..........	1949	Dr	45	5	P	J	E	D	Ls	....	....	5	....	
12ac.....	Kessler Dairy..........	1949	Dr	46	6	P	....	....	In	Ls	....	....	11	....	
13bb.....	U. S. Geol. Survey..........	1951	Dn	9.6	3/4	P	N	N	O	Tc	2.0	4,865	4.80	6-29-51	
13ca.....	Paul Jordan..........	....	Sp	....	....	....	N	F	D	....	....	....	....	....	Y250r
13cba...	G. M. Beatty..........	1949	Dr	37	6	P	C	E	D	Ls	....	....	5	....	
13cbb...	Emory Lutes..........	......	Dr	30	4	P	C	E	D	Ls	....	....	5	....	
13cbd...	David Wessel..........	....	Dr	46	4	P	J	E	D	Ls	....	....	5	....	
13cc.....	Fred Boylan..........	....	Dr	46	6,2	P	C	E,F	D,S	....	....	....	....	....	
14ac.....	U. S. Geol. Survey..........	1952	Dr	110.0	6	P	N	N	O	Tc	1.0	4,901	7.13	11- 8-52	TH265; L; A; Cp 20-110; P125; R; F125; Caf; T48
14cd1...	D. Girven..........	......	Dr	39	9	P	Cy	E	S	Ls	....	....	8	....	
14cd2...	.....do..........	......	Dr	45	6	P	J	E	D	Ls	....	....	8	....	
14da.....	Ralph and Nick Aakjer..........	......	Dr	45	6	P	Cy	E	D	Ls	....	....	5	....	
14dd.....	U. S. Geol. Survey..........	1951	Dn	9.7	3/4	P	N	N	O	Tc	2.0	4,931	6.41	6-29-51	
15aa1...	E. F. Boldt..........	....	Dr	16.4	5	P	Cy	H	S,O	Tc	.5	4,858	3.86	4-17-51	A; Caf; T52
15aa2...	.....do..........	....	Dr	39.7	5	P	Cy	H	D	Tc	0	4,859	3.92	.....do.......	
15dc.....	Charles Spick..........	....	Du	14	10	T	Cy	H	D	Ls	....	....	8	....	
16aa1...	A. Sanders..........	....	Du	8.4	20	T	N	N	O	Tc	.3	4,839	5.72	4-19-51	R
16aa2...	.....do..........	....	Du	11	15	T	J	E	D,S	Ls	....	....	2	....	T46
16ab.....	Laurence S. Knapp..........	....	Du	8.1	60,48	R	Cy	H	S	Tp	.2	4,833	3.85	4-19-51	
16bb.....	V. M. Haverly..........	1951	Dr	25	4	P	J	E	D	Ls	....	....	3	....	

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point			Distance to water level below measuring point (feet)	Date of measurement	Remarks
										Description	Distance above or below (-) land surface	Height above mean sea level (feet)			
D2-5-16cd	Ezra Allsop	......	Dr	28	6	P	Cy	H	D	Ls	......	......	6	......	
16dd	H. D. Fulker	......	Du	11	48	P	Cy	H	D,S	Ls	......	......	4	......	
17ba	O. A. Brenden	......	DD	63	6	P	J	E	D,S	Tc	0	4,813	18.54	5-14-51	
17da	J. L. Bradley	......	Dr	60	6	P	C	E	D,S	Ls	......	......	6	......	
18cd	Homer Wilson	1951	Dr	89.4	6	P	C	E	D	Tc	2.5	......	30.10	4- 7-51	
19bc	M. W. Beatty	......	Dr	65	6	P	J	E	D,S	Ls	......	......	25	......	
20aa	Ezra Allsop	......	Du	14	36	R	C	E	D	Ls	......	......	4	......	
20ad1	Mason Thompson	1950	Dr	36	6	P	C	E	D,S	Ls	......	......	3	......	
20ad2	.....do	......	Du	12	36	R	C	E	N	Ls	......	......	3	......	
20cc	T. B. Todd	......	Dr	65	4	P	C	E	D	Ls	......	......	8	......	
20da	Stephen White	......	Du	14	48	R	C	E	D	Ls	......	......	4	......	
21aa	George T. Bond	......	Du	23	16	T	C	E	D	Ls	......	......	5	......	
21da	Cora A. Kirchner	......	Dr	23.9	4	P	Cy	H	O	Tc	.4	4,956	6.39	5-22-51	
22aa1	Charles Spick	......	Dr	14	6	P	Cy	E	S	Ls	......	......	6	......	
22aa2	.....do	......	Dr	45	6	P	Cy	H	D	Ls	......	......	6	......	
22aa3	.....do	......	Du	20	10	T	C	E	D	Ls	......	......	6	......	
22ba	George Hohensee	......	Dr	40	4	P	C	E	D	Ls	......	......	6	......	
22ccc	Sherman Smith	......	Dr	43	6	P	C	E	D	Ls	......	......	5	......	
22ccd	U. S. Geol. Survey	1952	Dr	165.0	6,4	P	N	N	O	Tc	2.2	4,994	12.98	3-9-53	TH1,000; L; A; Cp 90-165; P165; R; Caf; T44-56

23aa1	Fred Boylan	......	Dr	87	6	P	C	E	D	Ls	......	......	5	......	
23aa2	....do	......	Dr	35	6	P	C	E	S	Ls	......	......	5	......	
23aa3	....do	......	Du	10	48	R	N	N	N	Ls	......	......	4	......	
23aa4	....do	......	Du	10	48	R	Cy	H	S	Ls	......	......	4	......	
23ad	....do	......	Du	8	48	R	C	E	D	Ls	......	......	5	......	
23bb	George E. Belshaw	......	Dr	40	6	P	Cy	E	D	Ls	......	......	10	......	
23bd1	Randolph Gee	......	Dr	25	4	P	C	E	D	Ls	......	......	5	......	
23bd2	....do	......	Du	14	36	R	C	G	S	Ls	......	......	5	......	
25cb1	M. P. Harris	......	Du	9.2	60 by 72	R	Cy	H	S,O	Tp	.8	5,069	5.99	5-10-51	
25cb2	....do	1904	Dr	30.4	6,4	P	Cy	E	D	Tc	1.0	5,067	8.23	....do	
25cd	Gerald H. Delin	......	Dr	43.2	5	P	Cy	H,G	D	Tc	1.0	5,086	5.24	7-30-51	
25db	Goldenstein Bros	......	Du	8	16	P	C	E	D	Ls	......	......	6	......	
26ad	Lola M. Lewis	......	Dr	40	6	P	C	E	D	Ls	......	......	8	......	
26cc1	L. M. Riddle	......	Du	11.4	8	P	Cy	H	D	Tc	1.6	5,098	5.73	5-14-51	
26cc2	....do	......	Du	3.7	14	T	Cy	H	S,O	Tc	.4	5,094	2.40	....do	
27ba	Helen W. Benepe	......	Dr	25	6	P	C	E	D	Ls	......	......	5	......	
27cc	Benepe Estate	......	Dr	19.0	4	P	Cy	H	D	Tc	.4	......	2.70	8- 4-52	A; T45
27dd1	....do	......	Dr	48	4	P	Cy	H	D	Ls	......	......	3	......	
27dd2	....do	......	Du	12	10	T	Cy	H	S	Ls	......	......	3	......	
28aa1	Vern White	......	Dr	25	6	P	P	H	D	Ls	......	......	5	......	
28aa2	....do	......	Du	12	42	R	Cy	E	S	Ls	......	......	5	......	
28cc	Nels Jensen	......	DD	10	4	P	J	E	D,S	Ls	......	......	6	......	
28da1	Edith E. Willson	......	Du	9.0	18	P	C	E	D	Tc	1.0	5,038	5.69	7-27-51	
28da2	....do	......	Dr	46.5	5	P	N	N	N	Tc	1.0	5,038	5.70	....do	
28da3	....do	......	Du	8.5	42	R	C	E	S	Tp	0	5,037	5.39	....do	
29ac	Steve O'Donnell, Estate	......	Dr	11.9	3.5	P	Cy	H	D,O	Tc	.4	4,966	5.10	8-13-51	
29cb	Harry J. Wilson	......	DD	8	4	P	J	E	D,S	Ls	......	......	4	......	
29cd	John TeSelle	......	Dr	75	5	P	C	E	D	Ls	......	......	6	......	
29da	N. L. Scheytt	......	Dr	20	6	P	C	E	D	Ls	......	......	5	......	
30aa	Robert H. Marshall	......	Du	20	10	T	C	E	D	Ls	......	......	6	......	
32aa	W. A. Figgins	......	Dn	......	1½	P	C	E	D	......	......	......	5	......	
32ac	John TeSelle	......	DD	8	4	P	J	E	D,S	Ls	......	......	4	......	
32db	Mary E. Gant	......	Dr	16	6	P	C	E	D	Ls	......	......	3	......	

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
D2-5-33aa	R. J. Pasha, Estate		Dr	30	4,5	P	C	E	D,S	Ls			20		
33bb	Fred Boylan		Sp				N	F	D,S						
33cb	W. W. Roberts		Dr	8	4	P	Cy	E	D,S	Ls			4		
33db1	Pasha Estate	1915	Du	12.1	6	T	Cy	H	O	Tp	0.6	5,119	9.22	5-14-51	
33db2	.....do	1939	Dr	30	4	P	Cy	E	D						
34aa	Peter M. Hansen		Du	15		T	Cy	H	D	Ls			10		
34ba	L. L. Benepe		Du	7.0	6	P	Cy	H	O	Tp	.2	5,093	4.34	5-15-51	
34cd	Benepe Estate		Dr	22.5			N	N	O	Tp	0	5,177	11.37	4-23-51	
35aa1	Hugh Heiskel		Dr	33	6	P	C	E	D	Ls			10		
35aa2	.....do		Du	30	36	R	Cy	H	S	Ls			10		
35cb	Henry B. Covey		DD		4	P	J	E	D,S	Ls			10		
35dc	H. E. Jones	1948	Dr	155	12	P	T	G	Ir,O	Tc	1.8	5,203	37.48	5-14-51	L; A; Cp
35dd1	.....do		Dr	18	6	P	J	E	D	Ls			10		
35dd2	.....do		Dr	45	6	P	Cy	E	S	Ls			10		
36aa	Abagail Smart		Sp				N	F	D,S						
36ba1	Harold Klumph		Du	20	10	W	C	E	D	Ls			6		
36ba2	.....do		Du	20	40	R	C	E	S	Ls			6		
36ba3	.....do	1952	Dr	36		P	N	N	N	Ls			3		P
36dd	Elizabeth Nash		Du		8	W	Cy	H	N	Tc	0	5,137	2.73	7-30-51	
6- 6bd	Bill Ford	1951	Dr	56	6	P			D	Ls			7		
7ac	City of Bozeman	1936	Dr	304	20,10	P	N	N	N						L; P; R; Y450-500

7da	R. A. Williams	1949	Dr	104	6	P			D	Ls			40		L; Y15r; D20r
8cd	Elks Country Club		Du	10.0	20	T	Cy	H	D	Tp	.8		3.46	7-23-53	
10dc	Myron Nuffer		Dr	19	6	P	J	E	D				5		TH32; L
17da	Otto E. Knutson		Sp				N	F	S						
18cb	U. S. Geol. Survey	1951	Dn	9.3	3/4	P	N	N	O	Tc	3.1	4,910	5.42	8- 3-51	
18db	F. A. Beltz	1952	Dr	55	6	P			S	Ls			8		L
19aa1	Susie Essex	1948	Dr	58	7	P			D	Ls			20		L; Y20r; D25r
19aa2	J. B. Essex	1953	Dr	100	6	P			D	Ls		4,974	20		L; Cp22-90; Y25r
19cb1	Roy Ayres	1952	Dr	80	6	P			D	Ls			18		L; Y16r; D32r
19cb2	Dan Ayres	1953	Dr	155	6	P			D	Ls			29		L; Y25r; D65r
19da	N. Helburn	1951	Dr	72	6	P	J	E	D	Ls			7		
20ab	Edwin E. Howard		Du	55	8	T	N	N	O	Tp	.5	4,948	40.85	8-15-51	
21ad	J. W. Lillard		Du	15	40	C	Cy	H	D,S						
22ad	Dean Barnett		Du	9.7	8	T	Cy	H	D,O	Tp	.2	5,003	1.52	5-27-52	
22cb	Charles P. Carolus	1902	Du	60	8	T	Cy	W	D,O	Tp	.5	5,061	37.50	8-15-51	Caf; T54
23bb	Dean Barnett		Dr	35	4	P	J	E,F	D	Tc	-3.5				
26cb	Harry Woods		Du	39.0	42	R	N	N	O	Tp	1.0	5,164	31.29	8- 6-51	
27aa	Williams Bros		Du	8.0	15	T	N	N	O	Tc	.2	5,085	3.70	5-25-51	
28aa	Harry Davis		Dr	135	4	P	N	N	N	Tp	0	5,198	90.42	5-23-52	
29cc	Nash Ranch		Dr	50	4	P	C	E	D	Ls			30		
30ca	W. W. McLeod		Du	11	10,8	T	C	E	D	Ls			8		
30db	Julia Martin		Dr	50	6	P	J	E	D	Ls			8		
31ad	Elanore McRoberts		Dr	80	5	P	C	E	D	Ls			10		
31db	Hoffman Bros		Du	20	24	T	Cy	H	D,S	Ls			8		
32cb1	R. P. Meyers, Sr.	1943	Dr	98	8	P	J	E	D,S	Ls			14		
32cb2	do		Du	15	12	T	Cy	E	D,S	Ls			10		
D3-4- 1ba	Gene A. Doornbos		Dr	90	6	P	J	E	D,S	Ls			20		Y700r
1db	do		Sp						S,Ir						
2ab	E. S. Ashford		Dr	40.0	4	P	J	E	D	Tc	-5.2	4,877	20.90	5-18-51	
2bb	Glen Smith		Du	5	8	T	Cy	H	D	Ls			2		
3aa	George T. Sinnock		Dn	11	1	P	N	N	N	Ls			5		
3ab1	do		Dr	11	4	P	J	E	D	Ls			7		Caf
3ab2	do		Du	5	36	T	Cy	H	S	Ls			4		

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
D3-4- 3ab3	Jim McReynolds		Sp				C	E,F	D						
3ca	Ben Stukey	1952	Dr	435			N	N	N	Ls			3		Caf; OT; T50; Y31
3daa	Otto Pinkerton		Dr	12	4	P	Cy	H	D	Ls			4		
3dad1	Charles Gray		Dr	25	5	P	C	E	D	Ls			6		
3dad2	.....do		Dr	21.0	6	P	N	N	S	Tc	1.0		5.72	6-30-53	Y1.5r
3dd1	Ben Stucky		Du	12.6	10	T	Cy	H	N	Tc	.5	4,886	4.54	8-22-51	
3dd2	.....do		Du	18			J	E	D,S	Ls			4		
8ad	Ernest Monforton		Dr	50	4	P	N	N	N	Ls	0	5,026	17		
9ba	.....do	1952	Dr	95.0	6	P			D	Tc	1.4	5,002	46.60	6- 6-52	
10ac1	Charles Gray, Jr.		Dr	25	6	P	J	E	D	Ls			4		
10ac2	.....do	1951	Du	15	30	T	N	N	S	Ls			4		
10ac3	.....do		Dr	25	5	P	C	E	D	Ls			4		
10ad	Emil Kuchling		Dr	30	5	P	C	E	D	Ls			4		
11bca	Roy Stillman	1953	Dr	50	4	P			D	Ls			13		
11bcc1	Frank Maryott		Du	10.2	60	R	Cy	H	D	Ls	0	4,910	4.60	8-22-51	
11bcc2	.....do		Sp				N	F	D						
11bcc3	Stephen Kaselnak		Dr	25	2	P	P	H	D	Ls			4		
11bdb	H. Hardgrove		Du	18.5	12	T	Cy	E	D,O	Tc	.8	4,923	6.97	8-22-52	A; T54
11bdc	J. Alberson		Dr	47	4	P	Cy	H	D	Tc	3.0		10.46	8-23-52	Y43m; T50
12ac	R. Hager	1950	Dr	35	6	P			D,S	Ls			10		
12cd	R. B. MacNab, Sr.		Dr	45	3	P	J	E	D	Ls			40		
13ab	Alice Hadzor		Dr	14.5	3	P	Cy	E	D	Tc	-5.5	5,081	3.58	4-18-51	

14ba	H. J. Neff	......	DD	61.9	4	P	N	N	O	Tp	1.0	4,991	47.50	5-18-51	
21da	Irvine Co.	......	Dr	60.1	6	P	Cy	H	N	Tc	1.8	......	18.30	7-14-53	
26ba1	George H. Montgomery.	1952	Dr	123	6	P	......	......	......	Ls	......	......	17	......	Cp30-50; Y16r; D2.5r
26ba2	Little Bear School	1953	Dr	145	6	P	Cy	H	P	Ls	......	......	36	......	L; Y60r; D89r
27ba	Wilson Creek School	......	Dr	28.1	4	P	Cy	H	O	Tc	.5	5,036	22.10	5-18-51	A
34aa	Alfred Wilson	1944	Dr	60	4	P	......	......	D,S	Ls	......	......	28	......	L
34bc	J. F. Daniel	......	Du	60	36	R	Cy	W,H	N	Tp	.4	......	40.65	6-25-53	
5- 1ac	Leverich School	......	Dr	57.9	4	P	Cy	H	O	Tc	.3	5,210	36.42	5-14-51	
1ba	Kenneth Kraft	......	Du	20	18	P	C	E	D,S	Ls	......	......	8	......	
1dc	Frank Wyatt	......	Du	40	10	T	J	E	D,S	Ls	......	......	20	......	
2ad	Lillie M. Lenz	......	Dr	85	5	P	Cy	E	D,S	Ls	......	......	50	......	
2cd	E. R. Poor	......	Dr	72	4	P	Cy	E	D,S	Ls	......	......	25	......	
2da	Walter Kraft	1915	Du	72	6	T	Cy	E	D,S	Ls	......	......	60	......	
3ab	B. L. Dusenberry	......	Dr	40	6	P	Cy	E	D,S	Ls	......	......	20	......	
3bb	Benepe Estate	......	DD	23.0	10,4	T,P	Cy	H	O	Tc	.7	5,178	12.98	5-15-51	
3da	B. L. Dusenberry	......	Dr	32.1	3	P	Cy	H	D,O	Tp	0	5,262	29.20	4-23-51	Caf; T45-53
4ab	C. G. Johnson	1916	Dr	34	4	P	C	E	D,S	Ls	......	......	4	......	
4ba	J. B. Monforton	1946	Dr	37	8	P	J	E	D,S	Ls	......	......	1	......	
4cd	.....do	......	Sp	......	......	......	N	F	D,S	......	......	......	......	4-19-51	Y5r
4da	Bert L. Dusenberry, Jr.	......	Dr	30	4	P	J	E	D	Ls	......	......	10	......	
5aa1	Edith Oliver	......	Du	7.9	40,36	W	Cy	H	S,O	Tp	1.0	5,114	5.51	4-23-51	
5aa2	.....do	......	Du	9.8	48	R	J	E	D	Tp	.3	5,116	6.57	.....do	
5cc	E. Enders	1918	Dr	360	6	P	Cy	E	D,S	Ls	......	......	240	......	
6ad	Virgil Hanks	1927	Dr	160	4	P	Cy	E	D,S	Ls	......	......	150	......	
6cd	Edith Oliver	......	Dr	80	4	P	J	E	D	Ls	......	......	20	......	
8cb	E. E. Kessler	......	Dr	70	6	P	J	E	D,S	Ls	......	......	10	......	
8dd	John Pasha	......	Dr	135	5	P	J	E	D	Tc	.8	5,396	41.51	8-28-51	
9aa	Anderson School	......	Dr	29.8	4	P	Cy	H	D	Tc	1.4	5,252	12.54	7-30-51	
9da	Clyde Bradley	......	Du	51.9	10	T	Cy	H	O	Tc	.2	5,287	33.10	5-25-51	
10ba	C. J. Bradley	......	Du	25	40	R	Cy	H	D,S	Ls	......	......	10	......	
10bb	.....do	......	Dr	25	5	P	N	N	N	Ls	......	......	12	......	
10db	J. L. Ferguson	......	Dr	80	4	P	Cy	E	D,S	Ls	......	......	50	......	
11bc	J. Edward	1943	DD	91.0	5	P	Cy	H	D	Tc	.7	5,339	73.16	5- 7-51	

Table 36.—*Record of wells and springs*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface	Measuring point: Height above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
D3-5-11da	Earl Kraft		Sp				N	F	D,S						
11ddb	Walter Kraft		Sp				N	F	D						
11ddc	.....do		Sp				N	F	D,S						
12cb	R. N. Spencer		Sp				N	F	D,S						
15ca	Frank R. Doney		Sp				N	F	D,S						
16aa	Nash Ranch		Dr	80	5	P	C	E	D	Ls			40		
17ca	Floyd Herron		Sp				N	F	D,S						
17dc	George Merklin		Du	20	10	T	J	E	D	Ls			6		
17ddc1	S. Kent Rancn		Dr	32	4	P	Cy	E	D	Ls			5		
17ddc2	.....do		Dr	8	4	P	N	N	N	Ls			5		
17ddd	Cottonwood School		Dr	19.5	4	P	Cy	H	D	Tc	0.7	5,376	8.99	8-20-51	
18ab	H. E. Figgins		Dr	31.4	$3\frac{1}{2}$	P	Cy	H	D,O	Tc	.2	5,187	19.07	4-19-51	
18ba1	.....do	1943	Du	11	12	T	Cy, J	E	D	Ls			9		
18ba2	.....do	1947	Du	6.6	24	P	Cy	H	D	Tp	.5	5,155	6.20	4-19-51	
19bb	E. Reiser		Sp				N	F	D,S						
20cc	Rosenberg Bros.		Dr	100	6	P	J	E,F	D	Tc	4.0	5,490	1		
21ab	T. E. Vincent		DD	30	42,6	C,P	J	E	D	Ls			10		
21bba	John M. Roberts		Du	16	42	R	C	E	D	Ls			6		
21bbd	H. D. Green		Dr	25	5	P	J	E	D	Ls			5		
21bd1	H. B. Ross		Du	17	42	R	Cy	H	N	Ls			8		

21bd2	.....do	......	Sp	....	....	.....	N	F	D	....	....	....	....	....	
6- 5bb	R. P. Myers, Sr.	......	Dr	80	6	P	N	N	N	Ls	....	....	14	....	
6ac	Donald Nash	......	Dr	43.4	5	P	Cy	H	O	Tc	0	5,163	15.40	8-13-51	
6ba	Nash Ranch	......	Sp	....	....	.....	N	F	D,S	....	....	....	....	....	
6da	.....do	......	Dr	80	4	P	J	E	D	Ls	....	....	15	....	
6dd1	A. Portnell	1949	Dr	168	6	P	J	E	D	Ls	....	....	50	....	L
6dd2	.....do	......	Dr	30	6	P	N	N	N	Ls	....	....	14	....	

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