Water Resources of the Raft River Basin Idaho-Utah

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1587

Prepared in cooperation with the Idaho Department of Reclamation

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By R. L. NACE *and others*

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WATER RESOURCES OF THE RAFT RIVER BASIN, IDAHO-UTAH

By R. L. NACE and others

ABSTRACT

Much arable land in the Raft River basin of Idaho lacks water for irrigation, and the potentially irrigable acreage far exceeds the amount that could be irrigated with the estimated total supply of water. Therefore, the amount of uncommitted water that could be intercepted and used within the basin is the limiting factor in further development of its native water supply. Water for additional irrigation might be obtained by constructing surface-storage works, by pumping ground water, or by importing surface water. Additional ground-water development is feasible. As an aid to orderly development and use of the water supplies, the report summarizes available geologic and hydrologic data and, by analysis and interpretation, derives an estimate of the recoverable water yield of the basin.

The Raft River basin includes about 1,560 square miles, of which about 360 is in the Raft River valley. Most of the irrigated and irrigable land lies in the lower Raft River valley and an adjacent section of basalt plain south of Lake Walcott.

The Raft River basin is a mountain-and-valley area in which rugged mountain ranges rise boldly above the aggraded alluvial plains of intermontane valleys. Topography and geologic structure strongly influence the climate and hydrology of the basin. The Raft River, the master stream, rises in the Goose Creek Mountains of northwestern Utah and flows generally northeastward and northward, joining the Snake River in the backwater of Lake Walcott, a Federal reclamation reservoir in the Snake River Plain.

The climate of the Raft River basin ranges from cool subhumid in the mountains to semiarid on the floor of the Raft River valley. Precipitation ranges from 10 to 12 inches on the valley floor to more than 32 inches at some places in the mountains. Rainfall is light during the growing season and irrigation is necessary for most cultivated crops. The mean annual temperature in the central lowland is about 45° to 48° F. The estimated average rate of evaporation from lowland free-water surfaces is slightly less than 41 inches per year. The average relative daytime humidity in the lowland in summer probably is about 25 percent.

About 43,000 acres of land is irrigated, most of it in the Raft River valley. Nearly all usable surface water in the basin is diverted for irrigation and about 18,000 acres is irrigated exclusively with surface water. Most stock, farm, and domestic water is from wells. Irrigation with ground water is widely practiced and 25,000 acres was irrigated partly or wholly with ground water in 1954.

Although much information is available about the geology of the basin, it is not sufficiently detailed to permit a complete analysis of the complex interrelations of the geology, climate, and hydrology. The Raft River basin has a complex structural, geologic, and physiographic history. The landforms and the geologic structures control the surface drainage pattern as well as the occurrence and movement of ground water. The principal water-bearing materials in the area are volcanic and lake deposits of the Salt Lake(?) formation, the Raft Lake beds, unnamed deposits of alluvial gravel and sand, and the Snake River basalt. Large-scale development of ground water would be possible only in the Raft River valley; therefore, only those geologic features that are most closely related to the occurrence of ground water in the valley are discussed. Nevertheless, much geologic information that is omitted from the report was considered in the hydrologic interpretations.

The estimated total volume of water contributed to the Raft River basin by precipitation is 1,290,000 acre-feet per year. Potential evapotranspiration, calculated by the Thornthwaite method for three locations in the valleys of the basin, ranges from 22.5 to 24.4 inches yearly. Actual evapotranspiration is much less because of the natural water shortage, and the estimated average for the entire basin is about 13.3 inches per year. The estimated total volume of actual evapotranspiration from the entire basin is 1,105,000 acre-feet yearly (not adjusted for increased consumptive use on irrigated land). This estimate is derived by a new method, not previously published. The method minimizes some of the consequences of unavoidable errors, which tend to be magnified in the Thornthwaite method.

Although potential evapotranspiration is about twice the precipitation in lowland areas, not all the precipitation is consumed. Precipitation is distributed unevenly through the year; runoff and recharge occur during periods of local and temporary excess of water. The excess of precipitation over actual evapotranspiration, averaged for the entire basin and called the water yield, is about 2.2 inches. This value is computed by methods explained in the report.

The Raft River discharges about 17,000 acre-feet of water yearly from the part of its watershed that lies above The Narrows. Below The Narrows the river alternately loses and gains water by seepage into and out of the ground. Most of the surface water is diverted for irrigation and the discharge of the river at its mouth is less than 10,000 acre-feet yearly. The unused surface-water yield of the basin therefore is only a small fraction of the total water yield.

Ground water occurs under both water-table and artesian conditions. Most of the readily accessible unconfined ground water of good quality occurs at shallow depth in alluvium below The Narrows and north of Strevell, and in basalt in the Northern Plains section. The Raft lake beds also are aquifers but their extent is not known. Artesian water occurs in the Salt Lake(?) formation, which is presumed to underlie most of the lowland in the Raft River valley. A water-table map of the central valley lowland shows that the slope of the water table ranges between 10 and 40 feet per mile in a general northward direction, and the depth to water is less than 50 feet in a narrow belt adjacent to the Raft River. In the northern section, or basalt plains, the depth to water is as much as 300 feet, and in places perhaps more.

Systematic observations have been made of water-level fluctuations in parts of the basin since 1948. In upland areas water levels are lowest in winter and early spring and highest in late summer. In the irrigated lowland of the Raft River valley water levels rise to their highest stage early in the irrigation

season, but drop soon thereafter. The yearly water-level fluctuations range from 1 or 2 feet in some lowland areas to 25 feet or more at higher altitudes. Despite recent increased pumping of ground water, there was no noticeable net decline of water levels from 1948 through 1956, even in heavily pumped areas.

Ground water is recharged in the Raft River basin by direct penetration of precipitation, by infiltration from streams, and by infiltration of irrigation water. Ground water in valley lowlands is replenished also by underflow from adjacent highlands. The ultimate origin of the water from all these sources is precipitation. Unconsumed precipitation, estimated to be about 184,000 acre-feet yearly, is divided between surface runoff and ground-water recharge. Very little runoff reaches the Snake River, so nearly all unconsumed water becomes ground-water recharge at some place above the mouth of the Raft River. Locally, as in the valley of the Raft River above The Narrows, the volume of runoff is appreciable.

Some ground water is discharged to streams, but these in turn lose some water to the ground. Owing to the complexity of relations between ground water and surface water, it is not realistic to treat the two separately.

The chemical quality of water in the Raft River basin is important in irrigation because some of the water is doubtful to unsuitable for the types of soils in the arable areas. The chemical quality varies widely and needs much additional study. The temperature of the ground water varies widely. Most is between 48° and 60° F but some is as warm as 211° F.

Pumpage of ground water increased tenfold from about 8,700 acre-feet in 1948 to 64,000 acre-feet in 1955. The amount of land irrigated with the water is not known because some land is irrigated with a combination of ground and surface water. In addition to the volume of evapotranspiration in the basin, which is computed to be 1,105,000 acre-feet yearly in the natural state, the 35,000 acres of irrigated cropland in the Raft River valley consume about 39,000 additional acre-feet of water; 8,000 acres in the Yost-Almo basin consume 5,000 additional acre-feet. The net consumptive use, therefore, is nearly 1,150,000 acre-feet. The unconsumed residual water yield of the whole basin is about 140,000 acre-feet. Less than 10,000 acre-feet leaves the basin by surface flow at the mouth of the Raft River; the rest leaves the basin by underflow. The loss in the Raft River is compensated partly by infiltration to the Northern Plains section from the bed of Lake Walcott. The uncommitted water supply of the basin, therefore, is assumed to be the same as the unconsumed residual water yield—140,000 acre-feet, in round numbers. The recoverable and usable part of that supply is the limiting factor in any further development of the basin with its native water supply.

The lowland area of the Raft River valley alone contains about 386,000 acres of undeveloped land. But if only 100,000 acres is irrigable the consumptive-use demand for its irrigation would be about 111,000 acre-feet per year in addition to the existing natural consumptive use. The total diversion or pumping demand would be 200,000 to 300,000 acre-feet, or far more than the estimated available supply of unconsumed and uncommitted water. Much of the unconsumed pumped water would return to the ground-water body within the area of use and be recirculated. The net pumping demand, therefore, would be much less than 200,000 acre-feet and probably not much more than 111,000 acre-feet. Hydrologic factors that would limit recovery and use of the water are the capacities of the aquifers to yield water to wells, the amount of water that wells or other structures can intercept, the effects of new pumping on established water rights, and the suitability of the water for irrigation.

Successful irrigation wells in the Raft River valley have specific capacities ranging from a few to 312 gpm (gallons per minute) per foot of drawdown, and are pumped at rates of about 90 to 3,125 gpm. The coefficient of transmissibility, as determined by pumping tests at two sites, is about 180,000 gpd (gallons per day) per foot. Estimates by other methods indicate an average of about 200,000 gpd per foot, but this probably represents only about the upper 200 feet of the aquifers. Similar aquifer characteristics undoubtedly prevail at many places in the valley. The general ability of the aquifers to accept recharge readily and to transmit water freely is evident.

Not all the available ground water could or should be intercepted by wells. If it is assumed that a pumping season lasts 120 days, during which wells are being pumped 18 to 24 hours per day, the pumping time would be equivalent to about a third of each year or less. Underflow of ground water out of the valley, however, occurs the year round, and even during the pumping season not all the underflow could be intercepted. Enough water—50,000 to 75,000 acre-feet—might be intercepted for the diversion demand of 25,000 to 30,000 acres of land. By temporary overpumping from strategically located wells during each irrigation season, a larger percentage of water would be recovered than if wells were pumped less. These and other estimates undoubtedly will be revised as development proceeds and more information becomes available.

The pumping of 75,000 additional acre-feet of water for irrigation would nearly double the 1955 pumping demand for water, and total pumpage would be about 160,000 acre-feet per year. The total acreage irrigated with ground water and surface water would be about 73,000, for which the consumptive-use demand not already accounted for as natural consumptive use would be about 81,000 acre-feet, or about 44 percent of the total natural water yield of the basin. This demand probably would not exceed the safe water yield of the basin, because the unconsumed pumped water would be available for return-recharge of ground water.

With proper management of the total water supply, whether from the ground or surface streams, new development on the scale indicated might entail local competition for water. Regional competition with users outside of and downstream from the Raft River basin would be negligible. If optimum development of all water in the Raft River basin is to be achieved, it may be necessary to manage and utilize all the water as a single resource. Perhaps water rights could be broadened to apply to any water, whether from the ground or from surface streams.

Logs of 81 wells and tabular records of the characteristics of nearly 400 wells, are given at the end of the report.

INTRODUCTION

PURPOSE AND SCOPE

The purpose of studies in the Raft River basin was to estimate the total water yield of the basin, the parts of that yield that are available as surface water and ground water, the amount of ground water that might be recovered for beneficial use, and the effect of such use on downstream water supplies.

Much arable land in the Raft River basin lacks water for irrigation. The basin contains only one small surface-storage reservoir, and nearly all the surface water discharged by streams during the irrigation season is appropriated. Supplemental water for old land and a supply for new land could be obtained only by constructing surface-storage reservoirs, by pumping ground water, or by importing water. The amount of surplus winter and flood runoff may be too small to justify storage. Moreover, surface storage would not solve the main problem in the valley, which is that the total water supply is not adequate for all the undeveloped irrigable land. Water might be imported from the Snake River but that possibility seemingly has not been studied. Many irrigation wells have been drilled in the Raft River valley since 1948, and more are in prospect.

For ground-water development and use to be orderly, with due attention to the problem of the total water supply, basic hydrologic information is needed by water users, by State and local officials who administer water rights, and by Federal agencies who are concerned with land and water use. The amount of ground water that might be used for irrigation in the Raft River basin is of direct concern to the public and public agencies. Federal agencies that administer the public lands need to know whether the perennial ground-water supply is sufficient to irrigate more than 30,000 acres of public land on which desert-entry and homestead applications have been allowed or were pending in 1956. About 20,000 acres of State-owned land might be sold to persons who plan to irrigate.

Data for this report were obtained during parts of several field seasons. The occurrence of shallow, unconfined ground water and deeper, confined (artesian) water; the relations of the water table in the Raft River valley to the channel conditions and regimen of the Raft and Snake Rivers and to the stages of Lake Walcott; the roles of precipitation, runoff, and ground-water recharge in the hydrologic cycle; and the relations of ground-water levels and fluctuations to the yearly withdrawals of ground water were studied.

Work in the Raft River basin included canvassing and measuring 420 wells, obtaining data on subsurface conditions, and making periodic measurements in observation wells. Thirteen wells were measured 1 to 12 times a year; recording gages were operated on five additional wells. Altitudes of many wells were determined with a spirit level in accordance with standards for third-order leveling. Bench marks of the U.S. Coast and Geodetic Survey furnished vertical control. Locations of most wells were determined by stadia traverse from section-corner markers. Pumpage data were collected for irrigation wells, and seasonal ground-water withdrawals were computed from records of electric-power consumption. Miscellaneous measurements of seepage losses and gains in the Raft River between The Narrows [1] and Lake Walcott were made with a pigmy current meter. The discharges of Raft River at Peterson Ranch near The Narrows, about 8 miles southwest of Bridge, and of Clear Creek near Naf are measured by the Geological Survey, and these records are published annually in water-supply papers.

Wells were canvassed and ground-water levels were measured in 1948 by R. L. Nace, R. W. Mower, S. W. Fader, Eugene Shuter, and Glenn Brandvold. Leveling was done by R. W. Mower and S. W. Fader. Supplemental records were collected by H. G. Sisco during several periods from 1950 to 1955, and the pumpage records are virtually complete as of the end of the 1955 water year. Hydraulic coefficients were computed by J. W. Stewart from pumping tests. Several authors contributed sections to this report and are specifically credited in the table of contents and text. Sections not so credited are the work of the senior author.

The field investigations and preparation of the report were part of the program of water-resources investigations by the Geological Survey in cooperation with the Idaho Department of Reclamation.

LOCATION OF THE AREA

The drainage area of the Raft River basin is about 1,560 square miles. About 715 square miles is in the Raft River valley, which includes the principal potential irrigation area; about 740 square miles is in upstream and bordering tributary areas; and about 175 square miles is in the Snake River Plain (fig. 1). The plains tract does not have well-defined surface drainage and is not part of the Raft River surface-drainage basin. It extends from about the north-south center line of R. 25 E. eastward to within 1 mile of the Raft River (pl. 1) and is bounded on the north by Lake Walcott and on the south by a line about half a mile north of T. 11 S. The boundary of the ground-water basin through R. 25 E. is arbitrary but includes all the area where recharge and underflow are derived largely from the Raft River basin. Much of the ground water west of the boundary consists of underflow from other areas.

About 270 square miles of the Raft River basin is in Box Elder County, Utah; most of the remainder is in Cassia County, Idaho, but a few square miles lies in Oneida and Power Counties, Idaho. The principal irrigable area is in Tps. 9 to 16 S., Rs. 26 to 27 E., in eastern Cassia County.

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[1] Local geographic name for a gorge, about 2 miles long, cut by the Raft River through the south end of the Malta Range.

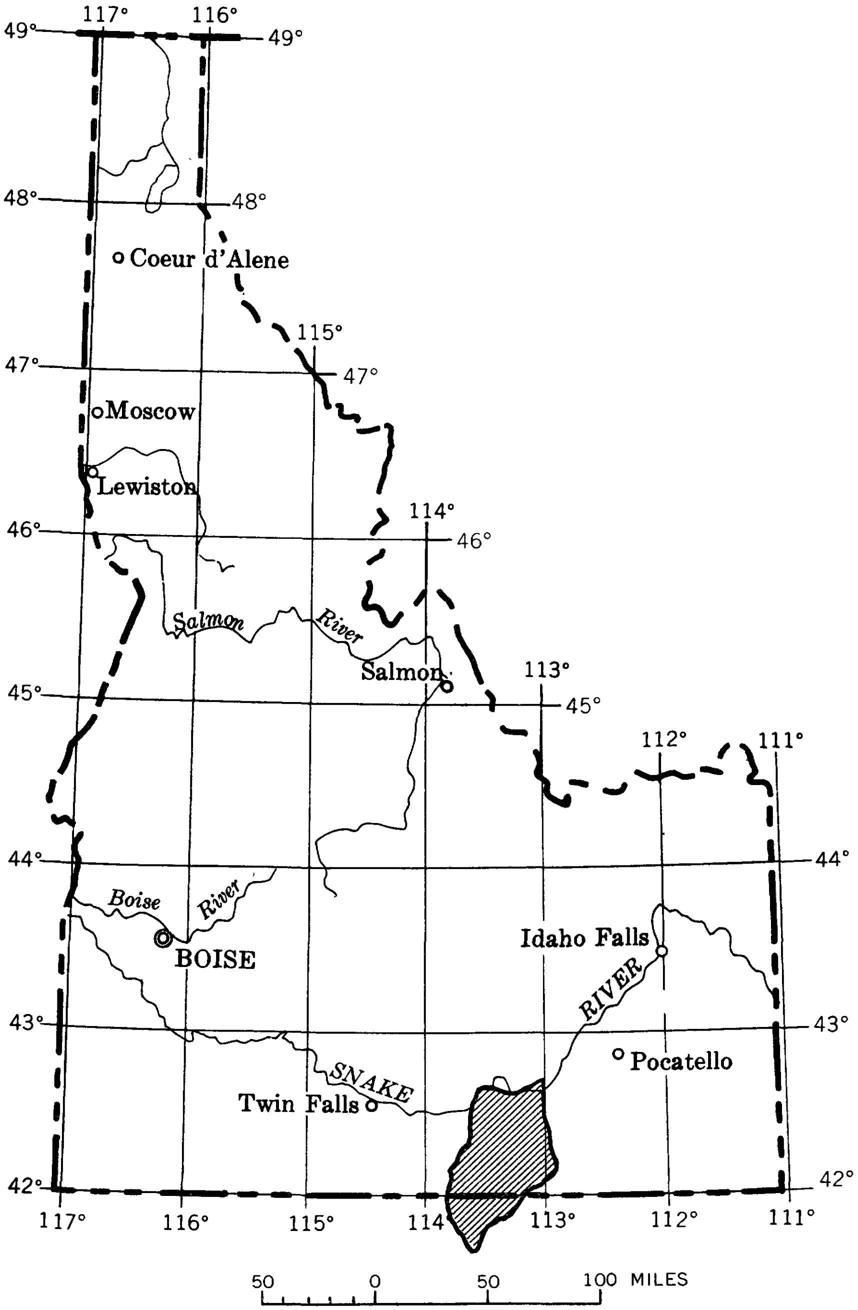

FIGURE 1.—Index map of southern Idaho and northern Utah, showing area covered by this report.

PREVIOUS INVESTIGATIONS

Several geologic studies have been made in the Raft River basin, and supplemental field studies were made by the senior author. Even so, the basic geologic information now available is not adequate for a complete hydrologic analysis of the basin. Although further investigation is needed, the information at hand is reasonably adequate for the purposes of this report.

Stearns and others investigated the Raft River Valley in 1928 as a part of a reconnaissance study of the ground-water resources of the entire Snake River Plain in Idaho. The results of that investigation, made by the Geological Survey in cooperation with the Idaho Department of Reclamation and the Minidoka Irrigation District, were incorporated in an unpublished preliminary report (Stearns, 1929) and in two published reports (Stearns and others, 1936, 1938). Kirkham (1931) compared the Tertiary stratigraphy of the Raft River basin with that of other areas in southern Idaho. Anderson (1931) described the general geology and mineral resources of eastern Cassia County, with special emphasis on the geology of upland areas, but he included relatively little information about the valley lowlands.

A preliminary report (Fader, 1951) on the Raft River basin contains records of wells, ground-water levels, and pumpage for irrigation. A report by Crosthwaite and Scott (1956) on ground water in the North Side Pumping Division of the Minidoka Project contains ground-water data that were used in preparing the present report. After fieldwork for the present report was completed, a report was published on the geology of the eastern part of the Raft River Range (Felix, 1956). A reconnaissance geologic map of Utah (Butler and others, 1920, pl. 4) covers the Utah part of the Raft River basin, but it is too generalized to be useful for this report.

ACKNOWLEDGMENTS

Well drillers furnished logs and other valuable information about wells. Residents and well owners supplied useful data about wells and permitted measurement of wells. The Raft River Rural Electric Cooperative furnished records of power consumption. The U.S. Bureau of Reclamation maintains and operates four recording gages on wells near the south side of Lake Walcott, and the records for these wells were available to the Geological Survey.

WELL-NUMBERING SYSTEM

Water wells are referred to in this report by numbers which indicate their locations within legal rectangular subdivisions of the public lands, with reference to the Boise base line and meridian. The first two segments of a number designate the township and range. The third segment gives the section number, followed by two letters and a numeral, which indicate the quarter section, the 40-acre tract, and the serial number of the well within the tract. Quarter sections are lettered a, b, c, and d in counterclockwise order, from the northeast quarter of each section. Within the quarter sections 40-acre tracts are lettered in the same manner. Thus, well 10S–25E–12cd1 is in the SE¼SW¼ sec. 12, T. 10 S., R. 25 E., and is the well first visited in that tract. The method of numbering is illustrated in figure 2.

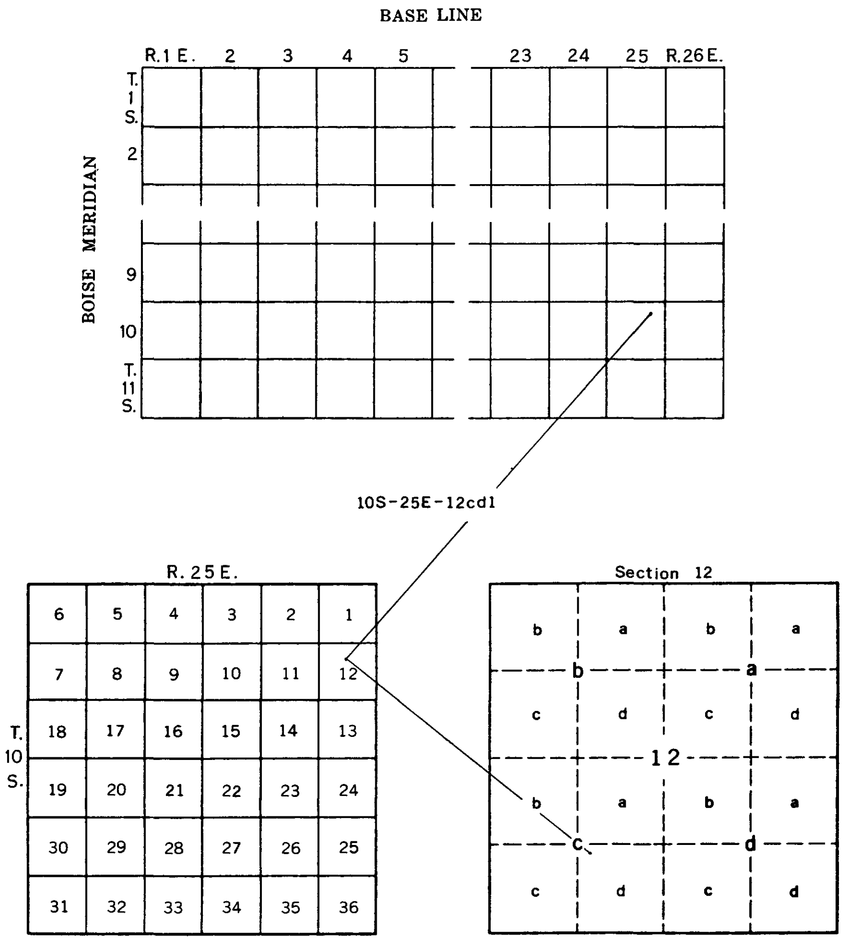

Figure 2.—Well-numbering system.

GEOGRAPHY

Most of the Raft River basin is in the Great Basin section of the Basin and Range province (Fenneman, 1928) and is characterized by rugged ranges rising boldly above aggraded alluvial plains. The northern part of the Raft River basin merges with the Snake River Plain, a vast expanse of rolling to broken land formed largely by flow sheets of volcanic rock. The topography in and around the basin strongly influences the climate, and local factors control runoff and ground-water recharge.

MOUNTAIN RANGES

Six mountain ranges occur in the Raft River basin (pl. 5) and along its borders. The Raft River Mountains trend eastward, but all other ranges extend northward. The Goose Creek and Albion Ranges lie along the western part of the basin, the Raft River Mountains along the southern boundary, and the Black Pine and Sublett Ranges along the eastern flank. Most of the Malta Range is within the basin.

The crest of the Goose Creek Range, a tilted fault-block range in northwestern Utah, is near the steep slopes of a fault-line scarp which forms part of the eastern slope of the mountains; the western back slopes are long and gentle. The highest altitude on the range is about 8,200 feet above sea level and about 2,400 feet above the floor of the adjacent part of the Yost Valley.

The Albion Range has a maximum altitude of about 10,335 feet at Cache Peak, and is bounded by steep slopes on the east and west. The peak is about 4,735 feet higher than the floor of the adjacent Almo basin. The range is dissected only moderately, except for steep-sided glaciated valleys on its eastern slopes.

The Raft River Mountains rise to an altitude of about 6,600 feet at the southern boundary of Idaho, and farther south in Utah reach a maximum altitude of about 9,890 feet. The range trends eastward from the valley of South Junction Creek to a low pass southeast of Strevell, which divides it from the Black Pine Range. The north flank slopes moderately steeply down to the floor of the Raft River valley.

The Malta Range is a titled fault-block mountain range east of the Albion Range. All the Malta Range, except a small northwestern segment that drains into Marsh Creek, is within the Raft River basin. The range is separated from the Raft River Mountains on the south by a broad pass and is bounded on the north by the Snake River Plain. The Malta Range is cut by two transverse gorges through which flow the Raft River and Cassia Creek. The east flank of the range is a steep scarp face, but the western slope is gentle. The crest is about 3,400 feet above the floor of the Raft River valley, and the altitude at the highest point in the central part of the southern segment of the range is about 8,050 feet.

The Black Pine Range rises steeply from broad piedmont alluvial slopes that border it on the east and west sides. The altitude of the highest peak is about 9,385 feet, nearly 4,600 feet above the general level of the floor of the Raft River valley at Bridge. The range has been dissected into narrow ridges and deep narrow valleys.

The Sublett Range lies north of the Black Pine Range, from which it is separated by the valley of Meadow Creek. On the west the range rises steeply above the aggraded floor of the Raft River valley to an altitude of about 7,400 feet. The north end of this range slopes gently downward, reaching the level of the Snake River Plain about 4 miles south of the Snake River. These mountains consist largely of parallel ridges separated by steep narrow valleys that trend northwestward.

PRINCIPAL VALLEYS AND SUBBASINS

The Raft River valley is the largest of the several valleys in the drainage basin of the Raft River. Its floor is an aggraded alluvial plain, 10 to 15 miles wide, bounded by the Malta Range on the west, the Raft River Mountains on the south, the Black Pine and Sublett Ranges on the east, and the Snake River Plain on the north. The Snake River Plain rises gently from the Raft River in the central part of the valley, but its slope steepens near the mountains. The altitude of the valley floor is about 4,200 feet near the mouth of the Raft River, about 4,530 feet near Malta, about 5,000 feet in The Narrows, and about 5,200 feet at some places on the piedmont alluvial plains where they grade up to the surrounding foothill slopes.

A plain, formed largely by volcanic rocks, lies immediately south of Lake Walcott and the Snake River and west of the Raft River. This plain is here called the Northern Plains section. This section, which extends southward to about 4 miles north of Idahome, is physiographically and genetically a part of the Snake River Plain. The section is not part of the surface-drainage area of the Raft River but is treated here with the Raft River basin because of its close hydrologic relation to the basin (pl. 5). The Northern Plains section retains much of its original volcanic form, having been modified only slightly by erosion since the volcanic rocks were emplaced. A few volcanic cones rise several hundred feet above the general level of the plain. The surface-drainage pattern is incipient on most of the

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plain, and some parts have only interior local drainage; small fringe areas drain intermittently to the Raft River, Lake Walcott, and the Snake River.

The Elba basin lies between the Albion and Malta Ranges; it is about 10 miles in length and width but the valley-floor area is much smaller. Talus slopes along the flanks of the surrounding mountains grade into the alluvial fill of the valley floor, which has a very steep slope except in the bottom lands along its lower reach. The outlet of the basin is a steep gorge that was cut transversely through the Malta Range by Cassia Creek.

The Yost Valley of Utah and the Almo basin of Idaho, which are grouped in this report as the Yost-Almo basin, are drained by the main-stem segment of the Raft River above The Narrows. The Yost-Almos basin is an alluvial valley of irregular form which slopes from the north and south toward The Narrows, a water gap through the southern nose of the Malta Range. The basin is surrounded by the Albion, Goose Creek, Malta, and Raft River Ranges. Alluvial fill underlies the valley floor.

DRAINAGE

The headwater tributaries of the Raft River rise in the Goose Creek Mountains of northwestern Utah and join to form the master stream in the Yost Valley (pl. 4). From the Yost Valley the river flows northeastward into the Almo basin through a narrow canyon, locally called the Upper Narrows. The Raft River then flows northeastward through The Narrows into the Raft River valley. In its generally northward course through the broad central lowland of the valley, the Raft River is only slightly incised. From Yale northward, however, the river occupies a narrow valley which is entrenched 150 to 200 feet below the general level of the Northern Plains section. The confluence of the Raft and Snake Rivers is submerged in the backwater of Lake Walcott, a Federal reclamation reservoir impounded by Minidoka Dam.

Johnson Creek, an intermittent tributary whose headwaters rise in the Raft River Mountains in Utah, flows northward into the Yost-Almo basin and joins the Raft River 3 miles above The Narrows. Almo Creek drains the northern part of the Yost-Almo basin and joins the Raft River a few miles southeast of Almo. The drainage divide between the Yost-Almo and Elba basins is about 5 miles north of Almo.

Clear Creek flows along a deep gorge in the north slope of the Raft River Mountains and debouches onto its alluvial fan near Naf but rarely carries water beyond.

Cassia Creek, the principal perennial tributary of the Raft River, drains the Elba basin. The creek and its tributaries converge eastward and the creek then traverses a gorge through the Malta Range and emerges on the floor of the Raft River valley. About 50 percent of the streamflow above the gorge is diverted for local irrigation. From the mouth of its gorge in the Malta Range, Cassia Creek crosses an alluvial fan and reaches the flood plain of the Raft River near Malta. On the Cassia Creek fan all water is diverted during the irrigation season; thus, water in the creek reaches the Raft River only during flood and freshet periods. The winter discharge is small.

Meadow Creek is a minor stream which is largely intermittent, even in its mountain reaches. It drains a small basin bounded by tips of the Black Pine and Sublett Ranges.

Sublett Creek drains the central western part of the Sublett Range. Some water is diverted for irrigation near Sublett, and most of the undiverted water sinks into the ground along a 12-mile reach of channel across alluvial slopes before the channel reaches the Raft River. Sublett Creek contributes very little surface flow to the Raft River.

Heglar Creek, an intermittent tributary of the Raft River, drains the western slopes of the Sublett Range, and passes through deep crooked canyons that were cut largely in fine-grained sedimentary rocks. Water in the creek reaches the Raft River only during floods and freshets.

CLIMATE

PRECIPITATION

The climate of the Raft River basin ranges from subhumid in the high mountains to semiarid on the floor of the Raft River valley. Snowfall at high altitudes commonly is rather heavy, and the total precipitation at some high places is equivalent to about 32 inches of water (table 1). The average annual precipitation ranges from about 10 to 12 inches on the valley floors (table 2), and from about 12 to 25 inches on most upland slopes. The estimated total annual precipitation, averaged for the entire basin, is about 15.5 inches. Most precipitation occurs from January through May; rainfall is light during the growing season and irrigation is necessary for most cultivated crops. Precipitation in southeastern Idaho generally was slightly above normal for 8 years before 1947. After 1947 precipitation declined somewhat, but there were a few years of high precipitation, especially at high altitudes.

TABLE 1.—*Estimated average annual precipitation in upland areas* [1]

Station	Location	Altitude, in feet (from topographic map)	Years of record	End date (1956)	Snowfall (average water content, in inches)	Total average precipitation (inches of water) [2]
Sublett Guard Station	Sec. 8, T. 12 S., R. 30 E.	6,000	19	Apr. 3	12.0	15
Bostetter Ranger Station	Sec. 35, T. 14 S., R. 19 E.	7,500	20	Apr. 2	19.2	22
Howell Creek Guard Station	Sec. 2, T. 13 S., R. 24 E.	8,000	6	Apr. 3	36.8	[3] 38

[1] Based on snow-cover records. See Nelson, M. W., Federal-State Cooperative snow surveys and water-supply forecasts for Columbia River basin: U.S. Soil Conserv. Service rept. (mimeographed), app. 7, April 1956.
[2] Total precipitation as rain and snow is slightly more than the water equivalent of the snow. Rainfall was estimated in order to derive the total.
[3] Six-year record. Adjusted average for past 20 years assumed to be about 32 in.

Snow-gaging stations (pl. 2) are maintained in the Raft River basin at Howell Creek Guard Station in the Albion Range north of the Elba basin, and near Sublett Guard Station in the Sublett Mountains. A gage at Bostetter Ranger Station lies a few miles outside the Raft River basin, about 27 miles west of Almo. Precipitation as snow and estimated rainfall at the Howell Creek station during the period of record averaged 38 inches, while that at Bostetter averaged only 22 inches. The two records, however, are not comparable because that for Howell Creek covers a period of only 6 years, while that for Bostetter is for 20 years. The two periods were not equivalent in precipitation. Precipitation at Howell Creek, if represented by a longer (20-year) record, probably would average about 32 inches.

Most records of precipitation in the Raft River basin are discontinuous, having gaps of two months or more in most years; some stations have been operated only during short periods, and others have been discontinued. The only records for Almo are discontinuous ones for parts of 1908–15. About 23 years of usable record is available for Albion, and comparison of this record with that for Oakley (Goose Creek basin, 52 years of record) indicates that precipitation in the two basins is roughly equivalent. Precipitation records for stations at Almo and Albion were compiled and adjusted by double-mass analysis to obtain a uniform basis for calculating the total volume of precipitation on the basin. Precipitation at Almo, adjusted to the long-term average is 15.6 inches.

TEMPERATURE, EVAPORATION, AND HUMIDITY

Recorded temperature extremes in the Raft River valley are about —14° and 99° F. The mean annual temperature in the central lowland probably is about 42° to 45° F (table 3) and the average frost-free period is about 100 days.

TABLE 2.—*Average monthly and annual precipitation in lowland areas*

[Inches of water. Based on published records of the U.S. Weather Bureau]

Station	Period of record (years)	Altitude (feet above mean sea level)	Average monthly precipitation												Average annual precipitation
			January	February	March	April	May	June	July	August	September	October	November	December	
Idaho:															
Albion	39	4,750	1.47	1.31	1.10	1.47	1.62	1.03	0.56	0.43	0.82	1.23	1.48	1.40	13.9
Almo	9	5,530													[1] 16
American Falls	39	4,316	1.40	1.13	1.28	1.32	1.49	1.02	.63	.56	.71	1.16	1.16	1.10	13.0
Burley	40	4,180	.94	.95	.72	1.15	.90	.79	.33	.48	.51	.82	.88	.92	9.4
Oakley	40	4,600	.76	.76	.81	1.15	1.30	1.10	.62	.60	.76	.92	.77	.65	10.2
Rupert	50	4,204	1.06	.95	.78	1.02	1.01	.84	.41	.45	.56	.94	1.00	.97	10.0
Strevell	[2] 12	5,275	.72	.64	.98	1.23	1.40	1.27	.86	.69	.73	1.04	.96	.70	11.2
Utah:															
Park Valley	38	5,620	.90	.85	.76	.97	.95	1.00	.86	.84	.74	.94	.79	.98	10.6
Snowville	32	4,550	1.21	.97	1.31	1.31	1.59	.85	.53	.48	.76	1.13	.98	1.06	12.2

[1] Estimated by double-mass analysis of incomplete records. Actual value computed is 15.6 in.
[2] Averages for 12-year period through 1952.

TABLE 3.—*Mean monthly and annual temperature in lowland areas*

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

Station	Period averaged (years)	Altitudes (feet above mean sea level)	Mean monthly temperature (° F)												Mean annual temperature (° F)
			January	February	March	April	May	June	July	August	September	October	November	December	
Albion	39	4,750	28.1	30.5	37.9	45.2	52.4	58.7	66.6	66.7	56.5	47.6	37	29.8	46.4
Burley	40	4,180	26	31.1	39	47.3	56.1	62.2	70.6	68.3	59	49.5	36	31.1	47.9
Oakley	40	4,600	28.1	31.6	38.8	47	54.2	61.7	71	69.3	59.5	48.9	38.5	29.9	48.3
Rupert	49	4,204	24.6	29.8	38.3	47	55.3	63.1	71.9	68.6	58.8	49.2	36.9	27.7	47.6
Strevell	[1] 11	5,275	21.8	26.8	34.7	44.3	52.5	59.2	70	68.7	59	48	33.3	27	45.4

[1] Averaged for 11 years through 1952.

Evaporation from a class A Weather Bureau land pan at Minidoka Dam near the north end of the valley averaged about 59.16 inches during May through November 1949–55 (table 4). Evaporation from natural open-water surfaces is much less than from land pans. Application of an adjustment factor of 0.69 (Follansbee, 1934) gives a probable average rate of evaporation from Lake Walcott of about 41 inches per year. A small amount of evaporation occurs during December through April, so the annual total probably is at least 45 inches.

The relative humidity in the semiarid lowlands commonly is low. The nearest humidity-measuring station is at the Pocatello airport, about 45 miles northeast of the mouth of the Raft River, where the average humidity in summer during late afternoons is 22 to 25 percent. Somewhat lower humidity may prevail in the lowlands of the Raft River valley because the valley is not as well watered nor as heavily vegetated as the Pocatello area.

TABLE 4.—*Evaporation from class A land pan at Minidoka Dam*

[Inches of water. Based on records of the U.S. Weather Bureau]

Year	April	May	June	July	August	September	October	November	Total
1949		8.61	12.17	13.56	11.69	9.14	3.68	2.94	61.79
1950		9.67	9.73	13.51	11.21	7.64	5.15		56.91
1951	7.71	9.21	11.25	13.77	10.24	9.24	4.20		65.62
1952		8.91	10.30	12.40	12.52	8.68	5.97		58.78
1953		6.80	9.16	13.84	12.29	9.20	4.77		56.06
1954		9.73	9.65	12.80	12.20	9.00	4.76	2.37	60.51
1955		7.80	10.27	11.37	11.39	8.21	5.42		54.46
Average	7.7	8.68	10.36	13.04	11.65	8.73	4.85	2.65	[1] 59.16

[1] Average of yearly totals. Average of monthly averages gives a value higher than the measured total in any one year. Estimated equivalent evaporation from natural open-water surface: 59.16 × 0.69=41 in.

VEGETATION

Native grasses, other edible plants, and sagebrush occur throughout the noncultivated lowlands in the Raft River basin. Giant rye-grass is abundant in parts of higher basins where the soil retains adequate moisture. Greasewood and rabbitbrush are plentiful in some bottom land and in sheltered mountain areas where there is late snowmelt. The poisonous weed halogeton is sufficiently abundant at some places to be a hazard to stock. Willow grows thickly along the stream channels, and where the water table is near the surface if the growth is not controlled artificially. Juniper and large shrubs are abundant on upland slopes. Dense stands of aspen grow at high altitudes, especially near springs and seeps and at the heads of small valleys. Lodgepole pine and fir also grow at high altitudes.

POPULATION AND AGRICULTURE

In the basin small unincorporated villages, of which the largest is Malta, contain a few to several hundred inhabitants each. There are no large towns. The total population of the basin, estimated from election-precinct data in the 1950 Census of Population, is about 1,300. Much land in the basin is controlled by absentee owners and much of the farm work is done by nonresident seasonal employees. U.S. Highway 30S traverses the Raft River valley from north to south and is connected by all-weather gravel roads to each tributary valley. The closest rail outlet is Declo, about 27 miles northwest of Malta.

The Raft River valley was settled by stockmen before 1870. The priority date of the earliest surface-water right for irrigation is said to be 1872. Stockraising and crop farming still are the principal industries, but there are several small lode mines in the mountains and a small milk- and cheese-processing plant near Malta.

The principal crops are hay and small grain, but potatoes, alfalfa, and seed clover also are grown. Most of the hay and much of the grain is fed locally to stock. Native hay grows in meadowland adjacent to the streams, where it is irrigated with floodwater and by natural subirrigation. Small grain is dry farmed on some upland alluvial slopes adjacent to the mountains. During a reportedly more humid climatic period that ended about 1922, large tracts on the alluvial slopes were dry farmed, but much of that land later reverted to the native state. Since 1947 some tracts of the abandoned land have been redeveloped by means of ground-water irrigation.

WATER USE

No data have been compiled on the use of surface water for irrigation in the Raft River basin, but nearly all usable surface water is diverted for irrigation; very little is used for other purposes. Stock, farm, and domestic water is obtained almost exclusively from wells and springs, and at Malta each of several wells supplies domestic water to about 10 families. A small amount of ground water is used at a food-processing plant near Malta.

Water in the basin is used principally for irrigation. About 43,000 acres of land is irrigated, of which about 35,000 acres is in the Raft River valley. About 10,000 acres in the valley is supplied wholly with surface water from the Raft River and Cassia Creek, and 3,840 acres in the Almo basin is irrigated from Almo Creek and its tributaries. In the Yost basin of Utah about 4,000 acres is irrigated with water from George Creek. The rounded total of 8,000 acres is used hereafter for the Yost-Almo basin. In the Raft River valley about 25,000 acres was irrigated partly or wholly with ground water in 1954. No later data are available and the acreage served exclusively with ground water is not known. In the other basins ground-water irrigation is negligible. Most ground-water irrigation in the basin is in the Raft River valley, and the greatest concentration of irrigation wells is in the vicinity of Malta and Idahome.

GENERAL GEOLOGY

The direct and indirect influences of geologic factors on all phases of the hydrologic cycle are apparent throughout the Raft River basin. The landforms affect the amount and pattern of precipitation (pl. 2) and runoff. The geologic materials and landforms control infiltration of precipitation and ground-water recharge. Subsurface stratigraphic and structural features control the occurrence and movement of ground water throughout the basin.

Although these general facts are apparent to an observant hydrologist, the geology and ground water have not been mapped or studied sufficiently to permit detailed analysis of the relations between them. Such an analysis would be further handicapped by inadequate data on precipitation, temperature, and streamflow.

Only the geologic features that are most closely related to surface drainage and ground water are outlined in this report. Much available geologic information that would be essential in a more comprehensive report is omitted, but the hydrologic interpretations in this report are based largely on that information.

ROCK UNITS

The rock units shown on plate 1 are the ones related most directly to water supply in the Raft River basin. Rocks older than those of the Cassia batholith (Late Cretaceous or early Tertiary) are grouped as a single unit (pre-Cretaceous) because in the basin as a whole they are approximately uniform in their effect on the hydrology. The units shown represent a range of geologic time from Precambrian to Recent, but there are notable gaps in the stratigraphic record. Much of Paleozoic time is not represented and little or none of Mesozoic and early Cenozoic time is represented.

Pre-Cretaceous rocks.—The pre-Cretaceous rocks are extremely diverse; they include metamorphic materials such as quartzite, marble, and schist and a wide variety of consolidated sedimentary rocks such as limestone, sandstone, shale, and chert. Identification and differentiation of these is essential in the field in order to recognize geologic structures and relations and to decipher the geologic history. The rocks have been described in some detail by Anderson (1931).

They are relatively impermeable, and ground water occurs in them chiefly in open joints and in solution cavities in limestone.

Granitoid rocks of the Cassia batholith and outliers.—The Cassia batholith and its outliers and satellite bodies are composed of granitoid rocks, chiefly massive granodiorite. Marginal facies of the rock tend to be granitic, and the granite commonly is porphyritic and gneissic. The batholith probably was emplaced in Late Cretaceous or early Tertiary time.

The rocks of the batholith contain ground water chiefly in fractures near the surface. Where the rock is weathered and comminuted, however, it forms a coarse permeable mantle which is readily infiltrated by water.

Salt Lake(?) formation.—The Salt Lake(?) formation consists of sedimentary and volcanic materials having an aggregate exposed thickness of at least 2,500 feet. The lower 1,700 feet, here called the lower unit, is largely well-stratified clay, shale, volcanic ash, sandstone, and conglomerate—all very similar to beds observed by the senior author in the Salt Lake(?) formation east of this area in Oneida County. Clay and shale predominate in the lower part of the lower unit and volcanic ash in the upper. The ash is white to gray and pumiceous. Other sedimentary materials are white to gray, greenish, and bluish.

The upper 800 feet of the formation, here called the upper unit, consists predominantly of silicic volcanic flow rocks, chiefly quartz latite, interbedded with tuff, ash, and minor amounts of clastic sedimentary rocks like those in the lower part of the formation. The two units are distinguished only by the relatively great abundance of volcanic rock in the upper unit, and of sedimentary materials in the lower; there is no sharp boundary between them. Much of the volcanic ash and tuff has been reworked by running water and at least some of the material was redeposited as lake beds. The formation is capped by quartz latite flow rock. This is similar to flow rocks within the formation, but it is mappable as a separate unit and is not here included in the Salt Lake(?) formation.

The entire sequence resembles that in the Goose Creek basin west of Oakley, as described by Piper (1923, p. 28). Similar rocks on the south side of the Raft River Mountains have been described by Felix (1956) and assigned to the "Salt Lake group or Payette formation." The typical Salt Lake formation commonly is thought to be Pliocene in age, but Anderson (1931), Kirkham (1931), and Felix (1956) all suggest correlation of the beds in the Raft River basin with the Miocene and Pliocene(?) Payette formation of central eastern Idaho. Piper (1923) assigned similar rocks in the Goose Creek basin to the late Miocene(?). The Salt Lake(?) formation, chiefly the upper unit, crops out in foothills and mountains east, south, and west of the Raft River valley. The Malta Range seems to be made up almost wholly of this formation and the overlying quartz latite caprock.

The Salt Lake(?) formation was deposited on a preexisting erosion surface which had considerable relief. The formation itself was eroded to form an irregular landscape. Hence, the thickness now present in the area probably varies widely from place to place.

The Salt Lake(?) formation is tapped by at least a few wells in the Raft River valley, and presumably it is widely present at depth under the valley floor beneath younger sediments, chiefly the Raft lake beds and Quaternary alluvium and hill wash. The Salt Lake(?) formation as a whole has low permeability, but at some places it includes thin beds of permeable gravel. These and some of the sand beds yield moderate amounts of water, chiefly to artesian wells in the Raft River valley.

Because of the lithology and thickness of the sequence of clay and sand beds penetrated by well 11S–26E–28ab1 (see log, p. 113), the well may be in the Salt Lake(?) formation. The "basalt," reported in the interval from 241 to 256 feet, might be one of the rare basalt flows in the Salt Lake(?) formation, but more likely it is a flow of dark latite. It does not seem possible that this is Snake River basalt, because nowhere in this area is that formation known to be overlain by a thick sequence of sediments like those shown in the well log. A few other wells in T. 11 S. Rs. 26 and 27 E. tap beds resembling the Salt Lake(?) formation beneath a few feet or tens of feet of alluvium. Farther south, some wells are entirely in alluvium and hill wash, whereas others are in what seem to be beds of the Salt Lake(?) beneath alluvial cover.

Belief that wells in the valley tap the Salt Lake(?) formation has one principal drawback. The valley is downfaulted and beds of the Salt Lake(?), buried beneath the younger sediments of the valley floor, should include the upper unit of the Salt Lake(?) formation. That unit includes many quartz latite flows and is overlain by a substantial thickness of quartz latite, which should be the first beds penetrated by the drill beneath the alluvium. However wells in this area do not penetrate rocks of the upper unit. Although the Salt Lake(?) formation and quartz latite were extensively eroded before deposition of alluvium, it seems improbable that all the latite was removed at each drilling location.

Massive volcanic rocks.—Volcanic flows of quartz latite are well exposed in the mountainous southwestern part of the mapped area, where single flow layers range from 50 to 300 feet in thickness (Anderson, 1931). The largest exposure, however, is that which overlies the Salt Lake(?) formation and covers practically the entire length and breadth of the Malta Range. Beds of the Salt Lake(?) are highly susceptible to landslide movement, and the quartz-latite caprock is a conspicuous marker that facilitates identification of the landslide blocks.

The flow rocks consist of black glassy latite or rhyolite, dark porphyritic obsidian, vesicular latite, and bluish-gray and pink felsite containing quartz and feldspar phenocrysts. The common felsitic phase is thinly planar, but some of the flows have very well defined columnar jointing. Flow banding is common.

The geologic age of the quartz latite is known only to the extent that it is within the limits of Miocene or Pliocene time. Anderson (1931) assigned the beds to the late Miocene(?), but in this report the quartz latite is considered to the Pliocene(?) because of its relations to the Salt Lake(?) formation and Raft lake beds of Pliocene(?) age.

The rock is unimportant as an aquifer because its average porosity is low and it contains saturated zones only locally. The platy and jointed materials, however, allow infiltration of appreciable amounts of precipitation. The rock occurs widely at higher altitudes where precipitation is high, so it has an important influence on the volume of runoff and infiltration.

Raft lake beds.—The Raft lake beds of late Pliocene(?) age have been identified in outcrops only in the extreme northeastern part of the mapped area. About the eastern two-thirds of the outcrop area shown on the geologic map is not drained by the Raft River or its tributaries, and that part is not included in later calculations in this report of the water yield of the Raft River basin.

The Raft lake beds are principally buff, yellow, and brown clayey silt, silt, and sand. Caliche layers are common in outcrops and the beds include a few lenses of gravel. The exposed thickness near the mouth of the Raft River is only about 50 feet, but thicknesses as great as 200 feet were reported east of the mapped area near Fall Creek by Stearns (1938, p. 48). Stearns said that the beds have been tilted and dip about 5° NW. The beds occur beneath the alluvium just east of the river in Tps. 9 and 10 S., but they do not crop out east of the mouth of the Raft River. In the Northern Plains section they have been largely eroded out and replaced by basalt flows. Stearns believed that much of the Raft River valley is underlain by Raft lake beds beneath a cover of alluvium. Well drilling has disclosed sediments of probable lacustrine origin at many places beneath the floor of the valley, and some of these resemble the Raft lake beds. Other beds, however, are certainly part of the Salt Lake(?) formation.

In general, subsurface lake beds at shallow depth beneath the north-central part of the valley floor probably are Raft lake beds or younger whereas, those at greater depth and along the flanks and southern part of the valley probably are beds of the Salt Lake(?) formation.

The Raft lake beds may be represented in the depth interval between 35 and 300 feet in well 11S–26E–25bc1. If so, the thickness of the unit is 265 feet at that point. It is entirely possible, however, that the interval is in the Salt Lake(?) formation. The same is true of the interval from 46 to 402 in well 27bb1, except that the Salt Lake(?) formation is the more likely choice. A thickness of 356 feet of Raft lake beds seems very unlikely.

In general, the Raft lake beds are not good aquifers. Most of the beds are low in permeability and their fine-grained texture makes it difficult to develop wells that do not pump sand. Several irrigation wells which have moderately large yields, however, withdraw water from these beds north of Yale near the Raft River (pl. 6).

Snake River basalt.—The Snake River basalt underlies the entire Northern Plains section. Windblown silt mantles the basalt in much of the area, reaching a thickness of tens of feet. Basalt is shown on the geologic map in areas in which it crops out or is mantled only by surficial material. The basalt flows are part of a thick series which is widely distributed in the Snake River Plain. Flows that occur at the surface in the Northern Plains section were derived largely from local volcanic vents. The cones and domes that formed around these vents are the most conspicuous landmarks in the Northern Plains section.

Most of the rock is dark-gray to black olivine basalt which has been practically unaffected by weathering or erosion. Many of the flow surfaces have the ropy and billowy structure characteristic of pahoehoe basalt, and most of the exposed flows are highly vesicular. Only minor erosion has occurred since the flows were emplaced, and no deep gullies have been cut, so no vertical cross sections of the rocks are exposed. However, many of the flows undoubtedly have the columnar jointing structure that is prominent in many flows in the Snake River basalt elsewhere. Well logs show that at some places beds of clastic sediments a few feet or tens of feet thick are intercalated with basalt flows.

An unbroken unit of basalt is practically impermeable, but the basalt is strongly jointed and creviced. Open joints and other fractures, brecciated layers, and blocky structure impart relatively high formational permeability to the basalt. Hence it is copiously water bearing at many places. Wells in the basalt commonly yield large quantities of water.

The Snake River basalt in this area was assigned a Pleistocene age by Anderson (1931) and Stearns (1938) but it is now thought by some authors to be of Pliocene to Recent age.

Hill wash, alluvium, and glacial deposits.—Deposits of silt, sand, mud, and gravel are widespread on valley floors and scattered on the mountain slopes. Much of the material has been transported for long distances by running water, as along the floor of the Raft River valley, where it is moderately to well sorted and distinctly stratified. Where the alluvium has not been moved far, as in alluvial fans along the bases and lower slopes of mountains, it is less well sorted and poorly stratified. Hill wash along the mountain slopes is commonly very poorly sorted and lacks stratification.

Morainal and outwash deposits in the Albion and Raft River Ranges, on South Mountain, and in the Albion Basin have been described by Anderson (1931). These materials are grouped on the map with the alluvium and hill wash. Anderson assigned the morainal and outwash deposits to the Pleistocene epoch and the hill wash and alluvium to the Pleistocene and Recent.

Windblown deposits are not distinguished on the geologic map, but they are widespread; they overlie much of the basalt in the Northern Plains section and other formations in the vicinity of Sublett, Heglar, and Albion. The deposits reach a thickness of 100 feet or more in depressions on the Snake River basalt, on leeward slopes of hills, and in sheltered basins. Most of the material is silt and is distinctly loessial; it is buff to brown, highly porous, unstratified, and has crude columnar structure. The age probably is late Pleistocene and Recent.

The windblown material is not an aquifer because it is above the zone of saturation. It makes rich soil and has a relatively high moisture-holding capacity.

Soils and subsoils.—Most parts of the Raft River basin are sites of either contemporary erosion or deposition. Owing to that and to the dry climate, only rudimentary soil profiles have developed. The term "soil," therefore, is used here in a very general sense. No soil map of the area has been published.

Some upland soils, such as windblown deposits, are excellent for dry farming because they absorb and retain moisture well. Much upland soil, however, is gravelly or sandy and shallow; it does not retain moisture well and contains little organic material. The principal farming area is in the Raft River valley, where irrigation is necessary for consistent success with most crops.

In the lowlands of the Raft River valley the soils near the Raft River are generally rather fine grained. In a belt about 1 mile wide on either side of the river channel, the subsoil is gravelly but is thinly covered at many places by windblown deposits. Toward the mountains the soil grades into loose gravel and talus breccia. The valley floor is bounded by coalescing piedmont alluvial fans which formed where ephemeral and intermittent mountain streams debouch onto the valley floor. These streams seldom reach the Raft River because water discharged from the mountains sinks into the fan gravel; therefore, the fans are important sites of ground-water recharge. Cassia Creek, the only tributary that contributes much runoff to the Raft River, crosses a large fan and, by infiltration, recharges the ground water that feeds springs along the Raft River channel near Malta, where the river crosses the toe of the fan.

From Idahome southward a few miles, the soil of the central valley floor is underlain by silt and pea-sized gravel to depths of 2 to 6 feet. This material is underlain in turn by coarse clean gravel to depths of 22 to 30 feet. Below is a sequence of alternating beds of clay, silt, sand, and loosely cemented gravel. The thickness of these materials is about 170 feet in well 15S–26E–23dd1 (see logs, p. 119, 116). Alternating layers of sand, silt, and clay underlie the cemented gravel to depths of 1,400 feet in well 13S–26E–1db1 and 540 feet in well 15S–26E–23dd1. The lateral extent of the cemented gravel is not known. The beds at depth beneath the gravel include lacustrine and volcanic materials as well as alluvium. Many wells tap beds of loosely cemented gravel at depths as great as several hundred feet. Some of the gravel is buried alluvial fill in ancient stream valleys which were cut in volcanic and lake beds. Other gravel is fan and flood-plain deposits interbedded with layers of buried soil, windblown material, and possibly local lake beds.

STRUCTURE

The principal structural features in the Raft River basin, many of which were worked out by Anderson (1931), are controlling factors in the hydrology of the area, as is explained later in the section on "Physiographic development." No structures other than faults are identified on the map (pl. 1), and it shows only the principal faults. Considerably more structural detail is shown on the map by Anderson (1931).

The varied geologic structures in the Raft River basin include complex folds, low-angle thrusts, and tilted blocks bounded by normal faults. The most conspicuous faulted features, and those most obviously related to the hydrologic peculiarities of the basin, are block-fault mountains formed by high-angle normal faults. Another important feature is the so-called Snake River downwarp, the most impressive single geologic structure in southern Idaho. The Northern Plains section of the Raft River basin is a small segment of the southern flank of the downwarp.

Thrust faulting occurred late in Cretaceous or early in Tertiary time, when compressive lateral forces of unknown origin threw the rocks into tight asymmetric folds. Under continued lateral pressure, low-angle shear planes developed, and along these planes great thrust sheets of folded rock overrode other rocks. According to Anderson (1931, p. 68) the thrust planes were nearly horizontal and movement along them produced displacements of tens of miles. The tight folds and thrust faults within the block-faulted mountains in the Raft River basin are similar to mountain structures in southeastern Idaho, which are typical of the Rocky Mountains generally.

High-angle tear and normal faults later broke and displaced the earlier structures and brought some of the ranges into their present topographic form. Some of this faulting occurred near or shortly after the close of the epoch of thrust faulting, but the normal faulting occurred mainly in middle and late Cenozoic time. Some faulting may have occurred as late as Recent time. In the Malta Range, high-angle normal faulting produced a tilted block mountain having a general resemblance to block mountains of the basin-and-range type in Nevada and Utah. Elsewhere, the normal faulting modified the older landforms to varying degrees, but did not produce typical tilted block-fault mountains.

The principal block faults trend generally northward and seem to be unrelated to the regional trend of structures which formed earlier. The normal fault along the east flank of the Malta Range produced an impressive scarp which was subsequently modified by extensive landslides. The landslide blocks rode out over the fault trace and onto the adjacent piedmont alluvial fans, so that the fault is concealed and some of the quartz latite shown on plate 1 on the east slope of the Malta Range overlies the fault line and the alluvium.

Inferred transverse high-angle faults, not shown on the map, are believed to truncate the south end of the Malta Range at The Narrows and to transect the range where Cassia Creek crosses from the Elba basin into the Raft River valley.

PHYSIOGRAPHIC DEVELOPMENT

The landforms and geologic structure of the Raft River basin largely control the main surface-drainage pattern and the occurrence and movement of water. The physiographic history of the area, therefore, helps to explain its unusual hydrologic features. The principal physiographic features are the result of geologic events, most of which occurred after the mountain-making earth movements around the close of the Mesozoic era. The following summary of these events is based largely on the interpretations of Anderson (1931, p. 96–101) and Streans (1929, p. 13–14).

Folding, thrust faulting, and related normal faulting that occurred around the close of the Mesozoic era produced mountain masses which subsequently were carved by erosion into rugged terrain of considerable relief. Great thicknesses of the older rocks were removed by erosion which continued during early Cenozoic time and probably reduced the area to a plain having only low relief.

Near middle Miocene time, regional uplift, possibly accompanied by normal faulting, led to renewed erosion and the ancient plain was cut again by broad deep valleys. Erosion was followed by aggradation, which produced thick fluvial and lacustrine deposits on the valley floors and some of the lower hills. An explosive volcanic episode followed, producing vast quantities of volcanic ash which blanketed much of the area. Some of the ash was reworked by running water and deposited as intercalations and tongues in alluvial and lacustrine sediments. Most of the ash, however, probably remained where it fell, blanketing the country and accumulating to depths of many hundreds of feet at some places. Occasional flows of lava during this period are represented by latitic flow rocks in the Salt Lake(?) formation. The volcanic episode culminated with extrusion of great quantities of latitic lava, which formed the quartz latite rocks shown on plate 1. Air-fall deposits of ash and tuff are intercalated with the latitic flows at some places. At the end of this volcanic episode the region probably was a vast lava plain on which erosion was active. In late Pliocene(?) time uplift occurred, accompanied by minor folding or tilting and faulting. Erosion again dissected the area, then reduced it to a plain. Quaternary time has been largely an interval of uplift, faulting, and erosion in elevated areas, and of deposition in the lowlands. High-angle normal faulting during Pleistocene time eliminated or modified many earlier topographic features, causing profound changes in drainage patterns and producing the block-fault mountains which are so prominent in parts of the area today. Relatively little erosion has occurred in Recent time.

Subsidence of the Snake River Plain began at least as early as Pliocene time and probably much earlier. A few basalt flows were extruded during the Pliocene, but the main period of basalt eruption was in Pleistocene time. Some basalt flooded the lower valley of the ancient Raft River for several miles above its mouth. No large displacement has occurred in any of the exposed basalt layers, indicating that the flows in that area postdated the main normal-faulting movements in the Raft River valley.

During Pleistocene time alpine glaciers were prevalent in the mountainous areas. South Mountain and the Albion Range were extensively glaciated, but evidence of glaciation in other mountain areas is less abundant.

Fluvial erosion of the uplands and deposition of sediments in the valleys and structural basins have been active processes since early Pleistocene time, and the alluvial deposits probably are hundreds of feet thick at some places in the lowlands.

Certain peculiarities of the drainage pattern of the Raft River valley are direct expressions of structural control. The present drainage system probably developed in the following way:

At one time, two principal valleys trended northward, parallel to each other, on either side of the Malta Range. These valleys, formed largely by normal faulting, were drained northward by separate streams. The eastern valley was the area now drained by the Raft River downstream from The Narrows and by Clear Creek, which was then the headward part of the Raft River. There was no transverse stream and The Narrows did not yet exist. The western valley included the drainage areas of modern Marsh Creek, upper Cassia Creek (Elba basin), and the reach of the Raft River upstream from The Narrows. At that time Cassia Creek did not flow through the Malta Range.

The early drainage system probably was disrupted by late normal faulting which probably cut transversely across the divide between the ancient valleys at two places. The fault blocks stemmed the northward course of the western stream at these two places, one near The Narrows and the other about 14 miles north of The Narrows. The upstream (southern) reach of the western stream turned eastward along the fault depression through The Narrows, joined the eastern watercourse, and became part of the modern Raft River. Fourteen miles north of The Narrows the middle segment of the western stream was diverted eastward through the new fault rift in the Malta Range and joined the Raft River in the eastern valley. This stream segment became Cassia Creek.

By these changes, all the runoff from the central and southern parts of the ancient western valley was diverted eastward to the present Raft River drainage system (see pl. 4). The northern remnant of the ancient western valley is occupied by Marsh Creek, which still flows northward to the Snake River.

During or near the time these drainage changes were occurring, the Raft lakebeds were accumulating, possibly in a lake or lakes impounded by basalt flows on the Snake River Plain. After the lake drained, the newly enlarged Raft River flowed across the lakebeds

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through the area here called the Northern Plains section, and joined the Snake River somewhere west of the present mouth of the Raft. The Raft lakebeds eventually were extensively eroded and entirely removed from parts of the northern section. The Raft River valley, at least north of Idahome, was cut much more broadly and deeply than the modern valley, and either the Raft or the Snake River deposited some alluvial sand and gravel in that area after the lake beds were eroded. Alluvium was deposited intermittently in the northern plains section during the later episode of basalt eruption. At well 11S–26E–12ab1, for example, about 29 feet of windblown sediment overlies a succession of basalt layers totaling 94 feet in thickness. Underneath the basalt is 32 feet of gravel, clay, and silt, beneath which is 48 feet of basalt. At well 11S–27E–3da1 the upper basalt sequence is 52 feet thick and is underlain by nearly 300 feet of fine sand. Well 9S–25E–23db1 near Lake Walcott was drilled through 174 feet of basalt and ended in basalt. This evidence indicates also that the ancient Raft River valley in the vicinity of the wells was cut at least several hundred feet lower than the present surface of the basalt flows.

Very late in Pleistocene time or early in the Recent, basalt erupted on the Snake River Plain, dammed the Raft River and covered its valley to a point several miles above its mouth. The later of these flows erupted from four small lava domes in the Northern Plains section. These domes rise 50 to 250 feet above the general level of the surrounding plain. The river established a new course eastward and northward around the margin of the basalt flows, subsequently cutting a moderately deep valley along the eastern boundary between the basalt and the Raft lakebeds.

The gravel deposits in the Raft River valley, which are important aquifers, undoubtedly have been accumulating continually since the interval of lakebed deposition closed. Alluvial fill extends northward from the central part of the Raft River valley, overlapping basalt flows and thinning to a featheredge on them.

HYDROLOGIC ROLE OF THE NARROWS

The floor of The Narrows is somewhat more than half a mile wide and about 2 miles long. The north valley wall is formed of volcanic quartz latite. The south wall, composed of the same material, seems to be an outlier, but it may be a landslide block. The volcanic rock probably is underlain by volcanic ash, tuff, and sediments of the Salt Lake(?) formation. Unconsolidated Quaternary alluvium underlies the present floor of The Narrows. This alluvial fill is in a buried valley that was cut through the quartz latite and into the Salt Lake(?) formation, which probably underlies the alluvium. South of the exposed volcanic rock, undifferentiated Cambrian rocks crop out and dip gently eastward. The Salt Lake(?) formation probably rests at depth on an irregular surface formed on Paleozoic rocks.

Owing to the physical character of the rocks that surround the Yost-Almo Basin and occur at depth beneath it, most of the ground water that is discharged by underflow from the Yost-Almo Basin probably enters the Raft River valley by way of The Narrows, just as the surface water does. Except for the permeable alluvium, rocks beneath The Narrows are generally low in permeability. Hence, much of the ground-water flows through the alluvium; flow through the Salt Lake(?) and older formations is small but is less restricted in width. Some water may leave the basin also along the transverse fault which is inferred to underlie The Narrows, or in permeable zones adjacent to the fault surface. Movement of water into and through the Salt Lake(?) formation is confirmed by artesian wells which tap this formation about 1 mile below the mouth of The Narrows.

No direct information is available about the depth through the alluvium to the older sediments. Old wells and test holes in The Narrows reportedly extended to depths of only about 30 feet, all in boulder gravel. The geologic history of the area indicates that the fill is much thicker—probably at least 10 times thicker. Much of the material evidently is very coarse and highly permeable.

WATER RESOURCES

All water in the Raft River basin is derived from precipitation. The amount of the precipitated water that can be used in the basin depends on its disposition and distribution before it leaves the basin. Much of the upland precipitation is snow, some of which disappears by sublimation. Some melt water and rainwater evaporates, some restores soil moisture, some runs off the mountain slopes at the surface, and any that is left over becomes ground water, which migrates toward the basins by underflow.

Native vegetation consumes a large percentage of the soil moisture. Most surface water that is discharged by the upland streams during the growing season is diverted for irrigation, and much of the diverted water is consumed by crops. An undetermined but large part of the intermittent runoff from upland slopes enters the soil and replenishes soil moisture and ground water. All water that is not consumed in the uplands and higher valleys reaches the Raft River valley by surface runoff and underflow. Water in the valley lowland is depleted by native and cultivated vegetation, and the unconsumed residual water is discharged from the Raft River valley to the Snake River Plain.

The purpose of this section is to appraise the basinwide contribution of water by precipitation, to analyze the movement and disposition of the water by natural and artificial means, and to estimate the residual perennial supply on and in the ground that may be available for use.

VOLUME OF PRECIPITATION

By W. B. LANGBEIN and R. L. NACE

The methods of analysis and computation employed here were developed by W. B. Langbein in unpublished notes. An extension of these methods to compute water yield is developed by Langbein on pages 36–47. To derive an estimate of the water yield of the Raft River basin, the volume of precipitation on the basin was first computed by the steps outlined below.

The few available precipitation data were organized and plotted against station altitudes. The trend of the relation between precipitation and altitude was defined (fig. 3), and its upward extension was guided by the relation in the Bonneville Basin as derived in a study by the University of Utah, (1953, p. 26). Precipitation at the Howell Creek Guard Station averaged 38 inches during the short period of record, but it is adjusted here to the probable long-term value of 32 inches.

Deviations from the curve, in inches of recorded rainfall, were plotted on an overlay of a topographic map having a scale of 1:250,000, and contours were drawn through points of equal deviation (pl. 2). The contours show rather systematic geographic variations in the deviations: the values are plus in the western part of the basin, minus in the southern part, and nearly zero in the eastern part. This pattern seems logical because many storms move in from the west and northwest, while the southern area lies in the rain shadow of the western mountain complex.

Isohyetal lines were drawn on the map in accordance with the precipitation-altitude graph in figure 3, but were shifted in accordance with the contoured regional deviations. The topographic contours and precipitation-altitude graph were followed literally, except that minor deviations in the contours were smoothed out when drawing the isohyets; also a 15-inch depression contour was drawn around Junction Creek valley, which probably is a rain-shadow area despite its high altitude and western location.

The area between each pair of isohyets in each subbasin was measured with a planimeter and the volume of precipitation was computed from the average in that area (table 5, columns 4 and 5).

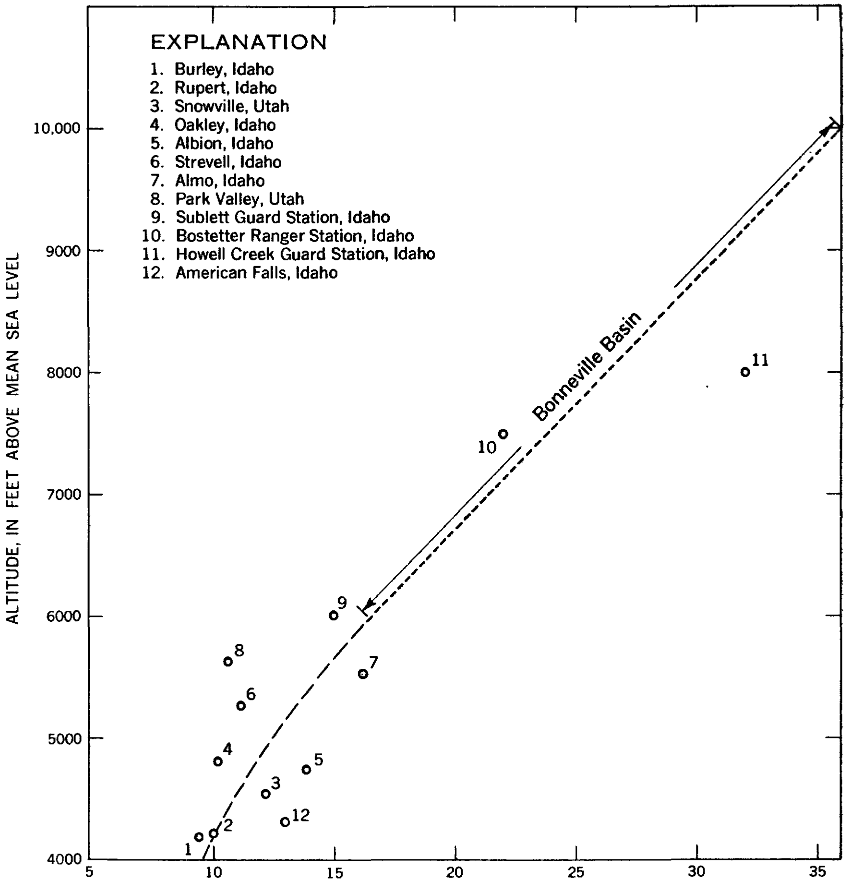

FIGURE 3.—Relation between altitude and precipitation in Raft River basin and vicinity.

TABLE 5.—*Estimated average yearly volume of precipitation and water yield in Raft River basin*

Subarea	Area		Average precipitation		Water loss		Water yield	
	Square miles	Acres	Rate (inches)	Volume (acre-feet)	Rate (inches)	Volume (acre-feet)	Rate (inches)	Volume (acre-feet)
Yost-Almo Basin	411	263,000	17.9	392,000	14.4	315,000	3.5	77,000
Elba Basin	105	67,200	21.1	118,000	16.2	90,600	4.9	27,400
Meadow Creek Basin	81	51,800	16.3	70,400	14.4	62,200	1.9	8,200
Sublett Creek Basin	62	39,600	16.2	53,500	14.0	46,200	2.2	7,300
Heglar Creek Basin	80	51,200	16.1	68,700	14.0	59,700	2.1	9,000
Raft River valley	716	458,000	13.7	523,000	12.3	470,000	1.4	53,500
Northern Plains section	107	68,500	11.0	62,800	10.8	61,600	.2	1,200
Total	1,562	999,500		[1] 1,288,400		1,105,000		[2] 183,600
Average rate			[3] 15.5		13.3		2.2	

[1] The rounded value of 1,290,000 acre-feet is used in the text.
[2] The rounded value of 184,000 acre-feet is used in the text.
[3] Basinwide average = 1,288,600 ÷ 999,500 × 12.

The estimated volume, thus derived, of yearly precipitation on the Raft River basin is 1,290,000 acre-feet. No means are available to estimate the accuracy of the computation. The method is reliable with adequate data, and in the present study the result is the best that the authors could obtain with available data.

EVAPOTRANSPIRATION

Evapotranspiration is the reverse of precipitation. It is the combined natural processes of evaporation and transpiration whereby water returns from the land to the atmosphere. Transpiration is the process whereby plants exhale moisture into the atmosphere. Evapotranspiration is sometimes called consumptive use. Only natural consumptive use is treated in this section. Cultivated vegetation occupies a relatively small area, and consumptive use by crops is discussed in the section on "water development and its effects," under the heading "Water depletion and net water yield." Owing to a great range in altitude, to varied topography, and to differences in vegetation in different altitudes and temperature zones, the rate of evapotranspiration in the Raft River basin varies widely.

Several methods are available for direct measurement of evapotranspiration (Thornthwaite and Mather, 1951), but no measurements have been made in the Raft River basin. The potential rate of evapotranspiration depends on climatic factors, but the actual rate is limited by the amount of moisture available in the soil. Potential evapotranspiration is defined as the amount of water that would be lost from a surface fully occupied by vegetation if there were no deficiency at any time of water in the soil for use by the vegetation. In dry climates actual evapotranspiration is less than the potential.

THORNTHWAITE METHOD OF ESTIMATION

A method for estimating potential evapotranspiration was described by Thornthwaite (1948). For application of the method precipitation and temperature records are needed and a correction factor is applied, depending on the latitude of the station from which the record was obtained. Potential evapotranspiration was computed by the Thornthwaite method for the weather station at Strevell, Idaho (table 6), and for the stations at Oakley and Albion (tables 7 and 8). From the computed values of the heat index at each station, nomograms were constructed (fig. 4). The relation between the logarithm of temperature and that of unadjusted potential evapotranspiration is linear. Therefore, straight lines on a logarithmic plot define this

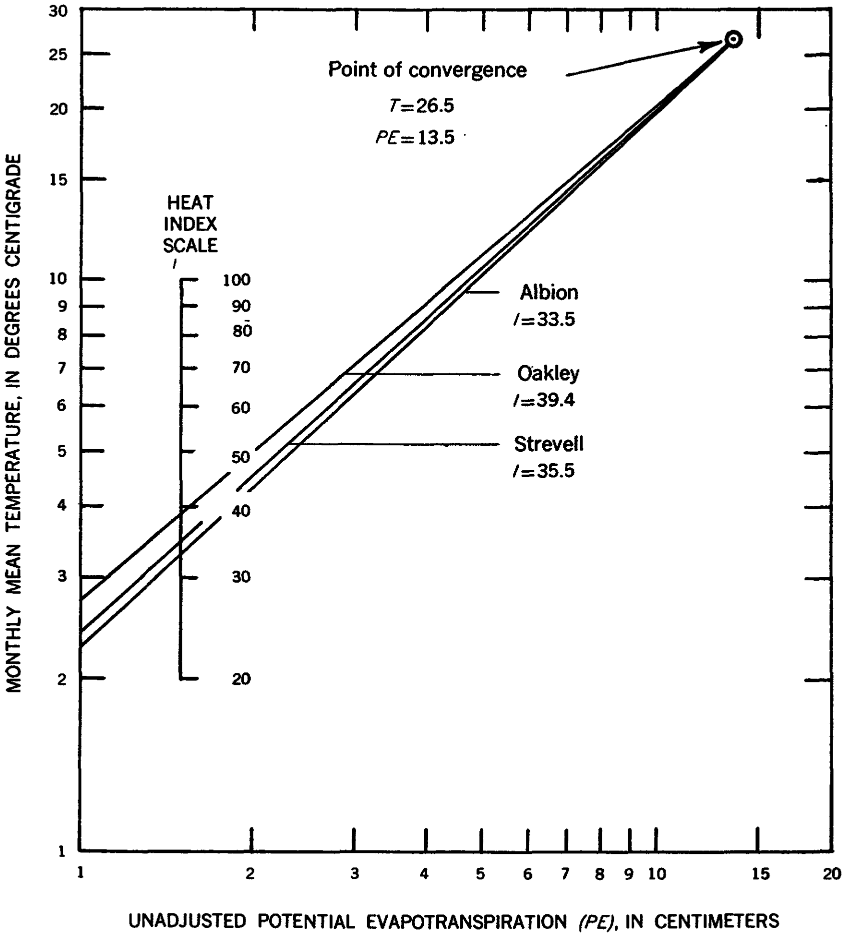

FIGURE 4.—Nomograms for estimating unadjusted potential evapotranspiration. (For explanation of nomograms see Thornthwaite, 1948.)

relation. All lines pass through a point of convergence where temperature is 26.5°C and potential evapotranspiration is 13.5 cm. The slope of the line is fixed by the heat index (*I*) for the station. At Strevell, for example, *I* is 36.5, and the line ruled through that point on the *I* scale shows the relation between temperature and unadjusted potential evapotranspiration at that station. From the nomograms, potential monthly evapotranspiration was computed, the correction factor was applied, and values computed in centimeters were converted to inches. The computations and derivation of nomograms are described fully by Thornthwaite (1948).

TABLE 6.—*Potential evapotranspiration at Strevell, Idaho*

[Altitude, 5,275 feet; lat. 42° N]

Month	Average temperature [1]		Heat index (*I*)	Potential evapotranspiration			
	°F	°C		Unadjusted (centimeters)	Correction factor	Adjusted	
						Centimeters	Inches
January	21.8	−5.67	0	0	0.82	0	0
February	26.8	−2.95	0	0	.83	0	0
March	34.7	1.50	.16	.7	1.03	.72	.28
April	44.3	6.83	1.59	3.1	1.12	3.47	1.36
May	52.5	11.4	3.48	5.2	1.26	6.56	2.58
June	59.2	15.1	5.33	7.6	1.27	9.67	3.78
July	70.0	21.1	8.85	10.7	1.28	13.7	5.40
August	68.7	20.4	8.41	10.2	1.19	12.1	4.76
September	59.0	15.0	5.28	7.5	1.04	7.81	3.04
October	48.0	8.89	2.39	4.2	.95	3.94	1.55
November	33.0	.56	.03	0	.82	0	0
December	27.0	−.56	0	0	.79	0	0
Sum			35.5	49.2		58.0	22.8

[1] Mean yearly temperature is 45.4 °F (7.63 °C).

TABLE 7.—*Potential evapotranspiration at Oakley, Idaho*

[Altitude, 4,600 feet; lat. 42° N+]

Month	Average temperature [1]		Heat index (*I*)	Potential evapotranspiration			
	°F	°C		Unadjusted (centimeters)	Correction factor	Adjusted	
						Centimeters	Inches
January	28.1	−2.17	0	0	0.82	0	0
February	31.6	−.22	0	0	.83	0	0
March	38.8	3.77	.66	1.54	1.03	1.5	.63
April	47	8.3	2.15	3.6	1.12	4.0	1.6
May	54.2	12.3	3.91	5.7	1.26	7.2	2.8
June	61.7	16.3	5.98	7.8	1.27	9.9	3.9
July	71	22	9.42	11.0	1.28	14.1	5.6
August	69.3	20.7	8.59	10.2	1.19	12.1	4.8
September	59.5	15.3	5.44	7.42	1.04	7.72	3.0
October	48.9	9.39	2.60	4.27	.95	4.05	1.6
November	38.5	3.61	.61	1.48	.82	1.21	.44
December	29.9	−1.16	0	0	.79	0	0
Sum			39.4	53.01		61.8	24.4

[1] Mean yearly temperature is 48.2 °F (9.01 °C).

TABLE 8.—*Potential evapotranspiration at Albion, Idaho*

[Altitude, 4,750 feet; lat. 42° N+]

Month	Average temperature [1] °F	Average temperature [1] °C	Heat index (I)	Potential evapotranspiration: Unadjusted (centimeters)	Correction factor	Adjusted: Centimeters	Adjusted: Inches
January	28.1	−2.17	0	0	0.82	0	0
February	30.5	−.83	0	0	.83	0	0
March	37.9	3.27	.53	1.47	1.03	1.51	.59
April	45.2	7.33	1.78	3.45	1.12	3.86	1.58
May	52.4	11.3	3.44	5.6	1.26	7.06	2.78
June	58.7	14.7	5.12	7.4	1.27	9.41	3.70
July	66.6	19.2	7.67	9.8	1.28	12.5	4.92
August	66.7	19.2	7.67	9.8	1.19	11.6	4.57
September	56.5	13.6	4.55	6.7	1.04	6.97	2.74
October	47.6	8.67	2.30	4.2	.95	3.95	1.55
November	37.0	2.77	.42	1.23	.82	1.01	.40
December	29.8	−1.22	0	0	.79	0	0
Sum	------	--------	33.48	49.65	--------	57.9	22.8

[1] Mean yearly temperature is 46.4° F (7.98° C).

The estimates derived from the computations show that potential evapotranspiration is about 22.5 inches at Strevell, 24.4 at Oakley, and 22.8 at Albion. That is, potential yearly evapotranspiration is about double the yearly precipitation at those stations. This result is not surprising because a permanent deficiency in the moisture supply is characteristic of semiarid climates. The vegetation adapts itself to moisture deficiency and does not cover all the available land area. At most places in the semiarid part of the basin, vegetation is somewhat sparse, probably ranging from 40 to 75 percent of full coverage.

The estimated potential evapotranspiration is compared to measured precipitation at the three stations in figure 5. The graphs show that during the growing season (April to October) potential evapotranspiration and precipitation are about equal only in the first and last months of the season. During the rest of the season there is a general moisture deficiency. During winter months the excess of precipitation ranges from 2.8 to 4.0 inches. If this were distributed evenly throughout the winter, about 9 to 12 inches of the soil column would be saturated, and the water would be held as a reserve for evapotranspiration in the following growing season. There would be no excess for runoff or ground-water recharge.

If the rain were distributed in gentle showers at regular intervals throughout the year and from year to year, it would serve only to restore soil moisture and would be dissipated entirely by evapotranspiration. Precipitation is not evenly distributed, however, and much

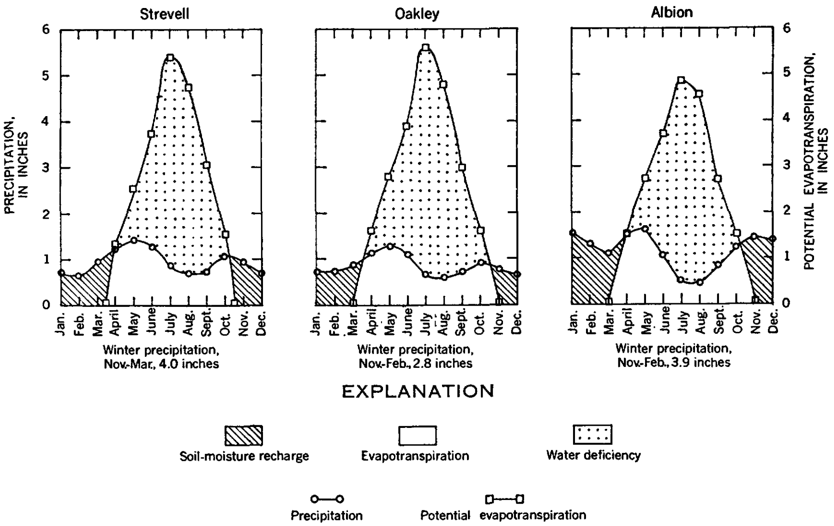

FIGURE 5.—Estimated potential evapotranspiration compared to precipitation at three stations in southern Idaho.

of the winter precipitation accumulates as snow, which melts rapidly in the spring. The supply of water from rapid snowmelt and from heavy showers in summer exceeds, at times, the field capacity of the sandy and gravelly soils and subsoils, and results in runoff and recharge of ground water.

Rough estimates might be made by the Thornthwaite method for several locations at different altitudes in the Raft River basin, using estimated values for temperature and precipitation. One could build up, piece by piece, a composite picture of estimated evapotranspiration in the basin. The Thornthwaite method, however, is cumbersome and requires many computations and adjustments. Fortunately, records of precipitation and of the water yield of drainage basins can be used in a simplified method, which is less costly in time and effort. The total consumptive use of water in the basin, computed by the simplified method, is 1,105,000 acre-feet yearly (table 5, column 7). The simplified method of estimation will now be developed to show the derivation of the estimate of total consumptive use and total water yield.

SIMPLIFIED METHOD OF ESTIMATION

By W. B. LANGBEIN

The method of estimating evapotranspiration introduced here was developed during a nationwide study of the streamflow and runoff characteristics of river basins. It is applied here to an important water problem in an area for which there is practically no direct information about water yield. The derivation of the relation between climate and water yield is explained on pages 43–46.

Computation of consumptive use and water yield.—The Raft River basin receives no migrant inflow of ground water from other basins, so the water yield equals the volume of precipitation less the water lost by evapotranspiration. The unconsumed residual water leaves the basin chiefly by ground-water underflow.

The estimate of consumptive use in the Raft River basin is based on the distribution of temperature in the area. The few available observed temperature data are not sufficient to define accurately the relation between altitude and temperature, especially because all the temperature stations are in valleys. The data, however, show a general relation which is represented graphically in figure 6.

A general idea of the regional lapse rate was obtained from a study of temperature records from stations in Idaho south of latitude 44° N. Mean annual temperatures at these stations were classified by even 1,000-foot zones. The highest station is at Deer Point in Boise County—7,150 feet—and the lowest at Parma Experiment Station in Canyon County—2,224 feet. The average temperature in each altitude zone was computed for the middle altitude of the zone and plotted on a graph. The solid line in figure 6 defines a lapse rate of 3.2°F per 1,000 feet, which is closed to the lapse rate of 3.5°F of the United States standard atmosphere (Berry and others, 1945, p. 373). The lapse rate of 3.2°F was used to extrapolate the temperature records available for the Raft River basin (dashed line in figure 6) and thus to estimate temperatures at different levels.

The temperature at given altitudes varies somewhat from region to region, and results of the study, therefore, are valid only to the extent that regional variations are averaged out in each altitude zone. The solid line in figure 6 shows only the lapse rate and does not necessarily show the altitude-temperature relation in any one area. The plotted points indicate a slightly curved line, but only a straight line is warranted on theoretical grounds.

The difference between annual precipitation and runoff in humid regions—especially in regions where runoff is more than half the precipitation—represents the water loss by evapotranspiration under optimum conditions for evapotranspiration. In such areas the water loss represented by this difference is related to the mean annual temperature and is independent of precipitation. This may not be true of some lowlands at very low altitudes where seasonal variations in precipitation are pronounced. An example is North Head, Wash., where annual precipitation is about 50 inches, or roughly twice the potential evapotranspiration. The net deficiency of precipitation

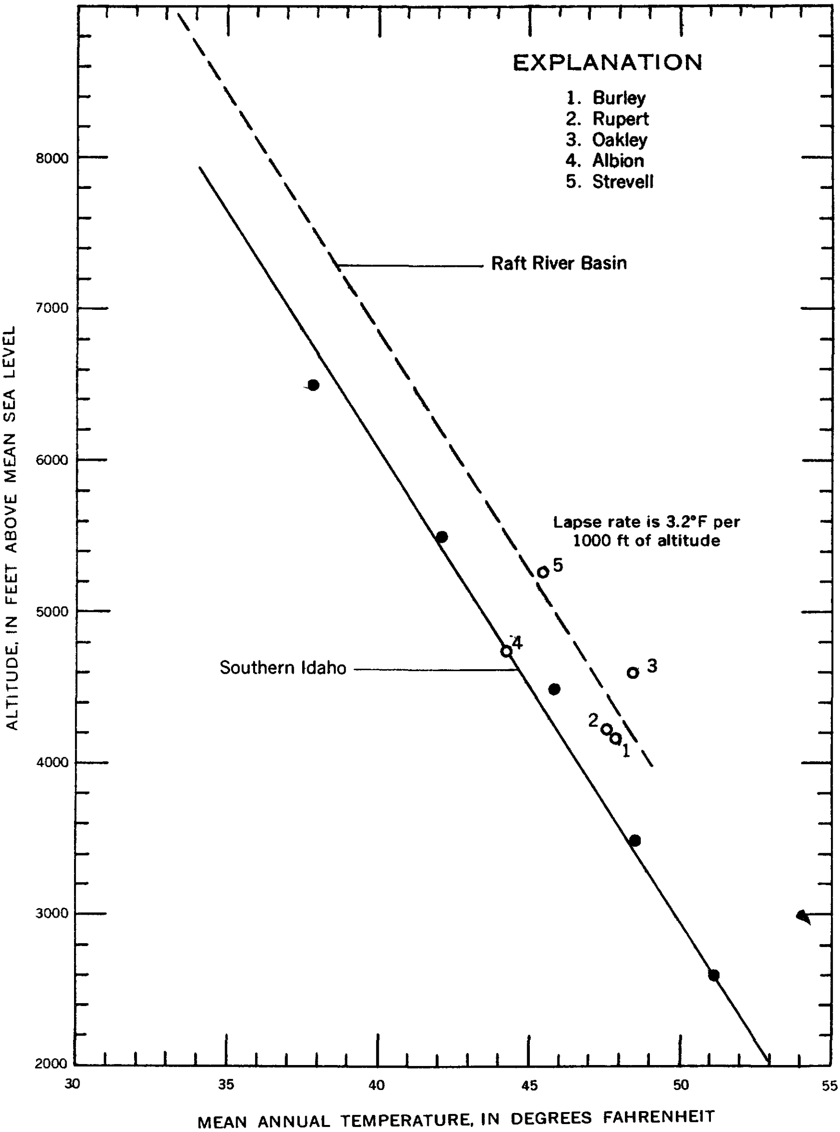

FIGURE 6.—Relation between temperatures and altitude (lapse rate). Solid circles represent averages for groups of stations in 1,000-foot altitude zones in southern Idaho. Open circles represent single stations in or near the Raft River basin.

there during the summer is about 7.5 inches below potential evapotranspiration. Therefore, if there were no actual deficiency of moisture, 7.5 inches of water from winter and spring rains would have to be carried over in the root zone. Perhaps only 5 or 6 inches of field capacity is available, so the unsatisfied deficiency is about 1.5 to 2.5 inches. At altitudes above about 1,000 feet, however, the summer deficiency of precipitation for potential evapotranspiration needs is only about 4 inches. At least that amount of moisture is carried over in the root zone, so the conditions described in the early part of this paragraph are met in the Raft River basin.

Figure 7 shows graphically the relation between mean annual temperature and water losses. The curve on figure 7, which was published in a report by Langbein and others (1949), is based on differences between measured precipitation and runoff in humid regions. The data used to define the curve seem to conform to the Thornthwaite definition of potential evapotranspiration. Many values for potential evapotranspiration, given by Thornthwaite (1948, table

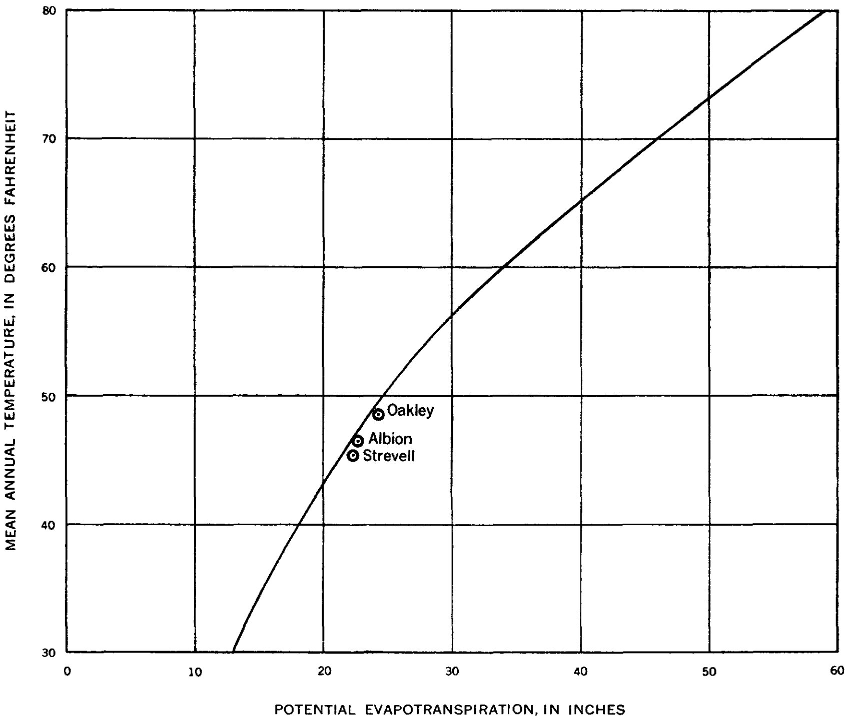

FIGURE 7.—Relation between mean annual temperature and potential evapotranspiration in North America. (After Langbein and others, 1949.)

3), plot very close to the curve in figure 7. The three values calculated by the Thornthwaite method for Strevell, Oakley, and Albion also plot very close to the curve.

Additional information is available on the magnitude of potential evapotranspiration in the Raft River valley. Although the Penman formula (Penman, 1956) gives a value of about 32 inches for Pocatello, Lowry and Johnson (1942, p. 1253) state that observed consumptive use of water in irrigated areas in the Mason Creek and Boise Valley areas of Idaho is 2.17 feet (26 inches). The mean temperature at the Boise and Caldwell weather stations is 50.7°F. This relation between temperature and potential evaporation plots very close to the curve in figure 7. Calculations by the Blaney-Criddle and Lowry-Johnson methods also indicate a loss of about 24 inches from irrigated areas in southern Idaho (Simon, 1953, p. 18). The weight of evidence, therefore, supports our computation that potential evapotranspiration in the Raft River valley is about 24 to 26 inches, although according to the Penman formula the potential evapotranspiration would be higher.

The water yield was computed as shown in table 9. In this table column 1 is the altitude corresponding to the precipitation shown in column 2. The precipitation as read from figure 3 was modified, as explained on page 30, according to the location. The adjustments are plus 1 inch for the western area, zero for the eastern area, and minus 1 inch for the southern area. Column 3 is the mean annual temperature, read from a graph of the temperature-altitude relation (fig. 6). The potential annual water loss by evapotranspiration, shown in column 4, was obtained graphically from figure 7. Column 5 shows the ratio, P/L, of annual precipitation (P) to potential water loss by evapotranspiration (L). Column 6 shows the ratio, R/L of the annual water yield (R) to the potential evapotranspiration. This ratio was obtained graphically from figure 8. The curve in the figure, drawn from data in table 10, in effect summarizes data given by Langbein and others (1949, p. 7, fig. 2) for certain locations in North America. The derivation of the relation between water yield and climate is explained on pages 43–46. The water-yield value, R, would represent actual runoff in basins where runoff equals the climatic yield of water. Climatic yield is defined as the difference between precipitation and actual evapotranspiration. In table 9 the R in column 7 is the water yield obtained by multiplying R/L (column 6) by L, the potential water loss (column 4). The method of deriving figure 8 is explained on page 46.

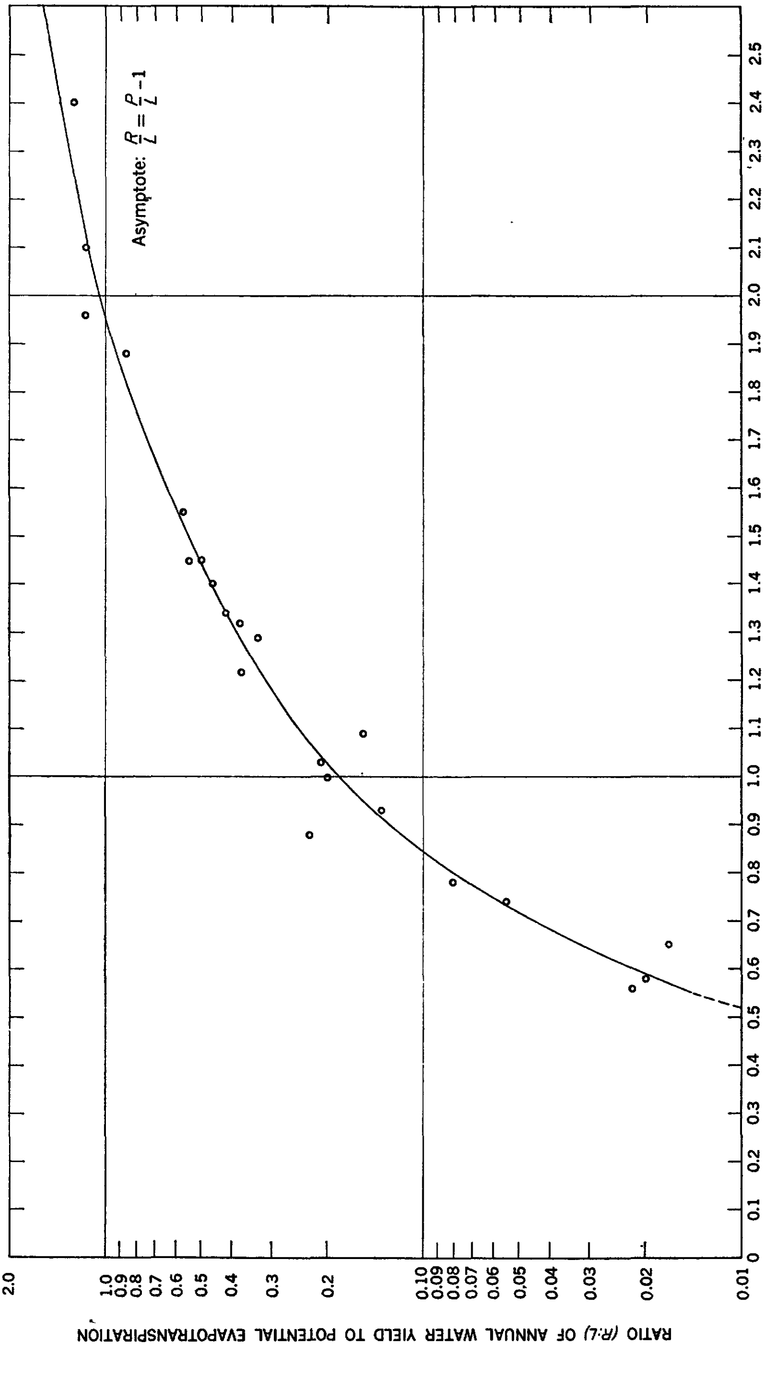

FIGURE 8.—Relation of annual water yield to precipitation and potential evapotranspiration in representative river basins in North America. Curve is based on data in table 10.

TABLE 9.—*Computation of water yield from precipitation in the Raft River basin*

[Computations explained on p. 40]

Altitude (feet)	Precipitation, *P* (inches)	Temperature, (°F)	Potential water loss, *L* (inches)	Ratio		Water yield, *R* (inches)
				P/L	*R/L*	
1	2	3	4	5	6	7
Western area						
8,500	30	35	15.5	1.94	1.00	15.5
7,500	25	38	17	1.47	.53	9.0
6,500	20	41.5	19	1.05	.22	4.2
5,500	16	44.5	21	.76	.063	1.3
5,000	13.5	46	22	.61	.023	.50
4,500	12	47.5	23	.52	.01	.23
4,000	11	49	24	.46	.007	.17
Eastern area						
8,000	27	36	16	1.69	0.73	11.7
7,000	22	39.5	18	1.22	.33	5.9
6,000	17	42.5	19.5	.87	.11	2.1
5,000	12	46	22	.55	.013	.29
4,500	11	47.5	23	.48	.008	.19
Southern area						
8,000	25	36	16	1.56	0.60	9.6
7,000	20	39.5	18	1.11	.25	4.5
6,000	16	42.5	19.5	.82	.09	1.8
5,000	11	46	22	.50	.009	.20
4,500	10	47.5	23	.43	.006	.14

The relations between precipitation and altitude differ somewhat in the western, eastern, and southern parts of the area. Therefore, in table 9 separate computations were made of the water yield of each of these three principal areas. From these computations, working graphs were prepared on semilogarithmic paper (fig. 9) to show the relation between altitude and annual water yield.

As a final step, the graphs in figure 9 were used in conjunction with the isohyetal map to develop another map showing estimated water yield (pl. 3). The water yield is shown by contours connecting points of equal water yield. The map was drawn on an overlay of the topographic map, so that the contours conform in general to the topography.

TABLE 10.—*Mean annual precipitation, potential water loss by evapotranspiration, and water yield in representative stream basins in North America* [1]

[Inches of water]

Stream	Precipitation (*P*)	Runoff (*R*)	Loss (*L*)	Ratio	
				P/L	*R/L*
Mexican Springs Wash at Mexican Springs, N. Mex	15	0. 4	23	0. 65	0. 017
Cannonball River at Breien, N. Dak	15. 6	. 61	27. 5	. 56	. 022
Churchill River at Island Falls, Saskatchewan	16	4. 1	18	. 88	. 23
South Fork Palouse River near Pullman, Wash	19. 6	2. 8	18	1. 09	. 155
Stream A, Wagonwheel Gap, Colo	21. 1	6. 1	16	1. 32	. 38
Saline River at Tescott, Kans	22. 1	. 76	38	. 58	. 02
Cajon River near Keenbrook, Calif	22. 8	4. 5	23	1. 0	. 20
Elkhorn River at Waterloo, Nebr	23. 0	1. 7	31	. 74	. 055
Deep Creek near Hesperia, Calif	27. 1	10. 0	17. 5	1. 55	. 57
Strawberry Creek near San Bernardino, Calif	30. 9	8. 0	24	1. 29	. 33
Washita River near Durwood, Okla	31. 2	3. 2	40	. 78	. 08
Kings River at Piedra, Calif	31. 4	18. 8	16	1. 96	1. 18
Ralston Creek near Iowa City, Iowa	33. 0	6. 7	32	1. 03	. 21
Miami River at Dayton, Ohio	37. 0	11. 5	27. 5	1. 34	. 42
Neuse River near Clayton, N.C	45. 4	13. 9	37	1. 22	. 375
Middle Westfield River at Goss Heights, Mass	45. 6	25. 9	22	2. 1	1. 17
West River at Newfane, Vt	46. 5	25	19. 5	2. 4	1. 27
Kissimmee River near Okeechobee, Fla	50	7. 3	54	. 93	. 135
Little River near Horatio, Ala	50. 7	17. 3	35	1. 45	. 50
Elk River at Queen Shoals, W. Va	51. 8	24. 0	27. 5	1. 88	. 87
Average of 10 comparable basins in southeastern Alabama	59. 3	22. 7	41	1. 45	. 55
Anita River near Denham Springs, La	59. 4	19. 5	42. 5	1. 40	. 46

[1] Based on data given by Langbein and others (1949, p. 7).

NOTE.—The potential water loss in this table corresponds to a mean annual temperature which was computed by weighting the mean temperature for each month by the amount of precipitation in each month. In the Raft River basin the difference between weighted and reported mean temperatures is small. The difference is most significant for areas where precipitation occurs dominantly in winter (such as on the West Coast) or dominantly in summer (such as on the Great Plains).

Derivation of relation between water yield and climate.—Runoff from many basins cannot be measured directly but must be estimated, so it seems logical to approach the problem by estimating water loss by evapotranspiration, the water yield being the residual or unconsumed component of precipitation. This can be done on the basis of

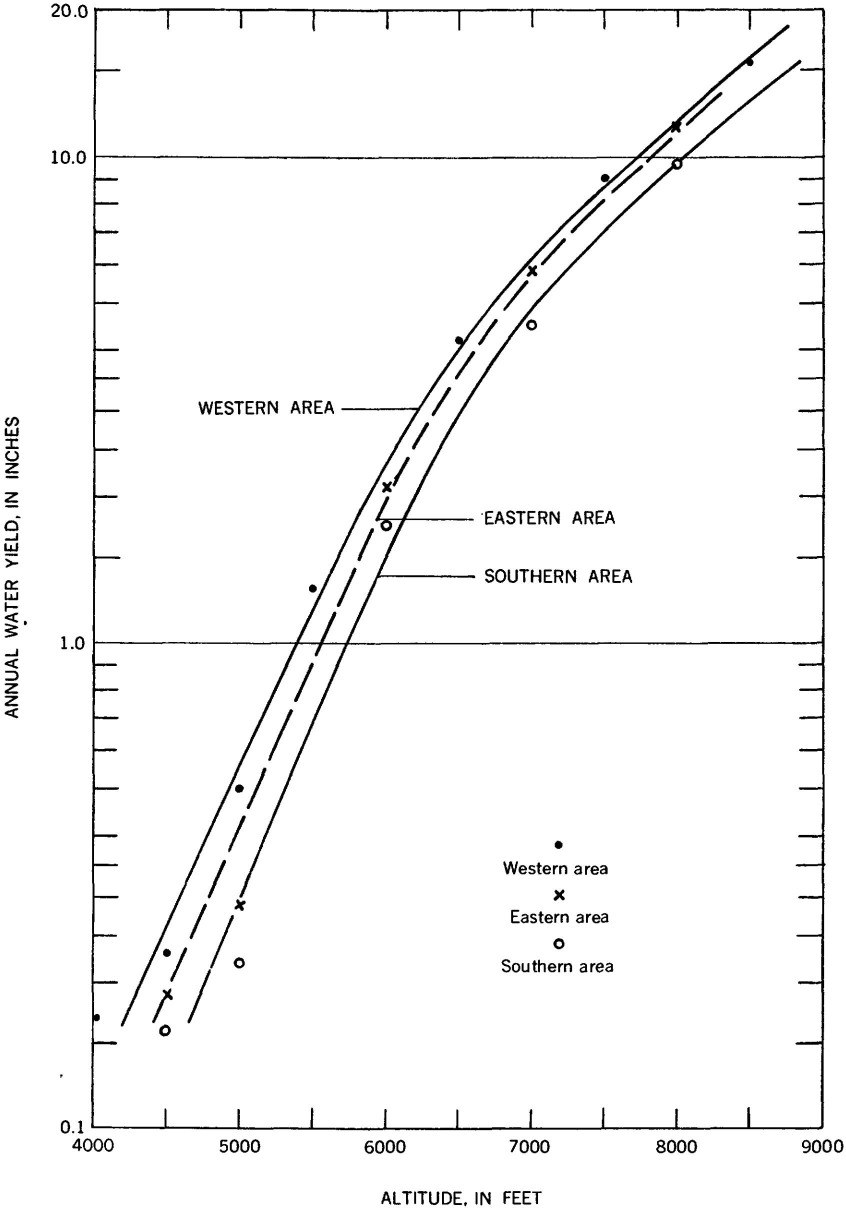

FIGURE 9.—Relation between altitude and water yield in principal subdivisions of the Raft River basin.

relations observed in areas for which there are good data on precipitation, runoff, and other factors that affect water loss and runoff, and where a basis can be developed for estimating potential evapotranspiration.

Water yield is the surplus of precipitation over water loss, and annual runoff is equivalent to water yield if no water moves into or out of a drainage basin by underflow. Water yield increases with precipitation, but a logical first step in computation of water yield is to determine how evapotranspiration varies in relation to precipitation and temperature.

Potential evapotranspiration is a function exclusively of solar radiation and other climatic factors that are reflected in the temperature. As annual precipitation increases from zero, actual water loss increases toward potential loss as an upper limit. Where annual precipitation is low, water loss nearly equals precipitation. Nevertheless, not all precipitation is consumed, even in dry climates, because: (a) at times the rate of precipitation exceeds the rate of infiltration and runoff occurs; and (b) filtration into the soil at times exceeds the amount necessary to restore soil moisture and ground-water recharge occurs. At increased rates of yearly precipitation, complete restoration of soil moisture occurs more frequently, and the frequency and volume of runoff and ground-water recharge increase. Where annual precipitation equals potential loss by evapotranspiration, actual water loss still is less than the potential by the amount of runoff and ground-water recharge generated when the rate of precipitation exceeds the capacity of the soil to absorb and hold water. The water in excess of soil-moisture requirements is not available for evapotranspiration during later dry periods. Only where precipitation is distributed uniformly throughout the year and is about twice the potential loss will soil moisture be sufficient to permit actual loss to equal potential loss. Under such circumstances, water yield equals precipitation minus potential loss. Since no such climate exists in the Raft River basin, actual evapotranspiriation must be estimated by a more complicated procedure.

The ratio of actual to potential evapotranspiration varies with the ratio of precipitation to potential evapotranspiration. Water yield is precipitation minus actual evapotranspiration, so the ratio of water yield to potential evapotranspiration probably also varies approximately as the ratio of precipitation to potential evapotranspiration. Rather than speculate about the mathematical aspect of this relation, it seems more practical in this report to explore the relationship graphically.

Figure 8 showed the relation defined by the data in table 10, which are computed from data previously published (Langbein and others, 1949, table 4). The river basins represented in the table are basins in which runoff equals water yield—that is, all the water yield is runoff and none is discharged by underflow. The ratio of runoff to potential evapotranspiration, R/L, increases rapidly at low values of P/L, but for values of P/L greater than 2, R/L approaches P/L values of minus 1. In areas represented by that part of the graph, annual water yield equals annual precipitation minus annual potential evapotranspiration.

The points plotted on figure 8 define a rather close relation, but the graph is not strictly applicable to a specific drainage basin. Evapotranspiration is affected appreciably by geologic and soil conditions. Permeable, deep soils, such as those in the Sand Hills of Nebraska absorb rainfall readily and allow deep infiltration beyond the root zone to the water table. In such areas water yield tends to be greater than that in areas not having permeable deep soil, or having deep but retentive soils. So-called tin-roof basins—those having impermeable soil cover—would have high runoff because a large part of rainfall runs off before it can be absorbed by the soil.

The relation defined by figure 8 applies to the water yield at points of generation. The net yield at a given point downstream in the Raft River basin depends on evapotranspiration by riparian and phreatic vegetation, which increases downstream in proportion to the increasing dryness of the climate, as it does in most other western basins.

Evaluation of the method.—The method described has not been published previously. It expresses the variation in water yield that is associated with the range of climates in the United States. It also tends to minimize the consequences of erratic variations that occur when methods of computing yield by subtracting potential evapotranspiration from precipitation are applied in arid climates. Where water yield is low—0.5 inch or less—and subtraction methods of computation are used, small variations in potential evapotranspiration can cause variations in computed yield which are exaggerated in comparison to those derived by the method used in this report.

Because water yield is not entirely explained by climatic variables, the method needs to be tested by comparing results and, if necessary, adjusted in accordance with local measurements of water yield.

Two crude checks can be made of the validity of the estimates derived herein, by use of the records for gaged streams where ungaged underflow probably is not a very large factor:

1. The observed average discharge of Cassia Creek near Conant during water years 1910–12 represents 4.5 inches of yield from the

Elba basin watershed. The water yield estimated from the map (pl. 3) is 4.8 inches, and the apparent error is slightly more than 6 percent. If allowance is made for a small amount of ungaged underflow from the basin, the agreement is even closer. The record for Cassia Creek is too short to have much significance and the close agreement of the two values probably is coincidental. The short (3-yr) record is for a period of greater than normal precipitation, and the average long-term water yield probably is less than the record shows. So the close agreement between estimated and actual water yield may be an illusion.

2. The observed average discharge of Clear Creek near Naf represents a yield of 7.0 inches from the watershed. The amount estimated from the map for this area of 19 square miles is 9.0 inches. Underflow through alluvium at that location undoubtedly is appreciable, so the divergence between actual and estimated water yield is really smaller than it seems. The estimate apparently is in error by 29 percent, but if allowance is made for some underflow the apparent error probably is not more than 15 percent and may be less. Very close agreement cannot be expected for such a small watershed.

Apparent errors were expected to be much larger because of the extreme scarcity of data on which to base calculations and estimates. The errors reflect principally deficiencies in the available data, not in the method of estimation itself. The estimated total water yield of the basin probably is within about 20 percent of the correct figure.

CREDIBILITY OF THE RESULTS

By R. L. NACE

Credibility, if not accuracy, of the computed water yield can be inferred by analysis of the water yield for the Yost-Almo Basin in relation to the geology. The basin has a "throat" discharge, and much of the water leaving the basin must go through The Narrows. Estimated water yield of the basin is 77,000 acre-feet per year (table 5). Average annual discharge of the Raft River at Peterson Ranch, just below The Narrows, during the period of record was 17,000 acre-feet (table 11), leaving 60,000 acre-feet of water to be accounted for.

The 8,000 acres of irrigated land in the Yost-Almo basin consumes about 5,000 acre-feet of water per year (p. 80) in addition to the 9,600 acre-feet (14.4 inches) per year assumed in table 5, and thus would account for a small part of the water. Some water leaves the basin also in the artesian aquifers of the Salt Lake(?) formation and perhaps in older rocks. The assumed amount is 10,000 acre-feet. About 45,000 acre-feet of water probably leaves the basin yearly by underflow, chiefly through the permeable alluvium in The Narrows. Is it reasonable to assume that the alluvial fill can transmit most of the 45,000 acre-feet of water per year.

Reconstruction of the probable subsurface geology at The Narrows indicates that the cross-sectional area of the alluvial fill at the most constricted part probably is on the order of 500,000 square feet. The 45,000 acre-feet of water yearly is equivalent to a continuous flow of about 62 cfs (cubic feet per second) or 40 million gpd (gallons per day). The rate of flow would be about 10.7 cubic feet per day per square foot through a cross-sectional area of 500,000 square feet. If the porosity of the gravel were assumed to be 30 percent, the velocity of underflow would be about 35 feet per day.

Springs and seeps occur along the Raft River above The Narrows, and the water-table gradient in that reach therefore is about the same as the straight-line grade of the river, or about 40 feet per mile. The authors assume that the gradient through The Narrows also is at least 40 feet per mile. The water-table gradient, estimated discharge rate, and area of discharging cross section imply a transmissibility coefficient in excess of 1 million gpd per foot and a permeability coefficient on the order of 7,000 to 10,000 gpd per square foot. These coefficients are high but reasonable. The coarse gravel in The Narrows was deposited from fast-moving water and probably contains negligible fine-grained matrix. Such coarse material would be extremely permeable.

The geologic and hydrologic unknowns are so numerous and significant that no rigorous test of credibility can be applied. The water yields computed by the simplified method are used throughout the remainder of this report. Although credible and reasonable, they are only estimates whose correctness can be neither proved nor disproved by using existing data.

SURFACE-WATER

DISCHARGE

Only a small part of unconsumed precipitation in the Raft River basin runs off in streams. The Raft River, the upstream part of Clear Creek, and Cassia Creek are the principal perennial streams; all others either are intermittent or have very small discharge. Records of discharge of the Raft River and Clear Creek have been published annually by the Geological Survey for many years. Gaging of the Raft River was interrupted after 1953 but was resumed in 1955. The discharge of these streams during 16 years of noncontinuous record, and 3 years of early record for Cassia Creek is summarized in table 11.

No other systematic measurements of stream discharge have been made in the Raft River basin.

Except during floods, most water discharged by the Raft River from the Yost Valley through the Upper Narrows into the Almo Basin either is diverted for irrigation within 4 or 5 miles below the gorge, or seeps into the ground. Late in the irrigation season springs contribute most of the flow of the river below the diversions. The channel of George Creek crosses about 6 miles of alluvial sediment before joining Johnson Creek and the Raft River, and the creek loses much water by infiltration in the alluvium. Only during flood and freshet stages is there enough water in these creeks to reach the river. Almo Creek contributes very little water to the river during the irrigation season.

TABLE 11.—*Yearly runoff of streams in the Raft River basin* [1]

[Acre-feet per water year. Square miles of drainage area above stations is given in parentheses]

Water year	Raft River near Bridge (505)	Raft River at Peterson Ranch (412)	Clear Creek near Naf (19)	Cassia Creek near Conant (104)
1910 [2]	27, 770		9, 070	23, 000
1911	[3] 11, 790		8, 420	18, 900
1912	32, 500			[3] 33, 300
1913	29, 200			
1914	38, 900			
1945			11, 630	
1946			6, 460	
1947		10, 410	6, 550	
1948		10, 250	7, 200	
1949		20, 690	7, 620	
1950		13, 400	7, 980	
1951		24, 000	7, 150	
1952		24, 950	7, 520	
1953		14, 750	5, 920	
1954		([4])	2, 810	
1955			4, 310	
Average (rounded)	28, 000	17, 000	7, 100	25, 000

[1] Published data are in the following U.S. Geol. Survey Water-Supply Papers: 272, p. 292–294; 292, p. 341–347; 312, p. 310–315; 332, p. 354–358; 362, p. 346–349; 393, p. 87–44; 413, p. 80–81; 1043, p. 85; 1063, p. 72; 1093, p. 73–74; 1123, p. 72–73; 1153, p. 75–76; 1183, p. 68–69; 1217, p. 53–54.
[2] Record for Clear Creek is fragmentary.
[3] Partly estimated.
[4] Station suspended after December 1953. Reactivated in May 1955.

Very little surface water is impounded in the Raft River basin. Sublett Reservoir, 6 miles east of Sublett, has an average surface area of about three-eighths of a square mile. Independence Lakes, natural small ponds having an aggregate area of about a quarter of a square mile, occupy a cirque high on the northwest side of Mount Cache.

Records for the Raft River basin afford no basis for computing total surface inflow to the Raft River valley from all sources, and there is little up-to-date information about outflow at the mouth of the Raft River. Miscellaneous measurements near the mouth of the Raft River in 1949 and 1950 were as follows: September 20, 1949, 11.6 cfs; June 30, 1950, 6.97; August 2, 1950, 8.04. For general computation it is assumed that in recent years the stream discharged an average of 10 cfs from May to October (3,560 acre-feet). Flow during the other 6 months of the year probably is no greater, and the total annual discharge of the river at its mouth undoubtedly is less than 10,000 acre-feet. Miscellaneous data led Stearns and others (1938, p. 213) to estimate that the discharge as long ago as 1927 was only about 9,000 acre-feet per year.

Early records of discharge of the Raft River at the gaging station near Bridge (table 11) no longer have much value because diversions have changed since 1914 and because the rate of flow at that station differs from the rate at Peterson Ranch. In the reach between the Peterson Ranch and Bridge stations the river alternately loses and gains water, and records for the two stations are not mutually comparable. The records of discharge that are most useful for this report are those of Raft River at Peterson Ranch in 1947–53 and Clear Creek in 1945–55.

The periods of record are too short to be a reliable basis for computing average-discharge values. The maximum recorded annual discharge at each station is about double the minimum. Average runoff in Raft River at Peterson Ranch during the 7 years of record was about 17,000 acre-feet. Average discharge of Clear Creek near Naf during 13 years of record was about 7,100 acre-feet.

LOSS AND GAIN IN THE RAFT RIVER

By S. W. FADER and R. L. NACE

Flow in the Raft River is augmented by ground-water discharge in the western (upper) part of The Narrows, but at times it may decrease slightly by percolation loss in the eastern part of sec. 6, T. 16 S, R. 26 E., in the reach extending about a quarter of a mile above the gage at Peterson Ranch. Measurements on August 22, 1952, showed that the river gained 3.3 cfs in a reach extending about 1.5 miles from the eastern part of sec. 10 to the western part of sec. 12, T. 16 S., R. 25 E. From there to the middle of sec. 6, T. 16 S., R. 26 E., a distance of about 1.75 miles, a gain of 1.6 cfs was measured. Within the next quarter of a mile downstream the river lost 3.3 cfs by percolation into the ground. On the other hand, in 1957 check measurements were made of the discharge at either end of the reach from the Peterson Ranch gage to 0.3 mile above the gage, with the following results:

Date (1957)	*0.3 mile above gage (cfs)*	*At gage (cfs)*	*Gains (cfs)*
Apr. 2	20. 4	23. 3	2. 9
Nov. 4	9. 7	10. 5	. 8

Evidently, the loss-and-gain regimen of the river is variable, not only from reach to reach at a given time but also in a single reach at different times.

Whether or not the stream gains in a given reach depends on the level of the water table in relation to the streambed, the condition of the channel, and the stage of the stream. When the water table is below the streambed the stream tends to lose water. At low-flow stages, however, the channel may be silted over so that infiltration is impeded. At high stages the silt is removed and the channel becomes permeable. Also, at higher stages river water may percolate outward through the channel walls, which are not ordinarily blanketed by silt.

Discharge of the Raft River alternately decreases and increases in successive reaches between the Peterson Ranch gaging station and the mouth of the river (table 12). The river regimen has special interest because pumping of ground water may affect it, especially in the central and northern parts of the valley. Miscellaneous measurements of river discharge were made in 1949 and 1950 at the gaging station, and at the temporary measuring stations shown on plate 4, to determine the general magnitude of percolation losses and gains and to segregate the principal loss-and-gain reaches at the times the measurements were made. Differences between rates of flow at successive measuring stations represent the net loss or gain between those points. Accurate determination of losses and gains by the method used was difficult or impossible at times, because of variable factors that could not be controlled. For instance, some reaches in the river channel are braided, and the volume of flow in the separate channels is too small to be measured accurately with a current meter. An appreciable amount of diverted water seeps into the ground from ditches and returns to the river within a short time. Much of the water that is spread for irrigation, especially around the mouth of Cassia Creek, returns to the river in seeps and small drainageways in which the flow is too small to measure by current meter. During spring periods of high runoff the excess or flood discharge of local streams and gullies is used for irrigation, and return flow in surface drains is greater than in the late summer. Thus determination of direct channel losses and gains probably is less accurate in April, May, and June than in July and August.

TABLE 12.—*Summary of losses and gains in reaches of the Raft River from Peterson Ranch to mouth*

[Cubic feet per second]

Station [1]	Sept. 13-20, 1949		Apr. 24-26, 1950		June 28-July 5, 1950		July 31-Aug. 2, 1950	
	Gain	Loss	Gain	Loss	Gain	Loss	Gain	Loss
1								
2		0.33	1.66		0.51			0.18
3		1.67		2.92		2.10		1.84
4		.91		1.20		.87		1.04
5		2.18		5.45		1.30		1.25
6	0.41		.64			.31		.13
7	0	0			0	0	0	0
8	4.90		11.8		8.77		5.48	
9			1.20		2.28			.19
10	.78				10.77		2.31	
11	.46		4.02			2.55		2.38
12						1.37		.02
13			8.23		5.29		.66	
14		.04		.95		5.32		.63
15								
16	1.46				7.79		2.99	
17	10.8				6.93		8.03	
Total	18.8	5.13	27.6	10.5	42.3	13.8	19.5	7.6
Net loss or gain	13.7		17.0		28.5		11.8	

[1] See plate 4 and table 13 for locations of stations.

The computed channel losses and gains were not adjusted for evaporation. The total amount of water evaporated from the 70 miles of river below Peterson Ranch probably was appreciable during the periods of measurements, but within single measured reaches the volume of evaporation doubtless was very small during those periods. In the computed values, errors from all causes probably are at least 10 to 15 percent, but these values indicate losses and gains in their correct relative magnitude. All the direct measurements are listed in table 13, and the mean daily discharge of Raft River at Peterson Ranch during periods of special measurements is shown in table 14. Data in tables 12 and 13 are illustrated graphically in figures 10, 11, 12, and 13.

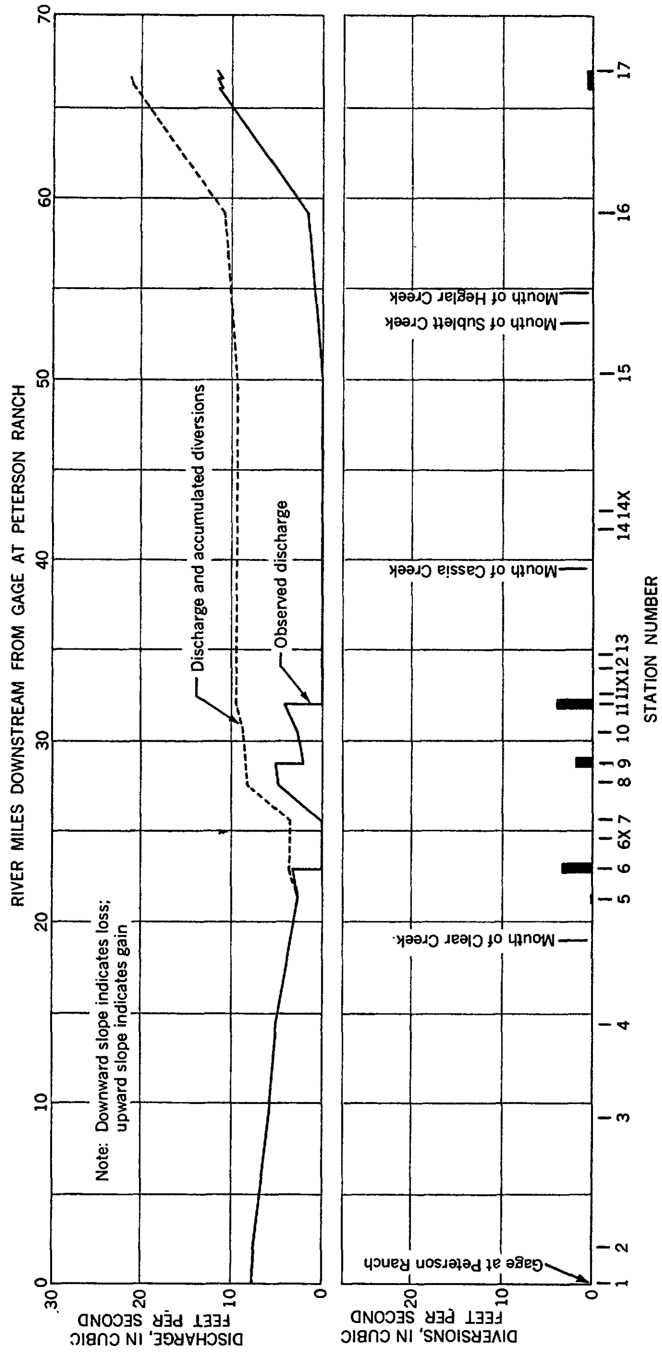

FIGURE 10.—Losses, gains, and diversions of Raft River below Peterson Ranch, September 13–20, 1949.

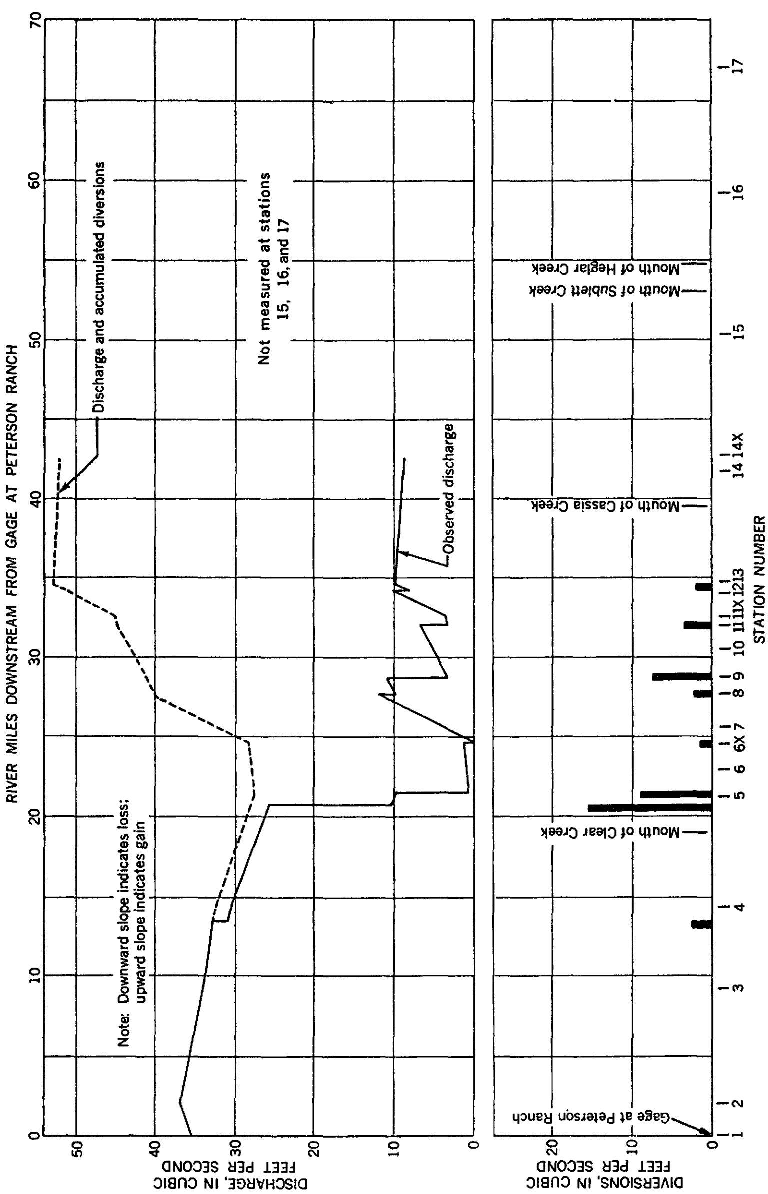

FIGURE 11.—Losses, gains, and diversions of Raft River below Peterson Ranch, April 24–26, 1950.

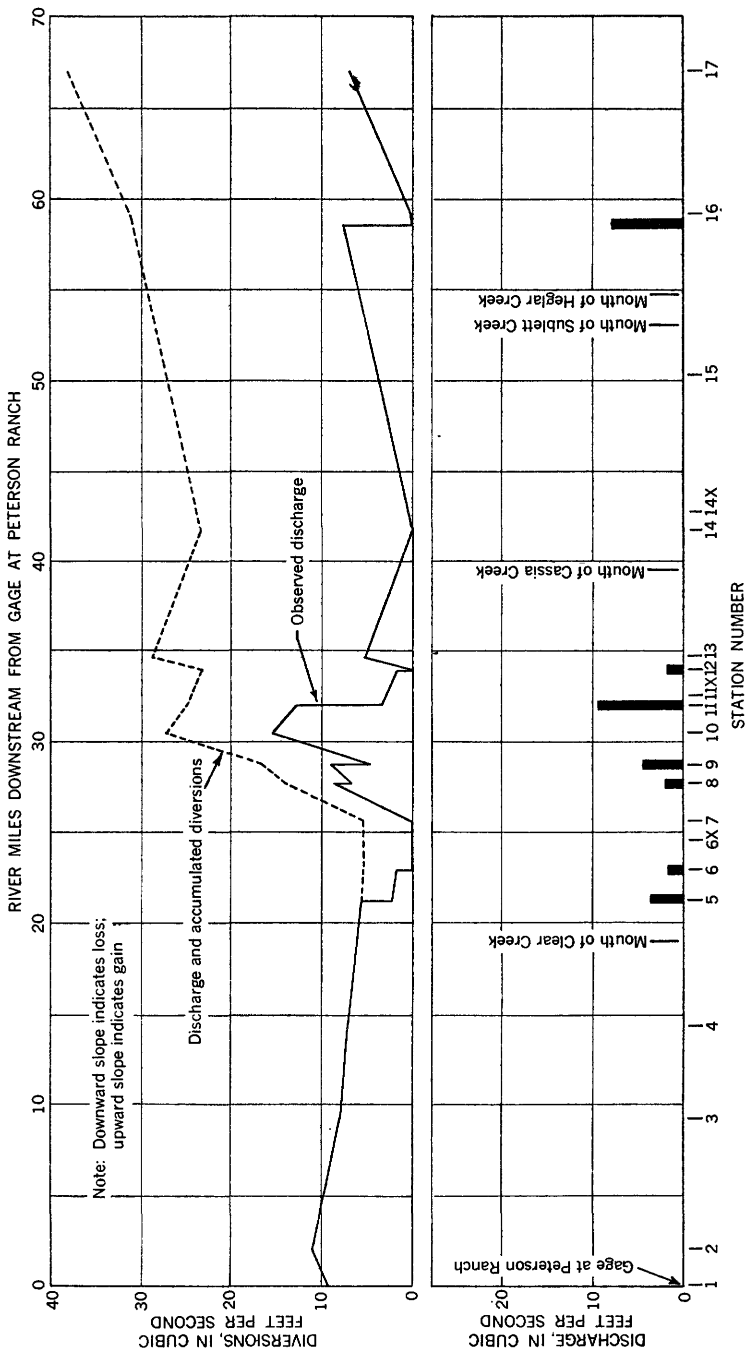

FIGURE 12.—Losses, gains, and diversions of Raft River below Peterson Ranch, June 28–July 5, 1950.

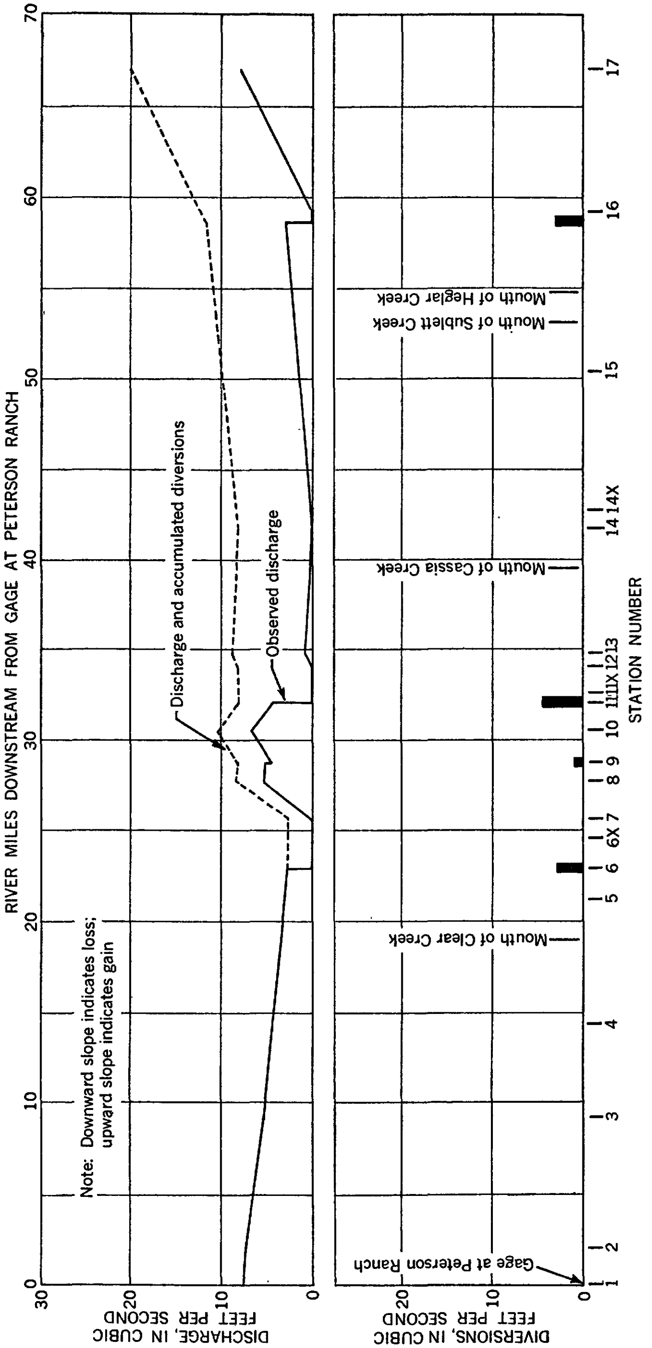

FIGURE 13.—Losses, gains, and diversions of Raft River below Peterson Ranch, July 31–August 2, 1950.

TABLE 13.—*Discharge, losses, and gains in the Raft River from Peterson Ranch to mouth*

[Cubic feet per second]

Station	Date	Location	Discharge			Seepage [1]	
			At station	Diversion below next upstream station	Total	Gain	Loss
September 13-20, 1949							
1	Sept. 13	NE¼NW¼ sec. 5, T. 16 S., R. 26 E	7.92	0	7.92		
2	13	SW¼NW¼ sec. 33, T. 15 S., R. 26 E	7.59	0	7.59		0.33
3	13	SW¼NE¼ sec. 24, T. 15 S., R. 26 E	5.92	0	5.92		1.67
4	13	NE¼SE¼ sec. 6, T. 15 S., R. 27 E	5.01	0	5.01		.91
5	13	NE¼SE¼ sec. 18, T. 14 S., R. 27 E	2.80	.03	2.83		2.18
6	13	NW¼NE¼ sec. 7, T. 14 S., R. 27 E	0	3.21	3.21	0.41	
7	14	SW¼NE¼ sec. 30, T. 13 S., R. 27 E	0	0	0	0	0
8	14	NE¼SW¼ sec. 18, T. 13 S., R. 27 E	4.90	0	4.90	4.90	
10	14	NE¼NW¼ sec. 7, T. 13 S., R. 27 E	2.71	[2] 2.97	5.68	.78	
11	15	NW¼NE¼ sec. 6, T. 13 S., R. 27 E	.04	3.13	3.17	.46	
14	15	NE¼NW¼ sec. 6, T. 12 S., R. 27 E	0	0	0		.04
16	19	SW¼NE¼ sec. 26, T. 10 S., R. 27 E	1.46	0	1.46	1.46	
17	20	NE¼NE¼ sec. 1, T. 10 S., R. 27 E	11.6	.68	12.38	10.8	
April 24-26, 1950							
1	Apr. 24	NE¼NW¼ sec. 5, T. 16 S., R. 26 E	35.4	0	35.4		
2	24	SW¼NW¼ sec. 33, T. 15 S., R. 26 E	37.0	0	37.0	1.6	
3	24	SW¼NE¼ sec. 24, T. 15 S., R. 26 E	34.1	0	34.1		2.9
4	25	NE¼SE¼ sec. 6, T. 15 S., R. 27 E	30.7	2.22	32.9		1.2
5	25	NE¼SE¼ sec. 18, T. 14 S., R. 27 E	.59	24.7	25.3		5.4
6X	25	NE¼NW¼ sec. 6, T. 14 S., R. 27 E	0	1.23	1.23	[3] .64	
8	25	NE¼SW¼ sec. 18, T. 13 S., R. 27 E	9.70	[4] 2.1	11.8	[5] 11.8	
9	26	SE¼SE¼ sec. 7, T. 13 S., R. 27 E	3.18	7.72	10.9	1.20	
11X	26	SW¼SE¼ sec. 31, T. 12 S., R. 27 E	3.54	3.66	7.20	4.02	
13	26	SE¼NW¼ sec. 30, T. 12 S., R. 26 E	9.77	2.0	11.8	[6] 8.3	
14X	26	NE¼SW¼ sec. 31, T. 11 S., R. 27 E	8.82	0	8.82		.95

See footnotes at end of table.

TABLE 13.—*Discharge, losses, and gains in the Raft River from Peterson Ranch to mouth*—Continued

[Cubic feet per second]

Station	Date	Location	Discharge: At station	Discharge: Diversion below next upstream station	Discharge: Total	Seepage [1]: Gain	Seepage [1]: Loss
June 28–July 5, 1950							
1	June 28	NE¼NW¼ sec. 5, T. 16 S., R. 26 E	9.60	0	9.60		
2	28	SW¼NW¼ sec. 33, T. 15 S., R. 26 E	10.1	0	10.1	0.5	
3	28	SW¼NE¼ sec. 24, T. 15 S., R. 26 E	8.01	0	8.01		2.1
4	28	NE¼SE¼ sec. 6, T. 15 S., R. 27 E	7.14	0	7.14		.87
5	29	NE¼SE¼ sec. 18, T. 14 S., R. 27 E	2.12	3.72	5.84		1.30
6	29	NW¼NE¼ sec. 7, T. 14 S., R. 27 E	0	1.81	1.81		.31
7	29	SW¼NE¼ sec. 30, T. 13 S., R. 27 E	0	0	0	0	0
8	29	NE¼SW¼ sec. 18, T. 13 S., R. 27 E	6.76	2.01	8.77	8.77	
9	30	SE¼SE¼ sec. 7, T. 13 S., R. 27 E	4.50	4.54	9.04	2.28	
10	27	NE¼NW¼ sec. 7, T. 13 S., R. 27 E	15.3	0	15.3	10.8	
11	27	NW¼NE¼ sec. 6, T. 13 S., R. 27 E	3.29	9.43	12.7		2.6
12	July 5	SE¼SW¼ sec. 30, T. 12 S., R. 27 E	.06	1.86	1.92		1.37
13	5	SE¼NW¼ sec. 30, T. 12 S., R. 27 E	5.35	0	5.35	[7] 5.29	
14	June 30	NE¼NW¼ sec. 6, T. 12 S., R. 27 E	.03	0	.03		5.32
16	30	SW¼NE¼ sec. 26, T. 10 S., R. 27 E	.04	7.78	7.82	7.79	
17	30	NE¼NE¼ sec. 1, T. 10 S., R. 27 E	6.97	0	6.97	6.93	

July 31–August 2, 1950

1	July 31	NE¼NW¼ sec. 5, T. 16 S., R. 26 E	7.40	0	7.40		
2	31	SW¼NW¼ sec. 33, T. 15 S., R. 26 E	7.22	0	7.22		0.18
3	31	SW¼NE¼ sec. 24, T. 15 S., R. 26 E	5.38	0	5.38		1.84
4	31	NE¼SE¼ sec. 6, T. 15 S., R. 27 E	4.34	0	4.34		1.04
5	31	NE¼SE¼ sec. 18, T. 14 S., R. 27 E	3.08	.01	3.09		1.25
6	31	NW¼NE¼ sec. 7, T. 14 S., R. 27 E	0	2.96	2.96		.12
7	Aug. 1	SW¼NE¼ sec. 30, T. 13 S., R. 27 E	0	0	0	0	0
8	1	NE¼SW¼ sec. 18, T. 13 S., R. 27 E	5.48	0	5.48	5.48	
9	1	SE¼SE¼ sec. 7, T. 13 S., R. 27 E	4.51	.78	5.29		.19
10	1	NE¼NW¼ sec. 7, T. 13 S., R. 27 E	6.82	0	6.82	2.31	
11	1	NW¼NE¼ sec. 6, T. 13 S., R. 27 E	.02	4.42	4.44		2.38
12	1	SE¼SW¼ sec. 30, T. 12 S., R. 27 E	0	0	0		.02
13	2	SE¼NW¼ sec. 30, T. 12 S., R. 27 E	.66	0	.66	.66	
14	2	NE¼NW¼ sec. 6, T. 12 S., R. 27 E	.03	0	.03		.63
16	2	SW¼NE¼ sec. 26, T. 10 S., R. 27 E	.01	3.01	3.02	2.99	
17	2	NE¼NE¼ sec. 1, T. 10 S., R. 27 E	8.04	0	8.04	8.03	

[1] The seepage value is the "total" discharge at any station minus the "at-station" discharge at the station next upstream. The seepage is a gain or loss according to whether the sign of the difference is positive or negative.
[2] Measured at station 9A (SE¼SE¼ sec. 7, T. 13 S., R. 27 E.).
[3] Probably inflow from small surface streams.
[4] Estimated.
[5] Estimated 1.5 cfs of gain is inflow from small streams entering above the gaging station.
[6] 6.23 cfs of gain is inflow from Cassia Creek.
[7] Gain is inflow from Cassia Creek.

TABLE 14.—*Daily mean discharge of the Raft River at Peterson Ranch (station 1 in this report) during periods of special measurements*

[From published records of the Geological Survey]

Date	Discharge (cfs)	Date	Discharge (cfs)
1949		*1950*—Con.	
Sept. 12	7.0	June 27	10
13	7.4	28	9.9
14	7.4	29	9.4
15	7.4	30	8.9
16	7.0	July 1	8.9
17	7.0	2	8.6
18	7.7	3	8.6
19	7.7	4	8.6
20	7.4	5	8.6
21	7.4	6	8.6
1950			
April 23	38	July 30	8.3
24	36	31	8.0
25	34	Aug. 1	7.4
26	34	2	7.4
27	32	3	7.4
28	34	4	8.3

Except during flood and freshet periods, none of which are represented in figures 10 to 13, nearly all the water in tributary streams either was diverted for irrigation or seeped into the ground. The Raft River received only very minor tributary inflow. Part of the gain from ground water between stations 7 and 11 was from land irrigated with water from Cassia Creek. Springs and seeps along the lower 15 miles of the Raft River channel are fed partly by underflow from the western slope of the Sublett Mountains. The main volume of underflow to the springs and seeps, however, probably comes from upstream areas of the Raft River valley.

GROUND WATER

The Raft River valley is a gathering ground for water derived from precipitation in a total area about twice the size of the valley. Main bodies of ground water in the valley lowland occupy no more than a third of the entire Raft River basin. This section describes the main occurrences and movement of the ground water; outlines the form, position, and fluctuations of the water table; identifies and evaluates sources of natural recharge and means of discharge; and summarizes a small amount of data on chemical characteristics of water. The locations of wells in the basin are shown on plate 4.

OCCURRENCE AND MOVEMENT

Ground water occurs in the Raft River basin under both water-table and artesian conditions. Artesian water occurs under physical situations that confine it under hydraulic pressure, so it may be called confined water. Under water-table conditions, ground water is not confined under pressure, so it is called unconfined water, or simply free water. Most readily accessible ground water of good quality in the report area is free (unconfined). It occurs chiefly in unconsolidated permeable alluvium below The Narrows and north of Strevell in the Raft River valley, and in basalt in the Northern Plains section.

Some precipitation on the uplands permeates the rocks and migrates toward the lowland, where it helps to replenish free ground water. Other precipitation on the upland enters artesian aquifers where they crop out and percolates to considerable depth as it moves to the valley, where it moves through confined aquifers scores to hundred of feet beneath the surface. The subsequent history of the artesian water is not known in detail. Some is withdrawn through deep wells, and some leaks upward along faults and through imperfectly confining beds and enters shallow aquifers. The remainder probably migrates northward and discharges from the Raft River valley at considerable depth. Most of the water yield of the basin is discharged to the Snake River Plain by underflow.

Beneath the floor of the Raft River valley, ground water occurs in flood-plain and alluvial-fan deposits of gravel, sand, and silt. Interbedded lenses and tongues of silt and clay locally support perched water at shallow depth. At somewhat greater depth the fine-grained deposits imperfectly confine beds beneath which water is under artesian pressure. Single beds of the fine-grained alluvium seemingly are not sufficiently extensive to produce widespread perched or artesian conditions, and most of the ground water in the alluvium is unconfined. The flood-plain and fan deposits are very permeable in general, but less permeable loosely cemented gravel occurs at places in the alluvial fan of Cassia Creek near Malta.

The temperature of water from wells in unconfined aquifers ranges from about 48° to 69° F. Unconfined water in this area having temperatures above 55° F probably contains some admixed water that has escaped from artesian aquifers.

Little is known about the hydrology of the Raft lake beds or the Salt Lake(?) formation. The Raft lake beds yield water to several irrigation wells near the Raft River north of Yale, but the beds have not been positively identified as aquifers elsewhere. Artesian ground water occurs in the Salt Lake(?) formation, which underlies younger rocks beneath most of the lowland areas in the Raft River valley and the Almo and Elba Basins. The information in most well logs is not sufficient to permit positive discrimination between the Salt Lake(?) formation and the Raft lake beds beneath the Raft River valley. The water-bearing properties of the Salt Lake(?) formation, therefore, are not known in detail. Most water-bearing beds identified with the Salt Lake(?) formation are fine grained and low in permeability. They do not ordinarily yield sufficient water to wells for irrigation. The lake beds contain the principal artesian aquifers in the Raft River valley, and a few deep artesian wells yield moderate amounts of water.

Artesian conditions in the Salt Lake(?) formation probably are controlled largely by the general structural system of the tilted fault blocks. Water is tightly confined where faults offset permeable aquifers against relatively impermeable material. Some fault zones may be brecciated, and where the faults intersect artesian aquifers they may be permeable avenues along which artesian water migrates upward into shallower saturated zones. The temperature of the artesian water tapped by wells in the Raft River basin ranges from about 100° to 211° F. Wells 15S–26E–23bb1 and 23dd1, which are 414 and 540 feet deep, respectively, yield water having temperatures of 198° and 211° F. Those wells tap water in the Salt Lake(?) formation, possibly in or near a fault.

A small amount of ground water is present in crevices in the consolidated sedimentary and igneous rocks in the mountainous parts of the basin. Water occurs also in unconsolidated talus and hill-wash sediments in upland basins, but at most places those materials are above the main water table and are not permanently saturated.

The slope and configuration of the water table near the Raft River from The Narrows to the Snake River is shown by water-table contours on plate 5. The slope of the water table indicates the approximate direction of ground water movement—down the hydraulic gradient roughly at right angles to the contours. The details of ground-water movement in the flanks of the Raft River valley, in upland valleys, and in the mountainous areas are not known. In general, however, ground water moves from the flanks of the basins toward their drainage stems and outlets.

Artesian ground water in the Raft River valley moves generally northward toward the Snake River Plain. Warm artesian ground water that leaks from deep sources and migrates into shallow unconfined ground-water zones causes the raised water temperatures observed in some irrigation wells. Waters having temperatures between 60° and 80° probably are mixed.

FORM AND POSITION OF THE WATER TABLE

Most wells in the Raft River basin are in the central Raft River valley, in a narrow belt about 1 to 2 miles wide on either side of the Raft River, and in a broader belt extending northward from Malta into the Northern Plains section. Therefore, the water table could be mapped with reasonable accuracy only in a narrow belt adjacent to the river in the Raft River valley and in part of the Northern Plains section. Plate 5 is a generalized representation of the water table. The piezometric surfaces of the artesian aquifers could not be represented on the basis of data available in 1957.

In the lowland of the Raft River valley the slope of the water table is northward, ranging from about 40 to 60 feet per mile in the central southern part to about 10 feet per mile in the vicinity of Idahome. In the eastern part of the Northern Plains section the direction of the water-table gradient is about parallel to the course of the Raft River; in the western part the direction varies between northward and westward. In that area the slope ranges from 10 to 40 feet per mile. Wells are scarce and widely spaced in the Northern Plains section, and water-level measurements were made in different wells in different years. Therefore, the water-table contours on plate 5 are not consistent with all the water levels shown in table 22, especially in the sector south of Lake Walcott.

The water table is less than 50 feet beneath the central floor of the Raft River valley in a belt 1 to several miles wide parallel to the river. In a narrower belt adjacent to the river the depth ranges from zero to less than 10 feet. Beneath high alluvial slopes the depth to water probably is as much as several hundred feet. To the north, in the basalt plains area, the depth to water is only a few feet in wells near Lake Walcott but reaches about 275 feet several miles south of the lake. Beneath elevated areas in the basalt plain the depth to water exceeds 300 feet. The depths to water and other data on wells are recorded in table 22 at the end of this report.

WATER-LEVEL FLUCTUATIONS

By R. L. NACE and S. W. FADER

An aquifer is a natural storage reservoir, and ground-water levels are an index of the amount of water in storage. Although fluctuations of ground-water levels are caused by many factors, the most important in the Raft River valley is changes in the volume of storage. A ground-water reservoir may contain in storage a volume of water equivalent to all the recharge during a few to many years, according to local conditions. If an aquifer contains 25 percent pore space, a column of the aquifer 100 feet long and 1 square foot in base area would contain 25 cubic feet of water if completely saturated. Removal of 1 cubic foot of water would cause lowering of the water level by somewhat more than 4 feet—more than 4 because not all the water can be removed from soil by gravity drainage, some being held against gravity by capillarity.

Periodic measurements were made in 9 observation wells in the Raft River valley and Northern Plains section. The hydrographs (figs. 14 and 15) show somewhat irregular short-term fluctuations,

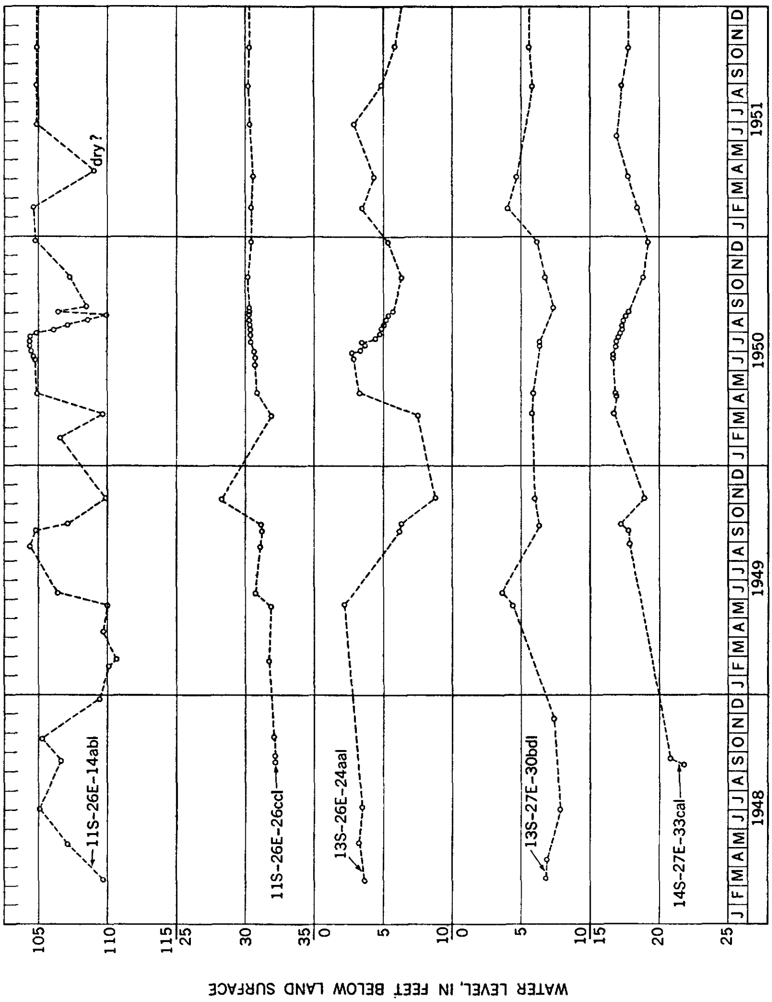

FIGURE 14.—Hydrographs of wells in the Raft River valley, 1948–51.

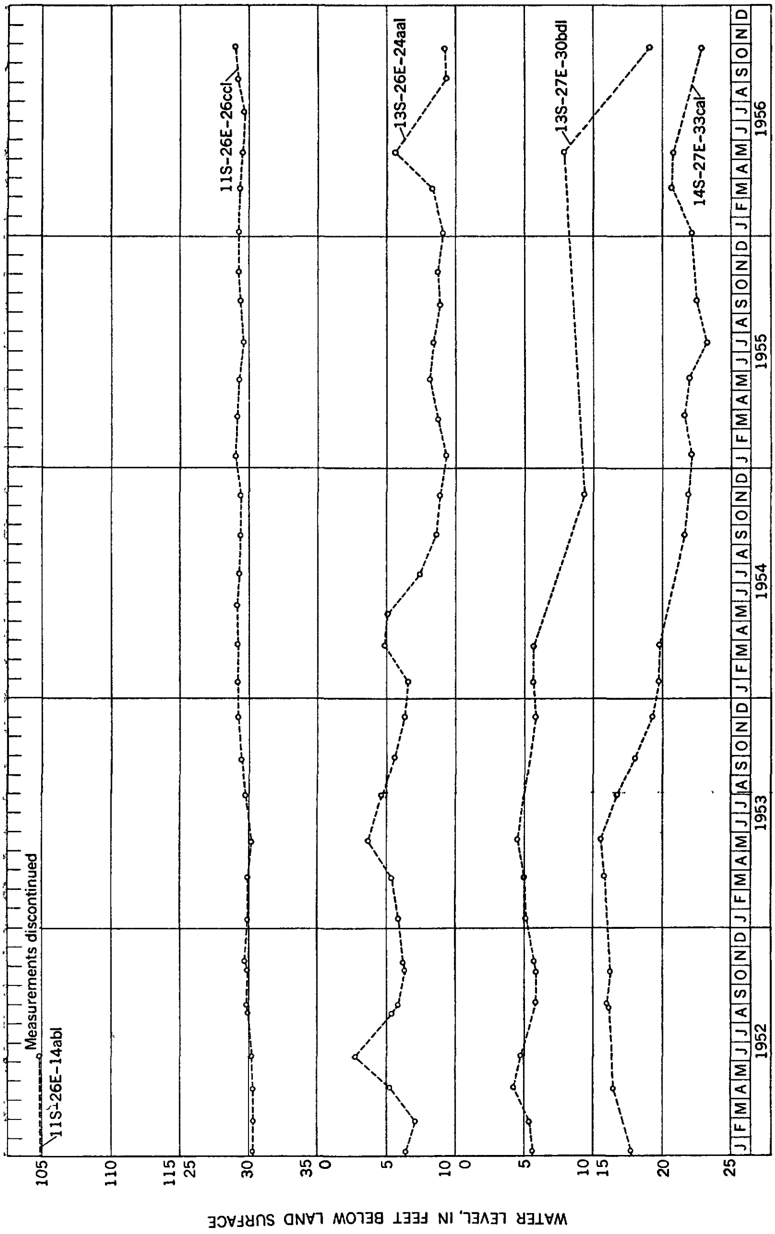

FIGURE 15.—Hydrographs of wells in the Raft River valley, 1952–56.

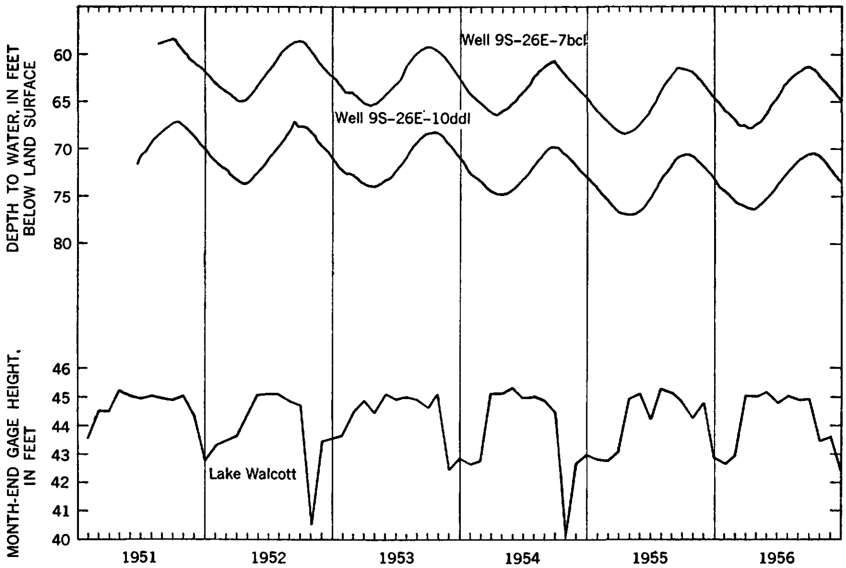

FIGURE 16.—Hydrographs of Lake Walcott and wells in the Northern Plains section.

which are superimposed on a long-term rising and falling of the water table. Irregularities are less pronounced in the Northern Plains section (fig. 16). The times of the high and low points in the yearly fluctuations differ in different parts of the basin and seemingly also in different years in a single part. Figure 16 shows little net change in surface storage in Lake Walcott from 1951 to 1956. Concurrently, the net decline of water levels in wells near the lake was nearly 3 feet. The annual rise of ground-water levels in that area lagged about 4 to 6 months behind the annual rise in stage of the lake.

Water levels in the irrigated lowlands of the Raft River valley tend to be highest early in the irrigation season but drop soon thereafter. (See figs. 14 and 15, hydrograph of well 13S–26E–24aa1.) Recharge of the shallow unconfined aquifers by unconsumed irrigation water is prompt, and water levels reach high stages soon after late-spring floodwater is applied to irrigated fields. The tendency toward an early rise of the water table is partly offset by drawdown from pumping in the irrigated area, and pumping contributes also to the later decline of water levels.

Outside the irrigated area and remote from heavily pumped irrigation wells, especially in foothill alluvial fans, the pattern of water-level fluctuations differs from that in the central lowland. The 17-year record for well 16S–26a1, near Naf, is an example (fig. 17). The extremes of low water levels at that location are not known because the well ordinarily is dry in the spring. The lower levels are reached between April and May. Thereafter, the water table rises

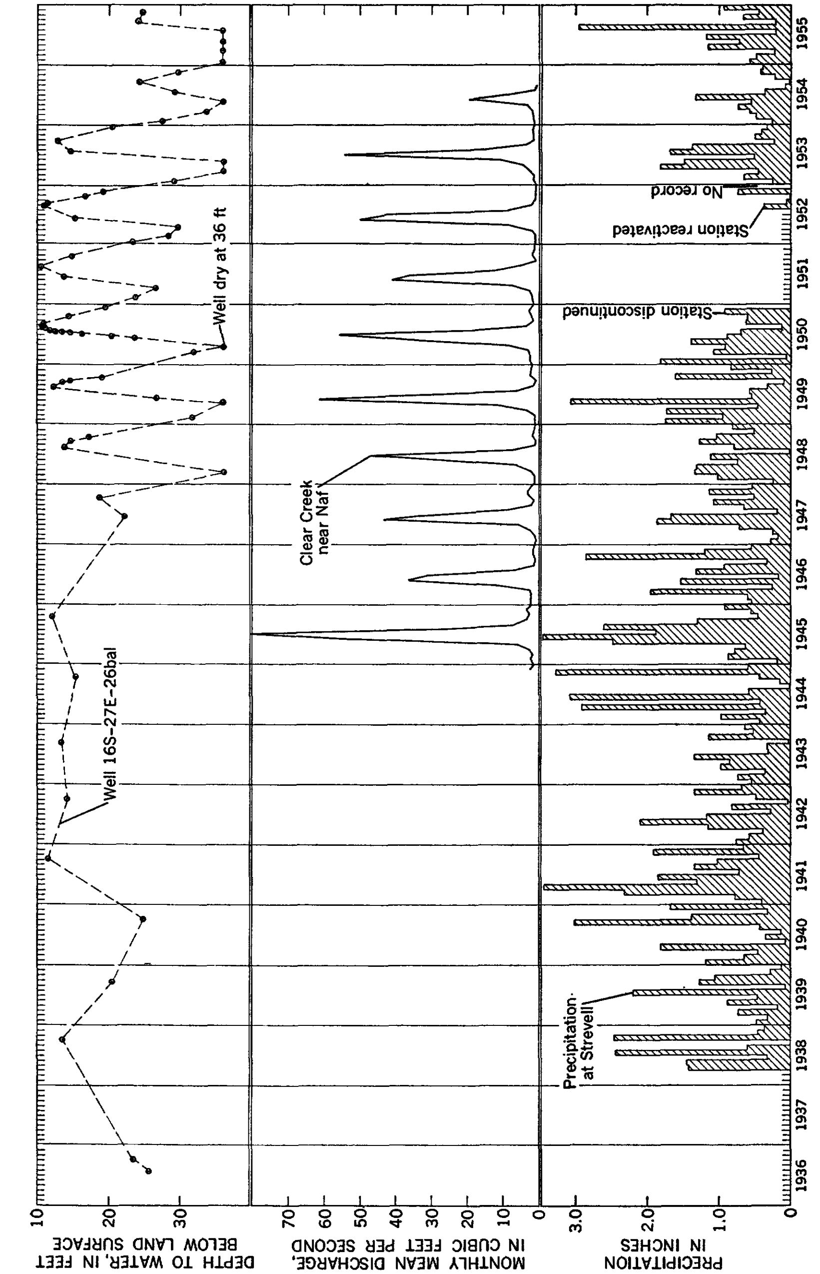

FIGURE 17.—Hydrograph of well 16S–27E–26a1, and Clear Creek near Naf, compared with precipitation and runoff.

rapidly to a peak in August or September. The well is distant from irrigation tracts and at a higher altitude than wells to the north. The late-spring rise, therefore, is not caused by recharge from irrigation. Comparison of the water-level changes with records of precipitation and stream runoff shows that the rise probably is caused by underflow after infiltration of late-spring rain and snowmelt in the mountains south of the well. The range of fluctuations is more than 25 feet in 6 months.

Runoff in the Raft River ordinarily increases in the spring shortly after average air temperature rises above freezing. The water level in the well near Naf rises a few weeks thereafter. Evidently the underflow "wave" from ground-water recharge in the upland lags several weeks behind runoff.

Clear and Rice Creeks, intermittent streams that are fed chiefly by snowmelt, converge toward the piedmont alluvial fan on which the well is situated. Records for Clear Creek indicate that the time of high runoff coincides approximately with that in the Raft River. Most of the creek water sinks into the piedmont plain and recharges the local aquifer. On the other hand, the water-level decline that begins about in August reflects diminished recharge and depletion of storage, owing to underflow of ground water out of the fan toward the lowland.

The annual rise and fall of the water table in the Raft River valley is superimposed on longer rising and falling trends that span terms of years (figs. 14 and 15). The long-term trends represent cumulative changes of storage corresponding to variations in precipitation and recharge, and to changes in ground-water pumping.

Water-level measurements in the Raft River basin, made early and late in several recent water years, are summarized in table 15. In some wells the net rise was 1 to 6 feet from 1948 to 1952, despite a rapid increase in pumpage for irrigation. During intervening years the water in several wells reached levels higher than in either 1948 or 1952. Therefore, the aquifers were receiving normal or more than normal recharge. Evidently, the increase in pumpage from 1948 to 1952, a period of ample precipitation and good water supply, did not appreciably deplete the amount of ground water in storage. During 1953 and 1954 the net decline in water levels was about 1 to 2.5 feet (figs. 15 and 16). However, in well 11S–26E–26cc1, which is in the northern part of the Raft River valley, the water level did not change appreciably in 1953–54, but rose slightly in 1955–56. Despite the recent heavy increase in pumpage, several wells showed little net change of water levels in 1955–56 (fig. 15). For the present, at least, there is no evidence that pumpage since 1947 has exceeded the average perennial recharge of the aquifers.

TABLE 15.—*Spring and fall water levels in observation wells*

[Water levels in feet below land-surface datum. All wells are in Idaho except where otherwise indicated]

Year	Spring	Water level	Fall	Water level
10S-25E-10ba1. Owner: Robert Simplot				
1948	----------	----------	Sept. 17	153.4
1949	Apr. 8	164.5	Sept. 28	153.8
1950	Apr. 21	161.1	Sept. 8	154.7
1951	Apr. 4	157.5	Aug. 28	154.2
1952	----------	----------	Oct. 19	154.2
1953	May 18	160.5	Sept. 27	154.6
1954	May 14	161.6	Sept. 17	156.0
1955	May 18	163.6	Sept. 20	156.9
Net change				−3.5
11S-26E-26cc1. Owner: Robert Simplot				
1948	----------	----------	Sept. 16	32.2
1949	May 19	31.8	Sept. 17	31.2
1950	Apr. 26	30.8	Sept. 8	30.3
1951	Apr. 4	30.6	Aug. 28	30.2
1952	Apr. 18	30.2	Sept. 2	29.9
1953	May 18	30.1	Sept. 27	29.4
1954	May 13	29.0	Sept. 16	29.3
1955	May 18	29.3	Sept. 21	29.3
Net change				+2.9
13S-26E-24aa1. Owner: John C. Hitt				
1941	----------	----------	Sept. 1	7.0
1942	Apr. 1	3.2	----------	----------
1943	----------	----------	----------	----------
1944	Apr. 5	4.0	Sept. 23	6.2
1945	Apr. 1	5.3	----------	----------
1946	Apr. 1	4.6	----------	----------
1947	Apr. 1	4.1	----------	----------
1948	May 7	3.08	----------	----------
1949	May 19	2.07	Sept. 17	6.19
1950	Apr. 22	3.10	Sept. 2	5.57
1951	Apr. 4	4.27	Aug. 28	4.96
1952	Apr. 18	5.20	Sept. 2	5.74
1953	May 18	3.56	Sept. 27	5.48
1954	May 13	4.98	Sept. 17	8.54
1955	May 18	8.21	Sept. 21	8.93
Net change				−1.93

TABLE 15.—*Spring and fall water levels in obervation wells*—Continued

Year	Spring	Water level	Fall	Water level
13S–27E–30db1. Owner: A. D. Pierce				
1948	May 7	6.91	----	----
1949	May 19	4.38	Sept. 28	6.27
1950	Apr. 20	5.88	Sept. 8	7.32
1951	Apr. 4	4.59	Aug. 28	5.75
1952	Apr. 18	4.28	Sept. 2	5.78
1953	May 18	4.48	Sept. 27	[1] 13.74
1954	May 13	[1] 13.63	Sept. 17	[1] 17.80
1955	May 18	[1] 16.10	Sept. 21	[1] 20.68
14S–27E–33ca1. Owner: Harold Oman				
1948	----	----	Sept. 10	21.6
1949	----	----	Sept. 17	17.8
1950	Apr. 19	16.9	Sept. 2	17.7
1951	Apr. 4	18.3	Aug. 28	17.3
1952	Apr. 18	16.5	Sept. 2	16.0
1953	May 19	15.5	Sept. 27	18.0
1954	Mar. 24	19.8	Sept. 17	21.6
1955	May 18	22.0	Sept. 21	22.5
Net change				−.9
15S–25E–6ab1 (in Almo Basin). Owner: Jenny Wake				
1948	----	----	Sept. 14	28.2
1949	May 19	24.1	Sept. 17	24.6
1950	Apr. 22	28.4	Sept. 2	24.6
1951	Apr. 4	29.6	Aug. 28	17.7
1952	Apr. 18	26.1	Sept. 2	20.2
1953	May 19	27.7	Sept. 27	17.9
1954	May 15	32.3	Sept. 17	30.2
1955	May 18	(2)	Sept. 21	32.6
Net change				−4.4
16S–27E–26ba1. Owner: Cook				
1948	May 7	(3)	Sept. 24	14.9
1949	May 19	(3)	Sept. 17	13.7
1950	Apr. 22	(3)	Sept. 2	10.9
1951	Apr. 4	26.7	Aug. 28	10.4
1952	Apr. 18	29.8	Sept. 2	11.3
1953	May 19	(3)	Sept. 27	12.9
1954	May 15	(3)	Sept. 17	24.3
1955	May 18	(3)	Sept. 21	24.1
Net change				−9.2

See footnotes at end of table.

TABLE 15.—*Spring and fall water levels in observation wells*—Continued

Year	Spring	Water level	Fall	Water level
(B-14-15) 3dddl, Utah.[4] Owner: M. A. Smith				
1935			Oct. 30	50.8
1936	Aug. 16	48.3	Oct. 9	51.2
1938			Oct. 11	49.1
1939			Sept. 28	50.8
1940			Oct. 9	51.7
1941			Oct. 8	47.9
1942			Oct. 5	47.8
1943			Sept. 25	48.3
1944			Oct. 23	49.1
1945			Oct. 25	43.7
1946			Oct. 25	49.7
1947			Oct. 28	50.3
1948			Oct. 22	50.5
1949			Oct. 18	49.9
1950			Nov. 15	51.2
1951	Aug. 28	46.5	Oct. 31	48.7
1952	May 28	28.8	Oct. 23	49.0
1953			Nov. 5	49.9
1954	Apr. 14	51.8	Oct. 12	51.6
1955			Nov. 1	51.8
1956			Oct. 31	50.2
1957			Oct. 16	46.8
(B-13-17) dabl, Utah.[4] Owner: Lynn School District				
1948			Oct. 22	24.1
1949			Oct. 18	21.4
1950			Nov. 15	23.4
1951			Oct. 31	22.5
1952			Oct. 23	23.0
1953			Nov. 5	22.3
1954			Oct. 12	26.0
1955			Nov. 1	24.8
1956			Oct. 31	24.5
1957			Oct. 16	24.6
(B-14-15) 11cc, Utah.[4] Owner: M. A. Smith				
1936			Oct. 9	25.9
1938			Oct. 11	23.3
1939			Sept. 12	23.5
1940			Oct. 9	26.7
1941			Oct. 8	17.8
1942			Oct. 5	20.1
1943			Sept. 26	22.9
1944			Oct. 23	21.9
1945			Oct. 25	22.5
1946			Oct. 25	21.1
1947			Oct. 28	24.0
1948			Oct. 22	23.8
1949			Oct. 18	22.4
1950			Nov. 15	22.9
1951			Oct. 31	23.9
1952			Oct. 23	24.2
1953			Nov. 2	24.7
1954			Oct. 12	26.8
1955			Nov. 1	26.4
1956			Oct. 31	25.4
1957			Oct. 16	24.0

TABLE 15.—*Spring and fall water levels in observation wells*—Continued

Year	Spring	Water level	Fall	Water level
(B-15-14) 36add, Utah.[4] Owner: H. Alberta				
1936			Oct. 9	5.5
1938			Oct. 11	4.6
1939			Sept. 23	8.7
1940			Oct. 9	5.7
1941			Oct. 8	4.3
1942			Oct. 5	4.4
1943			Sept. 26	4.1
1944			Oct. 23	4.0
1945			Oct. 25	3.9
1946			Oct. 24	3.9
1947			Oct. 28	4.0
1948			Oct. 22	4.1
1949			Oct. 18	4.2
1950			Nov. 15	3.9
1951			Oct. 31	4.0
1952			Oct. 23	4.7
1953			Nov. 5	4.1

1 Well being pumped.
2 Dry at 34 ft.
3 Dry at 36 ft.
4 Well-numbering system different from that used in this report.

The net decline of water levels after 1952 in most wells listed in table 15 probably was caused partly by the greatly increased draft of irrigation wells, but pumping was not the principal cause. Where recharge is normal in successive years, water levels rise between pumping seasons, although they may not rise to normal seasonal levels when pumpage is excessive. Progressive decline in both the high and low seasonal water levels generally is evidence of cumulative net reduction of storage and perhaps of overdraft; the yearly range of fluctuations also may increase with increased draft. Significantly, in the lowland of the Raft River valley water levels recovered but little between the 1953 and 1954 pumping seasons. Decline was nearly continuous from May 1953 to November 1954. (See lower two hydrographs, fig. 15.) This fact indicates that the net decline of water levels was largely a result of deficient recharge in a period of declining precipitation. In the Almo Basin, where no ground water is pumped for irrigation, the net decline in 1948–55 was 4.4 feet, indicating that deficiency in recharge was an important factor. Near Lake Walcott (fig. 16) decline was progressive after 1952, although there was no heavy pumping near the wells represented.

Figure 18 illustrates water-level fluctuations in the central Snake River Plain far from the Raft River valley. Well 8S–24E–31dc1 is in the midst of the heavily pumped area of the Minidoka North Side reclamation project. Well 2N–31E–35dc1 is many miles from

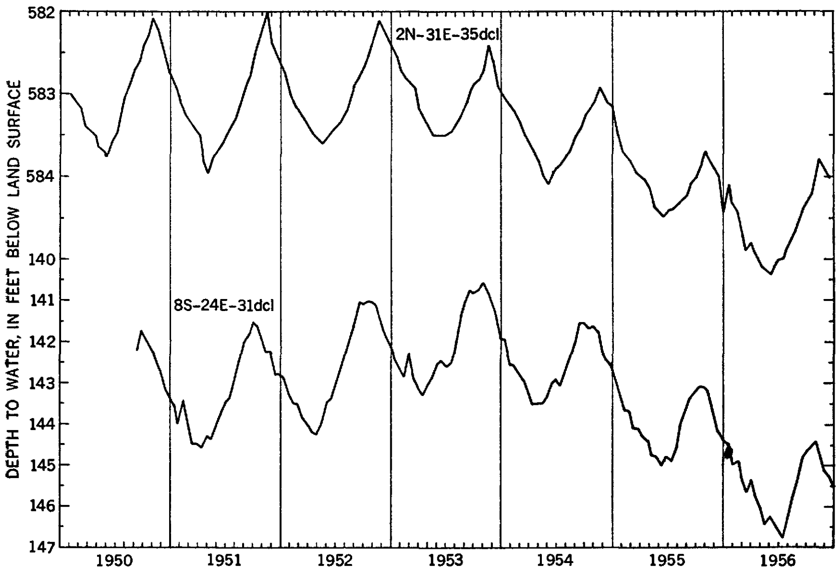

FIGURE 18.—Hydrographs of wells in the central Snake River Plain.

any heavy pumping. The graphs for both wells show declining water levels after 1952, just as in the Raft River valley.

Precipitation in 1953–54 was deficient at many places in southern Idaho and runoff and ground-water recharge were light. Runoff in Clear Creek in 1954 was little more than a third of the amount discharged in 1952 (table 11). Local residents in the Raft River basin reported that in 1954 springs, seeps, and streams discharged the smallest amount of water observed in many years. That condition reportedly existed in both lowlands and uplands. As the lowland pumping could not affect upland streams and springs, the principal cause of lowered water levels was deficient recharge.

RECHARGE

Recharge is the process of adding water to a ground-water reservoir. Recharge is also used as a noun, meaning recharge water. The source of practically all recharge in the Raft River basin is precipitation, some of which percolates downward to the zone of saturation and becomes ground water. The proportion of available water that becomes recharge is controlled largely by the physical character and moisture content of the soil, and the amount and intensity of precipitation. Recharge in the Raft River basin occurs principally by direct penetration of precipitation, infiltration from streams, and infiltration of unconsumed irrigation water. Because runoff in the basin is small and because water interchanges rapidly between surface streams and ground-water bodies, it is not practical to segregate quantities of recharge by sources and processes.

The water-table contours on plate 5 indicate a water-table gradient away from the south side of Lake Walcott and toward the Northern Plains section. The lake loses an appreciable amount of water by leakage (Crosthwaite and Scott, 1956, p. 15), but the amount of underflow from the lake into the Northern Plains section is not known.

Estimated average yearly precipitation in the Raft River valley is 13.7 inches, and estimated average evapotranspiration rate (water loss) is 12.3 inches (table 5). The unconsumed water yield is 1.4 inches, or 53,500 acre-feet from the whole valley. Probably at least half the yield—roughly 27,000 acre-feet—becomes direct recharge. The remainder runs off locally but practically all of it is recovered and diverted during the irrigation season. Most undiverted water in tributary streams sinks into the ground without reaching the Raft River. Most unconsumed irrigation water also enters the ground. The total volume of ground-water recharge in the Raft River basin evidently is about equal to the water yield minus that part of consumptive use by crops which is not supplied directly by precipitation.

In upland areas of the Raft River valley and its tributary subbasins undiverted runoff, especially at high-water stages, discharges from local drainageways onto alluvial fans, piedmont plains, and valley floors where most of the water enters the ground and recharges upland aquifers. Upland recharge replenishes the main ground-water bodies by underflow to the lowlands. On the other hand, the base flow of streams is effluent ground water, so it is unrealistic to attempt to make a sharp separation of ground water and surface water.

The estimated volume of precipitation on the entire Raft River basin is about 1,300,000 acre-feet yearly (table 5). About 1,100,000 acre-feet (86 percent) is consumed by evapotranspiration, and the residual water yield of 180,000 acre-feet (14 percent) is surface runoff and ground-water recharge. Although runoff occurs locally and some streams have perennial reaches, very little runoff reaches the Snake River, and most unconsumed water becomes recharge at some place above the mouth of the Raft River.

DISCHARGE

Ground water naturally discharges by evapotranspiration, seepage into stream courses, flow from springs, and underflow. Wells are the chief means for artificial discharge. From a local standpoint, underflow out of an area is a draft on the water supply and, in effect, is a discharge process, although the water remains in a zone of saturation. Water in the zone of saturation moves down the water-table gradient toward areas of natural or artificial discharge. In a natural regimen the average yearly discharge during a long term of years equals the average recharge; that is, recharge and discharge are about in equilibrium.

Evapotranspiration.—Water evaporates from open-water surfaces and the soil. Plant roots get water from the soil, from the capillary fringe above the water table, and directly from the zone of saturation. Plants store some water, but they exhale most of it to the atmosphere by a process called transpiration. The depth from which plant roots extract ground water ranges from a few inches for many grasses and field crops to tens of feet for some desert plants. Transpiration usually cannot be measured separately from evaporation, so the two processes commonly are referred to by the collective term "evapotranspiration."

In the Raft River basin evapotranspiration is especially rapid in bottom lands adjacent to the Raft River, where the water table seasonally is at or near the land surface and where native and cultivated water-loving vegetation abounds. Water-loving vegetation in some areas may consume on the average as much as 4 feet of water a year (Mower and Nace, 1957). The area occupied by such vegetation in the Raft River basin has not been measured, but undoubtedly it consumes a significant amount of water. Basinwide water consumption by water-loving plants is included in the estimates of evapotranspiration made earlier in this report.

Seepage into stream channels.—Seeps and springs discharge much ground water into stream courses in the bottom lands of the Raft River basin, and this water constitutes the base flow of the perennial streams. Discharge by seepage is small per unit area but large in aggregate. Springs discharge a lesser volume of water. Springs occur along the headwaters of all the streams in the Raft River basin and at many places along the Raft River channel between The Narrows and the Snake River. Inflow from springs and seeps generally is not directly identifiable, but along the lower 10 miles of the Raft River the amount probably is on the order of several thousand acre-feet a year.

Wells.—Ground-water withdrawal through wells has increased greatly since 1948 and now takes a substantial cut from the total water supply. The withdrawals are summarized and their relation to water development discussed on page 79.

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Underflow.—As surface discharge of water out of the basin is extremely small, the total volume of underflow out of the basin probably about equals the gross water yield minus consumptive use by irrigated crops. The proportions of underflow in unconfined and artesian aquifers are not known. An undetermined thickness of permeable basalt, interbedded sediments, and older sediments beneath the Northern Plains section is the conduit through which the water moves.

CHEMICAL QUALITY AND TEMPERATURE

The suitability of the water for irrigating the kinds of soils in the Raft River valley is a basic problem, because some of the lowland soils could be damaged by unsuitable water. Only a few chemical analyses have been made and all these are of ground water. The data are summarized in table 16.

TABLE 16.—*Chemical analyses of ground water from the Raft River valley*

[Chemical constituents in parts per million. Analyses by Geological Survey and Idaho Department of Public Health]

Well no.	10S-25E-10ba1	11S-26E-14ab1	13S-27E-30bd1	15S-26E-23bb1	15S-26E-23dd1
Depth of well (feet)	[1] 175	[1] 157	[1] 28	[2] 414	[2] 540
Date of collection	4-8-49	6-9-49	6-25-47	6-8-49	6-9-49
Temperature (°F)	57	54	49	199	211
Silica (SiO_2)	44	54	------	82	84
Iron (Fe)	------	------	.14	------	------
Calcium (Ca)	60	59	59	52	125
Magnesium (Mg)	40	11	18	1.7	3.3
Sodium (Na) and Potassium (K)	39	49	240	530	1,070
Bicarbonate (HCO_3)	242	151	220	58	45
Sulfate (SO_4)	56	26	54	59	64
Chloride (Cl)	98	105	360	820	1,800
Fluoride (F)	------	.4	.1	8.9	6.0
Nitrate (NO_3)	3.5	.3	------	.0	1.0
Boron (B)	.02	.0	------	.05	.04
Dissolved solids:					
Parts per million	460	379	618	1,580	3,180
Tons per acre-foot	.63	.52	.84	2.2	4.32
Hardness as $CaCO_3$:					
Total	314	192	221	136	326
Noncarbonate	116	68	41	89	288
Percent sodium	21	36	70	90	88
Sodium-adsorption ratio	1.0	1.5	7.0	20	26
Residual sodium carbonate	.00	.00	.00	.00	.00
Specific conductance (micromhos at 25°C)	780	658	------	2,920	6,010
pH	------	------	7.7	------	------

[1] Water-table well.
[2] Artesian well.

The temperature of the water from wells ranges from 48° to 211° F (table 17). Where hot water is used for irrigation it is cooled in open retention ponds before it is applied to cropland.

TABLE 17.—*Temperature of water from wells in the Raft River basin*

Well	Date of measurement	Temperature (°F)	Well	Date of measurement	Temperature (°F)
9S-27E-36ad1	July 19, 1950	52	13S-27E-30bd1	June 6, 1947	49
10S-25E-10ba1	Apr. 8, 1949	57		July 24, 1950	50
10S-26E-36dc2	Aug. 28, 1952	53	30ca1	Aug. 13, 1948	49
10S-27E-2ab1	Aug. 18, 1952	55	30da1	June 26, 1947	49
2cb1	do	53	30dc1	do	48
24cb1	July 19, 1950	62	30dd1	July 27, 1950	49
26dd1	Aug. 15, 1952	60	31bd1	Aug. 20, 1952	51
10S-28E-19cb1	do	59	32bb2	Sept. 10, 1948	51
11S-26E-12ab1	July 18, 1950	53	32cb1	Aug. 12, 1948	49
	Aug. 28, 1952	53		Aug. 19, 1952	51
12cb1	July 18, 1950	53	32cb2	do	51
	Aug. 28, 1952	53	33cb1	Aug. 21, 1952	51
13bb1	do	53	14S-27E-6ad1	Aug. 20, 1952	52
14ab1	June 6, 1949	54	6bb1	July 24, 1950	49
35bc1	July 6, 1950	57		Aug. 20, 1952	50
	Aug. 16, 1952	56	6db1	Aug. 19, 1952	51
35cc1	June 6, 1949	53	7ac1	Sept. 11, 1948	48
	Aug. 16, 1952	58		Aug. 20, 1952	49
35cc2	do	57	7ac2	do	52
35dc2	do	55	7ad1	Sept. 11, 1948	51
11S-27E-10aa1	Aug. 28, 1952	52		Aug. 20, 1952	53
15bd1	Aug. 15, 1952	55	7ad3	Sept. 11, 1948	51
35ad1	Aug. 18, 1952	56		Aug. 20, 1952	53
36ad1	do	70	8ac1	Aug. 21, 1952	50
			8ad1	do	50
12S-26E-1bc1	Aug. 16, 1952	53	17cc5	Sept. 13, 1948	50
1cc1	do	55	18ad1	do	51
2bc1	do	60		Aug. 21, 1952	50
25cd2	Aug. 18, 1952	53	28cc1	Sept. 10, 1948	50
12S-27E-19ca1	Aug. 29, 1952	51		Aug. 27, 1952	52
30dc1	do	54	29ab1	Aug. 21, 1952	52
13S-26E-1db1	Aug. 7, 1948	62	29bd1	do	51
13ba1	do	52	29bd2	do	50
	July 24, 1950	53	32ac1	Sept. 13, 1948	50
	Aug. 19, 1952	54		Aug. 27, 1952	50
13ba2	Aug. 7, 1948	52	32cc1	do	48
	July 27, 1950	53	15S-24E-13ab1	July 31, 1948	50
	Aug. 19, 1952	54	22ad1	Aug. 8, 1948	85
14ca1	do	55	15S-26E-23bb1	July 30, 1948	198
13S-27E-6cc1	July 29, 1948	50	23dd1	June 9, 1949	211
7cc1	Aug. 7, 1948	52	24ba1	June 23, 1950	111
	Aug. 29, 1952	54		Aug. 27, 1952	107
7cc2	Aug. 7, 1948	52	24bc1	June 23, 1950	68
	Aug. 29, 1952	54	24cd1	Aug. 14, 1948	94
18cb1	Aug. 7, 1948	49	15S-27E-7db1	Aug. 20, 1952	50
20cb3	Aug. 20, 1952	51	18ac1	Sept. 9, 1948	52
29bc1	Aug. 12, 1948	50		Aug. 27, 1952	53
	Aug. 20, 1952	52	18bc1	do	63
29dd2	Sept. 10, 1948	49	18bd1	June 26, 1950	55
29dd2	Aug. 21, 1952	50	16S-24E-12bd1	Aug. 3, 1948	49

SUITABILITY OF WATER FOR IRRIGATION

Well 10S-25E-10ba1, near the mouth of the Raft River Valley, obtains unconfined water from the Snake River basalt. The water contains no residual sodium carbonate (table 16). Classified with respect to percent sodium and dissolved solids (as electrical conductivity), the water is in the "good to permissible" class of Wilcox (1948). Classified according to the relation between the sodium-adsorption ratio (SAR) and electrical conductivity (U.S. Salinity Laboratory Staff, 1954), the water is in class C3–S1, which means that the salinity hazard (C3) is high and the sodium hazard (S1) is low.[2] Water having a high salinity hazard is permissible where the soil is drained adequately and salt-tolerant crops are grown. Water having a low sodium hazard can be used safely on most soils, except possibly where sodium-sensitive crops are grown. The sampled water thus seems to be good irrigation water for certain soil conditions.

In the sample of unconfined water from well 11S–26E–14ab1, the relation of the sodium percentage to dissolved solids indicates "excellent to good" quality in the Wilcox classification. The SAR class is C2–S1. There is no residual sodium carbonate. The water is of good quality for irrigation under most conditions. The source of the water is similar to that of the preceding sample.

Well 13S–27E–30bd1 taps unconfined water in Quaternary cobble gravel at shallow depth in an area where many irrigation wells draw water from a single aquifer. In terms of the sodium percentage and dissolved solids, the irrigation quality of the water is "permissible to doubtful." The SAR class is C3–S2 (alkaline). The water contains no residual sodium carbonate. This water would be unsuitable for poorly drained soil, and would be hazardous for fine-textured soil, especially where leaching action is poor.

The quality of the artesian water from well 15S–26E–23bb1 is "doubtful to unsuitable" in terms of the sodium percentage and the dissolved solids. The SAR class is C4–S4; that is, the salinity and sodium hazards both are very high. There is no residual sodium carbonate. The water would be unsuitable for irrigation under ordinary conditions because of the salinity hazard, which would require permeable, well-drained soil, considerable leaching, and salt-tolerant crops. Owing to the very high sodium hazard together with the high salinity hazard, the water is unsuitable for irrigation. The aquifer probably is the Salt Lake(?) formation, and the high temperature of the water indicates that part or all of the water comes from substantial depth. Comparatively few wells in the Raft River valley tap hot water or water of this class.

The artesian water from well 15S–26E–23dd1 may be similar in origin to water in well 23bb1. The water is "unsuitable" in the sodium percentage-dissolved solids classification. The SAR class is C4–S4 (very high salinity and sodium hazards). There is no residual sodium carbonate. The water is unsuitable for irrigation.

Perhaps the most notable characteristic of the water samples as a group is the extreme range in chemical composition. The latter two

[2] The Wilcox and U.S. Salinity Laboratory classification systems were summarized in a report on the Mountain Home, Idaho project (Nace and others, 1957).

samples noted above are conspicuous for their relatively high concentrations of dissolved solids and high temperature.

WATER DEVELOPMENT AND ITS EFFECTS

Present use of water and effects of this use on the water supply and water cycle are the basis from which future development will proceed. This section summarizes the history of developments and their status at the end of 1955.

GROUND-WATER PUMPAGE

By S. W. FADER and H. G. SISCO

Pumpage of ground water in the Raft River valley was only about 8,700 acre-feet in 1948 at the beginning of the recent period of rapid exploitation (table 18). By 1955 pumpage was 64,000 acre-feet, representing a sevenfold increase. Probably about 10,000 acre-feet of this ground water supplemented the supply for lands served chiefly with surface water. The residual 54,000 acre-feet was applied to 25,000 acres or more which has no other source of water.

TABLE 18.—*Estimated yearly pumpage from irrigation wells in the Raft River valley, 1948–55*

Township (south)	Range (east)	Number of wells [1]	Pumpage (acre-feet per year)							
			1948	1949	1950	1951	1952	1953	1954	1955
9	27	1	44	44	44	44	44	44	44	44
10	26	1–3	0	0	0	0	260	360	700	1,800
10	27	1–4	0	0	40	300	950	1,600	1,000	1,000
10	28	2–3	0	510	700	640	620	1,040	900	900
11	26	2–12	870	1,100	2,400	2,900	5,400	4,950	6,700	9,800
11	27	1–9	470	1,400	--------	1,300	2,800	2,900	5,000	8,800
11	28	0–1	0	0	0	0	0	0	1,000	1,300
12	26	1–8	44	41	190	1,800	2,200	2,850	5,900	6,701
12	27	0–6	0	0	70	210	500	520	1,700	2,100
13	26	4–12	380	440	250	340	490	520	750	2,300
13	27	16–26	3,600	3,900	4,800	3,300	4,200	4,700	8,200	9,300
14	27	12–39	900	1,600	2,500	2,200	3,000	3,100	8,200	11,500
15	26	4–7	1,300	1,400	1,500	1,200	1,100	910	2,200	2,100
15	27	2–10	840	800	1,000	790	1,100	1,800	4,200	6,400
16	24	2	180	200	220	200	200	220	--------	--------
16	25	1	73	73	73	73	73	73	73	73
Total (rounded)	-------	---------	8,700	11,500	13,800	15,300	22,900	25,600	46,500	64,000

[1] Number pumped in any one year, not total number present.

WATER DEPLETION AND NET WATER YIELD

The gross yearly rate of consumptive use of water on irrigated croplands in southern Idaho is commonly estimated to be about 2.2 feet, of which 0.2 to 0.6 foot may be supplied directly by precipitation, according to soil-moisture conditions in the spring and the distribution of rainfall during the growing season. Owing to the relatively high altitude, short growing season, and types of crops grown in the Raft River basin, the average consumptive use by crops probably is 2.0 feet (24 inches) in the Raft River valley and 1.8 feet (21.6 inches) in the Yost-Almo basin. On that basis crops on 35,000 acres in the Raft River valley now use 70,000 acre-feet of water yearly, and on 8,000 acres in the Yost-Almo basin they use 14,400 acre-feet. The total is 84,400 acre-feet. The computations in table 5, however, have already allowed for some depletion in the irrigated areas by including these areas in the total areas of the subbasins and allowing for evapotranspiration at the average rate for land in the native state. The net water-yield figure is adjusted by allowing for additional evapotranspiration on irrigated land as shown below. The precipitation, native-yield, and native-loss values used are estimates for the specific areas irrigated. Therefore, they differ slightly from the general values in table 5.

Additional demand for irrigation water in the Raft River basin

Raft River valley:		
Total use of water on irrigated land		2.0 ft
Precipitation in irrigated area	11 in	
Native water yield	.25 in	
Native water loss	10.75 in =	.89 ft
Additional demand for irrigation		1.11 ft
Total additional for 35,000 acres		38,900 acre-feet
Yost-Almo basin:		
Total use of water on irrigated land		1.8 ft
Precipitation in irrigated area	15 in	
Native water yield	.9 in	
Native water loss	14.1 in =	1.18 ft
Additional demand for irrigation		.62 ft
Total additional for 8,000 acres		4,950 acre-feet
Total additional demand for 43,000 acres in Raft River Valley and Yost-Almo basin (rounded)		44,000 acre-feet

Therefore, the apparent basinwide consumptive use of water is about 1,150,000 acre-feet yearly (1,105,000 computed in table 5 plus 44,000 additional acre-feet derived above for irrigated lands). The estimated unconsumed residual water yield of the entire basin, therefore, was about 140,000 acre-feet yearly at the stage of development at the end of 1955. Development since 1955 has reduced that amount somewhat. Some water leaves the basin at the mouth of the Raft River and this probably could not be salvaged. However, the Northern Plains section gains some water by leakage from the south side of Lake Walcott, and this tends to offset the loss in the river.

In a later section of this report, the credibility of the estimated total water yield is tested by calculations based on the transmissibility of the aquifers that would have to transmit this amount. (See p. 96.)

POTENTIAL DEVELOPMENT

Irrigation with surface water in the Raft River basin has reached the practical limit of development without surface storage. With the small amount of surface flow available, the ratio of cost to benefit for storage structures might be unfavorable. Nevertheless, good prices for farm products and a large amount of undeveloped land in the Raft River valley stimulated a strong demand for additional water in recent years. Much additional development is in prospect, and the uncommitted water supply available for additional irrigation is a critical factor in the economic future of the area.

The status of undeveloped land in the Raft River valley lowland is summarized in table 19. Exclusive of 43,000 acres of land estimated to have been under irrigation in the basin in 1955, about 30,000 acres of public land in the Raft River valley might be irrigated if desert-entry and homestead applications were allowed and proved up. The 158,000 acres of nonirrigated private land in the valley probably includes a large irrigable area. Some State-owned land, which is subject to sale, also could be irrigated. In addition to the land-entry applications shown in the table, 28 desert-entry applications have been disallowed because they apply to land that is part of an experimental halogeton weed-control area.

TABLE 19.—*Status of land in lowland of Raft River valley*[1]

[Based on unpublished records of the Bureau of Land Management, Feb. 29, 1956]

Status of land		Area (acres)
Federal land:		
Vacant land in Bureau of Land Management range reseeding project; not open to homesteading or desert entry		175,000
Subject to homesteading or desert entry		29,970
Applications allowed	12,165	
Applications pending field examination and report	14,045	
Public-sale applications and land proposed for exchange for private tracts (action suspended pending examination and report)	3,760	
Former Federal land, patented since 1949		2,960
State-owned land, subject to sale		19,720
Private land, nonirrigated		158,400
Total		386,050

[1] Tps. 9-16 S., Rs. 26-27 E., T. 13 S., R. 28 E., and western parts of Tps. 14-16 S., R. 28 E.

THE WATER BUDGET

The discharge of the Raft River at its mouth is very small and probably is less than 10,000 acre-feet per year. Thus, by far the larger share of water loss from the basin occurs by underflow. Surface discharge occurs within the basin, and approximate estimates may be made of the surface- and ground-water components of some local water supplies, as was shown for the Yost-Almo Basin above The Narrows. From an overall or basinwide standpoint, however, there is a single water supply, and most of that supply is underground.

Estimates derived on earlier pages indicate that the gross water supply contributed to the basin by precipitation is about 1,290,000 acre-feet yearly. The consumptive-use draft by native land and vegetation is 1,105,000 acre-feet, and 44,000 additional acre-feet is consumed by crops. The discharge at the mouth of the Raft River probably is near the irreducible minimum but it is compensated at least partly by leakage from Lake Walcott into the Northern Plains section. The residual unconsumed water yield of the basin is estimated to be 140,000 acre-feet yearly. That supply includes diverted and pumped irrigation water that is not consumed but returns to ground-water storage. The recoverable and usable part of the uncommitted water yield is the limiting factor in further development of the native water supply. Pumping of 208,300 acre-feet in the 8-year period 1948–55 (an average of 26,000 acre-feet per year), during which yearly pumpage increased tenfold, seems not to have caused any appreciable net decrease in ground-water storage. Most of the pumped water would have escaped by underflow had it not been pumped.

FACTORS THAT WOULD LIMIT WATER DEVELOPMENT

Factors that would limit further development and use of water in the Raft River basin are availability and cost of power for pumping, chemical suitability of water for use on soils in that area, topographic suitability of land for irrigation, and amount of suitable water that could be recovered.

Diesel and gasoline engines are sources of power for pumping at some places, but most pumping of ground water in Idaho is done with electric power. All pending applications for land entry that require a showing of water would depend on electric power (Idaho State supervisor, U.S. Bur. Land Management, oral communication, June 1, 1956). Existing power-transmission lines already were loaded about to capacity in 1955, and expenditure of about 2.5 million dollars would be necessary to accommodate a greatly increased powerload (manager, Raft River Electric Cooperative, oral communication, April 1956). Study of the power situation and other nonhydrologic factors is beyond the scope of this report.

No detailed soil- and land-classification studies have been made in the Raft River valley, but a large part of the land listed in table 19 undoubtedly is unsuitable for irrigation because of poor soil, rough topography, poor aquifers, and other factors. If only 100,000 acres is irrigable, the additional consumptive-use demand would be about 110,000 acre-feet, exclusive of that satisfied directly by precipitation. The gross diversion demand would be 200,000 to 300,000 acre-feet, or far more than the estimated supply of unconsumed and uncommitted water in 1955. Because much of the pumped water would not be consumed and could be reused, the net consumptive-use demand would be much less than 200,000 acre-feet.

Schemes for construction of dams and storage of surface water in the Raft River basin have been discussed repeatedly, but none has been adopted by the landowners. Only small water supplies could be made available by storage. Water might be imported from the Snake River, but no plan has been proposed. The amount of water available in the Raft River basin, or imported thereto, will be the final limiting factor in agricultural development, because the amount of arable land far exceeds that which could be served with the recoverable native water supply. Hydrologic factors that would limit utilization of the supply are ability of the aquifers to yield water to wells, amount of water that wells or other structures can intercept, effect of pumping on water rights within and downstream from the basin, and suitability of the water for irrigation.

ABILITY OF AQUIFERS TO YIELD WATER

By J. W. STEWART and S. W. FADER

The yield from a well depends on the hydraulic properties of the aquifer and on the constructional characteristics of the well. The principal hydraulic properties of aquifers are expressed mathematically as the specific yield, the coefficient of storage, and the coefficients of permeability and transmissibility. The performance of a well is sometimes expressed in terms of specific capacity.

In this context, the specific yield of an aquifer is the volume percentage of water that will drain by gravity from saturated sediments. In unconfined aquifers it is practically equal to the coefficient of storage. The coefficient of storage of an aquifer is the amount of water it 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.

The standard coefficient of permeability (P_m) used by the Geological Survey is the rate of flow of water, in gallons per day, through a cross-sectional area of 1 square foot of an aquifer, under a hydraulic gradient of 100 percent, at a temperature of 60°F. The field coefficient of permeability (P_f) is the same except that it is measured under prevailing conditions, particularly as to temperature of the water. Either coefficient can be expressed in terms of flow through a section 1 foot thick and 1 mile wide under a hydraulic gradient of 1 foot per mile.

The coefficient of transmissibility is a useful expression of the total capacity of a formation to transmit water under a given gradient. The coefficient of transmissibility is the rate of flow of water, in gallons per day, under prevailing conditions, through a vertical strip of the aquifer 1 foot wide (measured at right angles to the direction of flow), extending the full saturated thickness of the aquifer, under a hydraulic gradient of 100 percent; it is the average field coefficient of permeability multiplied by the thickness of the aquifer, in feet.

The specific capacity of a well is the quantity of water yielded by the well, in gallons per minute per foot of drawdown. The term is correctly applied only to wells in which the drawdown varies approximately in proportion to the yield. To compare wells, their average yield during a uniform period, divided by the drawdown at the end of that period, is taken as the specific capacity. Uniformly comparable data are not available for wells in the Raft River valley so the specific capacities shown in table 20 are only indicative and only roughly comparable.

TABLE 20.—*Specific capacities of some irrigation wells in the Raft River valley*

Well	Reported average pumping rate (gpm)	Reported drawdown of water level (feet)	Specific capacity (gpm per foot) (*C*)	Duration of test (hours) (*t*)
10S–27E–2cb1	1, 260	50	[1] 25	Several
26dd1	1, 100	35	31	----------
35ac1	900	70	13	----------
10S–28E–19cb1	1, 350	30	45	3
11S–26E–2dc1	990	26	38	24
10dd1	3, 125	55	56	24
12cb1	2, 380	17	140	72
13bb1	1, 080	30	36	72
25bc1	2, 700	40	67	72
25cc1	1, 080	100	10	72
26dc1	900	100	9	72
27bb1	1, 800	30	60	72
11S–27E–3da1	2, 500	35	71	Several
10aa1	2, 500	8	312	Several
12dd2	2, 160	81	26	72
15bb1	540	55	10	Several
28cc1	1, 125	45	25	Several
28cd1	1, 350	30	45	Several
31dd1	1, 500	50	30	¼
32ad1	1, 800	86	21	Several
34cd1	1, 300	25	52	2
12S–26E–1bb1	1, 620	22	73	4
1cc1	1, 800	40	45	72
2bc2	117	120	1	72
11bb1	630	32	19	17
11bd1	1, 530	44	34	10
11cc1	1, 440	105	14	5
12cc2	1, 440	40	36	Several
36ab2	1, 080	70	15	----------

See footnote at end of table.

TABLE 20.—*Specific capacities of some irrigation wells in the Raft River valley*—Con.

Well	Reported average pumping rate (gpm)	Reported drawdown of water level (feet)	Specific capacity (gpm per foot) (*C*)	Duration of test (hours) (*t*)
12S–27E–19ca1	1, 305	13. 7	95	120
30dc2	800	66	12	Several
31bb1	1, 125	30	37	Several
13S–26E–13ca1	130	13	10	72
22cb1	1, 800	100	18	Several
24aa1	763	13. 1	58	----------
13S–27E–7ad1	900	34	26	1
18db1	1, 170	17	69	2
13S–27E–19dd1	1, 290	17	76	15
32cb2	540	50	11	15
14S–27E–4cd1	2, 250	111	20	72
7ad1	265	5. 7	46	24
7dc1	1, 080	20	54	----------
8ac1	405	45	9	20
8cb1	990	74	13	10
16cd1	900	50	18	Several
16dd1	1, 125	90	12	Several
17ba1	900	62	14	6
17bd2	630	82	8	12
18dd1	2, 500	62	40	7
20ba1	450	60	7	Several
20cd1	900	86	10	----------
32bd1	720	49	14	8
15S–26E–27dc1	1, 230	42	29	----------
33bb1	585	86	7	----------
34bb1	1, 200	90	13	8
15S–27E–6ab1	1, 800	60	30	24
6ad1	2, 250	60	38	24
7db1	1, 120	69	16	Several
8cb1	1, 260	70	18	5
19cc1	810	78	10	24

[1] If the reported drawdown is correct, the specific capacity was 21.6 during the pumping test on September 4–5, 1957, when the pumping rate averaged 1,080 gpm during 22 hours.

PRINCIPLES OF AQUIFER TESTS

Direct information about the hydraulic properties of water-bearing materials in the Raft River Valley is limited to the data from two tests, made by observing water-level fluctuations during pumping from wells. The results of these tests were analyzed by means of the nonequilibrium formula (Theis, 1935), the generalized graphical method (Cooper and Jacob, 1946, p. 527–528), and the recovery method (Theis, 1935). The recovery method permits computation of the coefficient of transmissibility from observations of the rate of water-level recovery in a well after the pump is shut down. Several methods of solving the nonequilibrium formula were used in analyzing the test data because each method has certain advantages, and each serves as a general check on the other. Methods for analyzing aquifer tests have been summarized by Brown (1953) and Ferris (1945).

TEST OF DUNN IRRIGATION WELL

An aquifer test was made with well 10S–27E–2cb1 on September 4–5, 1952. The well was pumped for 22 hours at an average rate of about 1,080 gpm. The well reportedly is 299 feet deep and is completely cased with 18-inch steel casing, but the location, size, and number of perforations in the well casing are not known. The open bottom presumably is in sand. During the test, an automatic water-stage recorder was operated on observation well 10S–27E–3da1, 300 feet west of the pumped well. The coefficients of transmissibility and storage were computed by the type-curve method. Water-level fluctuations in the observation well are shown in figure 19.

The values of observed drawdown, s, plotted against corresponding values of $\frac{r^2}{t}$, are shown in figure 20 (r, distance from pumped well to observation well, in feet; t, number of days that well was pumped). Superposing this series of points on the type curve, a match point

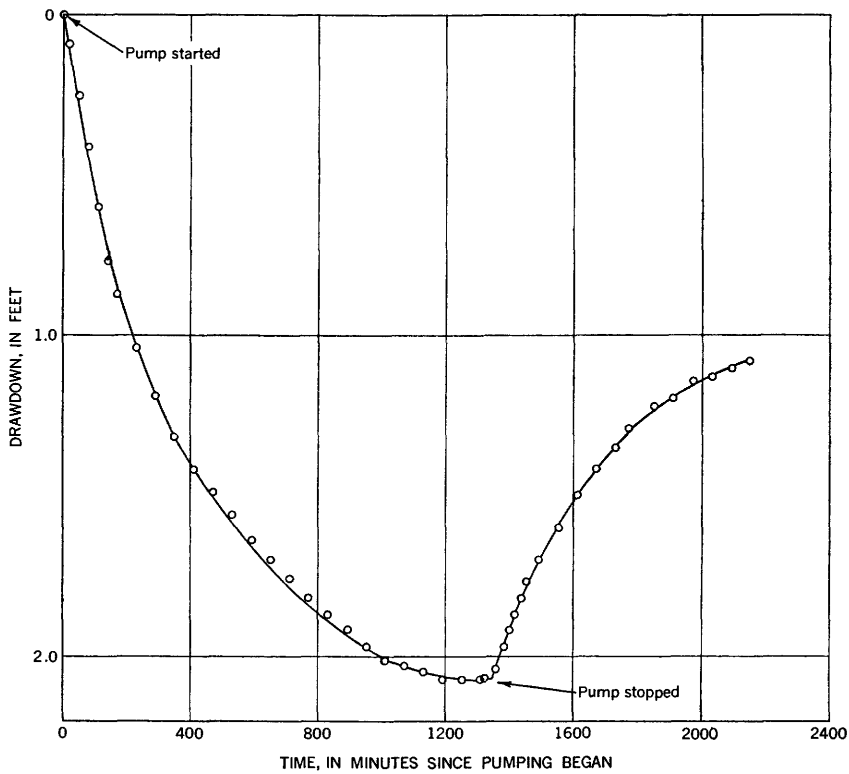

FIGURE 19.—Fluctuations of water level in well 10S–27E–3da1, caused by pumping well 10S–27E–2cb1 at an average rate of 1,080 gpm September 4–5, 1952.

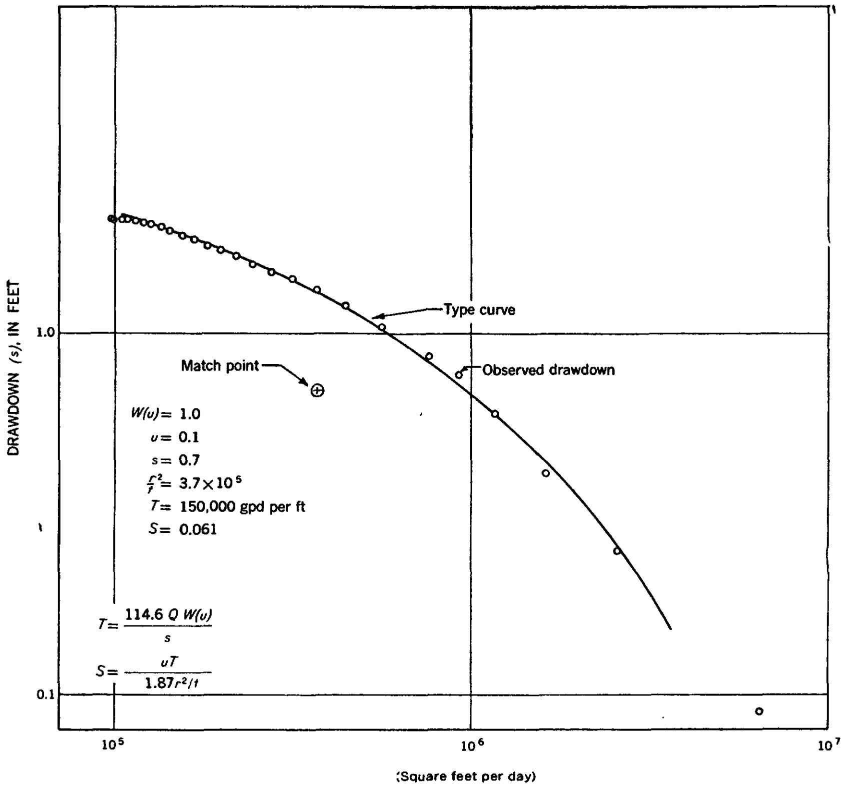

FIGURE 20.—Drawdown of water level in observation well 10S–27E–3da1, September 4–5, 1952 (type-curve method).

was selected having the following coordinates ($u=\frac{1.87\ r^2\ s}{T\ t}$; $W(u)$, is well function of u, obtained from reference tables):

Type curve	*Observed data*
$u=0.1$	$\frac{r^2}{t}=3.2\times10^5$
$W(u)=1.0$	$s=0.8$

Substituting these values in appropriate equations, the coefficients of transmissibility (T) and storage (S) were computed as 154,000 gpd per square foot and 0.026, respectively.

TEST OF MALTA LAND AND IRRIGATION CO. WELL

Another aquifer test was made by pumping irrigation well 14S–27E–7ad1 for 24 hours on October 17–18, 1952. The average pumping rate was 270 gpm. Three nearby wells (7ad2, 7ad3, and 7ac2) were used as observation wells during the test; the wells are 81, 161, and

280 feet, respectively, from the pumped well. Wells 7ad1, 7ad2, and 7ad3 are dug, about 30 feet deep, and finished with 48-inch perforated concrete casing. Well 7ac2 is drilled, about 63 feet deep, and is cased completely with 18-inch casing. The location, size, and number of perforations in the wells are not known.

From drillers' logs for other wells in the vicinity, it is inferred that at this well site there is about 3 feet of soil underlain by 28 feet of coarse gravel. About 2 feet of relatively impermeable clayey and silty material underlies the gravel. An underlying zone of sand and gravel extends from a depth of about 33 feet to at least 68 feet.

The drawdown and recovery of water levels in observation wells 7ad2, 7ad3, and 7ac2 are shown in figure 21. Figures 22, 23, and 24 are logarithmic graphs of drawdown in the wells. The coefficients of transmissibility and storage were obtained by the type-curve method as outlined for well 10S–27E–3da1. Based on observed data in the three observation wells, the computed value for T is 180,000 gpd per foot from well 7ad2, 200,000 from well 7ad3, and 170,000 from well 7ac2.

Figure 25 is a distance-drawdown graph showing drawndown in the observation wells after pumping irrigation well 7ad1 for 24 hours. The value of Δs over one logarithmic cycle is 0.8 feet; r is 590 feet at the intercept, $s=0$. From standard formulas the coefficients of transmissibility and storage are 180,000 gpd per foot and 0.16, respectively.

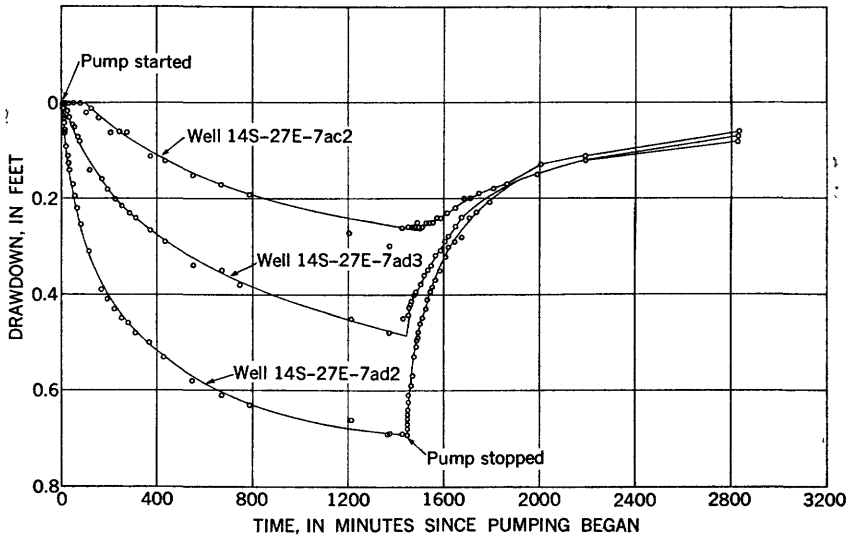

FIGURE 21.—Drawdown and recovery of water levels in wells 14S–27E–7ad2, 7ad3, and 7ac2, caused by pumping 7ad1 at an average rate of 272 gpm, October 16–19, 1952.

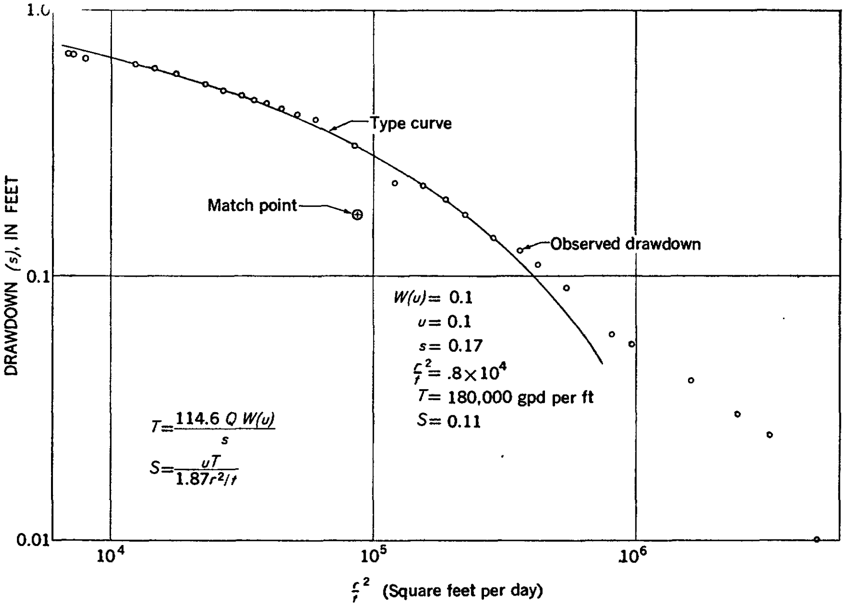

FIGURE 22.—Drawdown of water level in observation well 14S–27E–7ad2, October 16–19, 1952.

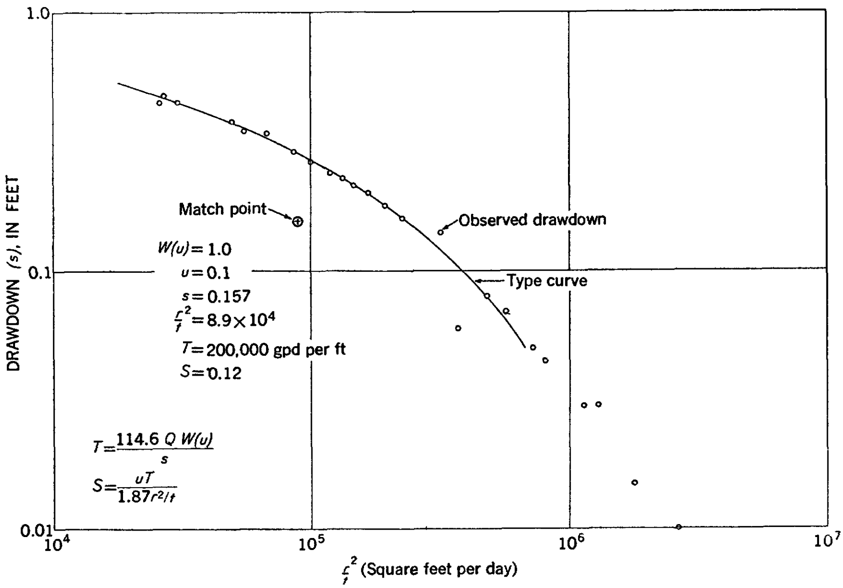

FIGURE 23.—Drawdown of water level in observation well 14S–27E–7ad3, October 16–18, 1952.

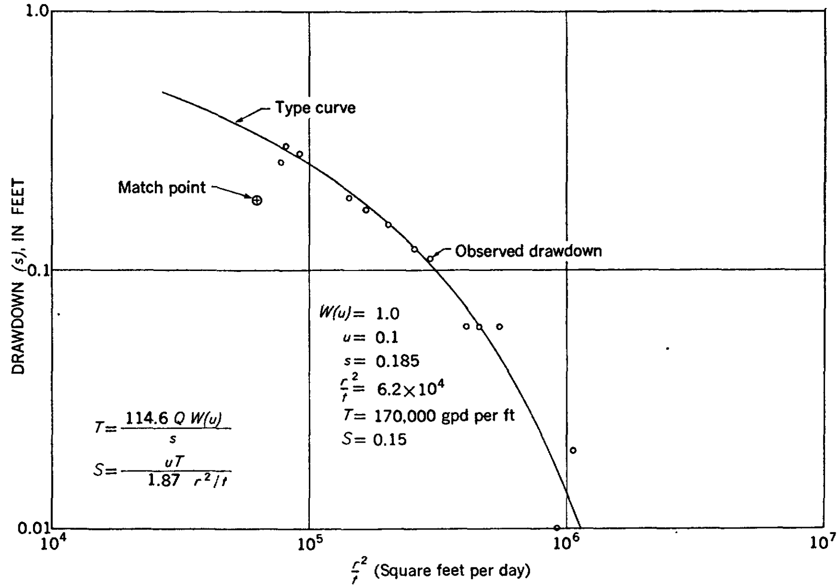

FIGURE 24.—Drawdown of water level in observation well 14S–27E–7ac2, October 16–18, 1952.

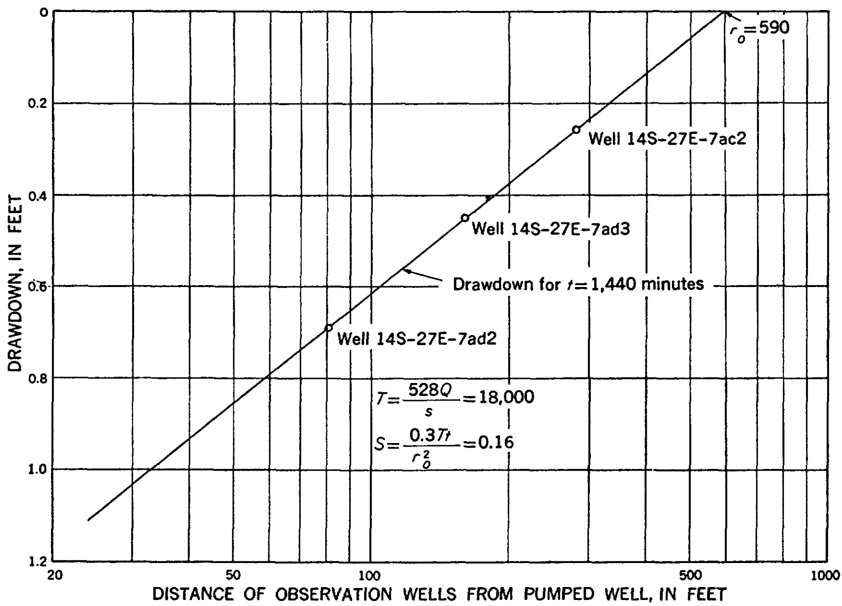

FIGURE 25.—Distance-drawdown graph for observation wells during test of well 14S–27E–7ad1, October 17–18, 1952.

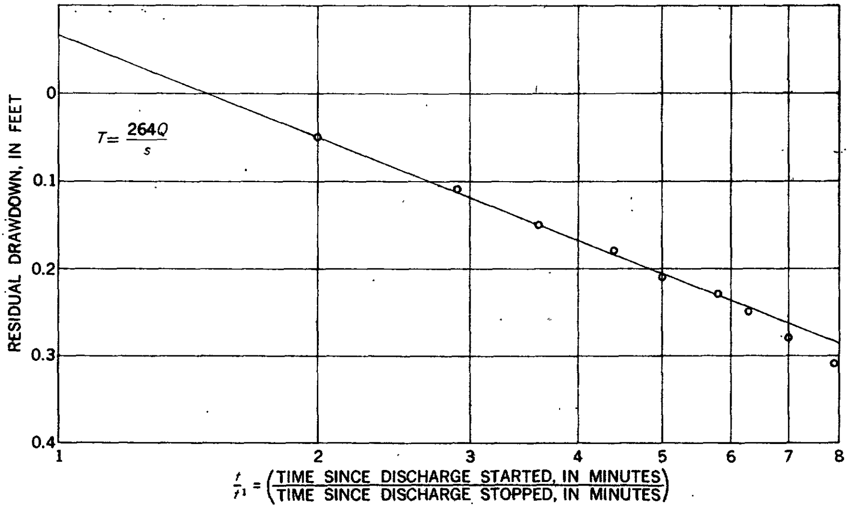

FIGURE 26.—Recovery of water level in well 14S–27E–7ad1, October 18–19, 1952.

The recovery method was used to determine the coefficient of transmissibility of the water-bearing material in the vicinity of pumped well 7ad1. Figure 26 is a plot of $\frac{t}{t'}$ (time since pumping started divided by time since pumping stopped) against corresponding values of the residual drawdown. The value of the s-intercept over one logarithmic cycle is 0.39 feet. The computed value of T is 180,000 gpd per foot.

SUMMARY OF AQUIFER TESTS

The tests of gravel and sand aquifers at two localities in the Raft River valley yielded the data summarized in table 21. The test of well 14S–27E–7ad1 indicates a coefficient of transmissibility in that vicinity of about 180,000 gpd per foot and a storage coefficient of about 0.12. The test of well 10S–27E–2cb1 indicates a coefficient of transmissibility of about 180,000 gpd per foot and a coefficient of storage of about 0.025.

The low storage coefficient indicated for the aquifer by observations at well 10S–27E–3da1 probably reflects the presence of water-bearing basalt in the upper part of the zone of saturation. The basalt, although very permeable, is low in average porosity and storage capacity. The main aquifer tapped by the well is not known, but much of the water probably is under slight artesian pressure in fine-grained sand.

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TABLE 21.—*Computed hydraulic coefficients of aquifers in the Raft River valley*

Pumped well	Observation well	Method of calculation	Coefficient of transmissibility (*t*) (gpd per foot)	Coefficient of storage (*s*)
10S-27E-2cb1	10S-27E-3da1	Type-curve	180,000	0.025
14S-27E-7ad1	14S-27E 7ad1	Recovery	180,000	.12
	7ad2	Type-curve	180,000	.112
	7ad3	do	200,000	.119
	7ac2	do	170,000	.146
	7ad2, 7ad3, 7ac2	Distance-drawdown	180,000	.156
Average			180,000	0.097

EVALUATION OF TESTS AND AQUIFERS

By R. L. NACE

The hydraulic coefficients calculated from the two sets of aquifer tests represent only a minute part of the aquifers in the Raft River valley. On the very liberal assumption that the effects of pumping each well extended to a radial distance of 1,000 feet from the well, the tests of the two wells represent the response of less than one-eighth of a square mile of the aquifer. The lowland aquifers underlie several hundred square miles of the valley, so the pumping tests did not adequately sample the aquifer characteristics. Nevertheless, from general geologic knowledge of the valley, and from the logs and other records of many wells, the author believes that aquifer characteristics in much of the central valley resemble those in the vicinity of well 14S-27E-7ad1, the Malta Land and Irrigation Co. well. The Dunn irrigation well is in the basalt area of the Northern Plains section and the aquifers there do not represent the Raft River valley generally. The well logs (p. 111-121) illustrate similarity of the geologic materials in areas where wells have been drilled.

The specific capacity of the Malta Land and Irrigation Co. well is 46 gpm per foot of drawdown, or about the average for wells listed in table 20. Wells in that vicinity tap water to depths of a few tens of feet in permeable sand and gravel, but there are intercalated layers of poorly permeable silt and silty clay. Similar beds occur below the bottoms of the wells. Some well logs in that vicinity show gravel and interbedded silt, clay, and sand to depths of several hundred feet. These facts raise a question whether the aquifer tests and calculated hydraulic coefficients are representative of the entire thickness of the aquifer.

The hydraulic computations are necessarily based on assumptions that the aquifer is perfectly uniform in its properties, vertically and horizontally, and that it is limitless in extent. Nevertheless, field observations show that the aquifers are far from uniform and certainly are not limitless. Unless the idealized calculations and the actual conditions are reconciled, the calculations from pumping tests can be misleading. The author believes that the tests represent the response of about the upper 200 feet of the aquifer. Poorly permeable beds beneath the bottoms of the wells prevent free communication of water in lower levels of the aquifer with the levels tapped by the wells. Since depth of freely communicating aquifer is an important factor in transmissibility, the calculated coefficients are evidently too low. Prolonged pumping would yield data for computing more nearly correct coefficients.

A method is available for computing approximate coefficients of transmissibility on the basis of specific capacities of wells where the geology is sufficiently well known to permit a reasonably accurate estimate of the coefficient of storage. The method is described by Theis and others (1954).

The solution is obtained in three steps: computation of the specific capacity of a well and estimation of the storage coefficient of the aquifer; arithmetic solution of a formula reduced to very simple terms, to obtain a tentative estimate (T') of transmissibility; use of a carefully constructed rectangular chart, having values of T' on the abscissa and specific capacity on the ordinate, to derive an adjusted estimated value of T. The method is useful for approximating the general magnitude of transmissibility.

To check the validity of the method for application in the Raft River valley, it was applied to the Dunn well and the Malta Land and Irrigation Co. well, for which values of T already are available from pumping tests (table 21). The formula used was the following:

$$T'=C(1\pm0.3)\ (k-264 \log 5S+264 \log t)$$

Where

T' = tentative value for transmissibility, in gallons per day per foot

C = specific capacity, in gallons per minute per foot of drawdown

S = coefficient of storage

t = duration of pumping test, in hours

k = a constant, read from a table of values, computed for values of r' (r' is the radius of the pumped well; in this case, it is used in place of r, "distance of pumped well from observation well," because the pumped well is also the observation well).

The factor of (1 ± 0.3) allows for upward adjustment of T' for a small or poorly developed well, or downward adjustment for a large or well-developed well.

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Substituting observed values of C, t, and S for the Dunn well (listed in tables 20 and 21), and a computed value of k (Theis and others, 1954, p. 3), we have

$T' = 25(1 \pm 0.3)\ [1600 - (264 \log 5 \times 0.026) + 264 \log 3]$
$T' = 56{,}000$
$T = 55{,}000$ (from chart)

Assuming that the reported drawdown of 50 feet in the Dunn well is correct, a somewhat different set of values can be substituted in the formula, using the pumping rate during the pumping test. At 1,080 gpm the specific capacity would be 21.6 gpm per foot. The duration of the pumping test was 22 hours. The derived adjusted value of T is 61,000 gpd per foot.

A similar computation was made for the Malta Land and Irrigation Co. well, using the values of C, t, and S shown in tables 20 and 21 (0.16 was chosen for S), and a value of 1,000 for k. The adjusted computed value of T is 80,000 gpd per foot.

These values are in the same general range and, as approximations, they are mutually in agreement. They are only about one-third the values computed from the pumping test, but are of the same order of magnitude, which is all that is claimed for the method. It is important to note that the specific capacity is an important function in the equation. If there is much loss of pressure head between the aquifer and the inside of the well, the drawdown in the well will be excessive, the calculated value for C will be too small, and the resultant value for T will be too small. Calculations from the pumping-test data were not subject to the same error because drawdown was measured in an observation well, not the pumped well. The low value obtained by the Theis approximation method is an indication of excessive loss of pressure head in the Dunn well.

The G. S. Matthews well (11S–26E–12cb1) was chosen as an example for applying the approximation method to a well having a high specific capacity, which is presumptive evidence of reasonably good well construction. The coefficient of storage at that location is not known, so an estimated value of 0.15 was used. The calculation (a value of 1,350 was used for k), gave an unadjusted value of 260,000 gpd per foot for T'. According to whether an adjustment factor of 1.3 or 0.7 is used, the value of T' is 180,000 or 340,000 gpd per foot. The same method was applied to well 11S–27E—10aa1, whose specific capacity is 310 gpm per foot. Assuming a storage coefficient of 0.2, and using a k value of 1,524, the unadjusted value of T' is 520,000.

Table 20 and plate 6 show that wells having very low specific capacities and low yields do not form any detectably systematic geographic pattern. Plate 6 shows that good wells are surrounded by poor ones at some places, and at others the reverse is true. At least some well groups have about the same depth and tap the same aquifers. This fact itself suggests that some wells having poor yields are not properly constructed. A well having a high yield and high specific capacity could not be surrounded by a poor aquifer because the well depends on the aquifer to transmit water to it. Of the wells listed in table 20, 34 that have moderate to large yields and seem to be representative have an average yield of 1,630 gpm, an average specific capacity of 54 gpm per foot, and an average pumping-test time of 26 hours. By use of an assumed storage coefficient of 0.15 and an average well diameter of 15 inches, the Theis approximation method gives an average unadjusted value of T' as follows:

$$\begin{aligned} T' &= 54\,[1{,}500 - (264 \log 0.75) + 264 \log 26] \\ &= 54\,(1{,}500 + 33 + 374) \\ &= 100{,}000 \text{ gpd per foot} \end{aligned}$$

Several other methods for approximating the coefficient of transmissibility were applied to wells in the Raft River valley. All methods point to a range of T values from about 50,000 to more than 500,000 gpd per foot. Application of all the methods is limited by the following: (a) Excessive loss of pressure head in a poorly constructed well vitiates the result, and (b) presence of a bed or beds of lower permeability below a well but within the aquifer limits applicability of the T value to beds actually penetrated by the well. In conclusion, a value of about 200,000 gpd per foot probably may be assumed for the central part of the Raft River valley, but this value represents only about the upper 200 feet of the aquifers.

Relation of coefficients of transmissibility to estimated water yield.—It was estimated earlier that the unconsumed water yield of the entire basin is about 140,000 acre-feet yearly, and that most of this water leaves the basin by underflow through the valley northward to the Snake River Plain. For a general check on the validity of the estimated water yield, it is desirable to assess the ability of aquifers in the Raft River basin to transmit the estimated amount of water. This may be done by the simple formula

$$Q = TIW$$

Q = quantity of water, in gallons per day
T = transmissibility, in gallons per day per foot
I = gradient of the water table, in feet per mile
W = cross-sectional width of the valley, in miles

No calculation can be made for the Northern Plains section because the transmissibility of its aquifers is not known and cannot be estimated. However, an east-west cross section about 3 miles north of Idahome is suitable for application of the above formula. The estimated aquifer width is about 12 miles, and the water-table gradient at that location was about 20 feet per mile. Less than 140,000 acre-feet of water moved through that section in 1955 because it lacked components from the Northern Plains section (1,200 acre-feet), the Heglar Creek basin (9,000 acre-feet), and the northern part of the Raft River valley (probably about 6,000 acre-feet). Some depletion from irigation also had occurred. In round numbers, about 120,000 acre-feet of water would have to move through the section north of Idahome.

Using the estimated coefficient of transmissibility (200,000 gpd) in the equation:

$$Q = 200{,}000 \times 20 \times 12$$
$$= 48{,}000{,}000 \text{ gpd}$$

Since 1,000,000 gpd = 3.07 acre-feet per day, the transmission capability of the alluvial aquifer seems to be about 148 acre-feet day (54,000 acre-feet per year) or less than half the volume of water estimated to be in transit through that part of the valley.

We saw in the preceding section that the estimated coefficient of transmissibility of 200,000 gpd applies largely to the alluvial aquifer. Owing to the presence of less permeable beds between the alluvial aquifer and underlying aquifers, the capability of those aquifers to transmit water would not be shown by an aquifer test unless the test were carried on for an extended time, or unless the well tapped the entire water-bearing section. If the coefficient of transmissibility of 200,000 gpd per foot represents 200 feet of alluvial sand and gravel, then the coefficient of permeability of these beds averages 1,000 gpd per square foot, which is within the known range for such materials.

The underlying beds—Salt Lake (?) formation and Raft lake beds—are more than 1,200 feet thick, as shown by the log of the Taylor Bros. well (13S–26E–1db1), which is 1,400 feet deep. If these beds have coefficients of permeability averaging only 100 gpd per square foot, the coefficient of transmissibility for a 1,200-foot thickness is 120,000. No information is available about hydraulic gradients in the deeper aquifers, at least some of which are artesian. However, aquifers beneath the Raft River valley probably have an aggregate transmissibility which is sufficient to accommodate the estimated amount of water in transit through the valley.

YIELD FROM WELLS

Yields from irrigation wells in the Raft River valley range between 0.2 and 6.9 cfs (about 90 to about 3,125 gpm), comparing favorably with those from irrigation wells in sedimentary aquifers in other parts of southern Idaho. Generally, wells in the Raft River valley that yield less than 0.35 cfs (about 150 gpm) are not successful for irrigation because they can serve only small tracts of land and the unit cost of pumping water is relatively high. Less than 0.5 cfs (about 225 gpm) is considered to be a poor yield. In general, irrigation wells in this area are economical when 1 well will serve 40 acres or more. Very large yields, however, are not necessarily desirable, because extensive water-distribution works are expensive in some circumstances and the loss of water in transit may be high.

If a minimum pumping requirement of 2.5 acre-feet of water per acre and a 100-day irrigation season were assumed, a well would have to produce 0.5 cfs continuously to serve a 40-acre tract, and round-the-clock irrigation would be required unless storage were provided for water pumped at night. A yield of about 2 cfs (about 900 gpm) is good under most circumstances, and yields of 5 to 10 cfs from single wells are successfully used in southern Idaho.

Wells having moderate capacities (as much as 2 cfs) are widely distributed in those parts of the Raft River valley where ground-water supplies have been developed. (See pl. 6). Copious producers occur in a belt near the river from a few miles south of Malta to the vicinity of Idahome, but the generally highest yields are from wells north of Idahome. Most of the irrigation wells are within 2 miles of the river and many are within 1 mile. Thus, much of the area in which undeveloped land is available has not been explored by drilling.

The complex geologic history of the area in comparatively recent time, especially during deposition of the water-bearing alluvium and older sediments, and the wide variance in the occurrence and water-bearing properties of the formations make it unlikely that ground-water conditions in outlying areas uniformly resemble those near the river. Although the alluvium may thicken toward the margins of the valley, it rises in altitude also and the water-bearing part may be thin. At some places wells would reach less permeable underlying beds of the Salt Lake(?) formation or Raft lake beds without having developed an adequate supply of water in the alluvium. Often it is difficult to develop an adequate volume of water from the underlying beds by the well-construction methods ordinarily used in this area. The prospects for satisfactory yields from these beds, therefore, are less favorable than from the alluvium, and deep drilling might be necessary. Also, the chance of striking warm water of poor chemical quality increases with increased depth.

Because the Quaternary alluvium in the Raft River valley was derived from many sources and deposited under varying conditions of time and place, it varies widely in its water-bearing properties. A wide range in yields from wells is to be expected. Probably, most wells in a wide belt of the arable lowland along the central part of the valley would be successful if properly constructed.

Along the Raft River near Malta, and in nearby localities, several wells have been put down by very economical methods. At some places large concrete caissons with perforations 2 to 3 inches in diameter were sunk by digging down inside the caissons, which settled as earth was removed. These wells extend only a few feet into the zone of saturation. Nevertheless the wells have been successful because the cobble gravel is very clean and little development of wells was necessary. Other wells were constructed by digging a trench to a few feet below the water table, laying in it a perforated or open-joint tile joined to a vertical casing extending to the land surface; the trench was then backfilled and a pump installed in the well casing.

A few more conventional wells have been installed by landowners who borrowed or improvised drilling rigs and used cheap thin-walled casing, which was perforated below the water table. Recently most drilling has been done by licensed drillers, but landowners generally contract for a low-cost well and a minimum of development work. Many of the wells are successful, but the presence of poor wells in areas where most wells are successful indicates a need for more care in well construction and full use of an experienced driller's time and skill in development work. This is especially true of wells in alluvium. Wells in the Salt Lake(?) formation and Raft lake beds require skill in construction and development to get good yields without pumping sand and without excessive drawdown. The cost of drilling and development work to get efficient wells in the older beds might be so great that their construction would not be economically feasible.

ABILITY TO INTERCEPT WATER

The estimated unconsumed ground-water outflow from the Raft River valley is 140,000 acre-feet yearly. (See p. 82.) Not all of that water could be intercepted by wells. The amount that could be intercepted feasibly cannot be computed, but the general magnitude is inferred as follows:

Most irrigation wells in the Raft River valley are pumped during only about 100 days or less a year, and many pumps operate less than 24 hours a day. That is, pumping occurs during somewhat less than a fourth of the year. The average frost-free period in the valley is about 100 days, but hardy crops probably have a longer growing season—possibly 120 to 140 days—depending on the weather in a given year. It is assumed here that the pumping season might be extended to 120 days, 18 to 24 hours a day. Thus, pumping might be done during nearly a third of the year.

Meanwhile, natural underflow out of the valley is continuous the year round, and much of the water yield leaves the basin during the nonpumping season. Wells pumped continuously during the irrigation season could dewater a substantial thickness of the aquifers, obtaining water from storage as well as from contemporary underflow. Storage would be replenished, wholly or partly, by recharge and underflow during the nonpumping season. That is, outflow during the entire year would be reduced by interception of water and reduction of storage, making room for off-season recharge during the nonpumping season. A sufficient number of properly placed wells might intercept efficiently about 50,000 to 75,000 acre-feet of water a year. With present irrigation practices, that amount of water would meet the diversion requirement for perhaps 25,000 to 30,000 acres of land.

Natural evapotranspiration on the native land that would be irrigated is about 0.89 foot per year. Introduction of an irrigation regimen on additional valley lands would create a new evapotranspiration regimen on those lands and consumptive use would be increased by about 1.11 feet. The new effective water depletion, by irrigation of 30,000 additional acres of land, would be about 33,000 acre-feet. The remaining 42,000 acre-feet of pumped water would run off or become return recharge to ground water, and would be available for reuse if it could be recovered.

CHEMICAL SUITABILITY FOR IRRIGATION

Because some chemical types of water are harmful to certain kinds of soil, the chemical and physical quality of soils and the chemical quality of the water available for irrigation commonly require careful study. Some soils in the Raft River valley are saline or are susceptible to sodium-adsorption damage; the acreage of such soils in the public domain is not known (Idaho State supervisor, U.S. Bureau of Land Management, oral communication, June 1, 1956).

The analytical data (table 16) show that the chemical types of ground water in the Raft River valley are varied, but little is known about the distribution or relative abundance of those types. Although some water in the valley is unsuitable or doubtfully suitable for irrigation, not enough data are available to correlate quality of water with specific aquifers. Because the chemical quality of the water is a potential limiting factor in long-term use and development, much further study of the water and soils is needed.

SAFE PERENNIAL WATER YIELD OF THE BASIN

The safe perennial yield of a ground-water basin is commonly defined as the amount of ground water that can be pumped year after year without permanently lowering water levels below the economic pumping lift, and without seriously impairing the quality of water. The safe yield of ground-water basins generally can be determined most readily by observation of water levels through a term of years during which pumping is constant or is increased by stages. In the Raft River basin, where surface water and ground water are closely related in the area having the principal development potential, it is more appropriate to think of safe yield in terms of total yield of water from all sources, whether from springs, wells, or streams.

If 50,000 to 75,000 acre-feet of the uncommitted water supply in the Raft River valley were pumped yearly, the rate of pumping in 1955 would be increased by 78 to 117 percent and total pumpage would be about 114,000 to 139,000 acre-feet per year. Compared to the estimated unconsumed supply of 140,000 acre-feet now available, an increase of 50,000 to 75,000 acre-feet may seem conservative, because less than half the pumped water would be consumed. If a diversion demand of about 2.5 to 3 acre-feet of water per acre were assumed for the types of crops that are grown in the valley (chiefly hay, small grain, sugar beets, and potatoes), 75,000 acre-feet of water would serve 25,000 to 30,000 acres of land, and consumptive use would increase by about 27,500 to 33,000 acre-feet. The unconsumed pumped water would be recoverable from surface drains or could return to the ground as recharge.

Certain tracts of bottom land in the Raft River valley, where the water table is at shallow depth, are occupied by low-value forage crops and native water-loving vegetation. The water-loving plants yield little or no profit but they consume excessive amounts of water—from 2 to 6 or 7 feet, depending upon the kinds of plants and their growth density (Mower and Nace, 1957). Lowering of the water table by heavy pumping would automatically deny water to some of the undesirable vegetation, which grows only where the water table is at or near the surface, and would salvage for beneficial use water that now is neither diverted from surface streams nor pumped from wells. The total area occupied by undesirable vegetation is not known, but salvaged water would amount to at least a few thousand acre-feet per year. Lowering of the water table might improve the quality of the soil by allowing leaching to occur. In addition, it would reduce the base flow of the Raft River.

It was noted on page 79 that pumpage increased more than sevenfold, from about 8,700 acre-feet in 1948 to 64,000 acre-feet in 1955. The increase, however, seems not to have depleted appreciably the amount of ground water in storage. For that reason, and in the light of estimates in paragraphs immediately above, pumping of sufficient water to irrigate 25,000 to 30,000 additional acres seems to be a reasonable estimate for a feasible new development. Nevertheless, much further study is needed to determine the effects of pumping and to determine accurately the safe perennial water yield of the Raft River basin.

COMPETITION FOR WATER

In foregoing pages little was said about the effect that increased pumping of ground water in the Raft River valley would have on the surface-water supply. Under natural conditions, ground-water reservoirs are full to overflowing. Springs and the base flow of perennial streams are sustained by the overflow, which is called effluent ground water. In areas where unused surplus runoff is large, depletion of effluent ground water commonly does not deplete usable surface runoff. In the Raft River basin, however, practically all the dry-season flow of streams is used and the winter flow is small. Wherever ground water is tributary to the streams, the pumping of ground water may deplete their flow. However, it would be unrealistic to contend that only surface water should be used under such circumstances, because such a restriction would prevent optimum use of the total water supply. Surface runoff in the Raft River valley is a thin trickle of overflow from a ground-water basin that discharges a much larger volume of water by underflow. Insistence upon an undepleted surface-water supply would require that the ground-water reservoir be kept at maximum stage, allowing most of the water crop to escape by underflow in order that the small surface overflow be maintained. This would be analogous to requiring that a surface reservoir be held at spillway level, and that no water be used from the reservoir except that running over the spillway. Coordinated management and use of all the water as a single resource would be advantageous.

LOCAL

The relatively small amount of ground water that is discharged to the Raft River below Peterson Ranch and to the other streams would be reduced by widespread pumping of ground water. Specifically, heavy pumping from shallow aquifers in the lowland near the Raft River channel might lower the water table below the river level, reduce or eliminate gains to the river from ground-water discharge, and increase percolation loss from the river by inducing infiltration. Pumping of ground water from shallow aquifers near the river, therefore, might be directly competitive with the use of surface water.

Pumping of ground water and increased consumptive use would deplete the water yield of the basin, and part of the depletion would be from surface flow. On the other hand, reasonable pumping of ground water need not infringe seriously on local surface-water rights. Pumping of ground-water, for instance, would not deplete streamflow during the pumping period unless the area of influence around pumped wells extended to the vicinity of the river and lowered the water table where ground water is effluent to the stream channel. Adverse effects would not be produced by (a) wells at a safe distance from the stream, (b) wells pumped only when there is excess water in the stream channel, (c) wells tapping deep aquifers that are not directly tributary to the river, or (d) wells pumped sufficiently late in the season that their effects on streamflow would occur after the principal surface-water diversions had been made.

Study would be necessary to determine the safe distance of wells from the Raft River. Such study should include analysis of representative pumping tests, observation of water-level fluctuations, measurements of stream discharge, and further geologic study. Linear distance would be very important for wells that tap shallow aquifers in which the ground water is hydraulically continuous with streams. Aquifers at intermediate depth, in which water occurs beneath partly confining or separating layers of impermeable material, could be tapped by wells without much risk of immediate or great effect on surface flows. Pumping of water from deep artesian aquifers would not affect surface flow directly if at all.

The wide area through which water is discharged to the Snake River Plain is an important factor in water use in the Raft River valley. Much of the ground-water underflow from the Raft River valley veers westward under the Northern Plains section south of Lake Walcott. Ground water in that area is not tributary to the Raft River except in a narrow belt on the east. Ground-water pumping in the Northern Plains section would have little or no effect on the discharge of the Raft River because the water there is outside the hydraulic system that controls the river.

REGIONAL

Important competition for water will be confined largely to the Raft River basin, and downstream effects from developments in the basin will be immaterial. Minor regional competition for water, however, is a distant possibility. The Raft River surface drainage and part of the ground-water drainage are tributary to the Snake River near the head of Lake Walcott, and an unmeasured amount of water is contributed by the Raft River basin to the Snake River's main stem. The size of the contribution cannot be determined from surface inflow-outflow records of the reservoir, because ground water from other areas also is discharged to the river and lake above Minidoka Dam. Moreover, the downstream part of the lake loses water by percolation into the ground. River and reservoir records show that in the reach from Minidoka Dam to Neeley (about 25 miles upstream on the Snake River) the net gain to the river system is about 82,000 acre-feet in an average year (Crosthwaite and Scott, 1956).

Milner Dam, the farthest downstream large diversion dam for irrigation on the Snake River Plain, is a key point in river operation. The long-time average yearly surplus discharge of the Snake River past Milner Dam before construction of Palisades Dam was somewhat more than 1,000,000 acre-feet, and the maximum in any recent year was about 3,000,000 acre-feet. In some years of low runoff, spill past Milner was almost nil. In those years the entire yield of the Snake River system above Milner was stored or diverted for irrigation and there was a water shortage. The 10 to 12 years before 1956 were years of generally ample water supply, and substantial new depletion upstream probably would not have caused a shortage of water at or above Milner. New upstream storage works, notably Palisades Dam, will relieve shortages in future droughts, but surface-water users are concerned that heavy pumping of ground water throughout the Snake River Plain may aggravate water shortages in years when runoff is low. Determination of the extent of such effect from pumping in any given area would be a major task, requiring careful study of extensive water data and thorough geologic investigation.

Some evidence indicates that at least some of the ground water that moves out of the Northern Plains section is not tributary to the Snake River above Milner, but passes beneath the river and joins a larger body of ground water north of the river. Ground water from that body is discharged to the Snake River through large springs below Milner Dam. The water discharged from the springs constitutes the principal flow of the Snake River between Milner and King Hill. Depletion of spring flow would decrease the amount of water available for generation of power by several hydroelectric installations in that reach.

SUMMARY OF PRINCIPAL CONCLUSIONS

The Raft River basin, hydrologically, is a unit area. The unit contains several subdivisions; in each of these the water supply is modest, but the aggregate amount is substantial. Ground-water underflow in all the subbasins is generally parallel to surface streamflow, and the Raft River valley is the master subbasin and collecting ground for the entire water yield of the basin. Runout from the valley moves northward to the Snake River Plain through a broad area at least 12 miles wide. Part of the water is discharged to the Snake River and to the upstream part of Lake Walcott. A large part, however, veers westward and probably moves into the Snake River Plain west of Minidoka Dam.

Nearly all usable surface water in the Raft River is diverted for full or supplemental irrigation of about 24,000 acres of land. Supplemental ground water is pumped for some of those lands. About 25,000 acres, chiefly in the lowland of the Raft River valley, is served partly or wholly with ground water. The total area irrigated in the entire basin is about 43,000 acres.

Ground water in the Raft River basin occurs in both unconfined and confined (artesian) aquifers. Much of the readily obtainable ground water of good quality is unconfined, occurring in lowland alluvial sand and gravel. In the Northern Plains section south of Lake Walcott, basalt is a copiously productive aquifer.

Fluctuations of ground-water levels in the Raft River lowland generally are moderate, the annual range being about 5 to 8 feet. During the 5-year period 1948–52 there was little net change in water levels, despite increased pumping of ground water, and water levels actually rose in a few wells during those years. After mid-1953 there was a small but steady net lowering of the water levels in most observed wells, amounting to about 1 to 2.5 feet at corresponding times of successive years. Much of the lowering probably would have occurred without ground-water pumping, owing to subnormal precipitation and deficient recharge. Deficient recharge is indicated by precipitation records and by the low water yield of springs and streams in uplands where there has been no pumping of ground water.

The water supply of the Raft River basin is derived from precipitation in the basin. No evidence was found to support the popular belief that a large amount of ground water enters the basin by migration from surrounding areas. The estimated total volume of precipitation is 1,290,000 acre-feet per year. About 1,105,000 acre-feet is consumed by basinwide natural evapotranspiration, and 44,000 additional acre-feet is consumed by crops. Surface outflow probably is less than 10,000 acre-feet. The estimated unconsumed total residual water supply of 140,000 acre-feet per year is discharged from the basin by ground-water underflow and surface outflow. The conservatively estimated unused and uncommitted ground-water supply which leaves the basin by underflow probably is somewhat more than 130,000 acre-feet per year.

Possibly as much as 100,000 acres of undeveloped land in the Raft River valley could be irrigated if a suitable water supply were obtained. The net consumptive-use demand for that land, assumed to be nearly 120,000 acre-feet yearly, over and above what would be satisfied directly by precipitation, would exceed the estimated water yield of the basin somewhat. The amount of uncommitted water that could be intercepted and used within the basin is the limiting factor in further development in the Raft River valley with its native water supply.

Existing irrigation wells in the valley yield 90 to 3,125 gpm; most wells yield more than 500 gpm, and very few yield less than 200 gpm. Well-performance tests and studies of well logs and well records indicate that the average coefficient of transmissibility of shallow aquifers in the lowland of the Raft River valley is on the order of 200,000 gpd per foot, and the coefficient for single aquifers may be much higher. Deeper aquifers also transmit a large volume of water yearly. A large percentage of properly situated and efficiently developed new wells in the Raft River Valley and Northern Plains section would be successful.

The 1955 pumping rate of 64,000 acre-feet of ground water per year probably could be safely increased sufficiently to irrigate 25,000 to 30,000 additional acres. If consumptive use on cultivated land were assumed to average 1.1 feet in addition to the natural consumptive use, with 73,000 acres under old and new irrigation, total water depletion in the basin would be about 1,180,000 acre-feet. The unconsumed residual water yield would be about 110,000 acre-feet. The water supply downstream on the Snake River would not be materially depleted.

The ground-water quality is not well known, but records show that water from some sources is doubtful to unsuitable for irrigation on some types of soil. The soil and the quality of water in the valley should be studied thoroughly.

Properly located wells in the Raft River valley would not seriously deplete the surface-water supply during the irrigation season if pumping were done on a moderate scale. Shallow wells near the Raft River might deplete the flow of the river below Peterson Ranch. Properly cased deep wells would not affect the river directly. Well users in most of the Northern Plains section would not compete with Snake River water users during the irrigation season, but wells adjacent to the Raft River or to the upstream part of Lake Walcott might be competitive to a very small extent in years of short water supply.

The preliminary general conclusion is reached that sufficient uncommitted water is available and recoverable in the Raft River basin to irrigate about 25,000 to 30,000 additional acres of properly situated land.

Estimates in this report indicate that a moderate increase in irrigation would further deplete the water supply only moderately. However, this indication is the result of a series of estimates and extrapolations made on the basis of scanty data. The analysis of hydrologic factors and the estimates of water yield were made carefully, but the result is still only an estimate which probably will be revised in time.

Conservatism is advisable in further development in the Raft River basin. If the water yield estimated in this report is much higher than the actual yield, the consequence of rapid exploitation might be unfortunate. Overdevelopment might occur before positive symptoms of it were detected by hydrologic means, but the authors believe that development on the scale suggested above would be conservative. If increased draft on the water supply were made in increments of a few thousand acre-feet per year, it would be feasible by hydrologic means to detect symptoms of overdevelopment before it became excessive. Two factors will potentially limit the development: the amount of water available, and the amount of the available supply that can be recovered economically from wells.

SUGGESTIONS

The total water supply in the Raft River basin is far from adequate for all irrigable land in the Raft River valley. The disparity between the amounts of land and water is so great that the inadequacy would remain even with optimum use of the total supply. The effective supply may exceed the accessible supply somewhat because unconsumed irrigation water may be reused. The effective supply might be increased also by artificial recharge—spreading surplus winter and freshet flow in selected areas. The amount of water available for artificial recharge is small, because surface runoff at the mouth of the Raft River averages only a few thousand acre-feet per year. Additional study would be required to determine the physical and economic feasibility of artificial recharge with surplus surface water.

Imported Snake River water also might be used for artificial recharge. Moderate excess winter flows are anticipated in the Snake River in some years, even with the new storage capacity at Palisades

Dam near the Wyoming border. In the existing pattern of water use, excess water would spill unused past Milner Dam. The possibility of diverting some of the excess to the Raft valley for artificial recharge of ground water seems to be worth study. The necessary diversion and transmission works probably would not be expensive because much transmission loss by percolation into the ground could be tolerated. Such loss could be counted as an artificial-recharge benefit if it occurred in areas where the ground water is usable. A principal problem probably would be canal ice in winter. Ice in water-spreading fields would not necessarily be undesirable because the ice would delay actual recharge until spring, when it would do the most good.

The water situation in the Raft River valley illustrates that, to achieve optimum development of water in some situations it may be necessary to broaden water rights so that they apply to all water, whether from surface or underground sources.

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BASIC DATA

LOGS OF WELLS

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The following pages contain drillers' logs and casing records of 81 wells in the Raft River valley. The logs were obtained either directly from drillers or from well owners' copies of drillers' logs. The terminology used by well drillers to describe the materials penetrated has been modified somewhat to achieve a degree of uniformity. Statements in brackets such as [clay and soil ?] are interpretations by the authors.

Material	Thickness (feet)	Depth (feet)
9S-25E-23db1		
[Casing: 8- and 6-in. black-iron to 170 ft]		
Soil	2	2
Hardpan	6	8
Basalt, gray	12	20
Basalt, chocolate-colored, broken, with a few solid ledges. Water at 121.5 ft	75	125
Basalt, black; very open; most of cuttings not recovered	49	174
9S-26E-7bc1		
Topsoil	1	1
Clay and rock	6	7
Basalt, black	80	87
9S-26E-10aa1		
[Casing: 8-in. black-iron from 0 to 46 ft; 5-in. from 0 to 96 ft; perforated from 66 to 96 ft. Concrete poured around 5-in. casing]		
Topsoil	2	2
Clay [1] and gravel	8	10
Gravel, water worn. Probably struck water at about 29 ft. Cemented hole from 10 to 36 ft., but this did not prevent caving; therefore cased to 46 ft	35	45
Clay, red and yellow, and basalt, black	10	55
Clay, blue, and basalt, black	5	60
Basalt, black. Struck water at 75 ft	35	95

[1] So-called clay is probably a contaminant of overlying topsoil, carried by drill into basalt.

Material	Thickness (feet)	Depth (feet)
9S-26E-10dd1		
[Casing: 8- and 6-in. black-iron to 118 ft; perforated from 88 to 118 ft]		
Soil	1	1
Clay, yellow	2	3
Clay and rock	9	12
Basalt, gray, broken	17	29
Cinders, black, with solid layers	10	39
Basalt, gray	21	60
Basalt, chocolate-colored	5	65
Basalt, black, very broken. Struck water at 73 ft	10	75
Cinders and layers of black basalt	14	89
Basalt, black	39	128
9S-26E-13cc1		
[Log obtained from Bureau of Land Management, Aug. 18, 1955]		
Soil	2	2
Basalt, gray	3	5
Basalt, red; crevice at 12 ft	16	21
Basalt, gray to reddish gray	8	29
Basalt, gray	9	38
Basalt, reddish-brown	13	51
Basalt, gray; crevice at 58 ft	22	73
Basalt, gray and red	15	88
Basalt, gray, and cinders	15	103
Basalt, gray, porous	36	139
Basalt, black; struck water at 140 ft	14	153
9S-26E-22bb1		
[Log obtained from Bureau of Land Management, Aug. 18, 1955]		
Soil	12	12
Basalt	18	30
Basalt, brown	18	48
Basalt, gray	14	62
Basalt, brown	23	85
Basalt, gray; struck water at 112 ft	33	118
Basalt	9	127

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9S-27E-36ad1

Material	Thickness (feet)	Depth (feet)
Soil	5	5
Gravel and clay, gray	4	9
Sand and clay, compact, in thin layers	111	120
Sand, coarse, and clay, in thin layers; water	10	130

9S-27E-36db1

[Casing: 16-in. wrought-iron to 111 ft; perforated opposite all gravel and sand layers]

Material	Thickness (feet)	Depth (feet)
Soil	3	3
Clay, gravelly	12	15
Gravel, medium; maximum diameter about half an inch	13	28
Clay, gray	2	30
Clay, blue	3	33
Sand, blue	14	47
Clay, blue	3	50
Sand, blue	22	72
Clay, blue	6	78
Sand, blue	27	105
Clay, blue	18	123
Sand, blue	13	136
Clay, sandy, yellow	9	145
Sand, yellow	13	158
Clay, yellow	11	169
Sand, yellow	35	204
Clay, yellow	26	230

10S-25E-24dc1

[Log obtained from Frank P. Conley, driller, Aug. 17, 1955]

Material	Thickness (feet)	Depth (feet)
Soil	25	25
Basalt, gray, "loose"	7	32
Basalt, black, hard	26	58
Basalt, light-gray, soft	50	108
Basalt, light-brown, soft; struck first water	117	225
Basalt, light-gray, soft	20	245
Basalt, brown, soft	60	205
Basalt, light-red, very soft	47	352
Basalt, light-gray; some of cuttings are coarse	23	375
Basalt, black	85	460
Basalt	25	485
Clay	40	525
Clay, gray	15	540
Clay, light green	25	565

10S-26E-36dc2

[Casing: 12-in. wrought-iron perforated from 121 to 268 ft. Driller reported water was struck at 128 and 130 ft and rose to 120 ft below land surface. Well yielded about 180 gpm when 235 ft deep]

Material	Thickness (feet)	Depth (feet)
Soil and hardpan	4	4
Clay	20	24
Basalt, gray	26	50
Basalt, brown	8	58
Basalt, purple	17	75
Basalt, gray	13	88
Basalt, brown	12	100
Basalt, black; cinders at 110 ft	15	115
Clay	4	119
Sand, loose	19	138

10S-26E-36dc2—Continued

Material	Thickness (feet)	Depth (feet)
Sand, tight, and gravel, fine; clay layers every few feet	17	155
Gravel, coarse	5	160
Basalt, black	2	162
Sand, moderately tight	2	164
Basalt, brown	2	166
Gravel, fine, with clay binder	8	174
Basalt, black	8	182
Clay and gravel, fine	2	184
Basalt, gray	23	207
Clay, gray	4	211
Basalt, black; cuttings heavy and coarse with a few cinders	24	235
Cinders	10	245
Sand, tan	15	250
Sand and gravel, very fine	5	255
Gravel, fine, very clean	10	265
Cinders and talc [?], brown	4	269
Basalt, black, broken	3	272
Cinders	8	280
Clay, tan, sandy, and gray sticky clay in layers 4 to 6 ft thick	35	315
Clay, tan, sticky	18	333
Gravel, clean; caved	2	335

10S-27E-26dd1

Material	Thickness (feet)	Depth (feet)
Soil	2	2
Clay, sandy, yellow	9	11
Gravel	19	30
Sand, clayey	42	72
Sand	46	118
Clay, sandy, yellow	7	125

10S-28E-6ba1

Material	Thickness (feet)	Depth (feet)
Soil	2	2
Clay, sandy, yellow	13	15
Gravel, medium; maximum diameter about half an inch	15	30
Clay, sandy, blue	45	75
Clay, sandy, yellow	27	102
Sand	39	141
Clay, yellow	33	174
Sand	27	201
Clay, yellow	10	211

10S-28E-6dc1

Material	Thickness (feet)	Depth (feet)
Soil	2	2
Clay, sandy, yellow	18	20
Clay, sandy, gray. Water struck at 70 ft and rose to 35 ft below land surface	50	70
Sand	94	164
Clay, brown, hard	12	176
Clay, sandy, yellow	19	195
Clay, grayish blue	5	200
Sand, gray, fine, loose	15	215
Clay, gray	15	230
Sand, gray, fine	10	240
Sandstone, gray	10	250
Quicksand, gray	12	262
Packsand, gray	13	275
Clay, sandy; some water	15	290
Gravel, small; limestone[?]	2	292
Sandstone and conglomerate with lime [?] boulders	27	319
Packsand	5	324

11S–26E–10db1

[Log obtained from Tim Mathews, driller, Aug. 11, 1955]

Material	Thickness (feet)	Depth (feet)
Soil and basaltic ash [?]	15	15
Basalt, hard	45	60
Cinders	5	65
Basalt	42	107
Clay	29	136
Cinders	6	142
Basalt, hard	79	221
Cinders	5	226
Basalt	8	234
Basalt, gravel, and clay	14	248
Gravel	10	258
Gravel and sand	7	265
Sand, clay, and gravel; small amount of water	5	270
Clay and gravel	3	273
Sand and gravel	5	278
Clay and gravel	40	318
Crevice; drill cuttings not recovered	3	321
Gravel	27	348
Sand	3	351

11S–26E–12ab1

Casing: 20-in. steel to 155 ft; cased out shallow sources of water above 155 ft]

Material	Thickness (feet)	Depth (feet)
Soil	29	29
Basalt, brown	36	65
Basalt, black	10	75
Basalt, brown	23	98
Basalt, black, hard	4	102
Basalt, boulders	8	110
Basalt, loose,and gravel	13	123
Gravel and sand	1	124
Gravel, sand, and mud	9	133
Gravel, water-bearing	8	141
Clay, light gray	7	148
Clay, blue, sticky	7	155
Basalt, solid	26	181
Basalt, broken, and cinders. Water at 203 ft	22	203
Not recorded	47	250

11S–26E–12cb1

[Casing: 16 in. wrought-iron to 120 ft]

Material	Thickness (feet)	Depth (feet)
Soil	14	14
Basalt, gray	34	48
Basalt, black	12	60
Basalt, creviced	6	83
Basalt, red, loose and caved	9	92
Basalt, black, creviced	4	96
Clay and sand	24	120
Sand and gravel. Struck water at 100 ft	12	132
Clay, gray, sticky; poorly water-bearing	5	137
Basalt, black, creviced. Water stood at 112 ft	18	155
Basalt, hard	7	162
Cinders	8	170
Basalt, broken	5	175
Basalt, black, broken, caved	15	190

11S–26E–25bc1

[Log obtained from Dean Rogers, driller, Aug. 17, 1955]

Material	Thickness (feet)	Depth (feet)
Soil	10	10
Gravel	25	35
Clay, yellow	20	55
Clay, blue	31	86
Clay, yellow	10	96
Gravel	12	108
Clay, yellow	7	115
Gravel, small	16	131
Clay, yellow	7	138
Sand, fine	25	163
Gravel, loose, and sand	3	166
Clay	1	167
Gravel and clay	10	177
Gravel	45	222
Clay, with sand layers	78	300

11S–26E–27bb1

[Log obtained from Dean Rogers, driller, Aug. 17, 1955]

Material	Thickness (feet)	Depth (feet)
Soil	10	10
Soil[2] and gravel	36	46
Sand and clay; small amount of water at 68 ft	46	92
Clay, blue	20	112
Sand and clay,[2] soft; small amount of water at 112 ft	62	174
Clay[2] and gravel	10	184
Clay with sand layers	162	346
Clay[2] and gravel, tight	46	392
Clay[2] and sand	10	402

11S–26E–28ab1

[Log obtained from Frank P. Conley, driller, Aug. 17, 1955]

Material	Thickness (feet)	Depth (feet)
Volcanic ash [?]	22	22
Sand, brown	6	28
Clay, brown, tough	15	43
Clay and sand, bluish-green, soft	7	50
Clay, yellow	23	73
Clay, yellow, sandy	22	95
Clay, blue	5	100
Clay, yellow; water stands at 65 ft	10	110
Clay, yellow, soft	5	115
Clay, brown, sandy, soft	27	142
Gravel, pink, and clay, hard	3	145
Clay, yellow, soft	2	147
Clay, yellow, hard	4	151
Clay, yellow, soft	4	155
Gravel, hard	11	166
Clay, brown, sandy, soft; water stands at 56 ft	32	198
Clay, brown, sandy, and gravel	8	206
Clay, brown, sandy, soft	12	218
Sand, gravel, and rocks	23	241
Basalt [?]; water rose 2 feet	4	245
Basalt [?], hard to soft	9	254
Basalt [?]	2	256

[2] So-called soil and clay in these zones probably are contaminants from overlying zones.

11S-26E-35cc2

[Casing: 14-in. steel to 275 ft; perforated from 75 ft to bottom]

Material	Thickness (feet)	Depth (feet)
Clay, sandy. Struck water at 39 ft	39	39
Sand, fine	5	44
Sand and clay	26	70
Clay, sandy, yellow	26	96
Clay, blue	9	105
Hardpan, sand, and clay	23	128
Sand and gravel, caved, water-bearing	4	132
Clay, yellow	7	139
Sand and fine gravel, water-bearing	44	183
Clay, yellow, soft, sticky	4	187
Gravel and sand	3	190
Clay, yellow, sticky	4	194
Sand and gravel; water-bearing	14	208
Clay, sandy, soft, layered	12	220
Gravel and sand, caved; maximum diameter about half an inch	12	232
Clay and sand	8	240
Sand and gravel, cemented, with some clay; very poorly water-bearing	35	275

11S-26E-35dc2

[Casing: 16-in. wrought-iron to 224 ft; perforated from 110 to 224 ft]

Material	Thickness (feet)	Depth (feet)
Soil	12	12
Gravel, cemented; some water	36	48
Sand; stands during drilling	32	80
Clay, yellow	10	90
Clay, blue	16	106
Gravel, water-bearing	6	112
Gravel, pea gravel, and sand	14	126
Clay, yellow. Drilled easily	6	132
Clay, gray	5	137
Gravel	68	205
Clay	15	220
Gravel, cemented	5	225
Clay, sandy	7	232
Gravel, cemented	11	243
Clay, yellow, sticky	2	245

11S-27E-15bb1

Material	Thickness (feet)	Depth (feet)
Soil	3	3
Clay, sandy	17	20
Gravel, coarse, and sand	10	30
Clay, gray, sandy	5	35
Clay, sandy, gray; some coarse gravel	65	100
Clay, brown, and sand, black; some coarse gravel	35	135

11S-27E-22cb2

Material	Thickness (feet)	Depth (feet)
Soil	45	45
Clay, sandy	15	60
Clay, sandy with some sandstone	10	70
Clay, sandy, yellow; layers of black pea gravel	8	148
Clay, sandy, yellow	22	170
Clay, yellow, sticky	5	175

11S-27E-31dd1

[Casing: 20-in. steel perforated from 0 to 185 ft. with Mills knife; slots about 7/16 in. wide and 2½ to 3 in. long in horizontal rows of 12 slots at 8-in. vertical intervals]

Material	Thickness (feet)	Depth (feet)
Topsoil	9	9
Gravel, dirty	11	20
Clay and sand	33	53
Sandstone, white	1	115
Clay	20	135
Gravel and clay	2	137
Clay and sandstone	11	148
Sandstone	4	152
Clay	33	185

11S-27E-33dd1

Material	Thickness (feet)	Depth (feet)
Topsoil	20	20
Clay	48	68
Gravel, fine-grained, and clay, sandy	42	110
Gravel	40	150
Clay; thin layers of fine gravel	40	190
Gravel; thin layers of clay	18	208

11S-27E-35ad1

Material	Thickness (feet)	Depth (feet)
Topsoil	12	12
Clay and gravel	100	112
Rock, loose	18	130
Clay, sandy; thin layers of water-bearing sand	70	200

11S-27E-36ad1

[Casing: 20-i .wrought-iron to 30 ft]

Material	Thickness (feet)	Depth (feet)
Soil, gravel, and clay	100	100
Rock, red, hard; reported to be quartzite	148	248

12S-26E-1bb1

[Casing: 14-in. wrought-iron to 195 ft; perforated from 109 to 195 ft]

Material	Thickness (feet)	Depth (feet)
Soil	17	17
Soil and small amount of gravel	13	30
Clay, yellow	15	45
Gravel, water-bearing	6	51
Clay, sandy	29	80
Clay, blue, sticky. Struck more water at 92 ft	12	92
Gravel, coarse	23	115
Clay, light-gray	5	120
Gravel	24	144
Gravel, cemented; drilled hard. Struck good flow of water at 150 ft	6	150
Gravel, coarse	6	156
Not recorded	39	195

12S–26E–1cc1

[Casing: 16-in. steel from 190 to 230 ft, perforated with ½- by 10-in. torch-cut slots]

Material	Thickness (feet)	Depth (feet)
Topsoil	3	3
Clay, brown; small amount of fine gravel	4	7
Gravel, fine, and clay	10	17
Gravel, fine, and sand; clay layers; struck water	18	35
Clay, brown	15	50
Clay, gray, sticky	35	85
Sand and gravel, fine; thin layers of	14	130
clay; struck more water	15	100
Sand and gravel, fine	16	116
Sand; caved badly from 85 to 120 ft	14	130
Gravel and sand with clay binder	28	158
Gravel, coarse	20	178
Clay, brown	2	180
Gravel	17	197
Gravel, cemented	4	201
Gravel, cobble (cobbles as much as 3 in. in diameter)	29	230

12S–26E–11bb1

[Casing: 18-in. steel to 220 ft, perforated]

Material	Thickness (feet)	Depth (feet)
Soil, sand, and gravel	45	45
Sand, fine-grained	30	75
Clay	50	125
Sand, and alternating beds of clay about 10 ft thick	60	185
Sand and clay in layers about 5 ft thick	35	220

12S–26E–11bd1

[Log obtained from Frank P. Conley, driller, Aug. 17, 1955]

Material	Thickness (feet)	Depth (feet)
Volcanic ash	8	8
Gravel	1	9
Clay, yellow, sandy	21	30
Clay, gray, sandy, soft	11	41
Gravel; clean; struck first water	6	47
Clay, sandy, soft	21	68
Clay, yellow	14	82
Clay, brown, sandy	8	90
Gravel, clean	5	95
Clay, yellow	17	112
Gravel, clean	32	144
Clay, brown, and gravel	16	160
Gravel, clean	13	173
Clay, yellow	4	177
Gravel, clean	18	195
Clay, yellow	9	204
Gravel	1	205

12S–26E–11cc1

[Log obtained from Frank P. Conley, driller, Aug. 17, 1955]

Material	Thickness (feet)	Depth (feet)
Soil	15	15
Clay	65	80
Sand	5	85
Basalt, broken, and clay	110	195
Sand, soft	5	200
Clay, brown, hard	8	208
Sand, coarse-grained, and gravel, pea	2	210
Clay, sandy, soft	17	227

12S–26E–11cc1—Continued

Material	Thickness (feet)	Depth (feet)
Clay, and basalt, broken	73	300
Clay, blue	5	305
Sand, blue, and gravel, pea	10	315
Clay, green	25	340

12S–26E–13bc2

[Owner reports water struck at 350 ft rose to 3 ft below land surface, but dropped to 27 ft below land surface when casing was perforated. Casing: 14-in. wrought-iron to 144 ft and 12-in. from 140 to 202 ft; perforated from 20 to 30 ft and 66 to 202 ft]

Material	Thickness (feet)	Depth (feet)
Soil	8	8
Gravel; struck water at 22 ft	22	30
Clay	36	66
Gravel, clean; water-bearing	24	90
Gravel, impure	7	97
Gravel, clean; water-bearing	36	133
Gravel, impure	11	144
Gravel (1-in. maximum diameter) and some fine sand	58	202
Clay, blue, and shale boulders	148	350

12S–26E–25cd2

[Casing: 14-in. wrought-iron perforated to about 222 ft]

Material	Thickness (feet)	Depth (feet)
Soil	20	20
Sand, water-bearing	15	35
Not recorded; poorly water-bearing	10	45
Clay	17	62
Gravel; poorly water-bearing	24	86
Clay	14	100
Gravel, sand, and clay	32	132
Clay, stiff	3	135
Gravel and clay, mixed	30	165
Clay, yellow	10	175
Clay, blue, sticky	310	485
Sand and clay; water-bearing. Water rose to land surface	25	510
Clay, green; drilled hard	55	565

12S–27E–19ca2

Material	Thickness (feet)	Depth (feet)
Topsoil, black	7	7
Gravel, coarse; struck water at 12 ft	29	36
Clay, brown	16	52
Gravel and clay	20	72
Gravel, coarse	48	120
Gravel	7	127
Hard formation	11	138
Clay	4	142
Clay; gravel layers	43	185
Gravel	13	198
Clay	4	202

12S–27E–30bc2

[Log obtained from Frank P. Conley, driller, Aug. 17, 1955]

Material	Thickness (feet)	Depth (feet)
Started at bottom of old dug well	35	35
Gravel	30	65
Gravel and sand, fine	2	67
Gravel	89	156

Material	Thickness (feet)	Depth (feet)
12S-27E-30dc2		
[Log obtained from Frank P. Conley, driller, Aug. 17, 1955]		
Soil	12	12
Gravel	34	46
Clay, silty	9	55
Gravel	33	88
12S-27E-31db1		
[Log obtained from Frank P. Conley, driller, Aug. 17, 1955]		
Started at bottom of old dug well	20	20
Gravel	37	57
Clay	4	61
Gravel	1	62
13S-26E-1cc1		
[Casing: 16-in. wrought-iron to about 65 ft; perforated from 24 to 43 ft and 46 to 64 ft]		
Soil and gravel; struck water at 20 ft	36	36
Gravel; water-bearing	2	38
Clay	Trace	38
Gravel, impure	5	43
Clay	1	44
Gravel, impure	11	55
Gravel, loose	7	62
Gravel, tight	2	64
Clay	1	65
Gravel, tight	4	69
13S-26E-1db1		
[Casing: 16-in. steel to 134 ft; 8-in. steel from 0 to 432 ft; open bottom]		
Soil	8	8
Gravel, coarse, mixed with clay; some water	65	73
Clay and gravel	97	170
Sand; would not stand without casing	80	250
Clay, blue, very sticky	170	420
Sand; well began to flow; water had strong sulfur odor; sand did not cave ;water cased off	4	424
Clay, blue; no additional water	326	750
Clay, white; drilled hard	50	800
Clay, blue, with gravel; cuttings warm	200	1000
Sand, blue, layered; cuttings too hot to hold in hand	400	1400
13S-26E-12ba1		
Tight formation [clay and soil?]	3?	31
Clay, soft	3	34
Gravel, impure [probably some sand mixed]	23	57
Gravel; fair water bearer	7	64
Tight formation [clay?]	2	66

Material	Thickness (feet)	Depth (feet)
13S-26E-13ba1		
[Casing: 12-in. light-gage steel to 148 ft, 10-in. from 148 to 281 ft]		
Soil	6	6
Gravel	23	29
Clay and gravel	5	34
Gravel and sand, water-bearing	6	40
Clay and gravel; no water	16	56
Gravel and sand, water-bearing	14	70
Gravel and yellow clay; no water	58	128
Clay, sandy, white; no water	20	148
Clay and sand	12	160
Gravel and clay; no water	14	174
Clay and sand; no water	51	225
Clay and some gravel; no water	45	270
Gravel	11	281
13S-26E-14cb1		
[Casing: 16-in. wrought-iron to 114 ft; perforated with Mills knife from 6 to 56 ft and from 74 to 100 ft, 12 holes to the round at 6-in. vertical intervals]		
Topsoil	4	4
Boulder gravel	29	33
Clay	1	34
Gravel	12	46
Gravel and clay; drilled fairly easily	5	51
Gravel and clay, tight	4	55
Gravel	1	56
Clay	18	74
Gravel, tight	6	80
Gravel; drilled fairly easily	3	83
Clay	4	87
Gravel	13	100
Clay, sandy	70	170
Gravel	1	171
Clay, sandy	20	191
Gravel, poorly water-bearing	18	209
13S-26E-23ca1		
Topsoil	2	2
Clay	2	4
Gravel and boulders	38	42
Clay	3	45
Gravel	5	50
Sand	6	56
Gravel	8	64
Clay	2	66
Gravel	7	73
Clay and gravel	9	82
Gravel and boulders	18	100
Gravel	12	112
Clay	6	118
Gravel, hard	22	140
Clay	4	144
Gravel	39	183
Clay	6	189
Gravel	4	193
Clay	4	197
Gravel	20	217
Clay	3	220
Gravel and clay layers	16	236
Clay	7	243
Gravel	7	250
Clay	6	256
Gravel	3	259
Clay	5	264
Gravel	6	270
Clay, hard, layered	12	282

Material	Thickness (feet)	Depth (feet)
13S-26E-23ca1—Continued		
Gravel	5	287
Clay and gravel, layered	11	298
Clay	6	304
Gravel	11	315
Gravel and boulders, hard	21	336
Clay	4	340
Gravel, hard	13	353
Clay	9	362
Gravel	6	368
Clay, hard, layered	2	370
Gravel and clay, hard	28	398
Sand	7	405
Clay and sand, layered	10	415
Not recorded	1,785	2,200

13S-26E-23cb1

[Casing: perforated with slot-type perforations from 0 to 350 ft]

Material	Thickness (feet)	Depth (feet)
Soil	4	4
Cobblestones and boulders	26	30
Clay and some gravel	15	45
Gravel and some clay	73	118
Clay	2	120
Gravel and some clay	30	150
Gravel and clay in alternating layers; poorly water-bearing	200	350

13S-26E-24aa1

[Casing: 36 in .perforated corrugated-steel to 24 ft]

Material	Thickness (feet)	Depth (feet)
Soil	6	6
Gravel	18	24
Clay	.7	24.7
Gravel	9.3	34

13S-26E-26aa1

[Casing: 16-in. wrought-iron from 0 to 348 ft; torch-cut perforations from 0 to 348 ft]

Material	Thickness (feet)	Depth (feet)
Soil and gravel. Struck water at 18 ft	20	20
Boulder gravel, tight	15	35
Gravel and clay	5	40
Clay	4	44
Gravel and clay	8	52
Clay	2	54
Gravel	2	56
Clay	2	58
Gravel, tight; clay pockets	24	82
Clay	3	85
Gravel; thin layers and pockets of clay	265	350

13S-27E-7ad1

[Log obtained from Frank P. Conley, driller, Aug. 17, 1955]

Material	Thickness (feet)	Depth (feet)
Soil	14	14
Sand and gravel	36	50

13S-27E-19dd1

[Casing: 48-in. perforated concrete from 0 to 32 ft; 24-in. black-iron perforated from 32 to 62 ft with ⅜- by 2-in. torch-cut slots, 13 holes per round on 8-in. vertical intervals]

Material	Thickness (feet)	Depth (feet)
Topsoil	7	7
Gravel and cobbles as much as 4 in. in diameter	55	62

13S-27E-29bc1

[Casing: 48-in. slotted concrete to 28 ft; 16-in. wrought-iron perforated from 28 to 57 ft with torch-cut slots, 10 holes per round and at 1-ft vertical intervals]

Material	Thickness (feet)	Depth (feet)
Not reported [probably topsoil and gravel]	29	29
Gravel, fine	28	57

13S-27E-31da1

[Casing: wrought-iron to 48 ft with 24-in. slot-type perforations]

Material	Thickness (feet)	Depth (feet)
Gravel	48	48

13S-27E-32cb2

[Casing: 16-in. wrought-iron to 78 ft; torch-cut perforations, 10 holes per round at 1-ft vertical intervals]

Material	Thickness (feet)	Depth (feet)
Topsoil	4	4
Gravel and cobbles, maximum diameter 4 in. Struck water at 11 ft	74	78

14S-27E-6cc1

[Log obtained from Frank P. Conley, driller, Aug. 17, 1955]

Material	Thickness (feet)	Depth (feet)
Soil	1	1
Gravel and soil	9	10
Gravel and clay, yellow	32	42
Gravel, small; struck first water	14	56
Clay, brown, soft	7	63
Gravel and boulders, small	12	75
Basalt(?), broken, and gravel	25	100
Clay, brown, sandy	110	210
Sand, and gravel, pea-size	5	215
Clay, brown, sandy	55	270
Sand, and gravel, pea-size	5	275

14S-27E-6db1

[Casing: 16-in. wrought-iron to 64 ft; perforated from 18 to 64 ft]

Material	Thickness (feet)	Depth (feet)
Soil	6	6
Gravel. Struck water at 18 ft	17	23
Not recorded [probably gravel]	35	58
Tight formation; water-bearing at 62 ft	6.5	64.5

14S-27E-8ac1

[Casing: 16-in. black-iron; perforated with ¾- by 6-in. torch-cut perforations, about 10 holes per round at about 1-ft vertical intervals from 0 to 68 ft]

Material	Thickness (feet)	Depth (feet)
Topsoil	13	13
Gravel and cobbles. Struck water at 19 ft	42	55
Clay	5	60
Sand	8	68
Clay, and sandstone in layers about 6 in. thick	110	178

14S-27E-8ad1

[Dug hole to 58 ft. Casing: 24-in. wrought-iron; perforated with ½- to 6-in. torch-cut slots, 13 holes per round, on about 1-ft vertical intervals, from 12 to 48 ft]

Material	Thickness (feet)	Depth (feet)
[Former dug hole to 24 ft, probably topsoil]	13	13
[Probably gravel]	15	24
Gravel and cobbles	24	48
Clay	10	58
Not recorded	627	685

14S-27E-8bc1

[Casing: 16-in. wrought-iron to 60 ft; perforated with Mills knife from 11 to 58 ft, 12 holes per round, at 6-in. vertical intervals]

Material	Thickness (feet)	Depth (feet)
Topsoil	6	6
Gravel. Struck water at 11 ft	30	36
Clay and gravel	1	37
Gravel, loose	2	39
Gravel, tight	19	58
Clay, sandy, yellow	14	72
Gravel	1	73
Clay	7	80

14S-27E-9bb1

[Casting: 16-in. wrought-iron; perforated from 19 to 43 ft]

Material	Thickness (feet)	Depth (feet)
Soil and gravel. Struck water at 19 ft	22	22
Gravel	21	43
Clay	10	53
Sandstone [possibly loosely consolidated gravel]; some water	19	72

14S-27E-16cc1

[Casing: 24-in. black-iron to 69 ft; perforated with 1- by 6-in. torch-cut slots, 10 slots per round, at about 1-ft vertical intervals, from 0 to 69 ft]

Material	Thickness (feet)	Depth (feet)
Topsoil	6	6
Gravel and cobbles. Struck water at 10 ft	20	26
Clay	7	33
Sand	5	38
Sandstone	1	39
Clay, sand, and sandstone layers	41	80

14S-27E-16dd1

[Log obtained from Dean Rogers, driller, Aug. 17, 1955]

Material	Thickness (feet)	Depth (feet)
Soil	1	1
Gravel	39	40
Clay	10	50
Sand	3	53
Clay; small amount of water at 55 ft	4	57
Sand and clay	24	81
Sand	43	124
Clay	42	166
Clay and sand	69	235
Sand	1	236
Clay	4	240
Sand	6	246
Sand and clay	39	285

14S-27E-18ad1

[Casing: 16-in. black-iron from 22 to 42 ft; perforated with torch-cut slots from 22 to 42 ft, 8 holes per round, at 6-in. vertical intervals]

Material	Thickness (feet)	Depth (feet)
Not recorded [probably topsoil and gravel]	22	22
Gravel	4	26
Sand	4	30
Clay, sandy	12	42
Clay	10	52

14S-27E-18dd1

[Log obtained from owner, Aug. 3, 1955]

Material	Thickness (feet)	Depth (feet)
Soil, sandy	6	6
Clay, crumbly	12	18
Gravel and sand, water-bearing	10	28
Silt, packed	17	45
Sand, coarse, water-bearing	5	50
Silt, packed	10	60
Clay	10	70
Sand, coarse, water-bearing	8	78
Clay, sandy	12	90
Sand, water-bearing	7	97
Clay, sandy	13	110
Limestone(?)	5	115
Sand and gravel, water-bearing	7	122
Clay, sandy	10	132
Sand, muddy	8	140
Sand, coarse-grained, and gravel; water-bearing	12	152
Clay	5	157
Sand, water-bearing	3	160
Clay, tough	20	180
Clay, sandy	10	190
Sand, coarse-grained and gravel, pea-size; water-bearing	10	200

14S-27E-20cd1

[Log obtained from Dean Rogers, driller, Aug. 17, 1955]

Material	Thickness (feet)	Depth (feet)
Not recorded	18	18
Gravel	6	24
Clay	2	26
Sand	4	30
Clay, sandy	9	39
Sand	3	42
Clay	38	80
Sand	4	84
Clay	12	96
Sand	18	114
Clay and sand	36	150

14S–27E–29bd1

[Casing: 48-in. concrete from 1 to 21 ft; perforated with eight 2¾-in. holes per foot of casing]

Material	Thickness (feet)	Depth (feet)
Sandy loam	8	8
Gravel	13	21
Clay	?	21+

14S–27E–29bd2

[Casing: 48-in. concrete from 4 to 22 ft; perforated with eight 2¾-in. holes per foot of casing]

Material	Thickness (feet)	Depth (feet)
Sandy loam	8	8
Gravel	14	22
Clay	?	22+

14S–27E–29ca1

[Casing: 40-in. concrete, perforated from 0 to 19 ft]

Material	Thickness (feet)	Depth (feet)
Topsoil	8	8
Gravel, fine	5	13
Gravel, coarse, and some cobbles	6	19

14S–27E–30aa1

[Casing: 48-in. concrete to 25 ft; perforated with eight 2¾-in. holes per foot of casing]

Material	Thickness (feet)	Depth (feet)
Sandy loam	8	8
Gravel	15	23
Clay	2	25

15S–24E–22ad1

[Casing: 6-in. wrought-iron to 60 ft]

Material	Thickness (feet)	Depth (feet)
Not recorded; water at 40 feet (cased out)	60	60
Rock, solid	136	196
Quicksand	?	196+

15S–26E–23dd1

[Casing: 16-in. to 148 ft]

Material	Thickness (feet)	Depth (feet)
Soil	7	7
Gravel, cemented	18	25
Gravel, water-bearing	5	30
Clay, yellow, soft; some water	22	52
Sand	33	85
Clay, yellow	60	145
Clay, yellow, sticky	20	165
Clay and gravel	10	175
Clay, blue, hard	15	190
Clay, blue	50	240
Clay, white, chalky	20	260
Clay, blue, sticky	10	270
Clay, light-blue	15	285
Clay, gray, chalky; water-bearing	40	325
Clay, blue	95	420
Sand; some increase of water	15	435
Clay, blue	15	450
Sand; more water	3	453
Clay, blue	20	473
Sand; water-bearing	2	475
Clay, hard, chalky	10	485
Sand; water-bearing	5	490
Sand and white lime	50	540

15S–26E–24ba1

[Casing: 16-in. steel to 224 ft perforated opposite all sand and gravel layers]

Material	Thickness (feet)	Depth (feet)
Soil; some water	23	23
Gravel, water-bearing	4	27
Gravel, cement gravel, and clay	8	35
Clay; drilled readily	21	56
Clay and gravel	54	110
Gravel, water-bearing	75	185
Clay	20	205
Sand	2	207
Clay	3	210
Gravel, water-bearing	13	223
Clay	13	236
Sand	4	240
Sand; heaved up in hole	5	245
Sand rock, very soft	20	265

15S–26E–33bb1

[Casing: 20-in. wrought-iron to 24 ft]

Material	Thickness (feet)	Depth (feet)
Soil	15	15
Boulders and clay	2	17
Clay, blue, hard	23	40
Clay, blue	20	60
Clay and sand, blue	13	73
Clay, dark	27	100
Clay, sandy, brown	80	180
Clay, blue	35	215
Clay, sandy, gray	25	240
Gravel, fine	2	242
Clay, dark	12	250
Clay, blue	50	300
Clay, sandy, dark	25	325
Clay, blue	25	350
Clay, dark	30	280
Clay, light-gray, warm-water-bearing	20	400
Clay, blue	30	430
Clay, white, chalky. Most of cuttings lost	30	460
Clay, chalky, warm-water-bearing	45	505

15S–26E–34bb1

[Casing: 12-in. wrought-iron, perforated opposite all gravel layers from 0 to 214 ft]

Material	Thickness (feet)	Depth (feet)
Topsoil	11	11
Quartzite, sand, and large boulders; interbedded clay layers from one-half to 2 ft thick	203	214

15S–27E–7db1

[Casing: 16-in. California stovepipe from 0 to 234 ft; perforated with Mills knife opposite all sand and gravel layers]

Material	Thickness (feet)	Depth (feet)
Soil	3	S
Clay	11	14
Gravel	36	50
Clay	6	56
Gravel	11	67
Clay	4	71
Gravel	3	74
Clay	13	87
Gravel	2	89
Clay	22	111
Clay, gravelly	9	120
Sand, packed, and gravel, fine	24	144
Clay	8	152

Material	Thickness (feet)	Depth (feet)
15S-27E-7db1—Continued		
Sand and gravel, fine, packed	4	156
Clay	3	159
Sand, packed, and some gravel	29	188
Clay	13	201
Sand	14	215
Clay	5	220
Sand and gravel, fine	5	225
Clay	9	234

15S-27E-8bb1

Log obtained from Dean Rogers, driller, Aug. 17, 1955]

Material	Thickness (feet)	Depth (feet)
Soil	12	12
Gravel; struck first water at 19 ft	7	19
Gravel; struck more water	19	38
Clay	6	44
Sand	16	60
Clay	15	75
Sand and clay	15	90
Clay	6	96
Sand	19	115
Clay	15	130
Sand and clay	32	162
Clay	3	165

15S-27E-8cb1

[Log obtained from Frank P. Conley, driller, Aug. 17, 1955]

Material	Thickness (feet)	Depth (feet)
Soil	18	18
Gravel and silt	10	28
Gravel and sand, packed	7	35
Gravel and sand; struck first water	10	45
Clay, brown, silty	17	62
Sand	6	68
Silt	7	75
Gravel, pea-size	3	78
Clay, soft	17	95
Sand	8	103
Clay, silty, soft	17	120
Sand and gravel, fine-grained	10	130
Clay, brown, silty	10	140
Sand, brown	5	145
Clay, brown, silty	25	170
Sand and gravel, coarse-grained	5	175
Clay, brown	17	192
Sand, coarse	3	195
Clay, brown, silty	10	205
Gravel	2	207

15S-27E-18bc1

[Casing: 14-in. light-gage steel to 262 ft; perforated opposite all sand and gravel layers]

Material	Thickness (feet)	Depth (feet)
Soil	2	2
Clay	8	10
Gravel	32	42
Sand, packed	6	48
Clay	5	53
Sand, packed	13	66
15S-27E-18bc1—Continued		
Clay	8	74
Sand, packed	7	81
Clay	5	86
Sand, packed	11	97
Clay	10	107
Sand, packed	7	114
Clay	33	147
Gravel	12	159
Clay	16	175
Sand and fine gravel	7	182
Clay	12	194
Clay, gravelly	16	210
Clay, soft	17	227
Gravel, sand, and clay	2	229
Clay, gravelly	8	237
Gravel and sand, impure	19	256
Gravel, fine, and sand	4	260
Clay	2	262

15S-27E-18ca1

[Casing: 14-in. California stovepipe from 0 to 212 ft; perforated with Mills knife opposite all sand and gravel layers; 8-in. wrought-iron from 212 to 320 ft, perforated opposite all gravel layers]

Material	Thickness (feet)	Depth (feet)
Soil	2	2
Clay	8	10
Gravel and cobblestones	18	28
Gravel	12	40
Clay	12	52
Sand, packed	19	71
Clay, sandy	23	94
Gravel	2	96
Clay	22	118
Sand and gravel	6	124
Clay	18	142
Gravel, sand, and clay	19	161
Clay	3	164
Sand and gravel, dirty	3	167
Clay	31	198
Gravel	3	201
Clay	2	203
Gravel	6	209
Clay	3	212
Sand; a thin layer of gravel and a 4-ft layer of rock at unknown depth	77	289
Gravel, coarse, water-bearing	1	290
Clay	30	320

15S-27E-19aa1

[Casing: 6-in. wrought-iron from 5 to 98 ft]

Material	Thickness (feet)	Depth (feet)
Soil	7	7
Cobble gravel	28	35
Gravel, water-bearing	3	38
Cobble gravel	8	46
Clay	24	70
Gravel, water-bearing	4	74
Clay	26	100
Clay, gravelly	2	102
Gravel, water-bearing	7	109

Material	Thickness (feet)	Depth (feet)
15S-27E-20cb3		
[Casing: 14-in. light-gage steel perforated with Mills knife opposite all beds of sand and gravel to 200 ft. Drilling deeper Nov. 6, 1952]		
Soil	3	3
Clay	3	6
Gravel, fine, and clay; struck water at 20 ft	16	22
Clay, sandy, soft	52	74
Gravel	1	75
Clay	8	83
Gravel	5	88
Clay	12	100
Gravel	4	104
Clay	10	114
Clay, gravelly	19	133
15S-27E-20cb3—Continued		
Clay	10	143
Gravel	3	146
Clay	5	151
Gravel, fine, and sand	13	164
Clay	6	170
Clay, gravelly	2	172
Clay	3	175
Sand and gravel	14	189
Clay	11	200
Not reported	3	203
Sandstone conglomerate, cemented	1	204
Sand, and fine gravel; maximum diameter ¼ in.	7	211
Sandstone conglomerate, cemented	1	212

CHARACTERISTICS OF WELLS

By S. W. FADER, R. W. MOWER, and H. G. SISCO

Descriptive information about nearly 400 water wells in the Raft River basin is summarized in table 22, and the locations of the wells are shown on plate 4. Part of the records tabulated for some of the wells were obtained from a report by Stearns and others (1936). These wells or well sites were visited during this investigation and additional information was obtained. Sixty-seven of the old wells have been destroyed but the data recorded earlier are included because they are pertinent to the objectives of this study, have much local interest, and would have value in the planning of new or extended water developments in the area. Most of the wells listed are dug or drilled irrigation wells equipped with turbine or centrifugal suction pumps that are powered by electric motors or gasoline or diesel engines.

TABLE 22.—*Records of wells in the Raft River basin, Idaho and Utah*

[Type of pump: C, centrifugal pump; J, jet pump; N, no pump; St, submersible turbine; T, shaft turbine; P, pitcher; L, lift; F, force. Use of well: D, domestic; I, irrigation; O, observation; S, stock; U, general. Principal aquifer: B, basalt; G, gravel; Q, highly fractured quartzite; S, sand. Asterisk (*) indicates reported depth]

Well	Owner	Year completed	Type	Depth (feet)	Diameter of casing (inches)	Type of pump or method of lift	Use	Aquifer	Altitude of land surface (feet)	Depth to water (feet below land surface)	Altitude of water surface (feet)	Date of measurement	Remarks
Cassia County, Idaho													
9S-25E-23db1	U.S. Bureau of Reclamation.	1951	Drilled	174	8-6	N	O	B	4,266.9	117.4	4,149.5	Oct. 30, 1952	Log on page 111.
9S-26E- 7bc1	do	1951	do	88	8-5	N	O	B	4,207.8	59.4	4,148.4	Oct. 23, 1952	Reported depth, 87 ft; log on page 111.
10aa1	do	1951	do	*95	8-5	N	O	B	4,221.0	71.6	4,149.4	Oct. 30, 1952	Log on page 111.
10dd1	do	1951	do	128	8-6	N	O	B	4,217.2	68.2	4,149.0	do	Log on page 111.
13cc1	U.S. Bureau of Land Management.	1954	do	*153	8	L	S	B	4,281.4	136.5	4,144.9	Aug. 18, 1955	Log on page 111.
20bb1	do	1954	do	*135	8	L	S		4,258.1	112.6	4,145.5	Aug. 31, 1955	
22bb1	do	1953	do	*127	8	L	S	B	4,251.2	106.3	4,144.9	Aug. 18, 1955	Flowing well; log on page 111.
9S-27E-36ad1	Joe Lynch	1950	do	*130	6	N	D	S	4,202.0				Discharge, 490 gpm; log on page 112.
36db1	D. L. Bush	1948	do	*230	16	T	I	S, G	4,215.8	11.6	4,204.2	Nov. 4, 1952	Log on page 112.
9S-28E-29bb1			do	102	4	N	U		4,328	Dry		Aug. 9, 1950	
29cb1			do		4	N	U		4,354	Dry		do	
10S-25E-10ba1	Robert Simplot		do	175	6	F	S, O	B	4,302.9	154.2	4,148.7	Oct. 19, 1952	
15ca1	do		do	*270	6	L	S	B	4,329.6	179.6	4,150.0	Sept. 16, 1948	
24dc1	Cline Preston	1955	do	*565	14		U			256.0		Aug. 18, 1955	Log on page 112.
24dd1	H. C. Mathews	1949	do	126	8		U			Dry		July 19, 1950	
10S-26E-23dc1	Leonard Funk	1950	do	*240	18		U			Dry		July 10, 1951	
26bb1	A. G. Shell	1954	do	*268	8	F	D, S			*245		Summer 1954	
33dd1	Arabella Anderson, Floyd Morris.	1955	do	*426	20	T	I			*180		May 1955	Reported discharge, 1,800 gpm.
34ba1	M. A. Mandell		do			L	S	B	4,484.4	*276	4,208.4	Nov. 23, 1929	
36bb1	Cline Preston	1952	do	*196	8	St	D	B	4,422.8	187.0	4,235.8	Oct. 22, 1952	
36bb2	do	1953	do	*356	14-12	T	I			*122		November 1953.	Reported discharge, 1,710 gpm.
36dc1	Rose (?)		do					B	4,435	119.0		Apr. 3, 1928	Destroyed.
36dc2	Cline Preston	1952	do	*335	12	T	I	B, S	4,428.9	124.9		Oct. 22, 1952	Discharge, 774 gpm; log on page 112.
10S-27E- 1da1	Lorraine Anderson		Dug	13	48	N	D	G	4,224.1	8.4	4,215.7	July 11, 1951	
2ab1	Charles Dunn	1950	Drilled	136	16	T	I	S	4,248.7	39.5	4,209.2	Oct. 19, 1952	Discharge, 765 gpm.
2cb1	Harry F. Dunn	1952	do	*299	18	T	I	S	4,242.1	30.3	4,211.8	do	Reported discharge, 1,260 gpm reported drawdown, 50 ft.
3da1	Charles Dunn	1950	do	64	8	N	O	S	4,261.9	51.8	4,210.1	do	

24cb1	Harold Johnson		Drilled	*120	16	T	I		4,276.6	*18	4,259	Sept. 1948	Reported discharge, 654 gpm.
25bb1	George Harrell		Dug	16					4,288	14.0	4,274	Oct. 4, 1928	Destroyed.
26dd1	do	1948	Drilled	105	16	T	I	S, G	4,304	24.7	4,280	Oct. 19, 1952	Reported discharge, 1,100 gpm; reported drawdown, 35 ft; log on page 112.
28cc1	G. Quarstrom		do	74	4	N	U		4,366.3	72.5	4,293.8	Aug. 9, 1950	
33bc1	M. B. Skaggs		do	80	4	N	U		4,374.0	78.7	4,295.3	do	
34bc1	J. N. Lewis		do	93	6	L	S		4,369	82.0	4,287	May 3, 1928	
35ab1	Frank Coffey		Dug						4,300	14.5	4,285	Oct. 4, 1928	Destroyed.
35ac1	G. W. Harrell	1948	Drilled	132	14	N	I	G	4,312.6	24.2	4,288.4	Oct. 19, 1952	Reported discharge, 900 gpm; reported drawdown, 70 ft.
35bb1	Frank Coffey	1940	do	*125		L	D	G		*40			
10S-28E- 6ba1	Barson Bros	1948	do	*211	18	T	I	G, S	4,231.1	17.0	4,214.1	Sept. 22, 1948	Log on page 112.
6dc1	Carl Follett	1950	do	*324		T	I	S	4,262.4	*36	4,226	Sept. 16, 1948	Log on page 112.
7dc1	Wadsworth								4,367	25.3	4,342	Sept. 21, 1928	Destroyed.
8cc1	C. Rehn		do	94	6	N	U		4,305.8	58.2	4,247.6	July 11, 1961	
9cb1	do		do			L	S		4,359.3	108.0	4,251.3	May 11, 1928	
17ad1	do	1913	do	161	6	L	S, D		4,372.5	117.8	4,254.7	July 10, 1951	
19cb1	Harold Johnson	1948	do	122		T	I		4,303.9	29.1	4,274.8	Sept. 16, 1948	Reported discharge, 1,350 gpm; reported drawdown, 30 ft.
20aa1			do	204	4				4,441	183.0	4,258	Sept. 20, 1928	Destroyed.
20bb1	C. Walter		do		4				4,352	89.4	4,263	May 10, 1928	Do.
20bc1	Harold Johnson		do	179	6	L	S		4,356.9	88.9	4,268.0	Nov. 4, 1952	
31bc1	R. Horsch		do		4				4,407	120.5	4,286	May 12, 1928	Do.
31cb1	A. H. Danforth		do		4				4,413	126.0	4,287	do	Do.
32bb1	C. E. Stanger		do		4				4,472	186.0	4,286	May 10, 1928	Do.
33bb1	A. Law		do	322	6		U		4,670	Dry		Aug. 9, 1950	
11S-26E- 2dc1	B. L. Hofman, Ivan Schrenk.	1954	do	*261	16-12	T	I			*152		Dec. 1954	Reported discharge, 990 gpm; reported drawdown, 26 ft.
10db1	Matthews Bros	1955	do	*351	22-18-16	T	I			*116		Mar. 1955	Reported discharge, 3,125 gpm; reported drawdown, 55 ft; log on page 113.
11ac1			do	103	4		U			Dry		July 18, 1950	
12ab1	H. C. Matthews	1950	do	*250	20	T	I	B	4,427.4	118.6	4,308.8	Aug. 7, 1950	Log on page 113.
12cb1	G. S. Matthews	1950	do	*190	16	T	I	B	4,427.9	110.5	4,317.4	Nov. 5, 1952	Reported discharge, 2,380 gpm; reported drawdown, 17 ft; log on page 113.
12cb2	Matthews Bros	1952	do	*180	10-6	St	D, S			*125		Fall 1952	
12db2	H. C. Matthews	1955	do	*180	6	St	D, S			*120		June 1955	
13bb1	D. C. Adams	1950	do	*355	12	T	I	S, G	4,422.9	72.7	4,350.2	Nov. 5, 1952	Reported discharge, 1,080 gpm; reported drawdown, 30 ft.
14ab1	G. S. Matthews	1947	do	157	4	L	S,O	G	4,428.2	104.9	4,323.3	Oct. 30, 1951	
21db1	H. H. Meyer		Dug	44		N	U		4,420	Dry		Sept. 23, 1948	
21db2	Martin F. Sanders	1954	Drilled	*400	16	N	U	G,S		*59		April 1954	
22cb1	C. E. Hunter		Dug	51					4,407	48.5	4,358	May 9, 1928	Destroyed.
25bc1	George H. Sanders	1953	Drilled	*300		T	I			*20		Dec. 1954	Reported discharge, 2,700 gpm; reported drawdown, 40 ft; log on page 113.
25cc1	J. R. Simplot	1952	do	*258	20	T	I			*30		Spring 1952	Reported discharge, 1,080 gpm; reported drawdown, 100 ft.

TABLE 22.—*Records of wells in the Raft River basin, Idaho and Utah*—Continued

Well	Owner	Year completed	Type	Depth (feet)	Diameter of casing (inches)	Type of pump or method of lift	Use	Aquifer	Altitude of land surface (feet)	Depth to water (feet below land surface)	Altitude of water surface (feet)	Date of measurement	Remarks
Cassia County, Idaho—Continued													
11S-26E-26bb1	J. R. Simplot		Dug	27		N	U		4,392	Dry		Sept. 23, 1948	
26cc1	Robert Simplot		do	33	36		O	G	4,401.2	29.9	4,371.3	Oct. 22, 1952	
26dc1	J. R. Simplot	1953	Drilled	*260	20	T	I			*27		Aug. 1955	Reported discharge, 900 gpm; reported drawdown, 100 ft.
27bb1	Martin F. Sanders	1953	do	*402	16	T	I			60		May 1953	Reported discharge, 1,800 gpm; reported drawdown, 30 ft; log on page 113.
27cc1	O. A. Powers	1950	do	*350	20	T	I	S,G	4,413.0	44.9	4,368.1	Oct. 22, 1952	
28ab1	Martin F. Sanders	1954	do	*256	16	N	U	S,G,B		*73		March 1954	Log on page 113.
35bc1	J. R. Simplot	1949	do	*277	18	T	I		4,408.1	30.7	4,377.4	Sept. 7, 1949	Discharge, 1,560 gpm.
35cc1	Robert Simplot		do	*270	12	T	I		4,416.7	36.1	4,380.6	Nov. 6, 1952	Discharge, 1,460 gpm.
35cc2	do	1948	do	*275	14	T	I	G,S	4,415.9	35.9	4,380.0	do	Discharge, 905 gpm; log on page 114.
35cc3	J. R. Simplot		do						4,417	36.6	4,380	Oct 3, 1928	Destroyed.
35dc1	J. J. McElhinney		Dug	34	48-36	N				29.6		Sept. 16, 1948	Do.
35dc2	do	1949	Drilled	*245	16	T	I	G	4,409.2	30.2	4,379.0	July 13, 1950	Discharge, 2,000 gpm; log on page 114.
11S-27E-1aa1	T. F. Pennington		do						4,395	104.0	4,291	May 12, 1928	Destroyed.
2cb1	Frank Coffey		Driven						4,311	*8	4,303	Oct. 4, 1928	Do.
3cb1	Lazy FC Ranch	1915	Drilled	87	6	N	U			Dry		Oct. 19, 1952	
3da1	do	1948	do	125	16	T	I	S	4,305.6	5.3	4,300.3	July 19, 1950	Reported discharge, 2,500 gpm; reported drawdown, 35 ft.
4cd1	Shell and Jones		do	105	4		U		4,384.2	73.0	4,311.2	Oct. 19, 1952	
6aa1	J. P. Michael		do	97	4		U		4,402	Dry		Aug. 7, 1950	
10aa1	Lazy FC Ranch	1947	do	*73	12	T	I	G	4,311.0	5.6	4,305.4	Oct. 19, 1952	Reported discharge was 2,500 gpm; reported drawdown was 8 ft; destroyed.
12dd1	J. Brown		do		4				4,460	167.3	4,293	May 12, 1928	Destroyed.
12dd2	Taylor Land Co., Inc.	1955	do	*375	20	T	I			*167		January 1955	Reported discharge, 2,160 gpm; reported drawdown, 81 ft.
14aa1			Dug	87	30		U			Dry		July 21, 1950	
15bb1	Lazy FC Ranch	1952	Drilled	*135	20	T	I	G,S	4,346.7	33.1	4,313.6	Oct. 19, 1952	Estimated discharge, 540 gpm; reported drawdown, 55 ft. log on page 114.
17bb1	S. Ophield		do	16						6.4		Oct. 4, 1928	Destroyed.
18bd1	do		Dug	17						Dry		Oct. 3, 1928	Do.
19dd1			do	9						Dry		Oct. 4, 1928	Do.

20ad1	Bishop Bros		do	23						Dry		do	Do.
21dc1			do						4,404	36.5	4,367	do	Do.
22cb1	Bishop Bros		do							43.4		do	Do.
22cb2	Lazy FC Ranch	1952	Drilled	*175		T	I	G, S	4,397.0	41.7	4,355.3	Oct. 15, 1952	Reported discharge, 765 gpm; log on page 114.
25dc1	Taylor		do	*185	6	St	S		4,513.6	137.1	4,376.5	July 21, 1950	
27aa1	L. Banta		Dug	60			U		4,431	Dry		do	
28bb1	Bishop Bros		Drilled	240	6	L	D		4,394.7	32.8	4,361.9	Nov. 5, 1952	
28cc1	Bailey Bros	1955	do	*260	20	T	I			*45		April 1, 1955	Reported discharge, 1,125 gpm; reported drawdown, 45 ft.
28cd1	do	1953	do	*220	20	T	I	G, S		*70		Spring 1953	Reported discharge, 1,350 gpm; reported drawdown, 30 ft.
28dd1	do	1953	do	*265	20	T	I	G		*60		Spring 1954	Reported discharge, 1,800 gpm.
29aa1	Bishop Bros		Dug						4,394	36.5	4,358	Oct. 4, 1928	Destroyed.
31dd1	H. Schodde	1951	Drilled	*185	20	T	I	G, S	4,389.9	8.4	4,381.5	Oct. 15, 1952	Reported discharge, 1,500 gpm; reported drawdown, 50 ft; log on page 114.
32ad1	Parr Bros	1954	do	*200	20	T	I	G		*45		March 1954	Reported discharge, 1,800 gpm; reported drawdown, 86 ft.
32dd1	Kenneth Henderson.	1955	do	*266	20	T	I			*55		April 1955	Reported discharge, 1,800 gpm.
33ad1	Bailey Bros	1955	do	*260	20	T	I			*70		do	Do.
33dd1	H. C. Bishop	1952	do	*208	20	T	I	G, S	4,453.3	68.9	4,384.4	Oct. 15, 1952	Reported discharge, 1,350 gpm; log on page 114.
34bd1	Parr Bros	1954	do	*266	20	T	I	G, S		*75		February 1954.	Reported discharge, 1,600 gpm.
34cd1	Bishop Bros	1950	do	391	20	T	I		4,467.1	85.0	4,382.1	Oct. 15, 1952	Reported discharge, 1,330 gpm; reported drawdown, 25 ft.
35ad1	Ray Silver	1952	do	*200	20	T	I	S	4,490.0	110.9	4,379.1	do	Log on page 114.
35ad2	do	1952	do	*190	6	N	D	S	4,488.9	109.9	4,379.0	do	
35bd1	Parr Bros	1954	do	*320	20	T	I	S		*104		Spring 1955	Reported discharge, 1,620 gpm.
36ad1	Ed Halverson	1950	do	*248	20	T	I	Q	4,548.9	180.0	4,368.9	Aug. 16, 1952	Log on page 114.
11S-28E-1bc1	F. E. Burns		do			L	S, D		5,890	124.0	5,766	May 11, 1928	
6ba1	Taylor Land Co., Inc.	1953	do	*325	18	T	I			*136		Fall 1953	Reported discharge, 1,910 gpm.
16ba1			do			L	S		4,680	309.0	4,371	June 2, 1928	
31cd1	Sayre		do						4,590	191.0	4,399	June 1, 1928	Destroyed.
12S-26E-1aa1	Abbott		do						4,396	16.4	4,380	Oct. 3, 1928	Do.
1bb1	Alva Temple	1950	do	188	14	T	I	G	4,405.5	22.8	4,382.7	Nov. 6, 1952	Reported discharge, 1,620 gpm; reported drawdown 22 ft; reported depth, 195 ft; log on page 114.
1bc1	Verl Chesley	1949	do	184	14	T	I	G	4,404.8	21.0	4,383.8	do	Discharge, 939 gpm.
1cc1	John Kobe	1952	do	*230	20-16	T	I	G, S	4,408.0	20.3	4,387.7	Oct. 23, 1952	Reported discharge, 1,800 gpm; reported drawdown, 40 ft; log on page 115.

TABLE 22.—*Records of wells in the Raft River basin, Idaho and Utah*—Continued

Well	Owner	Year completed	Type	Depth (feet)	Diameter of casing (inches)	Type of pump or method of lift	Use	Aquifer	Altitude of land surface (feet)	Depth to water (feet below land surface)	Altitude of water surface (feet)	Date of measurement	Remarks
Cassia County, Idaho—Continued													
12S-26E- 2ac1	White & Neilson	1950	Dug-drilled.	*197	20	T	I	G	4,415.4	32.0	4,383.4	Nov. 6, 1952	Discharge, 1,295 gpm.
2bc1	J. R. Simplot	1952	Drilled	*290	20–18–16	T	I	G	4,423.8	40.6	4,383.2	Oct. 23, 1952	Discharge, 936 gpm.
2bc2	Robert Simplot, J. R. Simplot	1952	do	*248	20	T	I			*37		Spring 1952	Reported discharge, 117 gpm; reported drawdown, 120 ft.
2cc1	Sarah McLendon		Dug						4,425	37.2	4,388	Oct. 31, 1928	Destroyed.
3aa1	L. W. Sanders								4,419	37.0	4,382	May 9, 1928	Do.
10ab1	do		Dug	43	60		U		4,444.3	39.2	4,405.1	Sept. 15, 1949.	
11ba1	M. L. Tannehill		do	25		N	U		4,415.7	23.1	4,392.6	Sept. 16, 1948.	
11bb1	M. V. Tannehill	1952	Drilled	*220	18	N	I	G, S	4,429.4	37.5	4,391.9	Oct. 23, 1952	Reported discharge, 630 gpm; reported drawdown, 32 ft; log on page 115.
11bc1			Dug	35	60	N	U			Dry		Sept. 15, 1949.	
11bd1	O. A. Power	1954	Drilled	*205	20	T	I			*35		March 1954	Reported discharge, 1,530 gpm; reported drawdown, 44 ft; log on page 115.
11cc1	O.A.Power, Joe W. Wells	1955	do	*340	18–16	T	I			*55		June 18, 1955.	Reported discharge, 1,440 gpm; reported drawdown, 105 ft; log on page 115.
11dd1									4,427	25.1	4,402	Oct. 3, 1928	Destroyed.
12cc1									4,423	21.5	4,401	do	Do.
12cc2	John P. Kobe	1954	Drilled	*202	20	T	I			*28		March 1954	Reported discharge, 1,440 gpm; reported drawdown, 40 ft.
13bc1	Thompson & Hall	1948	Dug	30	48	L	D	G	4,428.4	25.0	4,403.4	Nov. 6, 1952	
13bc2	Bortz	1950	Drilled	*350	14	T	I	G	4,427.6	29.8	4,397.8	Nov. 7, 1952	Discharge, 1,310 gpm; log on page 115.
14dc1	Frank P. Conley	1955	do	*508	16	N	U			*46		August 1955	
24ab1	R. W. Brown		Driven							*3		Oct. 3, 1928	Destroyed.
24ac1	John D. Hall	1949	Dug	33	48	T	I	G	4,434.3	6.5	4,427.8	Apr. 21, 1950	
25ac1	Williams Estate		Driven	21	2	N			4,453.9	15.1	4,438.8	Sept. 16, 1948.	
25ac2	do		Dug	20	48	N	I		4,445.1	5.8	4,439.3	Nov. 6, 1952	
25cd1			do	20					4,468	Dry		Oct. 3, 1928	Do.

25cd2	R. J. Harper	1945	Drilled	*565	14	T	U	S	4,468.2	5.4	4,462.8	Sept. 6, 1948	Log on page 115.
25dc1	do	1939	Dug	23	48	C	I	G	4,463.1	16.1	4,447.0	Nov. 7, 1952	Discharge, 293 gpm.
36ab1	H. A. Shaw		do						4,460	11.5	4,448	Oct. 3, 1928	Destroyed.
36ab2	Douglas Harper	1955	Drilled	*158	16	T	I			*19		May 1955	Reported discharge, 1,080 gpm; reported drawdown, 70 ft.
12S-27E- 4ab1			Dug	13			U		4,457	Dry		Sept. 23, 1948.	
4ad1	Harold L. Larson	1953	Drilled	*287	16	T	I			*100		Winter 1953	Reported discharge, 1,250 gpm.
6aa1	Fannie B. Williams		Dug	4					4,385				Destroyed.
13cc1	U.S. Bur. Land Management.	1954	Drilled	*185	6	L	S			*160		Nov. 30, 1954.	
19ca1	Taylor Bros	1952	do	*150	20	T	I		4,439.2	15.0	4,424.2	Oct. 16, 1952	Discharge, 1,305 gpm; draw down, 13.7 ft.
19ca2	do	1952	do	*202	20	N	U	G	4,437.2	14.1	4,423.1	do	Log on page 115.
30bb1	W. E. Williams		Dug						4,446				Destroyed.
30bc1	do	1930	do	15	48	C	I	G	4,447.4	11.2	4,436.2	Nov. 6, 1952	
30bc2	do	1955	Drilled	*156	16	T	I	G, S		14		Apr. 15, 1955	Reported discharge 1,400 reported drawdown, 50 ft; log on page 115.
30bd1	do	1930	Dug	22	48	N	U	G	4,449.8	8.8	4,441.0	July 12, 1950	
30cb1	W. Tracy		Drilled—driven.	*18	8–6	P	S		4,449.2	11.7	4,437.5	Sept. 20, 1948.	
30cd1	D. Tracy	1930	Dug	23	48	T	I	G	4,434.4	8.0	4,446.4	Nov. 6, 1952	Discharge, 342 gpm.
30dc1	I. J. Neddo	1930	do	17	48	T	I	G	4,457.2	10.6	4,446.6	do	Reported discharge, 720 gpm.
30dc2	Alice Neddo	1955	Drilled	*88	18	T	I			*18		May 1955	Reported discharge, 800 gpm; reported drawdown, 66 ft; log on page 116.
31cd1	Tell Taylor	1955	do	100	16	N	U			10.9		Aug. 9, 1955	
31db1	R. C. Wake	1955	do	*62	18	T	I	G		*12		April 1955	Reported discharge, 1,125 gpm; reported drawdown, 30 ft; log on page 116.
32bc1	Minnie Schodde		Dug	16									Destroyed.
13S-26E- 1aa1	Taylor Bros		do	22	42	C	D, I		4,477.8	9.1	4,438.7	Nov. 6, 1952	
1ba1	Jim Scott		do							12.9		Oct. 3, 1928	Do.
1bc1			do	20					4,498	Dry		do	Do.
1ca1	J. H. Thompson		do			P	U		4,485	15.9	4,469	do	
1cb1	do		do						4,507	20.2	4,487	do	Do.
1cb2	John E. Thompson		do	25	72–42	T	I	G	4,504.2				Discharge, 54 gpm.
1cc1	J. H. Thompson	1949	Drilled	64	16		I		4,517.6	23.7	4,493.9	Nov. 6, 1952	Reported depth, 69 ft; log on page 116.
1db1	Taylor Bros	1945	do	*1,400	16–8		U	S	4,495.4				Flowing. Log on page 116.
1dc1	Harvey Wight	1931	Dug	23	48	C	I		4,497.1	6.8	4,490.3	Nov. 6, 1952	Discharge, 500 gpm.
11dc1	H. F. Deardorff		do	33	6	L	U	G	4,555.5	29.1	4,526.4	do	
12aa1	S. Payne		do	13						Dry		Oct. 4, 1928	Destroyed.
12ba1	U.S. Forest Service	1949	Drilled	*66	6	T	D, S	G		*12		Aug. 30, 1952	Log on page 116.
12bc1	Scott Gamble		Dug						4,513	11.5	4,502	Oct. 7, 1928	Destroyed.
12bd1	Grant Cobley		Drilled	*60			D		4,511	11.6	4,499	do	
12bd2	Malta Ward of the Latter Day Saints.		Dug	16	60	C	I	G	4,513.3	12.9	4,500.4	Nov. 6, 1952	Discharge, 284 gpm.
12bd3	do	1955	Drilled	*56	16	T	I	G		*12		July 1955	Reported discharge, 315 gpm.

TABLE 22.—*Records of wells in the Raft River basin, Idaho and Utah*—Continued

Well	Owner	Year completed	Type	Depth (feet)	Diameter of casing (inches)	Type of pump or method of lift	Use	Aquifer	Altitude of land surface (feet)	Depth to water (feet below land surface)	Altitude of water surface (feet)	Date of measurement	Remarks
Cassia County, Idaho—Continued													
13S-26E-13ba1	Blaine Wight	1939	Drilled	*281	12–10	T	I	G	4,527.9	14.5	4,513.4	Nov. 6, 1952	Discharge, 653 gpm; log on page 116.
13ba2	Walter R. Hill	1935	do	*300	12	T	I	G	4,523.3	14.4	4,508.9	do	Discharge, 603 gpm.
13ba3	Blaine Wight		Dug						4,522	8.2	4,514	Oct. 4, 1928	Destroyed.
13bd1	Mrs. E. J. Nye		do	22	36	N	U	G	4,525.4	11.7	4,513.7	Nov. 6, 1952	
13ca1	do		Dug—drilled.	214	16	T	I	G	4,539.5	13.7	4,525.8	do	Discharge, 130 gpm; drawdown, 13 ft.
13cb1	Mrs. Jane Hitt		Dug						4,537.4	13.3	4,524.1	Oct. 5, 1928	Destroyed.
13cd1	John Hepworth		Dug-driven.	*18	36	C	D, S	G	4,540	*3	4,537	Spring 1948	
13dc1	Mrs. E. J. Nye		Dug	24	48	C	I	G	4,534.4	12.6	4,521.8	Nov. 6, 1952	
14ca1	L. D. Hall		do	16	36	T	I		4,560.9	9.7	4,551.2	Nov. 5, 1952	
14cb1	John Bowen	1950	Drilled	205	16		I	G	4,576.5	9.0	4,567.5	Nov. 6, 1952	Reported depth, 209 ft; log on page 116.
14cd1	L. D. Hall	1946	Dug	15	48	N	U		4,574.1	9.1	4,565.0	Nov. 5, 1952	
14db1	do		do	15			D		4,557.7	10.4	4,547.3	do	
14dd1	Bert Cottle		do						4,557	12.6	4,544.4	Oct. 8, 1928	Destroyed.
15dc1	Mrs. W. H. Robertson.		do	19		C	D		4,610.9	18.4	4,592.5	Nov. 5, 1952	
22ba1	Scott Gamble		do	17		N	U		4,612.3	17.2	4,595.1	do	
22cb1	Shirley Hitt, William W. Hitt	1955	Drilled	350	16–12–10	T	I			*8		March 1955	Reported discharge, 1,800 gpm; reported drawdown, 100 ft.
23db1	Jim Hitt		Dug						4,590	9.2	4,581	Oct. 8, 1928	Destroyed.
23ca1	Cougar Oil Co.	1950	Drilled	*2,200	8	N	U						Oil-test well; log on page 116.
23cb1	Wallace Ward	1950	do	350	14–12	N	U	G	4,593.1	12.5	4,580.6	Oct. 21, 1952	Log on page 117.
24aa1	John C. Hitt		Dug	*34	36–8	C	I, O	G	4,528.1	6.3	4,521.8	Oct. 24, 1952	Discharge, 763 gpm; drawdown, 13.1 ft; log on page 117.
24bd1	William Barrett		do	24	84	C	D, I	G	4,549.5	13.1	4,536.4	June 25, 1947	Discharge, 261 gpm.
24cd1			do	14					4,549	Dry		Oct. 5, 1928	Destroyed.
26aa1	Fred Gardiner	1949	Drilled	332	16	N	U	G	4,571.2	15.3	4,555.9	Nov. 5, 1952	Reported depth, 350 ft; log on page 117.
13S-27E-6bc1	R. J. Harper	1931	Dug	27	20	T	I	G		17.3		Nov. 6, 1952	Discharge, 600 gpm.
6cc1	I. J. Neddo	1924	do	14		C	I		4,490.2	6.8	4,483.4	do	Discharge, 1.050 gpm.
6cc2	do		do	*20		C	D		4,488.5	7.4	4,481.1	Oct. 4, 1928	
6cc3	Alice Neddo	1955	Drilled	36	24	N	U			*10		April 1955	
6dc1	I. J. Neddo	1947	Dug	16	36	C	I		4,479.7	.55	4,479.2	Nov. 6, 1952	Reported discharge, 810 gpm.

7ad1	Jay E. Wake	1955	Drilled	50	18	T	I			*13		March 1955	Reported discharge, 900 gpm; reported drawdown, 34 ft; log on page 117.
7bb1	Taylor Bros		Dug	*12		C	D, S		4,488.6	5.8	4,482.8	Nov. 6, 1952	
7cc1	do	1947	do	30	16	T	I	G	4,503.7	7.3	4,496.4	do	Discharge, 1,430 gpm.
7cc2	do		do	32	16	T	I	G	4,510.0	9.8	4,500.2	do	Discharge, 855 gpm.
8bb1	J. N. Spaulding		do							11.6		Oct. 8, 1928	Destroyed.
8cc1	E. P. Small		do	*12						11.3		do	Do.
12aa1	U.S. Bur. Land Management.	1954	Drilled	*180	6	L	S			*158		September 1954.	
13dd1	do	1954	do	*220	6	L	S			*198		October 1954.	
18ba1	Glen Park		Dug	12	36	C	D, S	G	4,507.4	6.1	4,501.3	Nov. 6, 1952	
18bd1	Grant Hitt	1945	do		36	C	I, D	G	4,511.9	9.0	4,502.9	do	
18cb1	Garrett Hutchinson		do	20	48	C	I, D, S	G	4,518.4	7.7	4,510.7	do	Discharge, 595 gpm.
18db1	Grant Hitt, Glen Parke.	1955	do	*28	54	T	I			*7		February 1955.	Reported discharge, 1,170 gpm; reported drawdown 17 ft.
18dd1	J. Deward Hall	1955	Drilled	*35	16	T	I			*5		March 1955	Reported discharge, 900 gpm.
19dd1	Art Pierce	1952	Dug-drilled	60	48-24	N	U	G	4,534.5	6.4	4,528.1	Oct. 21, 1952	Reported discharge, 1,386 gpm; reported drawdown, 17 ft; reported depth, 62 ft; log on page 117.
20cb1	George W. Neddo		Dug	*15						10.0		Oct. 7, 1928	Destroyed.
20cb2	do		do	19	48	C	I	G	4,533.9	8.8	4,525.1	Apr. 20, 1950	Discharge, 600 gpm.
20cb3	do		do	26	48	T	I	G	4,533.8	10.2	4,523.6	Nov. 5, 1952	Discharge, 382 gpm.
29bc1	Dean E. Rogers	1947	do	27	48	T	I	G	4,541.2	7.5	4,533.7	Sept. 6, 1950	Discharge, 730 gpm; reported depth, 57 ft; log on page 117.
29cb1	C. I. Sater		do						4,543	8.3	4,535	Oct. 5, 1928	Destroyed.
29cd1	Earnest Merrill		do	24	36	C	I		4,554.8	11.8	4,543.0	Nov. 4, 1952	Discharge, 300 gpm.
29dc1	Walt Taves	1950	Drilled	55	16	T	I	G	4,553.5	9.8	4,543.7	do	
29dd1	Warren McBride		Dug	*25					4,554	8.9	4,545	Oct. 5, 1928	Destroyed.
29dd2	Walt Taves	1948	do	*25	48	C	I		4,555.8	10.1	4,545.7	Nov. 4, 1952	Discharge, 395 gpm.
29dd3	Buddy Ward	1952	Drilled	75	16	T	I			*14		Spring 1952	Reported discharge, 630 gpm.
30bd1	A. D. Pierce	1940	Dug	28	72	T	I, O	G	4,541.6	5.8	4,535.8	Oct. 24, 1952	Discharge, 1,175 gpm.
30ca1	Jesse M. Pierce	1946	do	23	48	T	I	G	4,545.6	6.3	4,539.3	Nov. 7, 1952	Discharge, 920 gpm.
30cb1	J. F. Gilson		do						4,540	6.2	4,534	Oct. 5, 1928	Destroyed.
30cd1	Lano E. Elison	1948	do	23	48		I	G	4,548.8	8.6	4,540.2	Nov. 4, 1952	
30da1	Roger Neddo	1947	do	28	72	T	I	S, G	4,545.6	8.4	4,537.2	do	Discharge, 770 gpm.
30dc1			do	22	48	T	I	G	4,550.2	7.9	4,542.3	do	Discharge, 990 gpm.
30dd1	Art Pierce	1949	do	35	48	C	I	G	4,551.9	14.1	4,537.8	do	Discharge, 1,075 gpm.
31ba1	John A. Elison	1948	do	21	48		I	G	4,553.3	8.7	4,544.6	do	
31da1	Raymond C. Graham.	1951	Drilled	44	24	T	I	G	4,563.1	10.8	4,552.3	Oct. 21, 1952	Discharge, 700 gpm; reported depth, 48 ft; log on page 117.
32ba1	Earnest T. Merrill	1955	do	*150	16	T	I			*12		May 1955	Reported discharge, 540 gpm.
32bb1	do		Dug	21	60	C	I	G	4,556.4	10.0	4,546.2	Nov. 4, 1952	Discharge, 720 gpm.
32bb2	do	1950	Dug-drilled	*23	48	T	I			9.9		do	
32cb1	Dean E. Rogers	1947	do	27	48-16	T	I	G	4,563.5	11.6	4,551.9	Oct. 21, 1952	Discharge, 410 gpm.
32cb2	do	1952	Drilled	*78	16	T	I	G	4,563.6	10.3	4,553.3	do	Reported discharge, 540 gpm; reported drawdown, 50 ft. log on page 117.

TABLE 22.—*Records of wells in the Raft River basin, Idaho and Utah*—Continued

Well	Owner	Year completed	Type	Depth (feet)	Diameter of casing (inches)	Type of pump or method of lift	Use	Aquifer	Altitude of land surface (feet)	Depth to water (feet below land surface)	Altitude of water surface (feet)	Date of measurement	Remarks
Cassia County, Idaho—Continued													
13S-27E-32da1	Wayne Newcomb		Dug	*18					4,569	14.0	4,555	Oct. 7, 1928	Destroyed.
32da2	do		Drilled	*775	4				4,569	21.5	4,547	May 31, 1928	Do.
32db1	do		Dug	27	48	N	I		4,568.3	13.7	4,554.6	Nov. 4, 1952	
33bc1	Charles Hall		do	*10					4,562	9.5	4,552	Oct. 7, 1928	Do.
33cb1	Charles L. Hall	1940	do	23	36	T	I	G	4,567.7	13.0	4,554.7	Sept. 10, 1948	Discharge, 835 gpm.
13S-28E- 8dd1	U.S. Bureau Land Management.	1954	Drilled	*260	6	L	S			*240		November 1954.	
14S-25E-29bd1	Larry Knight		Dug						5,630	21.3	5,609	May 5, 1928	Destroyed
14S-27E- 3ac1	Mrs. V. G. Stanbaugh.		Drilled	*223						*52		Oct. 6, 1928	Do.
3ac2	do		do	*201						*52		do	Do.
4ba1	Wayne Newcomb		Dug	*13		P	D		4,573.1	11.1	4,562.0	Nov. 4, 1952	
4ca1	do	1945	do	17	48	N	I		4,587.4	12.9	4,574.5	do	
4cc1			do						4,586	10.4	4,576	Oct. 7, 1928	Do.
4cd1	Lester Thompson	1954	Drilled	250	20	T	I			*20		Spring 1954	Reported discharge, 2,250 gpm; reported drawdown, 11 ft.
5ad1			Dug						4,576	9.5	4,566	Oct. 7, 1928	Destroyed.
5dd1	Wayne Newcomb		Drilled	*20	6	N			4,589	12.0	4,577	do	Do.
6ad1	Lano E. Elison	1948	do	95	16	T	I		4,575.6	12.8	4,562.8	Nov. 4, 1952	Discharge, 642 gpm.
6bb1	J. H. Thompson	1949	Dug	26	48	T	I	G	4,571.2	12.9	4,558.3	Nov. 5, 1952	Discharge, 184 gpm.
6cc1	Eldon N. Chandler	1955	Drilled	*275	16-14-12	N	U			*42		July 20, 1955	Reported discharge, 2,000 gpm; reported drawdown, 36 ft; log on page 117.
6db1	John A. Elison	1948	do	*64.5	16	T	I	G	4,581.4	13.3	4,568.1	Nov. 4, 1952	Log on page 253.
7aa1	R. H. Pack		Dug							9.4		Oct. 8, 1928	Destroyed.
7ac1	Malta Land & Irr. Co.	1938	Drilled	59	18	T	I		4,592.9	14.5	4,578.4	Nov. 4, 1952	Discharge, 340 gpm.
7ac2	do	1938	do	58	18	T	I		4,592.3	13.5	4,578.8	do	Discharge, 160 gpm.
7ad1	do		Dug	31	48	T	I		4,590.8	12.0	4,578.8	do	Discharge, 220 gpm.
7ad2	do		do	31	48	T	I		4,591.1	12.2	4,578.9	do	
7ad3	do		do	31	48	T	I	G	4,590.9	12.0	4,578.9	do	Do.
7bd1	Floyd Bell	1949	Drilled	38	16	T	I	G	4,592.6	14.6	4,578.0	do	Discharge, 464 gpm.
7dc1	Vance T. Smith	1954	do	*150	16	T	I			*20		December 1954.	Reported discharge, 1,080 gpm; reported drawdown, 20 ft.
7dd1	do		do	60	18	T	I	G	4,608.5	13.3	4,595.2	Nov. 4, 1952	

8ac1	William Dilg	1951	do	67	16	T	I	G	4,605.1	20.0	4,585.1	Oct. 21, 1952	Reported discharge, 405 gpm; reported drawdown, 45 ft; reported original depth, 178 ft; log on page 118.
8ad1	P. H. Pewitt	1952	Dug-drilled.	*685	24-16-14	N	U			24.4		Aug. 5, 1955	Log on page 118.
8ad2	Wayne Newcomb		Dug	33	10		I		4,601.6	17.4	4,584.2	Sept. 10, 1948	
8bc1	Dale Smith	1950	Drilled	*80	16		I	G	4,590.0	10.7	4,579.3	Nov. 4, 1952	Log on page 118.
8bc2	Joe Barrett	1949	do	*93	6	T	D, S	G		*14		December 1949.	
8bd1	Malta Land & Irr. Co.		Dug	25	48	T	I	G	4,596.4	13.2	4,583.2	Nov. 4, 1952	Discharge, 432 gpm.
8bd2	do		do	30	48	T	I	G	4,595.1	11.9	4,583.2	do	Discharge, 94 gpm.
8bd3	do		do	28	48	T	I		4,595.6	12.6	4,583.0	do	Discharge, 373 gpm.
8ca1	Oscar Egbert		do	16	48	C	I	G	4,599.4	13.5	4,585.9	do	
8cb1	Don Shaw	1955	Drilled	*135	16	T	I			*16		June 1955	Reported discharge, 990 gpm; reported drawdown, 74 ft.
9bb1	Lester Thompson	1949	do	*72	16	T	I	G	4,593.6	16.2	4,577.4	Nov. 4, 1952	Discharge, 660 gpm; log on on page 118.
9bd1	R. D. Thompson	1953	do	*550	20-16	T	I			*20		Winter 1953	Reported discharge, 1,080 gpm.
9cc1	do	1953	do	*56	24	T	I			*20		do	
9cd1	do	1953	do	*585	24-18-14	T	I			*20		do	Do.
9cd2	do	1953	do	*500	16	T	I			*20		do	Do.
16cc1	Bert Logan	1952	do	69	24	N	I	G	4,629.8	10.1	4,619.7	Oct. 20, 1952	Reported depth, 80 ft; log on page 118.
16cd1	Carl Neiwirth, T. A. Arnold.	1953	do	*135	30-20	T	I	G		*35		Spring 1953	Reported discharge, 900 gpm; reported drawdown, 50 ft.
16dd1	do	1954	do	*285	20	T	I	S		*47		March 1954	Reported discharge, 1,125 gpm; reported drawdown, 90 ft; log on page 118.
17ba1	Frank C. Lee	1955	do	*130	16	T	I			*18		March 1955	Reported discharge, 900 gpm; reported drawdown, 62 ft.
17bd1	E. H. Paskett		Dug		48	C	I		4,618.3	14.6	4,603.7	Nov. 4, 1952	
17bd2	Edwin Paskett	1955	Drilled	*160	16	T	I			*18		March 1955	Reported discharge, 630 gpm; reported drawdown, 82 ft.
17ca1	W. R. Bronson	1955	do	200	18	T	I			*16		July 1955	
17cc1	Malta Land & Irr.	1938	do	116	18	N	U		4,626.6	13.6	4,613.0	Nov. 4, 1952	
17cc2	do		Dug	26	48	T	I	G	4,625.5	12.7	4,612.8	do	Discharge, 405 gpm.
17cc3	do		do	25	48	N	U		4,625.9	13.1	5,612.8	do	
17cc4	do		do	26	48	T	I	G	4,625.8	13.1	4,612.7	do	Discharge, 153 gpm.
17cc5	do		do	29	48	T	I	G	6,624.5	12.1	4,612.4	do	Discharge, 220 gpm.
18ad1	Milton Neddo	1945	Dug-drilled.	22	48	T	I	G	4,618.3	14.2	4,604.1	do	Discharge, 423 gpm; reported depth, 52 ft; log on page 118.
18dd1	do	1955	Drilled	*200	16	T	I	S, G		*33		June 1955	Reported discharge, 2,500 gpm; reported drawdown 95 ft; log on page 118.
20ba1	Charles Warr	1952	do	*70	16	T	I			*8		May 1952	Reported discharge, 450 gpm: reported drawdown, 60 ft.
20cd1	Lorenzo Tracy	1955	do	*150	16	T	I	S		*14		July 1955	Reported discharge, 900 gpm; reported drawdown, 86 ft; log on page 118.

TABLE 22.—*Records of wells in the Raft River basin, Idaho and Utah*—Continued

Well	Owner	Year completed	Type	Depth (feet)	Diameter of casing (inches)	Type of pump or method of lift	Use	Aquifer	Altitude of land surface (feet)	Depth to water (feet below land surface)	Altitude of water surface (feet)	Date of measurement	Remarks
Cassia County, Idaho—Continued													
14S-27E 28cc1	R. W. Baker		Dug	19	48	C	I, D, S	G	4,673.8	8.5	4,665.3	Nov. 4, 1952	Discharge, 243 pgm.
29ab1	Lawrence R. Jardine		do	20	18	C	I	G	4,657.8	9.1	4,648.7	do	Discharge, 745 gpm.
29bd1	F. C. Lee	1950	do	*21	48	T	I	G	4,661.3	10.0	4,651.3	do	Discharge, 342 gpm; log on page 119.
29bd2	E. H. Paskett	1950	do	*22	48	T	I	G	4,661.5	9.8	4,651.7	do	Discharge, 520 gpm; log on page 119.
29ca1	W. R. Bronson	1952	do	17	40	N	U		4,671.6	10.8	4,660.8	Oct. 20, 1952	Reported depth, 19 ft; log on page 119.
29ca2	Val Jones		do			C	U			*20		Aug. 3, 1955	
29ca3	Val Jones, Glenn L. Jones.	1955	Drilled	*160	16	T	I			*20		March 1955	Reported discharge, 1,440 gpm.
29da1	Winston Hutchinson.	1948	do	*72	14	T	I		4,669.0	12.1	4,656.9	Nov. 4, 1952	
30aa1	F. C. Lee	1950	Dug	26	48	T	I	G	4,656.3	10.8	4,645.5	Nov. 5, 1952	Discharge, 400 gpm; reported depth, 25 ft; log on page 119.
32ac1	J. E. Eklund	1919	do	21	96-36	T	I	G	4,688.4	11.4	4,677.0	Nov. 4, 1952	Discharge, 468 gpm.
32bc1	S. R. Barrett	1951	do	22	40	T	I	G	4,690.0	14.3	4,675.7	Oct. 20, 1952	Discharge, 450 gpm.
32bd1	J. W. Patterson	1954	Drilled	*107	18	T	I			19.1		Aug. 5, 1955	Reported discharge, 720 gpm; reported drawdown, 49 ft.
32cc1	S. R. Barrett	1950	Dug	*22	48	C	I	G	4,696.9				Discharge, 310 gpm.
33ca1	Harold Oman		Drilled	*265	12	T	I, O		4,690.6	16.2	4,674.4	Oct. 24, 1952	Reported discharge, 675 gpm.
34aa1	U.S. Bur. Land Management.	1953	do	*119	6		S			*102		June 1, 1953	
15S-24E- 9cd1	Rovertson		do	19	36	C	D		5,781.5	13.5	5,768.0	July 31, 1948	
10bd1			do	9	30		U			5.3		do	
10dc1	Earl J. Taylor		do	8	36	C	D	G	5,618.2	6.9	5,611.3	do	
12bd1		1948	do	9		N	U	G	5,353.2	5.5	5,347.8	do	
13ab1		1941	do	23		L	S	G	5,314.6	18.6	5,296.0	do	
13ca1	Owen Jones		do	*30		C	D			*5		Spring 1948	
14ab1	S. L. Jones		Driven	18	2	P	U			11.9		Aug. 2, 1948	
14bb1	H. H. Taylor	1912	Dug	*30		C	D			*12			
15dc1	Earl J. Taylor		do	*11		C	D	G		*7			
21dd1			do	10		N				5.3		July 31, 1948	Destroyed.
22ad1	Edwin Durfee	1948	Drilled	*196	6	N	I, D	S	5,403.7				Discharge, 3 gpm. (flowing); log on page 119.
23bb1			Driven	27	2	P	U		5,390.3	18.0	5,372.3	Aug. 2, 1948	
26bc1	Wallace Taylor		Dug	41		N	O		5,327.4	33.7	5,293.7	Sept. 2, 1952	

27ac1	Charles Johnson		Drilled	81	6	F	D, S		5,360.8	65.6	5,295.2	Aug. 2, 1948	
31aa1	A. E. Nicholson		Dug	*30	36	L	D			*15		Summer 1947	
15S-25E- 6ab1	Jenny Wake	1948	do	34	6	N	D, O	G	5,503.8	25.6	5,478.2	Oct. 23, 1952	
6ca1	do		do	14	6	L	D	G	5,482.6	10.2	5,472.4	July 31, 1948	
6ca2	Aseal Lowe		do	17	48	C	D	G	5,441.5	5.9	5,435.6	do	
7cb1	O. W. Ward		do	22	8	C	D	G	5,346.7	11.1	5,335.6	do	
15S-26E-23bb1	Ben Schmidt		Drilled	*414	8	N	I						Discharge, 59 gpm (flowing).
23dd1	Alvin Newbold	1948	do	*540	16	N	I	S	4,826.4				Discharge, 26 gpm (flowing); log on page 119.
24aa1	W. L. Hawkins	1935	do	*50	6	J	D			*35		Nov. 3, 1935	
24ba1	Orvil Udy	1945	do	*265	16	T	I	S	4,802.4	11.2	4,791.2	Nov. 3, 1952	Discharge, 1,500 gpm; log on page 119.
24bc1	Boyd Booth	1938	do	*153		T	I		4,827.8	33.8	4,794.0	Nov. 4, 1952	Discharge, 387 gpm.
24cb1	Alvin Newbold		Dug	22	84	C	D		4,816.1	17.1	4,799.0	do	
24cd1	W. L. Hawkins	1935	Drilled	*233	16–10	T	I	G	4,807.4	11.0	4,796.4	Nov. 3, 1952	Discharge, 954 gpm.
27dc1	R. H. Smith	1952	do	*215	12	T	I			*18		Winter 1952	Reported discharge, 1,230 gpm; reported drawdown, 42 ft.
33bb1	do	1948	do	*505	20	N	I		4,920.4	11.3	4,909.1	Oct. 24, 1952	Reported discharge, 585 gpm; reported drawdown, 86 ft; log on page 119.
34bb1	do	1952	do	*214	12	T	I	G	4,879.9	17.0	4,862.9	do	Reported discharge, 1,200 gpm; reported drawdown, 90 ft; log on page 119.
15S-27E- 4ca1	Delbert Holmgren	1955	do	*630	20–16–12	N	U			18.0		Aug. 2, 1955	Reported discharge, 1,300 gpm.
5db1	Ray Olson		Dug	17		N	D		4,711.6	13.3	4,698.3	Nov. 5, 1952	
6ab1	Vincent B. Tobin	1953	Drilled	*270	16–8	T	I			*38		March 1953	Reported discharge, 1,800 gpm; reported drawdown, 60 ft.
6ad1	do	1954	do	*254	18	T	I			28.2		Aug. 2, 1955	Reported discharge, 2,250 gpm; reported drawdown, 60 ft.
7cc1	Marlin Booth		Dug						4,840	25.5	4,815	May 30, 1928	Destroyed.
7cd1	do		Drilled	*70	6	C	D			*20		Fall 1952	
7db1	Frank Olson	1951	do	220	16	T	I	G, S	4,750.2	35.1	4,715.1	Oct. 20, 1952	Reported discharge, 1,120 gpm; reported drawdown 69 ft; reported depth 234 ft; log on page 119.
7dd1	Bridge School		Dug	30		L	D		4,746.9	26.2	4,720.7	Aug. 14, 1948	
8bb1	Ray D. Olson	1954	Drilled	*165	16	T	I			38.9		Aug. 2, 1955	Reported discharge, 1,125 gpm; log on page 120.
8cb1	R. M. Jones	1955	do	*207	16	T	I			48.6		Aug. 1, 1955	Reported discharge, 1,260 gpm; reported drawdown, 70 ft; log on page 120.
8db1	Ray D. Olson	1955	do	*200	16	T	I			38.0		Aug. 2, 1955	Reported discharge, 1,250 gpm.
18ac1	Albert P. Smith		do	*285	14	T	I		4,766.0	38.4	4,727.6	Oct. 20, 1952	Discharge, 576 gpm.
18bc1	Marlin H. Booth	1950	do	*262	14	T	I	G, S	4,775.6	40.4	4,735.2	Nov. 3, 1952	Log on page 120.
18bd1	do	1936	do	*250	14	T	I	G	4,769.3	25.8	4,743.5	do	Discharge, 705 gpm.
18ca1	Thomas Mills	1951	do	*320	14–8	N	I	G, S	4,774.4	37.4	4,737.0	do	Log on page 120.
19aa1	Junior Gunnell	1946	do	*109	6	J	D	G		*24		Spring 1947	Log on page 120.

TABLE 22.—*Records of wells in the Raft River basin, Idaho and Utah*—Continued

Well	Owner	Year completed	Type	Depth (feet)	Diameter of casing (inches)	Type of pump or method of lift	Use	Aquifer	Altitude of land surface (feet)	Depth to water (feet below land surface)	Altitude of water surface (feet)	Date of measurement	Remarks
Cassia County, Idaho—Continued													
15S-27E-19cc1	Oscar Edlund		Drilled	*400	12-10-8	T	I	S	4,800.9	30.5	4,770.4	Nov. 3, 1952	Estimated discharge, 810 gpm; estimated drawdown, 78 ft.
20cb1	I. J. Gunnell	1942	do	*98	6	N	D, S	G		*18		1947	
20cb2	do		Dug						4,750	15.7	4,734	May 31, 1928.	Destroyed.
20cb3	Lewis Gunnell, Jr.	1952	Drilled	199	14	T	I	S, G	4,779.4	29.3	4,750.1	Oct. 20, 1952.	Reported discharge, 90 gpm; reported drawdown, 140 ft; reported depth, 212 ft; log on page 121.
29ac1	I. J. Gunnell	1948	do	166	16-10	T	I	G	4,808.7	8.2	4,800.5	Nov. 3, 1952	
31ad1			Dug	69		N	U			Dry		Aug. 12, 1948	
31da1			do	56		N	U			Dry		do	
34dd1	I. J. Neddo	1948	Drilled	*180	6	J	D						
16S-24E-12aa1	John Ward		do	*54	6	F	D, S			*15			
12aa2	do		do	39	16	N				6.9		Aug. 3, 1948	Destroyed.
12aa3	do	1950	do	*137	16	T	I	G	5,160.1	9.4	5,150.7	Sept. 1, 1950	
12bd1	do	1947	do	*220	12-10	T	I	G	5,190.7	25.0	5,165.7	Apr. 19, 1950	Discharge, 810 gpm.
12cb1	Earnest Jensen	1938	do	*264	10-6	T	I	G	5,204.1	34.4	5,169.7	Sept. 7, 1950	Discharge, 250 gpm.
12cc1	Jensen Bros.	1949	do	253	14	N	I		5,204.3	14.5	5,189.8	Sept. 1, 1950	
12dc1	Earnest Jensen		Dug	20	48	P	D	G	5,187.7	16.7	5,171.0	Aug. 2, 1948	
16S-25E-29da1			do	11	48	N	U			9.9		do	
36ba1	Wallace Tracy		Drilled	158	8	N	I						Discharge, 5 gpm (flowing).
16S-26E-20da1	Max Barnes	1948	do	126	6	C	D			13.4		Aug. 3, 1948	
23cd1	Joseph Holland		Dug						5,540	14.5	5,526	May 31, 1928	
27cd1	W. I. Jardine		do	6	30	N	U		5,783	3.8	5,779	Aug. 4, 1948	Destroyed.
28cb1	Montgomery		do	35	48	N	U	G		18.0		Aug. 3, 1948	
28cd1	Oday McIntire		do	10			S	G		5.8		do	
28db1	Val Jones	1948	Drilled	*75	6	N	U	G, S		*15		January 1948.	
16S-27E-4ba1	D. Hollingreen	1948	Dug	*32		C	D			*6		Spring 1948	
10ca1	do		do			C	D						
13da1	Russell		do						5,147	10.5	5,137	May 31, 1928	Do.
26ba1	Cook		do	36	60-24	N	O		5,294.0	16.8	5,277.2	Oct. 23, 1952	
27aa1	Lee Hunter		do	45		J	D, S		5,321.9	22.5	5,299.4	Nov. 7, 1952	
27ba1	Mary Iverson		do	69		J	D, I	G	5,291.6	28.6	5,263.0	do	
27dd1	Lee Hunter	1875	do		72	N	U	G	5,414.2				
(B-13-17) dab1	Lynn School District		Drilled	*180	4	L	D			24.8		Nov. 1, 1955	Artesian well in valley fill.
(B-14-15) 3ddd1	M. A. Smith	1935	Dug	*56	48	L	D			51.9		do	Water-table well in alluvium.
11cc1	do	1905	do	31	48		U			24.2		Oct. 23, 1952	
(B-15-14) 36add1	H. Alberts		do	*10	24		U			4.5		Nov. 1, 1955	

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