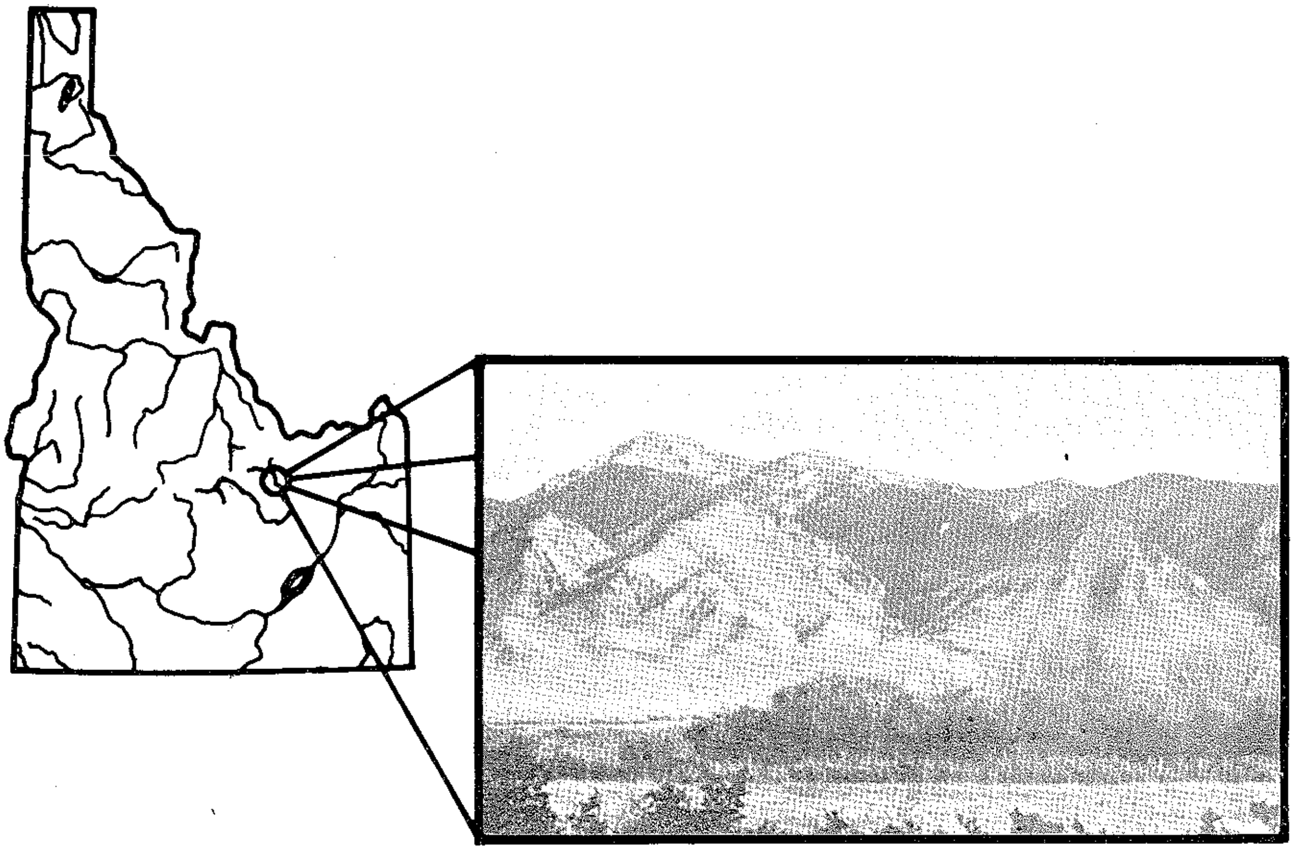
THE AVAILABILITY OF WATER
IN THE
LITTLE LOST RIVER BASIN, IDAHO



IDAHO DEPARTMENT OF WATER RESOURCES

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THE AVAILABILITY OF WATER IN THE LITTLE LOST RIVER BASIN, IDAHO

by

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and

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PREFACE

This report is an extensive revision by the senior author of an open-file report entitled "A Reexamination of Water Yield in the Little Lost River Basin, Idaho" by H. A. Waite and S. O. Decker (1967). In the course of evaluating certain technical criticisms of that report, it became evident that further interpretation of the available data would permit a more thorough appraisal of the water resources of the basin.

The principal new material consists of a discussion of the hydraulic characteristics of the alluvial fill and an estimate of the water yield of 10 small tributary basins for which stream discharge measurements were made periodically through the 1961 and 1962 water years. The latter necessitated making estimates of precipitation-altitude relations, and temperature-altitude relations. A method of estimating evapotranspiration losses proposed by Langbein as a short cut to the Thornthwaite method was applied. Its limitations are recognized, but it can be used with a minimum of climatological information. The effective cutoff date for data used in the report is 1966; however, certain streamflow data and information on irrigated acreage for 1967 are included.

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ABSTRACT

The Little Lost River basin, an elongated, northwest trending structurally formed intermontane valley, drains an area of about 900 square miles into a closed depression near the northwestern edge of the Snake River Plain. Runoff from snowmelt and rainfall on the Lost River Range on the west and the Lemhi Range on the east maintains the flow of the Little Lost River, and recharges the ground-water reservoir. Both mountain ranges are complexly faulted and are underlain by a variety of rocks, dominantly limestone, of Paleozoic age. The principal aquifers are highly transmissive alluvial fill in the middle and upper valley and alluvial fill interfingered with basalt in the southernmost part of the valley.

Precipitation on the basin is the source of virtually all the water resources in the basin, most of which originates high in the mountains. The average annual precipitation is about 8 inches near Howe, and a precipitation-altitude relation, developed from meager rainfall and snowcourse data, indicates that in the mountains above 9,000 feet precipitation is on the order of 40 inches.

Total water yield for the basin (the total precipitation less evaporation and the demand of nonphreatophyte natural vegetation) was estimated by three different methods. The water yield is usable as surface runoff on the valley floor and ground-water underflow beneath the valley floor. Using a method developed by Langbein, a total yield of 424,000 acre-feet per year was derived. Yield estimates independent of precipitation data were made using periodic measurements of discharge where mountain tributaries leave bedrock and enter the alluvial fill, and long-term streamflow measurements. Yield based on this *"perimeter-inflow" method is estimated at 271,000 acre-feet per year. Water yield estimated* by correlation with determinations for the Big Lost River basin immediately to the west is 224,000 acre-feet per year. The intermediate value is considered to be the best value.

Ground water in the basin occurs under water-table conditions and is intimately related to surface flow. Transmissivity values for the alluvial aquifer range from about 150,000 to 1,000,000 gallons per day per foot. The storage coefficient is on the order of 0.15 to 0.2.

An estimated 28,000 acre-feet of surface water, and 40,000 acre-feet of ground water are consumptively used annually for irrigation. Phreatophytes are estimated to use 36,000 acre-feet.

As of 1966, there had been no long-term depletion of ground-water storage. Although water levels in the lower basin declined for several years in the late 1950's and early 1960's, they recovered in 1965 in response to the high runoff of that year, and the infiltration of applied water.

Average outflow from the basin is about 167,000 acre-feet, of which an estimated 157,000 acre-feet is ground water. The total quantity of ground water in storage is on the order of 6.3 million acre-feet.

INTRODUCTION

The Little Lost River drainage basin is one of several basins along the northwest flank of the Snake River Plain (fig. 2). These basins are important contributors of water to the Snake Plain aquifer and are important segments of a State economy based largely on irrigated agriculture. For many years, the irrigators within the basin were dependent almost entirely on diversions of surface flow in Little Lost River and its major tributaries. Since about 1954, however, this diversion supply has been supplemented by an increasing amount of ground water pumped from wells.

In recognition of the need for evaluating the water resource of the basin as an integrated water system, the Idaho Department of Reclamation (now the Idaho Department of Water Resources) joined with the U. S. Geological Survey in the fall of 1959 in a preliminary study. The data available at that time to identify and define the various elements of the resource and its distribution and use were very meager. As a consequence, the study was necessarily confined to the development of estimates based on short-term records, a small amount of field investigation, generalized definition of geologic and hydrologic conditions, correlation procedures, and a large measure of professional judgment. The results of the study were described in Mundorff, Broom, and Kilburn, 1963.

Because of the importance of the basin in the water-resource economy of the State and because many of the estimates used in the preliminary report were tentative, additional data that would permit strengthening these estimates were required. Consequently, in 1960 the Geological Survey, in cooperation with the Idaho Department of Reclamation, began the collection of specific information with which to reexamine the earlier interpretations.

The objectives of this later phase of study were stated initially as follows: "To determine the relation between surface water and ground water in the basin, the total water yield of the basin, the hydraulic characteristics of the aquifer, and the amount of water within the basin."

This report utilizes data collected during 1959-66 to further define and strengthen knowledge of the water resources of the Little Lost River basin. However, for reasons that will be brought out more fully in the text, the stated objectives of the study cannot yet be attained with the data available. Complete and reasonably accurate answers to the broad questions implied by the objectives can be obtained only at high cost. For example, none of the existing wells penetrate the complete section of fill, and the total outflow from the basin cannot be estimated with confidence without knowing the depth and configuration of the base of the alluvial fill; nor can the total quantity of water in storage be determined without data from deep test drilling and geophysical exploration.

The information obtained since 1959 provides a better record of climatic conditions, water supply, and water use, which permits some refinement of previous estimates of these and other factors. In this report, which describes these refinements, an independent estimate of the amount of water derived from the mountainous periphery of the basin is developed, and the new information is applied in estimating a new water budget for the basin.

As a part of the field investigation for this report, one new continuous-record streamflow station was established, 10 major tributaries were measured every 5 or 6 weeks at one station each during two complete water years, wells constructed since 1959 were inventoried, water-level measurements were made in key observation wells, and data on power consumption for irrigation wells were obtained for the 1959-66 period.

The analysis of new information consisted of the following principal steps:

1. Periodic streamflow measurements were used, in conjunction with the data from continuous-record stations, to estimate annual discharges for water years 1961 and 1962 for the 10 tributary basins, which were then used to estimate a long-term average annual discharge.

2. Rainfall and snowcourse data on stations in and near the Little Lost River basin were used to develop a precipitation-altitude relation and to estimate the average annual precipitation based on the mean altitude of each tributary basin.

3. The geologic literature was reviewed to determine whether differences in geologic conditions in the 10 measured drainage basins would help to explain the differences in unit runoff.

4. An estimate of the total water yield was made, using the method developed by Langbein in Nace and others (1961), by summing the yield of the tributary basins, the intervening ungaged bedrock areas, and the valley-floor areas.

5. The runoff from the 10 tributary basins was used as a basis for computing yield by a "perimeter-inflow" method, similar to the method used by Mundorff and others (1963).

6. The hydraulic characteristics of the alluvial fill were reestimated, using as a basis aquifer-test data and interpretations made by E. H. Walker of the Geological Survey (written commun., 1963).

7. Ground-water pumpage, surface-water diversions, and consumptive-use factors, in conjunction with the yield estimates referred to above, formed the basis for a revised water budget of the basin.

Numbering of Stream-Gaging Stations

The stream-gaging stations from which data for this report were obtained are identified by numbers prefaced by the letter LL (Little Lost). The numbers are the same as those used by Mundorff and others (1963) and were retained to provide continuity of reference. However, because not all stations of that report were used, they are not in numerical sequence downstream as is the conventional practice.

The numbering system used for this investigation and the assigned numbers currently used by the Geological Survey are tabulated below:

LL	3A	Main Fork	13117200
	6	Sawmill Creek near Goldburg	*13117300
	7	Warm Creek	13117310
	14	Bell Mountain Creek	13117365
	16	Dry Creek	13117600
	22	Wet Creek	13118400
	27A	Little Lost River below Wet Creek, near Howe	*13118700
	29	Deer Creek	13118810
	31	Badger Creek	13118830
	35	Uncle Ike Creek	13118920
	36	North Creek	13118930
	39A	Little Lost River near Howe	*13119000
	41	South Creek	13119550

* Continuous-record station.

On most illustrations and in the text, the prefix, LL, has been omitted.

Well-Numbering System

The well-numbering system used by the Geological Survey in Idaho indicates the location of wells within the official rectangular subdivision 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, respectively. Quarter sections are lettered a, b, c, and d in counterclockwise order from the northeast quarter of each section (fig. 1). Within the quarter sections, 40-acre tracts are lettered in the same manner. Well 6N-29E-8bc1 is in the SWSW sec. 8, T. 6 N., R. 29 E., and was the first well inventoried in that tract.

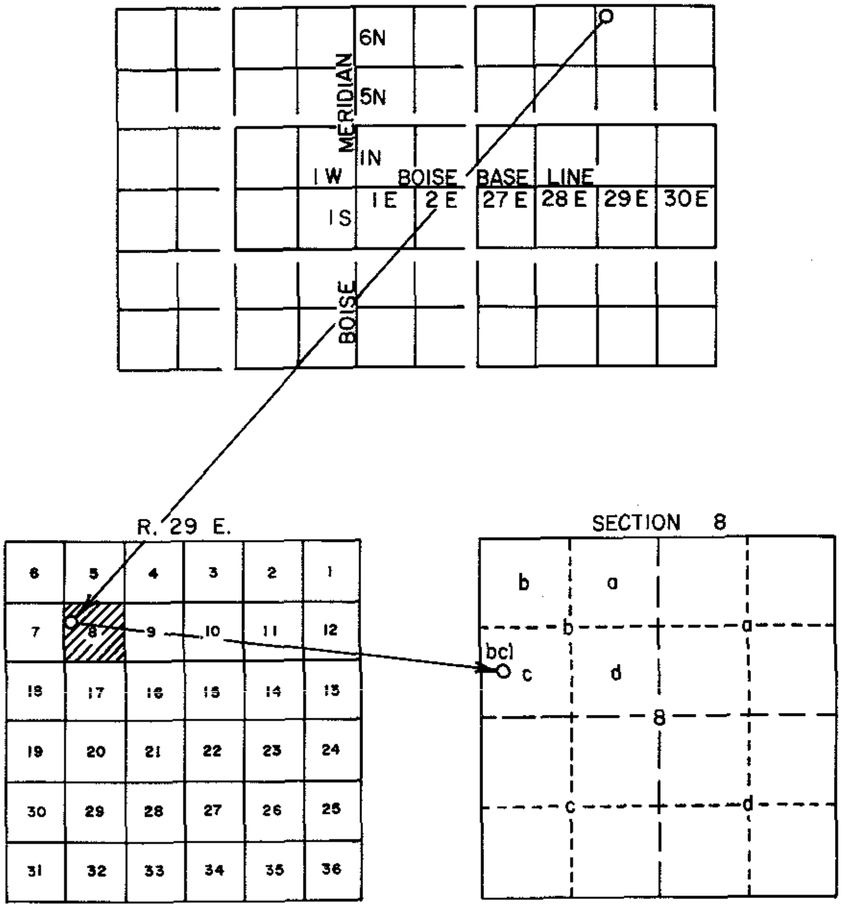


FIGURE 1. **Diagram showing well-numbering system. (Using well 6N-29E-8bc1)**

Acknowledgments

The cooperation of well owners in furnishing data and allowing measurements of water level in wells, and of the Utah Power and Light Company in furnishing power-consumption data is gratefully acknowledged. The assistance of R. L. Whitehead in measuring drainage areas, computing mean altitudes, and tabulation of other data facilitated the hydrologic interpretations. Technical review by E. H. Walker and W. L. Burnham was very helpful and is sincerely appreciated.

PHYSICAL SETTING

The Little Lost River basin is an elongated, structurally formed, drainage basin tributary to the northwest flank of the Snake River Plain. The channel leads to an undrained depression known as the Lost River sinks, but only in years of high runoff does flow reach the sinks. Although a part of the Snake River drainage basin, there is no overland flow to the Snake River. All the water of the Little Lost River basin is either consumptively used within the basin or moves as ground-water underflow into the Snake Plain aquifer.

Topography and Drainage

The topographic features and the distribution of the principal surface-water drainage channels are shown in figure 2. The Little Lost River is formed by the confluence of Sawmill and Summit Creeks near the northwest end of the valley and flows southeast between the very steep Lemhi Range rising to more than 10,000 feet on the east and the equally high but less steep Lost River Range on the west. The tributary drainages from the Lemhi Range are short and steep, while those from the west side, especially in the northern part of the basin, are much longer, less steep, and drain large areas of high mountains. These conditions, combined with wide variations in precipitation patterns, influence the distribution of runoff, both in time and space.

The basin is roughly rectangular, about 50 miles long and 15 to 25 miles wide, and encloses slightly more than 900 square miles of drainage area. This drainage area does not include the Lost River sinks; for the purpose of this study, the lower limit of the basin is defined, somewhat arbitrarily, as a line from the town of Howe to the southernmost tip of the Lemhi Range (fig. 2).

The alluviated valley floor, which extends nearly the entire length of the basin, ranges from about 5 to 8 miles in width, and is as wide at the head of the valley as at the mouth. Large masses of bedrock jut into the valley floor from both east and west sides.

The main part of the Lost River Range is separated from the Donkey Hills and Hawley Mountains by re-entrant alluviated valleys. Thus, the west side of the Little Lost valley floor is much more irregularly shaped than the east side.

Large alluvial fans have developed where some streams discharge from the mountains onto the valley floor; this is especially true in the lower and middle reaches of the valley. The fans built by Dry Creek, Badger Creek, Uncle Ike Creek, and Cabin Fork Creek are especially prominent. In the upper part of the valley alluvial fans are less impressive; for example, Sawmill Creek and others draining the northeastern part of the basin have not formed distinctive alluvial fans. The reasons for this distribution of alluvial fans are complex and numerous.

For the hydrologic analysis, the drainage basin has been subdivided into three reaches -- upper, middle, and lower -- by the two principal gaging stations LL27A, Little Lost River below Wet Creek near Howe and LL39A, Little Lost River near Howe. The drainage divides from the crest of the Lemhi and Lost River Ranges to those gaging stations are shown in figure 2.

Geologic Features

This brief description of geologic features is based largely on a review of published geologic studies by others. A principal source of information was the work of C. P. Ross and his coworkers (Ross, 1947 and 1961; Ross and Forrester, 1947 and 1958). The work of Mapel and others, 1965, and an unpublished map of the Hawley Mountain quadrangle, kindly provided by Mapel, also were useful.

Stratified, consolidated, folded and faulted, and highly jointed sedimentary rocks and volcanic rocks make up the mountains and hills surrounding the basin and form the bedrock lying beneath the basin. Alluvial boulders, gravel, sand, and silt eroded from these older rocks fill the valley trough to unknown depths. This fill is coarser and less well sorted in the extensive alluvial fans along the valley margins than along the valley bottom where major through-flowing streams reworked the materials during their accumulation. East and southeast of Howe, some of the basalt flows of the Snake Plain spread northwestward into the valley mouth and are interlayered with these sediments (fig. 3). Walker (1964) interpreted the thick sequence of clay and silt beneath the lower parts of the Little Lost and other tributary valleys on the north side of the Snake River Plain as lake deposits formed where lava flows dammed the tributary valleys. Consequently, south of T. 7 N., the alluvial fill is better stratified, finer textured, and more horizontally bedded than is generally true in the northern part of the valley.

Geologic structure and the physical characteristics of porosity and permeability control the effectiveness of hydraulic gradients in moving water from these mountainous areas of recharge out into the alluvial deposits of the valley.

The structural details of the bedrock that bounds and underlies the valley are largely unknown, but in gross aspects the Lemhi and Lost River Ranges are individual blocks that are each separately tilted northeastward. In general, the west side of the Little Lost River valley is formed by the sloping upper surface of the Lost River Range block, while the east side of the valley is the uplifted edge of the Lemhi Range block. The rocks of each of the blocks are also extensively folded and faulted. One of the more important structural complexities is that which forms the low bedrock ridge that constricts the valley in T. 7 N.

Limestone occupies much of the high parts of both the Lemhi and Lost River Ranges. In the northeastern part of the basin, and at lower altitudes along the western slopes of the Lemhi Range, quartzite and argillaceous rocks are fairly common. In the northern part of the basin and in the lower flanks of the Lost River Range, particularly in the Red Hills and the area drained by Wet Creek and Dry Creek, volcanic rocks are common.

Because so much of the available water in the basin (both surface runoff and ground water) originates as precipitation in the high mountains, the way in which the rocks influence the flow of water into the alluvial fill of the valley is highly important. In areas underlain by relatively impermeable rock types such as quartzite, argillaceous rocks, or siliceous volcanic rocks, runoff leaves the mountains largely as surface flow. In areas underlain by limestone, which may transmit significant quantities of water through solution openings along joints or bedding planes, more of the runoff probably discharges as ground water.

Although detailed observations of the hydrologic characteristics of bedrock units have not been made, either in previous studies or as a part of this one, several investigators refer to features that indicate high permeability in some of the bedrock units. For example, Anderson (1948, p. 5) refers to "... talus slides, cavernous limestones, and the brecciated quartzites along the fault zones ..." as water-storage reservoirs in his discussion of perennial flow in Uncle Ike Creek, North Creek, and South Creek.

Climate

The climate of the basin is characteristic of that of intermontane basins in the northwest: warm and dry in the summer, cold in winter, with precipitation mostly as snow. Rainfall is greatest in early summer, particularly in May and June.

Average monthly and yearly precipitation and temperatures at stations in and near the basin through 1966 are given in table 1.

Mean snowfall and water content of snow at five snowcourses in the mountains on both sides of the basin are given for the years 1957-66 in table 2 to indicate precipitation at higher altitudes in the basin. Note that the mean is for the particular date of measurement. The measurements do not indicate the seasonal totals. Note that the maximum commonly occurs in March at the two lower stations and in April at the three higher stations.

Precipitation-Altitude Relations

The only long-term records of precipitation in the vicinity of the Little Lost River basin are for stations at altitudes below about 6,000 feet. To estimate the precipitation at higher altitudes, where most of the runoff originates, a method outlined by Dawdy and Langbein (1960) was used. Using data from 10 stations in and near the Camas Creek basin in south-central Idaho for which both water content of snow and total annual precipitation were available, they developed a relation between mean annual precipitation and mean annual maximum water content of snow. For this report, the snowcourse data listed in table 2 were used to determine the slope of the precipitation-altitude curve (fig. 4) and the results of the analysis by Dawdy and Langbein served to fix the position of the curve for altitudes higher than 6,000 feet. An increase in precipitation of 8 inches per 1,000 feet is indicated. The slope of the curve would have been slightly different if the March measurements for the stations at the lower altitudes had been given greater weight. However, as drawn, the curve gives greater weight to the data from higher altitudes because they were felt to be more typical of the altitudes above 7,600 feet, the upper limit of the snowcourses. Figure 4 also shows the relation of precipitation to altitude for five stations with long records in and near the Little Lost River basin (Environmental Science Services Admin., 1966, and Yanskey and others, 1966). The principal assumptions made in constructing figure 4 are that the precipitation-altitude relation is the same for winter precipitation as for summer rainfall, and that the spring measurements of snow depths can serve as an index of total precipitation

TABLE 1

AVERAGE MONTHLY AND YEARLY PRECIPITATION, IN INCHES, AND MEAN MONTHLY AND YEARLY TEMPERATURE, IN DEGREES FAHRENHEIT, AT STATIONS IN AND NEAR THE LITTLE LOST RIVER BASIN, IDAHO, THROUGH 1966.

(From records of the Environmental Science Service Administration, formerly U. S. Weather Bureau.)

Precipitation

Station and Altitude, in Feet	Years of Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average Annual
Howe, 4,820	31	0.63	0.51	0.46	0.70	0.99	1.27	0.42	0.76	0.53	0.51	0.46	0.66	7.91
Arco, 5,300	60	.90	.66	.71	.70	1.24	1.18	.51	.54	.59	.61	.60	.95	9.19
Mackay Ranger Station, 5,897	59	.83	.69	.67	.63	1.14	1.30	.84	.83	.81	.63	.53	.78	9.68

Temperature

Station	Years of Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean Annual
Arco	50	14.9	20.6	30.6	42.9	51.8	58.0	66.8	64.9	55.2	45.1	31.1	19.9	41.9
Mackay Ranger Station	56	16.4	21.1	29.8	41.4	49.2	57.2	65.8	64.5	56.0	44.9	31.7	20.3	41.4

for the season.

TABLE 2

SUMMARY OF MEAN SNOWFALL AND WATER CONTENT OF SNOW IN INCHES, AT STATIONS IN THE LITTLE LOST RIVER BASIN, IDAHO, 1957-66.

(From records of U. S. Soil Conservation Service)

Station	Jan. 1		Feb. 1		Mar. 1		Apr. 1	
	Snow Depth	Water Content	Snow Depth	Water Content	Snow Depth	Water Content	Snow Depth	Water Content
1........	10.3	1.7	16.1	3.4	17.8	4.1	10.7	3.4
2........	8.9	1.6	13.5	2.8	14.4	3.4	8.3	2.5
3........	19	4	29.5	7.1	33.3	8.9	34	9.7
4........	17.1	3.6	24.9	6	27.7	7	24.8	7.3
5......	16.5	3.5	26.1	6.6	32.8	9	36.2	10.9

1. Fairview guard station, sec. 27 (revised), T. 12 N., R. 26 E., alt. 6,750 ft. (revised).
2. Lost-Garfield course, sec. 3, T. 11 N. (revised), R. 26 E., alt. 6,600 ft. (revised).
3. Moonshine course, sec. 31, T. 13 N., R. 26 E., alt. 7,450 ft. (revised).
4. Sawmill Canyon, sec. 17, T. 12 N., R. 26 E., alt. 6,900 ft. (revised).
5. Wet Creek Summit, sec. 15, T. 8 N., R. 25 E., alt. 7,600 ft. (revised).

The precipitation-altitude relation might be refined through consideration of exposure, orographic effects, and other climatological and environmental factors. Further refinement is unwarranted on the basis of the available field measurements of precipitation and other limitations of the hydrologic analysis. Some of the possible variations may be discussed qualitatively, however, and illustrate to a degree the complexity of precipitation patterns in the basin.

The winter storms that account for a substantial fraction of the yearly precipitation move generally from west to east. Therefore, the east slope of the Lost River Range would be expected to have lower annual precipitation than some other parts of the basin, as it lies in the rain shadow of mountains to the west. This should be particularly true of the area just east of Borah Peak and Leatherman Peak, in the central part of the range. (Borah Peak is about 10 miles northwest of Leatherman Peak, shown in fig. 2).

The snowcourse measurements are not distributed evenly around the basin perimeter, but, except for one station, are concentrated in the northern part of the area. Confidence in the results of these measurements would be increased by a more even geographic distribution of the data points.

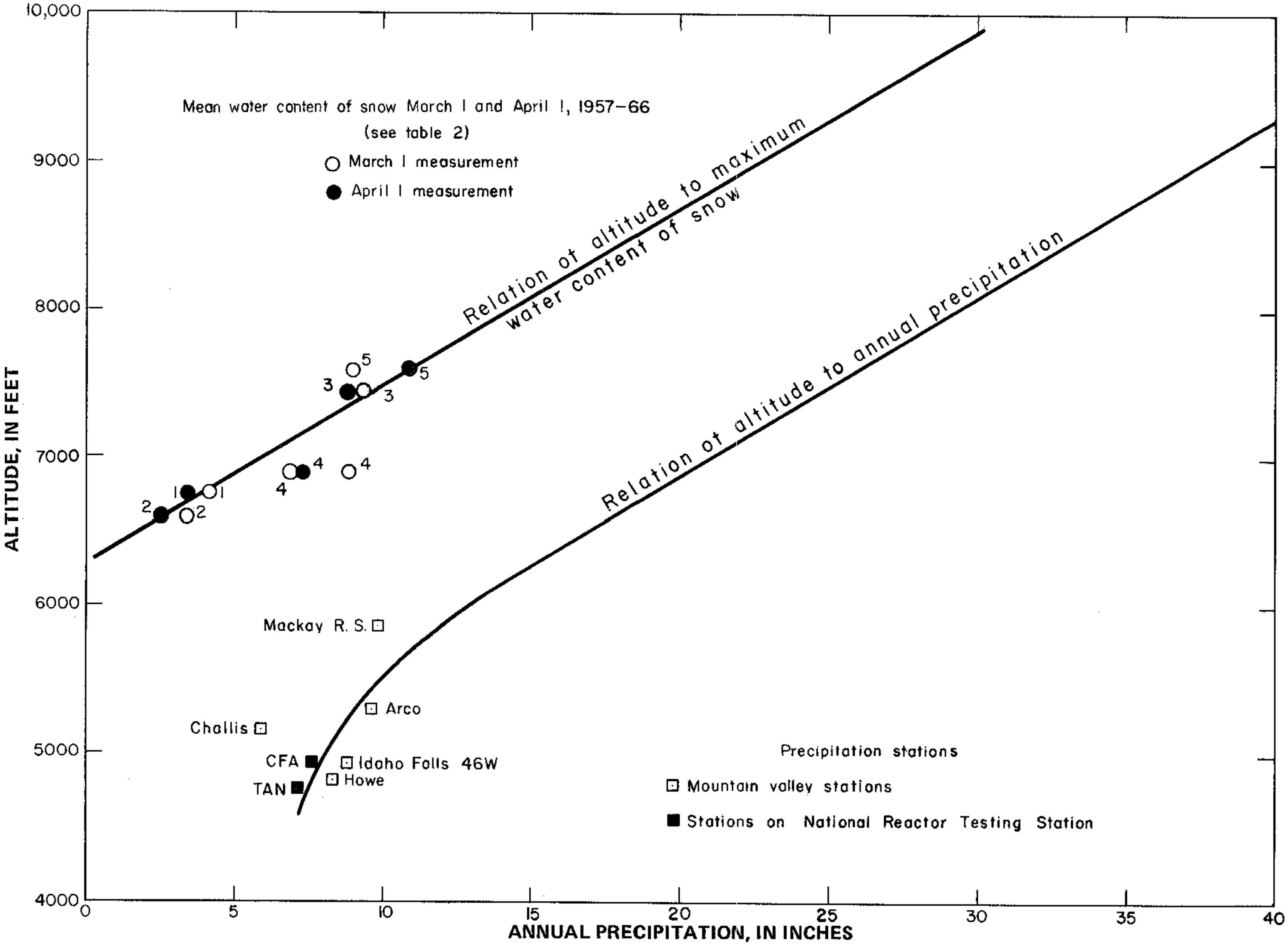


FIGURE 4. Estimated precipitation-altitude relations for the Little Lost River basin.

The mean altitude of the basin, determined by averaging the altitude of grid intersections on a contour map, is 7,140 feet above sea level. Application of the precipitation-altitude curve in figure 4 to the Little Lost River basin indicates that the mean annual precipitation is about 22.6 inches. In the mountains higher than 7,140 feet, the climate would, therefore, be classified as subhumid, and it is in that zone that most of the water yield originates.

The value of 22.6 inches for mean annual precipitation is 50 percent (7.5 inches) higher than previous estimates and could possibly be in error by that amount. However, the slope of the precipitation-altitude curve agrees well with the slope of similar curves developed by Crosthwaite and others (1970) for the Big Lost River basin immediately to the west, where many more data were available.

The length of the frost-free period in the basin, which generally determines the length of the growing season and the period during which irrigation may be required, is considered to be from about 95 to 105 days. During the growing season about 2.5 inches of rain falls in the Howe area and about 3 inches falls on the valley floor in the upper valley area.

Temperature and Evapotranspiration

Any analysis of the hydrologic cycle that attempts to estimate the quantities of water available for use, whether as surface flow or as ground water in transient storage, must measure or estimate the quantities that are returned to the atmosphere as water vapor. Neither evaporation nor evapotranspiration measurements are available for the Little Lost River basin. This fact, combined with the absence of data on temperature and wind, makes it necessary to apply estimating procedures that are based on correlation with data from other areas.

Temperature records from within the Little Lost River basin are virtually nonexistent. Long-term records for stations near the basin have, therefore, been used in conjunction with regionalized temperature data for southern Idaho to develop a temperature-altitude relation. See figure 5, which was adapted from Langbein in Nace and others (1961).

The method presented by Langbein for estimating evapotranspiration is a shortcut approach to the Thornthwaite (1948) method. Langbein determined that mean annual temperature is related to potential evapotranspiration as shown in figure 6. Although the original work on which the graph was based (Williams and others, 1940, and Langbein and others, 1949) applied to drainage basins in the humid parts of the eastern United States, Langbein showed that the Thornthwaite method and the shortcut method, both of which were applied to stations in the Raft River basin of southern Idaho, agreed rather well. For those stations, the mean annual temperature is in the upper forties and the annual precipitation ranges from 10 to 14 inches.

Estimating actual evapotranspiration by the Thornthwaite or Langbein methods involves the assumption that evapotranspiration can be approximated by an estimate of potential evapotranspiration. This is not likely to be true in arid climates; for example, in

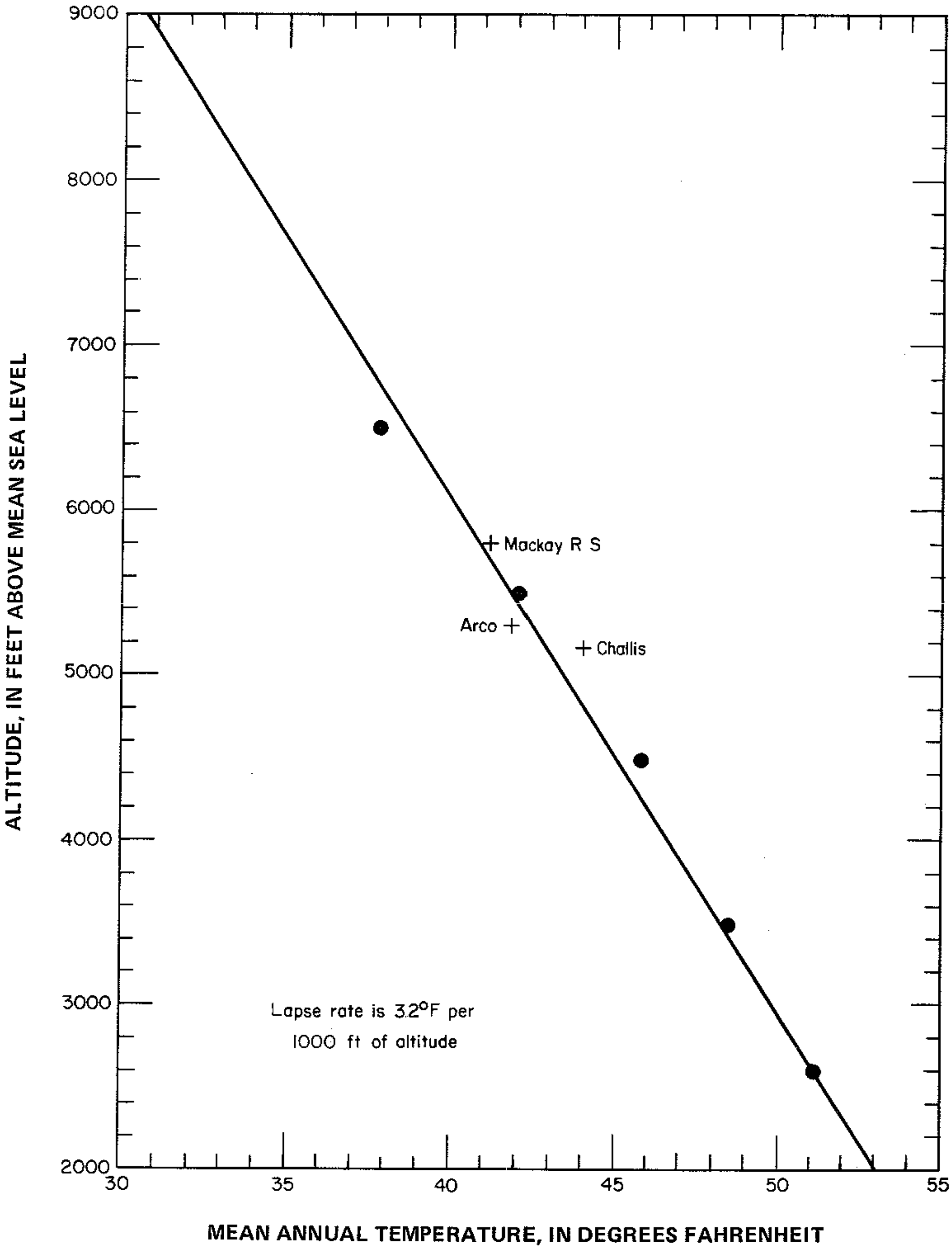


FIGURE 5. Relation between temperature and altitude for southern Idaho.

Solid circles represent averages for groups of stations in 1,000-foot altitude zones in southern Idaho. Crosses represent single stations near the Little Lost River basin.

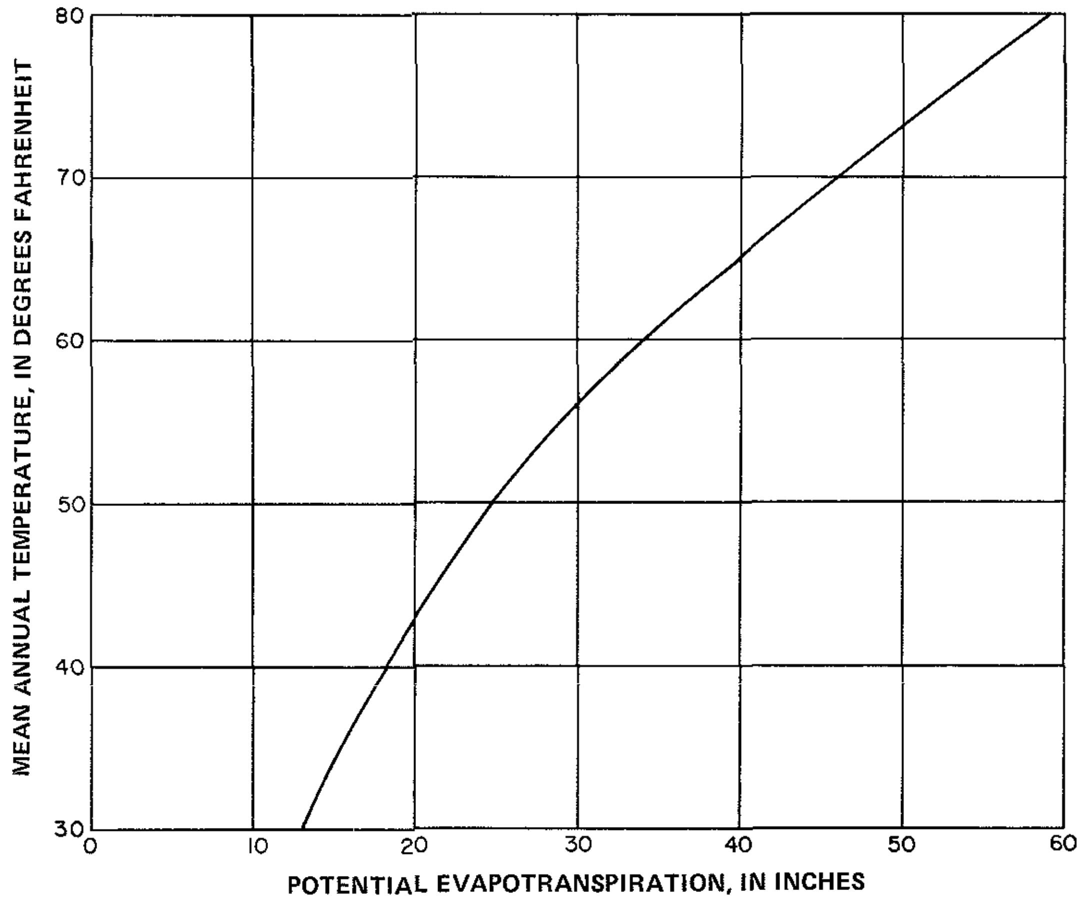


FIGURE 6. Relation between mean annual temperature and potential evapotranspiration in North America. (After Langbein, in Nace and others, 1961.)

hot, dry summers, when precipitation is characterized by shower activity, there may be long periods between showers when moisture is not available. Under such conditions, the potential evapotranspiration would greatly exceed actual evapotranspiration.

In view of the relatively high estimated average annual precipitation for the areas that contribute most of the water yield of the Little Lost River basin, the discrepancy between potential evapotranspiration and actual evapotranspiration may not be excessive.

WATER SUPPLY

The water supply of the basin is the total quantity of water available from any source. Virtually the entire water supply comes from precipitation on the drainage basin. There is only one minor diversion of water into the basin, which enters Summit Creek at the northwest end of the basin and averages about 300 acre-feet per year. It has been assumed that there is no interbasin underground flow into or out of the basin; thus, for the purpose of calculating a water budget, the ground-water divide bounding the basin is assumed to lie directly beneath the surface-drainage divide. The total quantity of water available is drawn upon by evaporation and by transpiration from native vegetation throughout the basin, by crops on irrigated land, and by the domestic and other requirements of the people within the basin. The residual after these demands are met leaves the basin by surface flow or by ground-water underflow.

The water yield of a basin, or the manageable part of the water supply, is the precipitation plus imports minus the water consumptively used by nonphreatophyte natural vegetation. The yield, minus consumptive use, principally irrigation gives the quantity leaving the basin by combined surface flow and ground-water underflow.

For this study, the water yield has been developed in such a way that it is not applicable on a unit area basis. It may be determined for a major subbasin where it is convenient to account for the total flow of water -- by measurement of streamflow and estimation of ground-water underflow. Gaging-station sites have been used, although they are not necessarily located at the best place for estimating ground-water underflow.

For the purpose of accounting for the water available in the Little Lost basin, the valley is divided into three segments, separated by the two principal gaging stations on the main stem of the river, the one near Howe (13119000) and the one below Wet Creek (13118700).

Three methods have been used to estimate the water yield of the basin and of a number of subbasins. The first is a modification of the method proposed by Langbein in Nace and others (1961). The second utilizes streamflow measurements on tributary streams, most of which were made as nearly as possible at the point where the stream channel crossed from bedrock to the alluvial fill of the main valley. For the third estimate, water-yield data for the Big Lost River basin were plotted as a function of altitude, and the correlation was used to estimate water yield in the tributary areas and subbasins of the Little Lost River basin. This method is not dependent on the precipitation-altitude relation described previously.

The Langbein method will be described first, as it relies only on precipitation and other climatological parameters that have been discussed previously. The "perimeter-inflow" method will be described following presentation of the streamflow data.

Water Yield by the Method of Langbein

Langbein computed precipitation, potential water loss, and water yield for the Raft River basin by altitude zone (Nace and others, 1961, table 9). For this study, it was desirable to make the computations for the principal tributary drainage basins within the Little Lost River basin, as well as for the drainage areas between principal tributaries and for the valley floor. It was also convenient to use the drainage divides that separate the principal segments of the basin.

The explanation of the Langbein method, comparison with the Thornthwaite method, and the justification for the use of such methods are discussed by Langbein in the cited report and are equally applicable to this area.

Estimates of the water yield for the tributary inflow basins, intervening bedrock areas, and valley-floor areas shown in figure 2 were made using the relation of two ratios, precipitation to potential evapotranspiration (P/L) and water yield to potential evapotranspiration (R/L), shown in figure 7. The estimates of precipitation for each subbasin are based on a determination of mean altitude made by overlaying a grid on a contour map of the subbasin and averaging the altitude of all grid points that fall within the subbasin. Mean altitude was then used to estimate mean precipitation over the subbasin (fig. 4) and its mean annual temperature (fig. 5). Potential evapotranspiration was then estimated from the relation of mean annual temperature to potential evapotranspiration (fig. 6). The ratio of precipitation to potential evapotranspiration was then computed, entered into figure 7, and used to estimate the ratio of water yield to potential evapotranspiration. The water yield of the subbasin was then calculated.

A plot of water yield against precipitation for subbasins was then used to define a curve of relation (curve A, fig. 8), from which the "adjusted yield" was derived, shown in column 7 of table 3. The yield of each subbasin was then converted to acre-feet for use in the water budget for the basin, to be discussed later. Although the true relation of precipitation to water yield is curvilinear, curve A of figure 8 has been drawn as a straight line. The scatter of points, introduced by errors in estimating P, R, and L graphically, does not warrant fitting a nonlinear curve.

The total yield of 424,000 acre-feet is equivalent to an average yield of 8.7 inches over the entire basin. Note that this is higher than the figure that would be obtained by entering the mean precipitation to curve A of figure 8. The method of summing the yield of tributary subbasins allows that water yield to be accumulated in parts of the basin with lower precipitation.

The value of water yield is more than twice the highest value estimated by Mundorff and others. The difference may be due largely to the different precipitation-altitude relation used herein. It is also much higher than the yield estimated by other methods used in the present study.

Until better precipitation data are available for the Little Lost River basin, the total yield of 424,000 acre-feet (table 3) probably should be considered as an upper limit.

Surface Water

Summit and Sawmill Creeks, the principal tributary streams of the river system, join near the northwest end of the basin to form Little Lost River. Most of the combined flow of Sawmill Creek and Warm Creek (a principal tributary from the east side of the basin) is diverted to a fairly well-sealed channel that empties into Summit Creek just above the natural confluence of the two streams. This was done to reduce infiltration to ground water

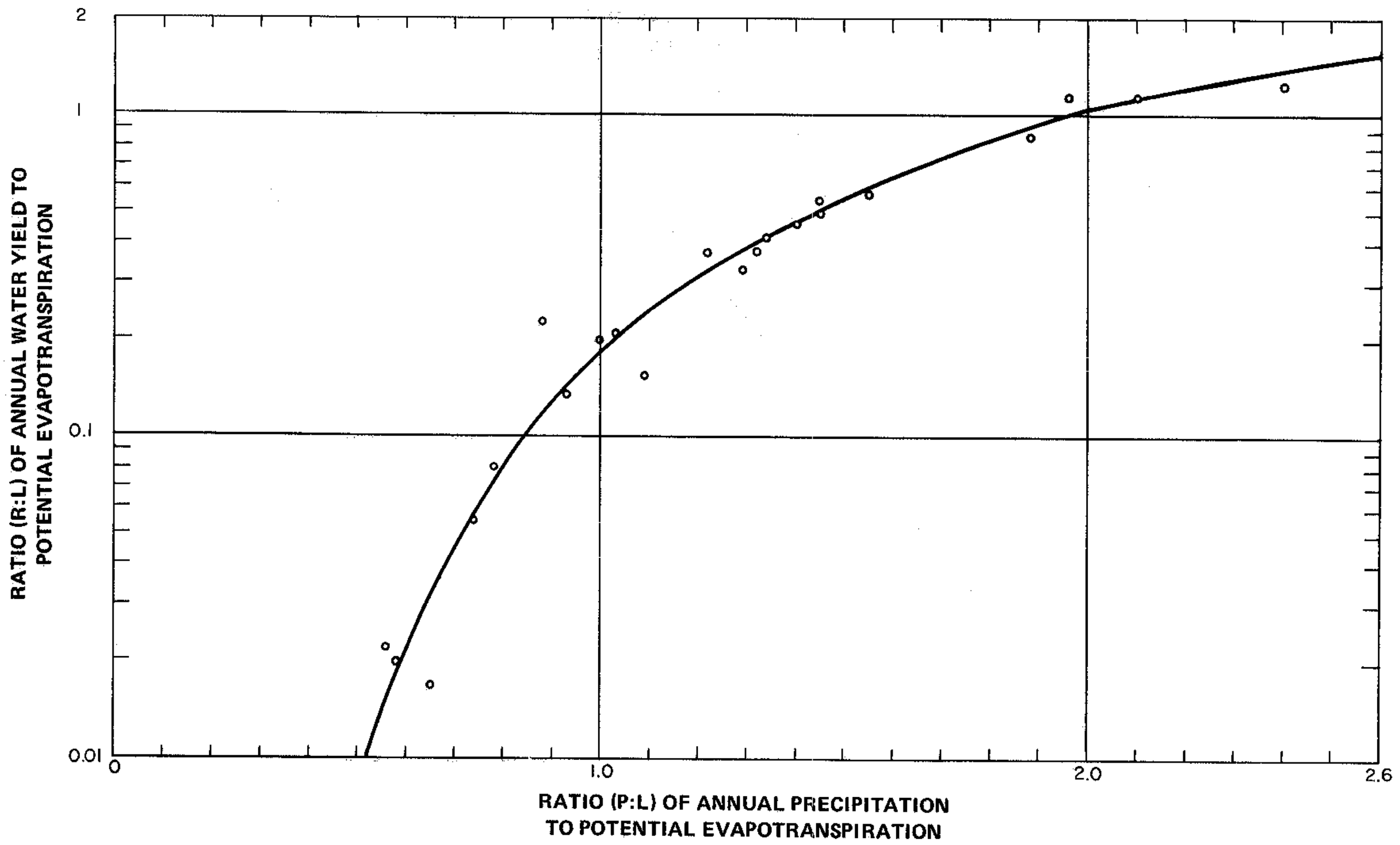


FIGURE 7. Relation of annual water yield to preciptation and potential evapotranspiration in representative river basins in North America. Curve is based on data in Nace and others, 1961, table 10.

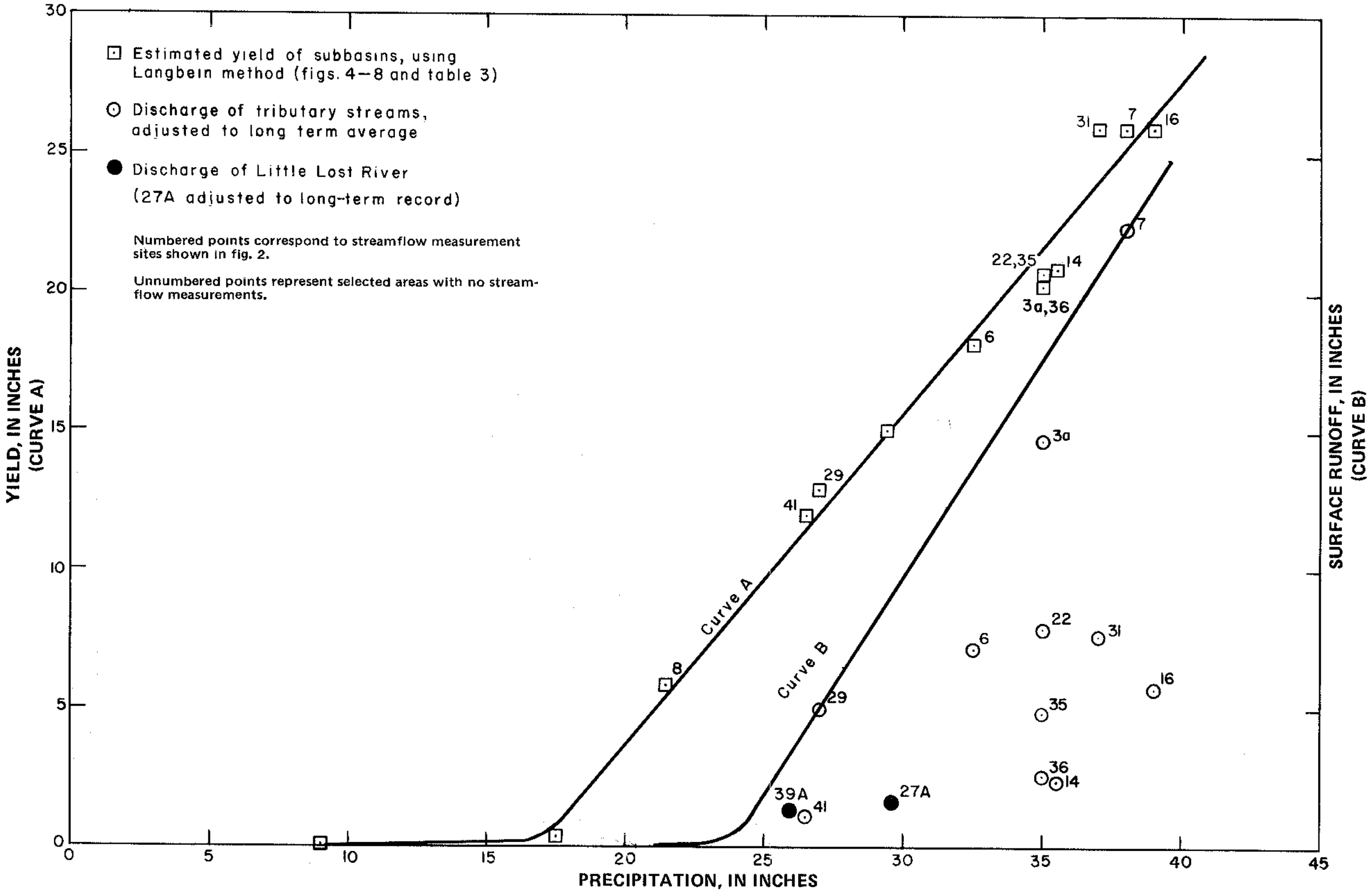


FIGURE 8. Relation of estimated precipitation to water yield and to surface runoff from measured tributaries, Little Lost River basin, Idaho.

TABLE 3

SUBBASIN TOPOGRAPHIC AND CLIMATIC FEATURES FOR ESTIMATING WATER YIELD

Tributary Basin or Subbasin*	Ungaged Bedrock Area	Mean Altitude (feet) (1)	Precipitation (P) (2)	Temperature (°F) (3)	Potential Evapotranspiration (L) (4)	P/L (5)	R/L (6)	Adjusted Yield** (R) (inches) (7)	Area (acres) (8)	Adjusted Yield** (acre-feet) (9)
Upper Valley										
Main Fork (3a)		8,700	35.0	31.5	13.5	2.59	1.5	21.5	9,980	*** 17,764
Sawmill Creek (6)		8,360	32.5	33.0	14.0	2.32	1.3	18.5	47,600	73,304
	1W	7,820	27.8	34.5	15.0	1.85	.87	12.7	11,264	11,827
	2W	7,750	27.3	35.0	15.5	1.76	.80	12.4	19,456	20,340
	3W	7,330	23.8	36.0	16.0	1.48	.52	7.7	5,312	3,400
Dry Creek (16)		9,160	39.0	30.2	13.0	3.00	2.0	27.0	27,000	60,480
	4W	8,340	32.0	32.5	14.0	2.28	1.2	18.0	16,516	24,609
Wet Creek (22)		8,680	35.0	31.8	13.5	2.59	1.3	21.5	7,170	12,763
	5W	7,740	27.2	34.5	15.0	1.81	.85	12.2	17,792	17,970
	1E	8,000	29.4	34.0	15.0	1.96	1.0	14.8	640	787
Warm Creek (7)		9,030	38.0	30.5	13.0	2.92	2.0	25.2	2,350	4,912
	2E	8,430	32.8	32.5	14.0	2.34	1.3	19.0	9,436	15,067
Bell Mountain Creek (14)		8,770	35.5	31.5	13.5	2.62	1.55	22.2	3,450	6,348
	3E	8,660	34.8	32.0	13.5	2.57	1.5	21.5	12,280	21,873
Valley Floor		6,570	17.5	38.5	17.5	1.00	.19	.33	100,480	3,014
Subtotal										276,694
Middle Valley										
	6W	7,150	22.4	36.5	15.0	1.49	.54	7.0	10,560	6,125
Deer Creek (29)		7,720	27.0	34.8	15.0	1.80	.85	12.0	4,610	4,610
	7W	7,530	25.5	35.5	15.5	1.64	.68	10.3	22,336	18,986

TABLE 3 (Continued)

SUBBASIN TOPOGRAPHIC AND CLIMATIC FEATURES FOR ESTIMATING WATER YIELD

Tributary Basin or Subbasin*	Ungaged Bedrock Area	Mean Altitude (feet) (1)	Precipitation (P) (2)	Temperature (°F) (3)	Potential Evapotranspiration (L) (4)	P/L (5)	R/L (6)	Adjusted Yield** (R) (inches) (7)	Area (acres) (8)	Adjusted Yield** (acre-feet) (9)
Middle Valley (Cont'd.)										
	4E	7,860	28.2	34.0	15.0	1.88	.91	13.3	6,784	7,462
Badger Creek (31)		8,950	37.0	30.8	13.0	2.84	2.0	24.0	9,730	19,460
	5E	8,310	31.9	33.0	14.5	2.20	1.3	17.4	9,088	13,087
Uncle Ike Creek (35)		8,680	35.0	31.8	13.5	2.59	1.53	21.5	4,760	8,473
	6E	8,840	36.2	31.0	13.0	2.78	1.6	23.0	4,096	7,823
North Creek (36)		8,640	35.0	32.0	14.0	2.50	1.45	21.5	4,100	7,298
	7E	7,440	24.8	35.5	15.5	1.60	.64	9.4	7,232	5,641
Valley Floor		5,820	11.8	41.0	18.5	.63	.025	.016	88,960	890
Subtotal										99,855
Lower Valley										
	8W	7,490	25.2	35.5	15.5	1.62	.65	9.8	44,032	35,666
South Creek (41)		7,630	26.5	35.0	15.0	1.76	.8	11.4	6,210	5,900
	8E	7,030	21.4	37.0	17.0	1.25	.35	5.3	13,568	5,970
Valley Floor		5,250	9.0	42.5	19.0	.47	<.01	<.002	65,920	0
Subtotal										47,536
Total										424,085

* See figure 2.

** Adjusted to curve A.

*** Not included in total yield; tributary to Sawmill Creek (6).

near the head of the basin, and to maintain larger streamflow in the upper part of the river. Other major tributaries to the river are Dry and Wet Creeks, which enter from the west at about T. 10 N. Dry Creek is similarly diverted into Wet Creek, which is a perennial stream emptying into the river. Part of this combined flow is diverted for irrigation locally.

A few minor tributaries occasionally discharge surface flow to the river, but generally all tributaries lose all their flow to their alluvial fans before reaching the river. Some water from these streams is diverted through pipelines for irrigation.

Station Records

The principal stream-gaging station on the Little Lost River is station LL39A, Little Lost River near Howe (fig. 2). This station has been in operation since 1921, but records are complete only since 1940. A second station, LL27A, Little Lost River below Wet Creek, near Howe, was installed in January 1958. Both these stations are located where the river is flowing on alluvial fill and do not measure the ground-water underflow. Details of these stations and their records are given in Mundorff and others, 1963, and in annual reports of streamflow published by the U. S. Geological Survey. A third continuous-record station was established as a part of the present study in the fall of 1960 at the mouth of the canyon of Sawmill Creek. This station is designated LL6, Sawmill Creek near Goldburg. The annual mean discharge at these continuous-record stations for appropriate periods is given in table 4.

Measurements of Streamflow

at Sites Other than Gaging Stations

Miscellaneous measurements of streamflow were made on most of the tributary streams in the basin in mid-September 1959 to gain the information that was used by Mundorff and others (1963). Those measurements, and some made by the district watermaster, Mr. Nephi Hansen, in August and September 1959, indicated that the total peripheral surface-water contribution to the valley at that time was about 95 cfs (cubic feet per second). Of this, only about 48 cfs was observed to reach the river as overland flow after traversing the alluvial fans.

Prior to 1960, no gaging stations had been operated on tributaries of the Little Lost River, and the few miscellaneous measurements made in 1959 provided meager data on which to base estimates of average annual discharge to the valley from the peripheral mountainous areas. In an effort to gain data to improve these estimates, in the fall of 1960 the Geological Survey began a program to measure tributary streamflow at 10 sites near the canyon mouths of peripheral drainages on a frequency of about every 5 to 6 weeks. This program continued through the 1961 and 1962 water years with only a few missed measurements at some sites owing to inaccessibility during severe winter weather. The sites where measurements were made were at or very near sites used for 1959 measurements; namely, LL7, 12, 14, 16, 22, 29, 31, 35, 36, and 41. In addition, outflow from Summit

TABLE 4

ANNUAL MEAN DISCHARGE FOR CONTINUOUS-RECORD GAGING STATIONS ON THE LITTLE LOST RIVER AND SAWMILL CREEK

	Little Lost River near Howe Discharge			Little Lost River below Wet Creek Discharge			Sawmill Creek near Goldburg Discharge	
Water Year	(cfs)	(acre-feet)	Water Year	(cfs)	(acre-feet)	Water Year	(cfs)	(acre-feet)
1967	81.2	58,820	1967	76.2	55,130	1967	54.8	39,710
1966	73.1	52,940	1966	57.1	41,310	1966	32.2	23,340
1965	90.7	65,670	1965	97.3	70,420	1965	77.2	55,900
1964	63.4	46,010	1964	61.4	44,540	1964	57.0	41,390
1963	56.4	40,820	1963	45.6	33,020	1963	41.0	29,690
1962	66.1	47,840	1962	49.9	36,160	1962	43.5	31,470
1961	49.3	35,660	1961	32.2	23,340	1961	23.6	17,060
1960	63.6	46,200	1960	40.7	29,530			
1959	72.4	52,380	1959	58.8	38,920			
1958	82.6	59,810						
1957	71.0	51,430						
1956	65.2	47,370						
1955	54.2	39,240						
1954	66.7	48,260						
1953	79.2	57,350						
1952	75.6	54,910						
1951	70.1	50,720						
1950	69.4	50,230						
1949	69.1	49,990						
1948	75.9	55,130						
1947	91.6	66,310						
1946	72.5	52,510						
1945	69.1	50,010						
1944	72.2	52,420						
1943	64.0	46,320						
1942	57.3	41,470						
1941	51.5	37,290						

Creek Reservoir (LL1) was measured throughout the 2-year period, and a new site (LL3A) on Main Fork was established. These sites are shown in figure 2.

The individual discharge measurements are published in U. S. Geological Survey, 1961 and 1962, and in Decker and others, 1970. Annual mean discharge values for each of the tributary basins were derived by a procedure that involved plotting the individual measurements alongside a graph of daily discharge for the three continuous record stations. A graph of estimated daily discharge was then drawn for each of the 10 tributary streams, taking into account, by visual comparison, the correlation with the discharge at the three continuous-record stations. Summation of the daily discharges produced the data shown in table 5.

The average discharge for the 2 water years was then adjusted by the ratio of the 1961-62 average discharge of the Little Lost River near Howe (LL39A) to the 1941-66 average discharge for that stream, to obtain an estimated long-term average for each measured tributary. The total inflow from the tributary basins (excluding Sawmill Creek, LL6, and its principal tributary, Main Fork, LL3A) adjusted to the long-term average is 33,500 acre-feet per year. A similar adjustment was made of the 7-year (1961-67) average discharge for Sawmill Creek. These adjustments were made to arrive at a value for surface runoff for each tributary given in table 6.

Precipitation-Runoff Relations in the Tributary Basins

The precipitation-runoff data plotted in figure 8 show a scatter that could be due in large part to areal differences in precipitation. For example, the precipitation on Dry Creek basin (16) probably is overestimated, because it lies in the rain shadow of high mountains to the west. On the other hand, Wet Creek and Deer Creek basins (22 and 29) are in somewhat similar topographic positions but deviate less from the expected relation.

Several sources of error may confuse the precipitation-runoff relationship. The principal source of error probably lies in the estimate of precipitation; but other sources are significant, as follows: (1) basing the estimate of total surface runoff on only 2 years' intermittent measurements, (2) a number of the individual discharge measurements were rated as fair to poor and the bulk of them were rated only fair to good, and (3) the use of a single precipitation-altitude curve over the entire drainage basin, rather than developing individual curves for different parts of the basin according to exposure, slope, and position relative to the rain shadow of other mountain ranges.

The use of a single precipitation-altitude relation for the entire river basin assumes, in effect, that any variation in runoff from one basin to another results from differences in mean altitude of the basins or from variations in other drainage-basin characteristics. A number of other factors influence runoff, and should be considered; these include vegetative cover, soil conditions, geology, orientation and slope of the drainage basin and channel, and channel characteristics. While it would be possible to examine statistically the relation of some of these variables to runoff with the data available on the tributaries, it would be justifiable only if better information were available on the actual precipitation.

TABLE 5

STREAMFLOW FROM TEN TRIBUTARY BASINS

1961 AND 1962

		Discharge			
		1961		1962	
		Ac. Ft.	cfs	Ac. Ft.	cfs
LL3A*	Main Fork	6,599	9.12	13,508	18.4
7	Warm Creek	3,522	4.9	3,674	5.1
14	Bell Mountain Creek	512	.71	608	.84
16	Dry Creek	9,552	13.2	12,079	16.7
22	Wet Creek	2,222	3.1	4,442	6.1
29	Deer Creek	1,602	2.2	1,618	2.2
31	Badger Creek	5,142	7.1	5,380	7.4
35	Uncle Ike Creek	1,368	1.9	1,900	2.6
36	North Creek	709	1.0	810	1.1
41	South Creek	392	.54	530	0.7

* See figure 2 for locations.

TABLE 6

ESTIMATED WATER YIELD USING PERIMETER–INFLOW METHOD AND ALTITUDE–YIELD RELATION FROM BIG LOST RIVER BASIN

Tributary Basin or Subbasin[a]	Ungaged Area	Perimeter-Inflow Method: Adjusted Yield (inches)	Perimeter-Inflow Method: Adjusted Yield (acre-feet)	Perimeter-Inflow Method: Surface Runoff[b] (acre-feet)	Perimeter-Inflow Method: Ground Water[b] (acre-feet)	Altitude-Yield Relation: Yield (inches)	Altitude-Yield Relation: Yield (acre-feet)
Upper Valley							
Main Fork (3a)		17.6	[c]14,670	[c]13,000	1,700	12.2	[c]10,146
Sawmill Creek (6)		13.7	54,264	29,000	25,300	11.9	47,203
	1W	6.3	5,970	-	-	6.1	6,012
	2W	5.5	8,950	-	-	5.5	9,323
	3W	0.6	266	-	-	2.8	1,239
Dry Creek (16)		24.0	54,000	13,000	41,000	15.4	34,650
	4W	16.0	21,966	-	-	9.6	13,213
Wet Creek (22)		17.5	10,468	4,000	6,500	12.0	7,170
	5W	5.2	7,651	-	-	5.5	8,154
	1E	8.8	467	-	-	7.4	395
Warm Creek (7)		22.1	4,300	4,300	0	14.5	2,840
	2E	14.2	11,134	-	-	10.3	8,099
Bell Mountain Creek (14)		18.5	5,313	700	4,600	12.6	3,622
	3E	17.4	17,806	-	-	11.8	12,075
Valley Floor		-	-	-	-	.4	3,349
Subtotal			202,555				157,344
Middle Valley							
	6W	-	884	-	-	1.8	1,584
Deer Creek (29)		5.0	1,936	1,900	0	5.3	2,036
	7W	2.6	4,914	-	-	4.0	7,445

TABLE 6 (Continued)

ESTIMATED WATER YIELD USING PERIMETER–INFLOW METHOD AND ALTITUDE–YIELD RELATION FROM BIG LOST RIVER BASIN

Tributary Basin or Subbasin[a]	Ungaged Area	Perimeter-Inflow Method: Adjusted Yield (inches)	Perimeter-Inflow Method: Adjusted Yield (acre-feet)	Perimeter-Inflow Method: Surface Runoff[b] (acre-feet)	Perimeter-Inflow Method: Ground Water[b] (acre-feet)	Altitude-Yield Relation: Yield (inches)	Altitude-Yield Relation: Yield (acre-feet)
Middle Valley (Cont'd.)							
	4E	6.8	3,867	-	-	6.3	3,562
Badger Creek (31)		20.7	16,833	6,300	10,500	13.9	11,270
	5E	12.8	9,724	-	-	9.4	7,119
Uncle Ike Creek (35)		16.5	6,569	1,900	4,700	12.1	4,820
	6E	19.5	6,676	-	-	13.2	4,506
North Creek (36)		16.5	5,658	900	4,800	11.7	3,998
	7E	1.7	1,012	-	-	3.4	2,049
Valley Floor		-	-	-	-	.05	371
Subtotal			58,073				48,760
Lower Valley							
	8W	2.2	7,926	-	-	3.8	13,943
South Creek (41)		4.2	2,174	600	1,600	4.7	2,432
	8E	-	271	-	-	1.4	1,583
Valley Floor		-	-	-	-	.01	55
Subtotal			10,371				18,013
Total			270,999				224,117

[a] See figure 2.

[b] Rounded; estimated long-term average.

[c] Not included in total; tributary to Sawmill Creek.

Inspection of the precipitation-runoff plot and comparison of it with figure 2 discloses no obvious correlation between exposure and runoff; that is, tributaries from the west-facing flank of the Lemhi Range do not show a consistently higher or lower ratio of runoff to precipitation than tributaries draining the east flank of the Lost River Range.

Detailed consideration of other drainage basin characteristics is beyond the scope of this study, but the geologic characteristics are especially important because the occurrence of limestone or other permeable rocks may permit a considerable fraction of the water yield to bypass gaging stations and because geologic conditions exert a primary control on other basin characteristics, such as soils and vegetation.

E. T. Ruppel (oral commun., 1971) notes that Warm Creek (7) is underlain mostly by the Kinnikinnic Quartzite of Ordovician age, except for a small area of Precambrian quartzite near the mouth. The underlying bedrock of Main Fork (3A) is also predominantly quartzite. Some volcanic rocks occur just east of Flatiron Mountain, but most of the basin is underlain by quartzite of Precambrian age. Warm Creek has the highest ratio of runoff to precipitation and Main Fork has the next highest.

According to W. J. Mapel (oral commun., 1971), Deer Creek basin (29) is underlain primarily by the White Knob Limestone and Jefferson Formation (dolomite with some limestone), and to a lesser extent by sandy limestone and sandstone of the Middle Canyon Formation and argillite of the Milligen Formation.

The presence of large springs in the Deer Creek basin suggests the possibility that ground water may enter the basin from beyond the surface drainage divide. On the other hand, the structural pattern opens up the possibility that the Milligen Formation constitutes a barrier which effectively forces ground water to the surface upstream from the measuring point, thus increasing streamflow.

Assuming that the latter situation is true, the surface runoff from Deer Creek would represent the total water yield of that basin.

The high ratio of surface runoff to precipitation of Main Fork and Warm Creek, combined with the fact that both are underlain by relatively impermeable bedrock, indicates that the surface runoff is the total water yield.

For the remaining tributary basins, it appears that surface runoff is less reliable as an indicator of total yield either because the measuring points were located on alluvium, which permitted underflow of part of the basin yield, or because the basins are underlain by permeable bedrock that permits ground water to discharge directly from bedrock to the alluvium of the Lost River valley.

Water Yield by Perimeter-Inflow Method

Mundorff and others (1963, p. Q37) used the relation between average annual precipitation and streamflow for 14 basins on the north flank of the eastern Snake River

Plain ranging in size from 38 to 3,880 square miles to estimate the yield of the Little Lost River basin. They assumed that if a gaging station is located on or near bedrock, the gaged surface runoff constitutes the total water yield of the basin. Indeed this assumption provided the basis for much of the data collection of the present investigation, described in the preceding section. These data may be used to estimate water yield.

One approach would be to consider the estimates of runoff from the 10 tributary basins as a representative statistical sampling of the mountainous fringe of the basin, even though their selection was biased in favor of those tributaries that produced measurable runoff.

Although such an approach would be valid and probably reliable in drainage basins that are underlain by relatively impermeable rocks or in basins where all underflow is forced to the surface over a bedrock ridge that otherwise dams the subsurface flow, the method is open to serious question if these conditions are not met. For example, in mountainous drainage basins where the alluvial fill is likely to be highly permeable and water-table gradients steep, even a relatively small section may transmit an appreciable fraction of the basin yield as ground-water underflow, and the method would greatly underestimate yield. Difficulties are also presented if the bedrock is permeable and permits a significant part of the yield to discharge as subsurface flow.

A somewhat different perimeter-inflow approach was attempted. For each site listed in table 5, the surface runoff was plotted against estimated precipitation. The resulting plot (numbered circles, fig. 8) was used as a basis for estimating basin yield by selecting those tributaries for which ground-water underflow past the measuring site was inferred to be minimal. Basins 3A, 7, and 29, discussed previously, were used as primary control to draw curve B, figure 8. The average precipitation over each of the tributary drainage basins was estimated using the mean altitude of the basin as listed in table 3 and the precipitation-altitude relation illustrated in figure 4.

Curve B, therefore, is considered to be an envelope curve for total yield of the subbasins and may be used to estimate an "adjusted yield" for the 10 tributary basins where streamflow was measured periodically, the intervening bedrock areas, and the valley floor. The estimates for each subdivision of the basins are given in table 6. Using this "envelope curve" method, an average annual water yield for the basin of 271,000 acre-feet is estimated (see table 6).

Note that with this method, precipitation on the valley floor does not contribute to the total yield.

If all the variability in measured surface runoff is due to ground-water discharge from bedrock to the alluvial fill, as is assumed with the "envelope curve" approach to basin yield, then the vertical distance between the envelope curve and each plotted point represents the ground-water fraction of basin yield.

No direct data are available (or probably obtainable at a realistic cost) with which to estimate ground-water discharge from the tributary basins, but in a later section data will be presented enabling an estimate of ground-water discharge through the alluvial fill beneath gaging stations LL27A and LL39A. The average annual discharge of the Little Lost River is, therefore, plotted in figure 8 (LL27A has been adjusted to the long-term record) as a means of checking the envelope curve.

Water Yield by Correlation

A third method of computing the water yield of the basin utilizes data from the Big Lost River basin (Crosthwaite and others, 1970). This method assumes that the relation between mean altitude of tributary drainage basins and water yield estimated for the Big Lost River, which is shown in figure 9, can be applied to tributaries and subbasin areas of the Little Lost River.

The data plotted in figure 9 were obtained from table 12 in Crosthwaite and others (1970). The trend line was fitted visually, placing greater emphasis on those points (totals for subbasins) at which gaging-station records were used in calculating or checking the water yield of the tributary basins. By entering the mean altitude of the tributary basins and subbasins listed in table 6, the estimated yields tabulated in the last two columns of table 6 were derived. The total yield derived using this method is about 224,000 acre-feet.

The justification for transferring the yield data from the Big Lost to the Little Lost River basin lies in the similarity between the two basins with respect to topographic configuration, geologic conditions, soil and vegetation cover, and proximity.

Estimates of water yield have not yet been made in other nearby basins that have similar environmental conditions. When such studies are undertaken, it is hoped that they will be able to develop new approaches to the estimation of water yield, or that they will collect the necessary meteorological and climatological data with which to determine the total precipitation, particularly at high altitudes, that will permit better determination of the total water supply, runoff, and evapotranspiration.

Comparison of Water-Yield Estimates

The three methods of estimating water yield range from a low of 224,000 acre-feet per year (by correlation with the Big Lost River basin) to a high of 424,000 acre-feet per year. Intermediate is the perimeter-inflow envelope estimate of 271,000 acre-feet per year. This is the preferred value. As mentioned previously, the total yield derived by the Langbein method, 424,000 acre-feet per year, is believed to be excessive.

The estimates derived by Mundorff and others (1963), about 190,000 acre-feet per year, are believed to be too low, possibly because they used a precipitation gradient with altitude that is lower than actual, and because the basins used in their correlation procedure, in which they assumed that surface outflow was a true measure of basin yield, did in fact discharge significant quantities of water by underflow, either through alluvial fill at gaging stations, or through permeable bedrock.

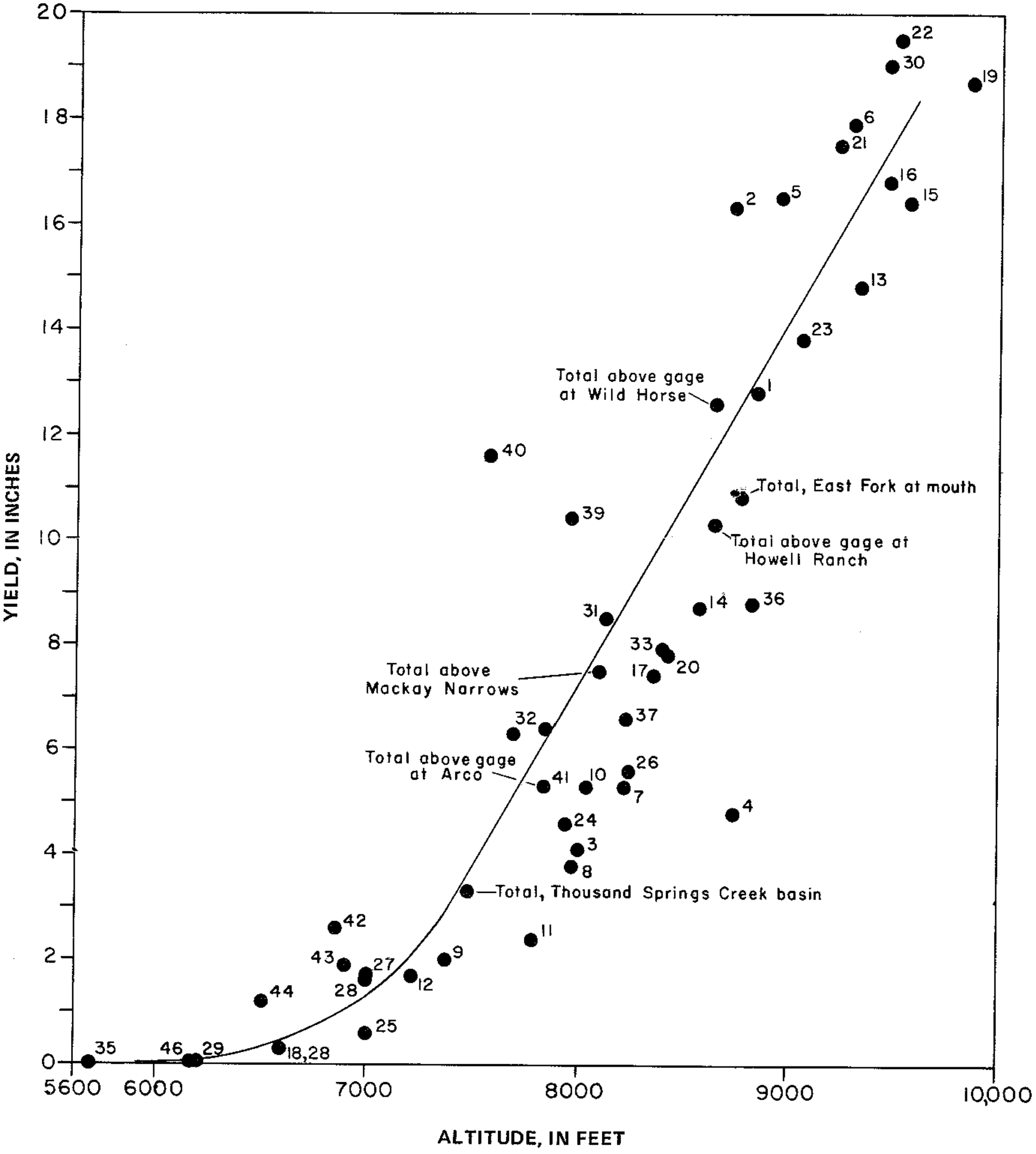


FIGURE 9. Yield data for subareas of the Big Lost River basin plotted against altitude. (From Crosthwaite, 1970, table 12.)

Ground Water

Source and Occurrence

That part of the precipitation falling on the peripheral mountains that does not run off promptly and is not consumed by natural evapotranspiration moves valleyward through the soil and talus mantle as unobserved underflow. In areas underlain by impermeable bedrock, the major part drains to the canyons and discharges at the canyon mouth as surface flow and ground-water underflow to the alluvial valley fill. Most of the streams lose their surface flow after they leave the mountains by infiltration to the permeable alluvium before reaching the axis of the valley. The ground-water body thus formed is in storage and in transit southeastward downvalley. The most important aquifer, or water-bearing unit, in the basin is the alluvial sand and gravel of the valley. The greatly fractured rocks of the mountains, talus and slope wash on the steeper slopes, and a fairly thick residuum on gentler slopes, form an important reservoir, not from the standpoint of pumping by man, but because they receive some of the rainfall and snowmelt and discharge it gradually through springs at the mountain margins and by underflow directly to the alluvium of the valley.

Beneath the extreme southeastern part of the basin as outlined in figure 2, basalt is an important aquifer, yielding water to several irrigation wells in the area east of Howe (see fig. 3). Basalts of the Snake River Group and their associated sedimentary interbeds are important to the hydrology because they are the drainways for ground-water outflow from the Little Lost basin into the Snake Plain aquifer.

So far as available data show, the aquifer in the valley alluvium contains a single water body with only local, if any, perched water bodies or artesian-pressure zones. Where basalt is interfingered with silty or clayey beds, however, important separation of the water body into zones of perching or artesian pressure may occur. Such zones should become more evident when heavy pumping from the various layers modifies the existing head distribution, causing local differences in water level, particularly during the irrigation season.

Water Table

The general longitudinal (downvalley) configuration of the water table is depicted by contours in figure 2. Control is not available to show adequately the water-table slope from the sides of the valley, but where major tributary valleys are thought to discharge ground water into the alluvial fill of the main valley, the contours have been drawn to reflect this interpretation. The configuration of the contours has also been made consistent with gaining or losing stretches of the river. Where ground water is known to discharge into the river, the contours are concave downstream; where the river is higher than the water table, or is known to be recharging the water table, the contours are convex downstream.

The water-table gradient is fairly uniform, averaging about 43 feet per mile from the junction of Sawmill and Summit Creeks to the central part of T. 8 N., R. 27 E., where there is an apparent steepening. However, the data available for constructing the contour map are inadequate for determining subtle changes in gradient that might result from changes in the width, depth, or permeability of the alluvial fill. The depicted change in gradient in T. 8 N., R. 27 E., is based on water levels in only three wells in T. 8 N., R. 28 E. and may be only apparent.

The steep gradient in T. 7 N., R. 28 E. indicates a water-table decline of about 200 feet in less than 2 miles (fig. 10). The contours are only a gross approximation of the water-table shape; the major drop in the water table may occur in a much shorter distance. The only controls used to determine the gradient were sites at either end of the reach -- springs at the upper end in sec. 28, T. 7 N., R. 28 E., and well 6N-28E-1bc1 at the lower end.

Downvalley from that area the water table is 40 to 100 feet below the surface, and the gradient ranges generally from 15 to 20 feet per mile. The alluvial materials of the lower valley consist of interbedded sand, gravel, clay, and silt. The proportion of silt and clay apparently increases downvalley, so that east of Howe the alluvial materials are predominantly very fine textured. These materials are of low permeability and are interbedded with tongues of basalt from the Snake River Plain. They are responsible for "damming" the ground water in the Howe area so that it is held at a level nearly 200 feet higher than water levels in the basalt of the Snake River Plain only a mile or so to the south. In the transition zone between the high water table in the Howe area and the lower water table of the Snake Plain aquifer, the water level in a well may stand at progressively lower levels as successively deeper aquifers are penetrated during drilling.

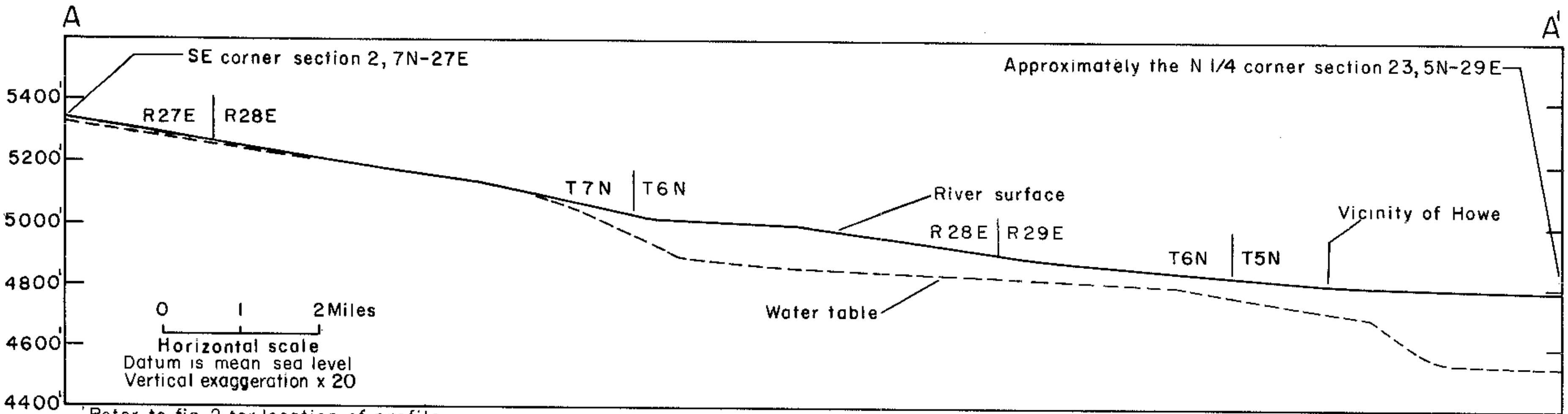
Comparison of the water-table contours for April 1966 in figure 2 with those for 1959 on plate 2 of Mundorff and others (1963) shows that, with few minor local exceptions, there has been virtually no significant change in the position or configuration of the water table. There have, however, been seasonal changes.

In some places, differences in placement of contours appear because of more data, differences in location of data, or slightly different interpretations. There is no evidence of a general decline in the water table, nor is there evidence of major pumping depressions, even in limited areas, that would reflect serious depletion of storage.

Hydraulic Characteristics of the Alluvial Fill

The rate of flow of ground water down the valley under a given hydraulic gradient is controlled by the permeability, thickness, and width of the alluvial fill. Permeability times thickness equals the transmissivity of the aquifer, which can be determined using pumping-well methods, or with other kinds of field data. To estimate the volume of water in storage in the aquifer, it is necessary to know the storage coefficient of the aquifer (volume of water released from storage per unit surface area of the aquifer per unit change in head) in addition to its total saturated volume.

The information on the hydraulic characteristics of the alluvial fill, which can be gleaned from aquifer test data and from specific-capacity calculations on wells distributed through the valley, is especially important to this report. It provides the basis for an independent estimate of ground-water underflow using Darcy's law to check the estimates



'Refer to fig. 2 for location of profile

Adapted from Mundorff and others, 1963

FIGURE 10. Longitudinal profile of the lower half of the Little Lost River valley showing the relation of the water surface of the river to the water table.

of underflow arrived at by difference. Such an underflow estimate would be superior to the difference determinations, except that the cross-sectional area of alluvial fill is very uncertain.

The best information available on the hydraulic characteristics of the alluvium was obtained from three aquifer tests conducted by E. H. Walker of the U. S. Geological Survey in September 1962 on wells in sec. 12, T. 7 N., R. 27 E., owned by L. R. Hawley of Howe. Two tests were made using different pumping wells. In each test, one well was pumped and drawdowns were measured in three observation wells at distances ranging from 70 to 278 feet from the pumped well. A third test was made by measuring the water-level recovery rate in three observation wells at distances of 47 to 420 feet from the pumped well after the pumped well was shut down following a long period of pumping. The pumped wells for the drawdown tests penetrated 86 and 87 feet of the aquifer. One was pumped at 1,400 gpm (gallons per minute), then the other at 1,640 gpm, each for about 6½ hours. The pumped well recovery test penetrated 60 feet of the aquifer and the well had been pumping at a rate of 560 gpm.

For water-table aquifers such as the alluvial fill of the Little Lost River valley, which contains a significant thickness of clay, accurate estimates of the storage coefficient cannot be made with the data from short-term aquifer tests. Gravity drainage of water from smaller voids in the aquifer takes place very slowly, and the available water may not drain out of clay layers for months after the water table has been drawn down around a pumping well. Using different graphical methods of data interpretation for the three tests, Walker estimated storage coefficients ranging from 5 to 15 percent and averaging about 12 percent. These estimates of storage coefficient may be considered as minimum values for the upper part of the alluvial fill. It is estimated that the true storage coefficient probably is on the order of 20 percent. This value will be used for the middle and upper basins in making calculations of the quantity of water in transient storage, to be presented later. In the lower basin, where basalt is a major part of the aquifer, calculations of changes in ground water in storage over a period of several months are based on a storage coefficient of 15 percent.

Walker's estimates of transmissivity ranged from 214,000 to 494,000 gpd/ft (gallons per day per foot). The values were obtained using several methods of analysis, which are described in Ferris and others (1962) and Bentall (1963a and 1963b). The highest values were based on data from the westernmost of the line of wells, which is the nearest to the Little Lost River. Those data may, therefore, reflect the effect of the river as a recharging boundary. The values for transmissivity resulting from the three tests clustered in the range of 250,000 gpd/ft.

The fact that test results most likely to have been influenced by recharging boundary effects from the Little Lost River (those near the western end of the line of wells) were in the range of 490,000 tends to corroborate the estimate of 250,000 as a good average value because the theoretical effect of a linear recharging boundary is to double the apparent transmissivity.

With the information available, it cannot be determined whether the estimates of transmissivity apply only to the section of alluvium penetrated by the wells used for the test or to some greater thickness. Wells that penetrate only part of an aquifer draw some of their water from below the bottom of the well if the vertical permeability of the materials below the bottom of the well is significant, and a transmissivity value from such test conditions overestimates the transmissivity of the section penetrated, but underestimates the true transmissivity of the total saturated thickness.

The subsurface geology is such that the aquifer test results seem to be more nearly applicable to the upper 100 feet or so of saturated sediments. Drillers' logs of wells finished in the alluvium (Mundorff and others, 1963, p. Q46-Q48) suggest layering of the materials and probable separation of highly permeable beds of sand and gravel by relatively impermeable beds of clay or poorly sorted and cemented material. Thus the transmissivity of the total thickness of alluvial fill is believed to be higher than that indicated by the aquifer tests, but the actual value cannot be estimated without knowing the total thickness and characteristics of the saturated alluvium below the bottoms of the wells.

A crude picture of the areal distribution of transmissivity is conveyed by the areal distribution of the specific capacity of wells. Specific capacity is the ratio of well yield to drawdown and is expressed in gallons per minute per foot of drawdown. The specific capacity of a well also may be used to make a rough estimate of transmissivity. For a discussion of this approach, see Theis and others, 1963, p. 331-341.

The specific capacity of wells in the valley for which discharge and drawdown data are available ranges from 12 to 163 gpm/ft (gallons per minute per foot) of drawdown. The average specific capacity for wells in the upper and middle valley (Tps. 7-10 N.) is at least 53 gpm/ft and for wells in the lower valley it is at least 51 gpm/ft. If the well-entrance loss is as high as Mundorff and others (1963) estimated it to be, about 75 percent of drawdown, this would indicate an average transmissivity of about 400,000 gpd/ft. This value is considerably higher than the values for transmissivity determined from the pumping tests on wells 7N-27E-12aa1, 12ba1, and 12ba2.

Specific capacities for those wells are as follows:

7N-27E-12aa1	23 gpm/ft
7N-27E-12ba1	55 gpm/ft
7N-27E-12ba2	55 gpm/ft

If their construction is typical, the specific capacity data indicate that entrance losses are more nearly half to two-thirds of the drawdown rather than three-fourths.

As Mundorff and others pointed out, specific capacity is influenced by a number of factors, most importantly by well construction, but also by the thickness and permeability of saturated aquifer materials to which the well is exposed, proximity to perennial streams that are potentially recharging boundaries, and others. In comparing wells of different depths, the effect of variable penetration of saturated aquifer materials may be partly eliminated by dividing the aquifer penetration into the specific capacity to obtain a numerical value in gallons per minute per foot of drawdown per foot of saturated thickness. The term "yield factor" has been applied by some authors to this ratio multiplied by 100.

It is possible to calculate actual values, or to estimate minimum values, for this index of well and aquifer performance for 40 wells in the basin, using data from Mundorff and others (1963), table 6. The yield factor ranges from a minimum of 0.22 to more than 2.5 and averages 0.84 gpm/ft of drawdown per foot of saturated thickness. The highest value is for well 10N-27E-19ab1, which is almost certainly influenced by Summit Creek, less than 500 feet away. The remaining eight of the nine highest are for wells in secs. 19, 22, and 27, T. 6 N., R. 29 E., indicating that the gravel and sand aquifers there are the most highly permeable in the valley.

If the data for the 40 wells are normalized to a uniform 100-foot saturated thickness and adjusted for entrance losses by applying a factor of 2.5, then a roughly comparable value for transmissivity of the aquifer at each of the 40 wells may be obtained by multiplying the product by 2,000. The resulting figures are the basis for the following discussion of areal variation of transmissivity. It is emphasized that the interpretations can be applied only in the most general way. They are subject to large error, although the numerical values have been derived in such a way as to represent minimal estimates, both because many of the drawdowns are maximum values and because, so far as is known, none of the wells penetrate the full thickness of the aquifer.

The northernmost data point is well 10N-27E-7cc1; no data are available on the transmissivity of the alluvial fans and underlying material crossed by Sawmill Creek, Summit Creek, and Dry Creek. Excluding the data from well 10N-27E-19ab1, discussed earlier, the apparent transmissivity of the alluvium in Tps. 9 and 10 N. is on the order of 150,000 to 200,000 gpd/ft. Southward the transmissivity increases, and along the axis of the valley in the northeastern part of T. 7 N., R. 27 E., it is on the order of 250,000 to 300,000. Between Fallert and the west line of T. 6 N., R. 29 E., no data are available, but presumably the subsurface geology is similar and a value similar to the preceding seems reasonable. The large number of data points in T. 6 N., R. 29 E., indicate a range of apparent transmissivity between 100,000 and more than 1,000,000 gpd/ft; the mean is about 500,000 gpd/ft. While this figure is higher than the one given by Mundorff and others (1963), a reexamination of the data available to them suggests that they may have used only the data for which an actual specific capacity could be calculated and omitted consideration of some of the data from which minimum figures can be derived. Furthermore, no well in the data array for T. 6 N., R. 29 E., penetrates as much as 100 feet of the aquifer, and most penetrate less than 50 feet, thus the method of normalizing to a uniform depth would produce a higher apparent transmissivity.

WATER USE

Use of the water resources of the Little Lost River basin includes the manmade diversions of surface water and ground water for irrigation, domestic, and stock use, plus the consumptive use of water by natural vegetation on the valley floor, particularly in areas where the water table is so near the surface that water-loving plants (phreatophytes) withdraw water from the saturated soil zone immediately above and below the water table.

Consumptive use of water for domestic and stock-watering purposes is negligible quantitatively; the total consumptive use by phreatophytes and for irrigation is summarized below and described on pages immediately following.

Consumptive Use of Water*

(acre-feet)

	From Land Irrigated with Surface Water	From Land Irrigated with Ground Water	Phreatophytes
Upper	3,000	2,000	15,000
Middle	10,000	10,000	14,000
Lower	15,000	28,000	7,000
Total	28,000	40,000	36,000

* Estimated average for 1961-66. Figures should be used only for order-of-magnitude comparisons.

Utilization of Surface Water

The use of surface water for irrigation in the Little Lost River valley began in the late 19th century. An expansion of activities took place between 1909 and 1913 when when 12,500 acre-feet of water was furnished to lands in T. 6N., Rs. 28, 29, and 30 E. for irrigation of about 4,035 acres. The early history of irrigation development was summarized by Mundorff and others (1963). According to oral reports from some of the residents, water shortages have been common.

Between 1961 and 1966, the following quantities of surface water were diverted for use in the lower basin.

Year	Approximate diversions (acre-feet)
1961	34,100
1962	39,600
1963	39,900
1964	44,200
1965	63,600
1966	45,800

Average - 44,500

The above figures, furnished by Steve Allred of the Idaho Department of Water Administration (now the Idaho Department of Water Resources), represent measurements at user turnouts and do not include conveyance losses between points of diversion from the river and user turnouts.

Diversions from the main stream are less extensive in the middle and upper reaches of the valley, but water from a number of the tributary streams coming off the Lemhi Range is used for domestic, stock, and irrigation purposes.

According to information furnished by the Soil Conservation Service, a total of about 30,000 to 34,000 acres was under irrigation in 1967, of which about 16,000 acres was with surface water. Of this 16,000, about 1,600 acres was in the upper basin; about 5,600 acres in the middle basin; and the remainder, 8,800 acres, in the lower basin. The Soil Conservation Service compilation included a small area south of the southern limit of figure 2, but the data are considered to apply in a general way to the basin as defined for this study.

Assuming a consumptive use of 1.3 acre-feet per acre in addition to growing-season precipitation (Jensen and Criddle, 1952), the total consumptive irrigation use on land irrigated with surface water in 1967 was about 28,000 acre-feet, distributed within the three reaches of the valley as follows:

Upper	3,000
Middle	10,000
Lower	15,000

The above figures indicate the relative magnitude of consumptive use within the basin, but they apply only to the 1967 irrigation season, and similar data were not available for the time period covered by this study.

Utilization of Ground Water

About 95 wells were used to pump ground water for irrigation in the Little Lost River valley in 1966. There are also several hundred domestic and stock wells in the valley, mostly shallow, dug or drilled wells, but the total quantity of water pumped from them is small compared to that pumped for irrigation. Most of the wells are less than 150 feet deep, although some deeper wells have been drilled since 1964. The deepest well known in the valley is about 6 miles east of Howe and is 601 feet deep. This well (5N-30E-4cd1) when first completed yielded an average of 4,250 gpm with a specific capacity of about 236 gpm/ft of drawdown. However, the well and its yield are not comparable to the average for wells in the Howe area because it undoubtedly obtains the greatest part of its yield from basalt aquifers and not from the alluvium of the valley. Also, the water level in the well relates to that in the Snake Plain aquifer and not to water levels in the main part of the Howe area.

A detailed discussion of the water-yielding capacity of wells in the valley is presented by Mundorff and others (1963), which emphasizes the importance of proper well construction and the relation of drawdown in a well to drawdown in the surrounding aquifer.

Prior to about 1948, all irrigation was with surface water (Mundorff and others, 1963). Since that time, the development of ground water for supplemental irrigation and for new land has progressed steadily. During the period 1959-66, the use of wells for irrigation and the amount of water pumped varied considerably, but by 1966 there were 95 wells in use -- 71 in the Howe area and 24 in the middle and upper basin area.

No records are kept by the ground-water users of the amount of water pumped, and it is necessary to utilize power-consumption data to estimate the total pumpage. All wells are equipped with electric pumps, so that the quantity of water pumped may be approximated by use of the equation

$$Q = \frac{0.977 \times Kw \times Emp}{H}$$

where

Q = discharge, in acre-feet

Kw = power consumed, in kilowatt hours

Emp = efficiency of motor and pump, in percent

H = head, or total height in feet that water is lifted.

An overall efficiency of 65 percent was assumed by Mundorff and others (1963), so that the equation reduces to

$$Q = \frac{0.635\ KW}{H}$$

By use of this equation, power-consumption data provided by the Utah Power and Light Co. and the measured or estimated average drawdown of the wells, it was shown that in 1959 approximately 12,000 acre-feet of water was pumped in the area north of T. 6 N. and 25,000 acre-feet in the lower basin area. The pumpage in each of these areas for each year since 1958 has been computed and is given in table 7. This table shows that total pumpage increased each year from 1959 through 1961, then declined to less than 30,000 acre-feet in 1965. During the dry year of 1966, however, pumpage increased spectacularly to more than 66,000 acre-feet. During the 8-year period, pumpage from the upper and middle basin areas averaged about 15,640 acre-feet per year, and from the lower basin area about 28,350 acre-feet per year. Total pumpage averaged about 44,000 acre-feet per year from the whole basin.

The pumpage quantities given in table 7 (and in Mundorff and others, 1963) are probably minimal because a low value of 65 percent was used for overall efficiency. Overall pump and motor efficiency depend on several factors, including the age and condition of

TABLE 7

ESTIMATED PUMPAGE AND NUMBER OF WELLS USED FOR IRRIGATION IN THE LITTLE LOST RIVER VALLEY, 1958-66

(Water pumped in acre-feet shown in left column; number of wells used shown in right column.)

	1958		1959[a]		1960		1961		1962		1963		1964		1965		1966	
Middle and Upper Basin																		
10N-27E	-	2	3,300	3	3,320	3	3,410	5	3,180	3	870	2	1,180	4	460	3	1,070	4
9N-27E	-	3	2,210	3	1,910	3	2,990	5	2,510	5	2,930	5	2,360	5	2,120	5	3,880	5
8N-27E	-	1	590	1	930	1	760	1	700	1	85	1	30	1	-	-	1,000	2
8N-28E	-	1	410	1	2,670	2	1,530	2	1,580	2	1,760	2	1,280	2	480	1	2,660	3
7N-27E	-	6	4,970	6	5,420	6	7,050	6	3,470	6	2,870	6	2,540	6	2,510	6	5,120	7
7N-28E	-	2	5,340	2	6,250	1	6,050	3	4,190	3	3,340	3	3,940	3	3,570	2	4,350	3
Totals	-	15	16,820	16	20,500	16	21,790	22	15,630	20	11,850	19	11,330	21	9,140	17	18,080	24
Lower Basin																		
6N-28E	-	-	-	-	-	-	3,200	6	3,870	6	2,600	5	1,340	5	1,480	5	4,880	5
6N-29E	-	40	24,760	46	27,650	50	25,230	54	20,610	53	25,150	55	24,310	56	16,630	55	37,780	61
6N-30E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,250	1	3,320	2
5N-29E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	940	2
5N-30E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	450	1	1,320	1
Totals	-	40	24,760	46	27,650	50	28,430	60	24,480	59	27,750	60	25,650	61	19,810	62	48,240	71
Grand Total	-	55	41,580	62	48,150	66	50,220	82	40,110	79	39,600	79	36,980	82	28,950	79	66,320	95

[a] Revised values based on re-calculation of data given in Mundorff and others, 1963.

the motor and pump, and the periodicity of pump operation during the irrigation season. Pump and motor efficiencies rarely approach 100 percent, and generally range between about 55 and 85 percent. In areas where irrigation pumps are relatively new, are maintained in good condition, and are turned on at the beginning of the irrigation season and left running for long periods within their designed capacities, efficiencies are known to average about 75 percent. In the lower valley, there is a rather wide range of pump conditions and pumping procedures, but in general the pumps are used sporadically. Thus, the effective average efficiency for the group is probably below 75 percent because of higher power consumption per unit of water pumped than would be the case if the pumps were left running throughout the irrigation season. Even, so, it is emphasized that this report considers the choice of 65 percent for overall efficiency to be a minimum value, and that in all probability somewhat larger quantities of water have been pumped than are indicated by use of the above equation. An efficiency of 75 percent would indicate a total average pumpage for the basin of 49,500 acre-feet.

Information furnished by the Soil Conservation Service indicates that in 1967 slightly less than 18,000 acres was under irrigation with ground water, 4,800 in the middle basin and about 13,000 in the lower basin. Applying a consumptive use factor of 1.3 acre-feet per acre plus growing-season precipitation (estimated at about 6 inches in the middle basin and a little less than 5 inches in the lower basin), in 1967 some 8,600 acre-feet of ground water and precipitation was used in the middle valley and 22,000 acre-feet in the lower valley. The Soil Conservation Service data indicate no use of ground water in the upper basin, whereas Mundorff and others (1963, table 6) indicate that in 1959 1,350 acres in the upper valley were irrigated with ground water. Assuming that irrigated crops transpire a total of 1.9 feet annually a total consumptive use of 2,600 acre-feet is indicated. The average ground-water pumpage for the period 1961-66 was 2,100 acre-feet per year in the upper valley (table 7) and although pumpage records were not compiled for 1967, it is doubtful that all pumping ceased during that year.

The apparent discrepancy may result from conjunctive use of ground water and surface water, but for the purpose of estimating total water use and its effect on the availability of water farther down the valley, it is assumed that 2,500 acre-feet of water was used consumptively on land irrigated with ground water in the upper basin in 1967.

Thus, the total consumptive use by crops irrigated with ground water in 1967 was about 33,000 acre-feet.

Inasmuch as surface runoff past the Howe gage (LL39A) in the 1967 water year was nearly 25 percent above average, it is likely that ground-water pumpage in the lower and middle basin in 1967 was less than average, because supplemental water would not have been as necessary on those farms that use ground water as when surface water is deficient. It is, therefore, estimated that the average consumptive use by crops irrigated with ground water has been about 40,000 acre-feet per year, distributed as follows:

Upper basin	-	2,000 acre-feet
Middle basin	-	10,000 acre-feet
Lower basin	-	28,000 acre-feet

The preceding discussion of consumptive use has considered total consumptive use and has included growing-season precipitation. A comparison of consumptive use with pumpage suggests an irrigation efficiency (ratio of consumptive use to applied water) on the order of 80 to 90 percent if the growing-season precipitation is neglected.

Even the lower of these two ranges is believed to be excessive. According to W. L. Burnham (written, commun., 1972), nowhere in Idaho has it been determined that irrigation efficiency exceeds about 60 percent. This suggests that either the pumpage estimates are too low, or the consumptive use estimates are too high, or both. However, for the purpose of calculating the water budget presented later, the consumptive-use figures will be used; they maximize the effect of water development on the availability of water in the basin.

Consumptive Use by Phreatophytes on the Valley Floor

Mundorff and others (1963) estimated that about 20 square miles (13,000 acres) of marshy and riparian lands on the valley floor support a light to medium growth of native phreatophytic vegetation which consumptively uses all the annual precipitation (which they estimated at 10 inches) plus an estimated 24 inches of ground and surface water.

They arrived at a figure of 26,000 acre-feet; however, this contains an arithmetic error and should have been 36,000 acre-feet. The manner in which the total area of phreatophytes was determined is not clear; it may have been estimated from areas of marshy vegetation shown on topographic maps at a scale of 1:250,000.

Comparison of the small-scale maps with 1:62,500 scale maps suggests that the actual area may be considerably smaller. Compensating for this difference, however, is the fact that the precipitation component of the consumptive use may be at least 30 percent higher than they estimated (13.3 inches average on the middle and lower valley floor and 17.5 inches on the valley floor in the upper valley) so that 36,000 acre-feet might have been consumptively used from 10,000 to 12,000 acres. In any case, the consumptive use of water by phreatophytes is considered to be no more than 36,000 acre-feet, of which probably 20 percent is in the lower basin and the remainder assumed to be equally distributed between the middle and upper basin.

Upper basin	-	15,000 acre-feet
Middle basin	-	14,000 acre-feet
Lower basin	-	7,000 acre-feet

INTERRELATION OF SURFACE WATER AND GROUND WATER

In a drainage basin such as the Little Lost River basin, it is assumed *a priori* by hydrologists that ground water and surface water are interconnected. The presumed interrelationship rests fundamentally on the knowledge that all ground water originates as precipitation in the form of rain or snow, just as all surface runoff is from the same source.

This does not mean that the relation is fixed and without variations, because the interchange between the ground-water reservoir and surface streams may vary in response to natural differences in rainfall, geologic conditions that control seepage and rates of ground-water flow or to manmade stresses, such as withdrawal of ground water or diversion and consumptive use of streamflow.

River-Channel Gains and Losses

Direct evidence of the interrelation is seen in the seepage "gains" and "losses" in several streams in the upper part of the basin. One example is the increase in discharge of Summit Creek recorded by Mundorff and others (1963) between Stations LL1 and LL3 (fig. 2) on September 1, 1959. The only surface inflow was 0.4 cfs from Summerhouse Canyon, yet the flow at station LL3 was 7 cfs greater than at LL1, about 6 miles upstream. The measurements were made following a protracted period when there was no rainfall, therefore, the downstream increase in discharge can result only from ground-water accretion to the stream.

Another example is the decrease in discharge of Dry Creek between LL17 and LL18 (Dry Creek canal) on September 15, 1959. The apparent "loss" of flow was 17.6 cfs in a distance of about 7 miles, which can only be accounted for as replenishment of the ground-water reservoir. It is a loss only in the sense that the water is no longer available for surface diversion after it has moved underground. It is not lost from the system and is recoverable, although such "losses" may serve to reduce streamflow at downstream points and may make it difficult to meet water needs with surface flow at a given time. However, "losses" of streamflow where the tributaries cross permeable parts of the valley fill return, at least in part, to the main stem as increase in streamflow, such as the 2.5 cfs measured on September 18 between LL27A and LL28.

In detail, the interrelation is extremely complex. As an example, in the vicinity of Fallert, where the Little Lost River flows southeastward through secs. 17, 18, 20, and 21, T. 7 N., R. 28 E., the hydraulic head indicated by ground-water levels was lower than the head in adjacent parts of the river, as measured by Crandall in December 1929 (Crandall and Stearns, 1930). In figure 11, the data collected by Crandall have been recontoured in a manner that is somewhat more consistent with the head relations between the surface streams and the water table than Crandall's original contours. In addition, short arrows have been added to emphasize the contrast between areas where ground-water discharged to surface streams and areas where hydraulic head in the aquifer was lower than stream level, indicating recharge of the aquifer by infiltration of streamflow. The relations between ground water and surface water probably are even more complex now than the contours and arrows indicate. The head differential favors infiltration (loss) of surface flow through the reach, yet a quarter of a mile to a half a mile northeast of the river numerous springs discharge ground water to the surface and sustain the flow of Big Spring Creek, Whittaker Creek, and others. A line approximately parallel to the river and about a quarter of a mile northeast of the river separates the zone of ground-water discharge from a zone to the southwest in which the streams recharge the ground water. An acceptable explanation for this condition lies in the distribution of bedrock and alluvial fill, perhaps as controlled by

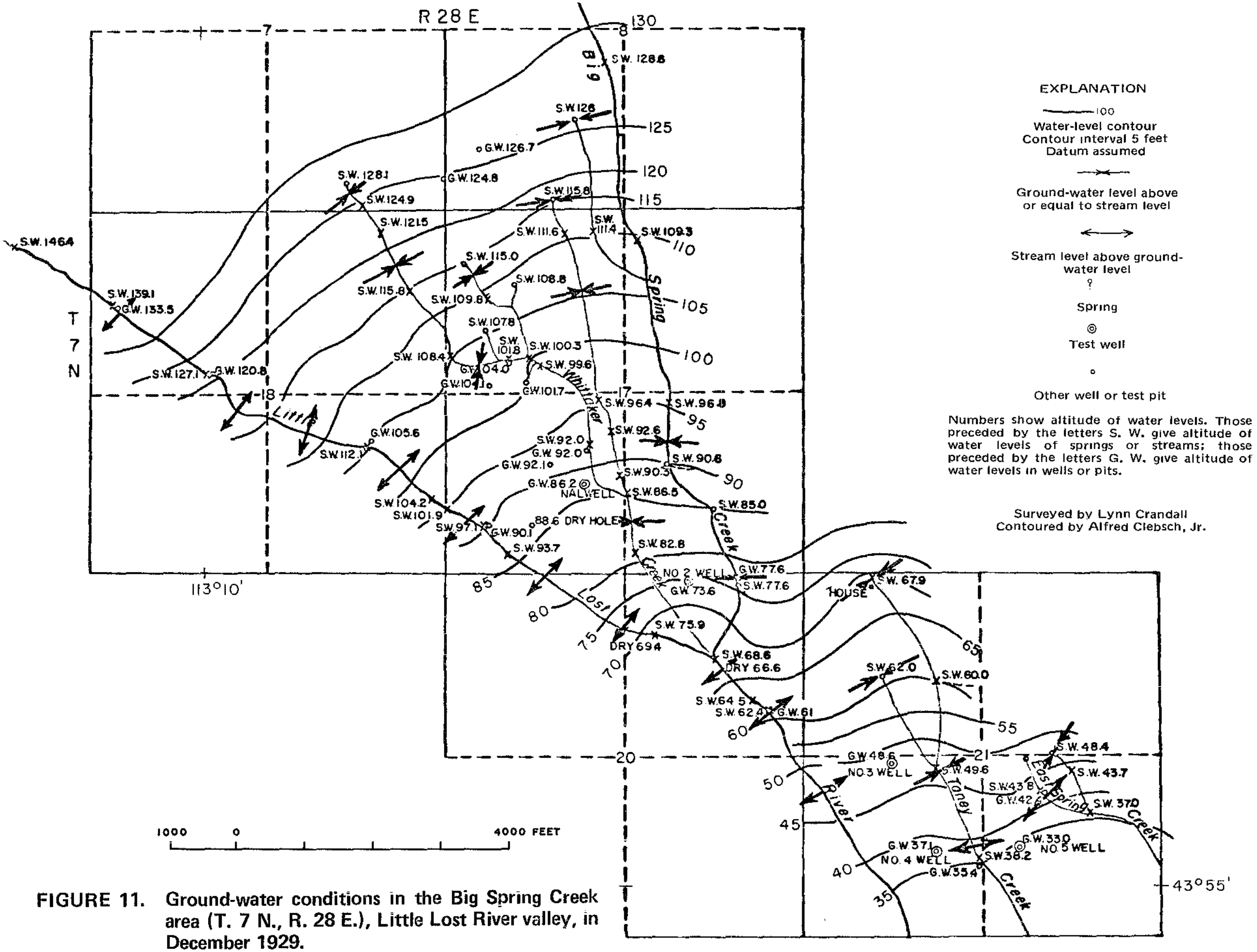


FIGURE 11. Ground-water conditions in the Big Spring Creek area (T. 7 N., R. 28 E.), Little Lost River valley, in December 1929.

faulting, but subsurface information is not available with which to confirm the actual structural model.

Previous interpretations have postulated the presence of a bedrock ridge beneath the permeable alluvium, which reduces the cross-sectional area through which ground water may move down the valley. Such a feature would force ground water to the surface to move past the restriction as increased surface flow.

The structural condition is undoubtedly much more complicated than a simple bedrock ridge and may involve a fault barrier within the alluvium, or the juxtapostion by faulting of beds of differing permeability against one another. This is thought to be true because (1) according to Crandall's map, the lowest part of the valley is along Whittaker Creek, Taney, Creek, and East Spring Creek, rather than along the Little Lost River, (2) detailed inspection of the Crandall data indicates that the line separating the zone of ground-water outflow from the zone of ground-water inflow is strikingly distinct and straight and cuts across the south-flowing tributaries listed above, (3) gravity data provided by D. R. Mabey (written commun., 1968) are not consistent with a westward projection in the subsurface of the bedrock ridge just east of Fallert, and (4) the steepened ground-water gradient indicated in figure 2 should occur farther northwest if it were caused simply by a reduction of the cross-sectional area of the alluvial fill.

In the Howe area, the water table is deep beneath the land surface (fig. 10). A substantial part of the surface water entering this part of the basin, and not consumed by natural or manmade uses, infiltrates to the ground-water body.

The infiltration of surface water from seepage through stream channels, deep percolation of applied water, and waste waters contribute much recharge to the ground-water reservoir beneath the lower valley. Of an average flow past the Howe gage of 50,000 acre-feet per year, plus an estimated 5,000 acre-feet that is ungaged, the average consumptive used probably is only about 15,000 acre-feet. The remaining 40,000 acre-feet is virtually all recharge to ground water.

The effect of this recharge, largely from water spread for irrigation, can be seen from a map showing water-table changes between September 1959 and September 1965 (figure 12). Even though streamflow was below average for 1959-64, and the increased flow in 1965 did not begin until late in April, the water table generally beneath the irrigated acreage, rose more than 2 feet over an area of more than 6 square miles and rose more than 6 feet over an area of more than half a square mile.

Water-table fluctuations, as illustrated by periodic measurements in well 6N-29E-33dc1, are shown in figure 13, which also illustrates the cumulative departure from the long-term average of the discharge of the river at Howe, and of monthly precipitation, and ground-water pumpage for 1959-66. On the precipitation and streamflow graphs, a rising trend indicates a period of greater than average streamflow or precipitation; a falling trend indicates less than average.

EXPLANATION

—— +2 ——

Line of equal water-level change, in feet

○

Observation well

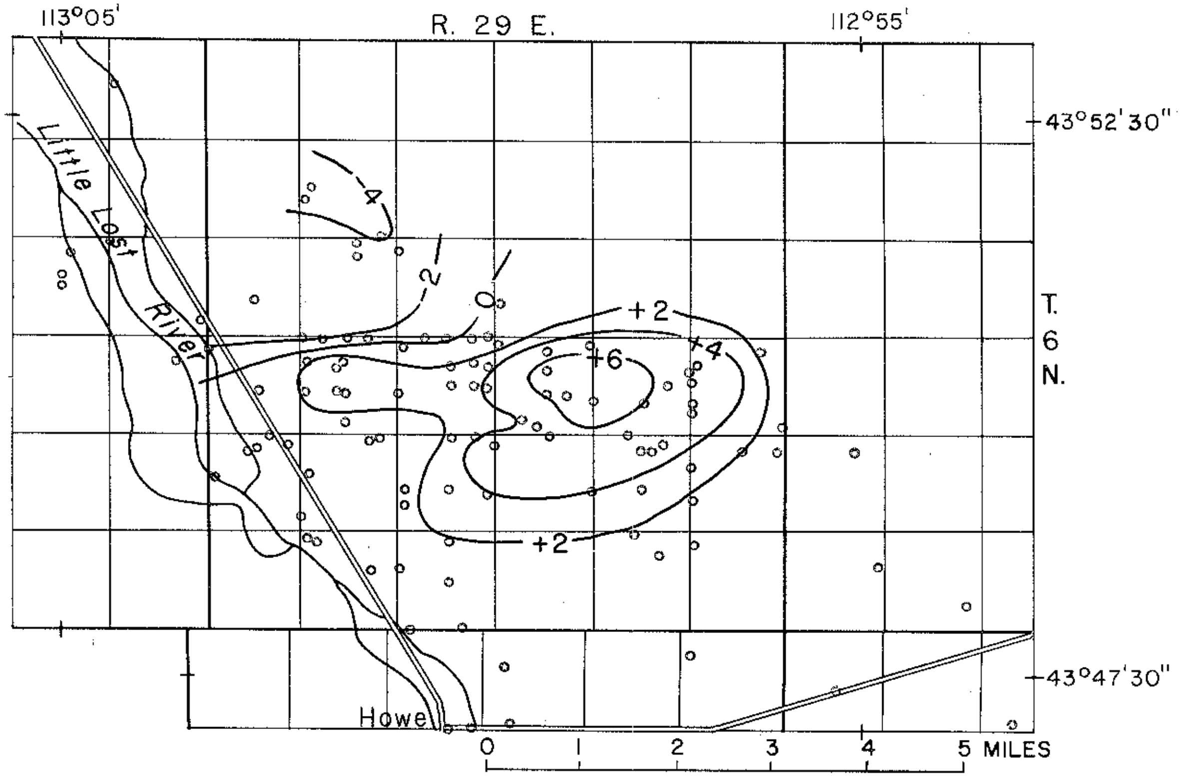


FIGURE 12. Changes in water level, (+) rise, (-) decline, in the Howe area, September 1959 to September 1965.

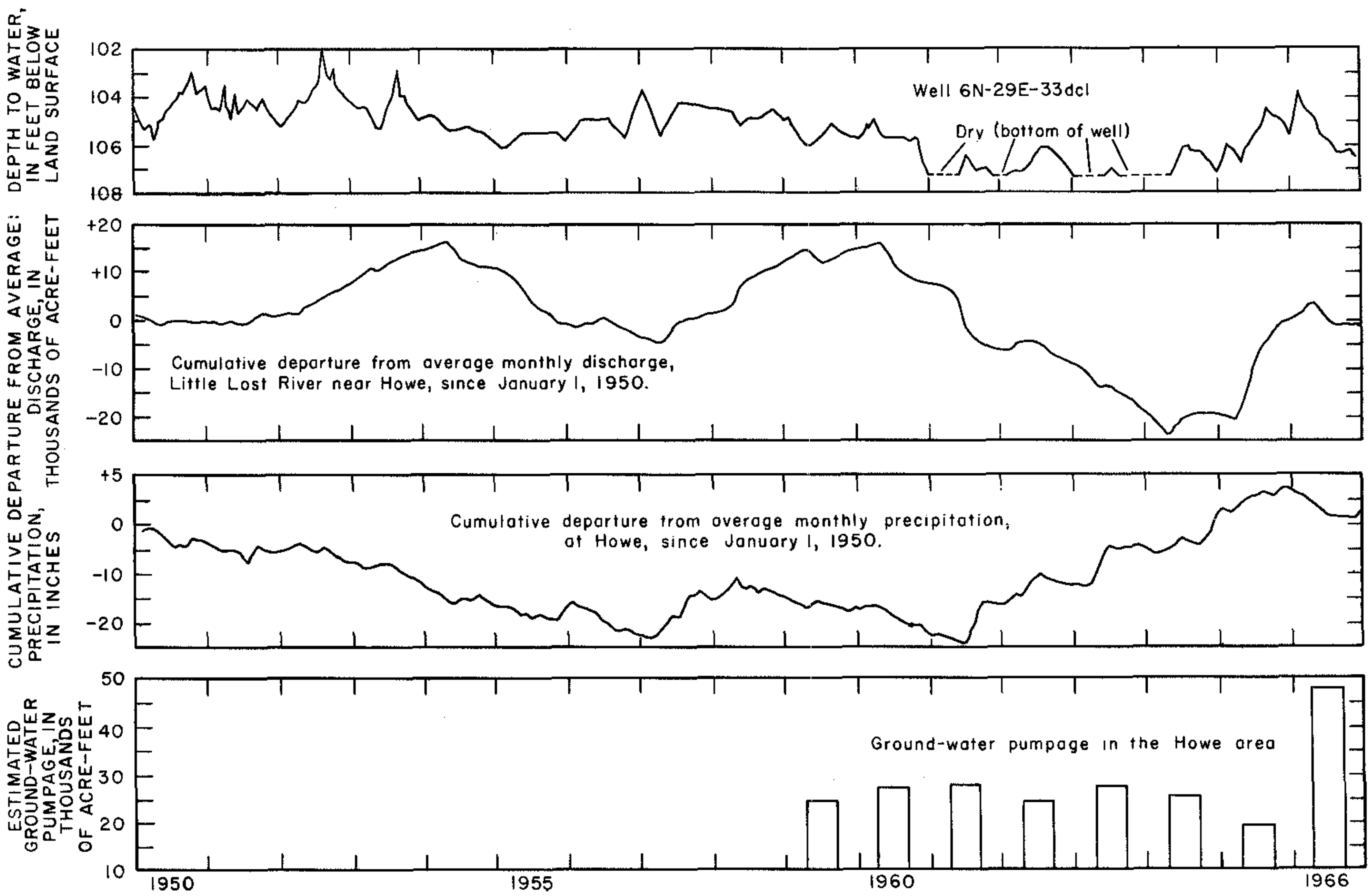


FIGURE 13. Graphs showing fluctuation of water level in well 6N-29E-33dc1, cumulative departure from average discharge of the Little Lost River, cumulative departure from average precipitation, and ground-water pumpage.

The response of the aquifer to the high streamflow of 1965 (the highest since 1946) is shown by a rising water-level change during the period May 1965 to April 1966 (fig. 14).

Assuming a storage coefficient of 0.15, a total of 16,000 acre-feet of water was added to the ground-water during the year in the 36 square mile area of T. 6 N., R. 29 E.

Effect of Ground-Water Withdrawals

A major concern in the Little Lost River valley is whether the withdrawal of ground water has diminished streamflow. This is important from the standpoint of water rights, as the prior water rights in the basin are those for surface water. Other concerns might involve increased pumping lifts due to water-table declines.

The immediate effect of pumping ground water from a well is to remove water from storage in the aquifer in the vicinity of the well. This must be reflected as a conically shaped decline of the water table. The degree to which the decline persists after a period of pumping ends is controlled by many factors: the rate and duration of pumping; the transmissivity and storage coefficient of the aquifer; the proximity and effectiveness of the hydraulic connection to sources of natural recharge or discharge, such as streams; the proportion of the pumped water that is lost to the atmosphere by evapotranspiration; the rate of return to the aquifer by seepage; and other factors.

In aquifers having a relatively high transmissivity and low storage coefficient, the drawdown due to pumping spreads rapidly away from the pumping well and water levels recover quickly after pumping is stopped. Similarly, the effects of recharge spread rapidly.

Although the transmissivity of the alluvial-fill aquifer is relatively high and would tend to spread pumping effects rapidly, the storage coefficient is extremely high, and this tends to counteract the effect of the high transmissivity.

In the lower basin, that is the area within T. 6 N., Rs. 28 and 29 E., withdrawal of ground water has had virtually no net effect on the water table, even though average withdrawals since 1959 have been on the order of 44,000 acre-feet per year and consumptive use of ground water was about 28,000 acre-feet per year. Water level changes between September 1959 and September 1965 did show declines as great as 4 feet in the northwestern part of T. 6 N., R. 29 E., but September measurements commonly include residual drawdown from the summer irrigation season; and in the southeastern part of the township the water table actually rose 2 to 6 feet over an area of more than 6 square miles. Water-level change maps prepared for other periods between 1959 and 1966 illustrate temporary changes, principally in response to such conditions as the excessive runoff of the 1965 water year, which resulted in a water-table rise of 2 to 7 feet between May 1965 and April 1966 (fig. 14).

Effects of ground-water withdrawals in the upper basin have not been substantiated by contouring of water-level changes; well control is inadequate to do so. Furthermore, so many of the wells are within half a mile of perennial streams that the expected effect of

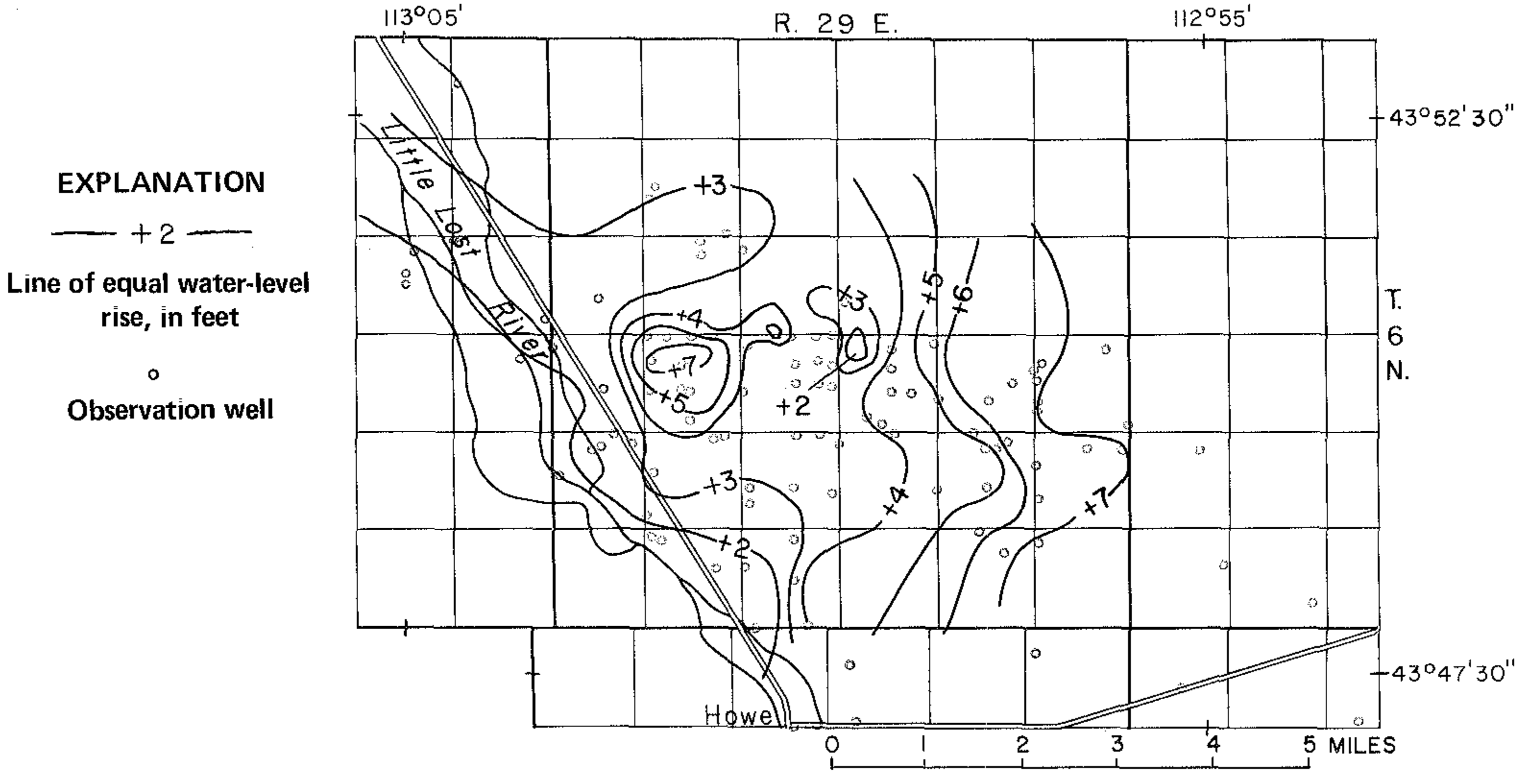


FIGURE 14. Rises in water level from May 1965 to April 1966 in the Howe area.

excessive ground-water withdrawals would be a reduction in streamflow.

Mundorff and others discussed the theoretical reduction in streamflow that might accompany or follow from pumping wells in an aquifer that supplies the base flow of a nearby stream. Their report did not emphasize, however, the limiting assumptions on which the theoretical derivations were based; namely, that the aquifer is homogeneous and isotropic, that the pumped well has an infinitesimal diameter and extends to the bottom of the aquifer, and that water taken from storage in the aquifer is discharged instantaneously with decline in head.

None of the above assumptions is met ideally in the Little Lost River basin. Not all of them are equally critical to the question of decreased streamflow as a result of pumping. The most important departure from the ideal postulated conditions results from the fact that stream alluvium, which is the principal aquifer in the Little Lost River upper basin, is neither homogeneous nor isotropic. Variations in lithology that accompany all sedimentary deposits, in particular the bedding, cause variations in permeability. Probably the second most important deviation from ideal conditions is the fact that none of the wells in the basin penetrate the full thickness of the aquifer. An equally important assumption in the theoretical analysis made by Mundorff is that the stream fully penetrates the aquifer. Obviously, it does not. Thus, it would be expected that the effect of ground-water use on streamflow would be delayed and somewhat less than predicted by theory.

There is, however, an extremely important point in the illustration of the effects of pumping on a nearby stream in the discussion of capture of streamflow by wells by Mundorff and others (1963, fig. 6).

A well two-tenths of a mile from a stream penetrating an aquifer having a transmissivity of 400,000 gpd/ft and a storage coefficient of 0.2 at the end of 100 days of constant pumping theoretically will be taking nearly 90 percent of its discharge from the stream. If, with the same aquifer parameters, the well is 2 miles from the stream, at the end of 100 days it will be taking only 15 to 20 percent of its discharge from the stream.

Although the actual percentages probably would be somewhat lower at the end of 100 days of continuous pumping, for the reasons discussed previously, the large difference in percentage captured is probably valid; and it emphasizes the need to locate wells as far as possible from streams if minimizing the capture of streamflow is of concern.

It would be difficult to detect flow reduction caused by ground-water use during a year of "average" streamflow conditions on the basis of annual totals because the 12,000 acre-feet per year of ground water from wells that is consumptively used in the middle and upper basin is only about 25 percent of the total streamflow, on the order of 50,000 acre-feet. However, comparative measurements of streamflow made throughout the irrigation season probably would show that streamflow is reduced, if it is feasible to account for all the streamflow diversions, waste-water returns, phreatophyte consumption, and other complicating factors.

An inspection of the record of annual discharges for the only gaging station with a sufficiently long record to be meaningful (LL39A) shows no secular trend toward decreased streamflow. The inherent variability of precipitation and other climatic factors that control streamflow mask out any decreasing trend. Unfortunately, the years in which streamflow is average or better are not the ones in which streamflow is most likely to be diminished because of ground-water use. It is when streamflow is already deficient due to natural causes that ground-water use becomes more intensive and the effects may be noticeable.

It does not necessarily follow, however, that pumping will result in decreased streamflow, even in years when streamflow is below normal. If other areas of ground-water discharge, such as wet meadows or substantial tracts of phreatophytes are nearby, water may be captured from them.

In the large irrigated area of the lower basin, the water level changes depicted in figure 14, as well as a comparison of figure 2 with plate 2 of Mundorff and others, 1963, shows that there has been no long-term depletion in the amount of ground water in storage. Water levels are essentially unchanged between 1959 and 1966.

Throughout the lower basin and extending upstream for some distance above gaging station LL39A, the river is perched above the water table (fig. 10). In most of the area, the water table is 50 feet or more below the surface. Thus, the flow of water from the stream channel into the ground-water reservoir in that reach is controlled more by the supply of water and the hydraulic characteristics of the near-surface alluvial materials than by the head gradient between the stream surface and the water table. Lowering of the water table will not increase the rate of infiltration; therefore, the pumping of ground water cannot have affected streamflow in the lower basin.

Even in the lower reaches of the river in the middle basin, the streambed is above the water table. This is illustrated in figure 11 by arrows pointing away from the stream. Although the condition illustrated is based on 1929 data, it very probably holds true today. Of course the flow of springs east of the river could be depleted by pumping from wells and that would reduce streamflow in the main stem by depleting tributary inflow.

WATER BUDGET

A water budget for the Little Lost River basin was computed to determine the various components of flow through the several segments of the basin. Separate budgets were computed for each of the three principal methods of estimating water yield (Langbein, perimeter-inflow, and correlation) as described in the section on Water Supply. Consumptive-use figures are those discussed in the section on Water Use. The water budgets are summarized in table 8.

Obviously, a number of items in the budget are the same in each of the three columns. The estimates of consumptive use are based on the one set of estimates discussed previously. The streamflow measurements, average values of discharge past the gages at the two transects at which water flow is calculated, are the same for all three methods. The

TABLE 8

WATER BUDGET FOR THE LITTLE LOST RIVER BASIN

(acre-feet per year)

	Langbein	Perimeter Inflow	Correlation with Big Lost
	Upper Valley		
Yield	277,000	203,000	157,000
Consumptive use			
Irrigation	5,000	5,000	5,000
Phreatophytes	15,000	15,000	15,000
Outflow	257,000	183,000	137,000
Streamflow	41,000	41,000	41,000
Ground water	216,000	142,000	96,000
	Middle Valley		
Residual	257,000	183,000	137,000
Yield	100,000	58,000	49,000
	357,000	241,000	186,000
Consumptive use			
Irrigation	20,000	20,000	20,000
Phreatophytes	14,000	14,000	14,000
Outflow	323,000	207,000	152,000
Streamflow	55,000	55,000	55,000
Ground water	268,000	152,000	97,000
	Lower Valley		
Residual	323,000	207,000	152,000
Yield	48,000	10,000	18,000
	371,000	217,000	170,000
Consumptive use			
Irrigation	43,000	43,000	43,000
Phreatophytes	7,000	7,000	7,000
Outflow	321,000	167,000	120,000

ground-water component of flow was determined by difference between the calculated total outflow from the reach and the average annual streamflow, based on measured stream discharge.

As an independent check, the ground-water flow past the two gaging stations was also calculated using the transmissivity data discussed in the section on hydraulic characteristics of the alluvial fill, water-table gradients measured in figure 2, and an estimate of the length of the cross section of saturated alluvial fill through which ground water flows. The calculation is based on an expression of Darcy's law $Q = TIL$

where

Q = rate of ground-water flow, gallons per day.

T = transmissivity, gallons per day per foot.

I = hydraulic gradient, feet per mile and

L = length of cross section, miles.

At the section separating the upper from the middle valley, the transmissivity is in the range of 150,000 to 200,000 gallons per day per foot, the gradient is about 50 feet per mile, and the length of section is about 6 miles. Using these values, a discharge of 50,000 to 67,000 acre-feet per year is calculated. Ground-water flow from the middle basin to the lower basin is calculated to be on the order of 146,000 to 175,000 acre-feet per year.

The calculated ground-water outflow from the upper basin is only about a third of the outflow calculated from the perimeter-inflow water budget given in table 8. The calculated ground-water inflow to the lower basin is comparable to the value indicated by the perimeter-inflow method.

As was mentioned in the discussion of hydraulic characteristics of aquifer materials, the transmissivity estimates are believed to be minimal values, as all the available data have been normalized to represent a uniform aquifer thickness of 100 feet. Inasmuch as none of the wells in the basin is reported to reach bedrock, it seems reasonable to assume that the aquifer is thicker than 100 feet. This is thought to be quite likely at the upper location because gravity data (D. R. Mabey, written commun., 1971) suggest that the alluvial fill might be several hundred feet thick. The relatively close agreement between the calculated ground-water flow and the perimeter-inflow water budget at the lower location may be fortuitous, and due to compensating errors. Because of the complicated subsurface geologic structure, the length of the cross section is uncertain, and because of the scarcity of water-level control, combined with the structural complexity the gradient may be in error also.

Outflow from the Basin

The estimated consumptive use on land irrigated with surface water in the lower basin is about 15,000 acre-feet. This represents only 31 percent of the average flow past the Howe gage (48,100 acre-feet) and 34 percent of the average quantity diverted (44,500 acre-feet) during the years 1961-66. (For the purpose of this comparison, the estimated 5,000 acre-feet per year that bypasses the gage is ignored, as it is uncertain whether the diversions include that flow.) The foregoing figures suggest that for the short period for which the data were tabulated, an average of 3,600 acre-feet per year was available but not diverted. Inasmuch as the long-term average flow past the Howe gage is about 50,000 acre-feet, the "unused" surface outflow might be more nearly 4,500 acre-feet. This is probably flow that occurs during the time when irrigation water is not needed.

If it is further assumed that the 15,000 acre-feet is a valid consumptive use figure for 1961-66, then the residual between water diverted (44,500, rounded to 45,000 acre-feet) and consumptive use must be accounted for as water that infiltrates to the water table, surface outflow as waste water, or flow that cannot be used because it occurs during the cold season.

A rough estimate of the amount of water added to the ground-water reservoir is provided by figure 14. Although strictly applicable only to the period May 1965 to April 1966, the data provide a conservative figure of the water added to the aquifer in a typical year. Using a storage coefficient of 15 percent and the volume indicated by the contours of water-level change, a total of 16,000 acre-feet was added to the aquifer only beneath the area of T. 6 N., R. 19 E. The total recharge for the 1-year period might be as much as 20,000 acre-feet, but it is not likely to be more because (1) practically all the irrigated area is within that township and (2) diversions in 1965 amounted to 63,600 acre-feet, well above the average for the 6-year period.

It follows then that the difference between surface-water diversions (45,000 acre-feet) and the sum of consumptive use (15,000 acre-feet) and water added to ground-water storage (20,000 acre-feet) is outflow from the basin, or 10,000 acre-feet.

Although the foregoing calculations are based on only rough approximations, they do indicate that a significant fraction of the water yield of the basin leaves the basin as surface flow. This conclusion is strengthened by the fact that the average flow for the period to which the calculations apply was at least 10 percent below the long-term average, and the quantity estimated to infiltrate to the water table is high and the residual surface outflow is minimal. If the total outflow from the basin is about 167,000 acre-feet, as indicated in table 8, the residual ground-water outflow is on the order of 157,000 acre-feet.

An independent check of that figure is difficult to make with any confidence because of the same uncertainties discussed earlier in connection with underflow estimates, and in addition, there is evidence of a strong vertical component of head gradient which cannot be evaluated quantitatively.

The total thickness of the aquifer system beneath the lower valley is unknown, but it may be several hundred feet. The fact that the water-bearing rocks, whether basalt or well-sorted coarse alluvial materials, are interbedded with silt and clay beds, is well documented in drillers' logs published in Mundorff and others (1963).

Using the apparent gradient at the southern limit of the basin as indicated in figure 2 (100 feet per mile), a transmissivity of 1,000,000 gpd/ft, and a length of cross section of 7 miles, the calculated outflow is 780,000 acre-feet per year -- an unreasonably high figure probably biased by a spuriously high apparent gradient influenced by strong vertical flow components. Using the average gradient through the northeastern part of T. 6 N., R. 28 E. and T. 6 N., R. 29 E., a transmissivity of 1,000,000 gpd/ft, and a length of section of 5 miles results in a discharge of 94,000 acre-feet per year.

Total Quantity of Ground Water in Storage

Data with which to make firm estimates of the total quantity of water in storage do not exist. It is possible to calculate such a volume by making several rather tenuous assumptions, but it is emphasized that the validity of the result is questionable. Moreover, the usefulness of the total quantity of water in storage in water management is also questionable because streamflow and ground water interact as a dynamic system; a hydraulic stress applied to any one part of the system is reflected as a change in some other part of the system, the nature of the change being controlled by the laws of fluid dynamics and the physical properties of the materials through which the change is propagated.

The items necessary to calculate the total volume of ground water in storage are the width, length, and thickness of the aquifer, plus its effective porosity, equivalent, in this case, to its storage coefficient inasmuch as it is a water-table aquifer.

Reasonable approximations of the width and length of saturated alluvial fill can be made from figure 2. However, the thickness is unknown. Aquifer thickness can be estimated at three transects by assuming that the rate of ground-water underflow indicated by the intermediate of the three water budgets is correct. The three transects are (1) the downstream end of the basin, (2) a line separating the middle and lower basins through gaging station LL39A, and (3) a line separating the middle and upper basins, through gaging station LL27A. It is further assumed that the transmissivity values derived in the section on hydraulic characteristics of the alluvial fill apply only to the upper 100 feet of saturated material, and that the average permeability of the underlying sediments is similar to that of the material penetrated by wells. An apparent saturated thickness can then be computed. The volume of water in storage is then calculated by applying a coefficient of storage (0.15 for the lower basin and 0.2 for the middle and upper basin) to the total volume.

	Mean length (miles)	Mean width (miles)	Mean thickness (feet)
Lower	11.0	5.5	170
Middle	19.4	6.1	190
Upper	13.8	6.5	210

The computed total volume of water in storage in the valley fill is on the order of 6.3 million acre-feet.

CONCLUSIONS

On the basis of this reanalysis of hydrologic information for the Little Lost River basin, the following conclusions are drawn.

1. The results of this investigation indicate that the total water yield is considerably larger than indicated by earlier hydrologic analyses. For this study, three independent methods indicate total yields of 224,000; 271,000, and 424,000 acre-feet per year. Virtually all the water yield is produced in the mountains and reaches the valley either as surface runoff or ground-water underflow. Outflow from the basin is on the order of 167,000 acre-feet per year, of which about 157,000 acre-feet is ground water.

2. The alluvial-fill aquifer in the middle and upper valley and combined alluvial fill and basalt aquifer system of the lower valley are highly transmissive. Transmissivity ranges from about 150,000 to 1,000,000 gpd/ft and storage coefficient is about 0.2. The water-table gradient is steep. The computed average annual rate of underflow far exceeds the average annual rate of surface runoff.

3. The amount of water stored per unit volume of aquifer material is large. Assuming that the aquifer is about 200 feet in thickness, the total quantity of water in storage is on the order of 6.3 million acre-feet.

4. The annual rate at which additional water can be developed for use by man depends on a number of complex factors, including the location of the proposed new water use and the acceptability of the ensuing hydrologic or economic consequences. This analysis indicates that on the average about 10,000 acre-feet of surface water leaves the basin unused. Most of this loss probably takes place during years when runoff is in excess of diversion needs, although some loss may occur even in years when streamflow during the irrigation season is deficient. This surplus water might be most effectively used through some artificial-recharge scheme.

5. Additional consumptive use of ground water in the upper basin and upper reaches of the middle basin, especially where wells are very near the stream, is likely to diminish streamflow during periods when streamflow is already deficient due to natural causes.

6. Additional consumptive use of ground water in the lower basin will not affect streamflow. Very extensive additional development of ground water would ultimately reduce the ground water contribution from the Little Lost River basin to the Snake Plain aquifer and would result in increased pumping lifts. Although the rate at which additional ground water could be developed without increasing

pumping lifts to an unacceptable degree depends in part on the amount of surface water that infiltrates to the water table after application; such effects probably would not be serious unless additional annual average consumptive use exceeded 20,000 acre-feet for a period of several years.

7. Future hydrologic investigations in the Little Lost River basin should consider the collection of the following kinds of data.

    a. Measurements of irrigated acreage by type of crops, consumptive use by crop, quantity and disposition of waste water, and other data necessary to evaluate quantitatively the infiltration of applied surface water.

    b. Seepage losses in canals.

    c. Depletion of streamflow in response to pumping of wells near the river. This will require seepage measurements of the river during controlled pumping of a large well or a well field with emphasis on low flow conditions in gaining reaches.

8. Consideration should be given to the development of a model to simulate response of the hydrologic system to various hydraulic stresses. Although the detailed data with which to develop a predictive model are not available (nor is there a management need for a highly sophisticated model), data are now adequate for the development of a model that would test flow concepts and with which to guide future data collection.

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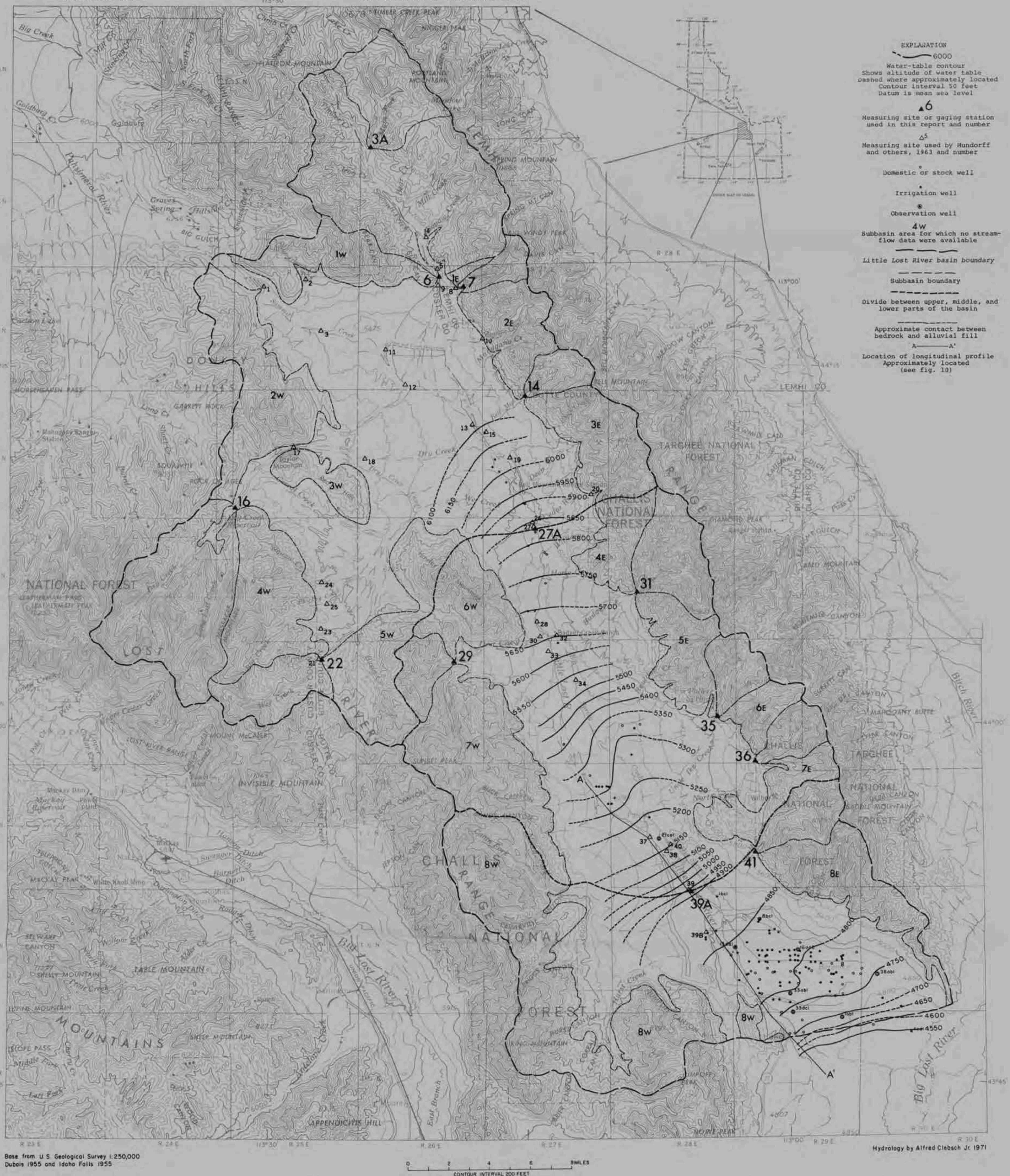
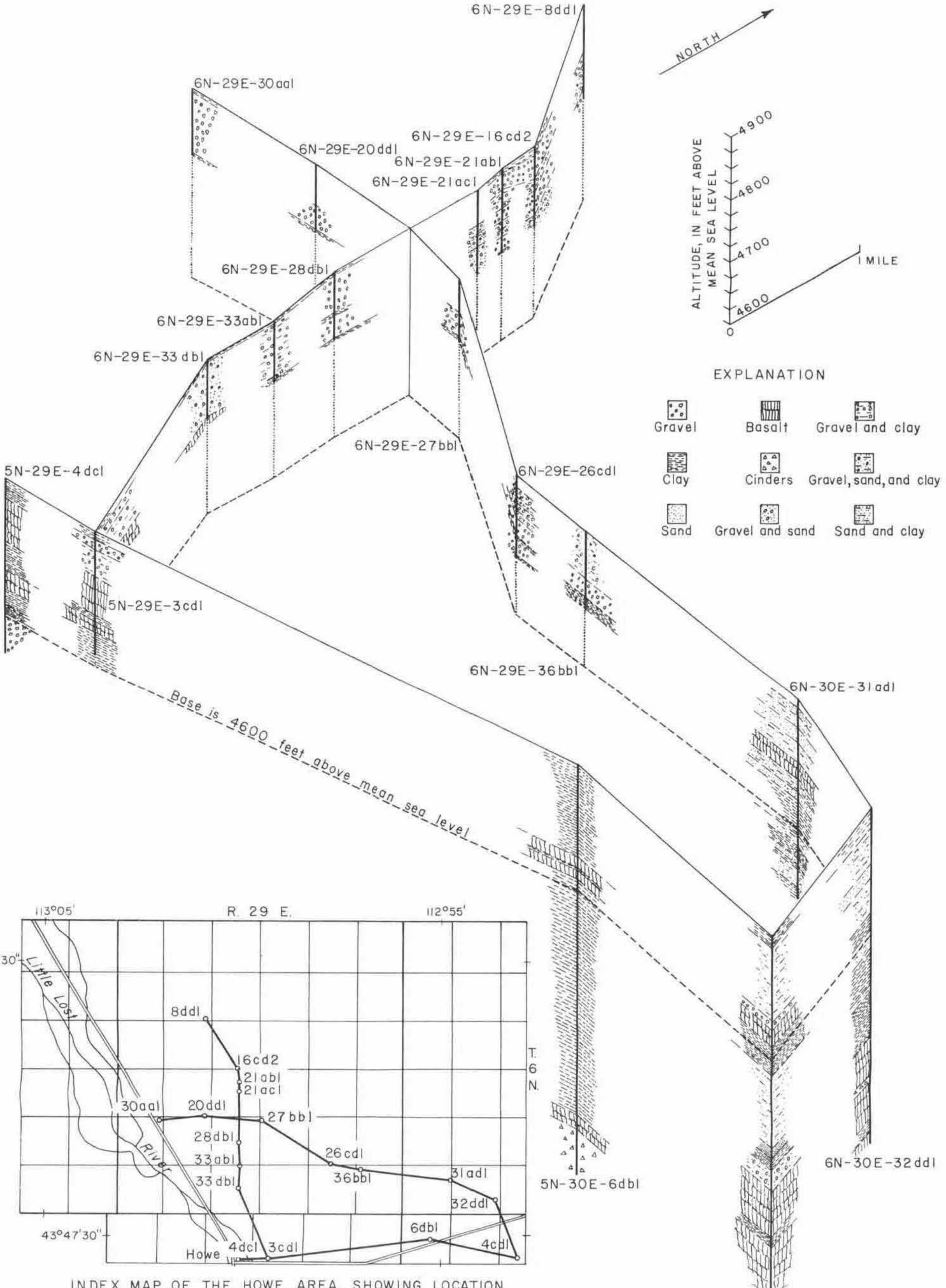


FIGURE 2.-- LITTLE LOST RIVER BASIN, IDAHO, SHOWING DRAINAGE BASIN BOUNDARIES, WATER-TABLE CONTOURS, APRIL 1966, DISTRIBUTION OF WELLS, AND LOCATION OF SURFACE-WATER MEASURING SITES.



INDEX MAP OF THE HOWE AREA SHOWING LOCATION OF THE FENCE DIAGRAM

Figure 3.-- Fence diagram showing the subsurface geology of the Howe area.