GROUND-WATER INFLOW TO THE DESCHUTES RIVER NEAR THE WARM SPRINGS INDIAN RESERVATION, OREGON, AUGUST 1985

By E. L. Bolke and Antonius Laenen

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ILLUSTRATIONS

[Plate is in pocket]

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CONVERSION FACTORS

For the convenience of readers who may prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
	<u>Length</u>	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	<u>Area</u>	
square mile (mi^2)	2.590	square kilometer (km^2)
	<u>Volume</u>	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	<u>Flow</u>	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

<u>Sea level</u>: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

Ground-water inflow to the Deschutes River near the Warm Springs Indian Reservation was estimated for August 1985 by (1) measuring streamflow at various sites along the river, (2) determining the portion of the streamflow that is ground-water discharge, and (3) analyzing the hydraulic gradients of the ground-water flow system to estimate the quantity of ground-water discharge to the Deschutes River from both sides of the river.

Results of streamflow analysis indicated that the Deschutes River gained 415 cubic feet per second between Round Butte Dam and Dant in August 1985. Results of the analysis on hydraulic gradients of the ground-water flow system indicated that the quantity of ground-water inflow from the west side ranged from about 207 to 216 cubic feet per second, and for the east side ground-water flow ranged from about 199 to 207 cubic feet per second.

September 1985 streamflow measurements along the Metolius River from the site above Jefferson Creek to the site below Camp Creek indicated a gain of 70 cubic feet per second. From the site below Camp Creek to the gage above Lake Billy Chinook, the results of discharge measurements indicated a loss of 112 cubic feet per second. Because of lack of ground-water lithologic and hydraulic data, no analysis of the ground-water flow system near the Metolius River was attempted.

INTRODUCTION

The Warm Springs Tribes need to know the total ground-water contribution from the Reservation to the Metolius and Deschutes Rivers so that they can support their legal claim to that water right in perpetuity.

The study area is in Jefferson and Wasco Counties in north-central Oregon, includes the Warm Springs Indian Reservation, and covers about 2,400 square miles (fig. 1). The study area includes the natural surface drainage from the point where the Deschutes River enters the area, south of Lake Billy Chinook, to where the river leaves the area, near Dant. The western boundary of the study area is the Cascade Range, and the eastern boundary is the Ochoco Mountains and associated uplands. Major tributaries to the Deschutes River within the study area are the Metolius River and the Warm Springs River.

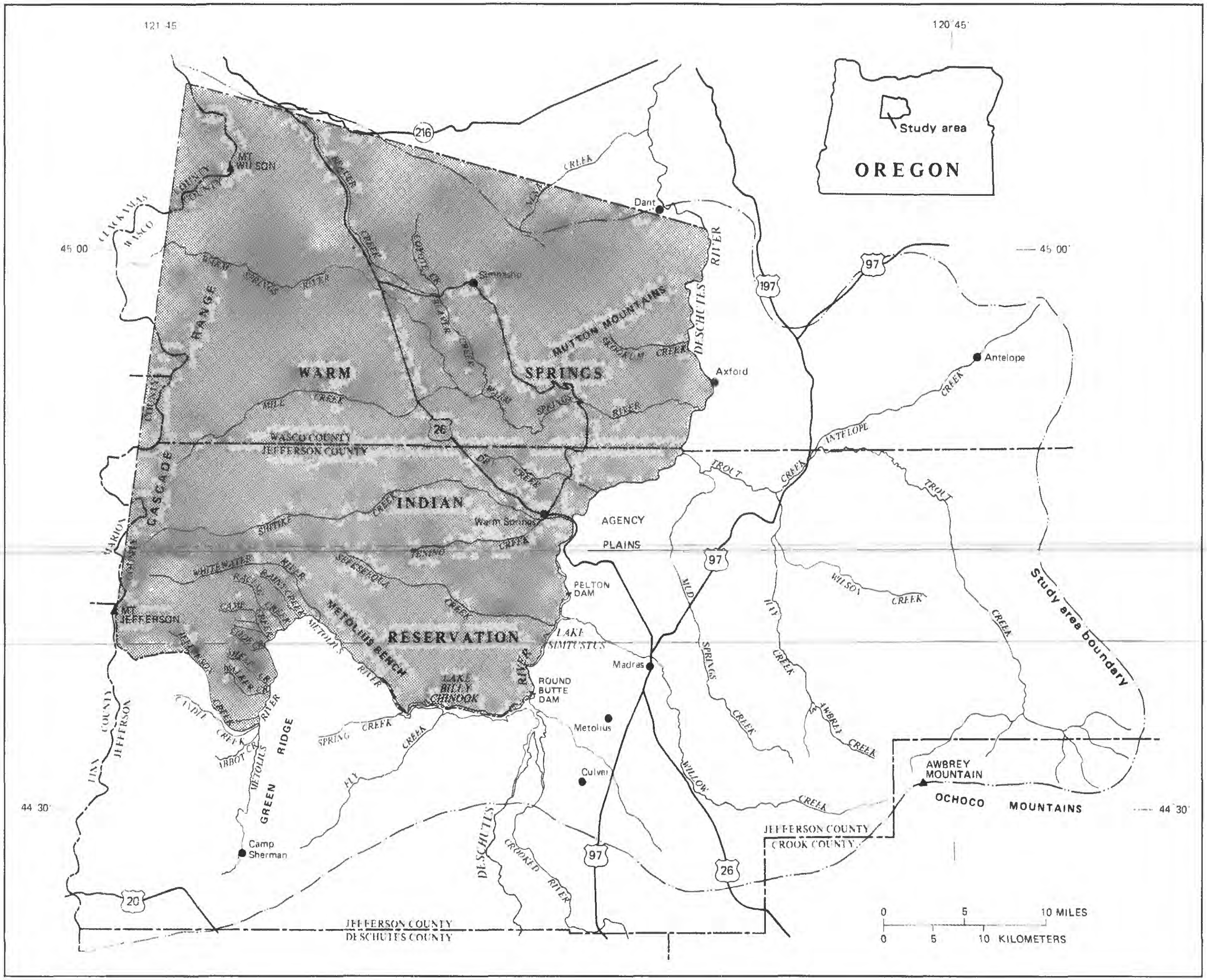

Figure 1.--Location of study area.

The Warm Springs Indian Reservation was established in 1855 by treaty with the Tribes of Middle Oregon and is now known as the Confederated Tribes of the Warm Springs Reservation. The Reservation covers about 1,000 square miles and is bounded on the east by the Deschutes River, on the south by the Metolius River and Jefferson Creek, on the west by the Cascade Range, and on the north by a line drawn from near Mt. Wilson to the Deschutes River near Dant, as shown in figure 1.

Land use includes irrigated crop farming, timber harvesting, cattle grazing, and recreation. Irrigation of crops from surface-water and ground-water sources occurs principally east of the Deschutes River. The quantity of irrigation water derived from ground-water sources is minor when compared to the quantity of irrigation from surface-water sources. Most ground water pumped from wells in the study area is for public supply, domestic, or stock uses.

Purpose and Scope

The purpose of this report is to present the results of a study of the water resources of the Warm Springs Indian Reservation. The purpose of the study was to (1) determine the ground-water contribution, during low-flow conditions, to the Deschutes and Metolius Rivers bounding the Warm Springs Indian Reservation, and (2) if feasible determine the portion of ground water contributed from aquifers underlying the Reservation to the rivers during the low-flow period.

The study involved two elements: (1) identifying total gains and losses in the Deschutes and Metolius Rivers by measuring streamflow of the rivers and all their tributaries and (2) using existing ground-water hydrologic data to separate the total ground-water discharge into flow components from each side of the Metolius and Deschutes Rivers.

Data for this study were collected from June 1985 to September 1986, but mostly in August 1985. The methods of data collection are discussed in later sections of this report. This study was done in cooperation with the Confederated Tribes of the Warm Springs Reservation.

Previous Studies

Previous water-resources work in the area includes a report by Robison and Laenen (1976), for which the authors determined the flow of major streams, the yield of water to wells and springs, and the quality of water of the Warm Springs Indian Reservation. Stearns (1931) discussed the geology and water resources of the middle Deschutes River basin. Bechtel Corporation (1958) prepared feasibility and geology reports for Portland General Electric Company relative to construction of Round Butte Dam on the Deschutes River. A report on the geologic and hydrologic conditions at the Pelton Dam site on the Deschutes River was prepared for Portland General Electric Company by Stearns (1957).

Acknowledgments

The assistance of officials of the Confederated Tribes of the Warm Springs Reservation, U.S. Bureau of Indian Affairs, and Portland General Electric Company is gratefully acknowledged. The cooperation and

assistance of the numerous land owners who permitted access to their property for well inventories and boat measurements is likewise gratefully acknowledged.

HYDROGEOLOGIC SETTING

Generalized geology of the study area, shown on plate 1, was adapted from geologic maps by Walker (1977), Wells and Peck (1961), Robinson and Stensland (1979), Robinson (1975), and Robison and Laenen (1976). Rocks in the study area range in age from pre-Tertiary to Holocene. For purposes of this report, each formation shown on plate 1 is briefly discussed in regard to its hydrologic significance. The report by Robison and Laenen (1976) contains a more detailed description of the hydrogeologic properties of each formation, and the following discussion mostly summarizes their work.

The Clarno Formation and older sedimentary rocks, shown as a single unit, are the oldest exposed rocks in the study area. The older sedimentary rocks include phyllite, slate, and graywacke and are exposed only in a small area near Aubrey Mountain. The Clarno Formation probably underlies most of the study area and is exposed in the northern and eastern part of the area. The Clarno Formation consists principally of altered greenish-gray andesite and basalt of unknown thickness and, where penetrated by wells, yields only small quantities of water. No known wells in the study area have been drilled into the older sedimentary rocks. Similarly, the John Day Formation probably underlies most of the study area and is exposed in much of the eastern and north-central part of area. Its outcrop area extends south to a point near Pelton Dam. The formation is chiefly air-fall and water-deposited ash and tuff, welded tuff and volcanic flows. The John Day Formation yields only small quantities of water to wells.

The Columbia River Basalt Group is a series of basalt flows exposed in the northeastern part of the study area and along the Deschutes River as far south as Round Butte Dam. The basalt is not known to be penetrated by wells on the west side of the Deschutes River. Wells on the east side of the river in the vicinity of Madras indicate that moderate quantities of water can be obtained from the basalt.

The Madras Formation consists of lake and river deposits of sandstone, clay, conglomerate, tuff, and some layers of basalt. This formation underlies much of the Warm Springs Reservation, the area south of the Metolius River, the area extending east of the Deschutes River to Hay Creek and to the vicinity of the city of Culver. The formation has been deeply incised by streams. Many of the wells in the uplands on the west side of the river are finished in the Madras Formation and yield moderate quantities of water.

Overlying the Madras Formation are basalt flows which form most of the plateaus in the study area and are locally known as "rimrock." Generally unsaturated, these basalt flows yield small quantities of water to wells in the uplands on the Warm Springs Reservation.

The west side of the study area is part of the Cascade Range, which is composed of andesite and basalt lava flows and volcanic breccia. Locally, large springs issue from the andesite, particularly near faults or fractures in the uplands, but the permeability of this formation is highly variable, and individual wells may yield only small quantities of water.

A local deposit of gravel derived from andesite of the Cascades lies in the northwestern part of the study area. Alluvium, which consists of gravel, sand, silt and clay, occurs discontinuously along streams. Both the gravel and alluvium yield moderate to large quantities of water to wells, but these materials are limited in areal extent.

The relative thicknesses and stratigraphic relations of the various formations are shown by generalized geologic sections (pl. 1), which were constructed by using data derived from drillers' logs and from several Master of Science theses from Oregon State University. Subjects of these theses include: the geology east of Deschutes River, Jefferson County, by Hayman (1983); the geology south of the Metolius River and near Round Butte Dam, by Hewitt (1970); a geologic quadrangle map near Prineville, by Thormahlen (1984); and the geology and stratigraphy of the volcanic rocks in the vicinity of Lake Simtustus and the city of Madras, by Jay (1982). (The formational thicknesses of the gravel and alluvium are not shown because they are discontinuous in the area and are relatively insignificant.)

The thicknesses of the Clarno and John Day Formations and the andesite of the Cascades are unknown. The thickness of the Columbia River Basalt Groups as determined by extrapolation and by well penetration varies from about 500 feet at section A-A^1 (pl. 1), to about 100 feet at section C-C^1 (pl. 1), to an unknown thickness in the northeastern part of the study area. The thickness of the Madras Formation varies from about 1,000 feet at section A-A^1 near Round Butte Dam to about 100 feet in sections B-B^1 and C-C^1. This formation generally tapers to a feather edge on the east side of the study area. The thicknesses of the basalt flows overlying the Madras range from 0 to about 300 feet.

Hydraulic Characteristics of Geologic Units

The geologic units in the area have different hydraulic characteristics, which were determined from specific-capacity data for wells in the study area. Values of horizontal hydraulic conductivity were calculated from estimates of transmissivity that were obtained from specific-capacity tests of about 75 wells using the method of Theis, Brown, and Meyer (1963). Of the 75 wells, about 10 percent are completed in the John Day and older formations. These values compare favorably with values obtained in other studies by the U.S. Geological Survey, particularly with values obtained from studies of the basalts of the Columbia River Plateau (Packard and others, U.S. Geological Survey, written commun., 1987). The range of available horizontal hydraulic-conductivity values for the hydrogeologic units in the study area is shown in table 1.

Table 1.--Hydraulic conductivity of geologic units

Hydrogeologic unit	Horizontal hydraulic conductivity range (feet per second)
Alluvium	1.0×10^{-2} -- 1.0×10^{-3}
Madras Formation	1.0×10^{-5} -- 1.0×10^{-6}
Columbia River Basalt Group	6.0×10^{-4} -- 1.0×10^{-5}
John Day Formation	1.0×10^{-6} -- 1.0×10^{-7}
Clarno Formation and older sedimentary rocks	1.0×10^{-7} -- 1.0×10^{-8}

GROUND-WATER INFLOW

Surface Water

Streamflow measurements were made at selected sites on the Deschutes River and its tributaries to determine the ground-water contribution to or from the river. Eight sites on the Deschutes River and one on each of ten tributaries were measured during the period August 20-22, 1985. These sites are shown in figure 2.

During the period September 22-26, 1986, streamflow measurements were made at three sites on the Metolius River and at several sites on tributaries to the Metolius River (fig. 2). All streamflow measurements are published by U.S. Geological Survey (1987).

Because differences between flow measurements indicate gains or losses in the stream, measurement accuracy is important. Recommended methods were used and extra care was taken in the measurement of stream discharge. Measurement accuracy is stressed in the following sections.

Deschutes River

Streamflow measurements of the Deschutes River downstream of the reservoirs were made with a standard Price AA[1] current meter. The same instrument was used for all measurements to insure the best possible relative accuracy for measuring differences. Streamflow measurements of the Deschutes River in the reservoir (Lake Simtustus) were made using an acoustic current meter (ACM) because velocities in the lake are slow and irregular and the ACM has a resolution of ±0.006 ft/s (feet per second). Velocity data were obtained at five points (0.1, 0.2, 0.4, 0.6, and 0.8 of the depth) in each of 20 verticals in the section. Because of the number of velocity measurements and the resolution of the ACM, the ACM measurements are considered accurate to within ±0.9 percent (determined by methods described by Rantz and others, 1982).

[1]Use of brand names in this report is for identification purposes only and does not constitute an endorsement by the U.S. Geological Survey.

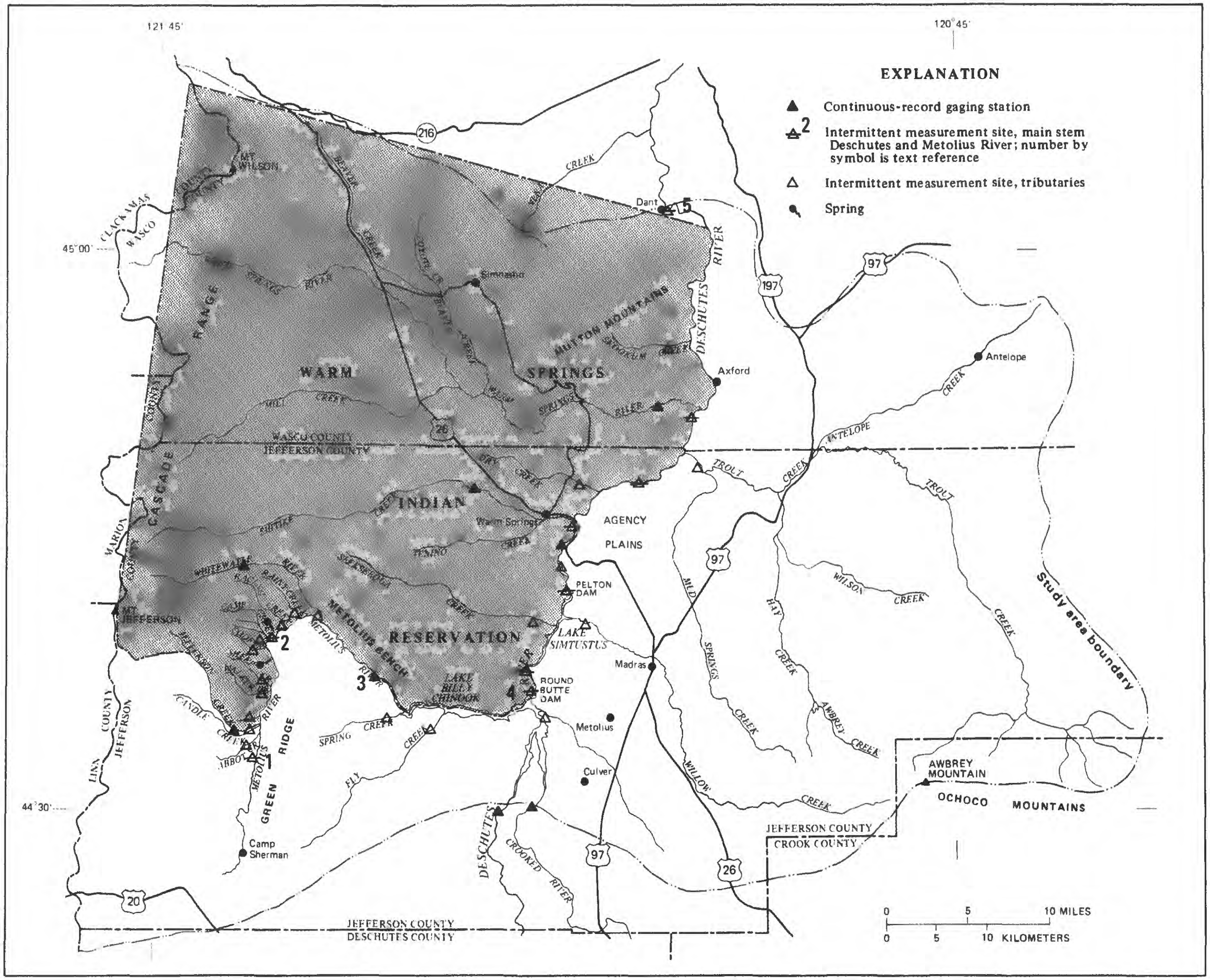

Figure 2.--Location of streamflow-measurement sites.

Three measurements were made to define the correlation between the Price meter and the ACM. These measurements were made at velocities that averaged 0.6 ft/s and had differences of +1.1, -0.3, and -2.6 percent. Additional velocity-measurement correlations between the Price AA meter and the ACM were made by using a moving boat. A boat was used to tow both meters at various speeds and the results were recorded for each. An average error of 2.5 percent resulted from 13 runs--6 measurements positive and 7 negative. The tests verified that both meters registered similar velocities and that there was no bias.

All measurements made for this study attempted to improve the accuracy of methods prescribed by Rantz and others (1982). That report contains the statement, "If single discharge measurements were made at a number of gaging sites using standard methods recommended in this manual, the errors of two-thirds the measured discharges would be less than 2.2 percent." Accuracy of a steady-flow discharge measurement is dependent on the ability to measure cross-sectional area without bias, to accurately measure velocity at points in the vertical, and to calculate the mean velocity from the point velocities.

For measurements made in this analysis, three precautions were used to minimize the error: (1) all measuring sections had regular bottoms (usually of gravel); (2) an adequate sounding weight was used, so that no wet-line correction was necessary; and (3) simultaneous fathometer soundings were made at each section to help define the entire cross section and to increase the number of statistical depths. Because of the aforementioned precautions and because of the uniform hydraulic cross sections (regular flow and cross-section geometry), the accuracy of the measurement made in the river by the Price AA meter is considered to be within ±1.2 percent.

The measured discharge of the Deschutes River below Round Butte Dam (site 4, fig. 2) was 3,572 ft^3/s (cubic feet per second) on August 22, 1985, and the measured discharge at Dant (site 5, fig. 2) was 4,350 ft^3/s on August 20, 1985. Measurements were adjusted to compensate for regulation of Deschutes River discharge from Round Butte and Pelton Dams on the basis of hourly turbine-power data. Other variations in streamflow during the measurements were small and had negligible effect. No elevation change occurred in Lake Simtustus during the measurements. The difference (778 ft^3/s) in discharge below Round Butte Dam and at Dant is the total ground-water and tributary inflow to the Deschutes River in this reach for this time period. The error associated with the streamflow measurements, as mentioned above, is about ±1.0 percent. Applying this error to the net ground-water contribution between Round Butte Dam and Dant gives a range of 698 to 858 ft^3/s, or ±10-percent error.

The total tributary inflow to the Deschutes River between Round Butte Dam and Dant was measured as 363 ft^3/s for the period August 7-15, 1985. Subtracting this sum from the total measured gain (778 ft^3/s) gives 415 ft^3/s, which represents the gain due to ground-water inflow directly to the Deschutes River between Round Butte Dam and Dant.

Metolius River

Streamflow measurements were made during the period September 22-26, 1986, at three sites on the Metolius River: site 1--Metolius River above Jefferson Creek; site 2--Metolius River below Camp Creek; and site 3--Metolius River above Lake Billy Chinook (fig. 2). Several springs and several small tributaries to the Metolius were also measured during the same period. All measurements were rated as ±3-percent accuracy, principally because of the nature of the hydraulic cross section at measuring sites.

From results of discharge measurements, it appears that the Metolius River gains in discharge from site 1 to a point between Camp Creek and the Whitewater River. The occurrence of numerous springs along the left bank of the Metolius River in the upper reach above Camp Creek indicates that it is a gaining reach. No spring flow or tributary inflow was observed in the upper reach of the Metolius along the right bank. Thus, most of the gain to the Metolius River above Whitewater River probably originates from springs and seepage on the left bank. From the mouth of Whitewater River to Lake Billy Chinook, no spring flow was observed along either bank of the Metolius River, and the river lost water during the measurement period.

Summing streamflow downstream along the Metolius River from the measuring site above Jefferson Creek to the site below Camp Creek indicates a gain of about 70 ft^3/s. From the site below Camp Creek to the gage above Lake Billy Chinook, the results of discharge measurements indicate a loss of 112 ft^3/s. A total net loss of streamflow of about 42 ft^3/s was estimated for the length of the Metolius River between sites 1 and 3. A net gain of 29 ft^3/s was measured on the Whitewater River between the continuous gage site and the river mouth (fig. 2). Although the gain in streamflow in the upper reach of the Metolius River can generally be supported by the occurrence of numerous springs, the loss in streamflow in the lower reach cannot be verified by using ground-water hydraulic-head data because there are no known wells near the river.

Because possible measurement error may equal the net loss (42 ft^3/s) in the Metolius River between the site below Camp Creek and the gage above Lake Billy Chinook and because supporting ground-water hydraulic-head data are not available, streamflow losses cannot be substantiated. However, it appears that the Metolius River loses water in the reach from Camp Creek to Lake Billy Chinook. Because of lack of supporting ground-water data, no further analysis of the flow system near the Metolius River was attempted.

Ground Water

Most of the ground water in the study area moves from natural recharge areas in the Cascade Range and the Ochoco Mountains through the geologic units (pl. 1) to discharge areas in and near major streams. The Deschutes River is probably the discharge sink for the study area. Individual water-bearing units or aquifers have not been delineated for this report because of the lack of definitive data. The entire ground-water flow system is regarded as a single water-bearing unit.

Ground-water discharge to the Deschutes River between Round Butte Dam and Dant, as derived previously from streamflow measurements, was calculated to be 415 ft^3/s in August 1985. Ground-water inflow was calculated for seven subreaches of the Deschutes River. These subreaches and the amount of gain from ground water are shown in figure 3. The largest inflow to the river occurs in the first subreach below the dam and represents discharge from numerous spring and seepage areas in the vicinity of the dam. According to a geology report by Bechtel Corporation (1958, p. 12), "...that the water table is contributing to the river flow in this area rather than drawing from it is evidenced by the large number of springs present throughout and adjacent to the reservoir site." The report indicated that in the reservoir area all of the sizeable spring flow (1 ft^3/s or greater) observed came from or could be clearly attributed to basalt flows. After the publication of the Bechtel report, many of these springs and seepage areas have been inundated by Lake Billy Chinook. A preliminary comparison between discharges of inflowing streams to Lake Billy Chinook and the discharge of the river below the lake, as adjusted for regulation, indicates a gain of nearly 400 ft^3/s. Although, the area above and below the reservoir is represented, the preliminary comparision does not include evaporation from the reservoir. Nonetheless, the comparison lends plausibility to the occurrence of large gains in the Deschutes River discharges over relatively short distances. Conversely, the lowermost reach, above Dant, showed no ground-water inflow to the river. Nearly all of this lowermost reach is underlain by John Day and Clarno Formations. As was indicated earlier in this report, these units yield only small quantities of water to wells because of their low values of hydraulic conductivity. Because of these low values, it is probable that most of the precipitation on this area runs off directly to streams, rather than recharging the ground-water system. The values (rounded) shown in figure 3 represent the total ground-water contribution from both sides of the Deschutes River.

A map showing the ground-water potentiometric surface for the study area was compiled from about 75 well measurements made during August 1985 (fig. 4). Existing ground-water data are sparse and poorly distributed, both laterally and vertically. There is only about one well for every 20 square miles of study area, and about 80 percent of the wells are relatively shallow in depth (less than 500 feet). Because of these constraints, the potentiometric surface was derived by using water levels from available wells. Thus, the potentiometric surface shown in figure 4 is a generalized composite of known water-level data and probably represents the regional distribution of water levels for the study area. Ground water flows "normal" (at right angles) to the contour lines shown in figure 4.

Some water moves from irrigated areas or from natural recharge areas downward through the unsaturated soil zone to the potentiometric surface, and some water from irrigated areas or from natural recharge areas moves downward to zones of low permeability, where it is shunted laterally to emerge as springs or seeps along cliff faces. These springs and seeps were observed principally in the Deschutes River canyon, but also along cliff faces in some of the tributary canyons.

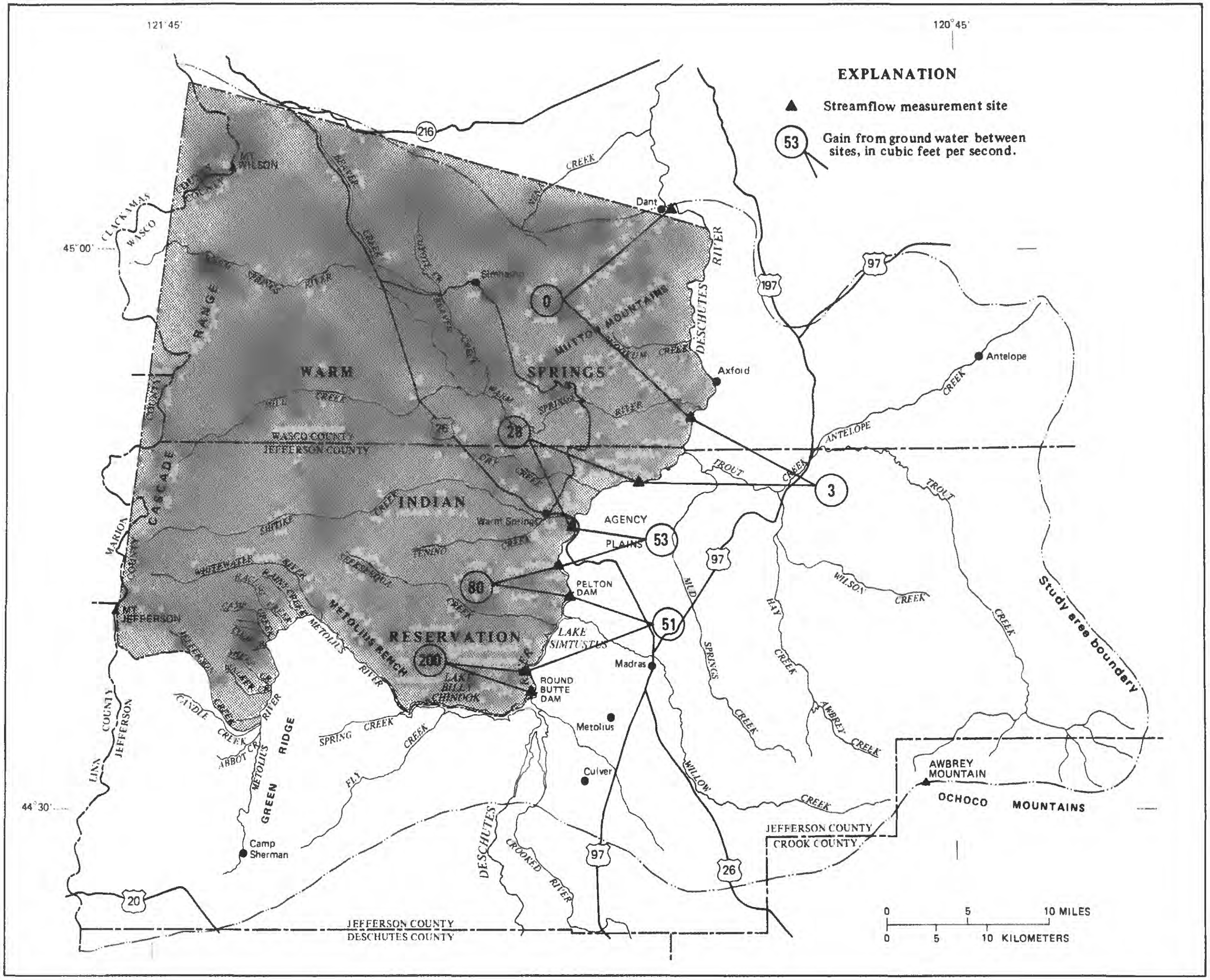

Figure 3.--Gain in Deschutes River discharge from ground water.

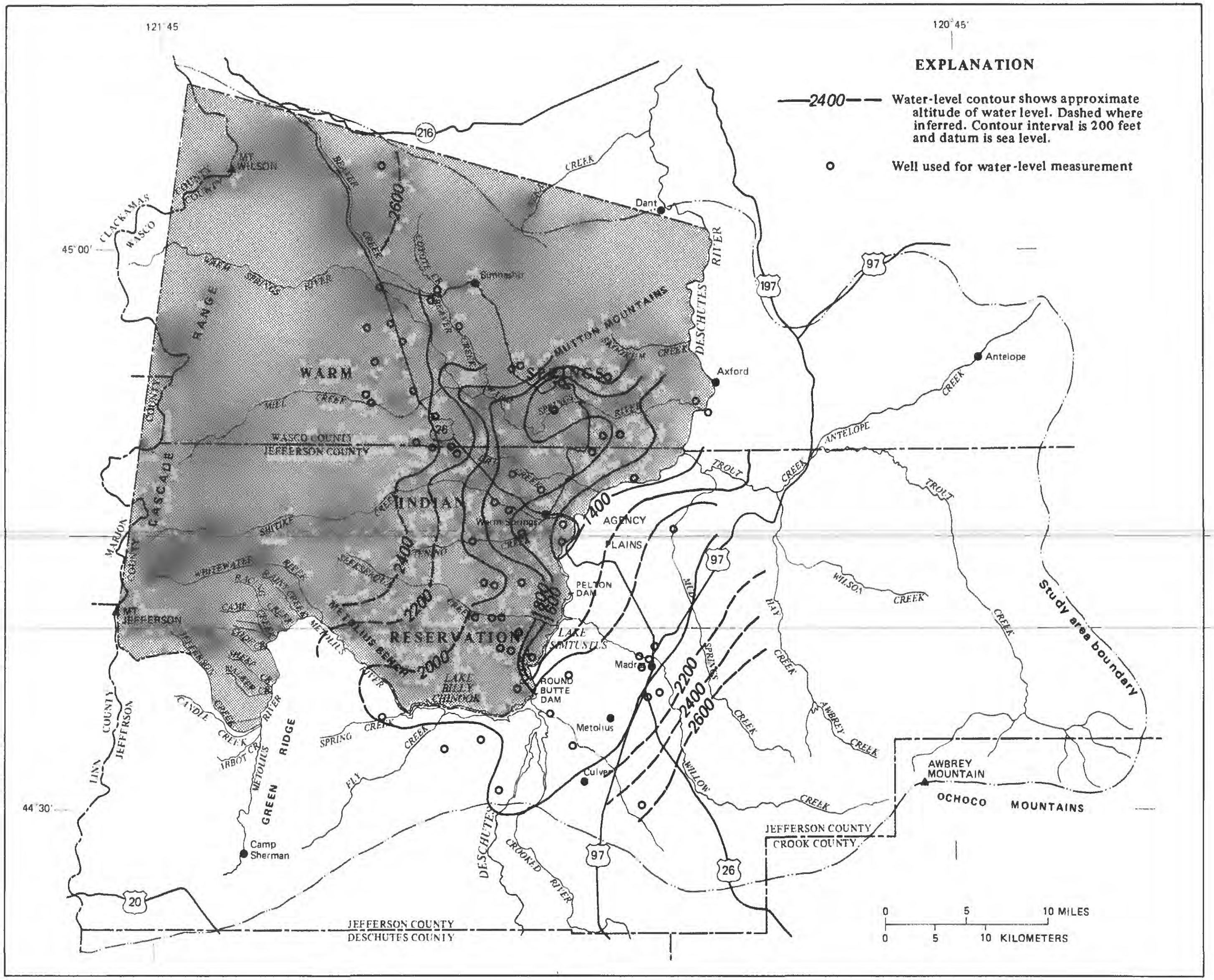

Figure 4.--Generalized ground-water potentiometric surface, August 1985.

Ground-water recharge and discharge in the study area are thought to be in dynamic equilibrium. No long-term water-level declines are apparent, and no large ground-water withdrawals are being made. The hydrograph of water levels for the Madras city well (fig. 5) is probably representative of local water levels. The seasonal declines in the hydrograph probably result from pumping for public supply, whereas the long-term changes in the hydrograph may be caused by climatic changes.

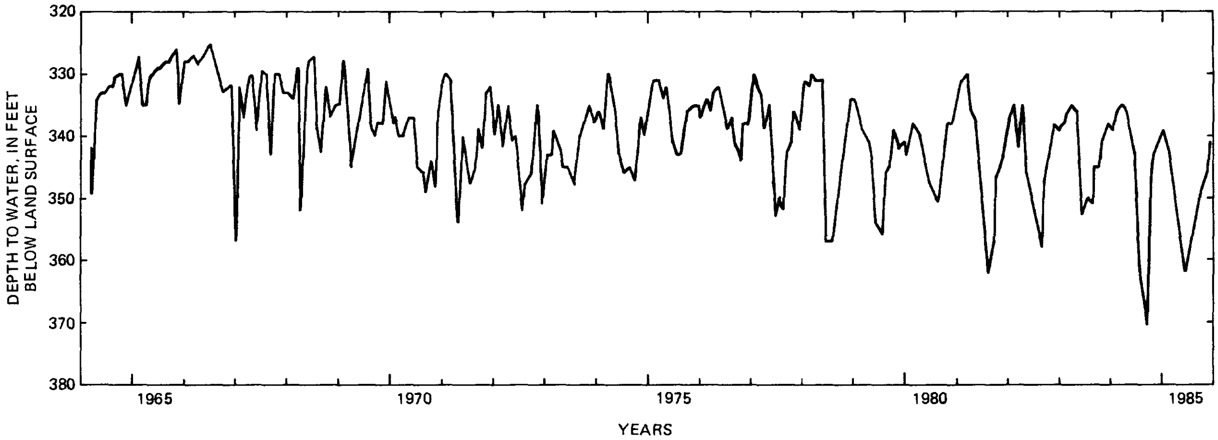

Figure 5.--Water levels for Madras city well number 1, 1964-85.

Two test wells, located about one-half mile northwest and southwest respectively of Round Butte Dam, showed water-level rises of about 100 feet, from 1962, when storage behind the Dam began, until about 1975, when the water level behind the dam stabilized. The ground-water rises were caused by filling of Lake Billy Chinook behind Round Butte Dam. Water levels in these wells have remained nearly unchanged from 1975 to 1985. Water levels in all other wells measured within the study area during the period July 1985 to September 1986 show only small seasonal changes, ranging from 1 to 4 feet.

Proportional Ground-Water Discharge to the Deschutes River

One of the purposes of this study was to determine the feasibility of separating the total ground-water discharge to the Deschutes River into east and west components, using existing data. The constraint of using only existing data precluded drilling new wells to obtain additional lithologic and hydraulic data.

Initially, in an attempt to determine the east and west components of the total ground-water discharge, three digital-computer cross-sectional flow models were constructed to coincide with the three geologic sections shown on plate 1. The intent of the models was to simulate steady-state ground-water discharge from each side of the Deschutes River at each of the three sections and then to extrapolate the results to appropriate river reaches of the Deschutes River between Round Butte Dam and Dant. However, during development of the models it was concluded that insufficient data existed, particularly at depths greater than 500 feet, to verify the model results. Without sufficient data to corroborate the model-calculated hydraulic-head distribution at depth, the models as constructed were regarded as preliminary.

Subsequently, because the model results were preliminary, the separation of total discharge into east and west components was made using a more simplified method as follows.

A form of Darcy's Law that is frequently used in ground-water hydraulics problems for flow through porous media is

$$Q = K \times B \times W \times I, \qquad (1)$$

where

Q = ground-water discharge (L^3/T),
K = average lateral hydraulic conductivity of geologic units (L/T),
B = average thickness of geologic units (L),
W = width of section perpendicular to flow direction through which discharge occurs (L), and
I = average hydraulic gradient parallel to flow direction; equals the change in head per unit change in distance (L/L).

Discharge for each side of the river can be calculated by applying equation (1) along lines of equal hydraulic potential, such as the contour lines shown in figure 4, provided that values for K, B, W, and I can be determined. In the study area in the vicinity of the Deschutes River, W and I can be determined, but K and B are poorly known. However, even though K and B are poorly known, if the product of K, B, and W can be assumed to be approximately equal for each side of the river, then for each side the value of Q differs only by the value of I. Thus, if the total ground-water discharge to the Deschutes River is known, it can be proportioned into east and west components on the basis of different hydraulic gradients. The total ground-water discharge to the Deschutes River between Round Butte Dam and Dant in August 1985, as determined from streamflow measurements, was 415 ft^3/s.

The hydraulic gradients of the ground-water flow system near the Deschutes River range from about 51 to 134 feet per mile, as determined from figure 4. The average gradients were determined for each side of the Deschutes River from Round Butte Dam to the confluence of Warm Springs River. The average gradients were calculated along nine equally-spaced transects of the contours on each side of the river between the 1,600- and 2,000-foot contours. The gradients were determined far enough away from the river to avoid large vertical head differences that may be associated with convergent flow to the river. The average gradients thus determined were about 78 feet per mile (0.0148) for the west side and about 72 feet per mile (0.0137) for the east side. The west side gradient was 52 percent (0.0148/(0.0137 + 0.0148)) of the total, and the east side gradient was 48 percent (0.0137/(0.0137 + 0.0148)) of the total.

On the basis of the assumption stated above and proportioning the discharge in relation to the hydraulic gradient, 52 percent of the total ground-water discharge (415 ft^3/s), or 216 ft^3/s, is contributed from the west side of the river and 48 percent, or 199 ft^3/s, is contributed from the east side.

However, the assumption that the products of K, B, and W are the same for each side of the river may not be valid; also the lines of equal hydraulic potential may be different from those shown in figure 4; for example, additional data would more accurately define the contours. Because of these uncertainties and because the difference between the calculated discharges from the east and west sides of the river is small (4 percent of the total discharge), it can be reasonably inferred that the average gradients may be approximately the same for both sides of the river. Equal average gradients and equal values for K, B, and W translate to about 207 ft^3/s of ground-water discharge from each side of the river.

Ground-water discharge to the Deschutes River, as summarized from the above analysis, was estimated to range from about 207 to 216 ft^3/s for the west side of the river to about 199 to 207 ft^3/s for the east side. The discharge occurs between Round Butte Dam and the confluence of the Deschutes River and the Warm Springs River. Below the confluence with the Warm Springs River to Dant there is no discernible gain or loss in the Deschutes River.

NEED FOR ADDITIONAL WORK

In order to improve the estimates for the amounts of ground-water discharge from each side of the Deschutes River and to apportion discharge for the Metolius River, there is a clear need for additional ground-water data. It would be desirable to drill test wells to depths as great as 2,000 feet. The test wells would provide lithologic and hydraulic data about the ground-water flow system.

As noted in the previous section, sufficient hydraulic-head data at depth is not available to verify model results. If new test wells could be drilled to allow for better definition of the head distribution in the flow system, a three-dimensional model analysis could become practical. However, the costs of drilling numerous wells to adequately define the flow system may preclude additional work.

SUMMARY

One of the purposes of this study was to determine the feasibility of proportioning the total ground-water discharge to the Deschutes River into east and west components based on available data. An attempt to proportion the discharge through use of digital-computer models proved unsuccessful because of the lack of data needed to verify model results. A more simplified method, a form of Darcy's Law for flow through porous media, was used to apportion the discharge.

The amount of ground water that discharged directly to the Deschutes River between Round Butte Dam and the confluence with Warm Springs River, as calculated from streamflow measurements, was 415 ft^3/s during August 1985. Calculations for the river reach from the confluence of the Warm Springs River to Dant indicated no ground-water inflow to the river during this period. An analysis of the hydraulic gradients in the ground-water flow system on both sides of the Deschutes River between Round Butte Dam and the confluence of Warm Springs River indicated that the quantity of ground-water inflow from the west side ranged from about 207 to 216 ft^3/s, and for the east side from about 199 to 207 ft^3/s. These amounts, determined during low-flow conditions, are probably affected seasonally and annually by changes in the hydraulic gradient in the ground-water system. As it appears from sparse data, however, there probably are no large seasonal or annual variations in ground-water levels in the system.

The quantity of measured ground-water inflow (415 ft^3/s) did not include water that seeped to tributaries of the Deschutes River. Rather, that water was accounted for by streamflow measurements of those tributaries and thus was regarded as surface runoff.

Streamflow measurements in September 1985 along the Metolius River from the site above Jefferson Creek to the site below Camp Creek indicated a gain of about 70 ft^3/s. From the site below Camp Creek to the gage above Lake Billy Chinook, the results of measurements indicated a loss of 112 ft^3/s. The lack of ground-water data precluded further analysis of the relation between streamflow and the ground-water flow system near the Metolius River.

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