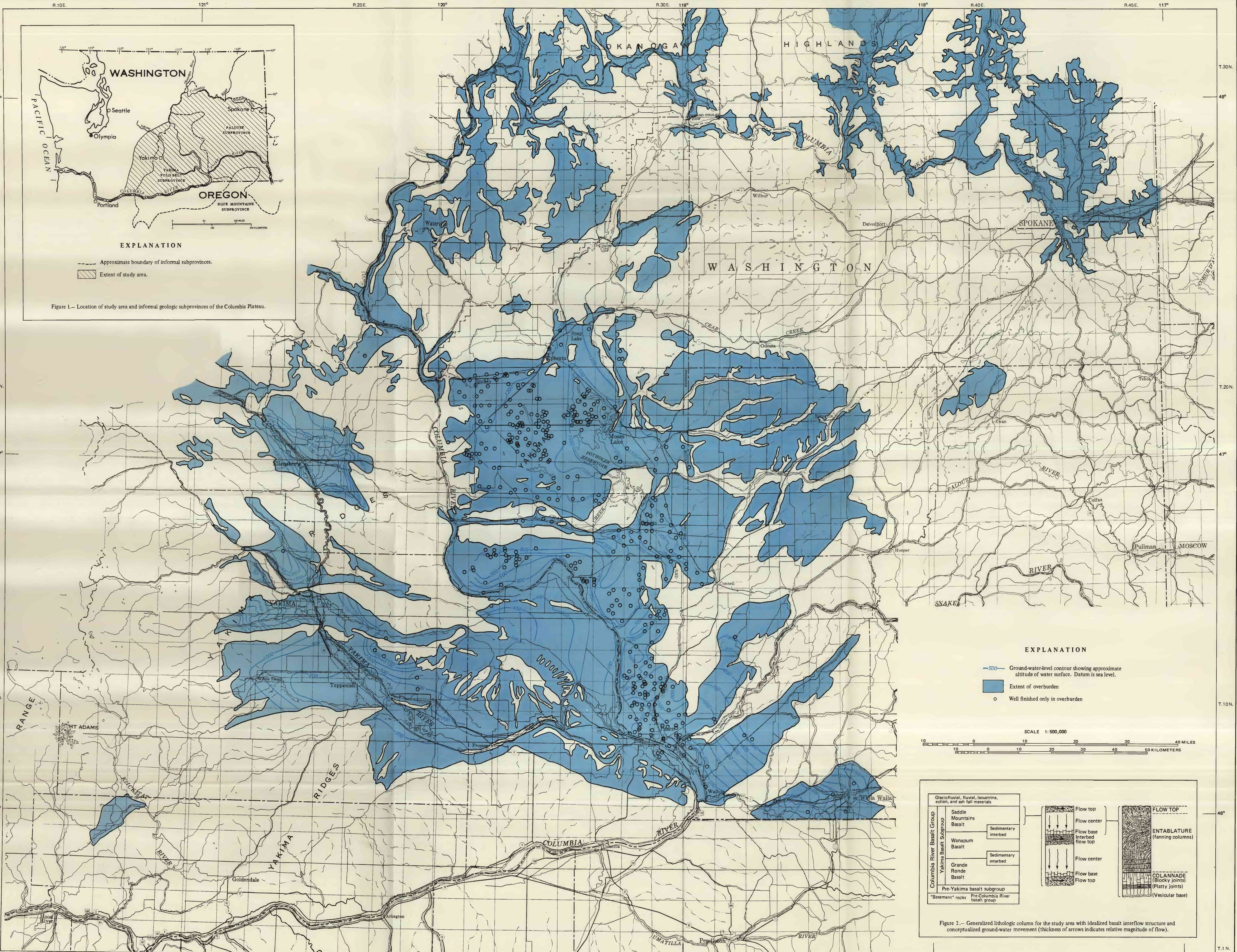

EXPLANATION

Approximate boundary of informal subprovinces.

Extent of study area.

Figure 1.– Location of study area and informal geologic subprovinces of the Columbia Plateau.

EXPLANATION

—500— Ground-water-level contour showing approximate altitude of water surface. Datum is sea level.

Extent of overburden

o Well finished only in overburden

SCALE 1:500,000

10 0 10 20 30 40 MILES

10 0 10 20 30 40 50 KILOMETERS

Figure 2.– Generalized lithologic column for the study area with idealized basalt interflow structure and conceptualized ground-water movement (thickness of arrows indicates relative magnitude of flow).

GROUND-WATER LEVELS IN THE COLUMBIA RIVER BASALT AND OVERLYING MATERIALS, SPRING 1983, SOUTHEASTERN WASHINGTON STATE

By

H. H. Bauer, J. J. Vaccaro, and R. C. Lane

ABSTRACT

Ground-water-level contour maps for three major aquifers of the Columbia River Basalt Group and for the major portions of the saturated overlying materials in Washington State were constructed using water levels measured at about 1,100 wells during spring 1983. Additional data were obtained from other U.S. Geological Survey studies in the area and by other indirect methods. Configuration of the ground-water-level contours is controlled by (1) distribution of natural and man-induced recharge and discharge, (2) hydraulic conductivity distribution in the system, and (3) pumpage. Upgradient flexures of water-level contours north of Connell, Washington, show effects of prolonged irrigation pumpage, and downgradient flexures in an area south of Potholes Reservoir in the vicinity of the East Low Irrigation Canal show the effects of increased man-induced recharge.

INTRODUCTION

The Columbia River Basalt Group underlies about 25,000 square miles of Washington State (fig. 1 on plate 1). Within much of this area, aquifers in the basalts are the principal source of water for irrigation, stock, rural domestic, and municipal use. The economy of the area is largely dependent on irrigated crops. Reconnaissance-level studies undertaken in recent years in parts of the Columbia Plateau in Washington State have indicated locally high sodium concentrations in the ground water. Irrigation water with high sodium content relative to calcium and magnesium tends to disperse the clays within the soil structure, which can lead to a decrease in soil permeability and cause irrigation water to be retained at the surface, away from plant roots where it is needed. Soil crusting, or hardening upon drying, can also occur.

In March 1982, the U.S. Geological Survey, in cooperation with the Washington State Department of Ecology, initiated a 2½-year study of the Columbia Plateau in Washington to define the spatial and temporal variability of dissolved-sodium concentration in the ground water of the Columbia River Basalt Group and to relate this to the ground-water flow system and its geologic environment. This report is one in a series of three that, collectively, describes (1) the ground-water flow system, (2) the geologic framework, and (3) the occurrence and quality of the ground water underlying the Columbia Plateau in Washington State.

This report illustrates and describes the spring 1983 configurations of the potentiometric surfaces for (1) the Grande Ronde Basalt, (2) the Wanapum Basalt, (3) the Saddle Mountains Basalt, and (4) the overlying unconsolidated materials and consolidated sediments.

Ground-water-level contours were constructed using the following information: (1) ground-water-level data obtained from about 1,100 wells in spring 1983, when water levels are at their seasonal high prior to summer pumping, (2) Geological Survey studies nearing completion (G.B. Deeter, F.A. Packard, D.R. Cline, and R.C. Lane, written commun., 1984), and (3) previous studies (Prych, 1983; MacNish and Barker, 1976; Tanaka and others, 1974; U.S. Geological Survey, 1975; Luzier and Skrivan, 1973; Brown, 1981; Barker, 1979; and Wilbur, 1983).

ACKNOWLEDGMENTS

The cooperation of the well owners, tenants, and well drillers who supplied information and allowed access to wells is gratefully acknowledged.

GEOLOGIC AND HYDRLOGIC FRAMEWORK

The Columbia Plateau is underlain by the Columbia River Basalt Group, a complex series of layered basalt flows with relatively minor amounts (when considered on a regional scale) of interbedded sediments, all of Miocene Age. The lowest part of the plateau, both topographically and structurally, is near Pasco, Wash. The overlying sedimentary materials are of Pliocene to Holocene Age. Along the margins of the plateau, the basalts are underlain by sedimentary, metamorphic, and granitic rocks (Precambrian to early Tertiary Age). In the interior, the nature of the underlying rocks is not well known. A generalized lithologic section for the study area is shown in figure 2 on plate 1.

Individual basalt flows range in thickness from a few inches to about 300 feet. The structure of an individual flow generally consists of three sections (fig. 2). From bottom to top they are: the colannade, the entablature, and the flow top. The basal colannade, commonly 20 percent of the flow thickness, consists of nearly vertical three- to eight-sided columns formed by vertical jointing during the slow cooling and contraction of the flow interior. The individual columns average about 3 feet in diameter and 25 feet in length, and are commonly crosscut by horizontal joints. Porous pillow structures, caused by underwater cooling, are locally present at the base of the colannade, and a vesicular zone may be present above. The entablature, generally comprising 70 percent of the flow thickness, consists of small-diameter (averaging less than a foot) columns in fan-shaped arrangements. The presence of irregular cross-jointing produces a hackly or friable structure. At times the upper part of the entablature is vesicular. The flow top (sometimes called the interflow) generally consists of vesicular basalt and clinker, and averages about 10 percent of the total thickness of a single flow. The most permeable water-bearing zone is usually the flow top where as the entablature is generally less permeable. The layered, jointed structure and permeability disbribution induce primarily lateral ground-water movement in the flow tops and vertical movement through the fractures of the colannade and entablature.

The Columbia Plateau in Washington can be subdivided into three informal structural subprovinces, according to Myers and Price (1979): the Yakima Fold Belt subprovince, the Palouse subprovince, and the Blue Mountains subprovince (fig. 1). The Yakima Fold Belt subprovince is characterized by long, narrow, tightly folded anticlines and broad intervening synclines trending in an easterly to southeasterly direction from the western margin of the plateau toward its center. The folds are generally asymmetrical with the steeper limbs to the north. Most of the major faults associated with anticlinal fold axes are thrust or reverse faults and are probably contmeporaneous with the folding. Northwest-to-northeast-trending shear zones and minor folds commonly transect the major folds. The Palouse subprovince is characterized by a regional dip to the southwest of less than 5 degrees and by a small number of broader, gentler folds of northeast and northwest orientation. The Blue Mountain subprovince is a broad, east-northeast-trending anticline with large structural relief that extends from central Oregon into the southeast corner of Washington. The anticline is cut by a series of north-to-northwest-trending faults that are nearly vertical. Beneath the basalts, the core of the anticline is composed of folded, faulted, and metamorphosed rocks of late Paleozoic and Mesozoic age.

In the project area, land-surface features tend to reflect the underlying geologic structure. The mountains are generally anticlines and the valleys generally synclines, and in the Palouse subprovince north of the Snake River the basalts have a gentle southwesterly dip slope, parallel to land surface, toward the south center of the project area.

The basalts and interbeds comprise the regional aquifer system of the Columbia Plateau. In general, changes of hydraulic head occur with depth at any given location. In this study, the regional multiaquifer system has been conceptualized as consisting of four major aquifers corresponding to the three upper basalt formations and the sedimentary overburden materials. The water-level contours presented for an aquifer are intended to represent the vertically averaged areal hydraulic head distribution for that formation, insofar as the data permitted.

Within the study area, the Columbia River Basalt Group is composed primarily of the Grande Ronde, Wanapum, and Saddle Mountains Basalts. The Grande Ronde Basalt underlies virtually all of the study area and is exposed mainly along the plateau margins and in the canyons of the Columbia and Snake Rivers near the central part of the study area. Its thickness ranges from a few feet along the northern margin, where it pinches out against the older rock, to at least 4,000 feet and perhaps as much as 9,000 feet in the central and southwest parts of the study area. The Grande Ronde Basalt is composed of at least 30 and perhaps as many as several hundred individual flows of mainly aphyric texture. Sedimentary interbeds within the Grande Ronde Basalt are rare and generally are only a few feet thick where present. These interbeds, as is common with virtually all the interbeds in the Columbia River Basalt Group, range in composition from clay to sand and gravel. A sedimentary interbed (called the Vantage Sandstone Member of the Ellensburg Formation in the central area) lies between the Grande Ronde Basalt and the overlying Wanapum Basalt in much of the study area. Where present, this interbed averages about 25 feet in thickness and ranges from nearly 0 to 100 feet or more.

The Wanapum Basalt underlies most of the study area and is exposed or is covered by only a veneer of sedimentary or colluvial material throughout most of the northern half of the study area. In the southern half, the Wanapum Basalt is generally covered by thick sequences of sediments or by the Saddle Mountains Basalt, or both. The Wanapum Basalt averages about 600 feet in thickness, ranging from a few feet where it pinches out against exposures of the Grande Ronde Basalt to more than 1,600 feet in the southwest part of the study area. The Wanapum Basalt may contain as many as 10 flows. Most Wanapum Basalt flows are medium grained and slightly to moderately plagioclase-phyric. Sedimentary interbeds in the Wanapum Basalt are more common than in the Grande Ronde Basalt, but are still rather rare and generally only a few feet thick where present. A sedimentary interbed (informally called the Mabton interbed of the Ellensburg Formation) lies between the Wanapum Basalt and the overlying Saddle Mountains Basalt in the southwest part of the study area. This interbed averages about 50 feet in thickness, but ranges from nearly 0 to at least 150 feet.

The Saddle Mountains Basalt is found mainly in the south-central part of the study area, where it is either exposed at the land surface or is covered by sediments. The Saddle Mountains Basalt averages about 600 feet in thickness in the south-central part of the study area, with maximum thicknesses of more than 800 feet near Pasco, Wash. The Saddle Mountains Basalt flows vary greatly in texture and composition. Sedimentary interbeds in the Saddle Mountains Basalt are common and rather thick, commonly 50 feet or more.

GROUND-WATER LEVEL CONFIGURATION

The configuration of the ground-water-level surfaces for the three basalt units and for the overburden are shown on plates 1 through 4. The overburden is generally in direct hydraulic communication with the immediately underlying basalts. Where thick enough, the overburden materials compose a water-table aquifer and provide ground water for domestic and stock use and in some places for irrigation.

The ground-water surface in the Saddle Mountains Basalt appears roughly to parallel land surface where there is little or no overburden. This is particularly noticeable at the higher elevations, where there are greater amounts of precipitation and probably more recharge. Water levels in shallow wells in these areas typically are only a few tens of feet below land surface. The lateral ground-water flow in this basalt is generally toward major surface-drainage features, but there are numerous local variations where small and intermediate-sized streams abstract base flow from the Saddle Mountains Basalt. This pattern of local variations occurs for the Wanapum Basalt and for the Grande Ronde Basalt where they are not overlain by the younger basalts or by a great thickness of overburden. (Plates 1 through 4 also show the extent of the formations.) Otherwise, flow in the Wanapum and Grande Ronde Basalts is controlled less by local surface-drainage patterns and more by the major rivers, streams, and coulees. Within the Palouse subprovince north of the Snake River the regional ground-water flow is generally to the southwest, roughly paralleling the regional dip slope of the basalts. Regional discharge is to the Columbia and Snake Rivers. In the Quincy Basin (between the Columbia River and Potholes Reservoir within the Yakima Fold Belt subprovince), ground-water movement in the Wanapum Basalt is toward Moses Lake and Potholes Reservoir. The dominant pattern in the Yakima Fold Belt, however, is ground-water movement downward from the anticlinal axes toward the streams and rivers lying within the intervening synclines.

In most areas, water-table conditions exist in the uppermost basalt flows, but owing to the wide difference between the horizontal and vertical hydraulic conductivities, the deeper aquifers of the Columbia River Basalt Group are generally semi-confined. In general, fine grained, tight interbed and flow-center rock units compose the semi-confining beds for the underlying flows. The hydraulic connection between flows is sufficient to allow some continuous vertical movement of water between them. From the water-level data, it appears that over most of the plateau, the vertical component of flow is downward except near discharge areas. A few anomalies to this overall pattern exist due to certain geologic structures of uncertain nature and due also to heavy pumping in some areas. Newcomb (1961) cited lateral flow impediments resulting in upward flow caused by faulting in the basalts for locations near Walla Walla and in the Cold Creek syncline east of Yakima in Washington, and southwest of the Dalles in Oregon. More recent work by the Survey (Frank A. Packard, written commun., 1984) has investigated an area of the Horse Heaven Hills in Washington, where wells tapping the Wanapum Basalt are artesian, but approximately 2 miles downgradient to the southeast the water levels are approximately 340 feet lower. The vertical head gradient is upward northwest of the impediment and downward southeast of the impediment.

More recently, ground-water pumping for irrigation has disturbed the regional pattern. The effects of pumping on ground-water level contours can be seen in the Connell, Wash., area, which extends from near Connell in a northerly direction towards the Odessa-Lind area (plate 3). The area shows a large upgradient bending or flexure of the contours, typical of lowered water levels.

The relation that surface-water bodies have to the ground-water flow system is also shown on plate 3. Downgradient flexures of the water-level contours near lakes and streams indicate flow into the aquifer, the upgradient flexures indicate ground-water discharge to lakes and streams. Both phenomena are found in the north-central and northeast parts of the study area, which include numerous lakes. The streams and lakes of the Channeled Scablands, in the northeast part of the study area, appear for the most part to be draining ground water from the Wanapum Basalt. Water-level contours near Crab Creek Valley, the Palouse Canyon, the Columbia Gorge, the Snake River Valley, and Grand Coulee indicate major ground-water drains.

Steep water-level gradients are depicted on the flanks of the Horse Heaven Hills, Frenchman Hills, Rattlesnake Hills, and Saddle Mountains anticlines. Wherever there are water-level data from locations on the flanks of anticlines and in other areas where the basalts are steeply dipping, lateral water-level gradients appear to be approximately equal to or slightly less than the structural gradients. This phenomenon is assumed to hold in similar areas where there is a lack of data. Water-level contours were drawn accordingly.

The effects of man-induced recharge on the water-level configuration are shown by the downgradient contour flexure just below Potholes Reservoir, between the 1,100- and 800-foot contours, where the large East Low Irrigation Canal, which is part of the Columbia Basin Irrigation Project, runs along the downgradient flexures.

Water levels in the deeply buried parts of the Wanapum and Grande Ronde Basalts show significant differences, even though there are much fewer data to establish water-level contours. Where data do exist, as in the south-central part of the plateau, water-level contours appear to be less influenced by the smaller surface drainage features, and consequently have a smoother form. This can be seen on plates 3 and 4. The "smoothing" is due, at least in part, to the fact that recharge to and discharge from the deeply buried basalts occurs by mainly vertical leakage to and from the overlying basalts, rather than by direct physical contact with surface-water bodies or drainage features.

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