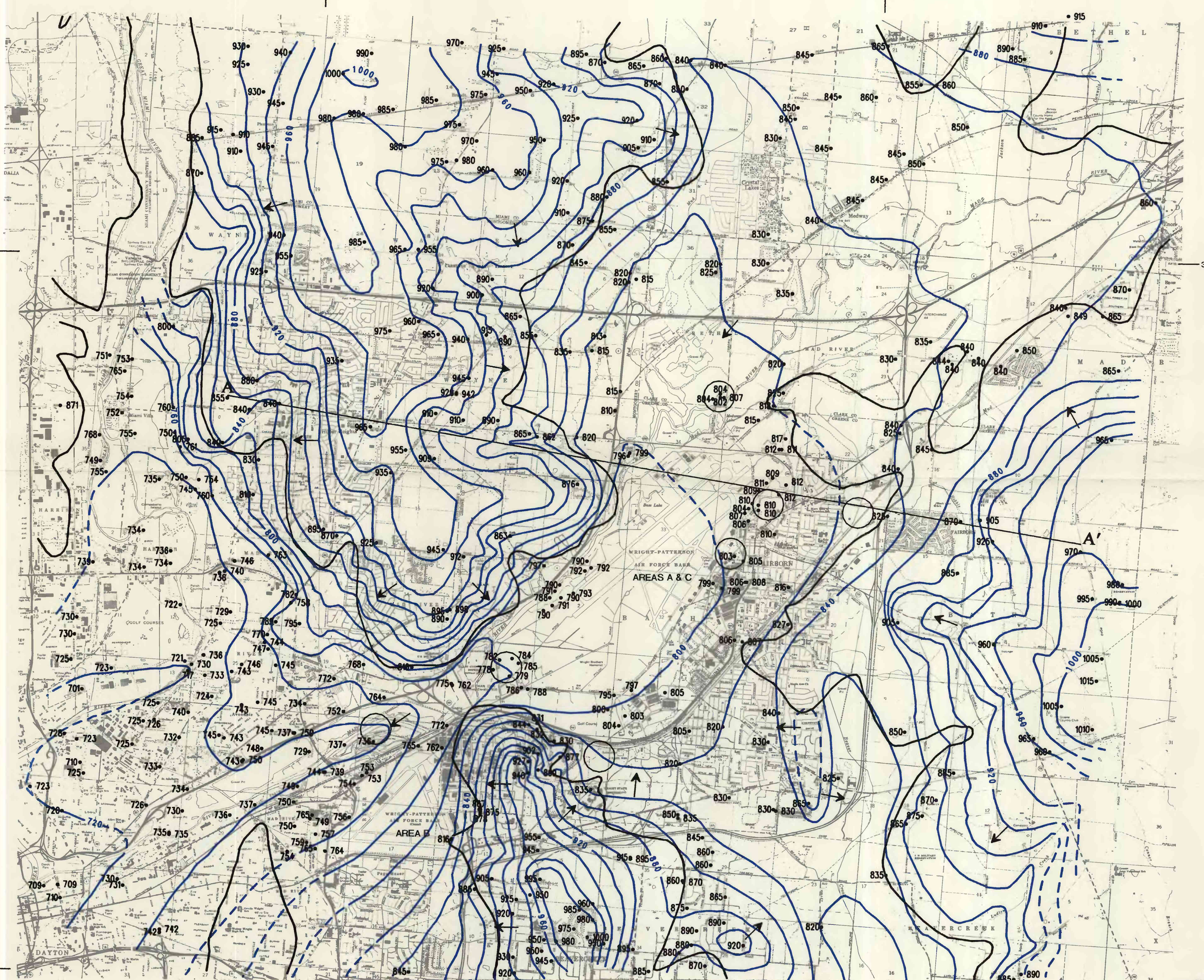
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH
U.S. DEPARTMENT OF DEFENSE WRIGHT-PATTERSON AIR FORCE BASE

WATER-RESOURCES INVESTIGATIONS
REPORT 92-4022



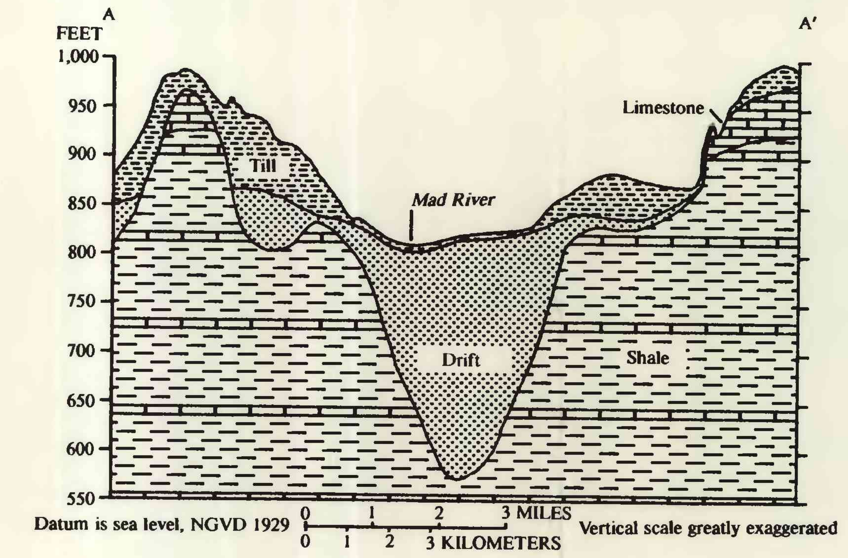


Figure 1.--Generalized geologic section (west-east) of the Mad River valley near Wright-Patterson Air Force Base

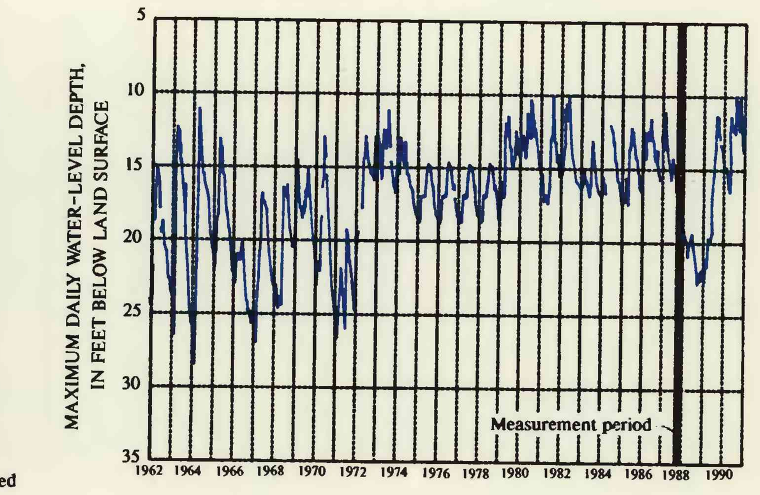


Figure 2.--Water levels in well CL-7, calendar years 1962-1990.

INTRODUCTION

The Mad River buried-valley aquifer system, which consists of highly permeable glacial-drift deposits, underlies the area of southwestern Ohio that includes Wright-Patterson Air Force Base (WPAFB), Huffman Dam, and the cities of Dayton and Fairborn. Because of the areal extent and permeability of the aquifer, water-supply wells completed in the aquifer are numerous and productive; some yield more than 1,500 gal/min (gallons per minute) with little drawdown. Dayton's municipal water is produced in part by wells on Rohrer's Island, southwest of WPAFB and just downstream from Huffman Dam. Fairborn, WPAFB, and several individual users produce municipal and industrial water from the aquifer upstream from Huffman Dam.

Volatile organic compounds and other organic chemicals have been detected in water from monitoring wells of WPAFB and Dayton (IT Corporation, 1990; Geraghty and Miller, 1987). Planning for remediation and protection of water supplies at WPAFB requires documented, current information on the directions, velocity, and volume of ground-water flow.

A ground-water-level map was prepared by the U.S. Geological Survey (USGS), as part of a cooperative study with WPAFB, to help address these concerns. This map report is one of a series of reports by the USGS addressing the hydraulics and water quality of the ground-water system at WPAFB. The purpose of this map report is to (1) define general directions of horizontal ground-water flow, and (2) determine the long-term stability of the ground-water-flow system in the region surrounding WPAFB. Water-level data from approximately 500 wells contributed to the definition of the ground-water surface. Directions of ground-water flow are discussed only as they affect WPAFB. Long-term stability of the flow system is deduced by (1) comparing this map with a map showing ground-water levels in 1955 for the same area by Walton and Scudder (1960), (2) comparing ground-water withdrawals from the buried-valley aquifer in 1954 with those in 1987, and (3) examining the 29-year water-level record of a nearby well.

The author thanks the many individuals, groups, and industries who allowed access to their wells. In addition, the author thanks the Ohio Department of Natural Resources (ODNR) for supplying well logs and the Miami Conservancy District (MCD) for supplying water-level and hydrographic data.

Geographic Setting

The study area, centered on WPAFB, includes parts of Clark, Greene, Miami, and Montgomery Counties. The Mad River is the dominant surface-water system in the area; included in its drainage basin are smaller streams from the uplands east and west of the river. The Great Miami River forms the western boundary and drains a small part of the study area. Abandoned sand and gravel pits in the river valleys are now filled with water.

Hydrogeologic Setting

The glacial aquifer is underlain by shale of Ordovician age. This shale includes interbedded layers of fossiliferous limestone that is more permeable than the shale. In upland areas surrounding the Mad River valley, the shale is capped by a thin layer of Brassfield Limestone of Early Silurian age. The limestone-shale interface is at an altitude of about 925 ft above sea level (Walton and Scudder, 1960). Springs and seeps can be found at many locations along the shale and limestone interface. In most of the uplands, a till layer of variable thickness overlies the bedrock; however, in some places, shale and (or) limestone beds are exposed at the surface (fig. 1). Detailed descriptions of the bedrock geology can be found in Norris and Spieker (1966) and Norris and others (1950).

In general, the Ordovician shale is not considered an aquifer; wells completed in this formaton yield less than 5 gal/min. Wells completed in the Brassfield Limestone, on the other hand, yield about 15 gal/min and thus are productive enough for domestic use (Norris and others, 1950).

The buried-valley aquifer consists primarily of sand and gravel but contains discontinuous clay layers north of Huffman Dam and a continuous confining unit south of the dam. The glacial deposits are as much as 250 ft thick; where the clay-till confining unit exists, it can be as much as 80 ft thick (Geraghty and Miller, 1987).

Areas A and C of WPAFB are in the Mad River backwater area northeast of Huffman Dam. Area B, south of the dam, overlies the outwash plain and the uplands.

METHODS OF INVESTIGATION

All wells used in this study were field-located by USGS, ODNR, or MCD personnel. Altitudes of the water surface, or hydraulic heads, were computed by subtracting the water level, in feet below land surface, from the land-surface altitude at the well site, in feet above sea level. The land-surface altitudes of off-base wells measured by the USGS and listed in drillers' logs were determined from USGS 7.5-minute topographic maps having 10-ft contour intervals. Accuracy of these altitudes is one-half of the 10-ft contour interval, or 5 ft. Water levels in wells whose land-surface altitudes are estimated from topographic maps are reported to the nearest 5 ft. Altitudes of on-base wells and of those reported by MCD were surveyed by leveling from USGS or U.S. Geodetic Survey bench-marks. Accuracy of altitudes determined by leveling is 0.05 ft.

Water levels were measured by chalked-steel or electric tape. General descriptions of these methods of measurement are given by Heath (1983, p. 72-73). The accuracy of these measurements is 0.01 ft.

Water levels in 499 wells contributed to the definition of the ground-water surface. Water levels in 227 wells on WPAFB were measured from October through December 1987. Static water levels from driller's logs of 197 wells were used to establish locations of ground-water divides and flow directions in the upland areas; these water levels had been measured when the wells were drilled (from 1960 through 1991). Water levels in late 1987 were estimated for 75 wells near Dayton. Water-level hydrographs recorded continuously in nearby wells indicate that water levels were about 7 ft lower in late 1987 than they had been in 1986, when water levels in the 75 wells were measured; consequently, the water levels in late 1987 in these wells were estimated by subtracting 7 ft from the 1986 water levels.

Only static water levels were used to prepare the map; no wells were being or recently had been pumped at the time of measurement. Water levels in observation wells near pumping centers can be affected by drawdown from nearby production wells.

The contour interval on the ground-water-level surface is 20 ft. The configuration of the surface was determined primarily from water levels in wells, with additional information from known altitudes of perennial streams and the land surface. Water-level data were contoured by hand and then digitized for use in a geographical information system.

For the purpose of contouring the ground-water surface, perennial streams are assumed to be gaining, except near known pumping centers. The aquifer discharges to the stream at the same altitude as the land-surface contour crossing the stream. Perennial-stream data were used where no well information was available.

GROUND-WATER LEVELS

The ground-water-level surface indicates the altitude to which water would rise in properly cased wells in the aquifers or confining units in which they were screened. Water in the glacial drift aquifer, delineated in the map by the heavy black line, is unconfined or semiconfined; water in the bedrock units generally is confined.

Most of the off-base wells in the study area are domestic water-supply wells. These wells can have long screened or uncased intervals that are open to much of an aquifer or parts of several aquifers. The water levels in these wells represent composite hydraulic heads over the length of the screened or uncased interval.

Observation wells on WPAFB have shorter screened intervals than those of most of the domestic water-supply wells. The water levels in these wells reflect the hydraulic heads in the upper-most aquifer at those places. Water levels in the buried valleys are measured in the glacial aquifer, whereas water levels in the uplands are measured in the limestone aquifer or shale lower-boundary unit. Thus, the ground-water surface is composed of water levels in several aquifers, and neither potentiometric (confined) nor water-table conditions prevail exclusively.

Typically, water levels decline from May through October because evapotranspiration rates are high; water levels begin to recover only during the last one-quarter of the year. Water-level records of nearby USGS wells CL-7, CL-9, and GR-1 (in Clark and Greene Counties, not located on the map) indicate that water levels were declining in late 1987 (Shindel and others, 1988), contrary to the normal pattern. A 30-year hydrograph of ground-water levels in well CL-7 is shown in figure 2. Since 1972, average yearly water-level fluctuation is about 5 ft; however, water levels were exceptionally low from late 1987 through mid-1988. Precipitation was 6 to 10 in. below normal in the region from October 1987 through June 1988 (National Oceanic and Atmospheric Administration, 1987 and 1988). Thus, water levels shown on this map are about 5 ft lower than those for a period of normal precipitation.

Analysis of the water-level records (USGS wells MT-6, GR-1, CL-7, and CL-9, not located on the map) shows relatively little fluctuation during the 3 months when the water levels were being measured. Water levels declined about 0.75 to 2.0 ft in three of the wells (GR-1, CL-7, and CL-9) and rose about 2.5 ft in MT-6. The water level in only one of these wells, GR-1, appeared to show any response to rainfall during this period.

For several reasons, ground-water-level contour lines, or lines of equal potential, were not adjusted for water-level trends in the ground-water surface during the 3 months that water levels were measured. First, nonsurveyed wells preponderate in 80 percent of the study area; the water-level fluctuations are within the altitude-estimation error for those wells. Second, the mapped area is approximately 160 mi^2; on a regional scale, a maximum water-level change of 2.5 ft is insignificant and would affect the positions of few, if any, lines of equal potential. Third, generalized flow directions can be readily interpreted from the map, and long-term system stability can be determined by comparing this map with that of Walton and Scudder (1960).

GROUND-WATER FLOW

Ground water flows in response to gradients caused by natural and manmade stresses. If the overall effect of these stresses, such as recharge and pumping, changes with time, the flow system is transient. The transitory nature of the ground-water system can be demonstrated by changes in flow direction and (or) rate. Ground-water-flow directions and system stability in the area near WPAFB are discussed in this section.

Directions of Flow

Ground water flows in the direction of decreasing hydraulic head. In unconsolidated homogeneous materials, flow is generally perpendicular to lines of equal potential. In shale and (or) limestone bedrock, directions can differ locally according to preferential pathways through fractures or solution channels, but, on a regional scale, is generally perpendicular to lines of equal potential also.

The highlands northwest of WPAFB Areas A and C form a regional ground-water divide—that is, ground water west of the divide discharges to the Great Miami River, whereas ground water east of the divide discharges to the Mad River. Because of the locations of the highlands and the course of the Mad River, regional ground-water flow in the basin tends to be east-to-west or west-to-east. Because WPAFB is entirely within the Mad River drainage area, all ground water passing through WPAFB flows toward the Mad River.

The uplands in this region serve in part as recharge areas for the buried-valley aquifer (Walton and Scudder, 1960). Ground water tends to form mounds in southeastern Fairborn and eastern Area B on till-capped bedrock that underlies hills; this ground water flows to and recharges buried valleys in the southeastern and southwestern parts of the study area. These mounds also modify the main flow directions in the region; for instance, some ground water discharges from Area B in a northeastern direction before turning again toward the west and the Mad River. A ground-water divide is created near southeastern Fairborn as flow separates into the drainage areas of Hebble and Beaver Creeks.

The large daily volume of pumping at Rohrer's Island has resulted in a depression in the ground-water surface south of Huffman Dam, as indicated by the positions of the 740- and 760-ft contours. Smaller pumping rates in WPAFB Area B and Fairborn, however, do not noticeably affect regional ground-water flow.

Close spacing of contour lines indicates steep hydraulic gradients, which commonly are due to low hydraulic permeability of the aquifer material. In most of the study area, the hydraulic gradient is similar to but more subdued than the land-surface gradient. Steep hydraulic gradients, primarily in low-permeability till and shale, are characteristic of the upland areas, whereas relatively flat hydraulic gradients, primarily in the high-permeability glacial drift, are characteristic of the valley.

Long-Term Flow-System Stability

Stability of the ground-water-flow system at WPAFB was evaluated by (1) comparing this map with a map of water levels in 1955 for the same area prepared by Walton and Scudder (1960); (2) comparing ground-water withdrawals from the buried-valley aquifer in 1954 with those in 1987; and (3) examining the 29-year water-level record of USGS well CL-7, located in the buried-valley aquifer several miles northeast of the study area.

Comparison of Ground-Water Levels in 1955 and 1987

The water levels shown on this map, measured in 1987, do not differ appreciably from those presented by Walton and Scudder for the Fairborn area (1960). Several important points of similarity exist between the Walton and Scudder map and this map.

1. Hydraulic gradient along length of WPAFB Areas A and C.—This gradient was about 0.0018 ft/ft in 1955 and 0.0017 ft/ft in 1987. The 780- and 820-ft contour lines have not moved significantly during the 32 years separating the two studies.
2. Water levels in the upland areas.—The top of the ground- water surface has remained at the same altitude; accordingly, recharge from the upland areas to the buried-valley aquifer probably has remained constant.
3. Directions of ground-water flow in the study area.—Walton and Scudder (1960) inferred the same flow directions as those presented in the last section.

Comparison of Ground-Water Withdrawals in 1954 and 1987

Data on ground-water withdrawals from the buried-valley aquifer in 1954 and 1987 are listed in table 1. The largest withdrawal in both years was by the City of Dayton at Rohrer's Island, which accounted for about 88 percent of the water withdrawn from the aquifer. About 3 Mgal/d less was pumped in 1987 than in 1954, but the reader should note that the 1987 data are incomplete. The yearly use of ground water from the buried-valley aquifer is relatively constant.

Table 1.—Ground-water withdrawals from the buried-valley aquifer near Wright-Patterson Air Force Base, 1954 and 1987

[Data from 1954 from Walton and Scudder (1960). Mgal/d, million gallons per day; n.d., no data.]

Use	Withdrawals (Mgal/d)	
	1954	1987
Public supply:		
Fairborn	1.01	1.1
Dayton	46	43
Industrial supply	1.31	>.5
Commercial supply	.05	n.d.
Military supply	2.91	3.8
Domestic supply	.60	.25
Total	51.88	48.65

Norris (1959). Geraghty and Miller (1987).

Change in Ground-Water Levels over Time, 1962-90

The 29-year record of ground-water levels in well CL-7 is shown in the hydrograph in figure 2. Well CL-7 was chosen for analysis because it is the nearest well of continuous record since 1960 in an aquifer similar to the buried-valley aquifer near WPAFB. It should be noted, however, that the ground-water-level record in CL-7 can reflect the effects of pumping at a nearby wellfield.

The average annual water level in 1962 was about 20 ft below land surface (bls); the average in 1990 was about 13 ft bls. Most of the difference in annual average water level occurred between 1971 and 1972, when average water levels rose to about 15 ft bls. Yearly water-level fluctuations decreased from 9 to 16 ft before 1972 to about 4 to 6 ft after 1972.

It is not known why the average annual water level rose after 1972, or why the yearly fluctuations in water levels were twice as large before 1972 as after. One possible explanation is the proximity of the well to the nearby wellfield; changes in pumped volumes or in the wells pumped can have a marked effect on the ground-water-level hydrograph.

The 29-year record of water levels in CL-7 does not indicate either stability or instability of the ground-water-flow system at WPAFB. The distance of CL-7 from WPAFB and the irregularity of its hydrograph minimize its usefulness to the evaluation of flow-system stability.

On the basis of the comparison of ground-water pumping and ground-water-level maps, the ground-water-flow system of the area around WPAFB seems to be stable.

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.785	liter
gallon per minute	0.06308	liter per second

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

EXPLANATION

800 — GROUND-WATER-LEVEL CONTOUR - Shows altitude of composite ground-water surface in the uppermost aquifer. Dashed where approximately located. Contour interval 20 ft. Datum is sea level

APPROXIMATE EXTENT OF BURIED VALLEYS - Coincides with 800-foot contour on the bedrock surface, in feet above sea level

LOCATION OF PUMPING CENTER - Size of circle does not indicate volume of withdrawal

← DIRECTION OF GROUND-WATER FLOW

• 790 WELL - Number is water-level altitude, in feet above sea level

Location of study area

SCALE 1: 46,980

0 1 2 3 MILES
0 1 2 3 KILOMETERS

Base from U.S. Geological Survey
Dayton North (1965), photoinspected 1098), Donnelsville (1965, photoinspected 1983), Fairborn (1965, photorevised 1988), New Carlisle (1955, photorevised 1968 and 1973), Tipp City (1965, photorevised 1982), and Yellow Springs (1968, photorevised 1975)

GROUND-WATER LEVELS AND FLOW IN THE VICINITY OF WRIGHT-PATTERSON AIR FORCE BASE, OHIO, OCTOBER - DECEMBER 1987

By Charles W. Schalk

1992

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