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THE EFFECTS OF MUNICIPAL PUMPING FROM A SHALLOW GLACIAL AQUIFER AT BRYAN, NORTHWESTERN OHIO[1]

JAMES M. KING, Department of Geology, Indiana University, Bloomington IN 47401
LON C. RUEDISILI, Department of Geology, University of Toledo, Toledo OH 43606

Abstract. The city of Bryan in northwestern Ohio has been recognized as the Fountain City because of its location within a well-known belt of flowing wells. Municipal pumping, however, has lowered the water table so that few wells in the vicinity of the city now flow naturally. The city plans to locate a new well field in its vicinity as the limits of its existing fields are approached. These plans have generated concern among local rural well owners who fear that a further decline in ground-water levels will necessitate deepening their shallow domestic wells or will require deeper pump installation. Some residents have offered alternatives to a new well field outside of Bryan including: (1) restricting the city to wells within its limits, (2) increasing the volume of ground-water withdrawn from existing wells, and (3) constructing a surface reservoir to meet future water requirements. As an alteranative, it is recommended that future well-field development focus upon a sparsely-populated area north of Bryan where significant thicknesses of sand and gravel are known to exist.

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Lowering of the water table or potentiometric surface is a natural and expected consequence of ground-water withdrawal from hydrologic systems. Only in recent years, however, have declining water levels near municipal and industrial well fields received more than local attention. In many areas, this phenomenon still goes unnoticed except by those directly affected. Incidents of dry shallow wells and reduced streamflow throughout the country, of land subsidence in the south and southwest, and of saltwater intrusion into coastal aquifers have been directly attributed to large-volume ground-water use. Growing public awareness, legislative mandates and physical limitations of ground-water systems have now prompted cities and industries to consider potential environmental consequences of their activities, including those related to ground-water supply.

Threatened with rapidly falling water levels due to municipal pumping, citizens in and around Bryan, Ohio voiced concern. Public response to the situation focused on ground-water conservation, water-supply alternatives, and potential economic losses to homeowners for deepening wells or lowering pump intakes. We undertook our study to describe the situation at Bryan, and to develop a comprehensive hydrogeologic data base for the area.

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METHODS AND PROCEDURES

We examined the occurrence and movement of ground water within the glacio-lacustrine mantle, regional and local flow patterns, and the potential water-supply problem at Bryan. Data from over 650 water-well, oil, gas, and core logs were compared with previously documented aquifer test information and published reports (Stout *et al* 1943; Ohio Department of Natural Resources, Div. of Water 1954, 1959a, 1959b, 1960, 1962, 1969a, 1969b; Burgess and Niple, Ltd. 1967; Williams County Regional Planning Commission 1968; Harlamert and Heck 1968; and Basic Design Associates 1973). An attempt was also made to delineate historical changes in ground-water conditions attributable to Bryan's increasing ground-water use and changing pumping patterns.

Geography and Physical Setting

Bryan is the seat and only city of Williams County, located in the extreme northwest corner of Ohio (figure 1). The city has grown steadily for the past several decades and the population now ex-

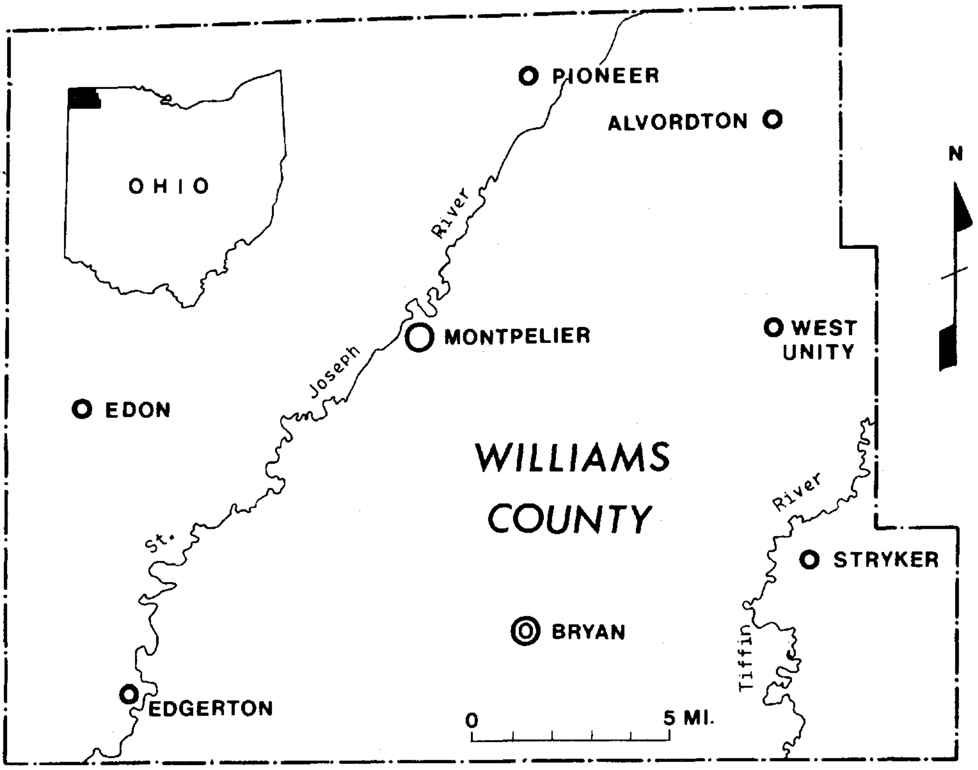

FIGURE 1. Location of Williams County, Ohio and its principal cities, villages and rivers.

ceeds 7,000 persons (Ohio Dept. of Natural Resources, Div. of Lands and Soils 1975). This growth has been accompanied by a corresponding increase in ground-water use.

The city lies within the Lake Plains section of the Central Lowlands physiographic province. The topography in this region ranges from nearly flat to gently undulating. West of Bryan is the Fort Wayne Moraine, a northeasterly trending feature of positive relief defining the western margin of the Lake Plains section. The moraine has significant hydrologic influence on the area in terms of surface drainage and ground-water recharge and flow.

Hydrogeology

Dependable ground-water supplies are obtained from aquifers within the unconsolidated surficial deposits of Williams County and, consequently, few wells tap the less productive underlying bedrock of Devonian and Mississippian shales and carbonates. Surficial deposits throughout the county are of glacial, glaciofluvial, and proglacial lacustrine origin (figure 2). These materials range from 120 ft (44 m) to approximately 200 ft (61 m) in thickness beneath Bryan and thicken to the west and north. A typical stratigraphic sequence near the city shows a thin veneer of silty lacustrine sand and sandy clayey silt at the surface, underlain by an interval of Wisconsinan recessional till (ground moraine) in which the coarser fraction characteristically is more abundant with depth. Thinner tills from previous Pleistocene glaciations may occur between the Wisconsinan interval and the bedrock.

The primary aquifers beneath Bryan and throughout Williams County are stratified lenticular bodies of outwash sands and gravels separating the Wisconsinan and pre-Wisconsinan till deposits. These materials were deposited

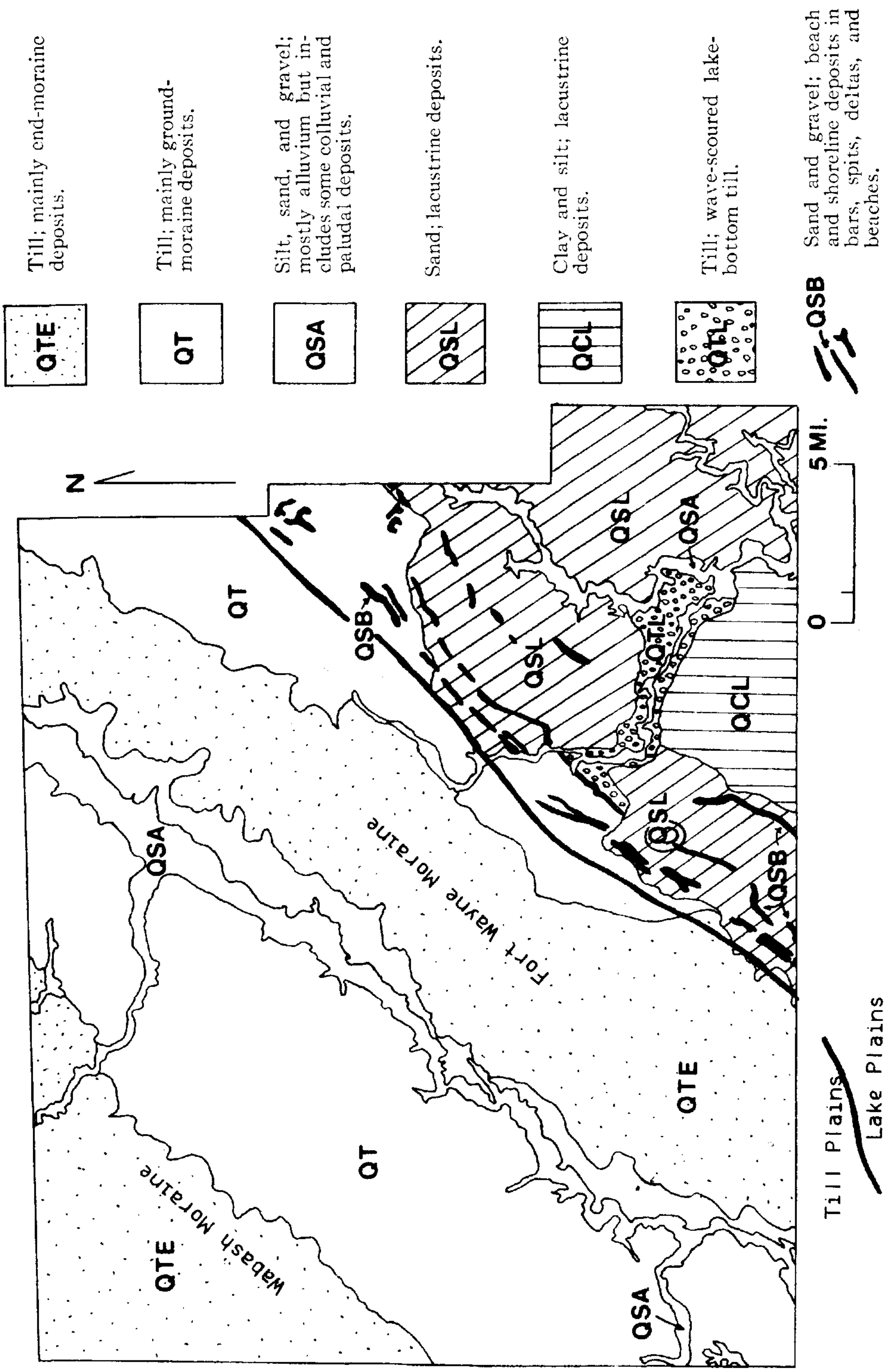

FIGURE 2. Map of unconsolidated surficial deposits in Williams County (after Johnson and Keller 1972).

along the front of the advancing Wisconsinan ice sheet and were subsequently overlain by a lower pebbly loam till and an upper clayey till. This order of deposition resulted in a somewhat continuous primary zone of saturated, coarsely granular material close to the bedrock surface beneath much of the county. Thicknesses of these lenses vary from less than 3 ft (1 m) to over 40 ft (12 m). Smaller discontinuous lenses of saturated sand and gravel also occur randomly at all elevations within the surficial cover. The deposits of the primary outwash zone and the shallower isolated lenses tend to become less numerous, thinner, and less continuous toward the southeast part of the county.

Pumping-test and static water-level data indicated that ground water within the outwash zones usually exists under confined conditions. The confined character of the water in the lenses results from their containment within the slowly transmissive till. This condition is further enhanced by thin layers of hardpan (sand and gravel in a dense matrix of clay, silt, and calcareous-ferruginous cements) that commonly occur in the upper portions of the lenses. Some vertical leakage may occur through the till separating individual outwash bodies in response to pumping and differences in elevation between lenses. The vertical leakage and normal horizontal flow appear to have resulted in a somewhat hydraulically continuous confined system within the buried gravels in many areas of the county, particularly within the lower portion of the surficial cover where the outwash bodies are most numerous and extensive. This system is thought to be recharged in the vicinity of the Fort Wayne Moraine west of Bryan (see figure 2) because of its relatively higher elevation and the existence of extensive zones of permeable outwash material within 30 ft to 60 ft (9 m to 18 m)of the ground

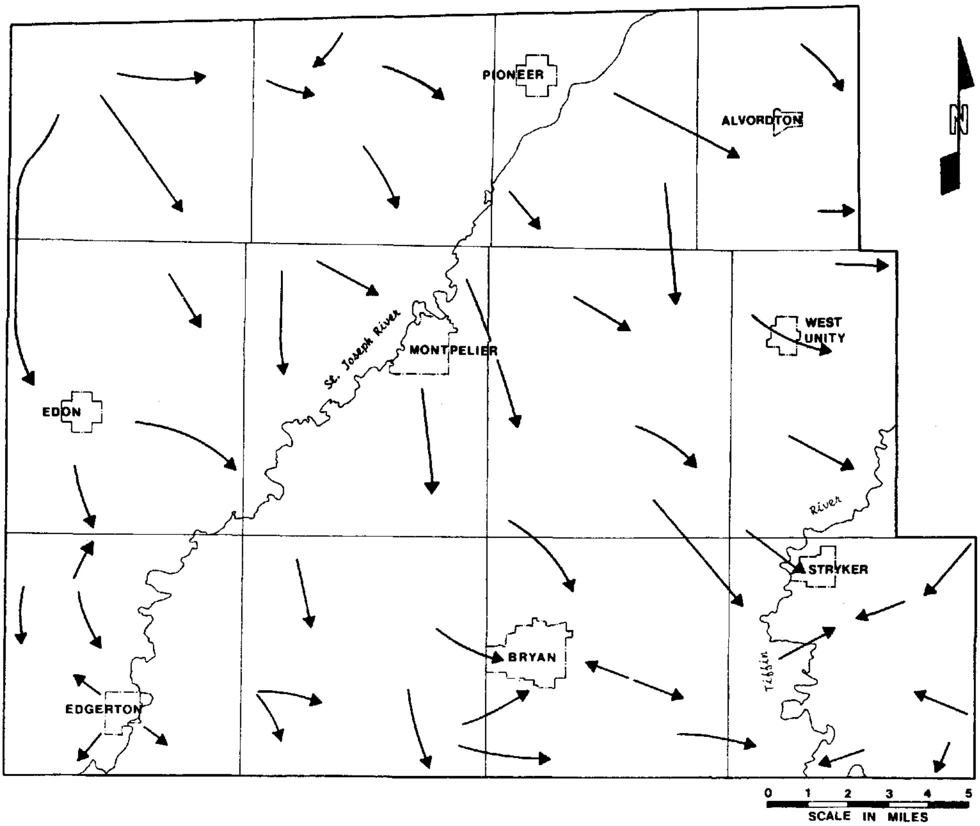

FIGURE 3. Generalized map of ground-water flow directions in Williams County.

surface in that area. Well-log data indicate a regional southeasterly ground-water flow gradient within the total system, as shown in figure 3. Average head loss across the county is about 11 ft/mile (2.1 m/km), although the gradient near Bryan approaches 17 ft/mile (3.2 m/km) at the present time.

GROUND-WATER USE IN BRYAN

Bryan currently withdraws ground water from well fields in the northeast and southeast corners of the city located approximately 1.3 miles (2.1 km) apart. The northeast field supplies about 75% of the city's annual water needs. The 5 wells within the 2 fields range in depth from 117 ft to 137 ft (36 m to 42 m). At present pumping rates, it is not possible to pump more than one well at each field simultaneously for long periods due to excessive drawdown interference, illustrating the high degree of hydraulic connection between the 2 pumping centers.

A study of the sand and gravel beneath Bryan (Harlamert and Heck 1968) indicates it is capable of safely yielding up to 4 million gal/day (mgd) (15,140 m^3/day). This analysis does not account for recharge by vertical leakage and may be too low. Total municipal pumpage averages about 2 mgd (7,570 m^3/day) during week days and about 0.8 mgd (3,000 m^3/day) on Saturdays and Sundays (Daggett 1979). Average annual pumpage is about 605 mg (2.3 x 10^6 m^3). In 1972, municipal water use was distributed as follows: 70% industrial, 17% residential, and 5% commercial. The remaining 8% was consumed through hydrant flushing or was classified as line loss due to leakage or unmetered use (Bryan Municipal Utilities 1972). Current water-use distribution does not vary significantly from these figures.

Ground-water withdrawal at Bryan has created a steadily enlarging cone of depression in the potentiometric surface, and local water levels indicate that the ground-water flow regime is being altered within a significant radius of the city. Figure 4 illustrates the approximate shape and extent of the cone as revealed by static water-level data from 1960 to 1964. During this time, the south well field was used much more extensively than the north field, as verified by the position of the cone. Figure 5 shows the same cone delineated by data from 1970 to 1974. Its notable northward expansion is attributed to a sharp increase in production from the north field between the 2 periods in addition to

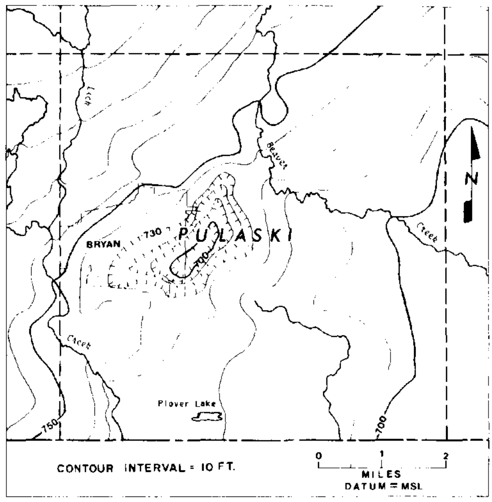

FIGURE 4. Map of Pulaski Township showing the shape and extent of the cone of depression produced by municipal pumping at Bryan, Ohio. Constructed from static water-level data from 1960 to 1964.

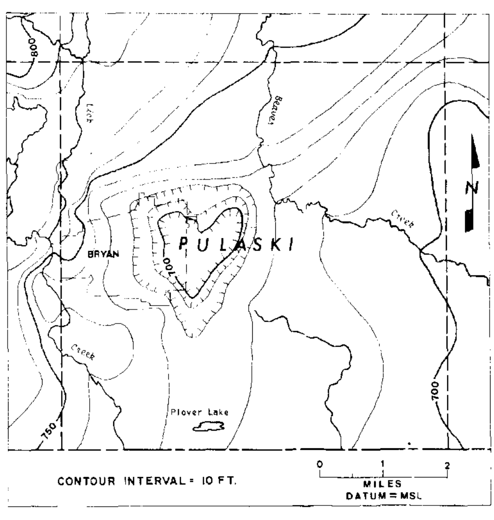

FIGURE 5. Map of Pulaski Township showing the shape and extent of the cone of depression produced by municipal pumping at Bryan, Ohio. Constructed from static water-level data from 1970–1974.

rises in water demand. The minor southerly expansion of the cone may be due to down-gradient elongation, thinning of the outwash aquifer in that direction, and/or to mutual interference between the 2 well fields. The cone was most probably changing in size and shape during the two 5 year periods represented in figures 4 and 5, but the data are still sufficient to illustrate the effects of the pumping on the surrounding potentiometric surface. By comparing the configuration of the potentiometric surface in both figures, it becomes apparent that the pumping at Bryan has influenced ground-water flow patterns throughout much of Pulaski Township, particularly down-gradient of the city. The gradient has been slightly steepened up-gradient, or northwest, of Bryan and has been flattened to the southeast. The extent of the influence may be estimated by noting the furthest potentiometric contour displaced by the pumping.

Other local evidence of the pumping's influence has been a gradual, but notable, decrease in the number of naturally flowing wells in and around Bryan, which once gave it local notoriety as the "Fountain City." The city is situated within a northeast-trending belt of flowing wells about 35 miles (57 km) long, which parallels the eastern flank of the Fort Wayne Moraine. The abrupt decrease in slope of the land surface southeastward from the moraine causes the potentiometric surface to be at or above ground level in this area (figure 6). As a result of ground-water use at Bryan, few wells in its vicinity now flow naturally. Quantitative evidence of water-level decline is provided in table 1, which lists static water levels in the 5 municipal wells at the times of their completion and in 1974.

TABLE 1

Static water levels in municipal wells at Bryan, Ohio, at the time of their completion and in 1974

Well No.	Year Completed Level*	1974 Level*
	Southern Field	
1	1950 flowing 6+	−50
2	1950 flowing 6+	−60
	Northern Field	
3	1957 −17	−49
4	1959 − 9	−47
5	1973 −30	−54

*Static water levels are in feet above (+) and flowing or below (−) ground surface and non-flowing.

CURRENT SITUATION

Several years ago, the city of Bryan announced plans to locate an additional well field outside of its corporate boundaries because the yields of its existing fields were being severely compromised by the mutual hydraulic interference. It was feared the fields' limits would be approached before the end of the decade.

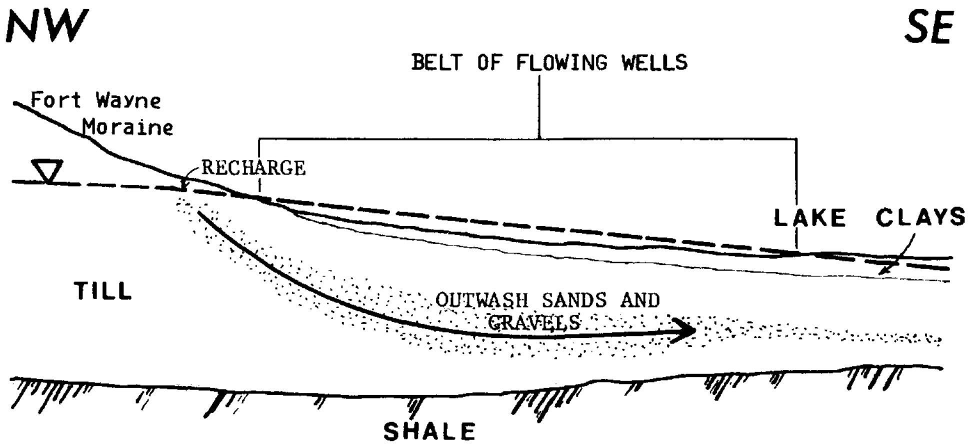

FIGURE 6. Schematic diagram of the probable geologic conditions responsible for the belt of flowing wells in northwestern Ohio. Arrow indicates direction of ground-water movement.

The announcement was followed by several exploratory drillings that prompted surrounding rural well owners to express concern about probable further lowering of already reduced water levels should the city expand its production to these sites. Their chief objections were personal expense associated with deepening their shallow wells or reinstalling the pumps at lower levels as water levels decline.

In response to the city's plans, some area residents proposed 3 alternatives:

1. restricting additional well-field development to within the city's corporate limits,
2. increasing pumpage from existing fields, and/or
3. constructing a surface reservoir to meet the city's growing water needs.

None of these alternatives, however, is feasible. Neither the Ohio Revised Code nor common-law precedence provides rural residents with legal recourse to restrict municipalities in locating well fields, nor are municipalities liable for damages directly related to their pumping of ground water (personal communication, M. A. Kitchen, Toledo attorney 1977). It is not possible to increase the volume pumped from existing fields because the system is already close to maximum capacity and well spacings and aquifer characteristics are such that drawdown interference occurs if more than one well is used simultaneously at each field. This situation would most likely be aggravated by establishing another well field within the city's boundaries. In addition, some portions of the municipal distribution system are already near capacity, particularly the mains from the well fields to the treatment facilities. The 3rd alternative, that of constructing a surface reservoir, is inadvisable because ground water is readily available in the area and sound economics and good water-management practices dictate that water-supply development take advantage of this resource. Secondly, past experiences of many small municipalities have demonstrated that construction of surface impoundments is often prohibitively expensive, regardless of redeeming aesthetic and recreational value. In addition, expensive treatment technology is commonly required for surface water destined for domestic use due to large loads of sedimentary, agricultural, and atmospheric pollutants. Finally, the topography surrounding Bryan is not readily conducive to natural reservoir containment and the construction of artificial boundaries adds significantly to the already prohibitive costs of such a project.

The problems facing private well owners near Bryan are not unfounded, but neither are they entirely insurmountable. An examination of the bedrock topography north of the city revealed the probable presence of a buried preglacial valley in which coarsely granular valley-fill deposits approaching 120 feet (36 m) in thickness are known to exist (figure 7). This valley may be the answer to Bryan's future water needs, although exploration may be hampered by its lack of definition resulting from a paucity of bedrock elevation control. Careful well-field location and design by the city, coupled with proper well construction, development, and maintenance, will minimize effects on smaller ground-water users within the area of influence. Regardless of the degree of conscientiousness of Bryan's utility planners, however, the hydraulic effects of large-scale pumping cannot be totally eliminated and some private well owners will undoubtedly experience reduced water levels or, perhaps, even dry wells in some instances. Such conflicts-of interest between large and small users have become more common in areas where ground water is the major source of potable water. Reduced water levels may thus be a reality that must be accepted as a consequence of concentrated ground-water use. Proper planning by domestic well owners, such as the initial construction of deeper wells in areas of high ground-water use potential, may be in order to prevent more costly problems in the future.

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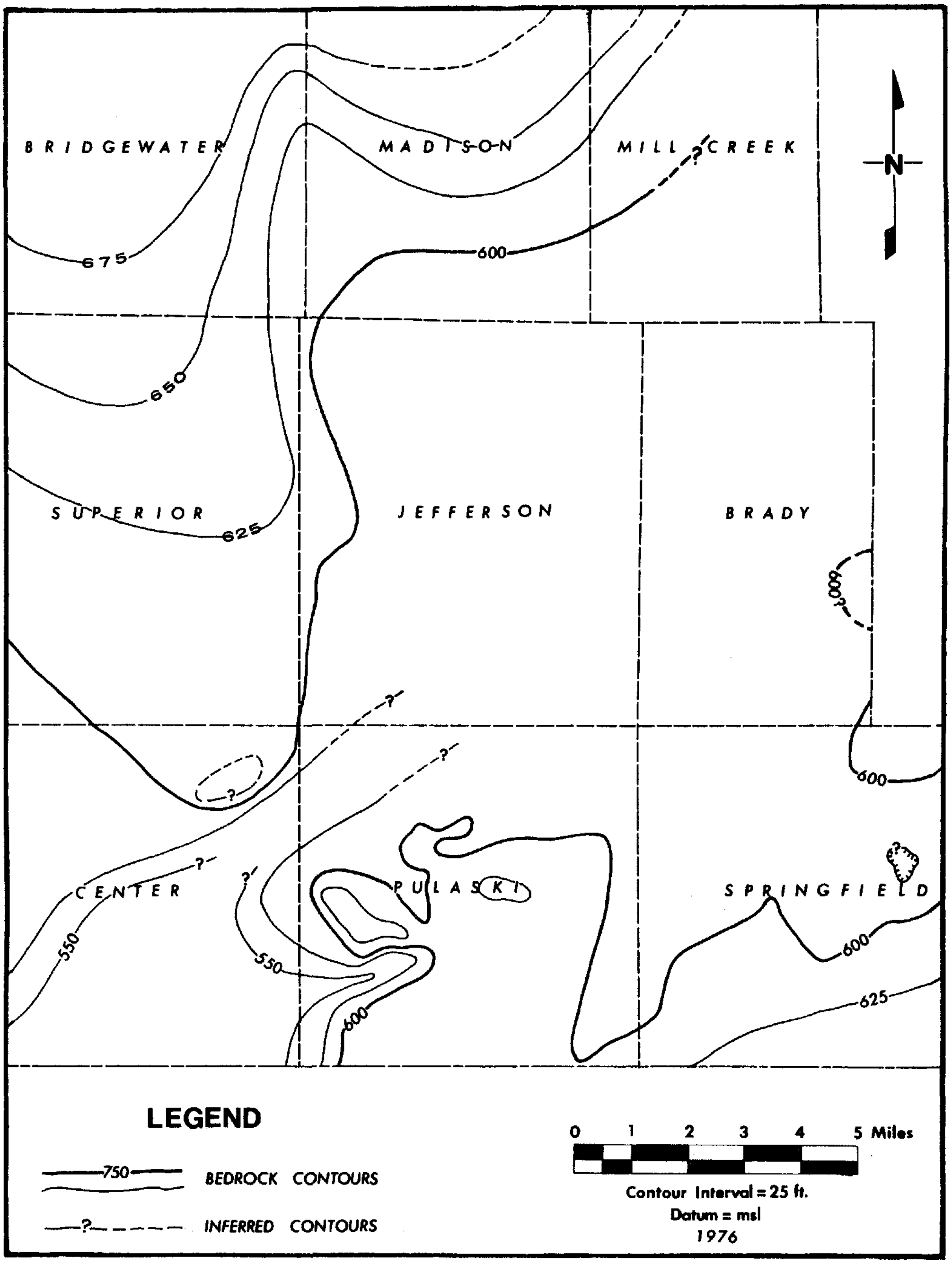

FIGURE 7. Probable bedrock topography of a portion of Williams County, Ohio.

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