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

HYDROLOGIC INVESTIGATIONS ATLAS HA 725
Water levels—SHEET 2 OF 3
Eberts, S.M., 1999; Water levels and ground-water discharge, regional aquifer system of the Midwestern Basins and Arches region, in parts of Indiana, Ohio, Illinois, and Michigan

GROUND-WATER LEVELS

Review of historical water-level data indicates long-term steady-state conditions throughout the glacial-deposit and carbonate-bedrock aquifer system at the regional scale of the study area. Extensive ditching to drain marshes in northwestern Indiana and northwestern Ohio in the late 1800's and early 1900's resulted in some dewatering of shallow glacial-deposit aquifers in Indiana (Indiana Department of Natural Resources, 1990) and possibly similar dewatering of shallow aquifers in Ohio; however, a new equilibrium has likely been established in these aquifers. Water levels in wells that produce water from local flow systems throughout the aquifer system undergo greater seasonal fluctuation than do water levels in wells that produce water from intermediate and regional flow systems. Annual high water levels are reached between March and June, and annual low water levels are reached near the end of the growing season. Annual ground-water-level fluctuations related to variations in recharge from precipitation range from 3 to 7 ft (Clark, 1980; Shindel and others, 1991a, b). No long-term rises or declines in water levels are apparent in the aquifer system. Pumping for irrigation has induced seasonal ground-water-level declines of as much as 88 ft in the carbonate-bedrock aquifer in northwestern Indiana (Glatfelter and others, 1989). The effect of irrigation on water-table aquifers in glacial deposits is not as great as the effect on the semiconfined carbonate-bedrock aquifer in northwestern Indiana (Indiana Department of Natural Resources, 1990).

The altitude of the water table, which typically is within glacial deposits, is a controlling factor for ground-water flow in the glacial-deposit and carbonate-bedrock aquifer system within the study area. In unstressed aquifer systems in humid regions, most variation in water-table altitude is a consequence of the variation in land-surface altitude, and depth to the water table varies predictably at a regional scale. Depth to the water table is greatest in topographically high areas and decreases in areas such as stream valleys. The relation between land-surface and water-table altitudes in the glacial-deposit aquifers was determined to help conceptualize and describe regional ground-water flow in the glacial-deposit and carbonate-bedrock aquifer system. Because most glacial-deposit aquifers are locally semiconfined or confined except in outwash sediments along regional drains, a general relation between land-surface altitude and water levels in unconfined (water-table), semiconfined, or confined glacial-deposit aquifers also was determined. In addition, a potentiometric-surface map of the carbonate-bedrock aquifer was constructed from synoptically measured ground-water levels to improve the definition of regional ground-water flow in the aquifer system.

DATA COLLECTION AND ANALYSIS

Water levels and corresponding land-surface altitudes for wells that are completed in the glacial-deposit aquifers were retrieved from the GWSI data base. The specific relation between land-surface and water-table altitudes in unconfined glacial-deposit aquifers and a more general relation between land-surface altitude and water levels in unconfined, semiconfined, or confined glacial-deposit aquifers were determined by use of the least-squares method of linear regression.

Drillers' logs were retrieved from files of the Indiana and the Ohio Departments of Natural Resources for all wells completed in the carbonate-bedrock aquifer and the upper weathered zone water-bearing unit within the Ordovician rocks in which water levels were to be synoptically measured. Each well was located in the field, and permission to measure was secured in advance to ensure that most measurements were made within a few days.

Land-surface altitudes were estimated from USGS 7.5-minute topographic maps for most of the wells measured in July 1990. The accuracy of the land-surface-altitude determinations is plus or minus one-half the contour interval of the topographic maps. Accuracies range from ±2.5 to ±10 ft throughout the study area. Water levels in some wells selected for measurement had been measured for site-specific projects. Land-surface altitudes for some of these wells were surveyed and are more accurate than land-surface altitudes estimated for the remainder of the wells. Altitudes for all wells in Illinois were surveyed by the staff at the Illinois State Water Survey, and reported land-surface altitude accuracies are ±0.1 ft (S.D. Wilson, Illinois State Water Survey, oral commun., 1991).

Water levels were measured in 395 carbonate-bedrock aquifer wells and 51 wells that are completed in the upper weathered zone water-bearing unit by use of chalked steel tape or water-level recorders during the third week of July 1990. The accuracy of all water-level measurements is ±0.01 ft. Water levels from wells with recorders in Ohio are the daily water-level lows for July 15, 16, or 17, 1990, whereas water levels from similar wells in Indiana are the daily water-level highs. This difference between the Ohio and the Indiana water levels from wells with recorders results from differences in the way water-level data from recorders are stored for each State. Data from the wells with recorders are either published in Shindel and others (1991a, b) or in Stewart and Nell (1991) or filed at the USGS office in Indianapolis.

The water-level measurements were entered into the GWSI data base. The data were retrieved from the data base and converted for use in a geographic information system (GIS) by use of software developed by Scott (1991). The GIS was used to project water-level data into an Albers Equal-Area Conic Projection, and the potentiometric-surface map was hand contoured from the water-level data. Digitized land-surface data (U.S. Geological Survey, 1973, 1977) were considered when contouring the water-level data. The potentiometric-surface map was contoured without regard for the depth of penetration of the wells because a 50-ft contour interval was used. In addition, measurements in wells instrumented with packers to isolate productive zones within the carbonate-bedrock aquifer indicate that vertical differences in hydraulic heads across the aquifer are less than 4 ft (L.D. Arihood, U.S. Geological Survey, written commun., 1991; Ron Smith, Wright State University, written commun., 1991; R.H. Hanover, U.S. Geological Survey, written commun., 1992). Two of these wells are in regional discharge areas that include the Kankakee River and Lake Erie.

GLACIAL-DEPOSIT AQUIFERS

The relation between land-surface and water-table altitudes in wells that are completed in unconfined glacial-deposit aquifers within the study area is illustrated in figure 5A. The more general relation between land-surface altitude and water levels in wells that tap unconfined, semiconfined, or confined glacial-deposit aquifers within the study area is illustrated in figure 5B. These two relations (the equations in figure 5) were defined by the least-squares method of linear regression and are nearly identical. In addition, the relations were defined without regard for the date of water-level measurements and can be considered to represent long-term steady-state conditions in the aquifers.

CARBONATE-BEDROCK AQUIFER

Water levels that represent conditions in the carbonate-bedrock aquifer during July 1990 and the corresponding 50-ft potentiometric contours are shown in figure 6. In addition, water levels measured during July 1990 in wells that are completed in the upper weathered zone water-bearing unit also are included in figure 6. July was selected for water-level measurement because ground-water levels in July typically correspond with annual mean water levels throughout most of the carbonate-bedrock aquifer. Precipitation in July 1990, however, was above average in Ohio and the northern half of Indiana. These areas also were unusually wet in May and June 1990 (Changnon and Dennison, 1990).

Water levels recorded during the third week of July 1990 at observation-network wells, which were instrumented with recorders for at least 10 years, were compared with the corresponding mean daily water-level low or high for the period of record to assess July 1990 conditions with reference to the historical record. Because data for 5 of the 30 wells instrumented with recorders had been collected for less than 10 years, data for only 25 wells were used for this comparison. The period of record differs among stations; missing record commonly is concentrated during winter months. Regardless of these factors, the data are believed to be useful for making general statements about conditions in the carbonate-bedrock aquifer during July 1990. Water levels recorded at 72 percent of the observation-network wells during July 1990 were higher than the corresponding mean daily water-level low or high computed from historical record; however, the difference between the July 1990 water levels and the corresponding mean daily water-level low or high was only ±2 ft for all but 7 of the 25 observation-network wells. The difference was less than ±5 ft for three wells, whereas the difference was as great as ±25 ft for four wells. These four wells are scattered throughout Ohio and do not exhibit similar trends. Consequently, they are thought to represent changes in local conditions rather than regional trends in the carbonate-bedrock aquifer.

Although water levels in the upper weathered zone water-bearing unit within the Ordovician rocks are shown in figure 6, potentiometric contours in the figure terminate at the contact between the carbonate-bedrock aquifer and the Ordovician rocks, where the contact is exposed at the bedrock surface. This is because the Ordovician rocks are much less productive than the carbonate-bedrock aquifer and do not constitute an aquifer.

The potentiometric surface in the carbonate-bedrock aquifer is a subdued reflection of the land surface and further illustrates the effect of variations in land-surface altitude on the aquifer system. Hydraulic gradients are the most gentle in the northern part of the study area, except along the Wabash River and east of the Sandusky River, and they become steeper in the central and southern parts of the study area. Regional potentiometric highs are in west-central Ohio and near the southern limit of the carbonate-bedrock aquifer along the border between Indiana and Ohio. Potentiometric lows less than or equal to 600 ft are along the Wabash and the Ohio Rivers and Lake Erie. Only one depression contour is noticeable on the potentiometric-surface map; this is the only area where withdrawal from the carbonate-bedrock aquifer is indicated by the ground-water-level data. This 550-ft depression contour is near Lake Erie and is likely a result of local industrial pumping and quarry dewatering.

Ground water flows from areas of high hydraulic head to areas of low hydraulic head. In an aquifer where no direction of permeability is predominant, ground-water flow is perpendicular to potentiometric contours. General directions of regional ground-water flow in the carbonate-bedrock aquifer can be inferred from the potentiometric-surface map. The map indicates that regional flow is from several potentiometric highs, which generally coincide with regional recharge areas, toward the regional drains, their principal tributary streams, and Lake Erie, which generally coincide with regional discharge areas. Water levels in the carbonate-bedrock aquifer are lower than water levels in the overlying glacial deposits in the regional recharge areas, whereas they are higher than water levels in the glacial deposits in the regional discharge areas. The potentiometric-surface map also indicates that ground water flows toward the contact between the carbonate-bedrock aquifer and the upper weathered zone water-bearing unit within the Ordovician rocks. Water in the carbonate-bedrock aquifer discharges as springs along this contact, but it can also be deflected into the overlying glacial deposits or be hydraulically connected with the upper weathered zone water-bearing unit.

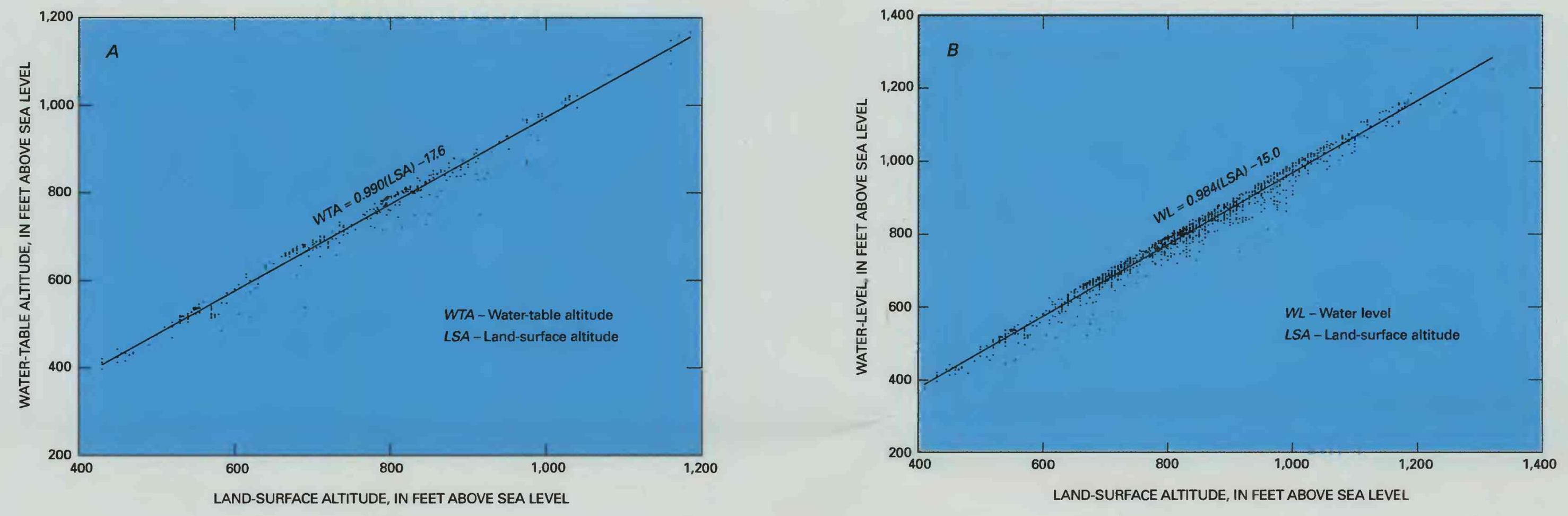
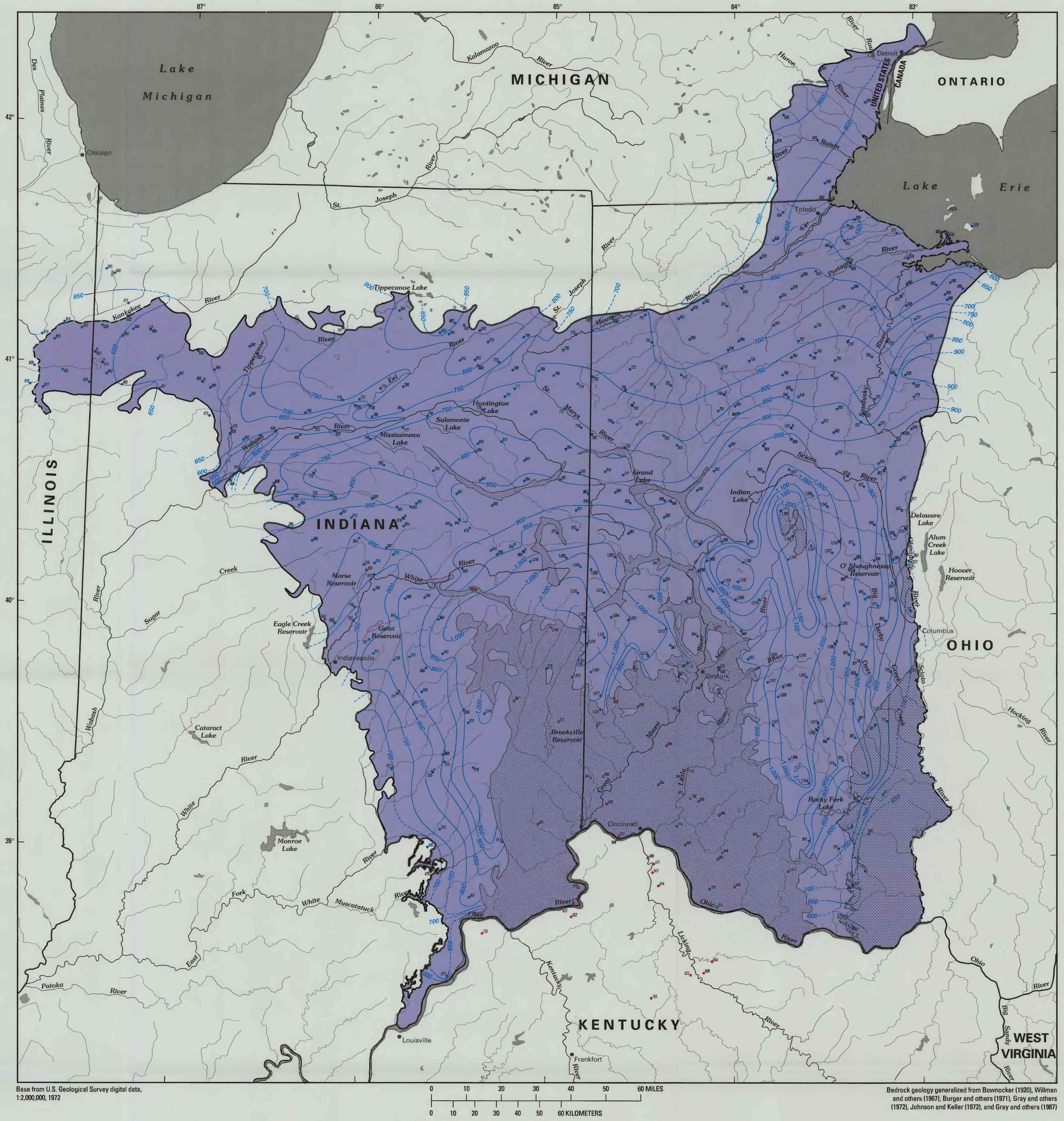


Figure 5. Relation between land-surface altitudes and (A) water-table altitudes in wells that are completed in unconfined glacial-deposit aquifers and (B) water levels in wells that are completed in unconfined, semiconfined, or confined glacial-deposit aquifers.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972

Bedrock geology generalized from Bownocker (1920), Willman and others (1967), Burger and others (1971), Gray and others (1972), Johnson and Keller (1972), and Gray and others (1987)

EXPLANATION

- ▨ **Confining unit**—Subcrop or outcrop area within the study-area boundary (Mississippian and Devonian shales)
- ■ **Carbonate-bedrock aquifer**—Subcrop or outcrop area within the study-area boundary (Devonian and Silurian limestones and dolomites)
- ▩ **Upper weathered zone water-bearing unit**—Subcrop or outcrop area within the study-area boundary (interbedded Ordovician shales and limestones)
- —— – – **Study-area boundary**—Solid where coincident with contact between Devonian limestones and younger Devonian shales. Dashed where coincident with surface-water body
- —900– – **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells, July 1990. Dashed where approximately located. Hachures indicate depression. Contour interval 50 feet. Datum is sea level
- 912 ● **Well**—Carbonate-bedrock aquifer. Number is water level, in feet above sea level
- 1,003 R **Well**—Instrumented to collect hourly or continuous water-level data. Carbonate bedrock aquifer. Number is water level, in feet above sea level
- 1,011 ● **Well**—Flowing artesian. Carbonate-bedrock aquifer. Number is top of well casing, in feet above sea level
- 713 ● **Well**—Upper weathered zone water-bearing unit within Ordovician rocks. Number is water level, in feet above sea level

Figure 6. Altitude and configuration of the potentiometric surface in the carbonate-bedrock aquifer, July 1990.

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WATER LEVELS AND GROUND-WATER DISCHARGE, REGIONAL AQUIFER SYSTEM OF THE MIDWESTERN BASINS AND ARCHES REGION, IN PARTS OF INDIANA, OHIO, ILLINOIS, AND MICHIGAN

By

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