Geology and Hydrology of the Piqua Area, Ohio

GEOLOGICAL SURVEY BULLETIN 1133-A

Prepared on behalf of the U.S. Atomic Energy Commission

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By STANLEY E. NORRIS *and* ANDREW M. SPIEKER

STUDIES OF SITES FOR NUCLEAR ENERGY FACILITIES

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By Stanley E. Norris and Andrew M. Spieker

ABSTRACT

This report on the geology and hydrology of the Piqua area, Ohio, was prepared as an aid in determining the feasibility of operating a nuclear-power reactor at a site on the west bank of the Miami River in the southern part of Piqua.

Piqua is in Miami County in west-central Ohio, which is in the Till Plains section of the Central Lowlands physiographic province. The city is in the valley of the Miami River at an altitude of about 870 feet, about 100 feet below the surrounding till plain. The Dayton and Brassfield limestones of Silurian age and the Richmond group of Ordovician age, which compose the bedrock, are overlain by 20 to 40 feet of glacial till west of the Miami River and by a thick section, as much as 200 feet of till, east of the river. The Silurian limestones and the Pleistocene till and outwash deposits yield supplies adequate for domestic, rural, or limited industrial use. Several buried lenses of sand and gravel in the thick till east of Piqua are especially productive aquifers. The ground water is characteristically hard and has a high iron content.

The rate of movement of ground water in the Piqua area is probably on the order of 10 feet per day in the sand and gravel and a few inches per day in the till. Owing to the highly variable permeability of the limestones, the rate of ground-water movement in them has not been estimated.

The only significant use of surface water at Piqua is at locations upstream from the proposed reactor site. Downstream from Piqua, however, the Miami River is important as a source of municipal and industrial water supply, either directly or by induced infiltration to wells. About 200 mgd (million gallons per day) of ground water is pumped from wells in the outwash sand and gravel deposits in the Miami River valley downstream from Piqua, most of it at Dayton, Middletown, and Hamilton. Probably 75 to 90 percent of the ground water has the Miami River as its source.

The site for the nuclear-power reactor is on the flood plain of the Miami River, and it requires protection against occasional floods.

Owing to the proximity of the site of the proposed nuclear reactor to the Miami River and to the hydraulic gradient of the aquifer, which slopes from the site toward the river, the greatest danger in the event of a leak in the reactor cell would be that the effluent could enter the river, either overland or through the ground water. Dilution and time of travel of a contaminant, once it entered the river, would depend on river conditions at the time. Detailed time-of-travel and dilution computations to individual water supplies located downstream cannot be made on the basis of presently available information.

INTRODUCTION

PURPOSE AND SCOPE

The purpose of this report is to present the geology and hydrology of the Piqua area, Ohio, with special reference to the effects of accidental loss of radioactive fluid to the ground. The report was prepared on behalf of the U.S. Atomic Energy Commission as an aid in determining the feasibility of operating a nuclear-power reactor at a site on the west bank of the Miami River in the southern part of Piqua (fig. 1).

Well data on which this report is based were obtained from the files of the Ohio Division of Water, and were supplemented by a field investigation made by the authors on July 15–17, 1958.

LOCATION OF AREA

Piqua is in west-central Ohio, about 80 miles west of Columbus and 30 miles north of Dayton, in the valley of the Miami River at an altitude of about 870 feet. (See fig. 2.)

TOPOGRAPHY AND DRAINAGE

Piqua is the Till Plains section of the Central Lowland physiographic province, a region characterized by generally flat topography except for minor relief along the streams and in areas of glacial moraines. The terrain west of Piqua, underlain by only a thin mantle of till over limestone, is nearly flat, whereas the terrain east of town, underlain by as much as 200 feet of glacial drift over shale, has a much more pronounced relief. The town of Piqua is in the valley of the Miami River, about 100 feet lower than the adjacent till plain. North and east of Piqua is a belt of higher, hummocky land, a few miles wide, whose southern boundary forms a broad arc that extends through Lockington and Kirkwood (fig. 3). This belt of higher land is a recessional moraine formed during a temporary halt in the retreat of the final stage of the Wisconsin glacier.

The Miami River, the principal stream in western Ohio, has a drainage area above Piqua of 842 square miles. South of Piqua it flows through Troy, Dayton, Middletown, Hamilton, and several other cities, to a junction with the Ohio River near Cincinnati. Downstream from Piqua the Miami River is an important source of municipal and industrial water supply, either directly or by induced infiltration to wells.

An important tributary of the Miami River is Loramie Creek, which joins the Miami about 3 miles north of Piqua. Loramie Creek is regulated by a dam at Lockington, which is one of five detention dams built by the Miami Conservancy District to protect Dayton and other downstream cities from floods. The dams have automatic outlets and the reservoirs are kept empty except during flood periods.

CULTURE

Piqua, which has a population of about 20,000 (1957 estimate), is primarily an industrial community; 50 manufacturing establishments

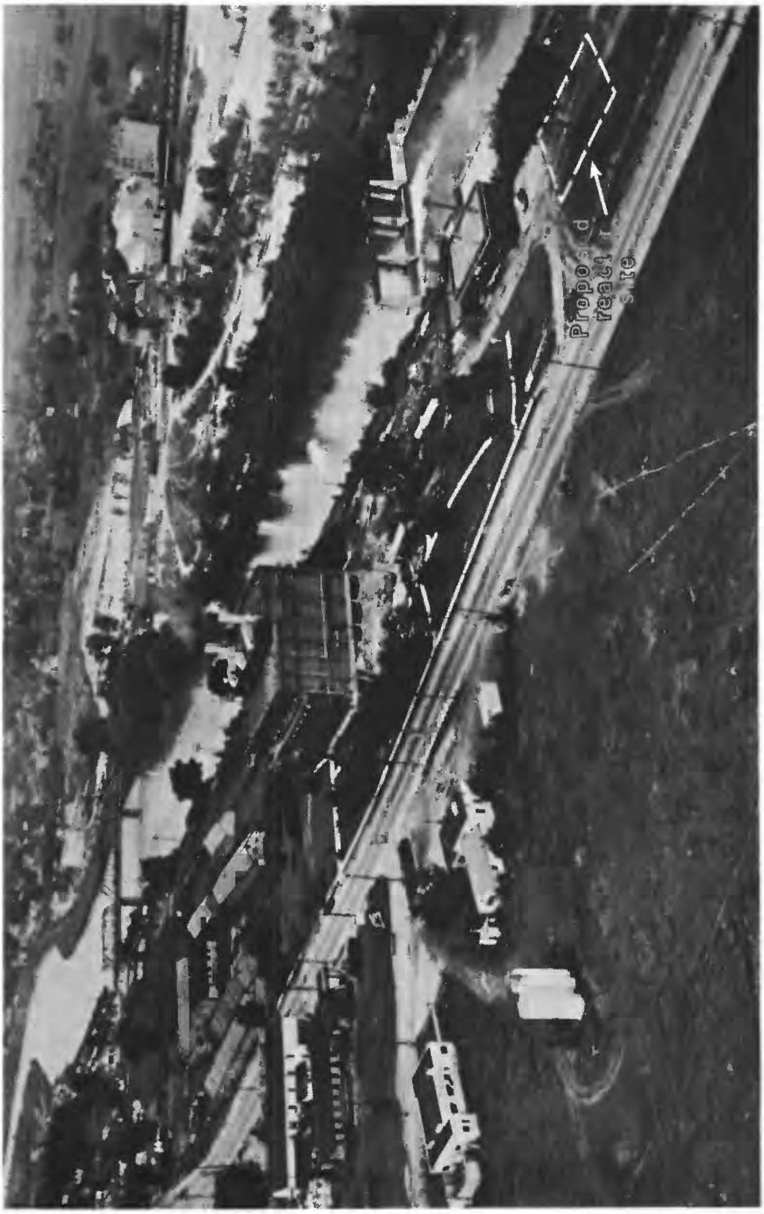


FIGURE 1.—Aerial photograph of Piqua, Ohio, showing location of proposed reactor site.

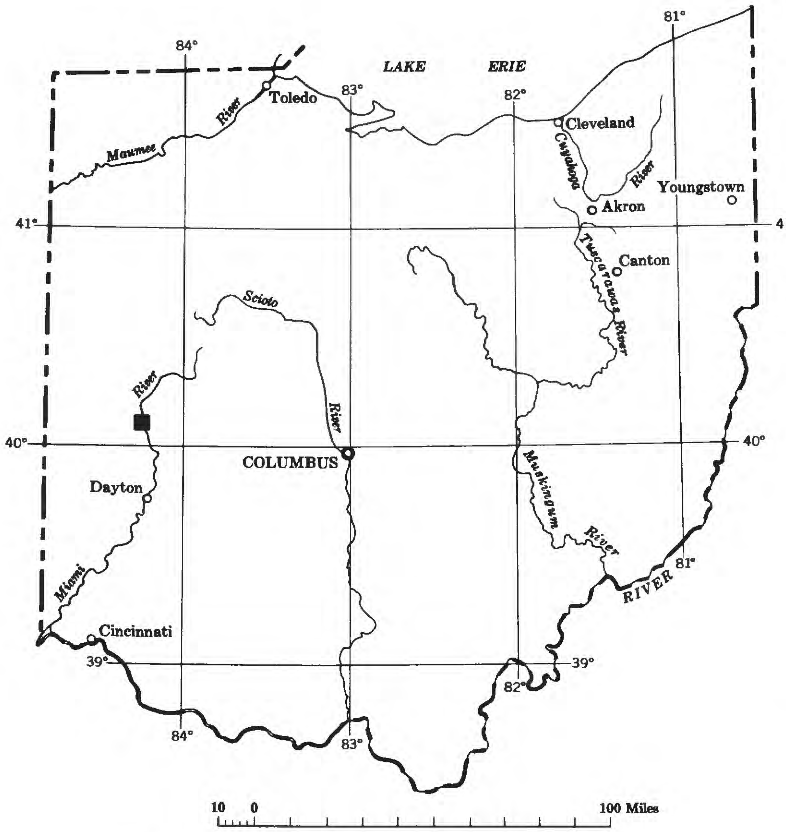


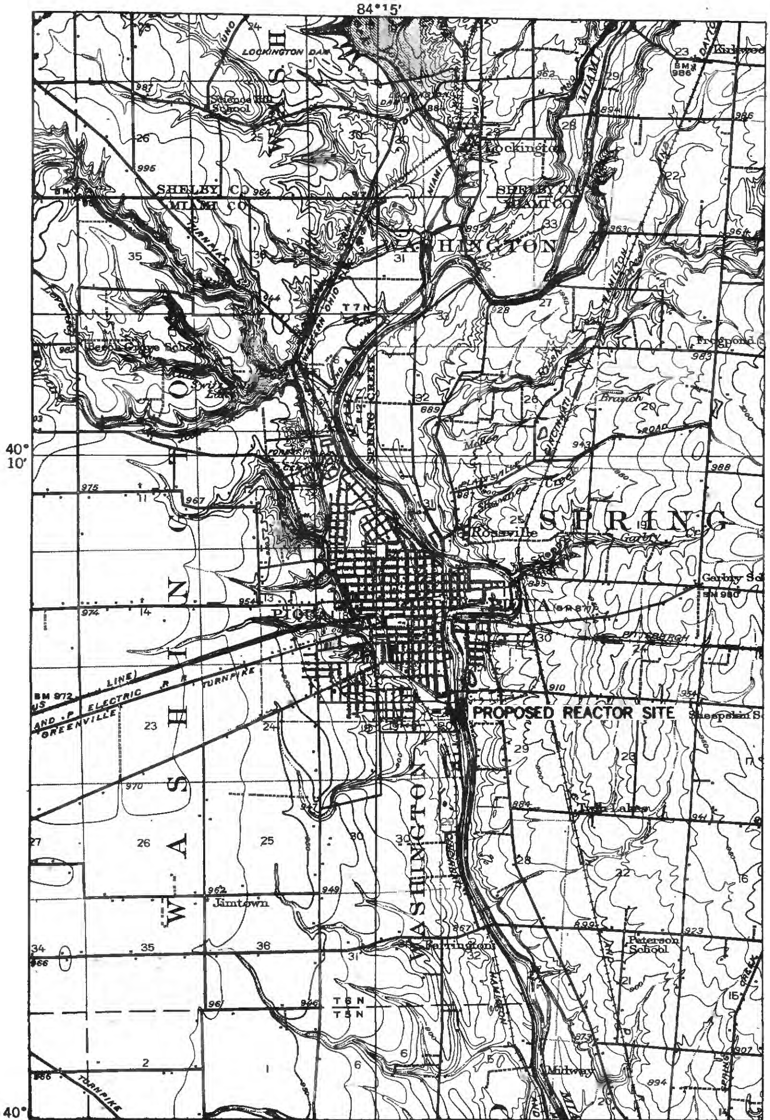
FIGURE 2.—Map of Ohio showing location of the Piqua area.

and 11 utility companies are located there. Most of the surrounding rural area consists of productive farmland. Piqua is served by the Baltimore and Ohio and Pennsylvania Railroads and by U.S. Highways 25 and 36.

ACKNOWLEDGMENTS

General information on the Piqua area and aerial photographs of the proposed reactor site were supplied by Mr. John P. Gallagher, Director of Municipal Utilities, Piqua, Ohio. Most of the well records used in this report were supplied by the drilling firm of Hole and Middlebrook, Piqua, Ohio. Mr. Herbert Hole was very helpful to the authors in discussing with them general ground-water conditions in the Piqua area.

E. S. Simpson, U.S. Geological Survey, made a brief reconnaissance of the site and vicinity in company with the authors and made helpful suggestions with respect to the preparation of the report.



Planimetry from U. S. Geological Survey Covington (1909) and Troy (1912) topographic maps

1 0 1 2 3 MILES

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

FIGURE 3.—Topographic map of the Piqua area, Ohio.

GEOLOGY

SOILS

The soils in the Piqua area are derived from glacial deposits in which fragments of limestone are an important constituent. Richard B. Jones, Ohio Division of Lands and Soils (*in* Cross and Hedges, 1959, p. 51) stated:

> The soils are derived from glacial deposits of both early and late Wisconsin Age. Miami, Celina, Crosby, and Brookston are the dominant soils of the late Wisconsin till area, and Russell, Xenia, and Fincastle are the principal soils of the early Wisconsin area. Classification of these soils depends on the drainage condition under which they developed. The less well-drained soils are relatively impermeable. Rather extensive terrace and alluvial soils occur, generally with good drainage and high permeability. Fox and associated soils are prevalent on the terraces. Genesee soils are the dominant alluvial soils.

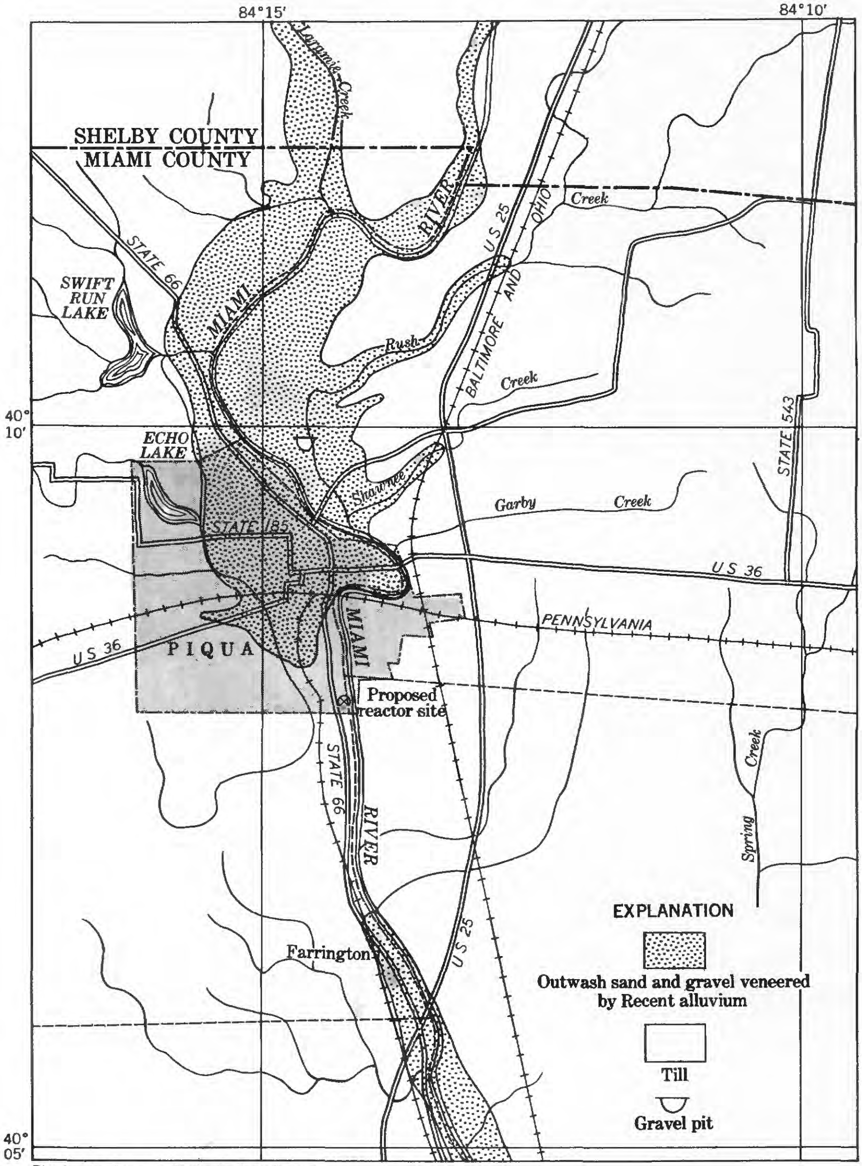
The soil and underlying alluvium in the vicinity of the proposed reactor site are about 5 feet thick and directly overlie limestone. The soil is probably correlative with the Genesee series. The Genesee series (Conrey and others, 1934, p. 15) consists of nonacid silt loam that has fair to good natural drainage properties.

SURFICIAL DEPOSITS

The surficial deposits (fig. 4) in the Piqua area are of glacial and alluvial origin and consist of till on the uplands and generally of sand and gravel outwash in the Miami River valley. The flood plain of the Miami River is underlain by alluvial deposits of silt and clay, deposited by the stream during times it has overflowed its banks. At the proposed reactor site the alluvium is less than 5 feet thick and rests directly on the limestone bedrock.

The outwash sand and gravel deposits in the area are thickest and most extensive immediately north of Piqua at the site of a large commercial sand and gravel pit; they are thinner and of smaller areal extent both north and south of this pit. The deposits are less than 10 feet thick near the center of Piqua and pinch out entirely a few blocks north of the proposed reactor site. The sand and gravel deposits are absent in the narrow part of the valley between the reactor site and a point near Farrington, about 2 miles downstream. Below Farrington, along the rest of its course, the Miami valley contains extensive deposits of sand and gravel. For example, at well 54, about 3 miles south of the reactor site (fig. 8), the sand and gravel is 68 feet thick.

On the upland west of Piqua the till is thin, 20 to 40 feet thick, and lies directly on the limestone bedrock. East of the town the till is comparatively thick, as much as 200 feet or more thick, and is interbedded with three or more fairly extensive sand and gravel layers which are sources of water to farm and domestic wells. These



Planimetry from U. S. Geological Survey Covington (1909) and Troy (1912) topographic maps

1 0 1 2 3 MILES

FIGURE 4.—Map of the Piqua area, Ohio, showing the distribution of the glacial deposits.

buried sand and gravel lenses represent outwash fans or valley trains deposited by melt water as glacial fronts advanced or retreated over a lowland eroded by preglacial streams. These streams had cut through massive limestone into the underlying, less resistant shale. Some or all of the buried sand and gravel deposits may be absent from the stratigraphic sequence at specific sites east of Piqua, for they are not reported consistently by drillers. Detailed logs, however, usually show these layers, and the authors believe that some of these layers are generally extensive. The following logs are typical of the well records (table 1) that show these deposits.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well 10					
Soil and till	25	25	Till	50	120
Sand and gravel	3	28	Sand and gravel	10	130
Till	32	60	Till	10	140
Sand and gravel	10	70	Sand and gravel	20	160
Well 18					
Soil and till	23	23	Sand and gravel	16	122
Sand and gravel	11	34	Till	27	149
Till	19	53	Sand and gravel	10	159
Sand and gravel	8	61	Till or clay	4	163
Till	45	106	Sand and gravel	3	166
Well 56					
Soil and till	15	15	Till	8	204
Sand and gravel	17	32	Sand	5	209
Till	85	117	Clay	1	210
Sand and gravel	13	130	Sand	2	212
Till	57	187	Till	4	216
Sand and gravel	9	196	Shale	19	235

Well 56 was logged by a gamma-ray logging device, owned by the driller, D. J. Roe, Vandalia, Ohio, and this log probably is the most accurate of the three. The well was screened between depths of 120 and 130 feet and 190 and 196 feet. A pumping test of well 56, at a rate of 400 gpm (gallons per minute), produced a sizable drawdown in well 21, nearly 3,000 feet distant (fig. 8); this drawdown indicates continuity of the princiapl aquifer between these points.

CONSOLIDATED ROCKS

The distribution of consolidated sedimentary rocks of Ordovician and Silurian age that underlie the Piqua area is shown in figure 5.

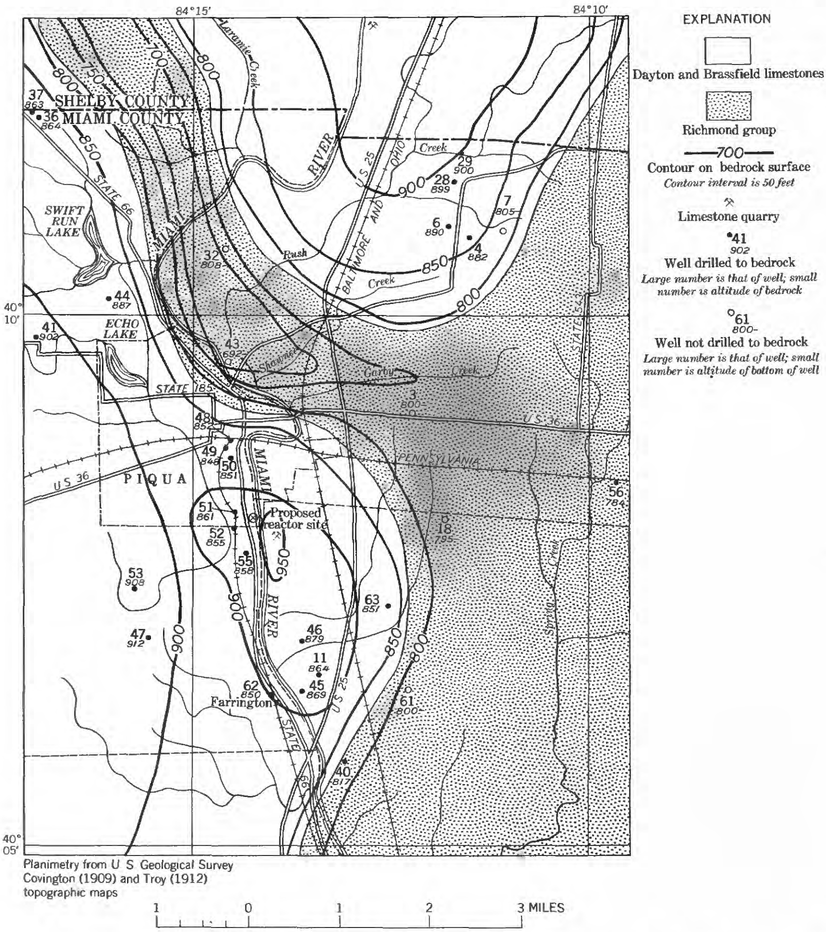


FIGURE 5.—Map of the Piqua area, Ohio, showing the distribution of the principal consolidated-rock units and approximate contours on the bedrock surface.

A generalized geologic section follows:

System	*Rock unit*	*Approximate thickness (feet)*
Silurian	Dayton limestone	7
	Brassfield limestone	30
Ordovician	Richmond group	100±

These strata lie on the west flank of the Cincinnati arch, near the crest, and dip northwest at a low angle, probably about 10 feet per mile. The altitude of the top of the Richmond group is approximately 826 feet at the proposed reactor site, where the Richmond lies beneath a few feet of the Brassfield limestone and alluvial deposits.

The Brassfield limestone and the Dayton limestone are exposed across the river from the proposed reactor site in a large quarry owned by the Armco Steel Corp. (figs. 6 and 7). The section was described by Stout (1941, p. 187) as follows:

	Ft	in
Dayton limestone:		
Dolomite, gray to buff, medium to massive layers, rather uniformly bedded, fine-grained, hard, few fossils	7	0
Shale, blue, irregular in thickness		2
Brassfield limestone:		
Limestone, hard, light to buff, parts pinkish tint, fossiliferous	9	4
Bedding plane, irregular with stylolites		
Limestone, light to drab, mainly porous texture, grainy	4	8
Shale, irregular, with stylolites above		½
Limestone, light, hard, part porous, massive layers	4	9
Shale, greenish, with stylolites above		1
Limestone, light, massive, rather porous, crystalline, some fossils	6	9
Floor of quarry, limestone, gray, earthy.		

The Richmond group consists principally of soft greenish-blue or blue-gray shale, interbedded with layers of hard limestone. The

FIGURE 6.—Exposure of the Brassfield limestone and Dayton limestone in a quarry on the east bank of the Miami River opposite the proposed reactor site.

FIGURE 7.—Exposure of the Brassfield limestone in a quarry on the east bank of the Miami River opposite the proposed reactor site.

limestone layers average 1 to 5 inches in thickness and may make up 25 to 50 percent of the whole sequence. The Richmond group is similar lithologically to the shale units of the Maysville group which it overlies; the strata are differentiated on the basis of fossils. The aggregate thickness of the Richmond group and the underlying Maysville and Eden groups is a little more than 1,000 feet, according to the record of a well drilled for oil or gas in 1886 (Orton, 1888, p. 273). Shale of the Richmond group is very poorly permeable and generally marks the lower limit of ground-water supplies in the area.

Locally in western Ohio the uppermost unit of the Richmond group, the Elkhorn formation, is a soft greenish-blue puttylike shale, in which the limestone layers are few and thin. The Elkhorn formation is as much as 50 feet thick in places. At Piqua the lithologic character of the Richmond group was not determined, owing to lack of exposures.

THE BEDROCK SURFACE

Figure 5 shows contours on the bedrock surface in the Piqua area, based largely on drillers' records of wells listed in table 1. East of Piqua the surface of the consolidated rocks forms a broad lowland east of and parallel to U.S. Highway 25. A narrow channel in the bedrock surface leads off northwestward from this lowland and underlies the area immediately northeast of Piqua. Such buried valleys were eroded by streams which drained the area prior to the Pleistocene glaciation, probably by northward-flowing tributaries of the ancient Teays River. The Teays River was the main stream of the principal preglacial drainage system in Ohio, and flowed northwestward across the State a few miles north of Piqua (Stout and others, 1943, p. 51–53; Norris and Spicer, 1958, fig. 16).

GROUND WATER

SOURCE AND OCCURRENCE

Ground water in the Piqua area has its source in local precipitation which percolates downward into the various aquifers and moves through these aquifers to points of discharge along the Miami River. In the areas immediately west and south of Piqua the Brassfield limestone is the principal source of water for farm and domestic wells, which generally yield as much as about 20 gpm. A much larger yield than this was reported at the Decker Packing Co., in the eastern part of Piqua, but the packing-company wells draw from both the limestone and an overlying sand and gravel bed. Where the Brassfield limestone has been thinned by erosion, as it is near the center of Piqua, it commonly yields less than 5 gpm or is totally unproductive.

East, north, and northwest of Piqua, in the immediate vicinity of of the city, most wells tap sand and gravel aquifers interbedded in till. These aquifers generally range from 5 to 10 feet in thickness and underlie areas at least a few square miles in extent. The buried sand and gravel deposits show wide variation in character from place to place. Locally the deposits may consist of clean well-sorted coarse sand and gravel, ideally suited to the development of wells, but elsewhere they may be clayey, or made up chiefly of fine sand, making well development difficult or impractical. Because of these variable characteristics, wells located within a comparatively small area may be drilled to different depths and tap different sand and gravel aquifers. The elevations of water levels in such wells usually show correspondingly wide differences.

Generally the depth to water in wells in the Piqua area is roughly proportional to the depth of the well; that is, the deeper the well, the farther the water level is below the surface. Wells 7 and 8, located near each other about 3 miles northeast of Piqua, illustrate this point. Well 7 is 205 feet deep and the water level, in April 1955, was 97 feet below the surface. Well 8 is 142 feet deep and the water level in April 1955 was only 65 feet below the surface. Both wells are open in sand and gravel aquifers interbedded in till at the respective depths indicated by the wells.

The buried sands and gravels are sources adequate for farm and domestic wells, and locally these aquifers yield sufficient water for limited industrial use. Well 56, drilled for the F. S. Royster Guano Co., about 3 miles east of Piqua, yielded, during a 24-hour pumping test, 400 gpm with a drawdown of 48 feet at the end of the test. This relatively high yield is not representative of these aquifers, however. Well 56 is screened in two aquifers, separated by 60 feet of till. Moreover, the water level in the well was still declining at a fairly rapid rate at the end of the test. Pumping in well 56 also produced a drawdown of 37 feet in well 21, nearly 3,000 feet away, which is evidence of the lateral continuity of these aquifers and the pronounced interference effects caused by pumping from them at a relatively high rate. No doubt a pumping rate in the magnitude of 100 gpm would be more practical for well 56, and more representative of the water-yielding properties of the buried sand and gravel aquifers.

The most productive source of ground water in the Piqua area is the outwash sand and gravel deposits in the Miami River valley. This source is not used extensively at Piqua, however, because at most places within the city the deposits are thin or absent. About 1900 Piqua obtained its municipal supply from 14 wells (Stout and others, 1943, p. 465) drilled in outwash deposits in the north end of town, but the wells were abandoned in favor of the present surface-water supply. At the present time a theater and one or two other commercial establishments have the only wells that tap the outwash deposits in Piqua.

The small use made of the valley-fill deposits at Piqua as sources of ground water is by no means representative of the importance of these aquifers generally in the Miami valley. Downstream from Piqua the outwash deposits are the source of about 200 mgd (million gallons per day) of ground water, or nearly one-sixth the total pumped in the State. The pumping is most concentrated at Dayton, where pumpage at two plants, the Frigidaire Div., General Motors Corp. and the National Cash Register Co., totals more than 25 mgd. Closer to Piqua, the municipal wells at Troy, which range in depth from 45 to 84 feet, yield 350 to 1,500 gpm each from sand and gravel deposits along the Miami River. Most wells drilled in the valley-fill deposits receive recharge by the induced infiltration of streamflow. Probably 75 to 90 percent of the water pumped from wells in the Miami valley has the river as its source.

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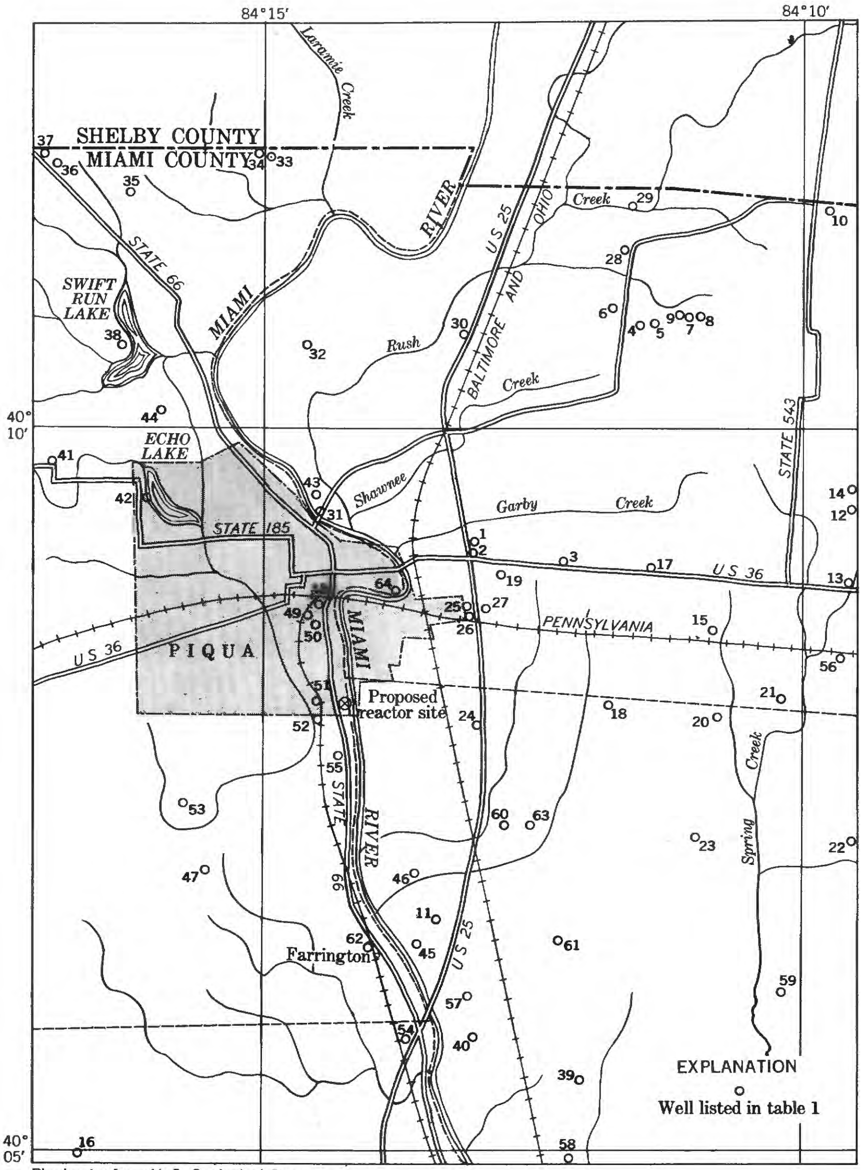

Planimetry from U. S. Geological Survey Covington (1909) and Troy (1912) topographic maps

Figure 8.—Map of the Piqua area, Ohio, showing location of wells listed in table 1.

RATE OF GROUND-WATER FLOW

The rate of ground-water movement in the Piqua area varies greatly from place to place, owing to the complexities of the geology and local hydrologic conditions, and it is difficult to estimate with confidence the rate of movement in most areas. Water movement in the limestone is along joints and cracks, commonly along the contact with shale of the underlying Richmond group. Where the limestone is thinly covered and lies close to the point of ground-water discharge, as it does in the area of the proposed reactor site, water probably moves at a comparatively high rate, probably measurable in feet or tens of feet per day.

Of importance with respect to hazards of contamination to downstream wells is the rate of ground-water movement through the outwash deposits in the Miami valley. Under natural hydraulic gradients in the Mad River valley near Dayton, where geologic conditions are similar to those in the Miami valley, W. C. Walton, of the U.S. Geological Survey (written communication, 1954), calculated the rate of ground-water flow through the outwash deposits as about 7 feet per day. In the Miami valley at a site near Hamilton, where pumpage from two ground-water collectors is in the magnitude of 15 mgd, G. D. Dove, of the U.S. Geological Survey (written communication, 1958), calculated the rate of movement of water through the outwash deposits from the river to the collectors as being as much as 13 feet per day. Hydraulic gradients at the site near Hamilton are not very steep, however, compared to the gradients at certain sites near Dayton—notably at the National Cash Register Co. plant, whose wells are very close to the stream—and it may be assumed that water moves through the outwash deposits in some areas at rates considerably greater than 13 feet per day.

The rate of travel of ground water into and through the sand and gravel aquifers interbedded with till on the uplands east and north of Piqua is conjectural. Water moves relatively slowly in the till, perhaps a few inches per day at most. The rate of movement would be many times greater once the water entered a buried sand and gravel lens, particularly in the vicinity of a pumped well.

The Richmond group, especially the clayey Elkhorn formation, transmits water very slowly. Tolman (1937, p. 219) reports that the effective velocity of water moving through clay under a hydraulic gradient of 1 percent is less than 0.004 foot per day. This figure is probably in the correct order of magnitude for the rate of movement of water through the Elkhorn formation.

The direction of movement of subsurface water at the reactor site is a matter of some uncertainty. The land-surface altitude is about 858 feet. The static level of ground water on September 3, 1958, in borings drilled for foundation exploration at the reactor site, was about 846 feet. The river is about 200 feet to the east, and its level was about 837 feet. There is a dam in the river about 300 feet upstream from the reactor site, and the river level above the dam was about 845 feet. These measurements suggest that ground water is flowing from the site toward the river. An element of uncertainty results from two unknowns, however:

1. The effect of the buried Miami-Erie Canal: the reactor site is on the old Miami-Erie Canal. There is evidence indicating that the old canal bottom may still be relatively watertight and may perch water above the water table. If so, the levels measured in the foundation borings may have been indicative of a perched body of water along the old canal.
2. The effect of pumping from wells to the northwest and southwest within about a thousand feet from the site: One commercial well has a reported capacity of 12 gpm (Piqua Granite Co.) and an undetermined but small number of domestic wells pump water from the same limestone formation that underlies the reactor site. Drillers' records for two wells of measurements made at the time the wells were drilled show both static and pumping levels to be above river level, but present levels are not known.

SURFACE WATER

The only appreciable use of surface water in the Piqua area takes place upstream from the proposed reactor site. The municipal supply of Piqua comes from the Miami River and two impounding reservoirs (Swift Run Lake and Echo Lake), and the main pumping station is 2 miles north of town. Municipal water use averages about 3 mgd. The Piqua municipal powerplant circulates for cooling purposes as much as 44 mgd from the Miami River. The plant intake and discharge are immediately upstream from the proposed reactor site.

A 3-year record (1915–17) of streamflow at Piqua is listed in table 3A. This record is too short to be very meaningful, however, and is included only as supplemental data. The most significant streamflow data collected in the Piqua area come from gaging stations on Loramie Creek at Lockington (tables 2A, 3B, and 4A) and on Miami River at Sidney, about 10 miles upstream from Piqua (tables 2B, 3C, and 4B). The drainage area of Loramie Creek above Lockington is 261 square miles, and the drainage area of the Miami River above Sidney is 545 square miles; the area gaged, therefore, is 806 square miles, only 36 square miles less than the total drainage area above Piqua. The records from Lockington and Sidney taken together, therefore, give a close approximation of flow at Piqua.

The lowest daily flow recorded at Sidney, since the beginning of record, in February 1914, was 8.0 cfs (cubic feet per second) on September 23, 1935. The minimum daily flow recorded at Lockington since October 1915 was 2.4 cfs, on August 18, 1931, and September 19–21, 1936. Thus, the daily flow at Piqua, under extreme drought conditions, might be expected to be in the magnitude of 10 to 15 cfs, or between 6 and 10 mgd. The flow equaled or exceeded at Piqua 90 percent of the time, based on the records from Lockington and Sidney, is in the magnitude of 53 cfs, or about 35 mgd.

Two lakes in the Miami drainage basin upstream from Piqua have a decided effect on streamflow. Lake Loramie (capacity 13,000 acre-feet, area 70 square miles), on Loramie Creek in the western part of Shelby County, and Indian Lake (capacity 45,900 acre-feet, area 110 square miles), on the Miami River in the northwest corner of Logan County (fig. 2), act as reservoirs and tend to stabilize the dry-weather flow of the two streams. Gate openings are seldom changed on either reservoir.

Inasmuch as the proposed reactor site is on the flood plain of the Miami River, the frequency and magnitude of floods merit consideration. Figure 9 shows the probable recurrence interval of floods on the Miami River based on the records of the U.S. Weather Bureau gaging station at Ash Street, Piqua, about 1½ miles upstream from the reactor site, from 1930 to 1959. The approximate altitude of the site is 858 feet. Because the site is 1½ miles downstream from the gaging station, the altitude of flood crests at the site is several feet lower.

The 1913 flood, the most serious on record, reached an altitude of 873 feet at Main Street, three-quarters of a mile upstream from the Ash Street gaging station and 2¼ miles upstream from the reactor site. Lockington Dam, completed in 1922 on Loramie Creek, would reduce by several feet the height of a flood comparable to that of 1913 flood in Piqua. Even considering the reduction, a flood of the 1913 magnitude would be on the order of twice the 1959 flood discharge. The site requires protection, perhaps a levee, against rare floods.

CHEMICAL QUALITY OF WATER

No analyses of ground-water samples in the Piqua area are available. Table 5*A* shows several analyses from wells drilled in Montgomery County into aquifers similar to those in the Piqua area. These analyses are believed to be characteristic of water that would be found in the various aquifers at and near Piqua. Such water is generally hard and high in iron content. As a general rule the iron content increases with depth, other things being comparable. (See wells 184 and 197, table 5*A*.)

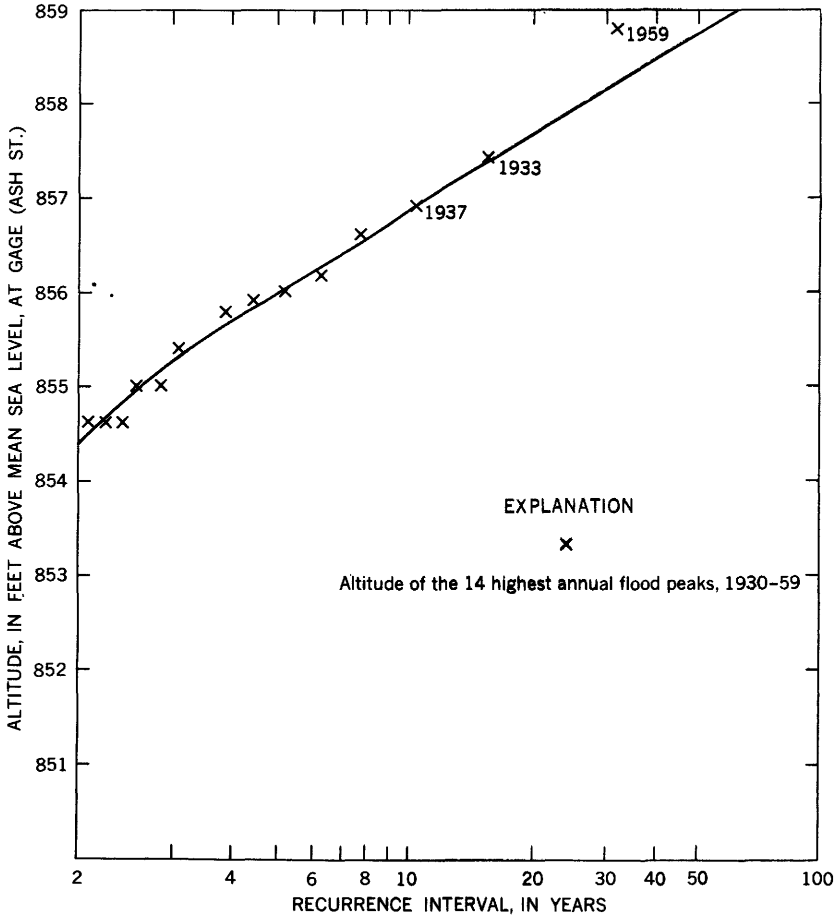

FIGURE 9.—Flood-frequency diagram, Miami River at Piqua, Ohio, 1930–59.

Table 5*B* shows analyses of three samples from streams in the vicinity of Piqua. The samples from Miami River at Sidney and Loramie Creek at Lockington were taken upstream from the proposed reactor site, and the sample from Miami River near Troy was taken downstream from the reactor site.

Table 5*C* shows analyses of water from three public supplies near Piqua. The Piqua supply is taken from the Miami River above the proposed site. The Troy and Vandalia supplies come from wells which are recharged by infiltration from the Miami River below the proposed reactor site.

The analyses shown in tables 5*A* and 5*B* were made by the U.S. Geological Survey. Those shown in table 5*C* were made by the Ohio Department of Health.

It may be of interest that Miami River at Venice, 70 miles downstream from Piqua, was found in June 1958 to contain 0.7 ppm strontium, a relatively high concentration for a stream water. No other analyses for strontium have been made in or near the area under investigation.

Besides the data presented herein, the Geological Survey has a daily sediment record at Dayton for the period October 1951 to September 1953, and a record of periodic and daily determinations of chemical quality of Miami River at Dayton for the period July 1946 to September 1948.

EARTHQUAKE ACTIVITY

At least 11 earthquakes have been recorded whose epicenters were in the State of Ohio. According to Heck (1947), 6 of these shocks had an intensity of 6 or greater on the Rossi-Forel scale (see table below), and 5 of these had epicenters in the vicinity of latitude 40° to 41° N., longitude 84° W., not far from Piqua.

Earthquakes in Ohio

[After Heck, 1947]

Date	Hour	Locality		Area felt (square miles)	Intensity (Rossi-Forel scale)
		Lat. N.	Long. W.		
June 18, 1875	0743	40. 2	84. 0	40, 000	6–7
Sept. 19, 1884	1414	40. 7	84. 1	125, 000	6
May 17, 1901	0100	39. 3	82. 5	7, 000	6
Sept. 20, 1931	1705	40. 2	84. 3	40, 000	8
Mar. 2, 1937	0948	40. 7	84. 0	90, 000	8
Mar. 9, 1937	0045	40. 6	84. 0	150, 000	8

The earthquakes of March 2 and 9, 1937 (Rouse and Priddy, p. 25–27), both had their epicenters near the village of Anna, 17 miles north of Piqua. These tremors were felt in most of Ohio, but damage was apparently restricted to a radius of about 4 miles from the epicenters. Chimneys toppled, windows shattered, and cracks appeared in the walls of houses at Anna. A school and two churches were severely damaged. The walls of the school were so severely cracked that the building had to be condemned.

No damage from these quakes was reported in Piqua or anywhere else in the Miami valley, according to the Dayton Journal and the Sidney Daily News. Many Miami valley residents were awakened by the quake of March 9, which occurred at 12:45 a.m. Ominous rumbling was reported by some residents of Dayton.

The cause of these earthquakes has never been established. Plausible hypotheses are that the quakes were due to collapse of limestone caverns about 25 miles northeast of Piqua or that they were the result of movement along the Bowling Green fault.

The Bowling Green fault can be traced from the Michigan line near Toledo southward to Kenton in Hardin County, where it is lost under a thick cover of glacial drift. A continuation of the trace of this fault passes through the east edge of Logan and Champaign Counties, about 30 miles east of Anna and Piqua. The relation of this fault to earthquake activity has not been established.

SUMMARY AND CONCLUSIONS

The proposed reactor site is on the west bank of the Miami River at Piqua, Ohio, about 30 miles upstream (north) from Dayton, Ohio. The estimated daily flow of the river at Piqua under drought conditions would be 10 to 15 cfs; the flow expected to be equaled or exceeded 90 percent of the time is about 53 cfs.

The site is underlain by horizontally bedded, highly fractured limestone about 25 feet thick which is underlain by shale interbedded with limestone of undetermined thickness. The site is, in part, on the now-abandoned and buried Miami-Erie Canal, which here paralleled the river. Hence, the surficial material, as much as 9 feet thick, consists of dumped rock used to fill in the canal. In the vicinity of the site, and for a mile or two downstream along the river, the natural unconsolidated overburden (glacial drift) is thin or absent, and the limestone is at or near the land surface. However, thick and extensive deposits of glacial till overlie the limestone to both the east and the west of the site. At the site and for about 2 miles downstream, the flood plain of the Miami River is relatively narrow; beginning about 2 miles downstream and continuing to Dayton and beyond, the flood plain of the river is considerably wider and is underlain by permeable sand and gravel deposits.

The Piqua municipal water supply is pumped from the Miami River upstream from the reactor site. Downstream from the site virtually all water used for municipal and industrial purposes is pumped from wells that tap the sand and gravel underlying the river flood plain. Total daily pumpage from such wells is estimated to average 100 million gallons, most of it pumped in or near Dayton. Of particular importance is the estimate that 75 percent or more of the water pumped from wells is derived from the river by induced infiltration to the various well fields. The nearest downstream well field open to recharge from the river is that of the municipal supply of Troy, about 8 miles downstream. Pumpage at Troy is on the order of 1 or 2 mgd.

Owing to possible effects of nearby ground-water pumping and to the presence of the buried Miami-Erie Canal, the direction of ground-water movement in the vicinity of the site is unknown.

What, then, might happen to a liquid spilled on the land surface at the reactor site? According to the soil condition at the time of the spill, the volume of liquid spilled, the rate of spill, and other factors:

1. The liquid might be absorbed by the soil in whole or in part. However, the soil and unconsolidated overburden are quite thin and cannot be dependend on for significant hold-up of a spilled contaminant.
2. The liquid might flow overland to the river some 200 feet away.
3. The liquid might percolate down to the water table and thence move with ground water to the river. Because the aquifer is a fractured limestone, it would not be prudent (without evidence to the contrary) to depend on a time of travel of more than several hours before the liquid reached the river. However, the relatively impermeable fill in the old canal bed might act to delay movement of the contaminant to the river.
4. The liquid might percolate down to the water table and thence move with ground water westward toward one or more pumped wells. The evidence available to the authors, however, favors the previous assumption—that is, that ground water at the site moves to the river and away from the wells. But even if this is true for existing conditions, there is no guarantee that future development of ground-water supplies in the immediate vicinity could not reverse the natural gradient at the reactor site.

In short, the on-site retention by the natural environment of a spilled liquid contaminant cannot be depended on to be more than a matter of a few hours, or at most a few tens of hours. The most probable assumption is that the liquid would enter the river either by overland flow or by subsurface flow, or by both. Once in the river it would, of course, move downstream with the river water. Dilution and time of travel would depend on river conditions at the time. Travel time to Dayton, which would vary greatly with discharge, might range from a few hours to several days. Where river water recharges a subjacent aquifer the rate of flow through the aquifer is estimated to range from a few feet to several tens of feet per day. Detailed time of travel and dilution computations for a "slug" of contamination to individual well fields cannot be made on the basis of presently available information.

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BASIC DATA

TABLE 1.—*Records of wells in the Piqua area, Ohio*

Character: g, gravel; ls, limestone
Geologic unit: Pl, Pleistocene; Sil, Silurian.

Drawdown: Lowering of the water level at rate of pumping indicated.
Use: Dom, domestic; Ind, industrial; PS, public supply.

Well (See fig. 8 for location)	Owner or user	Altitude at well (feet above sea level)	Depth to bedrock (feet)	Depth of well (feet)	Principal water-bearing material		Water level		Yield		Diameter of well (inches)	Use	Remarks
					Character	Geologic unit	Below land surface (feet)	Date	Capacity (gpm)	Drawdown (feet)			
1	Richard Anderson	930	------	81	g	Pl	33	5-22-56	6	2	4	Dom	
2	Trion	930	------	102	g	Pl	30	8-15-56	20	10	4	Dom	
3	State of Ohio	960	------	161	g	Pl	68	9-16-54	30	1	6	Dom	
4	John Good	990	108	126	ls	Sil	60	2-11-57	15	5	4	Dom	
5	do	1,000	------	88	g	Pl	49	4-18-56	10	18	4	Dom	
6	Walter's Tavern	980	90	134	ls	Sil	67	8-24-55	10	2	6	Dom	
7	Owen Darting	1,010	------	205	g	Pl	97	4-14-55	------	------	4	Dom	
8	Leroy Nicholson	1,010	------	142	g	Pl	65	4- 4-55	------	------	4	Dom	
9	Wayne Darting	1,010	------	113	g	Pl	53	2-11-57	10	------	4	Dom	
10	Henry Redlinbaugh	1,035	------	160	g	Pl	46	9-18-56	24	15	6	Dom	
11	D. W. Johnston	880	16	46	ls	Sil	16	11-24-58	5	15	4	Dom	
12	Edward Cottrell	1,000	------	131	g	Pl	20	8-17-53	20	15	4	Dom	
13	Clarence Brush	995	------	105	g	Pl	85	5- 7-52	10	2	6	Dom	
14	Andy Bryant	1,010	------	98	g	Pl	10	4-20-56	8	25	4	Dom	
15	John Bair	985	------	151	g	Pl	86	6-10-56	20	5	4	Dom	
16	John Siegel	950	------	32	g	Pl	16	9-29-54	5	8	6	Dom	
17	Duncan Tharp	990	------	41	t	Pl	6	4-12-54	20	5	4	Dom	
18	Emmitt Zoll	960	------	166	g	Pl	63	8-31-57	6	25	4	Dom	
19	Myron Fuller	950	------	134	g	Pl	48	6- 4-56	8	5	4	Dom	
20	B. V. Steinman	975	------	145	g	Pl	66	6-28-56	6	14	4	Dom	
21	James Fox	980	------	126	g	Pl	6	7-16-58	10	4	4	Dom	Water level declined 37 feet when well 56 was pumped at 400 gpm.
22	Herbert Starry	980	------	220	g	Pl	90	5-29-54	20	130	6	Dom	
23	David Guenther	965	------	145	g	Pl	68	6- 3-53	15	2	6	Dom	
24	Ohio Dept. of Highways	940	------	81	g	Pl	22	4-18-58	30	3	6	Dom	
25	Ray Scherer	920	------	102	g	Pl	30	7-25-54	7	4	4	Dom	
26	John Ryan	920	------	58	g	Pl	38	10-31-52	8	12	4	Dom	
27	Ella Perkins	935	------	104	g	Pl	22	5-27-54	20	5	4	Dom	
28	Elden Hayes	975	76	114	ls	Sil	35	10- 8-55	20	15	4	Dom	
29	Edward Christ	955	55	91	ls	Sil	15	7-10-56	10	10	4	Dom	
30	Henry Collins	930	------	109	g	Pl	40	3-12-57	30	10	4	Dom	
31	Frank Cottrell	860	------	31	g	Pl	18	11-10-54	10	2	4	Dom	
32	B. L. Webster	890	------	82	g	Pl	Flows	11- 7-55	20	------	4	Dom	

33	B. Keyt	920	---	128	g	Pl	32	10–12–56	20	---	4	Dom	
34	J. C. Ostendorfe	900	---	125	g	Pl	26	10–27–56	24	44	6	Dom	
35	Charles McKinney	970	---	113	g	Pl	65	9–27–55	6	3	4	Dom	
36	Brown	990	126	190	ls	Sil	75	5– 8–54	20	15	4	Dom	
37	Harry Starker	985	122	210	ls	Sil	72	4– 6–57	10	47	4	Dom	
38	Lawrence Lange	950	---	74	g	Pl	44	6–12–53	7	4	4	Dom	
39	William Buchman	900	---	92	g	Pl	37	8–20–56	13	5	6	Dom	
40	Edgar Anderson	870	53	70	ls	Sil	30	11–16–53	15	30	6	Dom	
41	Alice Fox	965	63	79	ls	Sil	4	8–22–55	20	1	4	Dom	
42	Robert Grosvenor	950	---	63	g	Pl	55	4–19–55	10	7	4	Dom	
43	Walter Calton	870	---	178	g	Pl	12	9– 3–55	8	70	4	Dom	
44	William Cummins	930	67	123	ls	Sil	34	6–12–56	5	40	4	Dom	Top of shale of Richmond group at 120 feet.
45	Clarence Austerman	875	6	75	ls	Sil	10	9–15–52	10	60	6	Dom	
46	J. F. Beachler	885	6	60	ls	Sil	6	3–10–55	10	50	6	Dom	Top of shale of Richmond group at 56 feet.
47	Mae Hiegel	945	33	56	ls	Sil	Flows	11–17–57	20	---	6	Dom	
48	City of Piqua	870	18	57	ls	Sil	18	5– 5–54	5	30	8	Ind	Top of shale of Richmond group ar 56 feet.
49	Yield More Feed Co.	870	22	54	ls	Sil	Dry	9–10–52	---	---	8	Ind	Abandoned.
50	Market	870	19	40	ls	Sil	17	6– 2–55	7	15	4	Ind	
51	Piqua Granite Co.	865	4	45	ls	Sil	15	6–13–56	12	---	6	Ind	Top of shale of Richmond group at 36 feet.
52	Edward Creath	860	5	38	ls	Sil	17	6–29–55	8	4	4	Dom	
53	H. R. Weaver	945	37	50	ls	Sil	Flows	6–25–56	15	---	4	Dom	
54	Dettmar Hospital	860	---	70	g	Pl	32	9–11–56	400	---	8	PS	
55	Six Industries Corp.	860	2	30	ls	Sil	10	3–24–54	20	10	6	Ind	
56	F. S. Royster Guano Co.	1,000	216	235	g	Pl	16	6– 2–57	400	48	8	Ind	See well 21.
57	Paul Cress	880	---	43	g	Pl	10	7–23–53	20	5	4	Dom	
58	Clarence Birnkman	880	---	84	g	Pl	43	5–26–52	6	4	4	Dom	
59	Robert Armstrong	930	---	83	g	Pl	21	12–22–52	10	18	6	Dom	
60	C. R. Torrence	925	---	54	g	Pl	25	1–15–54	20	16	4	Dom	
61	N. M. Kerns	915	---	116	g	Pl	45	10–24–54	20	20	4	Dom	
62	Russell S. Taylor	870	20	47	ls	Sil	21	9–18–54	3	20	4	Dom	
63	Paul Cress	930	79	103	ls	Sil	30	8–14–56	15	45	4	Dom	
64	Decker Packing Co.	860	10	45	ls	Sil	---	---	80	---	8	Ind	Two identical wells.

TABLE 2.—*Flow-duration data at two gaging stations near Piqua, Ohio*

Period	Discharge, in cfs (upper number) and cfs per sq mi (lower number), for indicated percent of time discharge was equaled or exceeded														
	5	10	15	20	25	30	40	50	60	70	75	80	85	90	95
A. Loramie Creek at Lockington, Ohio [After Cross and Hedges, 1959, p. 137]															
1916–55	1,010 3.86	560 2.15	320 1.23	221 0.847	161 0.617	120 0.460	67.0 0.257	40.0 0.154	25.8 0.099	17.2 0.066	14.0 0.054	11.6 0.044	9.57 0.037	7.91 0.030	6.20 0.024
1921–45	950 3.64	478 1.83	286 1.10	193 0.739	137 0.525	101 0.387	58.2 0.223	36.9 0.141	23.4 0.090	15.3 0.059	12.7 0.049	10.7 0.041	9.00 0.034	7.60 0.029	5.95 0.023
1916–20	1,000 3.84	680 2.61	385 1.48	250 0.958	184 0.705	140 0.536	88.0 0.337	62.0 0.238	47.5 0.182	32.5 0.125	27.0 0.103	22.3 0.085	16.8 0.064	12.9 0.049	10.6 0.041
1921–25	1,000 3.84	505 1.93	305 1.17	205 0.785	150 0.575	117 0.448	70.0 0.268	53.0 0.203	38.0 0.146	22.0 0.084	16.5 0.063	13.2 0.051	11.0 0.042	9.00 0.034	7.32 0.028
1926–30	1,100 4.21	700 2.68	425 1.63	290 1.11	210 0.805	164 0.628	95.0 0.364	58.0 0.222	34.5 0.132	20.5 0.079	16.8 0.064	14.2 0.054	12.1 0.046	10.5 0.040	9.17 0.035
1931–35	637 2.44	330 1.26	170 0.651	120 0.469	90.0 0.345	70.0 0.268	46.0 0.176	30.0 0.115	19.0 0.073	12.8 0.049	10.5 0.040	9.00 0.034	7.50 0.029	6.20 0.024	5.17 0.020
1936–40	1,000 3.85	495 1.90	295 1.13	195 0.747	135 0.517	103 0.395	61.0 0.234	33.0 0.126	21.2 0.081	14.0 0.054	11.5 0.044	9.80 0.038	8.50 0.033	6.90 0.026	4.92 0.019
1941–45	920 3.52	385 1.48	210 0.805	135 0.517	94.0 0.360	73.0 0.280	39.5 0.151	24.5 0.094	16.0 0.061	10.3 0.039	9.60 0.037	9.00 0.034	8.10 0.031	6.90 0.026	5.14 0.020
1946–50	1,300 4.98	700 2.68	439 1.68	295 1.13	200 0.766	142 0.544	76.3 0.292	45.5 0.174	29.0 0.111	18.7 0.072	15.0 0.057	12.5 0.048	10.3 0.039	8.40 0.032	7.50 0.029
1951–55	1,010 3.86	560 2.15	340 1.30	201 0.770	137 0.525	94.3 0.361	55.0 0.211	34.2 0.131	20.5 0.079	12.5 0.048	10.4 0.040	8.45 0.032	7.24 0.028	6.20 0.024	5.23 0.020

B. Miami River at Sidney, Ohio

[After Cross and Hedges, 1959, p. 137]

1917–18	1,930	1,160	805	630	500	395	262	167	117	85.5	73.7	63.7	54.8	45.9	36.4
1921–55	3.54	2.13	1.48	1.16	0.917	0.725	0.481	0.306	0.215	0.157	0.135	0.117	0.101	0.084	0.067
1921–45	1,940	1,100	784	588	463	369	246	166	112	83.9	74.0	63.2	53.9	44.5	35.0
	3.56	2.02	1.44	1.08	0.850	0.677	0.451	0.305	0.206	0.154	0.136	0.116	0.099	0.082	0.064
1921–25	2,030	1,110	895	705	550	450	300	177	110	78.0	68.5	61.5	57.0	54.0	45.9
	3.73	2.04	1.64	1.29	1.01	0.826	0.550	0.325	0.202	0.143	0.126	0.113	0.105	0.099	0.084
1926–30	2,600	1,590	1,070	820	680	580	400	308	225	150	127	106	90.0	76.0	49.0
	4.77	2.92	1.96	1.50	1.25	1.06	0.734	0.565	0.413	0.275	0.233	0.194	0.165	0.139	0.090
1931–35	1,300	790	525	370	272	210	142	102	79.0	62.5	56.5	50.0	43.0	34.5	26.3
	2.39	1.45	0.963	0.679	0.499	0.385	0.261	0.187	0.145	0.115	0.104	0.092	0.079	0.063	0.048
1936–40	1,900	1,080	790	580	455	370	247	170	123	84.0	72.0	62.5	55.0	45.5	34.9
	3.49	1.98	1.45	1.06	0.835	0.679	0.453	0.312	0.226	0.154	0.132	0.115	0.101	0.083	0.064
1941–45	1,460	900	600	455	345	262	160	112	77.0	58.0	51.0	46.0	42.0	38.3	32.8
	2.68	1.65	1.10	0.835	0.633	0.481	0.294	0.206	0.141	0.106	0.094	0.084	0.077	0.070	0.060
1946–50	2,350	1,500	1,090	830	660	520	350	250	180	127	106	86.0	72.1	59.8	47.2
	4.31	2.75	2.00	1.52	1.21	0.954	0.642	0.459	0.330	0.233	0.194	0.158	0.132	0.110	0.087
1951–55	1,870	1,200	848	605	442	330	200	130	86.0	64.0	56.5	50.5	46.1	40.1	35.0
	3.43	2.20	1.56	1.11	0.811	0.606	0.367	0.239	0.158	0.117	0.104	0.093	0.085	0.074	0.064

	A	*B*
Location	Lat 40°12'35", long 84°14'32", at highway bridge, 1,300 ft downstream from Lockington Dam, half a mile northwest of Lockington, Shelby County, and 1½ miles upstream from mouth.	Lat 40°17'14", long 84°08'57", 100 ft upstream from North Street Bridge in Sidney, Shelby County, and half a mile downstream from Tawawa Creek.
Drainage	261 sq mi	545 sq mi.
Period of record	October 1915 to September 1955	February 1914 to September 1955.
Maximum daily discharge	6,590 cfs, May 7, 1916, and Apr. 21, 1920	17,400 cfs, Mar. 21, 1927.
Minimum daily discharge	2.4 cfs, Aug. 18, 1931, and Sept. 19–21, 1936	8.0 cfs, Sept. 23, 1935.
Mean discharge	40 years, 1916–55; 207 cfs, 0.793 cfs per sq mi, 10.76 in.	41 years, 1915–55; 484 cfs, 0.888 cfs per sq mi, 12.05 in.
Mean discharge	1921–45; 194 cfs, 0.743 cfs per sq mi, 10.09 in.	1921–45; 475 cfs, 0.87 cfs per sq mi, 11.83 in.
Maximum recorded discharge	10,400 cfs, May 7, 1916	20,700 cfs, Mar. 20, 1927.
Minimum recorded discharge	2.0 cfs, Aug. 19, 1931	7.4 cfs, Sept. 23, 1935.
Remarks	Slight regulation by Lake Loramie (13,000 acre-ft, 70 sq mi). Flood flow regulated by Lockington retarding basin (70,000 acre-ft, 261 sq mi) beginning in 1921.	Flow regulated by Indian Lake (45,900 acre-ft, 110 sq mi). Records include flow in Miami-Erie Canal, abandoned in 1925.

TABLE 3.—*Monthly and annual discharge, in cubic feet per second*

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
***A*. Miami River at Piqua, Ohio**													
[Drainage area 842 square miles]													
1915	310	28.5	208	587	2,590	143	210	117	794	2,800	1,280	952	824
1916	739	473	821	4,300	1,700	2,690	1,080	1,790	723	84.2	71.9	228	1,230
1917	98.4	67.3	264	972	864	1,530	685	688	710	1,360	77.5	56.7	615
***B*. Loramie Creek at Lockington, Ohio**													
[Drainage area 261 square miles]													
1916	78.2	136	209	1,420	507	825	360	593	155	25.7	10.8	68.9	367
1917	17.2	12.0	62.4	598	439	636	180	390	280	513	28.1	13.0	294
1918	25.6	34.4	25.6	130	.959	388	105	179	44.5	31.8	29.2	46.9	161
1919	29.0	34.8	359	111	60	800	350	250	60	40	35.8	17.4	181
1920	210	396	117	45.0	232	583	1,040	82.5	51.9	102	43.5	57.9	246
1921	75.1	336	233	319	325	936	288	72.2	110	51.1	50.0	52.9	237
1922	61.4	359	356	115	250	521	1,300	102	41.7	584	28.2	14.1	310
1923	12.5	11.7	65.5	374	174	436	120	460	19.1	15.8	20.4	29.2	146
1924	7.74	8.37	413	573	256	961	208	95.7	970	41.2	11.1	5.67	296
1925	6.06	8.30	105	96.3	206	319	53.3	20.3	39.4	15.0	7.81	83.9	79.4
1926	77.5	541	72.2	167	488	317	474	57.0	20.1	27.9	31.5	1,090	276
1927	432	109	45.0	470	437	939	461	568	174	21.4	12.0	15.1	307
1928	9.26	54.0	384	198	375	324	327	35.9	556	173	14.5	9.23	204
1929	9.48	12.0	42.9	614	482	320	327	409	137	123	55.2	11.3	211
1930	24.9	145	447	1,450	498	199	109	33.9	32.6	13.6	8.86	9.72	248
1931	10.1	7.93	9.15	15.4	34.2	86.0	212	19.4	15.6	93.6	66.0	67.8	53.0
1932	67.5	52.0	337	748	229	151	94.4	25.1	29.3	32.9	7.27	12.3	149
1933	21.2	280	537	429	100	568	370	1,020	30.0	20.6	34.9	328	314
1934	124	18.8	160	98.7	27.1	365	99.3	17.7	31.5	11.6	36.6	8.16	84.2
1935	5.74	6.35	7.61	34.0	24.4	166	97.7	581	37.2	35.2	44.2	6.69	88.2
1936	8.91	16.3	49.0	86.6	588	420	183	84.0	11.0	5.35	3.37	3.70	120
1937	28.6	87.5	49.9	1,728	381	147	475	84.9	164	564	139	14.2	323
1938	38.9	25.0	300	71.4	530	761	649	174	91.0	152	176	20.0	247
1939	7.50	19.9	30.5	118	381	563	505	28.0	256	142	69.7	7.24	175
1940	20.0	11.0	11.8	45.3	255	285	712	127	209	13.5	9.26	5.20	140

1941	4.78	10.8	45.6	70.8	118	21.4	71.8	11.9	173	187	10.2	5.01	60.4
1942	45.5	49.5	120	52.8	532	350	495	94.3	32.6	63.8	65.5	15.8	157
1943	7.35	17.9	185	203	250	714	105	723	241	25.6	375	12.2	240
1944	11.4	11.8	8.44	8.89	96.5	691	783	83.1	22.9	6.36	28.6	4.94	146
1945	4.98	9.40	8.24	8.15	531	848	469	235	495	145	83.5	114	243
1946	228	106	326	263	297	302	53.9	188	193	40.0	8.81	5.19	167
1947	6.94	13.1	86.3	457	146	277	664	534	623	85.0	27.0	18.2	245
1948	8.67	14.1	24.7	303	448	783	786	306	31.0	18.6	29.0	7.08	229
1949	9.80	269	488	1,297	462	518	214	86.5	48.9	63.2	27.3	9.10	291
1950	12.6	8.54	27.4	1,630	1,119	363	308	136	114	82.1	18.0	22.9	316
1951	150	381	638	644	839	561	283	129	29.7	14.7	6.52	5.73	304
1952	6.04	30.3	537	986	495	614	537	106	20.7	12.6	44.0	56.7	287
1953	11.5	17.5	160	398	200	351	61.2	567	55.0	14.8	25.0	6.15	156
1954	4.29	6.34	7.87	60.6	37.2	212	258	53.4	57.4	7.31	121	6.79	69.4
1955	99.4	37.5	145	313	543	545	129	27.5	27.5	25.1	9.65	14.3	158
1956	92.8	449	43.1	30.3	749	355	292	271	123	24.4	12.2	9.43	201
1957	6.08	6.78	33.1	162	283	86.5	1,148	186	406	453	14.3	11.2	231
1958	14.7	80.9	713	119	168	162	228	228	1,754	456	188	123	352

C. **Miami River at Sidney, Ohio**

[Drainage area 545 square miles]

1914	------	------	------	------	676	1,110	1,210	515	36	35.1	88.1	144	------
1915	228	22.1	113	442	1,440	254	137	64.1	302	1,180	510	450	423
1916	466	336	510	2,620	1,130	1,810	596	940	489	56.4	53.4	104	762
1917	100	43.6	167	547	527	816	388	335	416	625	60.4	38.4	338
1918	107	235	207	204	1,250	589	196	431	106	118	59.5	170	300
1919	210	167	585	338	109	1,210	737	446	150	100	70	49.5	350
1920	209	716	458	150	300	1,170	2,330	520	176	364	98.1	162	553
1921	123	931	789	644	1,070	2,250	1,120	781	293	88.9	91.3	67.2	685
1922	89.7	855	667	288	487	1,040	2,590	865	216	408	81.7	115	639
1923	56.9	54.4	168	873	538	826	357	1,180	154	61.3	63.1	94.8	370
1924	92.4	70.8	939	1,190	628	1,850	573	227	1,900	376	64.1	105	669
1925	44.1	54.4	227	173	621	677	157	88.9	79.6	55.9	48.1	146	195
1926	178	896	282	188	921	707	1,130	184	99.3	188	231	2,360	606
1927	1,710	598	259	1,220	1,100	2,510	1,210	1,460	734	269	202	268	963
1928	122	327	1,680	585	853	595	741	165	1,110	396	83.6	176	568
1929	78.5	112	243	1,430	1,390	1,160	1,010	992	244	416	417	65.2	627
1930	240	535	1,091	3,846	1,407	693	287	134	135	57.4	37.2	78.0	711
1931	66.7	55.5	63.4	75.0	155	327	547	83.9	75.8	129	58.3	57.9	141
1932	113	145	628	1,600	702	484	299	121	227	118	32.5	38.1	376
1933	62.9	531	859	951	304	1,390	914	2,010	183	134	89.7	293	648

TABLE 3.—*Monthly and annual discharge, in cubic feet per second*—Continued

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
C. Miami River at Sidney, Ohio—Continued													
[Drainage area 545 square miles]													
1934	151	145	250	225	68.6	608	226	70.6	58.1	24.6	37.7	27.9	159
1935	29.3	36.3	41.3	88.5	73.9	281	277	826	114	449	398	40.1	223
1936	78.9	105	328	463	1,174	1,123	569	169	60.8	39.9	33.9	37.8	346
1937	76.8	204	82.5	3,334	935	404	990	408	433	575	124	65.9	636
1938	168	152	585	293	1,170	1,678	1,539	331	187	407	119	187	564
1939	116	110	124	227	781	1,488	1,244	197	1,054	426	246	60.1	502
1940	82.8	112	91.5	185	597	964	1,653	232	325	71.1	43.6	30.9	363
1941	36.7	80.3	200	269	297	106	204	77.9	517	198	35.7	25.4	169
1942	58.6	111	189	135	737	682	1,082	157	162	68.0	74.1	39.3	287
1943	36.2	68.1	326	597	631	1,668	288	943	349	188	882	63.0	506
1944	53.2	67.4	92.1	67.1	193	1,183	1,444	253	217	42.6	134	34.9	314
1945	41.4	59.8	45.6	47.3	724	1,958	948	902	1,513	360	356	253	599
1946	470	374	515	618	777	741	164	297	445	144	47.9	33.1	384
1947	49.0	69.0	252	913	456	462	1,237	1,281	1,499	333	278	294	593
1948	192	274	230	878	1,150	1,477	1,889	1,103	168	151	67.7	42.3	633
1949	59.8	515	888	2,238	1,203	1,015	655	272	305	255	203	103	641
1950	86.3	67.7	151	3,433	2,186	907	1,042	432	216	128	95.2	152	734
1951	370	762	1,502	1,389	1,521	1,072	822	547	184	92.8	47.8	45.3	692
1952	42.7	86.4	815	2,198	997	1,255	1,200	376	138	64.0	62.0	65.1	609
1953	43.5	49.6	129	552	351	575	214	1,166	166	87.0	177	38.2	297
1954	36.8	43.9	51.6	124	111	330	577	120	366	43.6	319	33.2	179
1955	170	125	254	534	1,141	1,407	302	110	67.2	150	51.5	44.9	359
1956	141	607	141	114	1,478	1,170	636	507	383	371	111	55.1	471
1957	62.2	92.9	144	374	492	314	2,500	710	1,101	925	93.3	108	573
1958	92.4	349	1,266	419	370	448	555	635	2,073	970	589	293	672

TABLE 4.—*Momentary maximum, minimum daily, and annual mean discharge, in cubic feet per second*

Year	Water-supply paper	Water year ending Sept. 30				Mean for calendar year
		Momentary maximum		Minimum daily	Mean	
		Amount	Date			
A. Loramie Creek at Lockington, Ohio						
1916	523, 923	10,400	May 7, 1916	5	367	340
1917	523	[1] 6,110	Mar. 13, 1917	12	264	264
1918	523	[1] 7,000	Feb. 12, 1918	11	161	190
1919	523	[1] 7,230	Mar. 16, 1919	----------	181	205
1920	523	[1] 8,190	Apr. 20, 1920	24	246	239
1921	523	[1] 6,590	Mar. 27, 1921	32	237	248
1922	543	4,900	Apr. 15, 17, 1922	12	310	253
1923	563	3,750	May 15, 1923	8	146	175
1924	583	5,970	Mar. 29, June 8, 1924	5	296	270
1925	603	2,190	Mar. 14, 1925	5	79.4	126
1926	623	5,280	Sept. 5, 1926	9.5	276	268
1927	643	5,870	Mar. 21, 1927	8.8	307	296
1928	663	4,170	Dec. 14, 1927	8	204	171
1929	683	5,420	Feb. 26, 1929	8	211	257
1930	698	4,710	Jan. 14, 1930	7.2	248	198
1931	713	1,660	Apr. 3, 1931	2.4	53.0	89.3
1932	728	3,190	Jan. 15, 1932	4.1	149	181
1933	743	5,810	May 13, 1933	5.8	314	269
1934	758	2,430	Mar. 27, 1934	3.4	84.2	60.1
1935	783	4,130	May 3, 1935	3.8	88.2	92.8
1936	803	4,130	Feb. 27, 1936	2.4	120	127
1937	823	5,290	Jan. 15, 1937	7.1	323	340
1938	853	4,120	Apr. 7, 1938	8.0	247	221
1939	873	3,550	June 19, 1939	5.2	175	174
1940	893	3,340	Apr. 20, 1940	3.8	140	142
1941	923	1,800	June 15, 1941	2.6	60.4	73.3
1942	953	3,550	Apr. 10, 1942	2.8	157	156
1943	973	4,960	Mar. 20, 1943	5.4	240	225
1944	1003	4,840	Apr. 11, 1944	3.7	146	145
1945	1033	4,840	June 18, 1945	4.4	243	297
1946	1053	2,680	Feb. 27, 1946	4.4	167	121
1947	1083	4,160	June 2, 1947	4.3	245	240
1948	1113	4,260	Mar. 24, 1948	5.8	229	289
1949	1143	4,580	Jan. 5, 1949	6.1	291	231
1950	1173	5,300	Feb. 15, 1950	7.4	316	410
1951	1205	4,820	Feb. 21, 1951	4.5	304	254
1952	1235	4,940	Jan. 27, 1952	4.7	287	255
1953	1275	3,200	May 17, 1953	4.0	156	142
1954	1335	2,420	Mar. 30, 1954	3.8	69.4	91.8
1955	1385	3,180	Feb. 21, 1955	3.5	158	182
1956	1435	4,700	Nov. 16, 1956	3.8	201	157
1957	1505	4,940	June 29, 1947	3.0	231	----------

See footnotes at end of table.

TABLE 4.—*Momentary maximum, minimum daily, and annual mean discharge, in cubic feet per second*—Continued

Year	Water-supply paper	Water year ending Sept. 30				Mean for calendar year
		Momentary maximum		Minimum daily	Mean	
		Amount	Date			
***B.* Miami River at Sidney, Ohio**						
1914	403	[2] 5,530	Apr. 8, 1914	------------	------------	------------
1915	403	[1] 4,770	Feb. 6, 1915	18	423	502
1916	433	12,200	Jan. 31, 1916	38	762	678
1917	523	[1] 4,940	Mar. 14, 1917	9	338	358
1918	523	[1] 5,100	Feb. 12, 1918	20	300	335
1919	523	[1] 6,730	Mar. 17, 1919	------------	350	384
1920	523	15,500	Apr. 21, 1920	33	553	591
1921	523	[1] 9,300	Mar. 28, 1921	33	685	666
1922	543	[2] 9,300	Apr. 17, 1922 [1]	46	639	529
1923	563	5,080	May 13, 15, 1923	33	370	440
1924	583	14,900	Mar. 29, 1924	31	669	603
1925	603	2,430	Mar. 14, 1925	16	195	280
1926	623	10,800	Sept. 5, 1926	64	606	710
1927	643	20,700	Mar. 20, 1927	111	963	926
1928	663	9,780	Dec. 14, 1927	43	568	424
1929	683	18,000	Feb. 26, 1929	44	627	747
1930	698	13,800	Jan. 13, 1930	27	711	570
1931	713	2,280	Apr. 4, 1931	[3] 27	141	200
1932	728	3,870	Jan. 17, 1932	20	376	423
1933	743	17,700	May 13, 1933	34	648	572
1934	758	2,360	Mar. 4, 1934	14	159	122
1935	783	5,200	May 3, 1935	8.0	223	258
1936	803	7,110	Feb. 27, 1936	11	346	333
1937	832	12,400	Jan. 15, 1937	34	636	682
1938	853	7,040	Apr. 8, 1938	34	564	516
1939	873	5,660	Mar. 12, 1939	33	502	497
1940	893	6,740	Apr. 20, 1940	14	363	365
1941	923	2,300	June 15, 1941	12	169	173
1942	953	5,450	Apr. 10, 1942	22	287	293
1943	973	11,600	Mar. 19, 1943	18	506	487
1944	1003	8,490	Apr. 11, 1944	25	314	309
1945	1033	9,020	June 18, 1945	30	599	701
1946	1053	3,550	Feb. 14, 1946	28	384	301
1947	1083	8,490	June 2, 1947	30	593	620
1948	1113	8,840	Apr. 13, 1948	34	633	697
1949	1143	6,510	Jan. 5, 1949	42	641	544
1950	1173	11,600	Jan. 16, 1950	48	734	930
1951	1205	8,470	Dec. 3, 1951	36	692	550
1952	1235	10,800	Jan. 27, 1952	36	609	548
1953	1275	3,460	May 24, 1953	30	297	290
1954	1335	6,510	June 16, Aug. 5, 1954	26	179	215
1955	1385	4,470	Feb. 21, 1955	25	359	387
1956	1435	6,650	Feb. 25, 1956	36	471	423
1957	1505	9,210	June 29, 1957	36	573	------------

[1] Not previously published.
[2] Revised.
[3] Corrected.

TABLE 5.—*Chemical analyses of water near Piqua, Ohio*

[Results in parts per million except specific conductance, pH, and color]

	Date of collection	Aquifer	Mean discharge (cfs)	Depth (feet)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color
A. Wells in Montgomery County, Ohio [After Norris and others, 1948, table 19]																					
Owns well																					
City of Dayton [1]	4-3-47	Sand and gravel	-----	74	4.8	0.3	90	32	8.4	1.8	287	87	8.9	0.1	7.3	406	356	-----	660	7.9	1
Do [2]	4-3-47	do	-----	163	13	1.5	85	34	7.8	1.4	355	60	8.8	.3	.0	379	352	-----	654	7.8	2
Village of Farmersville [3]	5-16-47	do	-----	150	18	1.6	85	44	35	2.7	470	63	18	2.0	3.0	532	393	-----	836	7.4	0
R. E. Miller	5-19-47	Silurian limestone	-----	64	18	.76	81	44	15	5.5	460	25	10	1.0	2.0	433	383	-----	736	7.1	0
United Fireworks Co	5-19-47	Ordovician shale	-----	80	12	.14	102	44	9.7	3.3	371	71	39	.3	36	522	435	-----	841	7.3	0
B. Streams near Piqua, Ohio [After Lamar and Schroeder, 1951]																					
Stream																					
Loramie Creek at Lockington	6-26-47		39	-----	8.6	0.04	79	31	7.6	1.6	302	72	4.8	0.3	4.3	376	325	77	597	7.9	7
Miami River:																					
At Sidney	6-26-47		361	-----	5.4	.07	80	28	3.0		283	72	6.0	.6	5.2	362	315	83	570	8.0	12
Near Troy	6-26-47		446	-----	5.0	.05	80	28	6.5		290	69	8.4	.5	7.6	368	315	77	590	7.8	11
At Piqua	6-5-41		-----	-----	3.1	.05	46	23	3.8	3.7	219	36	6.0	.3	3.2	241	210	30	413	7.7	17
C. Drilled wells for public water supplies near Piqua, Ohio [After Ohio Dept. of Health, 1952]																					
City																					
Troy	12-19-50		-----	-----	8	0.7	96	31	-----	-----	-----	-----	9	0.3	-----	410	368	71	-----	7.4	-----
Vandalia	7-16-51		-----	-----	8	.15	86	29	-----	-----	-----	-----	7	.1	-----	384	336	55	-----	7.8	-----

[1] Well log 184 from Norris and others, 1948, pl. 48.
[2] Well log 197 from Norris and others, 1948, pl. 48.
[3] Well log 137 from Norris and others, 1948, pl. 48.