STATE OF OHIO
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SAND AND GRAVEL RESOURCES OF BUTLER COUNTY, OHIO

by Richard A. Struble
1986

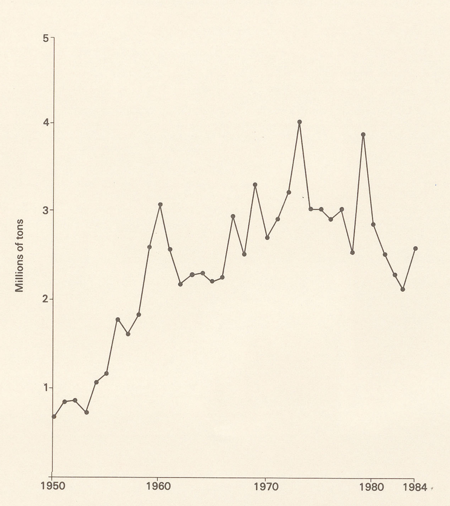

FIGURE 1.—Butler County sand and gravel production for the years 1950 to 1984 (Ohio Department of Industrial Relations, 1951-1982, and Division of Geological Survey, 1983-1985).

ABSTRACT

The remaining 6.9 billion tons of sand and gravel resources in Butler County will be adequate to meet the future demands for this commodity for years to come if population- and industrial-growth projections prove accurate. Laboratory analyses indicate that the major portion of the mineable resource will assure a good supply of high-quality coarse and fine aggregates for Butler County and surrounding areas.

INTRODUCTION

Resources of sand and gravel are important for the expansion of today's rapidly growing and changing society. Large volumes of sand and gravel are essential for (l) the continuing expansion and maintenance of Ohio's transportation network, (2) the construction of dams, and (3) projected remodelling and new construction projects in the building trades. Southwestern Ohio is fortunate that large quantities of glacially derived sands and gravels occur within the drainage area of the Great Miami River. This resource extends from its northern limit in Logan County southward to the confluence of the Great Miami and Ohio Rivers in southern Hamilton County. Through Logan, Champaign, Clark, and Greene Counties the major portion of the resource lies within the Mad River and Buck Creek valleys. South of Greene County through Montgomery, Warren, Butler, and Hamilton Counties the resource lies primarily in the valleys of the Great Miami River and its principal tributaries. The Butler County sand and gravel resource inventory is one of a series of county reports intended to define the quality, quantity, and distribution of the sand and gravel resources in Ohio.

Butler County, located in extreme southwestern Ohio, lies midway between the cities of Cincinnati in Hamilton County and Dayton in Montgomery County. The county is rural in nature, but there is some heavy industry in the metropolitan areas of Hamilton and Middletown. In 1984 Butler County was third in the state in the production of sand and gravel, with only Hamilton and Franklin Counties reporting larger volumes. Prior to 1959, production of sand and gravel in Butler County averaged approximately 1.3 million tons per year (fig. 1). Between 1958 and 1979, residential and commercial building and the completion of Ohio's interstate-highway network pushed production of sand and gravel in the county to a yearly average of approximately 3 million tons, with a peak production of about 4 million tons in 1973. It is likely that production will remain in the range of 2 million tons per year for the remainder of the century, based upon an upturn in the economy and census figures which project a moderate population growth of 20 percent through the year 2005 (Ohio Department of Development, 1982).

In Butler County a large portion of the sand and gravel resource occurs in terraces along major drainage routes. Because the terrace levels are above the highest historical flood levels and provide good foundation conditions, they are valuable sites for industrial and urban development. Easily accessible sand and gravel resources, available for many years for production of construction aggregate and base and fill materials, are no longer available because of the pressures brought about by land-use competition and accompanying zoning regulations. In order to make the best use of the remaining extractable resource, it is in the best interest of the citizens that municipal authorities and planners have available detailed maps and reports, such as this report for Butler County, which define the quality, quantity, and distribution of all nonrenewable mineral resources.

GEOLOGICAL OCCURRENCE

The land surface of Butler County is covered almost entirely by unconsolidated glacial materials of the most recent glaciation, the Wisconsinan. Evidence of previous glaciations in the region has been substantiated by deposits interpreted to be of Kansan and Illinoian age in Hamilton County and of Nebraskan, Kansan, and Illinoian age in northern Kentucky and southeastern Indiana. However, deposits of Nebraskan and Kansan age have yet to be verified at the surface or in the subsurface in Butler County. These early glaciations played key roles in the modification of the preglacial and interglacial drainage patterns in Ohio and in the establishment and evolution of the present-day drainage system. The lobate pattern of the Wisconsinan end moraines across Ohio (Goldthwait and others, 1961) indicates the ice sheet advanced across the state in several distinct lobes. The Hartwell Moraine is the southern boundary of the Miami lobe and marks the southernmost position of the Wisconsinan ice sheet approximately 20,000 years ago. Butler County, in extreme southwestern Ohio, lies within the Miami lobe just north of the Hartwell Moraine.

Glacial features which dominate the Butler County landscape are thought to be the result of processes associated with the retreat of the Wisconsinan ice sheet from Ohio. Except for a few scattered bedrock outcrops along stream or road cuts, Butler County is blanketed by unconsolidated materials deposited by glacial ice or running water. Glacial and postglacial features which dominate the Butler County landscape are: (1) end moraines, (2) ground moraine, (3) kames and eskers, (4) outwash terraces, (5) lake deposits, and (6) modern alluvium (floodplain deposits).

The ground moraine and end moraines in Butler County extend generally in an east-west band across the county from the Ohio-Indiana border on the west to the Butler-Warren County line on the east. The morainic materials are composed primarily of till, which is a heterogeneous mixture of clay, silt, sand, pebbles, and boulders deposited directly by the glaciers.

The end moraines in Butler County occupy only small areas in the extreme northern and southern parts of the county. End moraines mark the position of the ice sheet when a balance between forward movement and melting was reached or when moving ice and debris were thrust and stacked upon stagnant ice along the ice front. When such conditions persisted at one position for a long period of time, materials incorporated within the ice accumulated as a hummocky ridge at the front of the glacier. In Butler County the hummocky end-moraine topography rises only slightly above the ground-moraine surface.

Ground moraine is similar in composition to end moraine but forms a nearly flat to hummocky surface of moderate relief. Generally the tills of the ground moraine are thinner than the tills which make up end moraine. Ground moraine forms when materials picked up and enclosed in ice are plastered on the land surface during glacial advances or are dropped to the surface as the ice melts during glacial recessions.

Because of the high clay and silt content, glacial tills are not considered to be good sources of sand and gravel. Therefore, areas of end and ground moraine in Butler County are not shown on the resource map.

Only a small portion of the surface area of Butler County is covered by kame and esker deposits. Kames are hills composed predominantly of coarse, stratified water-laid sands and gravels. In Butler County, kames rise from a few feet to 50 feet above the land surface. Kames form when coarse materials are carried by meltwaters into holes in the surface of the ice sheet or at fracture intersections in the ice. Kame terraces form when tongues of glacial ice extend down deep valleys. As the ice tongue retreats from the valley, coarse debris incorporated within the ice is carried by meltwaters from the ice tongue to the margins of the valleys to form kames or kame terraces. In Butler County kames are present 1 mile southeast of Hamilton in secs. 27, 28, 33, and 34, Fairfield Township, and secs. 21 and 22, Union Township.

Eskers are similar in composition to kames but are elongate ridges, which in Butler County rise from a few feet to 10 feet above the land surface. Eskers form by the deposition of coarse materials carried by meltwaters through tunnels in the base of the ice. One esker has been interpreted to extend northwest-southeast across secs. 4 and 34, Union Township. Approximately 1 percent of the sand and gravel resource of Butler County lies within kames and eskers.

The largest resource of sand and gravel in Butler County lies within glacial outwash deposits, which consist of sequences of well-graded, stratified sands, gravels, cobbles, and some boulders. Outwash occurs in two morphologic types—outwash plains and valley trains. Outwash-plain deposits in Butler County are more or less restricted to the broad, nearly flat upland areas of the county. During advances and retreats of the glaciers, sands and gravels incorporated within the thin, rapidly melting ice front were deposited in thin fans or coalescing fans across the upland surfaces as outwash plains, and the finer silts and clays were washed away. Outwash-plain deposits in Butler County, because of the mode of deposition, have thicknesses ranging from a few feet to 20 feet and have little lateral continuity. For these reasons, gravel lenses interpreted as outwash-plain deposits in the moraine-covered upland areas of the county have not been mapped.

Valley-train deposits are the principal source of sand and gravel in Butler County. They occur as a series of matched terrace levels along the valleys of the Great Miami River and major south-flowing streams tributary to the Great Miami. The valley-train deposits originated when great quantities of coarse glacial debris were discharged into valleys leading away from the ice front. As the ice front began to retreat from the drainage basin a relatively short period of stream aggradation took place, followed by a longer period of degradation after the ice had retreated from the drainage basin. The valley trains were formed during the time of aggradation; during the following period of degradation, erosion of the aggraded valley floor produced the valley-train terrace remnants along the margins of the valleys. Valley-train outwash deposits account for 58 percent of the sand and gravel resource of Butler County.

In local areas of Butler County, outwash deposits of sand and gravel are overlain by glacial till. Where the glacial till overlying these deposits is less than 25 feet thick the sands and gravels have been included in the resource inventory. One till-over-outwash resource is located in southeastern Butler County in Union and Fairfield Townships, approximately 6 miles east-southeast of Hamilton. The other area, in northwestern Butler County, is located within and adjacent to the village of Darrtown in Milford Township. The sands and gravels interpreted to lie beneath less than 25 feet of till in Union, Fairfield, and Milford Townships make up 3 percent of the total resource for the county.

In two areas of eastern Butler County, lake deposits overlie thick deposits of outwash sand and gravel. One area lies south and southeast of Middletown and the other area is east of Hamilton. The lake deposits are thinly laminated silts and clays from a few feet to 25 feet thick. The distribution of the lake deposits overlying sand and gravel in Butler County is related to the glacial history of the area and the effect of multiple glaciations on the preglacial and glacial drainage patterns in Ohio and adjacent states. The lakes formed when advancing or retreating ice blocked the valleys of north-flowing rivers and their tributaries. The lakes persisted until the ice retreated from the drainage basin or they overtopped a divide and established a new outlet around the ice. Other lakes formed when large volumes of outwash filled the primary stream channels to elevations well above the floors of the tributary stream valleys, causing streamflow to back up in the tributary valleys. The sands and gravels which occur beneath less than 25 feet of lake deposits make up 8 percent of the total resource for the county.

Outwash deposits underlying alluvium in Butler County are an important part of the sand and gravel resources of Butler County. This resource occupies river and stream valleys where modern floodplains have intrenched into the valley-train deposits. The alluvial deposits themselves, which consist of stratified fine sands, silts, and clays, are not generally considered as sources for large deposits of sand and gravel but have been mapped because some alluvium (river wash) has been mined locally and used for coarse and fine aggregate. In Butler County the alluvium overlying outwash ranges in thickness from a few feet to more than 25 feet. For purposes of this report, only outwash deposits overlain by less than 25 feet of alluvium have been included in the resource inventory.

Because floodplains are subject to periodic flooding, the competition for land use is not as intense as in other gravel-producing areas, so sand and gravel operators may experience more favorable rulings by local zoning boards for development of resources within the floodplains. Therefore, the floodplains appear to offer the greatest potential for future sand and gravel operations in Butler County. Approximately 30 percent of the total resource of sand and gravel in Butler County lies within the floodplains of the county.

RESOURCES

The distribution of the sand and gravel resources of Butler County, differentiated by type of deposit, is shown on the accompanying map. For mapping purposes kames and eskers have been mapped together and outwash includes both outwash-plain and valley-train deposits. The resource categories used in the sand and gravel inventory are defined below:

Measured resources include all sands and gravels within a specific deposit that is within a ½-mile radius of a control point. Control points are locations where information on the thickness of the sand and gravel resource has been determined from (1) a measured stratigraphic section, (2) logs from water wells that have penetrated the deposit, or (3) verbal communications from pit or dragline operators. The thickness data are used to estimate the thickness of each mapped unit. Where there are multiple control points within a single deposit the average of the combined data is taken as the thickness of the unit.

Indicated resources are sands and gravels associated with and contiguous with measured resources but which occur farther than ½ mile from a control point. An indicated resource is assumed to have the same thickness as the associated contiguous measured deposit. Where an indicated resource is bounded by more than one measured resource, the thicknesses of the measured resources are averaged to define the thickness of the indicated resource.

Inferred resources are those sand and gravel deposits which are not contiguous with a related measured resource but which are interpreted to exist from analysis of aerial photographs or soil surveys. Thicknesses of inferred resources are estimated from topographic relief or the thickness of nearby measured or indicated resources of similar types.

The distribution of the sand and gravel resources of Butler County as shown on the map was determined from analysis of data derived from field examination, air-photo interpretation, soil surveys, and water-well logs. The 7½-minute (1:24,000) series of quadrangle maps was used as the mapping base for compiling field, water-well, and soil data. In each township the thickness of sand and gravel in each resource category was estimated from water-well-log and measured-section data. The estimated thickness and the number of acres within each resource category provided the data needed to calculate the tonnage-per-township volume estimates (table 1). The tonnages shown in table 1 represent an estimate of the portion of the original resource of sand and gravel deposited in Butler County which now occurs at the surface or beneath a thin (less than 25 feet) veneer of till, lake deposits, or alluvium and in no way reflect the quantities of sand and gravel currently available for extraction. Previously extracted sand and gravel and the amount of the resource lost to production because of zoning regulations and residential and industrial expansion have not been taken into consideration in the tonnage calculations.

This report provides general information regarding the distribution, quality, and thickness of the sand and gravel resources of Butler County and should not be used as a substitute for the detailed site-specific investigations necessary to determine the potential of an area as a site for a commercial sand and gravel operation. However, fairly reliable thickness data are available from the water-well logs and measured sections included in the report.

ANALYSIS OF MATERIALS

Seventy samples of sand and gravel weighing 15 to 20 pounds each were collected for laboratory analysis from stream cuts, road cuts, all active gravel pits, and most semi-active, intermittently active, and abandoned commercial sand and gravel pits in Butler County. Letter designations following location numbers indicate multiple samples taken from the face of a pit or stockpile samples dredged from different elevations below the water level in the pit. All samples were oven dried at 105°F for 24 hours prior to splitting and subsequent sieve analysis. Material passing the No. 5 U.S. Sieve Series was sieved on a Ro-Tap mechanical shaker for 15 minutes. Material retained on the No. 5 U.S. Sieve Series was hand sieved for up to 10 minutes. Sieve-analysis results are given in table 2.

To determine the percentage of constituent rock types represented in the gravels, approximately 100 pebbles 1 to 2 inches in diameter were collected at each of 33 widely separated sampling locations (road and stream cuts and active and inactive gravel pits). These samples were washed, broken, and examined under a binocular microscope to determine the rock type of each. The percentage of constituent rock types at the selected sites is shown in table 3.

The stone-count and sieve-analysis data show that most of the sand and gravel resource of Butler County is suitable for many types of construction materials. The composition and texture of the deposits in the Great Miami River valley and the lower reaches of Indian, Four Mile, and Seven Mile Creeks show that with a minimum of preparation the materials can meet specifications for use in concrete, aggregate, mortar, aggregate for flexible pavement, base materials, and fill. Terraces in the upper reaches of the secondary drainages are composed predominantly of boulders and cobbles of local Ordovician limestone and would require some washing and crushing in order to meet specifications for most construction aggregate.

CONCLUSIONS

Much of the 6.9 billion tons of resource of sand and gravel in Butler County is lost to production because of urban and industrial sprawl. However, this resource inventory indicates that deposits not already lost to urbanization are sufficient to meet the needs of the county and surrounding areas for a long period of time if population-growth projections are correct. Because much of the remaining extractable resource exists in rural areas or within the floodplains of the major stream valleys, development of the resource should not experience the intense land-use competition so evident on the outwash terraces in the metropolitan and industrial areas of the county. The texture and composition of the sands and gravels suggest that most of the deposits will be good sources for high-quality aggregates.

ACKNOWLEDGMENTS

The author expresses his appreciation to the sand and gravel operators of Butler County whose cooperation was essential for the completion of this study.

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Naturally OHIO the heart of it all!

Total copies printed: 800
Unit cost: $5.191
Publication date: 9/86

Outwash resources: Measured; Indicated; Inferred

Outwash resources underlying less than 25 feet of till: Measured; Indicated; Inferred

Outwash resources underlying less than 25 feet of alluvium: Measured; Indicated

Outwash resources underlying less than 25 feet of lake deposits: Measured; Indicated

Kame/esker resources: Measured; Indicated; Inferred

Alluvium

Sand and gravel pit, active (as of July 1984)

Sand and gravel pit, intermittently active or abandoned (as of July 1984)

Boundary of deposit

Water-well location

Measured-section and sample location

Sample location only

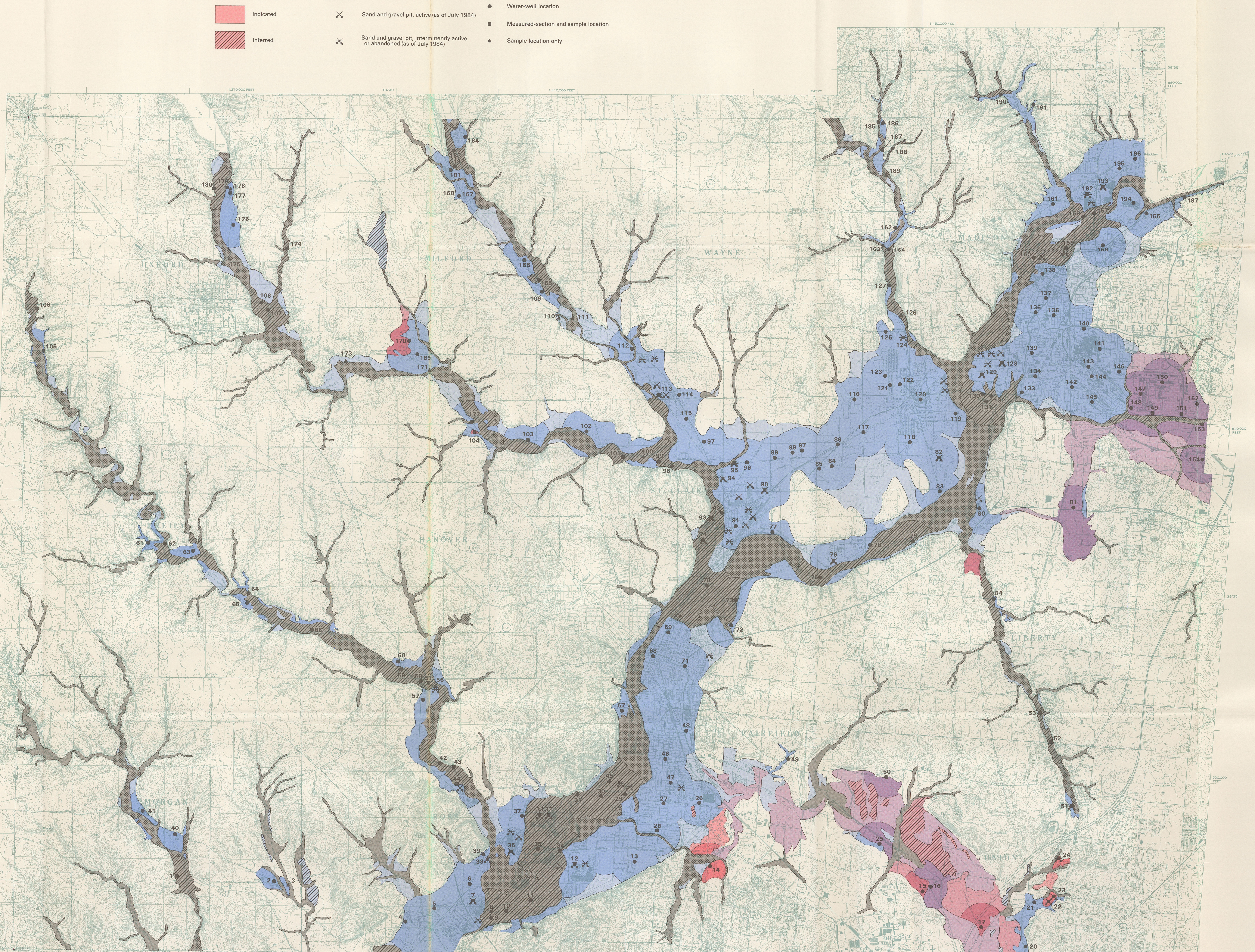


TABLE 1.—*Estimated sand and gravel resources, Butler County*

Township	Outwash: Measured	Outwash: Indicated	Outwash: Inferred	Outwash underlying <25 feet of till: Measured	Outwash underlying <25 feet of till: Indicated	Outwash underlying <25 feet of till: Inferred	Outwash underlying <25 feet of lake deposits: Measured	Outwash underlying <25 feet of lake deposits: Indicated	Outwash underlying <25 feet of alluvium: Measured	Outwash underlying <25 feet of alluvium: Indicated	Kames and eskers: Measured	Kames and eskers: Indicated	Kames and eskers: Inferred	Total
	Sand and gravel resources (tons)													
Fairfield	780,666,600	144,279,000		339,800				68,294,900	350,997,500	195,001,100	20,570,300	23,837,100		1,583,646,500
Hanover	42,403,000	28,552,900							92,515,100	67,427,200				231,238,000
Lemon	636,314,900	97,576,100		2,823,600			220,941,000	102,217,400	97,644,300	114,249,200				1,268,942,900
Liberty	1,404,400	3,804,100					622,900		12,423,300	13,734,200				34,812,500
Madison	523,613,900	99,642,400							67,464,200	36,376,500				727,097,000
Milford	108,809,200	120,778,600	32,673,300	49,244,600	10,031,900				21,908,900	109,552,100				452,998,600
Morgan	15,608,900	2,115,600	1,277,300						45,803,300	45,417,800				110,222,900
Oxford	35,153,800	40,817,900							29,192,400	70,001,800				175,165,900
Reily	19,609,000	20,691,200							33,421,400	56,574,600				130,296,200
Ross	451,513,600	76,491,100	4,924,500						279,067,800	100,234,800				912,231,800
St. Clair	494,845,100	103,627,100							116,193,000	77,124,200				791,789,400
Union	26,020,800	3,967,700	2,785,400	23,171,700	54,382,500	61,079,800	44,678,600	138,887,400	1,791,800	3,666,400	5,597,900	505,700	923,500	367,459,200
Wayne	86,174,100	47,899,900							1,714,500	23,694,500		322,300		159,805,300
TOTAL	3,222,137,300	790,243,600	41,660,500	75,579,700	64,414,400	61,079,800	266,242,500	309,399,700	1,150,137,500	913,054,400	26,168,200	24,665,100	923,500	6,945,706,200

TABLE 2.—*Results of sieve analyses*

Grain size (% retained). ASTM scale: Boulders and cobbles; Gravel; Sand; Silt. Wentworth scale: Boulders and cobbles (-4.0"+3.0" and -3.0"+2.5"); Pebbles (-2.5"+4 and -4+5); Granules (-5+10); Coarse to very coarse sand (-10+35); Medium sand (-35+60); Fine to very fine sand (-60+200 and -200+230); Silt and clay (-230).

Sample no.	-4.0"+3.0" U.S. Sieve Series[1] (3.0-4.0 inch diameter)	-3.0"+2.5" U.S. Sieve Series (2.5-3.0 inch diameter)	-2.5"+4 U.S. Sieve Series (0.187-2.5 inch diameter)	-4+5 U.S. Sieve Series (0.157-0.187 inch diameter)	-5+10 U.S. Sieve Series (0.0787-0.157 inch diameter)	-10+35 U.S. Sieve Series (0.0197-0.0787)	-35+60 U.S. Sieve Series (0.0098-0.0197 inch diameter)	-60+200 U.S. Sieve Series (0.0029-0.0098 inch diameter)	-200+230 U.S. Sieve Series (0.0025-0.0029 inch diameter)	-230 U.S. Sieve Series (<0.0025 inch diameter)	Total
3			47.6	4.1	11.8	18.8	6.2	4.3	0.3	7.0	100.1
7A			40.5	3.5	10.7	21.6	16.7	4.8	0.2	2.0	100.0
7B			47.6	4.1	11.3	15.7	14.0	5.9	0.2	1.3	100.1
12A			31.8	3.8	14.2	33.3	13.2	3.0	0.1	0.7	100.1
12B			28.9	4.2	15.0	32.9	15.0	3.5	0.1	0.5	99.7
18			37.5	4.4	17.8	27.0	5.0	3.2	0.3	4.8	100.0
19		9.0	35.2	3.4	11.5	24.4	12.0	3.4	0.1	1.0	100.0
20			31.1	3.0	13.0	33.8	9.6	3.6	0.2	5.7	100.0
22			46.4	4.7	13.2	13.2	7.9	9.5	0.3	4.9	100.1
23			37.3	2.7	10.4	25.1	7.9	8.6	0.5	7.2	99.7
24A		6.0	42.0	3.6	11.5	25.4	5.2	2.4	0.2	3.6	99.9
24B			48.6	2.6	10.1	21.5	6.1	4.0	0.3	6.6	99.8
28		13.1	33.3	3.1	10.7	24.6	10.1	2.7	0.2	2.3	100.1
32B			34.9	3.3	12.6	29.4	14.5	4.5	0.1	0.9	100.2
33A			56.0	3.4	9.9	18.1	10.8	1.3	0.1	0.5	100.1
33B			35.7	4.2	15.4	32.3	10.9	1.3	0.0	0.2	100.0
33C			30.5	3.0	10.8	32.3	18.2	4.4	0.1	0.6	99.9
36A		12.9	56.7	2.2	7.3	16.8	3.3	0.5	0.0	0.3	100.0
36B			58.5	3.9	11.7	19.3	4.8	1.1	0.0	1.4	100.8
38			23.5	2.4	11.2	31.3	27.3	3.7	0.0	0.5	99.9
44A		5.7	46.4	3.1	10.8	22.5	7.8	2.4	0.1	1.3	100.1
44B			49.5	3.8	10.5	18.3	10.8	3.7	0.2	3.2	100.0
51			6.9	1.2	5.0	25.0	42.1	17.5	0.4	1.8	99.9
56A		6.1	58.0	2.6	6.0	9.9	13.3	3.4	0.1	0.4	99.8
56B			61.8	2.6	7.3	17.2	8.7	1.8	0.1	0.8	100.3
56C		12.8	74.0	2.3	5.5	3.0	0.4	0.6	0.1	1.2	99.9
74A			42.9	3.1	10.9	25.6	13.1	3.6	0.1	0.7	100.0
74B			54.2	2.7	10.1	22.5	8.0	1.4	0.1	0.9	99.9
76A		4.3	52.7	2.4	9.8	20.7	8.0	1.3	0.0	0.6	99.8
76B			69.0	4.2	11.7	10.2	3.6	0.8	0.0	0.4	99.9
82A			61.6	4.1	9.0	13.8	8.1	1.5	0.1	1.7	99.9
82B		4.6	53.6	5.1	12.3	14.5	7.2	1.9	0.1	1.1	100.4
82C			60.8	3.6	9.7	14.7	8.7	1.8	0.1	0.7	100.1
90A			33.7	5.2	16.1	31.1	10.2	2.4	0.1	1.0	99.8
90B			40.7	3.5	10.7	34.7	8.4	1.7	0.1	0.5	100.1
90C	9.5		42.1	4.0	10.3	17.7	12.1	3.3	0.1	1.0	100.1
90D			39.4	3.7	11.6	23.9	11.9	5.0	0.3	4.3	100.1
93A			37.2	2.2	10.1	42.9	6.0	1.1	0.0	0.4	99.9
93B		5.4	53.8	2.0	5.9	19.5	8.8	2.5	0.1	2.1	100.1
94			56.2	3.4	10.2	17.9	7.2	3.4	0.1	1.6	100.0
95			57.5		10.4	6.0	22.4	2.8	0.0	0.5	99.6
100			68.1	2.9	9.0	13.5	3.4	1.8	0.1	1.1	99.9
110			39.6	4.4	13.3	22.6	5.9	4.2	0.3	9.5	99.8
111			63.7	3.6	10.6	13.8	6.4	1.5	0.1	0.4	100.1
113			62.2	3.5	9.8	14.3	6.1	2.3	0.1	1.7	100.0
124A			49.6	2.6	9.5	21.6	11.1	5.1	0.2	0.5	100.1
124B			41.4	3.3	12.0	26.1	11.5	3.6	0.1	2.2	100.2
126		4.3	53.3	3.0	9.3	24.2	4.5	1.1	0.1	0.4	100.2
128A			77.7	5.0	10.4	4.9	1.0	0.3	0.0	0.7	100.0
128B			65.4	3.0	8.1	14.6	7.7	1.0	0.0	0.2	100.0
128C			54.3	4.1	12.5	19.5	7.3	1.4	0.1	0.7	99.9
129A			65.3	3.9	13.2	11.4	4.8	1.0	0.0	0.3	99.9
129B			41.5	3.6	12.7	22.1	13.4	4.5	0.2	2.2	100.2
163	13.1		41.2	2.6	9.8	21.3	6.2	3.1	0.2	2.5	100.0
167			35.1	4.3	17.4	31.3	8.8	2.4	0.1	0.6	100.0
171		8.0	51.0	2.3	7.5	15.1	6.9	6.7	0.2	2.3	100.0
173	10.2		32.0	6.8	22.6	23.2	2.6	1.2	0.1	1.4	100.1
175			54.0	3.7	18.0	21.3	1.9	0.9	0.0	0.3	100.1
178			35.2	3.1	11.9	26.6	13.5	6.3	0.3	3.1	100.0
179A			62.9		9.6	9.8	15.2	1.9	0.0	0.5	99.9
179B			15.5		13.5	20.0	45.7	4.7	0.0	0.6	100.0
179C			84.1		4.0	3.5	5.7	2.2	0.0	0.6	100.1
179D			31.6		18.6	19.2	27.8	2.4	0.0	0.2	99.8
182A			47.1	3.0	12.2	22.1	9.5	5.6	0.1	0.4	100.0
182B			45.2	4.2	14.3	25.9	7.4	2.0	0.1	1.0	100.1
189	12.5	3.9	53.3	2.1	7.9	13.1	4.5	1.9	0.1	0.8	100.1
192A			73.5		8.7	8.7	7.2	2.1	0.0	0.2	100.4
192B			55.4		20.3	17.0	6.5	0.5	0.0	0.2	99.9
193A			64.3	3.4	9.4	15.1	5.5	1.6	0.1	0.6	100.0
193B			68.9	3.2	8.6	13.0	4.3	1.5	0.1	0.4	100.0

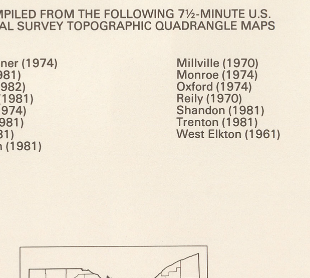
[1]-indicates particle passes through mesh; + indicates particles retained on mesh.

TABLE 3.—*Pebble counts*

Sample no.	Igneous and metamorphic: Count	Igneous and metamorphic: %	Carbonate: Count	Carbonate: %	Sandstone: Count	Sandstone: %	Siltstone: Count	Siltstone: %	Deleterious, Chert: Count	Chert: %	Deleterious, Ironstone: Count	Ironstone: %	Deleterious, Shale: Count	Shale: %	Deleterious, Clay clasts: Count	Clay clasts: %	Total: Count	Total: %
3	3	3.0	94	91.9	4	4.0					1	1.0					102	99.9
7	11	9.8	101	89.4	1	0.9											113	100.1
12	11	10.7	88	85.5	2	1.9	1	1.0	1	1.0							103	100.1
19	5	5.0	94	94.0	1	1.0											100	100.0
20	5	4.9	94	91.2	2	2.0			1	1.0					1	1.0	103	100.1
22	4	4.0	88	88.0	4	4.0	1	1.0	1	1.0					2	2.0	100	100.0
24	8	8.0	92	92.0													100	100.0
32	13	12.7	88	86.3					1	1.0							102	100.0
33	10	10.0	87	86.2	4	3.9											101	100.1
36	14	13.8	83	81.3	4	3.9			1	1.0							102	100.0
44	5	5.0	87	87.0	3	3.0	2	2.0	3	3.0							100	100.0
56	5	5.0	94	94.0			1	1.0									100	100.0
74	8	7.7	93	89.4	3	2.9											104	100.0
76	10	9.6	91	86.7	2	1.9			1	1.0	1	1.0					105	100.2
82	11	11.0	82	82.0	5	5.0			2	2.0							100	100.0
90	11	10.7	84	81.6	6	5.8			2	1.9							103	100.0
93	8	8.0	85	85.0	7	7.0											100	100.0
100	2	1.9	100	95.2	2	1.9	1	1.0									105	100.0
111	11	11.0	84	84.0	3	3.0			2	2.0							100	100.0
113	8	7.9	89	87.3	3	2.9			1	1.0					1	1.0	102	100.1
124	5	4.9	92	87.6	6	5.7			2	1.9							105	100.1
126	10	10.0	82	82.0	7	7.0			1	1.0							100	100.0
128	10	10.0	80	80.0	8	8.0			2	2.0							100	100.0
129	15	14.5	79	76.7	6	5.8	1	1.0	2	1.9							103	99.9
163	7	7.0	90	89.1	3	3.0			1	1.0							101	100.1
167	8	7.2	95	85.5	5	4.5			2	1.8	1	0.9					111	99.9
171	6	6.0	92	91.0	2	2.0	1	1.0									101	100.0
173	8	8.0	85	85.0	3	3.0	1	1.0	3	3.0							100	100.0
175	9	8.1	92	82.8	8	7.2	1	0.9	1	0.9							111	99.9
178	10	8.5	101	85.6	5	4.2			1	0.8	1	0.8					118	99.9
182	8	8.0	89	89.0	2	2.0							1	1.0			100	100.0
189	9	9.0	86	86.0	5	5.0											100	100.0
193	18	17.8	78	77.2	3	3.0			2	2.0							101	100.0

BASE COMPILED FROM THE FOLLOWING 7½-MINUTE U.S. GEOLOGICAL SURVEY TOPOGRAPHIC QUADRANGLE MAPS

College Corner (1974)
Franklin (1981)
Glendale (1982)
Greenhills (1981)
Hamilton (1974)
Harrison (1981)
Mason (1981)
Middletown (1981)
Millville (1970)
Monroe (1974)
Oxford (1974)
Reily (1970)
Shandon (1981)
Trenton (1981)
West Elkton (1961)



LOCATION MAP

CARTOGRAPHIC DRAFTING BY EDWARD V. KUEHNLE

Area west of the Great Miami River lies within the Miami River Survey Area east of the Great Miami River lies within the Between the Miamis Land lines based on the Great Miami River Base. Dotted land lines established by private subdivision of the Symmes Purchase

10,000-foot grid based on Ohio coordinate system, south zone

1 0 1 mile

1 0 1 kilometer

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

MN GN 1° 18 MILS 1°33' 28 MILS

UTM GRID AND 1974 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

EXPLANATION

- Clay
- Sand
- Gravel
- Shale
- Limestone
- fill Manmade land

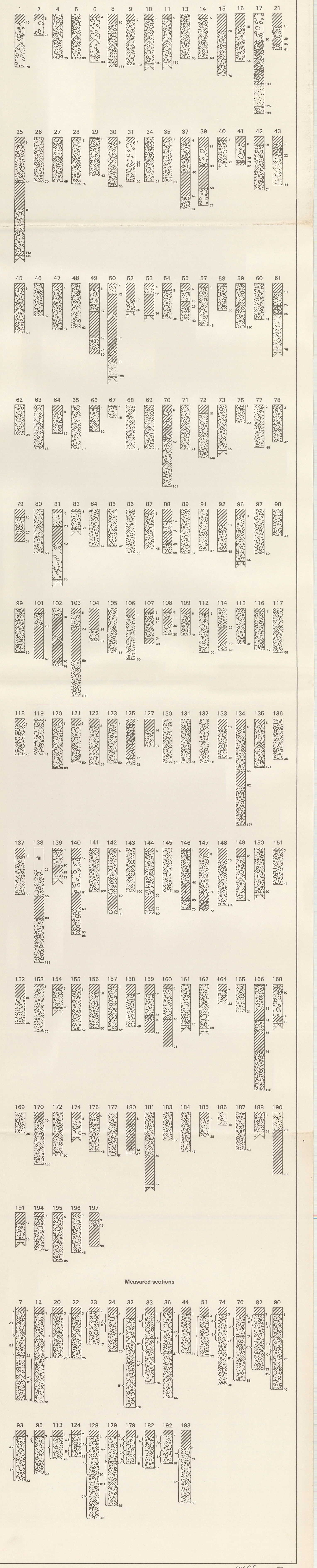
20 — Water-well or measured-section number
— Depth in feet to unit contact
— Sample interval (measured sections only; asterisk indicates stockpile sample)
— Water table (measured sections only; information not available for all sections)

VERTICAL SCALE

Water-well logs: 0–0; 50–15; 100 feet–30 meters

Measured sections: 0–0; 20–6; 40 feet–12 meters

PHOTOTYPESETTING BY JEAN M. LESHER



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