STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief

Report of Investigations No. 76

SAND AND GRAVEL RESOURCES OF THE MAUMEE RIVER ESTUARY, TOLEDO TO PERRYSBURG, OHIO

by

Charles E. Herdendorf

Columbus
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INTRODUCTION

In January 1967 the State of Ohio designated a portion of the lower Maumee River in Lucas and Wood Counties as an area available for commercial dredging of sand and gravel. The Maumee-Toledo Dredging Corridor, as it is called, is located between Toledo and Perrysburg, from about 6 to 13 miles upstream from Maumee Bay (fig. 1). The corridor is approximately 7.3 miles long, and has an average width of 1,100 feet and an area of 1.53 square miles (approximately 1,000 acres). A more detailed description of the corridor with reference to dredging restrictions can be found in the following section of this report.

Section 123.03 of the Ohio Revised Code declares: "...the waters of Lake Erie consisting of the territory within the boundaries of the state, extending from the southerly shore of Lake Erie to the international boundary line between the United States and Canada, together with the soil beneath and their contents, do now and have always, since the organization of the state of Ohio, belonged to the state as proprietor in trust for the people of the state, for the public uses to which it may be adapted, subject to the powers of the United States government, to the public rights of navigation, water commerce and fishery, and further subject to the property rights of littoral owners, including the right to make reasonable use of the waters in front of or flowing past their lands."

Geologic and hydrologic studies of the lower Maumee River have shown that this reach is, in actuality, an estuary of Lake Erie. Water levels in the estuary are controlled by Lake Erie as far south as the rapids at Perrysburg, where the true mouth of the Maumee River is located.

Section 1505.07 of the Ohio Revised Code states: "...the chief of the Division of Geological Survey with the approval of the director of Natural Resources, the Attorney General, and the Governor, may issue permits and make leases to parties making application, for permission to take and remove sand, gravel, stone, gas, oil, and other minerals or other substances from and under the bed of Lake Erie, either upon a royalty or rental basis, as he deems best for the state. Such permits shall be issued for terms of not less than one year nor more than ten years, and such leases shall be for a term of years or until the economic extraction of the minerals or other substances covered thereby has been completed. Such taking and removal shall be within certain fixed boundaries that do not conflict with the rights of littoral owners. Upon request from the holder of such permit, it shall be cancelled, but in the case of any permit or lease, any equipment or buildings owned by the permittee or lessee shall be held as security by the chief for payment of all rentals or royalties due the state at the time of cancellation."

Section 1505.07 states in addition: "No person shall remove sand, gravel, stone, gas and oil or other substances from and under the bed of Lake Erie without first obtaining a permit or lease therefor from the chief."

Over half a million cubic yards of sand and gravel are removed commercially from the Ohio portion of Lake Erie annually. The Ohio Division of Geological Survey has designated six areas in Lake Erie as Commercial Sand and Gravel Dredging Areas. Six companies presently hold permits for the removal of sand and gravel from one or more of the six areas: (1) Maumee Bay, (2) Cedar Point, (3) Lorain-Vermilion, (4) Fairport, (5) Maumee River, and (6) Sandusky River. Detailed resource studies of the first four areas have been completed by the Ohio Division of Shore Erosion and published in 1960 in Technical Report No. 5, "Sand Dredging Areas in Lake Erie," by Robert P. Hartley.

The objectives of the study described in this report are (1) to map the sand and gravel deposits of the lower Maumee River, (2) to estimate the quantity of commercial sand available, and (3) to ascertain the quality and potential uses of the sand and gravel lying within the Maumee-Toledo Dredging Corridor.

DESCRIPTION OF MAUMEE-TOLEDO DREDGING CORRIDOR

The Maumee-Toledo Dredging Corridor (fig. 2, in pocket) extends upstream from the centerline of the abandoned Fassett Street bridge (1,100 feet south of

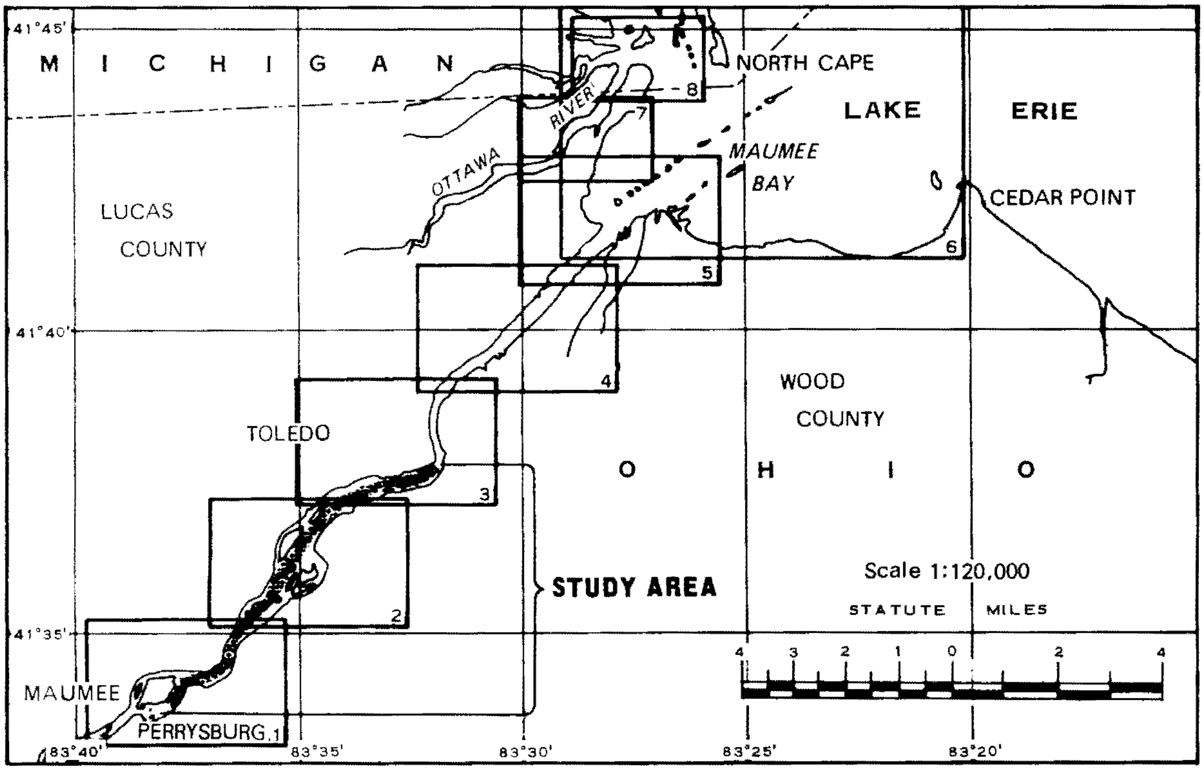


FIGURE 1.—Locality map of the Maumee-Toledo Dredging Corridor showing U.S. Lake Survey Navigation Chart 370 coverage of the area.

the Penn Central RR. bridge) to a line that is the projection (N. 30° W.) of Rte. 23 (Louisiana Avenue) in Perrysburg. The edges of the corridor are defined by lines 200 feet from the shore of the mainland or the islands. The passages between the mainland and the islands are excluded from the dredging corridor.

River crossings or manmade structures in the river will be given clearance as shown on navigation charts and as described below:

Commercial dredging activity is prohibited in the area bounded by the east edge of the turning basin and a direct northerly extension of this line approximately 500 feet east of the pipeline crossing and by a line 200 feet west of the Interstate 75 Highway bridge.

A 200-foot zone is reserved for the water pipeline crossing between Rossford and the end of Stebbins Avenue across Corbutt Island about 10,700 feet south and west of the Penn Central RR. bridge. The zone is marked by the wall on the east side of the Rossford Marina. The pipeline is located on the centerline of the restricted area.

An area 200 feet by 500 feet off the southern part of Clark Island is reserved by the City of Toledo. The corridor line in this area lies approximately 400 feet offshore (southeast) from Clark Island.

A zone 200 feet wide is reserved for the cable crossing approximately 15,700 feet south and west of the Penn Central RR. bridge and is located between the Eagle Point shore and Walbridge Park. The cable occupies the centerline of this prohibited zone.

The area in the vicinity of the water intake structure of the River Road filtration plant is restricted. It is about 20,500 feet south and west of the Penn Central RR. bridge. Commercial dredging is prohibited within 200 feet of the bridges of the Toledo Terminal RR. and the Ohio Turnpike.

METHODS OF INVESTIGATION

Field investigations were conducted in August and September 1964, May 1965, May and November 1967, April 1968, and September 1969.

The 1964 study included bottom profiling, sampling, and test boring. An 8,000-foot baseline was set up along the southeast shore, from Mid-States Terminal to the vicinity of Corbutt Island (fig. 2, in pocket). From this baseline, perpendicular profile sections were run from shore to shore at intervals of 500 feet. The bottom depths were recorded with a Raytheon portable fathometer mounted in a small outboard motorboat. Horizontal control for the profile lines was obtained by stretching a tag line, marked every 10 feet, across the section being profiled. Vertical control was achieved by relating all depths to feet below Low Water Datum (568.6 feet above mean water level at Father Point, Quebec, International Great Lakes Datum, 1955). Water levels during the study period were obtained from a recording water-level gage located at the Toledo office of the U.S. Army, Corps of Engineers, in Bay View Park.

Bottom samples were taken at 500-foot intervals along each profile line. Samples were taken with a 100-cubic-inch capacity La Fond-Dietz type snapper sampler.

Three test borings (MR-1 through MR-3) were made during the 1964 study. Subsequently, 2 borings (MR-4 and MR-5) were made in 1965 and 25 (MR-6 through MR-30) in 1967. The test borings were made by the hydraulic jetting method. This operation consists of jetting water under 40 pounds per square inch pressure through 2-inch, 1-inch, or ½-inch aluminum pipe. The 2-inch pipe generally penetrates unconsolidated silt, clay, sand, and fine gravel; but in many cases it meets refusal in compact clay, medium gravel, and glacial till. The 1-inch or ½-inch pipe is then used inside the larger pipe. The smaller diameter pipe can usually penetrate clay, till, and medium gravel but meets refusal in coarser material. Samples are taken with a hollow-tube check-valve sampler driven into the subsurface material by hand. Cores up to 3 feet in length are obtained by this procedure. Sampling of the subsurface material is normally performed at 5-foot intervals. Wash samples, which often come to the surface between the 2-inch and smaller diameter pipe, and the resistance to penetration also give valuable information on the character of the material being penetrated.

In May 1965 a Stevens A-35 recording water-level gage was installed at the Rossford Municipal Dock in order (1) to correlate water levels in the study area with those recorded by the Corps of Engineers at the Harbor entrance and (2) to provide vertical control for bottom deposit investigations.

In April 1968 and September 1969 current velocities were measured in the river at three stations with a Hydro Products model 460/465 current meter. Measurements were taken at 5-foot depth intervals from surface to bottom to determine the sediment-carrying capacity of the river. The sand and gravel deposits on Ewing Island were also investigated in April 1968.

RESULTS OF INVESTIGATION

Bottom samples

The bottom samples were mechanically analyzed for grain size by the hydrometer method. The results of these analyses and field descriptions of the samples are given in table A of the Appendix. Selected sand fractions from the hydrometer tests were retained and passed through a series of sieves. The sieve grouping used for the size analyses is that used by the Ohio Highway Testing Laboratory for construction aggregate analyses. Specifically the sieves used were U.S. sieve series nos. 4, 8, 16, 30, 50, 100, and 200. A conversion table from sieve numbers to millimeters and phi units is given in table B and figure 7 of the Appendix. The results of the sieve analyses, showing phi median (ϕm) and Trask sorting coefficient (So), are given in table C of the Appendix.

The 48 bottom surface samples from the north limit of the study area upstream to Corbutt Island had the following grade distribution:

	Percent
Mud (silt and clay sizes)	59
Sand and gravel	41

The high percentage of mud in the bottom surface sediment may be a result of the time of sampling. The samples were collected in the late summer when little coarse material is being contributed from upstream and silt has the opportunity to settle to the bottom.

Surface samples from the 30 test borings, which were taken at various times of the year throughout the study area, yield the following grade distribution:

	Percent
Mud (silt and clay sizes)	21
Sand	54
Gravel	25

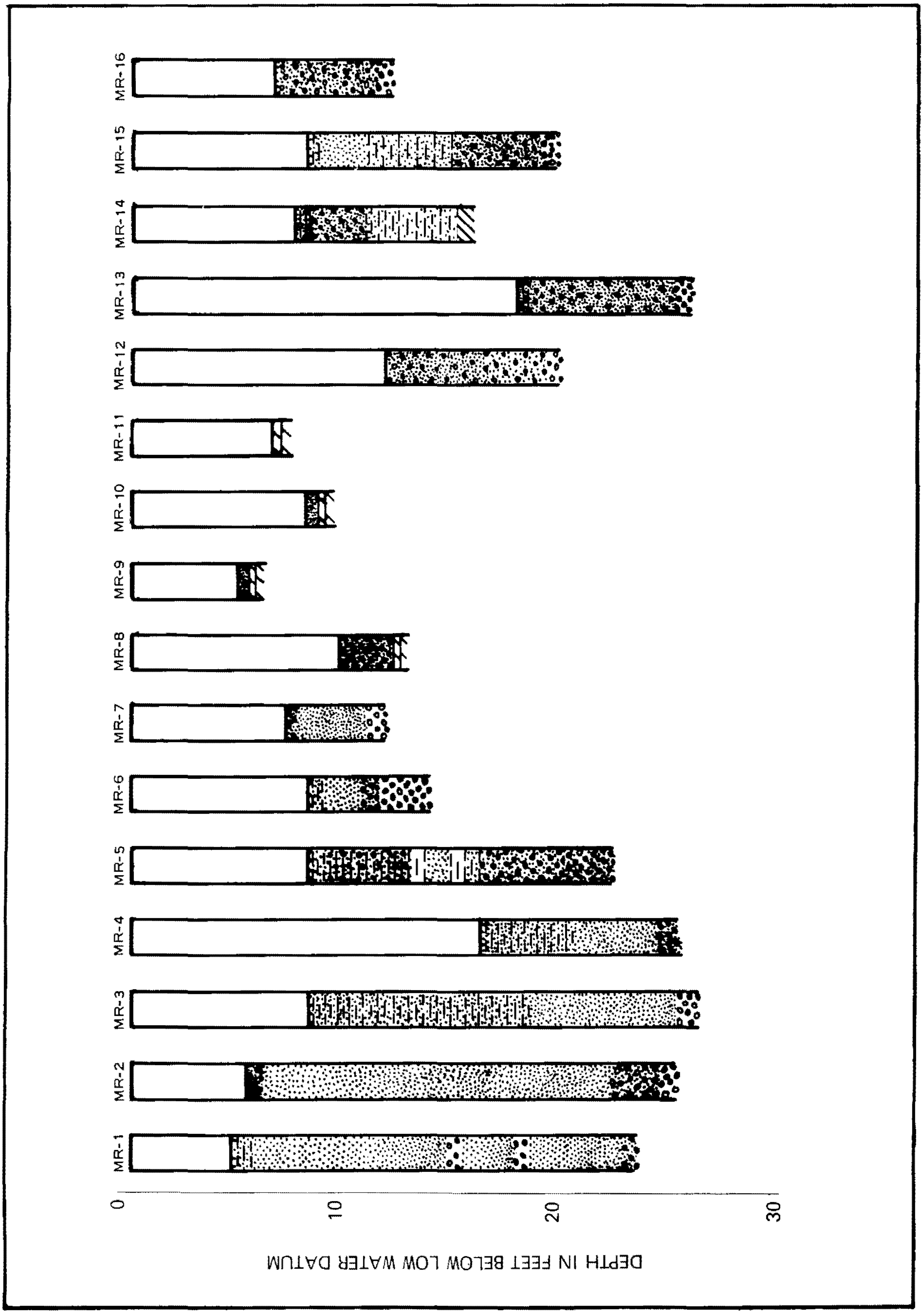
The distribution of surface deposits within the dredging corridor is shown in figure 2 (in pocket). Data for this map were taken both from bottom surface samples and from the top sample of test boring cores.

The Trask sorting coefficient (So) is a measure of the uniformity of particle sizes in a sediment sample. It is based on the statistical spread of the first and third quartiles on the percent passing curve (Krumbein and Pettijohn, 1938). These quartiles lie on each side of the median particle diameter (ϕm) or 50 percent passing and correspond to 25 and 75 percent passing. A sediment that is perfectly uniform in particle diameter has a sorting coefficient of 1.0. As this number increases the sediment is more poorly sorted. In general, Maumee River surface sand deposits are medium or well sorted. The following classification is useful in describing uniformity of diameters in the sand and gravel ranges:

Sorting coefficient	*Classification*
1.0-1.5	well sorted
1.5-2.5	medium sorted
>2.5	poorly sorted

Test borings

Generalized graphic logs of the 30 test borings are shown in figure 3. Detailed descriptions of test borings are given in table D of the Appendix. Eighty-two samples were retrieved from the test boring cores. Samples containing predominantly fine material were analyzed


MR-1
MR-2
MR-3
MR-4
MR-5
MR-6
MR-7
MR-8
MR-9
MR-10
MR-11
MR-12
MR-13
MR-14
MR-15
MR-16
0
10
20
30
DEPTH IN FEET BELOW LOW WATER DATUM

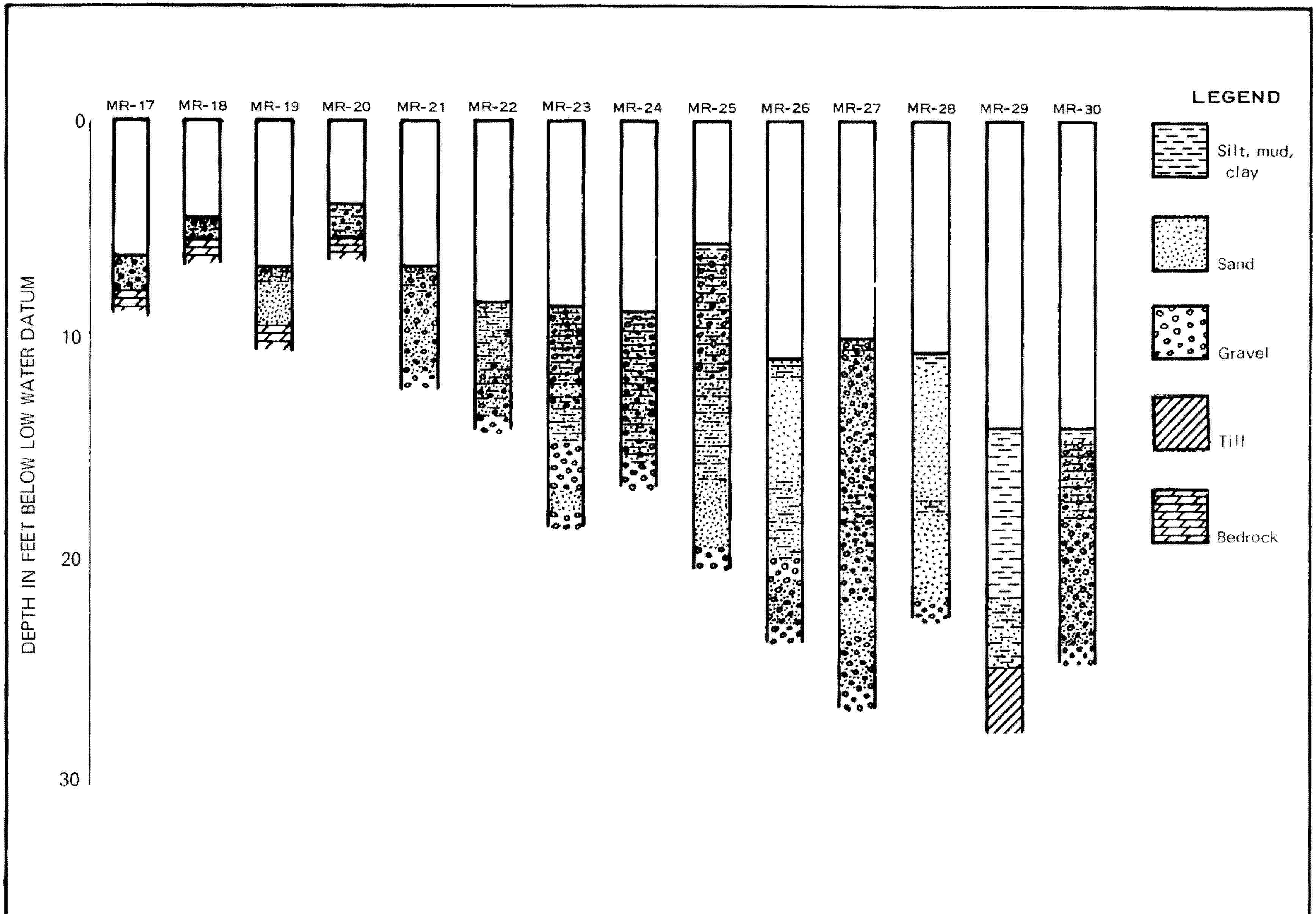


FIGURE 3.—Graphic logs of borings MR-1 through MR-30; depths below Low Water Datum of 568.6 feet above mean water level at Father Point, Quebec (IGLD, 1955).

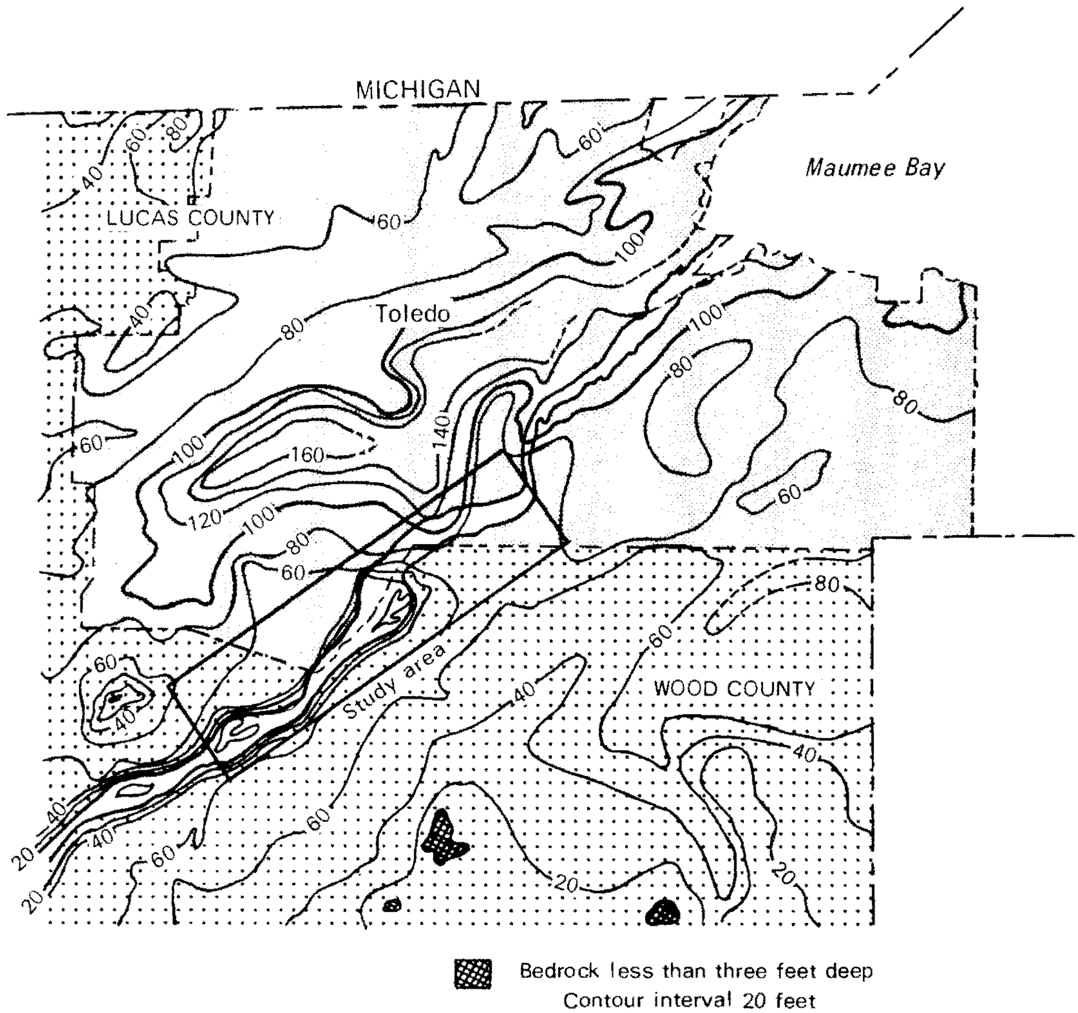


FIGURE 5.—Depth to bedrock in the vicinity of the Maumee-Toledo Dredging Corridor (modified from Forsyth, 1968).

by the hydrometer method and the coarser samples were tested by sieving. The coarse samples were washed to remove any silt and clay and screened to remove gravel larger than ⅜ inch in diameter before sieving. The analyses results are given in tables D and E of the Appendix.

Data from test borings MR-1 through MR-13 have been used to construct a cross section of the dredging corridor (fig. 4, in pocket). The cross section generally follows the centerline of the corridor. Figure 4 shows that commercially usable sand deposits extend from the north limit of the dredging area southwest to the vicinity of boring MR-7. Borings MR-8 through MR-10 indicate sand of good grade but of limited thickness. Bedrock was reached at shallow depths at the south end of the dredging corridor.

Test borings MR-14 through MR-30 were made near the shoreward limits of the dredging corridor. Generally the edge borings indicated considerably more silty material than did the central borings. However, in the vicinity of borings MR-25 through MR-28, edge sand deposits are of good quality.

The jetting method used for these borings is not satisfactory in gravel. Usable sand and gravel beds probably extend to depths greater than those reached during this study. Test data from the construction of the Interstate 75 bridge over the Maumee River indicate that sand and gravel deposits may extend as deep as 40 feet below water level. Forsyth (1968) plotted the depth to bedrock in the vicinity of the lower Maumee River (fig. 5). Her map shows bedrock ranging from about 10 feet below water level at the south limit of the dredging corridor to 115 feet near Walbridge Park to approximately 70 feet at the north limit.

Quality and potential uses

Sieve analyses of test boring samples (table E, Appendix) show that subsurface sand deposits are coarser and more poorly sorted than surface sand beds.

The median diameter of the test boring sand samples ranged from 0.1 mm to 7.4 mm and averaged 0.7 mm. Gravel layers were found at the bases of two-thirds of the test holes.

Midriver deposits (test borings MR-5 and MR-12) adjacent to Delaware and Clark Islands yielded material of the best grade for concrete sand. The best mortar and mason sand was found in samples (MR-1 and MR-2) from the north limit of the dredging corridor and north (MR-23) of Burns Island. Good mix and cover sand was found in samples throughout the corridor. Ohio Highway Department specifications for aggregate grading are given in table F of the Appendix.

Island sand deposits

Ewing Island, situated below the rapids of the Maumee River at Perrysburg, was investigated to determine (1) the composition of material forming the island, (2) the potential use of the mineral resources on the island, and (3) the geologic origin of the island. Samples of the island material were collected and analyzed optically for grain size and mineral composition.

The material forming the surface of the island was found to be river-deposited alluvium ranging in size from silt to large gravel. Large cobbles and boulders were found mixed with sand at the south (upstream) terminus of the island. The deposited sediment graded to finer sand and silt toward the north (downstream) end of the island.

The island appears to have been formed by the deposition of material carried by a rapidly moving stream as it flowed into the quiet water of the drowned river mouth. Evidence on the island, such as recently deposited coarse material, indicates that this process is continuing to build the island at the present time. Because the sand is mixed with abundant amounts of gravel and silt its extraction would demand an elaborate screening operation. The smaller downstream islands contain smaller amounts of coarse gravel and are considered better sources of commercial sand.

Maumee River mouth

The geologic mouth of the Maumee River is located just above the Maumee-Perrysburg bridge. This is the place where the bed of the river rises above Low Water Datum for Lake Erie, *i.e.,* where Low Water Datum intersects the shoreline on either side of the river. A line drawn between these points is the demarcation between the Maumee River and the estuary of Lake Erie.

The location of the mouth of the Maumee River in the vicinity of the Maumee-Perrysburg bridge is further supported by water levels recorded at the Rossford Marina, which is abreast of Corbutt Island. A comparison of water levels recorded at the Rossford gage and at the U.S. Army Corps of Engineers gage at the harbor entrance, for September 15, 1965, through November 8, 1965, indicates that the average water level in the dredging corridor is essentially the same as the average level of Lake Erie. During the period of record, the average hourly level at Rossford was 0.52 foot above Low Water Datum and the corresponding level at the harbor entrance was 0.51 foot, a difference of only 0.01 foot (fig. 6, in pocket).

Crustal movements account for the fact that water at the level of Lake Erie extends so many miles inland. These movements have depressed the lower Maumee River valley to the point where Lake Erie has encroached on the valley, forming the drowned river mouth or estuary that exists today.

Moore (1948) studied crustal movements in the Great Lakes area. His measurements showed that the Toledo area was depressed at a rate of 0.72 foot per century for the period 1877 to 1944. Considering that Lake Erie has been at its present level for several thousands of years, significant drowning of the lower Maumee River valley is understandable.

Current studies

In the spring of 1968, currents were measured midstream near the Interstate 75 bridge, near the Rossford Municipal Dock, and between Delaware and Grassy Islands. Current directions at each station were downstream and within the northeast quadrant. Velocities ranged from 0.72 foot per second to 0.17 foot per second. Surface velocities averaged 0.33 foot per second while bottom currents averaged 0.28 foot per second. These velocities are insufficient to erode sand but a velocity of only 0.23 foot per second is sufficient to transport particles as large as coarse-grained sand (Hjulström, 1939) once the particle is in motion.

Current measurements on September 4, 1969, at 1500 hours yielded quite different results. With wind velocities of 15 to 20 mph from NNE, the surface currents near the Rossford Municipal Dock were moving upstream (210°) at 0.51 foot per second. However, at depths greater than 5 feet the direction was nearly reversed (70°) and the flow was downstream at 0.17 foot per second. Records for this period show water level rising at a rate of 0.23 foot per hour in response to the wind. By 1600 hours the force of the wind-driven lake water was apparently strong enough to stop the downstream river flow and currents from top to bottom were moving upstream at an average velocity of 0.23 foot per second.

RESERVES

The Ohio Department of Natural Resources has kept records of sand and gravel removal from the Maumee River since 1948:

Year	*Cubic yards removed*
1948	137,933
1949	159,553
1950	185,687
1951	221,975
1952	213,422
1953	127,033
1954	117,722
1955	149,797
1956	170,163
1957	132,341
1958	121,938
1959	143,406
1960	123,293
1961	119,749
1962	78,605
1963	97,423
1964	137,942
1965	175,542
1966	193,290
1967	130,520
1968	122,192
Total	3,059,526
Average per year	145,692

The average rate of sand removal is somewhat under 150,000 cubic yards per year. The average thickness of commercially usable sand throughout the dredging corridor, based on the 30 test borings, is approximately 10 feet. This yields a volume of about 16,000,000 cubic yards of sand: a 110-year reserve at the present rate of removal. Considering the likelihood of usable deposits below the limits of test borings, sand reserves could amount to two or three times this figure.

Investigations of Ewing Island and the bottom surface sediments indicate that the sand and gravel resources of the dredging corridor are being added to as a result of upstream erosion, but only slowly. The recently deposited material, particularly in the northern limits of the study area, is much finer than the subsurface deposits. Apparently higher stream velocities occurred in the Maumee River during a low water level stage in western Lake Erie about 12,000 years ago (Lewis and others, 1966, and Herdendorf, 1968) and resulted in the deposition of much of the coarser material found at depth within the dredging corridor.

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APPENDIX

TABLE A.—*Description of Maumee River bottom samples*

Profile line	Distance from baseline (ft)	Water depth (ft)	Munsell color	Field description	Hydrometer analysis (percent)			Sieve sample number
					Sand and gravel	Silt	Clay	
0+00	500	26.0	5*Y* 4/1	Mud, olive-gray	20.0	77.1	2.9	
	1000	14.5	5*Y* 4/1	Mud, olive-gray	27.0	67.2	5.8	
5+00	500	1.3	5*Y* 3/2	Sand, fine- to medium-grained; shell fragments	100.0	0.0	0.0	1
	1000	22.0	5*Y* 4/1	Mud, olive-gray, sandy	52.3	25.8	1.9	2
10+00	500	1.7	5*Y* 4/1	Silt, olive-gray, sandy	74.1	25.5	0.4	3
	1000	3.3	5*Y* 4/1	Mud, olive-gray	26.6	72.7	0.7	4
	1500	15.0	5*Y* 4/1	Mud, olive-gray	24.9	73.8	1.3	
15+00	500	1.6	5*Y* 3/2	Sand, fine- to medium-grained; shell fragments	72.7	27.3	0.0	5
	1000	13.8	5*Y* 3/2	Sand, fine- to medium-grained; shell fragments				6
20+00	500	2.1	5*Y* 4/1	Mud, olive-gray, sandy	51.2	47.7	1.1	7
	1000	11.0	5*Y* 4/1	Silt, olive-gray, sandy	44.0	56.0	0.0	8
25+00	500	16.3	5*Y* 5/2	Mud, light-olive-gray	12.0	86.2	1.8	
	1000	15.2	5*Y* 4/1	Mud, olive-gray	17.6	74.9	7.5	
30+00	500	9.9	5*Y* 4/1	Mud, olive-gray	18.2	78.2	3.6	
	1000	7.7	10*YR* 5/4	Pebbles and cobbles, yellowish-brown	100.0	0.0	0.0	9
	1500	13.8	5*Y* 4/1	Mud, olive-gray	15.1	82.9	2.0	
35+00			(profile line through 175 bridge abutments)					
40+00	500	14.0	5*Y* 4/1	Mud, olive-gray	27.2	70.0	2.8	
	1000	12.0	mixed colors	Gravel, pebbles, cobbles, and shells	100.0	0.0	0.0	10
	1500	12.3	5*Y* 4/1	Mud, olive-gray; gravel, pebbles and shells	99.7	0.3	0.0	11
45+00	500	14.0	5*Y* 4/1	Mud, olive-gray, sandy	42.4	57.6	0.0	
	1000	12.4	5*Y* 4/1	Mud, olive-gray	22.5	70.5	7.0	
	1500	13.7	5*Y* 4/1	Mud, olive-gray, sandy	34.6	61.7	3.7	12
50+00	500	16.5	5*Y* 4/1	Mud, olive-gray, sandy	60.5	37.5	2.0	
	1000	15.0	5*Y* 4/1	Mud, olive-gray, sandy	51.9	46.7	1.4	13
	1500	18.7	5*Y* 4/1	Mud, olive-gray	4.9	79.7	15.4	
55+00	500	15.0	5*Y* 3/2	Sand, fine- to medium-grained; shells and wood	83.7	16.3	0.0	14
	1000	10.4	5*Y* 4/1	Mud, olive-gray, sandy	15.4	80.0	4.6	
	1500	9.7	5*Y* 4/1	Mud, olive-gray	10.5	86.0	3.5	
60+00	500	14.7	5*Y* 4/1	Mud, olive-gray	22.0	43.6	1.4	
	1000	10.5	5*Y* 4/1	Mud, olive-gray	5.2	93.9	0.9	
	1500	11.5	5*Y* 4/1	Mud, olive-gray	21.4	77.3	1.3	
	2000	3.1	5*Y* 4/1	Mud, olive-gray	27.5	71.6	0.9	
65+00	500	17.0	5*Y* 4/1	Silt, olive-gray, sandy	54.3	45.1	0.6	15
	1000	11.0	mixed colors	Sand, fine- to medium-grained; gravel, pebbles, and shells	100.0	0.0	0.0	16
	1500	20.3	5*Y* 4/1	Mud, olive-gray	0.0	98.4	1.6	
	2000	2.0	5*Y* 3/2	Sand, fine- to medium-grained; shell fragments	77.0	22.2	0.8	17

TABLE A.—*Description of Maumee River bottom samples*—Continued

Profile line	Distance from baseline (ft)	Water depth (ft)	Munsell color	Field description	Hydrometer analysis (percent)			Sieve sample number
					Sand and gravel	Silt	Clay	
70+00	500	10.6	mixed colors	Gravel, pebbles, and shells	100.0	0.0	0.0	18
	1000	6.5	5Y 4/1	Sand, fine-grained, silty	54.0	43.9	1.3	19
	1500	19.5	5Y 4/1	Mud, olive-gray	2.2	96.4	1.4	
	2000	2.3	5Y 4/1	Mud, olive-gray, sandy	34.4	64.4	1.2	20
75+00	500	16.1	5Y 4/1	Mud, olive-gray	3.6	94.0	2.4	
	1000	8.8	5Y 4/1	Mud, olive-gray, sandy	27.5	69.6	2.9	
	1500	15.3	5Y 4/1	Mud, olive-gray	0.2	96.1	3.7	
	2000	2.0	5Y 4/1	Mud, olive-gray	21.2	77.1	1.7	
80+00	500	13.0	5Y 4/1	Mud, olive-gray	8.7	86.1	5.2	
	1000	10.5	5GY 4/1	Sand, fine- to coarse-grained, sticky	90.7	9.3	0.0	21
	1500	4.7	5GY 4/1	Sand, fine- to medium-grained, sticky	46.8	51.6	1.7	22
	2000	2.4	5Y 4/1	Mud, olive-gray, sandy	24.3	75.2	0.5	

TABLE B.—*Wentworth sediment grade scale*[1]

Grade limits			Grade name	ϕ units ($-\log_2$ diameters in mm)
microns (approx.)	mm	in		
	4096	160		-12
			Very large boulders	
	2048	80		-11
			Large boulders	
	1024	40		-10
			Medium boulders	
	512	20		-9
			Small boulders	
	256	10		-8
			Large cobbles	
	128	5		-7
			Small cobbles	
	64	2.5		-6
			Very coarse pebbles	
	32	1.3		-5
			Coarse pebbles	
	16	0.6		-4
			Medium pebbles	
	8	0.3		-3
			Fine pebbles	
	4	0.16		-2
			Very fine pebbles	
	2	0.08		-1
			Very coarse sand	
1000	1			0
			Coarse sand	
500	1/2			+1
			Medium sand	
250	1/4			+2
			Fine sand	
125	1/8			+3
			Very fine sand	
62	1/16			+4
			Coarse silt	
31	1/32			+5
			Medium silt	
16	1/64			+6
			Fine silt	
8	1/128			+7
			Very fine silt	
4	1/256			+8
			Coarse clay	
2	1/512			+9
			Medium clay	
1	1/1024			+10
			Fine clay	
1/2	1/2048			+11
			Very fine clay	
1/4	1/4096			+12

[1]Modified from Dunbar and Rodgers (1957).

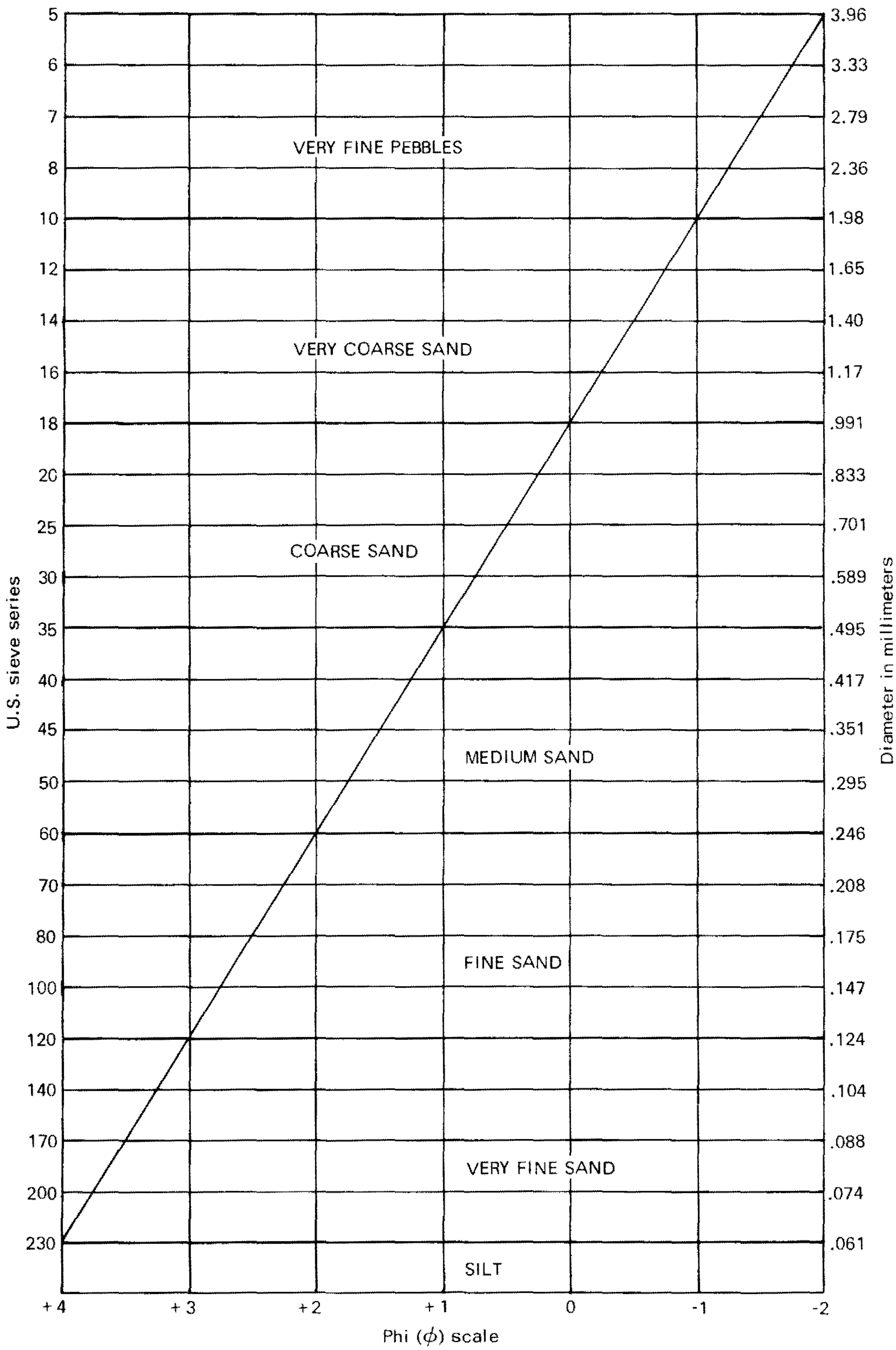

FIGURE 7.—Grain-size conversion table.

TABLE C.—*Sieve analyses of hydrometer sand fractions from Maumee River bottom samples*

Sample number	U.S. sieve series (percent passing)						ϕm (mm)	So	Water depth (ft)	Location
	4	8	16	30	50	100				
1	100.00	100.00	100.00	98.82	77.87	12.45	2.3	1.32	1.3	Profile line 5+00, 500 ft
2	100.00	100.00	100.00	100.00	88.64	26.28	2.4	1.32	22.0	Profile line 5+00, 1000 ft
3	100.00	100.00	100.00	98.63	82.84	33.81	2.4	1.57	1.7	Profile line 10+00, 500 ft
4	100.00	100.00	100.00	100.00	97.40	70.29			3.3	Profile line 10+00, 1000 ft
5	100.00	97.37	93.21	78.69	24.09	8.35	1.3	1.37	1.6	Profile line 15+00, 500 ft
6	100.00	100.00	96.90	89.60	67.09	17.94	2.3	1.74	13.8	Profile line 15+00, 1000 ft
7	100.00	100.00	100.00	100.00	100.00	99.89			2.1	Profile line 20+00, 500 ft
8	100.00	100.00	100.00	100.00	98.03	77.94			11.0	Profile line 20+00, 1000 ft
9	0.00								7.7	Profile line 30+00, 1000 ft
10	1.95	0.00							12.0	Profile line 40+00, 1000 ft
11	19.04	7.61	5.16	4.09	2.92	1.04			12.3	Profile line 40+00, 1500 ft
12	100.00	100.00	100.00	98.98	85.17	32.25	2.4	1.42	13.7	Profile line 45+00, 1500 ft
13	100.00	100.00	100.00	100.00	97.12	35.25	2.6	1.32	15.0	Profile line 50+00, 1000 ft
14	100.00	100.00	99.45	97.35	90.16	47.65	3.8	1.52	15.0	Profile line 55+00, 500 ft
15	100.00	100.00	98.99	93.48	75.07	35.13	2.4	1.62	17.0	Profile line 65+00, 500 ft
16	5.45	0.00							11.0	Profile line 65+00, 1000 ft
17	100.00	100.00	100.00	100.00	88.90	40.34	2.4	1.42	2.0	Profile line 65+00, 2000 ft
18	0.00								10.6	Profile line 70+00, 500 ft
19	100.00	100.00	100.00	98.48	82.85	30.76	2.4	1.42	6.5	Profile line 70+00, 1000 ft
20	100.00	100.00	100.00	100.00	94.45	67.67			2.3	Profile line 70+00, 2000 ft
21	100.00	100.00	100.00	99.12	86.23	40.55	2.5	1.57	10.5	Profile line 80+00, 1000 ft
22	100.00	100.00	100.00	100.00	100.00	78.72			4.7	Profile line 80+00, 1500 ft

TABLE D.—*Logs of Maumee River test borings*

Boring no. Water depth Date	Sample number	Particle size (percent)				Depth and *elevation* (ft)	Bottom penetration (ft)	Field description
		Gravel	Sand	Silt	Clay			
MR-1 4.5 ft 8-25-64	MR-1-1	0.00	35.80	64.20	0.00	4.5 *564.1*	0.0-0.5	Sand, mixed with olive-gray mud, shells
	MR-1-2	0.00	89.20	10.80	0.00	7.5 *561.1*	3.0-3.4	Sand, medium- to coarse-grained
	MR-1-3	0.00	14.90	77.30	7.80	12.5 *556.1*	8.0-8.7	Sand, medium- to fine-grained
						14.5 *554.1*	10.0	No sample, appeared to be gravel layer with sand below
						17.5 *551.1*	13.0	No sample, appeared to be gravel layer with sand below
	MR-1-4	69.30	6.44	24.18	0.08	22.5 *546.1*	18.0-18.3	Sand, coarse-grained; with gravel
						23.0 *545.6*	18.5	No sample, refusal in compact sand and gravel layer
MR-2 5.0 ft 8-25-64	MR-2-1	16.08	65.52	18.40	0.00	5.0 *563.6*	0.0-0.5	Sand and gravel, medium- to fine-grained; mixed with brown mud, shell fragments, and wood detritus
	MR-2-2	1.15	77.95	20.90	0.00	8.0 *560.6*	3.0-3.8	Sand, medium- to fine-grained; with shell fragments
	MR-2-3	0.00	89.60	10.40	0.00	13.0 *555.6*	8.0-8.7	Sand, medium- to fine-grained, with shell fragments and wood detritus
	MR-2-4	1.95	85.65	12.40	0.00	18.0 *550.6*	13.0-13.5	Sand, fine- to coarse-grained; with shell fragments
						22.0 *546.6*	17.0	No sample, appeared to be compact gravel layer
	MR-2-5	20.35	75.65	4.00	0.00	23.0 *545.6*	18.0-18.4	Sand, coarse-grained; with pebbles and shell fragments
						25.0 *543.6*	20.0	No sample, refusal in compact gravel layer
MR-3 8.0 ft 8-25-64	MR-3-1	0.00	36.50	63.50	0.00	8.0 *560.6*	0.0-0.5	Mud, gray-brown, silty; with fine-grained sand
	MR-3-2					13.0 *555.6*	5.0-6.5	Mud, gray, laminated; with silt and fine-grained sand, shell fragments
	MR-3-3					18.0 *550.6*	10.0-10.5	Mud, gray-brown, silty
	MR-3-4					18.5 *550.1*	10.5-11.0	Sand, medium- to coarse-grained
	MR-3-5					23.0 *547.6*	15.0-15.4	Sand, medium- to coarse-grained; with clay material
						25.0 *543.6*	17.0	No sample, appeared to be gravel layer
						26.0 *542.6*	18.0	No sample, refusal in compact gravel layer
MR-4 16.0 ft 5-19-65	MR-4-1	0.00	51.90	46.70	1.40	16.0 *552.6*	0.0-0.5	Mud, dark-brown, silty, sandy
	MR-4-2					20.0 *548.6*	4.0-5.0	Mud, dark-brown, silty
						20.5 *548.1*	4.5	No sample, appeared to be sand layer
						24.0 *544.6*	8.0	No sample, appeared to be gravel layer
	MR-4-3					24.5 *544.1*	8.5-8.6	Sand, fine-grained; with pebbles, shell fragments, and wood detritus
						25.0 *543.6*	9.0	No sample, refusal in compact sand and gravel layer

TABLE D.—*Logs of Maumee River test borings*—Continued

Boring no. Water depth Date	Sample number	Particle size (percent)			Depth and *elevation* (ft)	Bottom penetration (ft)	Field description
		Gravel	Sand	Silt and clay			
MR-5 8.0 ft 5-19-65	MR-5-1	0.09	93.19	6.72	8.0 *560.6*	0.0-0.5	Sand, dark-brown, medium- to fine-grained, silty; with shells and wood detritus
	MR-5-2	7.40	87.12	5.48	13.0 *555.6*	5.0-5.3	Sand, coarse-grained; with pebbles and gray-brown silt
					13.5 *555.1*	5.5	No sample, appeared to be compact clay layer with sand below
					15.0 *553.6*	7.0	No sample, appeared to be compact clay layer with sand below
	MR-5-3	1.70	97.27	1.03	15.5 *553.1*	7.5-8.0	Sand, medium-grained, silty; with shells
	MR-5-4	41.35	58.49	0.16	16.0 *552.6*	8.0-8.5	Sand, medium- to coarse-grained; with pebbles
	MR-5-5	9.23	86.77	4.00	20.0 *548.6*	12.0-12.4	Sand, medium- to coarse-grained, silty; with pebbles
					20.5 *548.1*	12.5	No sample, appeared to be compact gravel layer
	MR-5-6	5.21	93.39	1.40	21.5 *547.1*	12.5-13.7	Sand, medium- to coarse-grained; with pebbles and shell fragments
					22.0 *546.6*	14.0	No sample, refusal in compact gravel layer
MR-6 8.0 ft 5-3-67	MR-6-1	2.11	96.61	1.28	8.0 *560.6*	0.0-0.5	Sand, medium- to fine-grained, silty; shells
	MR-6-2	50.29	49.12	0.58	10.5 *558.1*	2.5-3.3	Sand, medium- to coarse-grained; with gravel and snail shells
					11.5 *557.1*	3.5-5.5	No sample, appeared to be gravel layer
					13.5 *555.1*	5.5	No sample, refusal in compact gravel layer
MR-7 7.0 ft 5-3-67	MR-7-1	57.08	42.01	0.91	7.0 *561.6*	0.0-0.5	Sand, poorly sorted; gravel up to 0.2 ft in diameter
	MR-7-2	1.82	93.93	4.25	10.5 *558.1*	3.5-4.2	Sand, medium- to fine-grained; shell fragments
					11.5 *557.1*	4.5	No sample, refusal in compact gravel layer
MR-8 9.5 ft 5-3-67	MR-8-1	15.49	83.32	1.19	9.5 *559.1*	0.0-0.5	Sand and gravel, thin layer of brown sand and gravel over dark-gray mud mixed with sand and gravel
	MR-8-2	39.16	60.14	0.70	10.0 *558.6*	0.5-2.0	Sand, medium- to coarse-grained; with gravel
					12.0 *556.6*	2.5	No sample, refusal at bedrock
MR-9 5.0 ft 5-3-67	MR-9-1	4.63	94.99	0.38	5.0 *563.6*	0.0-0.5	Sand, medium-grained, clean; pebbles
					5.5 *563.1*	0.5	No sample, refusal at bedrock
MR-10 8.0 ft 5-3-67	MR-10-1	2.40	96.96	0.64	8.0 *560.6*	0.0-0.5	Sand, medium- to coarse-grained; with a few pebbles
					8.5 *560.1*	0.5	No sample, refusal at bedrock
MR-11 6.5 ft 5-3-67					6.5 *562.1*	0.0	No sample, bedrock at bottom surface
MR-12 11.7 ft 5-3-67	MR-12-1	5.33	94.17	0.50	11.7 *556.9*	0.0-0.5	Sand, medium- to coarse-grained; pebbles, shells
					12.3 *556.3*	0.5-4.5	No sample, appeared to be compact sand and gravel layer
	MR-12-2	42.86	56.27	0.87	16.2 *552.4*	4.5-5.0	Sand, medium- to coarse-grained; with pebbles and shells
	MR-12-3	72.20	25.62	2.18	18.7 *549.9*	7.0-8.0	Sand and gravel; coarse-grained sand and pebbles
					19.7 *548.9*	8.0	No sample, refusal in compact gravel layer

TABLE D.—*Logs of Maumee River test borings*—Continued

Boring no. Water depth Date	Sample number	Particle size (percent)			Depth and *elevation* (ft)	Bottom penetration (ft)	Field description
		Gravel	Sand	Silt and clay			
MR-13 17.7 ft 5-3-67	MR-13-1	78.55	21.08	0.37	17.7 *550.9*	0.0-0.5	Mud, gray-brown; mixed with sand, pebbles, and plant detritus
	MR-13-2	23.66	75.36	0.98	18.7 *549.9*	1.0-1.7	Sand, medium- to fine-grained; pebbles
	MR-13-3	45.62	54.06	0.32	23.7 *544.9*	6.0-6.4	Sand, medium- to coarse-grained; with pebbles and shells
					25.7 *542.9*	8.0	No sample, refusal in compact gravel layer
MR-14 7.6 ft 11-14-67	MR-14-1	30.19	62.59	7.22	7.6 *561.0*	0.0-0.5	Sand, medium-grained; mixed with silt and gravel
					10.5 *558.1*	2.9	No sample, appears to be clay
	MR-14-2	3.39	28.63	67.98	12.0 *556.6*	4.4-5.7	Clay, medium-gray, smooth, sandy
	MR-14-3		2.08	97.92	15.0 *553.6*	7.4-7.7	Glacial till, very hard compact yellow-brown till clay
					15.6 *553.0*	8.0	No sample, refusal in hard till clay
MR-15 8.1 ft 11-15-67	MR-15-1	3.30	89.41	7.29	8.1 *560.5*	0.0-0.5	Sand, medium- to fine-grained; silty at surface
	MR-15-2	0.37	44.35	55.28	10.6 *558.0*	2.5-3.6	Clay, smooth, soft, sandy
	MR-15-3	0.41	37.78	61.81	11.7 *556.9*	3.6-3.8	Sand, silty; with shell fragments
					14.7 *553.9*	6.5	No sample, appeared to be a gravel layer
	MR-15-4	44.66	48.08	7.26	15.6 *553.0*	7.5-8.0	Sand and gravel, with shell fragments
					18.6 *550.0*	10.5	No sample, hard layer, appeared to be sand and gravel
					19.4 *549.2*	11.3	No sample, refusal in compact gravel layer
MR-16 6.4 ft 11-15-67	MR-16-1	28.09	67.09	4.82	6.4 *562.2*	0.0-0.5	Sand, medium- to coarse-grained; with gravel
					11.5 *557.1*	5.1	No sample, appeared to be coarse sand and gravel
					11.9 *556.7*	5.5	No sample, refusal in compact gravel layer
MR-17 6.1 ft 11-15-67	MR-17-1	44.52	54.41	1.07	6.1 *562.5*	0.0-0.5	Sand, brown; with pebbles and cobbles
					7.6 *561.0*	1.5	No sample, refusal at bedrock
MR-18 4.3 ft 11-15-67	MR-18-1	63.10	25.12	11.78	4.3 *564.3*	0.0-0.5	Sand and gravel, mixed with mud
	MR-18-2	46.46	43.36	10.18	4.8 *563.8*	0.5-1.0	Sand, with silt and gravel
					5.3 *563.3*	1.0	No sample, refusal at bedrock
MR-19 6.6 ft 11-15-67	MR-19-1	17.78	80.85	1.37	6.6 *562.0*	0.0-0.5	Sand, medium- to coarse-grained; silty at surface
					9.4 *559.2*	2.8	No sample, refusal at bedrock
MR-20 3.7 ft 11-15-67	MR-20-1	92.10	7.13	0.77	3.7 *564.9*	0.0-0.5	Gravel, pea-sized pebbles with sand and silt
					5.2 *563.4*	1.5	No sample, refusal at bedrock
MR-21 6.5 ft 11-15-67	MR-21-1	62.62	32.30	5.08	6.5 *562.1*	0.0-0.5	Gravel, mixed with sand and mud
	MR-21-2	14.41	85.14	0.45	12.0 *556.6*	5.5-5.7	Sand and gravel, medium- to coarse-grained; with shell fragments
					12.2 *556.4*	5.7	No sample, refusal in compact gravel layer
MR-22 8.2 ft 11-15-67	MR-22-1	0.00	28.19	71.81	8.2 *560.4*	0.0-0.5	Mud and sand, gray-brown, smooth
	MR-22-2	37.43	58.78	3.79	11.0 *557.6*	2.8-5.3	Sand, coarse-grained; with gravel and silt
					14.0 *554.6*	5.8	No sample, refusal in compact gravel layer

TABLE D.—*Logs of Maumee River test borings*—Continued

Boring no. Water depth Date	Sample number	Particle size (percent)			Depth and *elevation* (ft)	Bottom penetration (ft)	Field description
		Gravel	Sand	Silt and clay			
MR-23 8.4 ft 11-16-67	MR-23-1	9.52	86.64	3.84	8.4 *560.2*	0.0-0.5	Sand and gravel, medium-grained; silty at surface
	MR-23-2	39.22	54.41	6.37	11.5 *557.1*	3.1-3.5	Silt, gray-brown; mixed with sand and gravel
	MR-23-3	0.52	92.46	7.02	11.9 *556.7*	3.5-3.9	Sand, yellow-brown, fine-grained
	MR-23-4	33.40	61.22	5.38	12.3 *556.3*	3.9-4.2	Sand, gray-brown, very fine-grained; mixed with silt and gravel
	MR-23-5	0.00	46.41	53.59	12.6 *556.0*	4.2-4.5	Clay, yellow-brown, compact, sandy
					14.5 *554.1*	6.1-8.3	No sample, appeared to be compact gravel layer
	MR-23-6	1.02	96.05	2.93	16.7 *551.9*	8.3-8.5	Sand, brown, medium- to coarse-grained
					17.5 *551.1*	9.1	No sample, appeared to be compact gravel layer
					18.5 *550.1*	10.1	No sample, refusal in compact gravel layer
MR-24 8.7 ft 11-16-67	MR-24-1	74.50	23.19	2.31	8.7 *559.9*	0.0-0.5	Sand and gravel; brown sand, cobbles; silty
	MR-24-2	37.11	58.72	4.17	11.5 *557.1*	2.8-3.1	Sand, with fine-grained gravel and compact clay
					15.5 *553.1*	6.8	No sample, appeared to be compact gravel layer
					16.5 *552.1*	7.8	No sample, refusal in compact gravel layer
MR-25 5.6 ft 11-16-67	MR-25-1	55.64	37.24	7.12	5.6 *563.0*	0.0-0.5	Sand and gravel, 0.2 ft of brown mud at surface over silty sand to cobbles
	MR-25-2	27.45	70.45	2.10	11.5 *557.1*	5.9-6.2	Sand and gravel, coarse-grained sand and fine-grained pebbles, with shells
	MR-25-3	0.54	36.47	62.99	11.8 *556.8*	6.2-6.7	Sand, fine-grained; with gray-brown clay
	MR-25-4	19.78	76.60	3.62	16.5 *552.1*	10.9-11.2	Sand, medium- to coarse-grained; with shells
					19.5 *549.1*	13.9	No sample, appeared to be compact gravel layer
					20.2 *548.4*	14.6	No sample, refusal in compact gravel layer
MR-26 10.8 ft 11-16-67	MR-26-1	9.21	86.66	4.13	10.8 *557.8*	0.0-0.5	Sand, medium-grained; silty at surface; shells
	MR-26-2	12.79	81.30	5.91	16.8 *551.8*	6.0-6.7	Sand, medium- to fine-grained, silty; clay at base
					19.7 *548.9*	8.9-9.9	No sample, appeared to be gravel layer
	MR-26-3	68.41	29.37	2.22	21.8 *546.8*	11.0-11.5	Sand, with abundant snail shells and pea-sized pebbles
					23.7 *544.9*	12.9	No sample, refusal in gravel layer
MR-27 9.9 ft 11-16-67	MR-27-1	81.50	11.45	7.05	9.9 *558.7*	0.0-0.5	Sand and gravel, silty; cobbles, shells
	MR-27-2	18.76	78.29	2.95	16.9 *551.7*	7.0-9.0	Sand, medium- to fine-grained; shells, pebbles; two thin (0.1 ft) clay layers
	MR-27-3		100.00		21.9 *546.7*	12.0-12.5	Sand, medium- to fine-grained; shell fragments
					23.7 *544.9*	13.8	No sample, appeared to be compact sand and gravel layer
					26.5 *542.1*	16.6	No sample, refusal in gravel layer
MR-28 10.5 ft 11-16-67	MR-28-1	0.72	85.36	13.92	10.5 *558.1*	0.0-0.5	Mud, gray-brown; mixed with fine-grained sand and plant detritus
	MR-28-2	3.88	93.01	3.11	16.8 *551.8*	6.3-8.3	Sand, medium-grained; shells; thin (0.2 ft) clay layer at 7.0 ft penetration
	MR-28-3	51.74	46.47	1.79	21.8 *546.8*	11.3-11.5	Sand, with pebbles and shells
					22.3 *546.8*	11.8	No sample, refusal in compact gravel layer

TABLE D.—*Logs of Maumee River test borings*—Continued

Boring no. Water depth Date	Sample number	Particle size (percent)			Depth and *elevation* (ft)	Bottom penetration (ft)	Field description
		Gravel	Sand	Silt and clay			
MR-29 13.8 ft 11-16-67	MR-29-1	0.00	7.77	92.23 (silt only)	13.8 *554.8*	0.0-0.5	Mud, gray-brown, sandy
	MR-29-2	0.66	9.73	89.61 (silt only)	16.8 *551.8*	3.0-4.5	Clay, gray-brown, smooth
	MR-29-3	7.10	34.16	58.74 (silt only)	21.8 *546.8*	8.0-8.3	Clay, medium-gray, compact; with fine-grained sand
					24.8 *543.8*	11.0	No sample, hard layer, appeared to be top of till
	MR-29-4	7.13	38.64	54.23 (silt only)	26.8 *541.8*	13.0-13.7	Glacial till, reddish-gray, compact, gritty; till clay
					27.8 *540.8*	14.0	No sample, refusal in hard till clay
MR-30 13.8 ft 11-16-67	MR-30-1		12.86	87.14	13.8 *554.8*	0.0-0.5	Mud, gray-brown, smooth, sandy
	MR-30-2	30.93	53.31	15.76	16.8 *551.8*	3.0-4.0	Sand and gravel, silty
	MR-30-3	33.04	65.30	1.66	21.8 *546.8*	8.0-8.3	Sand and gravel, medium-grained sand to fine-grained pebbles; shells
					24.3 *543.3*	10.5	No sample, refusal in compact gravel layer

TABLE E.—*Sieve analyses of Maumee River test boring samples*

Sample number	U.S. sieve series (percent passing)								ϕm	So	Water depth (ft)	Bottom penetration (ft)
	⅜ in	4	8	16	30	50	100	200				
MR-1-2	100.00	100.00	100.00	91.75	54.74	8.20	0.31	0.00	0.8	1.8	4.5	3.0-3.4
MR-1-4	100.00	34.35	8.68	1.68	0.68	0.42	0.20	0.08	−2.9	1.3	4.5	18.0-18.3
MR-2-1	100.00	91.05	84.61	73.66	50.57	24.14	17.98	2.94	0.8	2.2	5.0	0.0-0.5
MR-2-2	100.00	100.00	98.46	97.88	94.39	54.93	9.77	0.79	1.8	1.3	5.0	3.0-3.8
MR-2-3	100.00	100.00	100.00	99.94	98.17	62.91	14.68	1.19	2.1	1.3	5.0	8.0-8.7
MR-2-4	100.00	100.00	97.77	94.26	83.17	48.04	6.16	0.78	1.6	1.6	5.0	13.0-13.5
MR-2-5	100.00	90.37	85.18	75.73	63.31	36.41	3.49	0.39	1.3	2.5	5.0	18.0-18.4
MR-5-1	100.00	100.00	99.91	99.26	95.77	65.34	20.24	6.72	1.9	1.5	8.0	0.0-0.5
MR-5-2	100.00	97.25	92.60	87.36	79.37	33.83	9.41	5.48	1.3	1.5	8.0	5.0-5.3
MR-5-3	100.00	99.12	98.30	97.41	92.13	39.24	3.31	1.03	1.5	1.4	8.0	7.5-8.0
MR-5-4	100.00	81.58	59.83	35.39	10.58	0.94	0.22	0.16	−0.8	2.1	8.0	8.0-8.5
MR-5-5	100.00	98.91	90.77	79.27	52.39	18.22	7.39	4.00	0.8	1.8	8.0	12.0-12.4
MR-5-6	100.00	100.00	94.79	52.91	19.27	2.48	1.81	1.40	−0.3	1.6	8.0	13.5-13.7
MR-6-1	100.00	99.25	97.89	95.85	92.48	42.59	4.41	1.28	1.5	1.5	8.0	0.0-0.5
MR-6-2	100.00	75.44	75.44	36.64	21.57	8.68	2.82	0.62	−1.2	2.6	8.0	2.5-3.3
MR-7-1	100.00	66.02	46.57	34.47	20.48	7.46	2.00	0.99	−1.4	3.3	7.0	0.0-0.5
MR-7-2	100.00	100.00	98.18	84.40	50.37	21.67	11.60	4.25	0.7	1.7	7.0	3.5-4.2
MR-8-1	100.00	94.30	88.95	83.29	72.30	28.31	5.11	1.25	1.5	1.6	9.5	0.0-0.5
MR-8-2	100.00	82.10	66.60	53.51	36.37	6.63	1.82	0.77	−0.2	2.7	9.5	0.5-2.0
MR-9-1	100.00	98.43	95.81	87.27	56.85	5.63	1.04	0.38	0.9	1.3	5.0	0.0-0.5
MR-10-1	100.00	99.79	97.60	90.89	66.91	8.01	1.04	0.64	1.1	1.4	8.0	0.0-0.5

TABLE E.—*Sieve analyses of Maumee River test boring samples*—Continued

Sample number	U.S. sieve series (percent passing)								ϕm	So	Water depth (ft)	Bottom penetration (ft)
	3/8 in	4	8	16	30	50	100	200				
MR-12-1	100.00	98.66	94.67	82.50	47.85	7.23	0.82	0.50	0.7	1.6	11.7	0.0-0.5
MR-12-2	100.00	79.05	61.76	46.41	29.71	13.09	3.32	0.94	−0.7	3.1	11.7	4.5-5.0
MR-12-3	100.00	56.97	29.81	20.13	12.80	5.86	3.58	2.34	−2.2	--	11.7	7.0-8.0
MR-13-1	100.00	47.24	33.97	27.50	20.39	10.60	2.55	0.58	−2.7	--	17.7	0.0-0.5
MR-13-2	100.00	90.48	81.32	72.25	58.83	29.61	4.66	1.06	0.8	2.5	17.7	1.0-1.7
MR-13-3	100.00	74.67	57.41	44.80	32.47	10.16	1.25	0.34	−0.8	2.6	17.7	6.0-6.4
MR-14-1	100.00	91.65	73.95	57.00	38.02	9.93	1.79	0.20	0.2	2.5	7.6	0.0-0.5
MR-15-1	100.00	98.27	97.09	96.33	95.62	49.63	1.56	0.12	1.7	1.2	8.1	0.0-0.5
MR-15-4	100.00	73.45	61.18	49.28	33.71	14.04	3.45	0.49	−0.3	3.3	8.1	7.5-8.0
MR-16-1	100.00	92.46	76.12	61.21	36.18	11.41	2.86	0.41	0.2	2.1	6.4	0.0-0.5
MR-17-1	100.00	73.86	59.98	53.27	46.32	26.14	5.96	0.75	0.2	4.1	6.1	0.0-0.5
MR-18-1	100.00	60.50	45.22	37.06	30.43	18.95	7.50	1.51	−1.8	4.2	4.3	0.0-0.5
MR-18-2	100.00	75.41	58.06	42.32	30.39	17.09	4.96	0.62	−1.0	3.6	4.3	0.5-1.0
MR-19-1	100.00	94.47	87.79	80.97	65.08	17.16	3.04	0.89	1.2	1.6	6.6	0.0-0.5
MR-20-1	100.00	29.48	12.51	8.82	6.55	3.57	1.29	0.32	--	--	3.7	0.0-0.5
MR-21-1	100.00	64.17	53.55	50.38	47.80	32.94	6.69	1.21	0.4	2.0	6.5	0.0-0.5
MR-21-2	100.00	92.92	68.50	28.62	4.36	0.86	0.06	--	−0.8	2.0	6.5	5.5-5.7
MR-22-2	100.00	87.55	73.74	60.16	42.46	25.05	4.40	0.40	1.8	1.4	8.2	2.8-5.3
MR-23-1	100.00	95.11	90.77	88.80	85.97	74.17	31.52	2.22	2.3	1.5	8.4	0.0-0.5
MR-23-2	100.00	81.52	66.58	55.97	41.06	19.99	5.86	0.54	1.8	1.2	8.4	3.1-3.5
MR-23-3	100.00	100.00	99.55	98.96	97.48	91.08	21.52	2.09	2.6	1.1	8.4	3.5-3.9
MR-23-4	100.00	85.85	74.40	66.91	54.87	34.32	9.21	1.09	1.1	3.1	8.4	3.9-4.2
MR-23-6	100.00	100.00	99.64	95.59	75.62	33.08	7.13	0.63	1.5	1.5	8.4	8.3-8.5
MR-24-1	100.00	64.08	47.17	38.50	29.29	11.19	3.05	0.39	−1.7	3.5	8.7	0.0-0.5
MR-24-2	100.00	87.03	68.91	51.94	35.95	17.10	4.03	0.29	0.3	2.7	8.7	2.8-3.1
MR-25-1	100.00	86.20	69.03	56.70	47.67	26.94	4.70	2.27	1.5	4.0	5.6	0.0-0.5
MR-25-2	100.00	93.07	79.55	60.91	42.80	18.92	4.26	0.51	0.3	2.4	5.6	5.9-6.2
MR-25-4	100.00	92.64	83.79	76.75	68.12	44.24	9.02	1.23	2.5	2.2	5.6	10.9-11.2
MR-26-1	100.00	95.07	91.60	87.32	74.79	21.49	1.25	0.11	1.5	2.8	10.8	0.0-0.5
MR-26-2	100.00	94.40	91.00	88.24	80.63	33.51	3.40	0.43	1.4	1.4	10.8	6.0-6.7
MR-26-3	100.00	71.81	41.23	33.14	27.12	18.73	3.93	0.42	−1.9	3.3	10.8	11.0-11.5
MR-27-1	100.00	53.29	31.68	25.69	21.59	14.84	5.98	1.13	−2.4	--	9.9	0.0-0.5
MR-27-2	100.00	92.68	82.79	74.02	55.04	22.70	4.18	0.71	0.9	2.1	9.9	7.0-9.0
MR-28-1	100.00	100.00	99.59	98.80	96.70	89.51	76.97	18.15	3.3	1.3	10.5	0.0-0.5
MR-28-2	100.00	98.95	97.28	92.76	80.46	41.14	7.15	0.83	1.6	1.6	10.5	6.3-8.3
MR-28-3	100.00	79.34	58.91	45.63	31.94	11.32	2.35	0.34	−0.8	1.7	10.5	11.3-11.5
MR-30-2	100.00	86.31	76.02	66.58	50.75	13.54	3.43	0.56	0.7	2.5	13.8	3.0-4.0
MR-30-3	100.00	96.43	75.26	54.90	34.76	9.67	1.98	0.26	0.0	2.2	13.8	8.0-8.3

TABLE F.—*State of Ohio Department of Highways aggregate specifications*[1]

Section 703.02: Aggregate for Portland Cement Concrete

1. *General.* The fine aggregate shall be natural or manufactured sand composed of clean, hard, durable, uncoated particles of stone, well graded from coarse to fine, with the coarse particles predominating, free from lumps of clay and all organic matter.

2. *Grading (U.S. Standard Sieve Series).* The sand shall be well graded from coarse to fine and when tested by means of laboratory sieves shall conform to the following grading:

Sieve No.	*Total Percent Passing* Natural	Manufactured
⅜"	100	
No. 4	95-100	100
No. 8	70-95	90-100
No. 16	45-80	50-75
No. 30	25-60	30-60
No. 50	10-30	14-30
No. 100	1-10	4-12
No. 200	0-4	0-5

Section 703.03: Fine Aggregate for Mortar and Grout

1. *General.* The fine aggregate shall be either a natural or manufactured sand and shall be composed of clean, hard, durable, uncoated particles of stone, and free from lumps of clay and all organic matter.

2. *Grading (U.S. Standard Sieve Series).* The sand shall be well graded from coarse to fine and when tested by means of laboratory sieves shall conform to the following grading:

Sieve No.	*Total Percent Passing* Natural or Manufactured
No. 4	100
No. 8	95-100
No. 16	85-100
No. 100	0-10
No. 200	0-4

Section 703.05: Aggregate for Asphalt Concrete, Bituminous Cold and Road Mix, and Tack, Prime and Seal Coat

1. *General.* The fine aggregate shall be natural sand or sand manufactured from stone, gravel or air-cooled slag.

2. *Grading (U.S. Standard Sieve Series).* The sand shall be well graded from coarse to fine and when tested by means of laboratory sieves shall conform to the following grading:

Sieve No.	*Total Percent Passing* Natural and Manufactured
⅜"	100
No. 4	90-100
No. 8	65-100
No. 16	40-85
No. 30	20-60
No. 50	7-40
No. 100	0-20
No. 200	0-10

Section 703.06: Sand Cover

1. *General.* The sand shall be natural sand or sand manufactured from stone or air-cooled slag.

2. *Grading.* The sand shall have the same grading as Section 703.05.

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[1]Sieve analysis from 1969 edition of "Construction and Materials Specifications."

FIGURE 2.—Map of Maumee-Toledo Dredging Corridor showing locations of borings and bottom surface deposits; base composited from figures of U.S. Lake Survey Navigation Chart 370.

FIGURE 4.—Test borings along center of Maumee-Toledo Dredging Corridor, showing profile of bottom surface and level of commercial sand and gravel deposits.

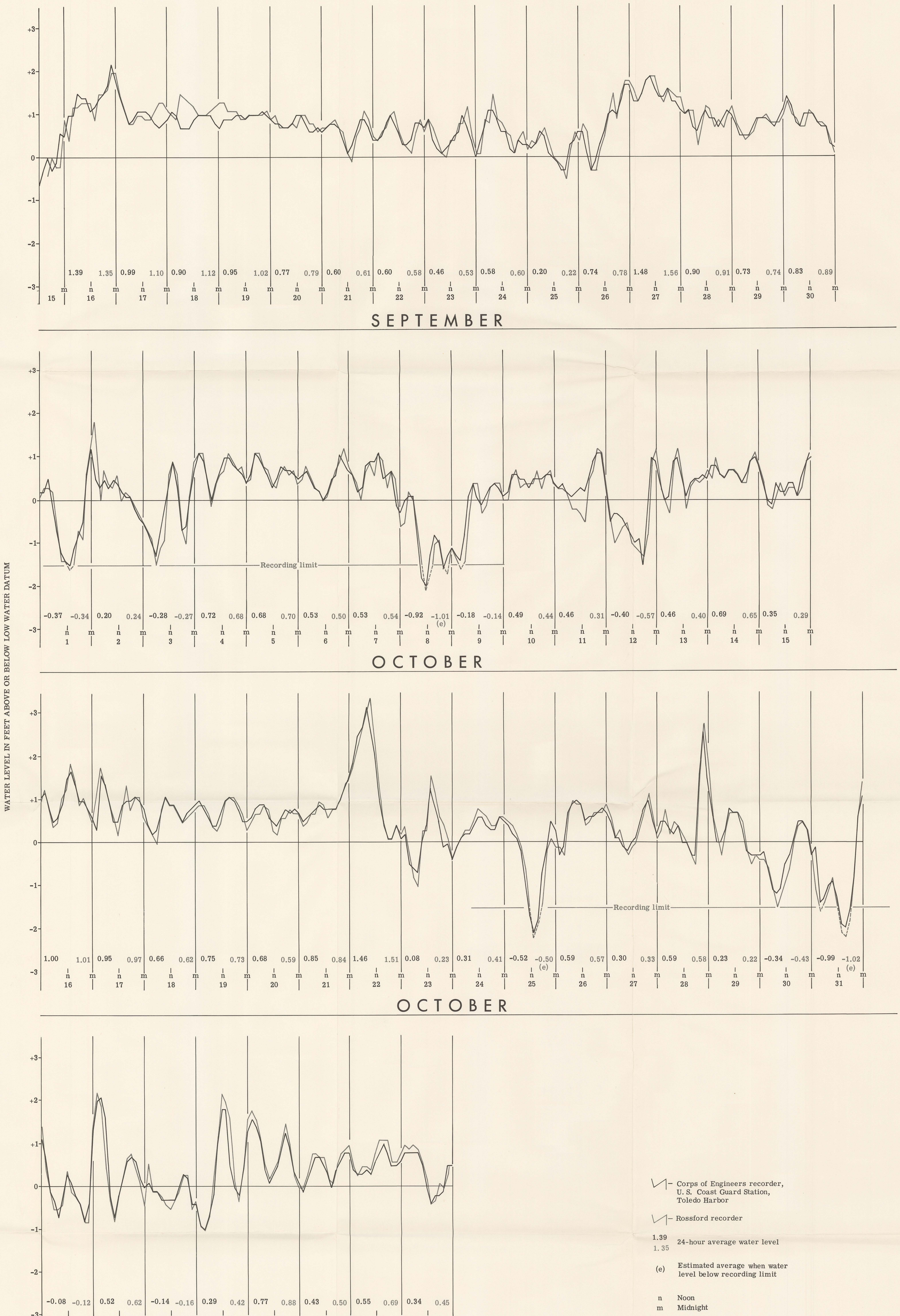

FIGURE 6.–Comparative water levels of Corps of Engineers recorder, Toledo Harbor, and Rossford recorder, 1965.