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BANK EROSION OF THE ILLINOIS RIVER

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Illinois State Water Survey

Urbana, Illinois

January, 1979

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INTRODUCTION

A 5-year study and demonstration program to determine the effects of increased Lake Michigan diversion on water quality of the Illinois Waterway and on the susceptibility of the Illinois Waterway to additional flooding is authorized in Section 166 of the Water Resources Development Act of 1976 (P.L. 94-587). It is planned during the 5-year demonstration program to increase Lake Michigan diversion from the presently authorized 3200 cfs to a maximum of 10,000 cfs.

The incremental flow may or may not have any effect on the regime of the river. In order to get a better understanding of the effects of increased flow on the hydraulics of flow and its effect on bank erosion, the U. S. Army Corps of Engineers through the Illinois Division of Water Resources has funded the Illinois State Water Survey for a study of the present bank erosion areas of the Illinois river. It is hoped that after this preliminary study is completed, some answers may be given as to the probable effects of the increased diversion on the stability or erosion of the banks of the Illinois river.

This report summarizes the objectives of this study, a description of a field trip on the river, the method of analysis, the results of the study and a program of monitoring the bank erosion areas of the Illinois River.

A proposed research project is also summarized.

Acknowledgements

This research was conducted by the authors as their regular duties at the State Water Survey under the general supervision of William C. Ackermann, Chief, Illinois State Water Survey. The U. S. Army Corps of Engineers supplied the boat and the pilot utilized to travel on the river. Sam Nakib of the Corps of Engineers accompanied the data collection crew during the field trip. Ms. Karen Kabbes and Mike Diedrichsen of the Division of Water Resources, State of Illinois helped in the collection of the field data during the boat trip. Water Survey employees Bill Bogner, Jim Gibb, Ken Smith, Keu K. Kim and Misganaw Demissie assisted in the field data collection program. Misganaw Demissie, Rose Mary Roberts and Katalin Bajor helped in the analysis of the field data. The Graphic Arts Group of the Water Survey under the supervision of John Brother prepared the illustrations.

A & H Engineering, a soil testing firm from Champaign, Illinois analyzed the grain size distribution of the bank and bed materials under a separate subcontract. Dodson - Van Wie Engineering and Surveying, Ltd of Mattoon, Illinois performed the detailed surveying at twenty selected reaches along the length of the river.

BACKGROUND

The Illinois River and its main tributaries stretch from Milwaukee in Wisconsin and South Bend in Indiana to Grafton in Illinois. It is one of the main waterways of the State of Illinois. The tributaries of this river basically drain farm lands. Figure 1 shows the drainage basin of the Illinois River. The drainage area of the Illinois River is equal to 28,906 square miles.

Physiographically, the river basin is located in the till plains section of the central United States (Fenneman, 1928). Large scale relief features are absent within the State of Illinois. There are some local features however, which effectively change the physiographic features of the basin from one location to the other.

Based on the topography of the bedrock surface, glaciations, age of the drift and other factors, the State of Illinois was divided into a number of physiographic divisions by Leighton and others (1948). These divisions indicated that the Illinois River flows through about 5 physiographic divisions. However, all these divisions are characterized by broad till plains which are in the youthful stages of erosion.

The river in its upper part above the big bend of the river near Depue has a broad flat bottom valley with steep walls. Between Depue and Peoria, the floodplains of the river are rather narrow. Downstream from Peoria, the floodplains of the river are rather wide. This is especially true for the length of the river from Pekin to Meredosia. Downstream from Meredosia, the floodplain of the river gradually narrows until it

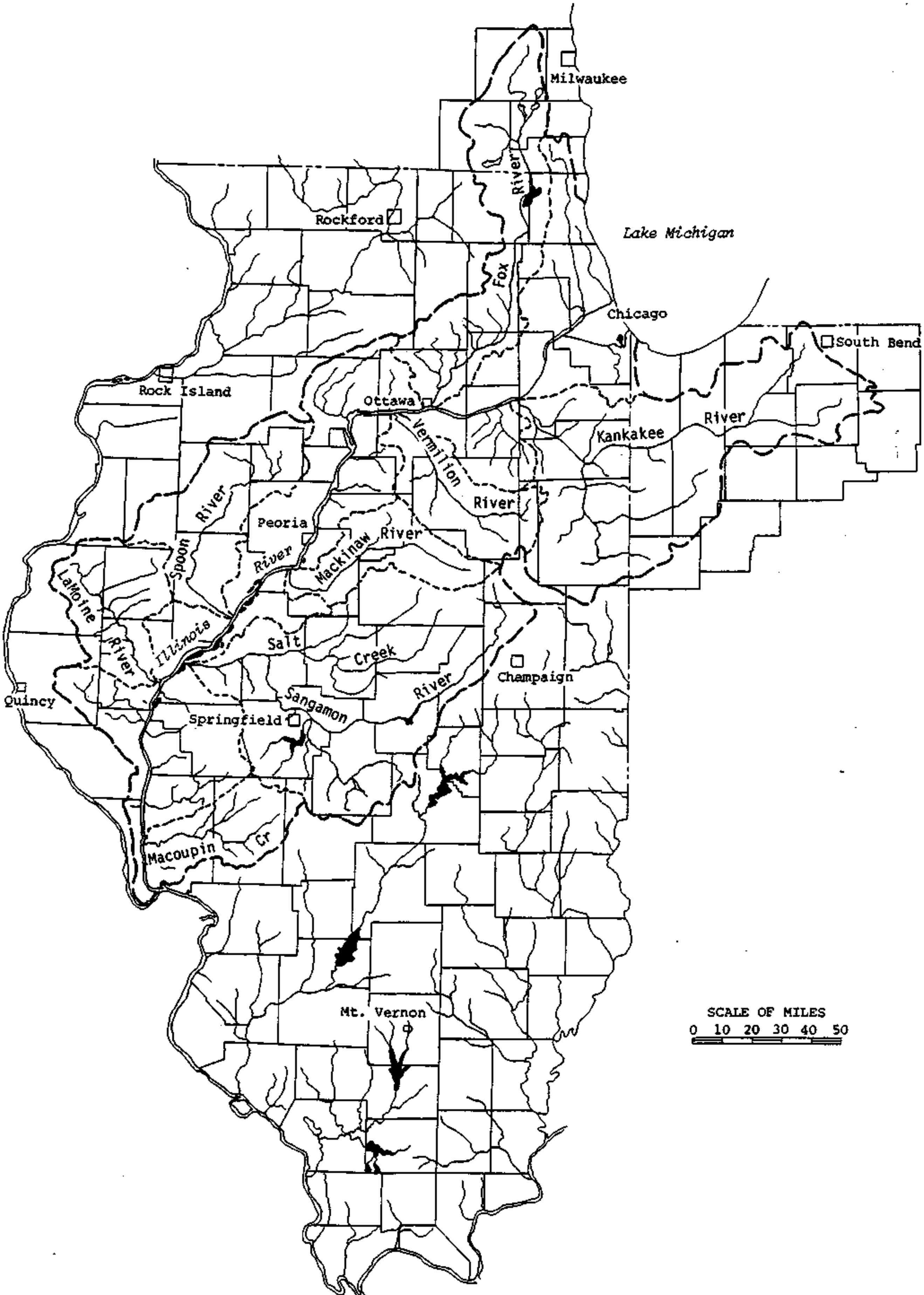


Figure 1. Drainage Basin of the Illinois River

meets with the Mississippi River near Grafton.

The Illinois River in its present form is made of a series of pools created by the eight locks and dams. The water surface profile and the average depths of flow are maintained by these locks and dams. The U.S. Army Corps of Engineers maintain a 9 foot navigational channel along the length of the river. The river, a major waterway, has carried a tremendous amount of barge traffic since the opening of the locks and dams in 1933. Presently over 40 million tons of traffic traverse the river in a year (Carlisle, 1977). Tows operating on the river may be composed of as many as 15 barges (carrying 1,500 tons each) pushed by a 5,000 horsepower tow boat. This size tow, nearly 105 feet wide and 1,200 feet long, can move at a speed in excess of 8 miles per hour with a draft of 9 feet and could move 11,000 cubic feet of water per second.

The hanks of any stream or river that flows through noncohesive or partly cohesive materials will erode unless there is natural or artificial protection. The main factors that can initiate bank erosion are: the normal flow of the river, waves generated by the wind and waterway traffic, increase in flow velocity because of passage of barge traffic, and a variety of other reasons including prop wash. It is suspected that for the Illinois River waterway, the causative factors for bank erosion are either a combination of all or part of the above mentioned factors.

OBJECTIVES

The main objectives of this research project are as follows:

a. Document present bank erosion areas.

b. Develop present plan view of severely eroded bank or banks at about 20 selected reaches.

c. Make bank stability analyses for each reach.

d. Attempt to assess the effect of the increase in the Lake Michigan diversion on bank erosion.

e. Propose monitoring system to document any future changes in bank conditions.

f. Suggest future research areas that should be undertaken to better identify the causes of the bank erosion of the Illinois River.

DATA COLLECTION

A 5-day boat trip on the Illinois River was taken from July 17-21, 1978 to document the severity of bank erosion. The U.S. Army Corps of . Engineers supplied the boat and a pilot for the trip. The trip started at Joliet and ended at Pere Marquette State Park near Grafton, Illinois. Photographs of the boat are shown in Figure 2.

During the trip, severely eroded banks were photographed and soil samples from the eroded banks and the river bed were collected at intervals of 3 to 4 miles. A total of 24 river reaches were selected during the field trip for analysis and further study. Figure 3 shows the locations of these reaches. Each selected reach included only one side of the river. The data collection procedure used is described as follows.

Whenever a portion of the river bank appeared to be severly eroded, the main boat was anchored and a flat bottom metal boat was used to land

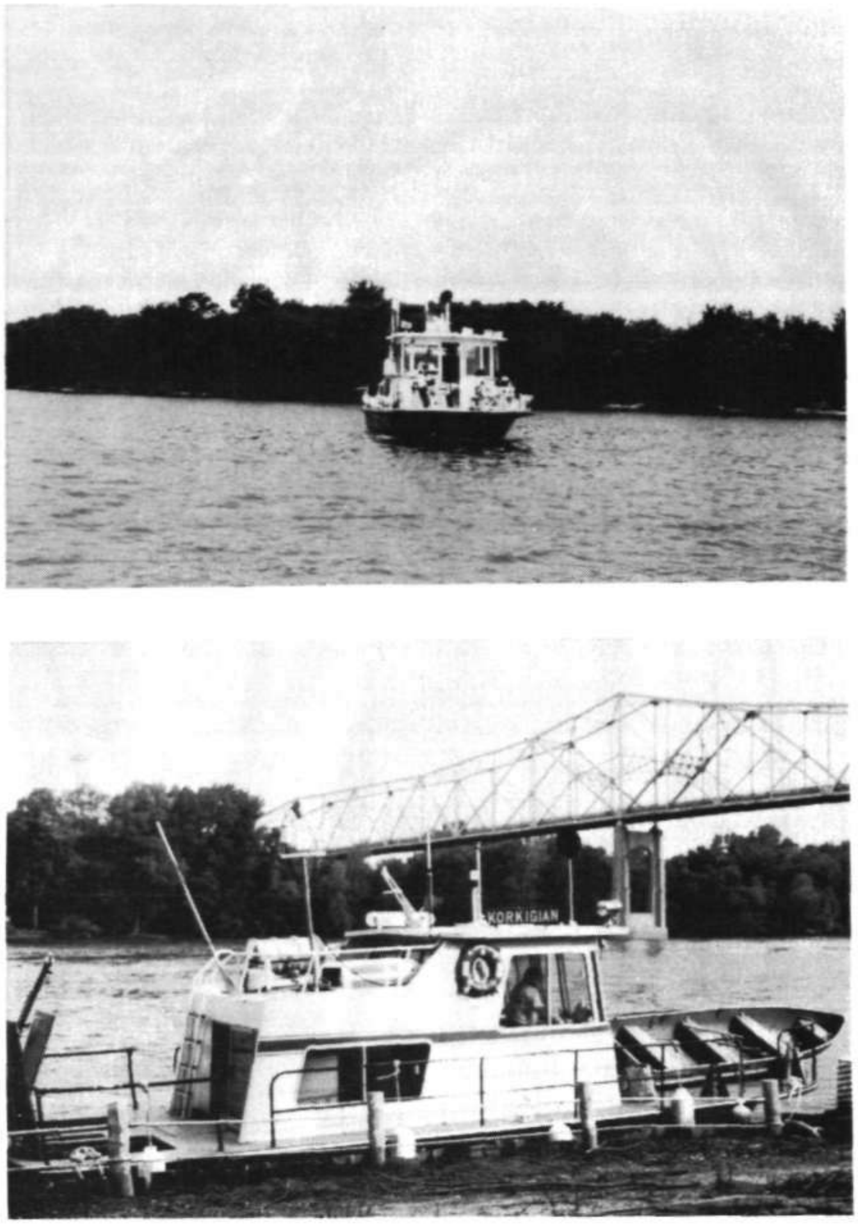


Figure 2. Photographs of the Boat used in the Data Collection

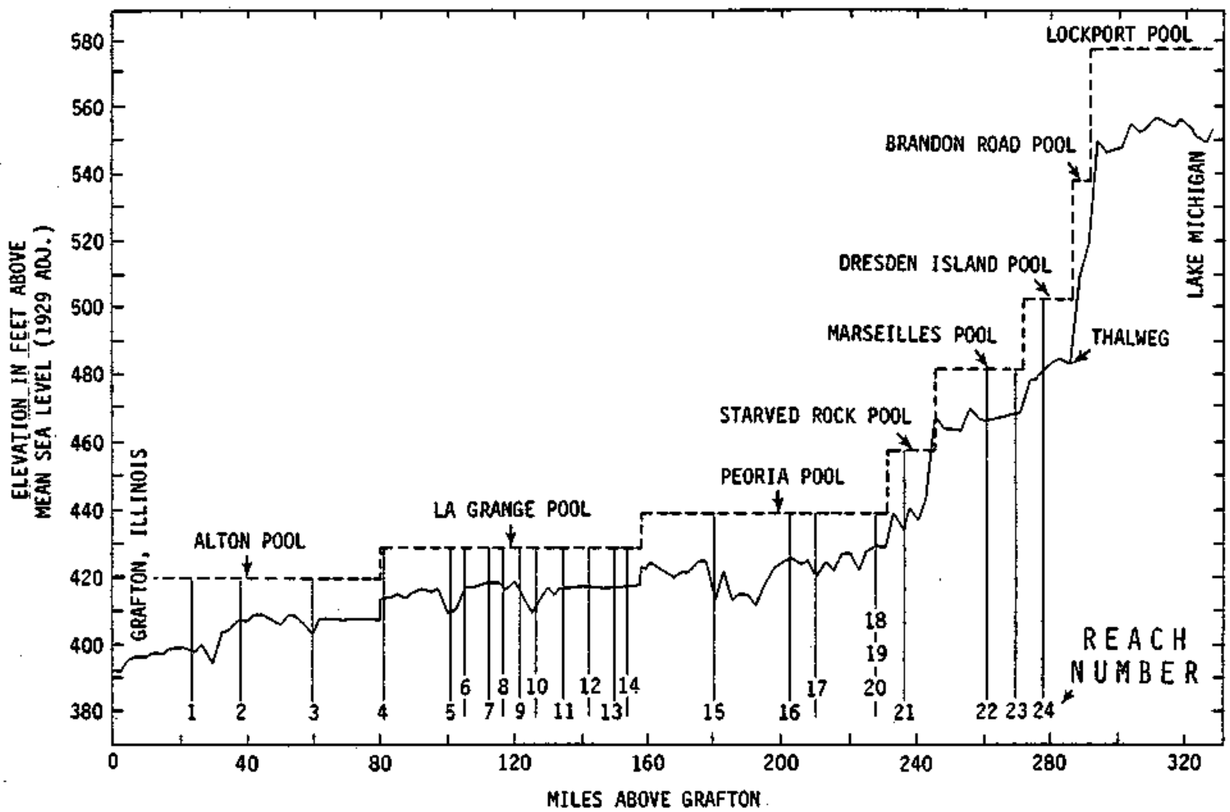


Figure 3. Profile of the Illinois River and the Location of the Reaches Selected for Further Bank Erosion Investigations.

at the site of the eroded bank. First photographs of the eroded banks were taken. A few representative areas of the banks were then selected to collect bank material samples. Photographs of banks at Reach 6 and 18 respectively are shown in Figure 4. A 2 foot by 2 foot grid with mesh points of 0.1 foot interval was placed on top of the undisturbed soil samples and a photograph was taken to show the areal distribution of the undisturbed bank materials. A photograph of the undisturbed bank is shown in Figure 5. Subsequently, the top layer of the material was scraped, bagged and brought to the office for further analysis. This procedure was repeated for each selected reach.

The bed material samples were collected using either an Ekman Dredge, a Ponar Sampler or a Shipwek sampler depending upon the condition of the flow and the effectiveness of the sampler. However, the majority of the bed material samples were collected by using the Ponar sampler. Figures 6 and 7 show the Ponar sampler and the Shipwek sampler during the sampling process. Two field personnel were needed to operate the Ponar and the Shipwek samplers. Figure 8 shows locations where bank and bed material samples were collected.

During the course of this boat trip, no other field data were collected. Hydraulic and flow data that were needed for further analysis, were either obtained from the Chicago District Office of the U.S. Army Corps of Engineers or from the files of the U.S. Geological Survey.

The Army Corps of Engineers supplied the following data: (a) sounding data all along the Illinois River, (b) stage and discharge data for 17 locations along the Illinois River with and without increased diversion,

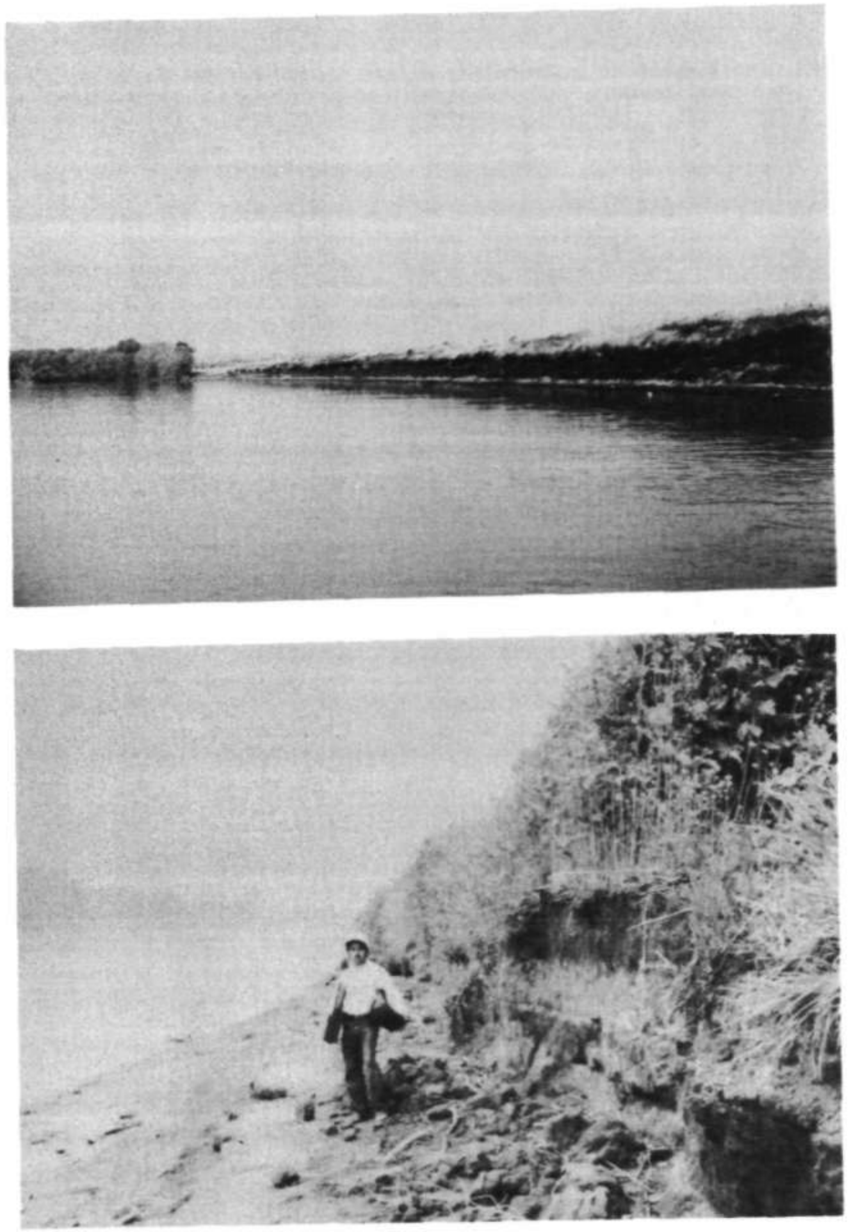


Figure 4. Photographs of Reach 6 (Top) and Reach 18 (Bottom)

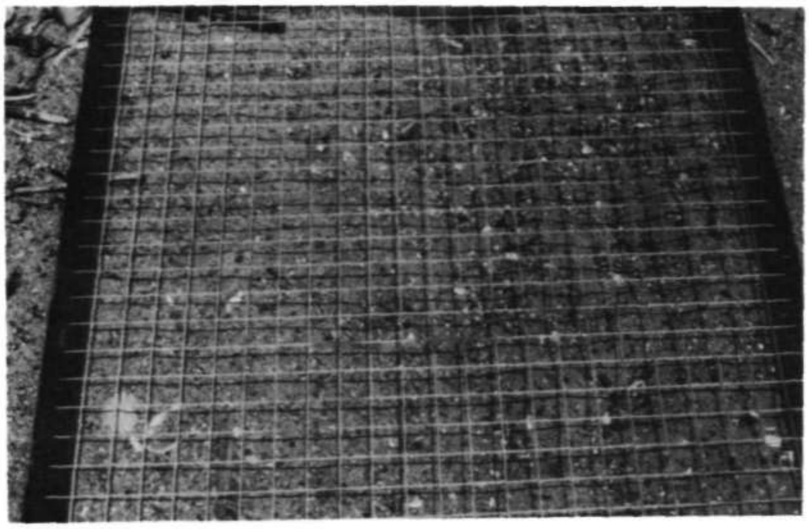


Figure 5. Undisturbed Bank Material

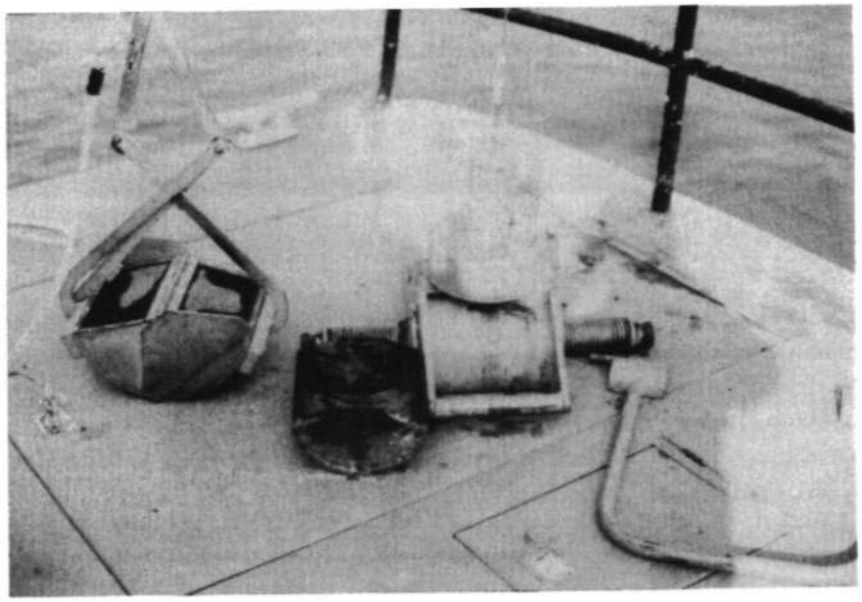


Figure 6. Photograph of the Ponar (Left) and Shipwek (Right) Samplers

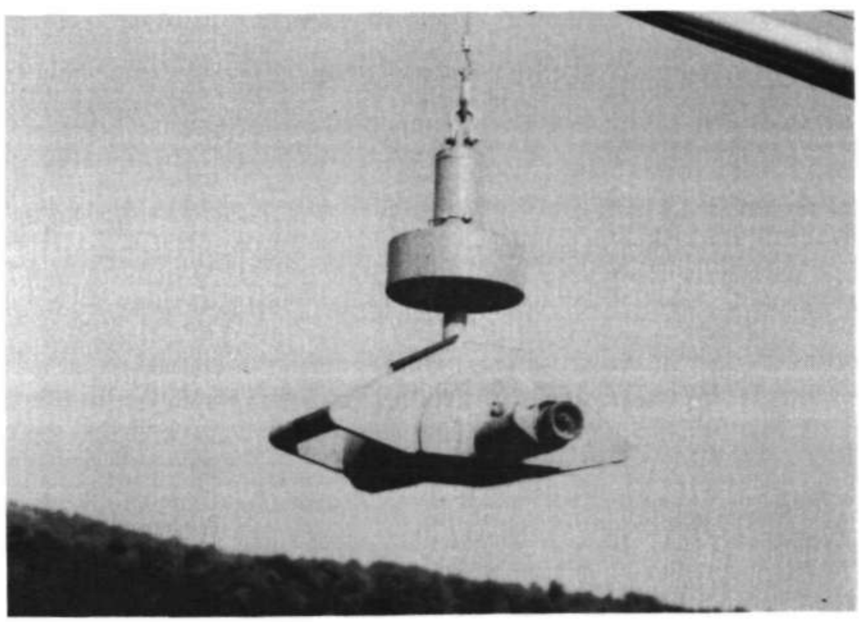


Figure 7. Photograph of the Shipwek Sampler

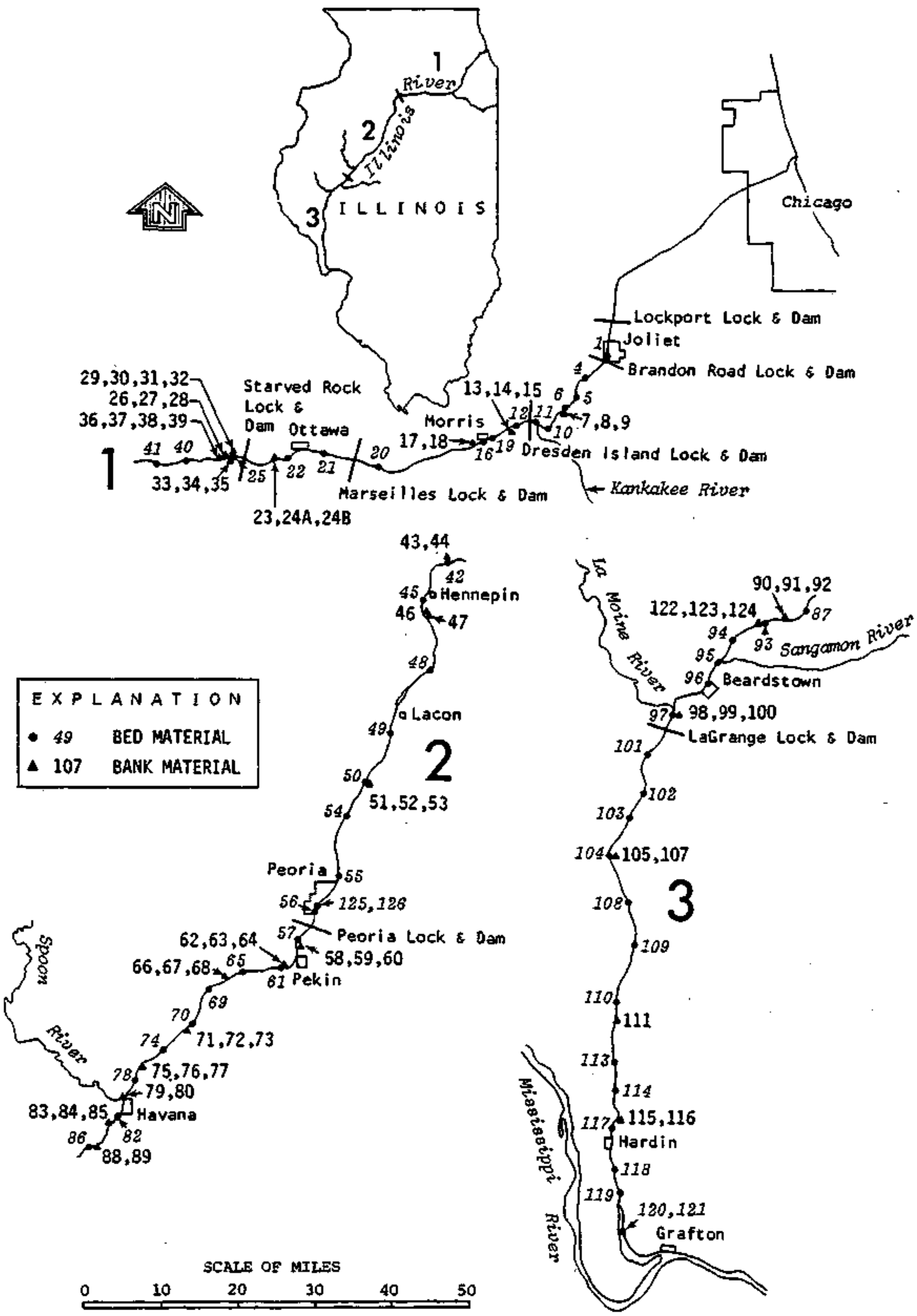


Figure 8. Locations where Bed and Bank Material Samples were Collected

and (c) geometric data along the river at about 1/3 to 5 miles intervals.

DATA ANALYSIS

Geometric and Hydraulic Characteristics of the Eroded Banks

There are numerous reaches of the river bank where erosion was present. The severely eroded reaches were marked on the "Chart of the Illinois Waterway (1974)" during the course of the boat trip. Twenty of these(Figures 9-14) reaches of the river were later selected for analysis and further investigation. Figures 9-14 were traced from the "Chart of the Illinois Waterway 1974" and show the flow direction, river mile, north direction, and active channel width. The bank of the river that was selected for detailed analysis is also shown.

After these reaches were selected, a professional surveying firm was subcontracted to conduct a detailed survey of each of the reaches to determine the plan view and the bank slopes at about 3 to 6 sections for each reach. A permanent concrete monument was installed at or near each of the reaches. Appendix A shows the methodology utilized in the surveying as submitted by the Surveying Firm. Descriptions for each of the individual monuments installed at each reach are also shown in Appendix A. Monuments will be useful in the future to facilitate surveying the change or changes in the plan view of the selected eroded banks.

Figures 15 through 25 show the plan view of the selected reaches along the Illinois River. The plan view, locations of the measured bank slope sections and direction of the flow are taken from the original plan and sectional view of the reach submitted by the sub-contractor. The

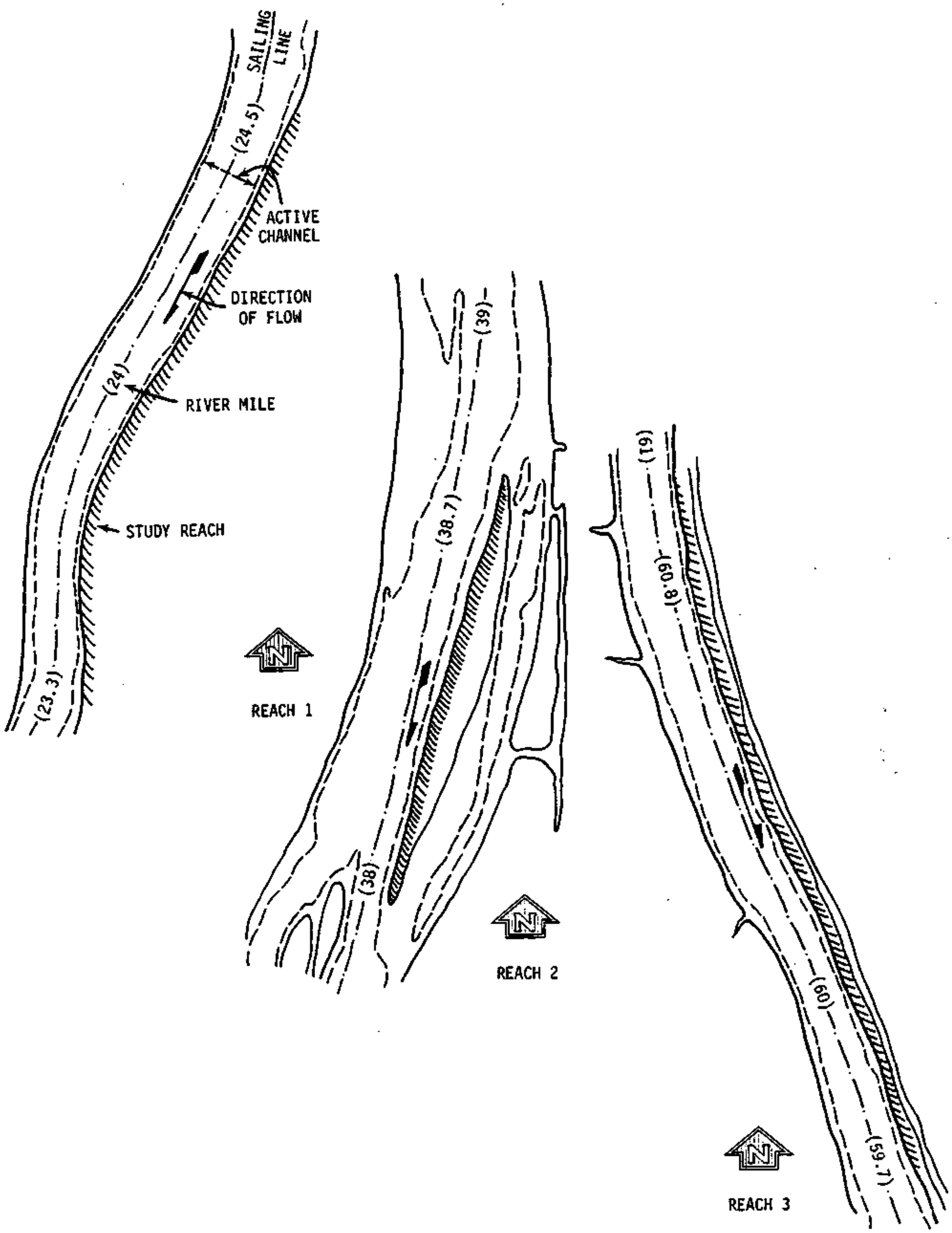


Figure 9. Reaches 1, 2 and 3 Showing the Severely Eroded Banks

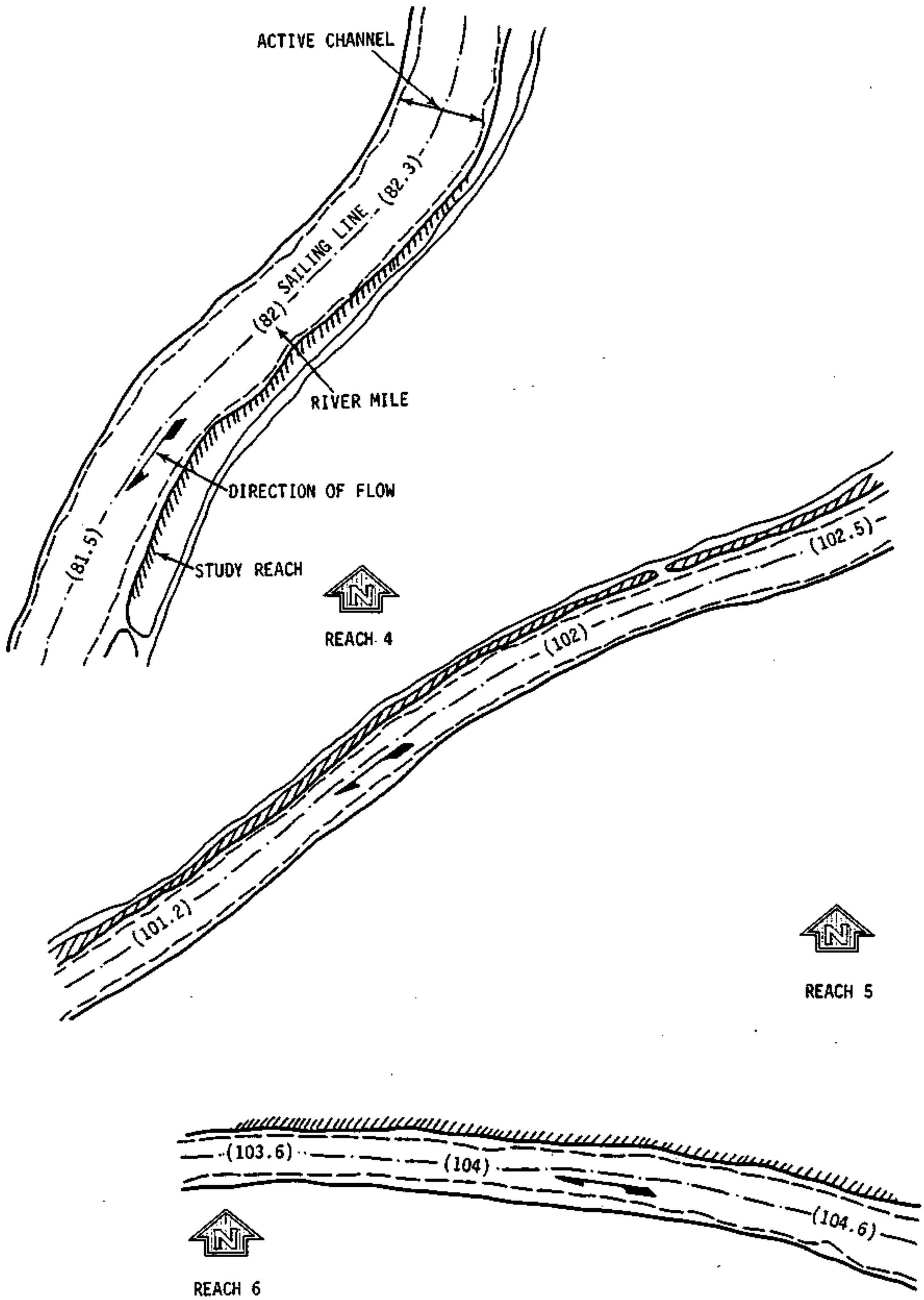


Figure 10. Reaches 4, 5 and 6 Showing the Severely Eroded Banks

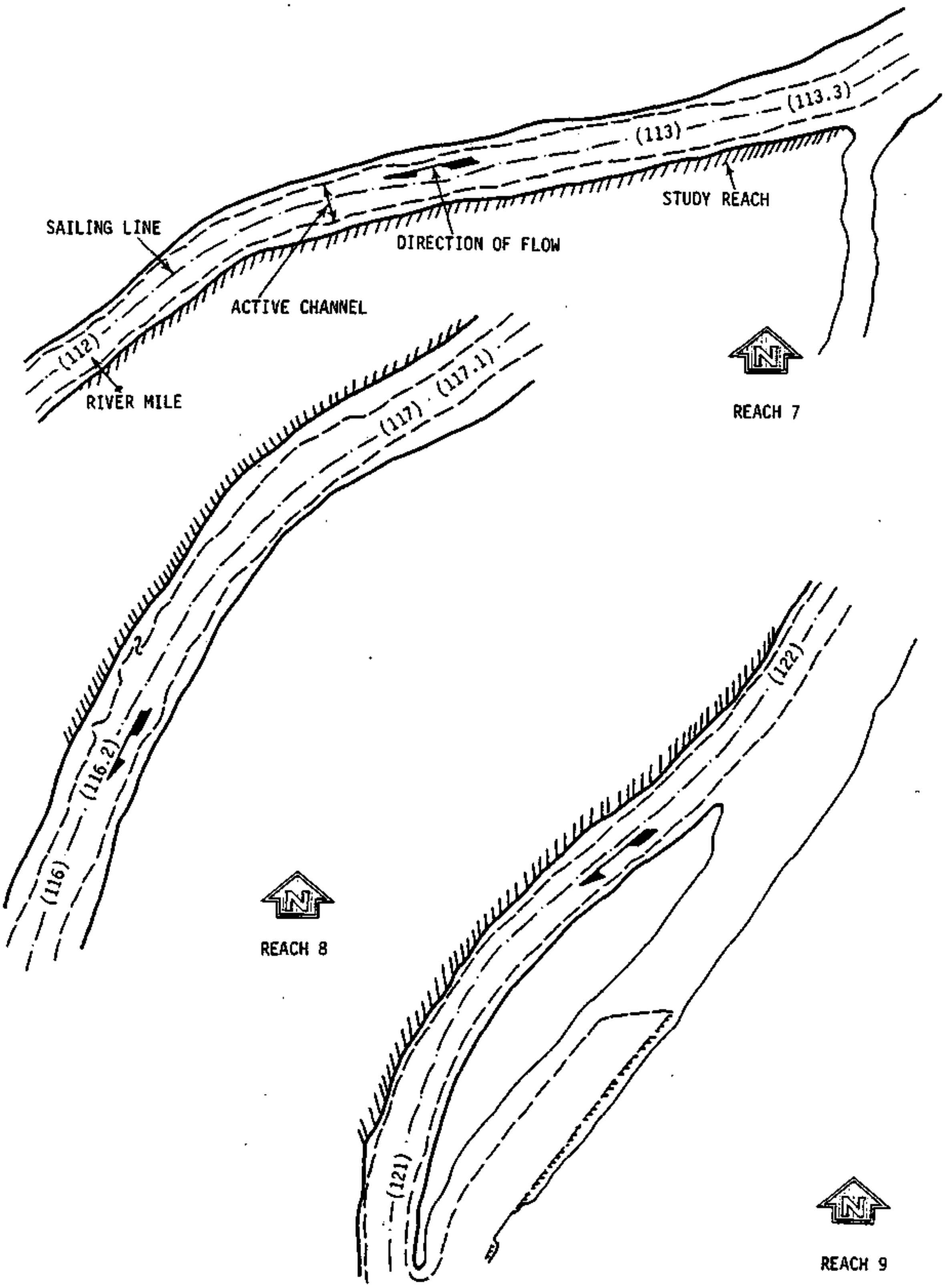


Figure 11. Reaches 7, 8 and 9 Showing the Severely Eroded Banks

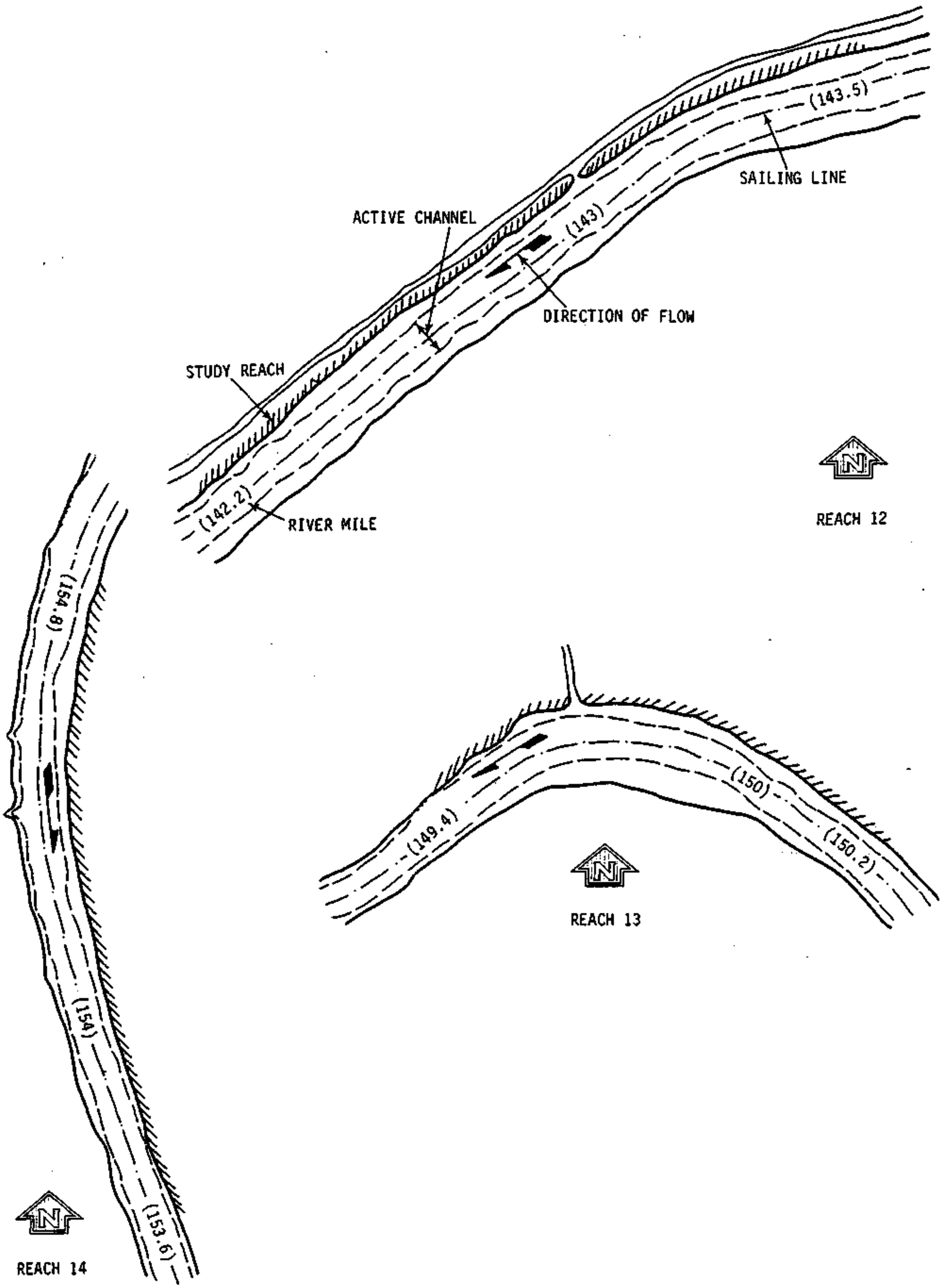


Figure 12. Reaches 12, 13 and 14 Showing the Severely Eroded Banks

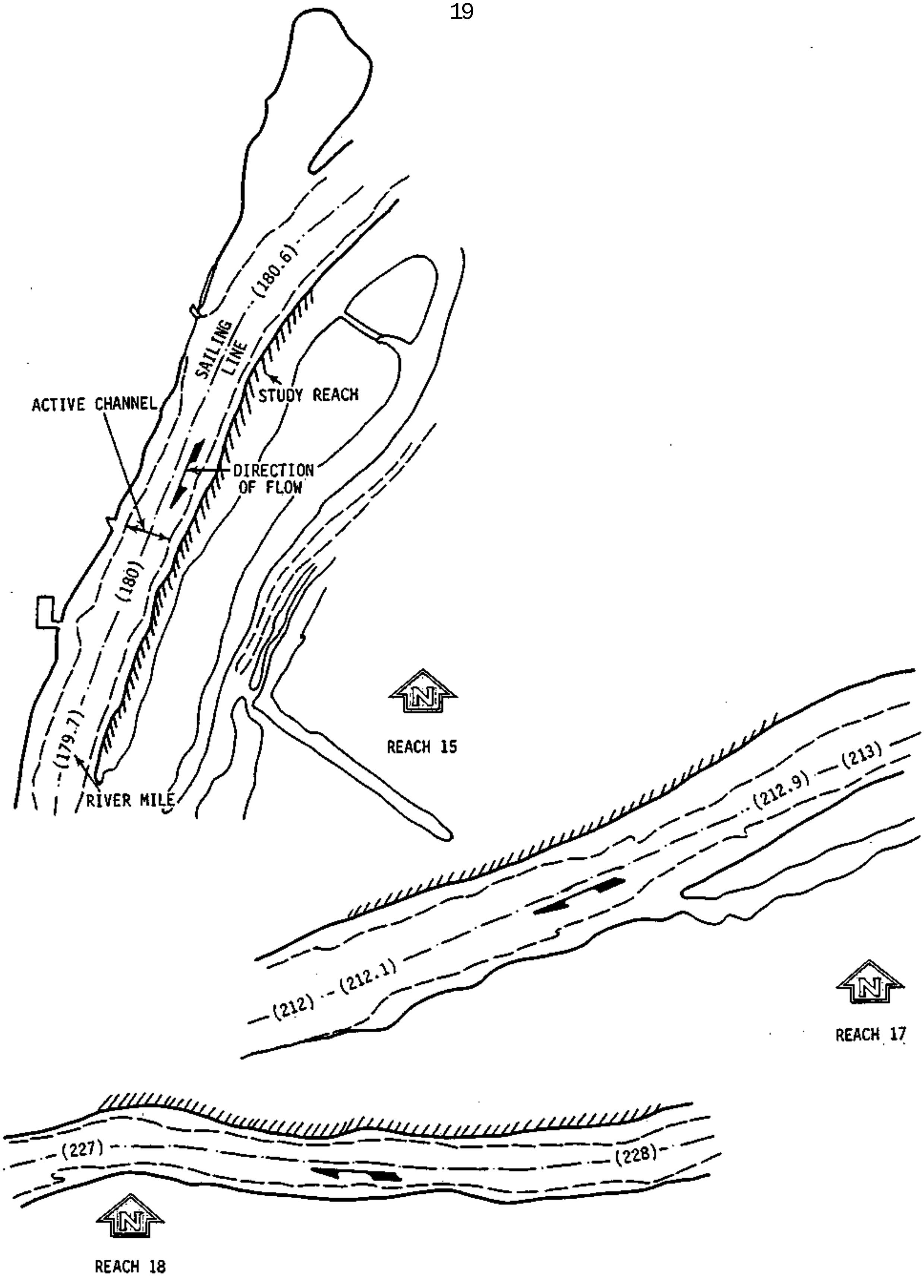


Figure 13. Reaches 15, 17 and 18 Showing the Severely Eroded Banks

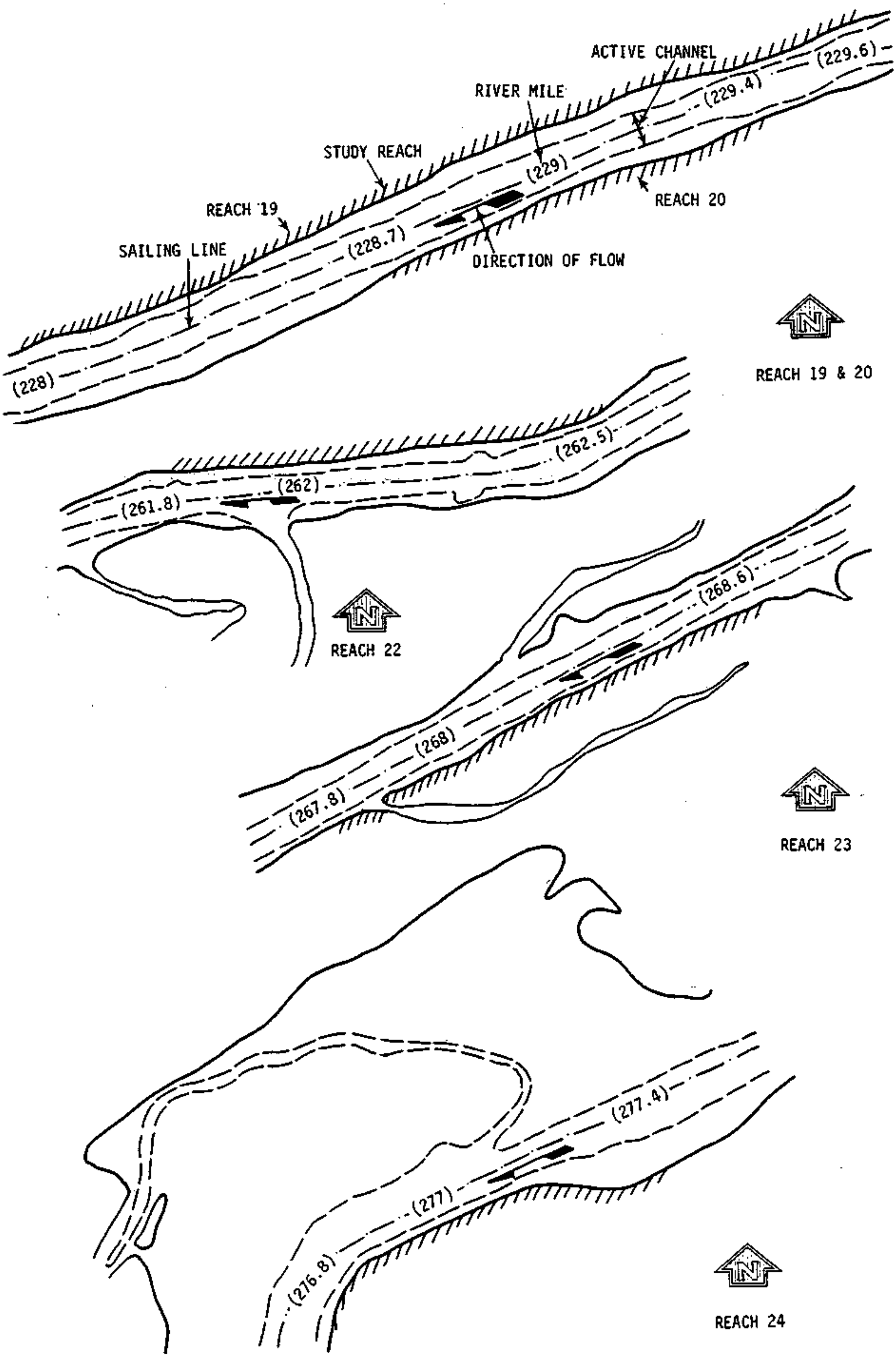


Figure 14. Reaches 19, 20, 22, 23 and 24 Showing the Severely Eroded Banks

locations where the bank material samples were collected are also shown in these figures. One set of these original drawings are included with this report for the U.S. Army Corps of Engineers use.

The upstream part of Reach 1, Figure 15, is just downstream of a bend and constitutes the outside bank of this bend. The radius of curvature, R, of this bend is equal to 4,700 feet with a deflection angle, A, equal to 41 degrees. The rest of the reach, constitutes the outside bank of another bend with reverse characteristics. For the second bend the value of R is equal to 3,100 feet and A is equal to 37.5 degrees. Close to River Mile 24, near the upstream part of the reach, the high velocity flow stayed close to the eroded bank and may be partially responsible for the erosion of the bank at this location. The deflection angle, A in degrees of a bend is defined as the included angle between the centerlines of the upstream and downstream reaches of the bend.

Reach 2, shown in Figure 16, is located on a straight portion of the river and constitutes the one side of a low lying island.

Reach 3, also shown in Figure 16, is along a straight portion of the river just downstream of a bend with a long radius of curvature and small deflection angle.

The upstream part of Reach 4, Figure 17, constitutes the outside downstream bank of a bend with radius of curvature of 3,200 feet and A equal to 67 degrees. The downstream part of the reach constitutes the inside bank of a bend with R equal to 4,800 feet and A equal to 41 degrees. The high velocity flow and the sailing line stays close to this bank especially near the upstream part of the reach.

Reach 5 also shown in Figure 17 is the outside bank of a bend with

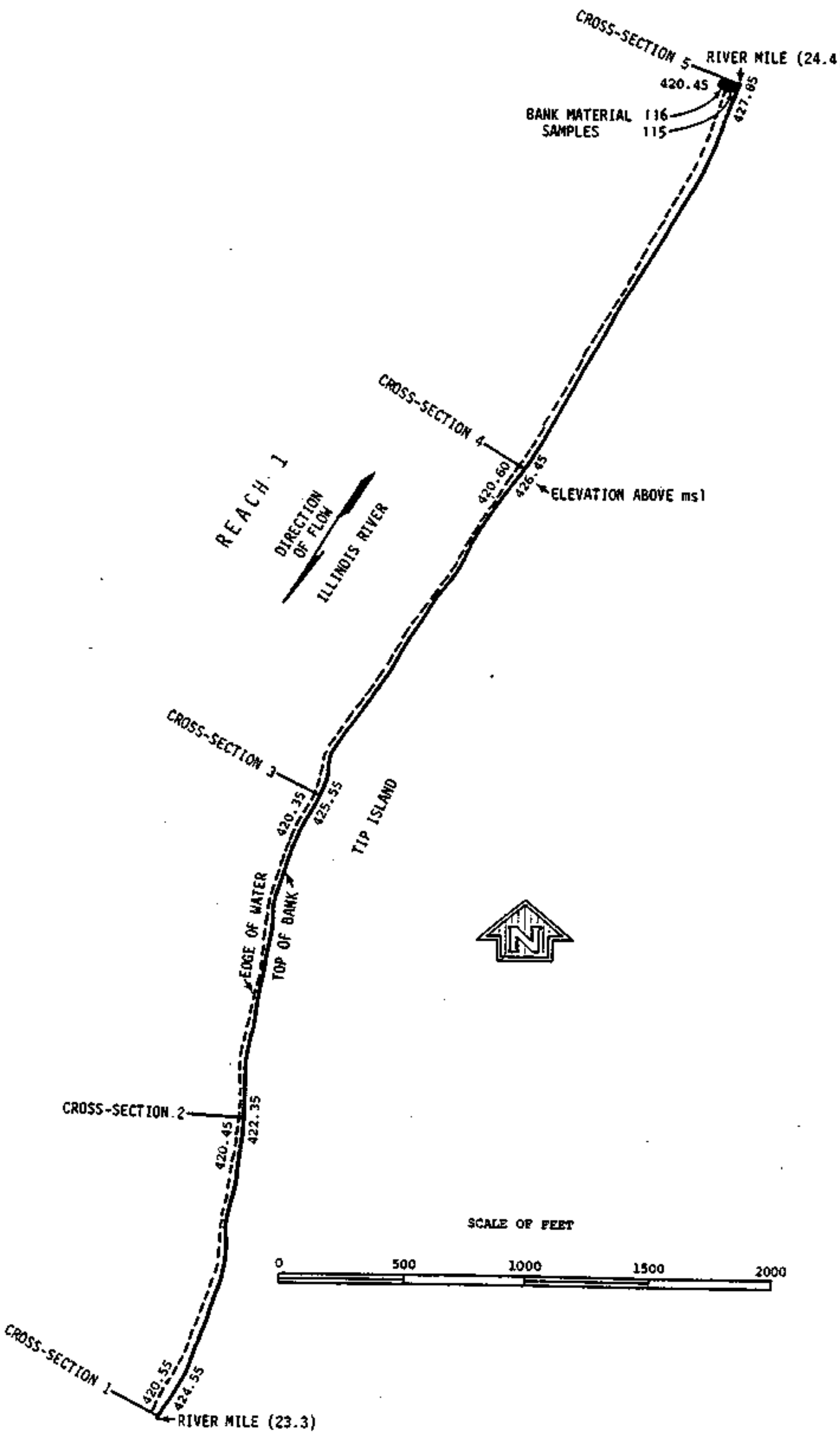


Figure 15. Plan View of Reach 1

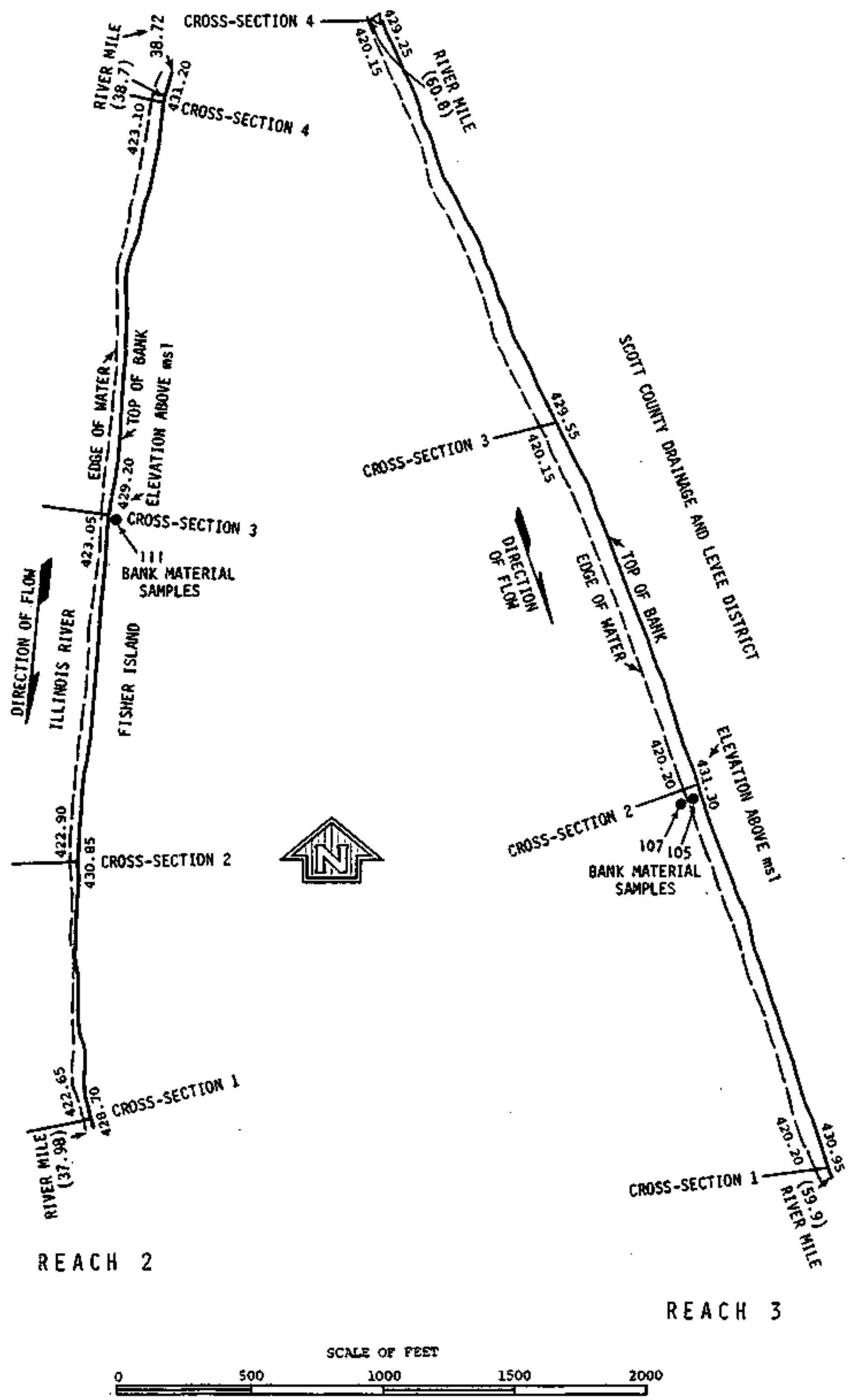


Figure 16. Plan View of Reaches 2 and 3

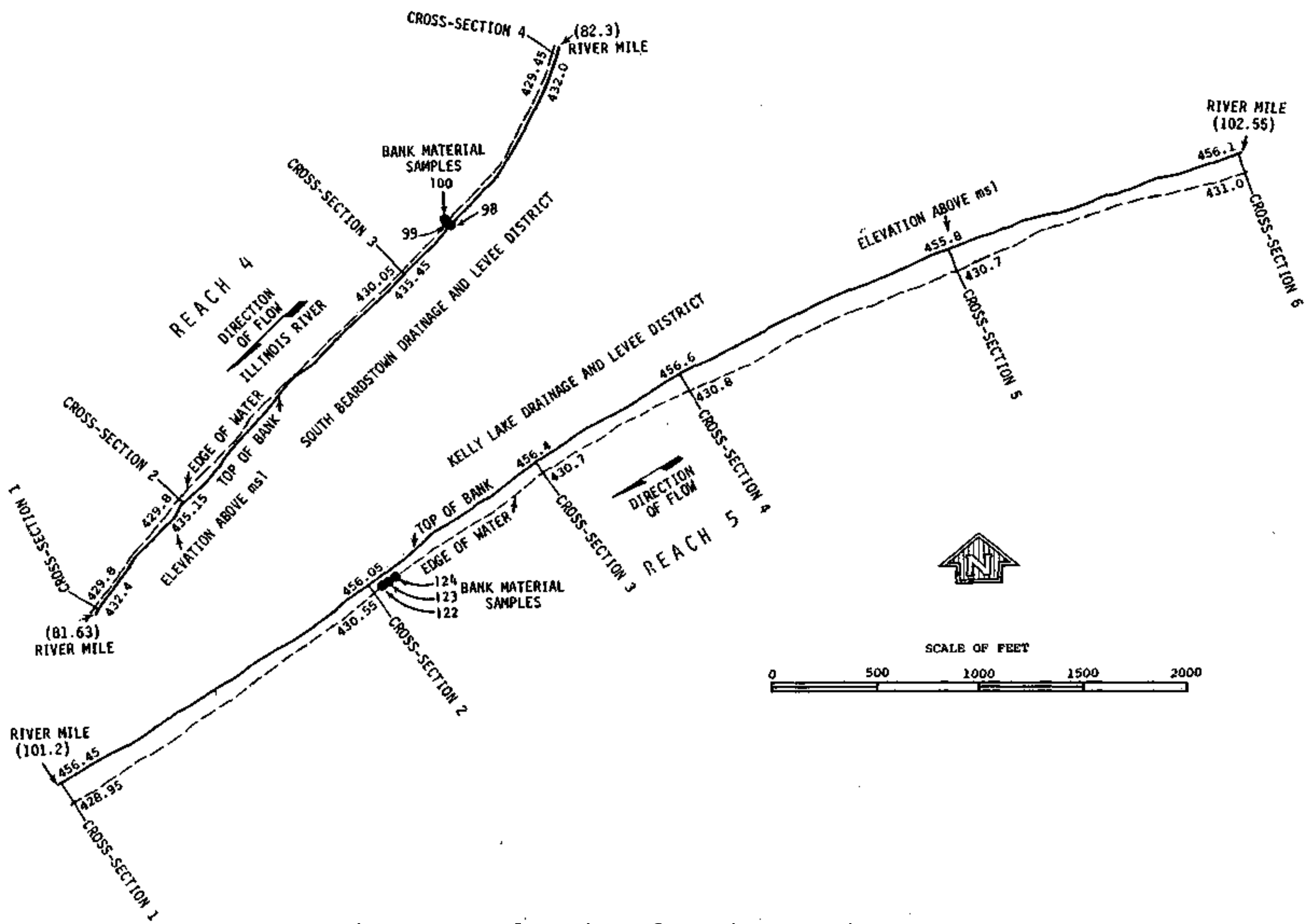


Figure 17. Plan View of Reaches 4 and 5

R equal to 13,000 feet and Δ equal to 22.5 degrees. This is an extremely flat bend at a point where the river is relatively narrow.

Reach 6 (Figure 18) is located outside of an extremely flat bend with a long radius. For all practical purposes, this reach can be assumed to be a straight reach. Here the river is relatively narrow and the sailing line is close to the eroded bank.

Reach 7 shown in Figure 18 is the outside downstream bank of a bend. The lower part of this reach forms the inside bank of the next bend. Again, the river is narrower at this location.

Reach 8 shown in Figure 19 is the outside bank of a bend with R equal to 7,500 feet and A equal to 44 degrees. This is a rather sharp bend where the effect of the bend on the flow hydraulics may be a prime factor in the erosion of this bank.

Reach 9 shown in Figure 19 is also the outside bank of a bend with R equal to 4,900 feet and A equal to 55.5 degrees. The sailing line for this location is rather close to this bank.

Reach 12 shown in Figure 20 is the outside bank of a very flat bend with R equal to 19,000 feet and A equal to 23 degrees. This reach can be assumed to be a straight reach.

On the other hand Reach 13, which is also shown in Figure 20 is the outside bank of a very sharp bend with R equal to 2,500 feet and A equal to 97 degrees. The bank erosion at this location is being accelerated because of the effects of the bend on flow characteristics and possibly because of the ihcreasedwave activity caused by the barge traffic around such a sharp bend.

Reach 14 shown in Figure 21 constitutes the inside bank just down-

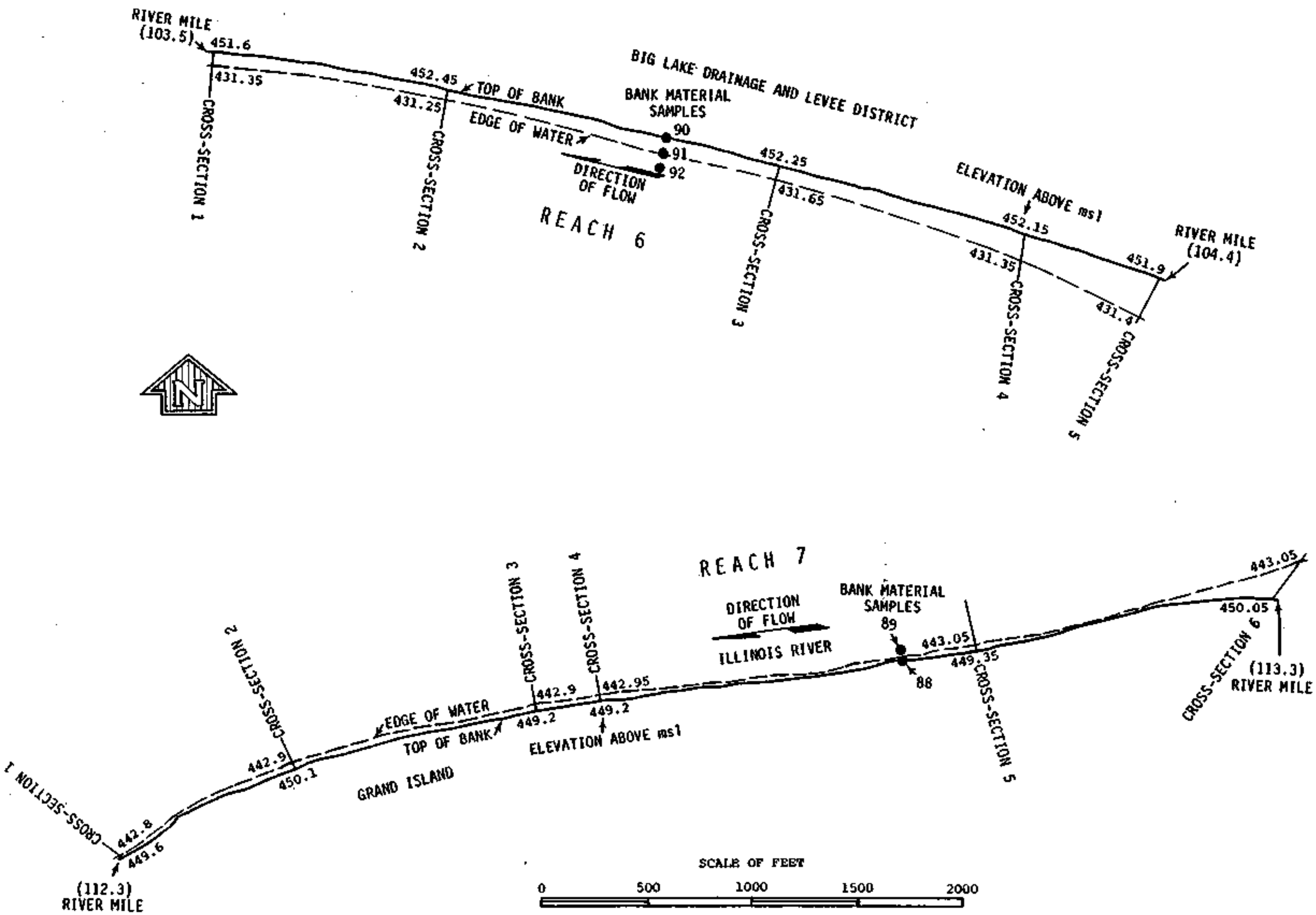


Figure 18. Plan View of Reaches 6 and 7

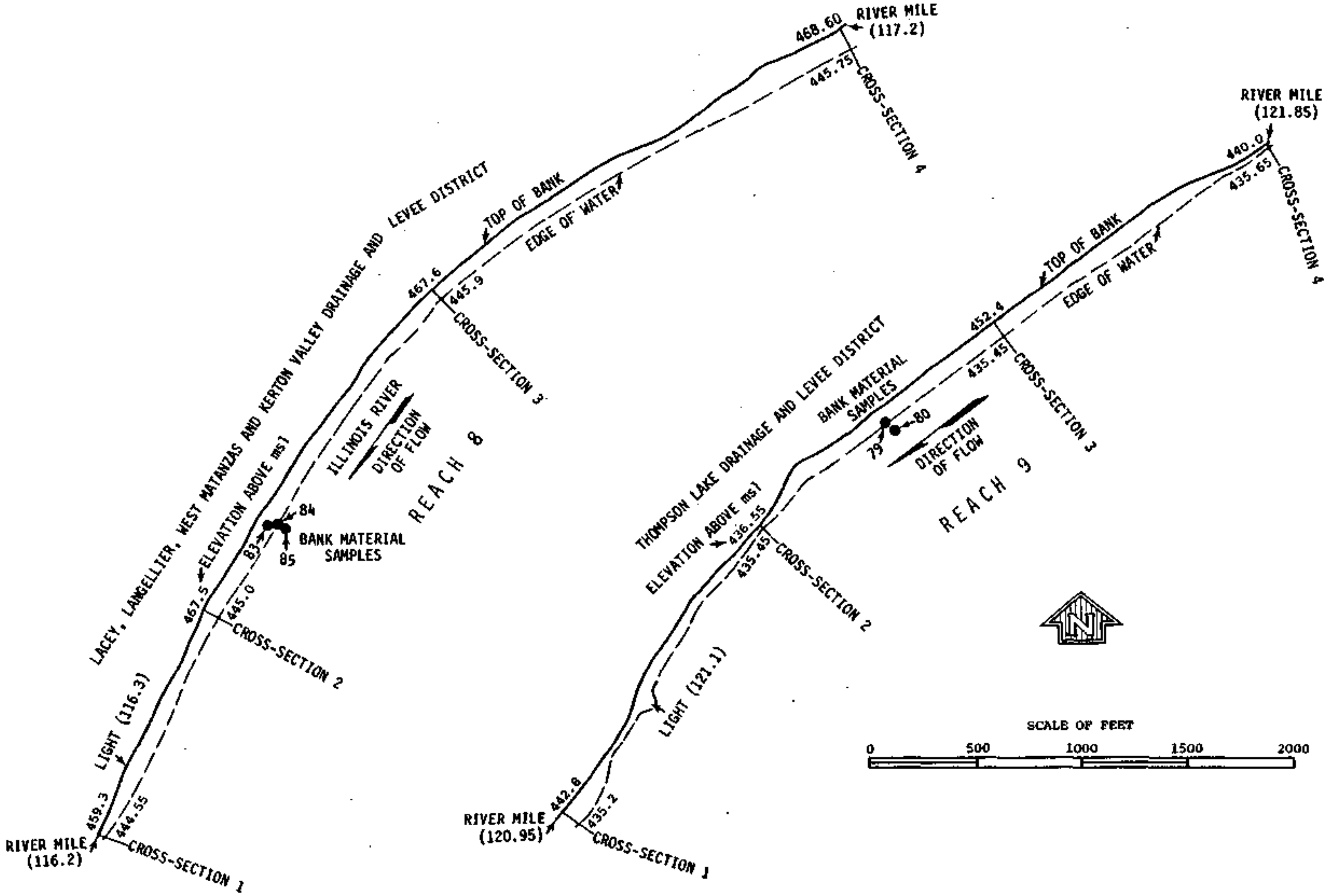


Figure 19. , Plan View of Reaches 8 and 9

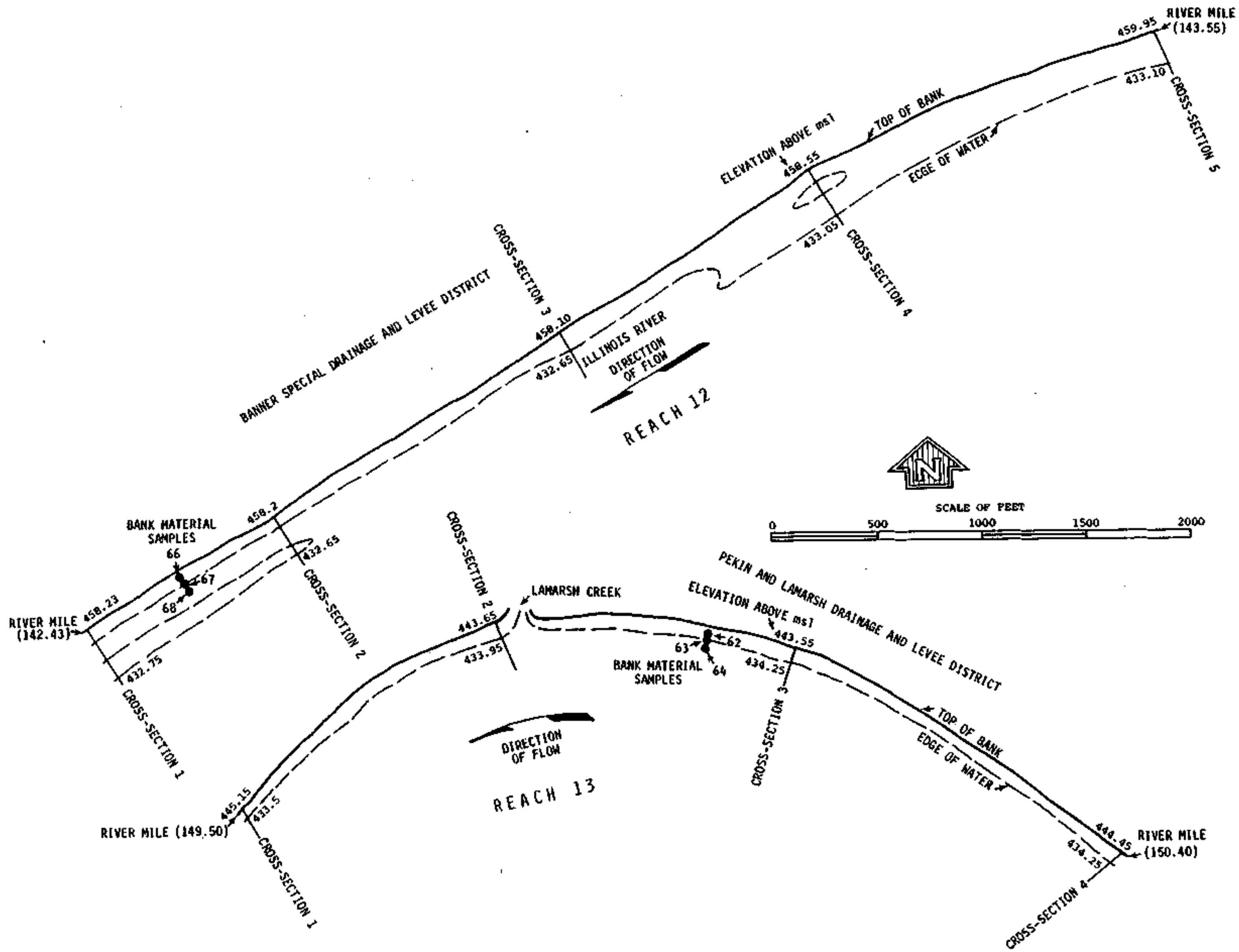


Figure 20. Plan View of Reaches 12 and 13

stream of a bend with R equal to 8,400 feet and Δ equal to 43 degrees. The bank erosion at this location is possibly because of the barge traffic and wind wave action.

Reach 15 shown in Figure 21 is the left bank just upstream of the Peoria Lake. This reach can be considered to be a straight reach.

Reach 17 shown in Figure 22 is basically a straight reach and is on the right hand side of the river. Here the river is relatively wide and the bank erosion is probably due to the wave action.

Reach 18 shown in Figure 22, Reaches 19 and 20 shown in Figure 23 can almost be assumed to be straight reaches. There is an extremely flat bend with a very long radius of curvature just upstream of these reaches. Note that Reach 18 is located just upstream of Reach 19 and is on the same side of the river. River banks at Reaches 18 and 19 are very low and extensive erosion is present at these locations. It is suspected that the main cause of the erosion may be the wave action in the river.

Reach 22 shown in Figure 24 is the inside downstream bank of a bend with R equal to 12,000 feet and Δ equal to 30.5 degrees. Here the cause of bank erosion is probably a combination of flow velocity and wave action in the river.

Reach 23 shown in Figure 24 is at a straight segment of the river. Bank erosion is not very severe at this location. The sailing line is very close to this side of the river and possibly wave action plays an important role in the unstability of the bank.

Reach 24 shown in Figure 25 is near the confluence with the DuPage River. This reach constitutes the left bank of the river. There is a

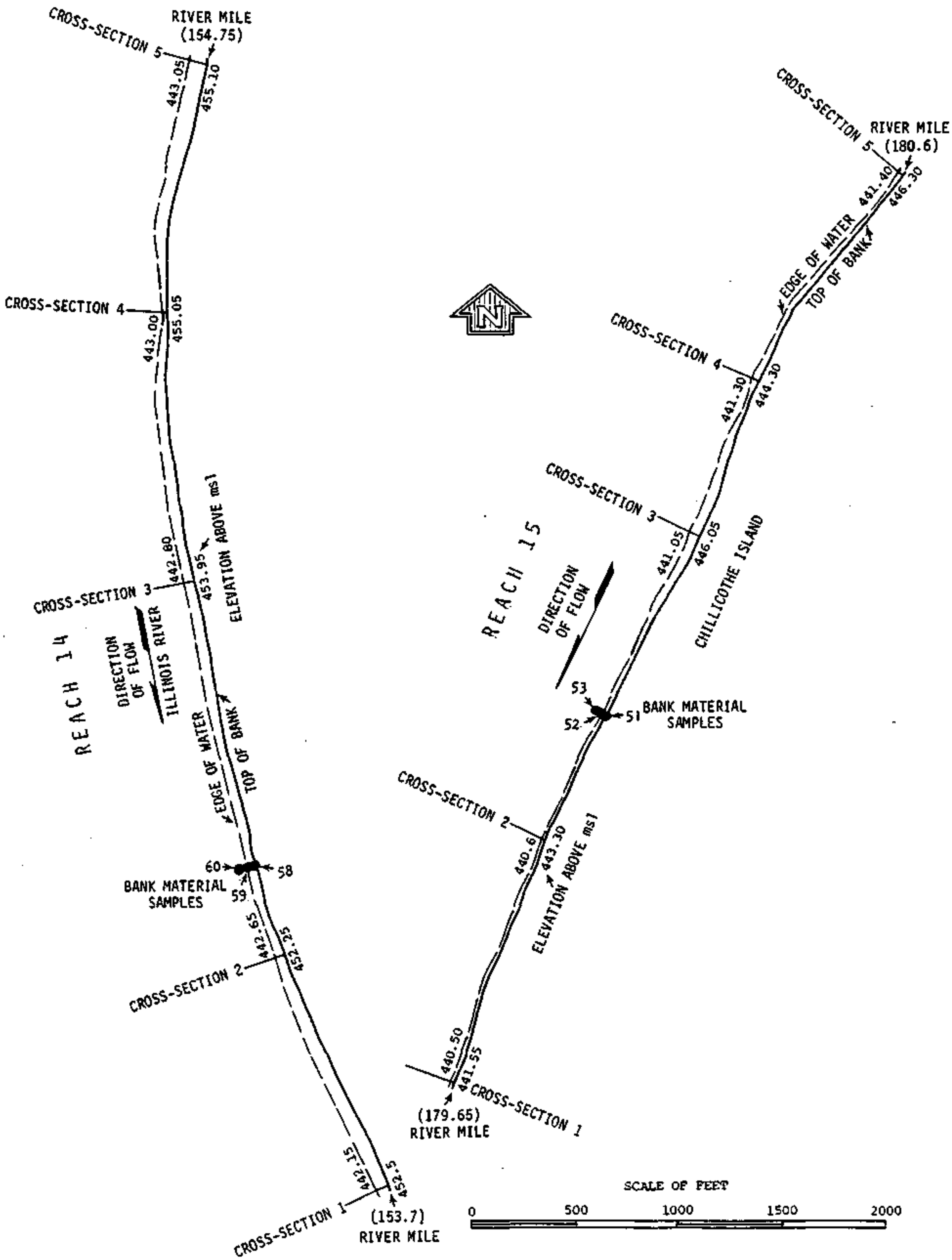


Figure 21. Plan View of Reaches 14 and 15

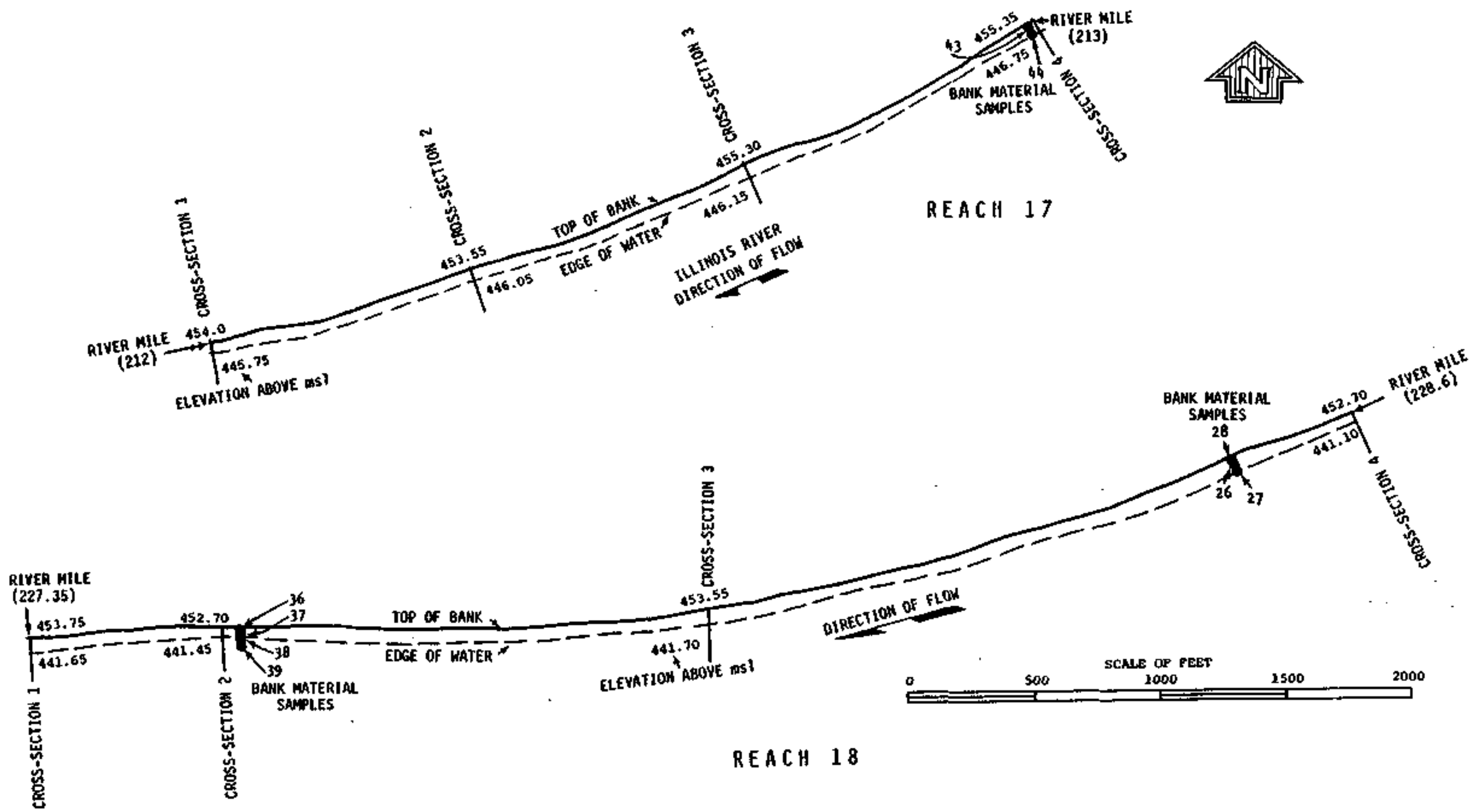


Figure 22. Plan View of Reaches 17 and 18

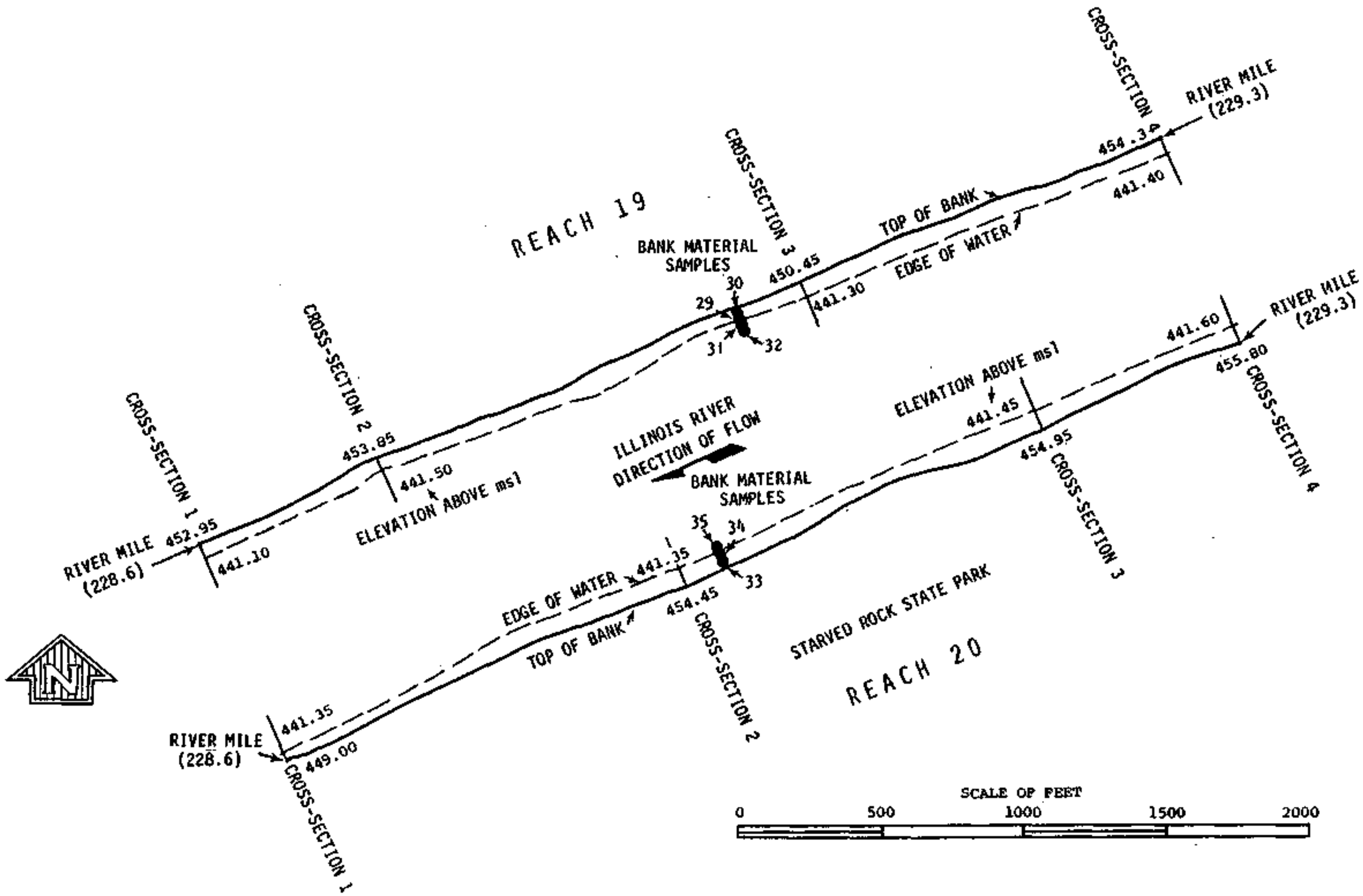


Figure 23. Plan View of Reaches 19 and 20

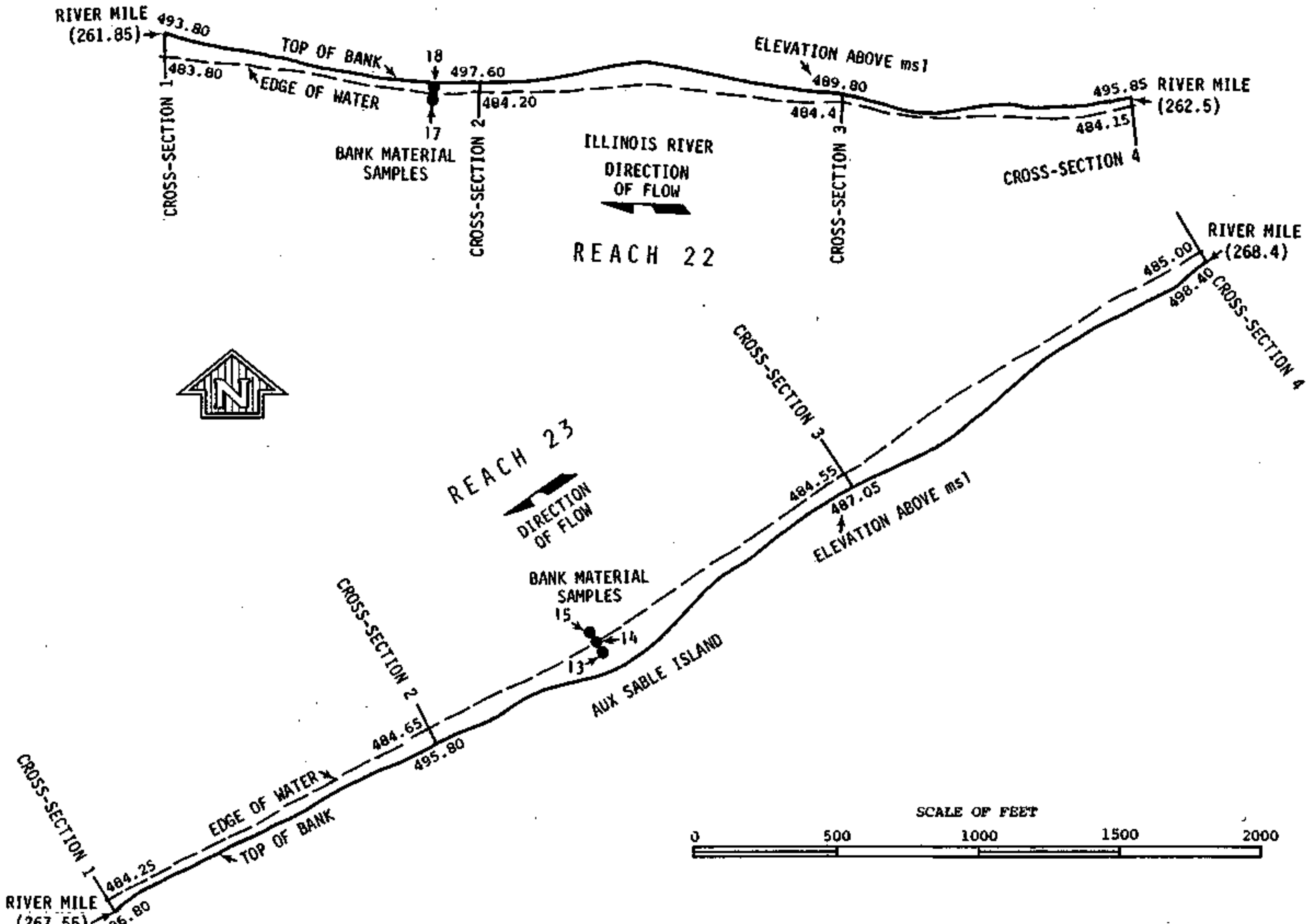


Figure 24. Plan View of Reaches 22 and 23

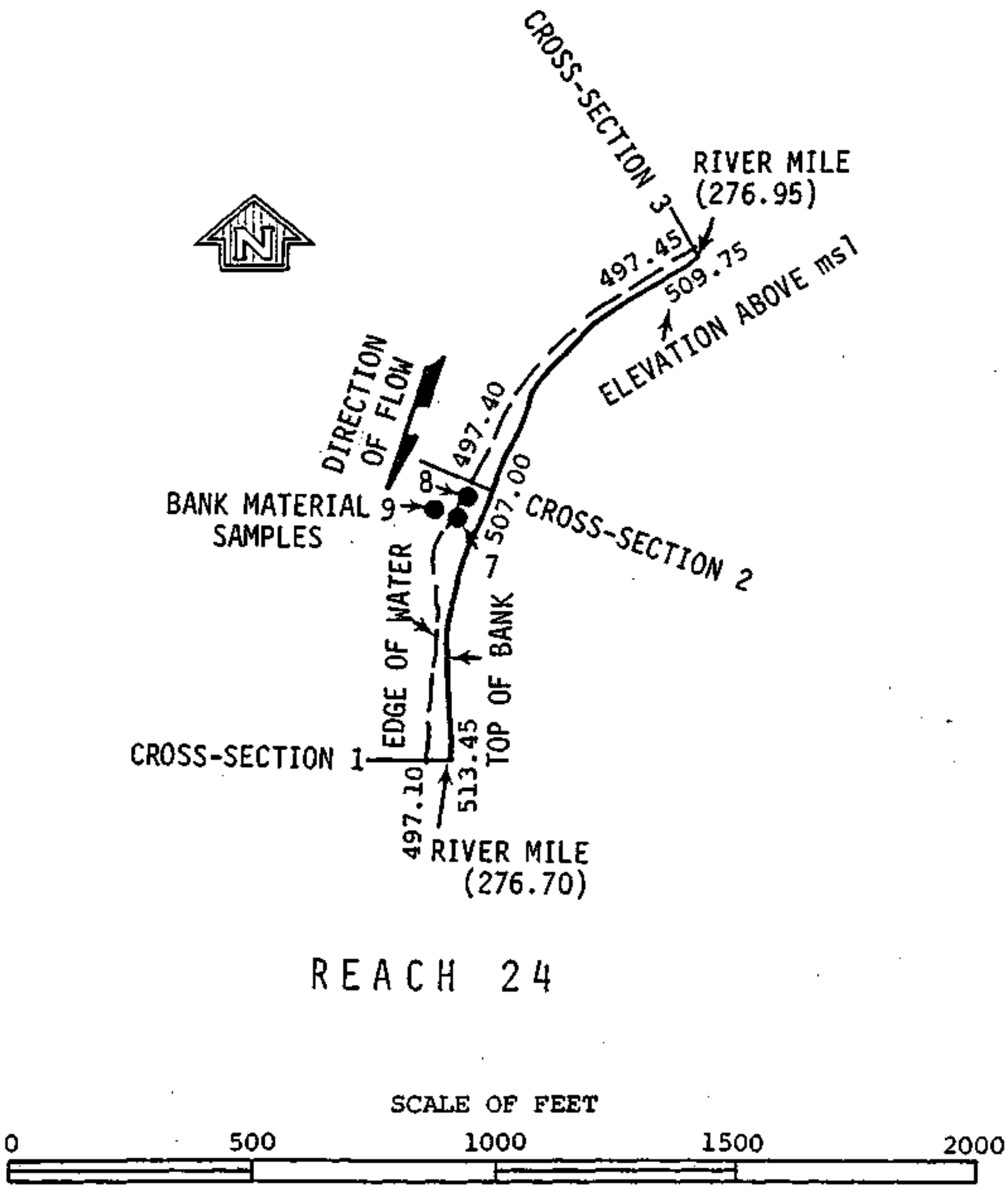


Figure 25. Plan View of Reach 24

very large rectangular shaped lake just north-west of this reach. The lake is about 1/2 miles by 1 mile in size. The sailing line is very close to this reach. Bank erosion is suspected to be caused by the wave action in the river. The geometric parameters described above are summarized in Table 1.

The reaches described above were selected to study a sample of the representative bank erosion areas along the Illinois River. There are numerous other segments of the river where bank erosion is as bad. It was not meant to be an all inclusive investigation showing all the bank erosion areas with detailed analysis. It is the contention of the researchers that an analysis of these selected reaches should shed some light as to the causative factors that contribute toward bank erosion along the Illinois River.

Bank Slope

The bank slope is an important parameter in the stability analysis of any river bank. The surveying crew determined the bank slope at each selected reach for a minimum of 3 to a maximum of 6 sections. The data were plotted individually for each reach taking the bed of the river as the datum. The plot shows the lateral displacements of the bank with each foot of drop from the top of the bank. Figures 26 and 27 show two typical plots that were developed for Reaches 3 and 14, respectively. Data from Reaches 1, 2, 3, 4, 7, 8, 9, 13, 15, 17, 18, 19, 20, and 24 indicated that a single average bank slope determined from plots similar to Figure 26 can be used as the representative bank slope for each one of these reaches. However, data analyzed from Reaches 5, 6, 12, 14, 22, and 23 indicated that either two distinct slopes do exist in the same reach

TABLE 1. Characteristics of the Selected Reaches

Reach No.	River Mile from - to	Straight or Curved	Radius of Curvature, R feet	Deflection Angle, degrees	Avg. Top Width at Bankful Stage, W feet	R/W	Bank Slope
1	23.3 - 24.4	Curved	3,100	37.5	500	6.2	1:7
1	23.3- 24.4	Curved	4,700	41.0	700	6.7	1:7
2	37.98- 38.72	Straight	-	-	900	-	1:5.5
3	59.9 - 60.8	Straight	-	-	600	-	1:6.5
4	81.63- 82.3	Curved	3,200	67.0	800	4.0	1:7.5
4	81.63-82.3	Curved	3,200	67.0	800	4.0	1:4
5	101.2 -102.55	Curved	13,000	22.5	420	31.0	1:2.1
5	101.2-102.55	Curved	13,000	22.5	420	31.0	1:53
6	103.5 -104.4	Straight	-	-	500	-	1:3.5
6	103.5-104.4	Straight	-	-	500	-	1:9
6	103.5 -104.4	Straight	-	-	500	-	1:18
7	112.3 -113.3	Curved	11,150	51.5	500	22.3	1:10
8	116.2-117.2	Curved	7,500	44.0	650	11.5	1:6
9	120.95-121.85	Curved	4,900	55.5	500	9.8	1:7
12	142.43-143.55	Curved	19,000	23.0	600	31.7	1 :4
12	142.43-143.55	Curved	19,000	23.0	600	31.7	1:26
13	149.5-150.4	Curved	2,500	94.0	600	4.2	1:7.5
14	153.7 -154.75	Curved	8,400	43.0	480	17.5	1:5
14	153.7-154.75	Curved	8,400	43.0	480	17.5	1:100
15	179.65-180.6	Straight	-	-	700	-	1:12.5
17	212.0-213.0	Straight	-	-	900	-	1:7
18	227.35-228.6	Straight	-	-	650	-	1:6.5
19	228.6-229.3	Straight	-	-	650	-	1:8
20	228.6-229.3	Straight	-	-	650	-	1:8
22	261.85-262.5	Curved	12,000	30.5	500	24.0	1:9
22	261.85-262.5	Curved	12,000	30.5	500	24.0	1:3.5
23	267.55-268.4	Straight	-	-	500	-	1:7.5
23	267.55-268.4	Straight	-	-	500	-	1:7.5
23	267.55-268.4	Straight	-	-	500	-	1:6
23	267.55-268.4	Straight	-	-	500	-	1:2.5
24	276.7-276.95	Curved	1,400	50.0	2400	0.6	1:5

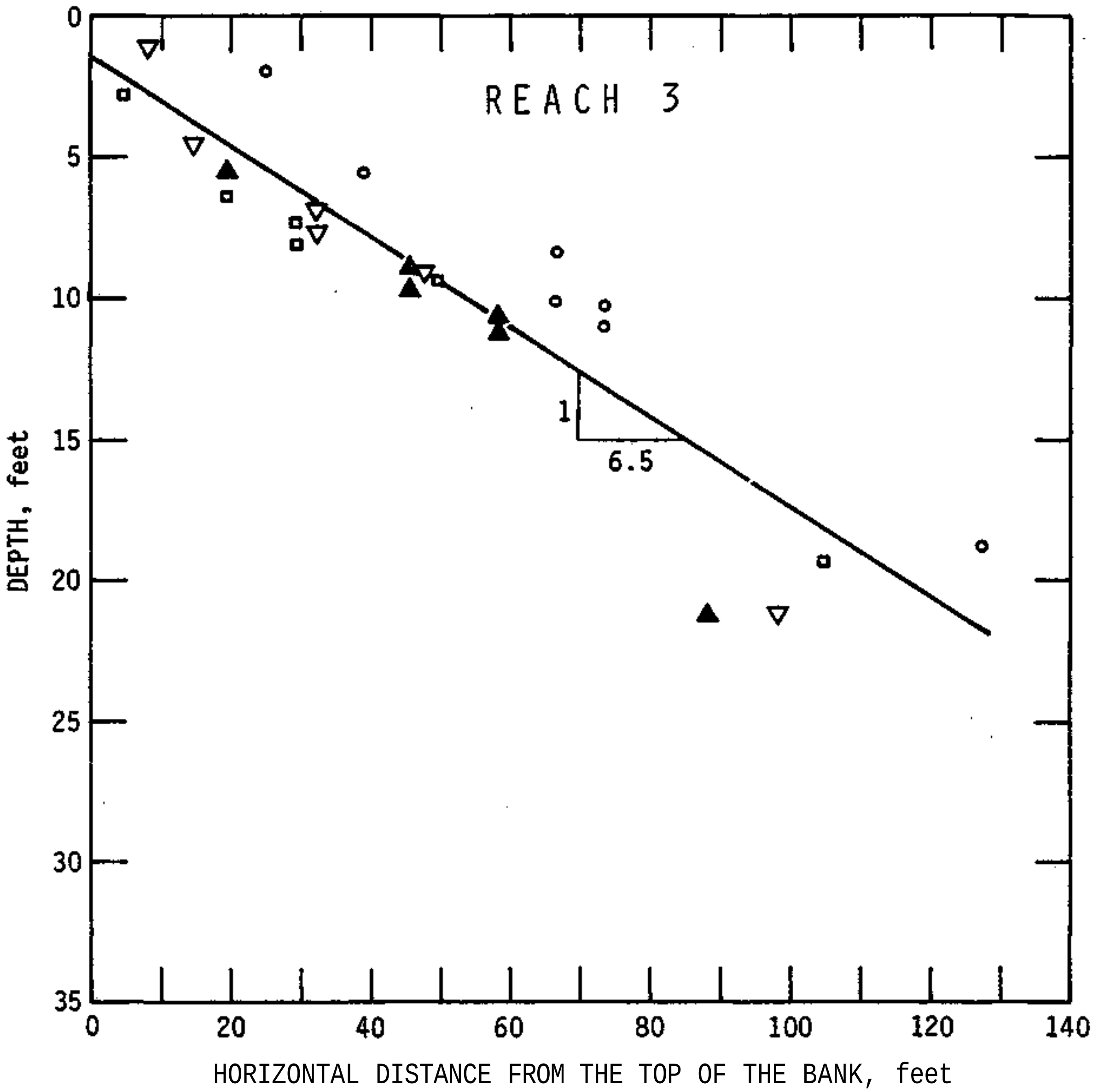


Figure 26. Typical Plot Showing the Bank Slope for Reach 3

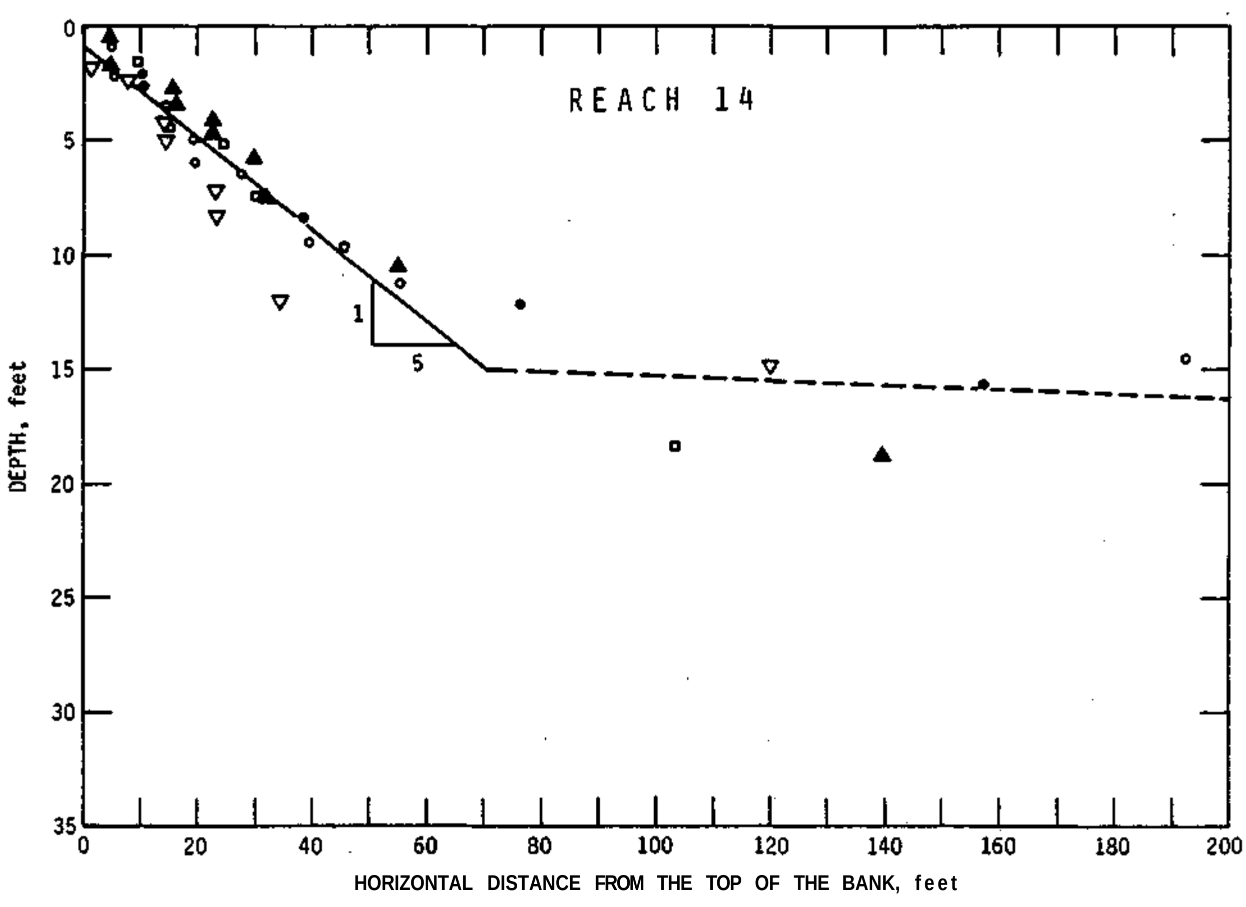


Figure 27. Typical Plot Showing the Bank Slope for Reach 14

similar to the one shown in Figure 27 or different parts of the same reach have different slopes. The bank slopes for all the reaches vary anywhere from 1:3.5 to 1:9. The first number stands for the vertical drop and the second number stands for the horizontal displacement.

Bed Slope

Figure 3 shows the profile of the Thalweg for the length of the Illinois River. This figure shows the elevation of the lowest points along the river, however, it is quite apparent that no uniform bed slope exists for the entire river length. The U.S. Army Corps of Engineers supplied a set of computer printouts showing the sounding data at various locations along the river. These sounding data were plotted and an average bed elevation was determined for each location. Using these average bed elevations, plots were developed showing the bed elevation versus distances for each pool. Figure 28 shows such a plot for two segments of the Illinois River. Similar plots were also developed for other segments of the river covering all the reaches under investigation.

In the stability analysis of the river bank or to find the erosion potential of the bed, one of the hydraulic parameters that is needed is the hydraulic gradient of the river. Since data related to the water surface profiles at each reach for various discharges are not available, it is proposed to use the average bed slope as the hydraulic gradient The bed slopes determined for each reach (similar to Figure 28) will be used as the hydraulic gradient of the river.

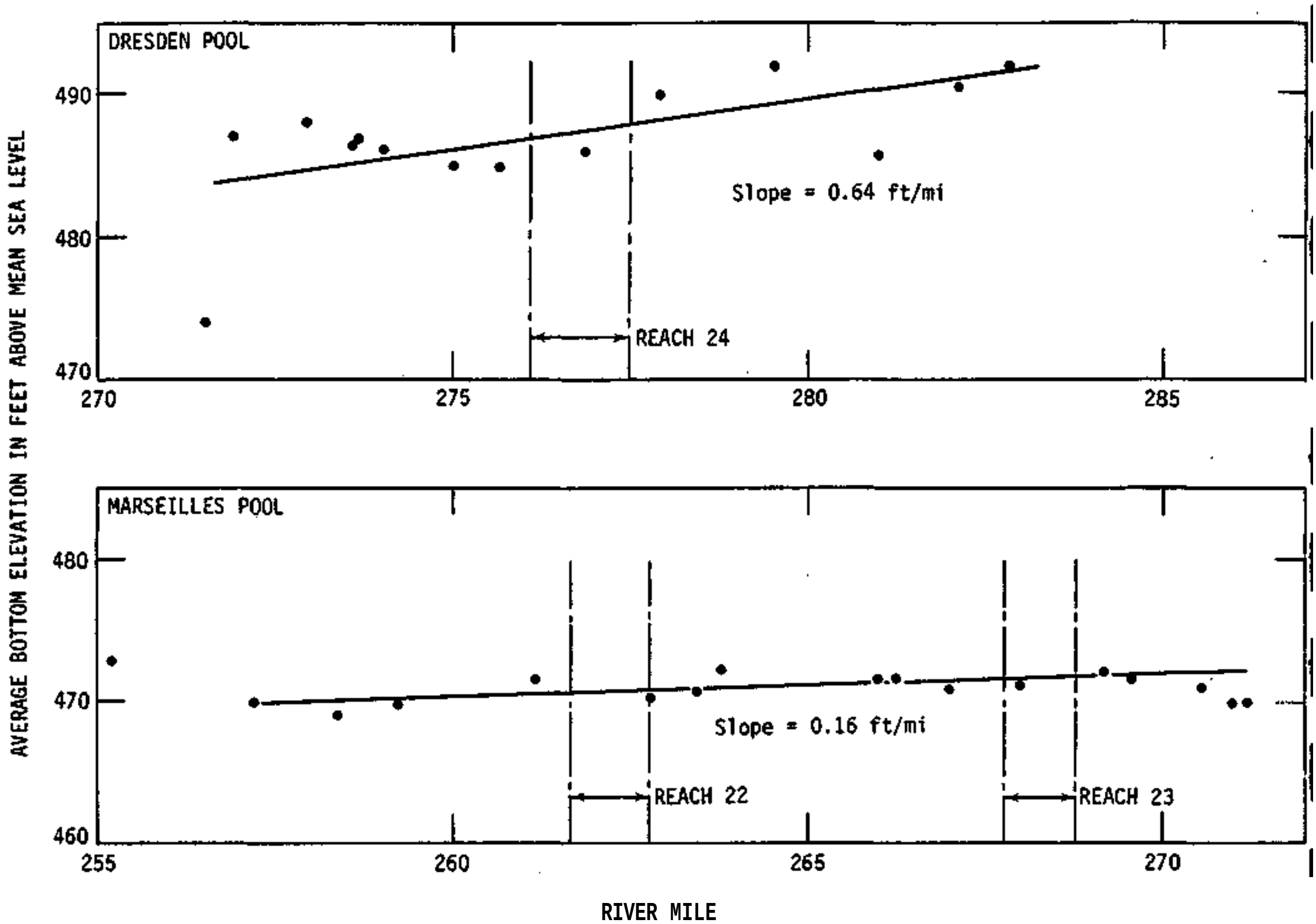


Figure 28. Bed Slope of the Illinois River at Two Different Locations

Bank Material Sizes

A total of 67 bank material samples were collected from different locations(Figure 8) along the Illinois River. The exact locations for most of these bank material samples are shown in Figures 15 through 25. The rest of the bank material samples were collected from other reaches that were not selected for further investigation.

All these samples were analyzed using both sieve and hydrometer techniques to determine the particle size distribution. Plots were developed showing the percent by weight versus the particle size for each one of the samples. Descriptions such as the reach number and specific location, river mile, date of data collection, sample number, and a general description of the materials as to its size distribution or classification as to sand, gravel, silt, etc. are also shown in Appendix B.

Table 2 shows geometric parameters that are used in describing and. identifying the particles sizes and the particle distribution. The d_{50} and d_{95} indicate the equivalent particle diameters for which 50 percent and 95 percent, respectively, of the particles are finer in diameter. The standard deviation, a, is defined in Equation 1 given below.

$$\sigma = \tfrac{1}{2} \left[(d_{84.1}/d_{50}) + (d_{50}/d_{15.9}) \right] \qquad (1)$$

Here $d_{84.1}$ and $d_{15.9}$ indicate the equivalent particle diameters for which 84.1 percent and 15.9 percent, respectively, of the particles are finer in diameter.

The other parameter that is shown in Table 2 is called the Uniformity Coefficient, U, and is defined by the ratio given in Equation 2

TABLE 2. Particle Size Characteristics of the Bank Materials

Reach No.	River Mile	Sample No.	dr_{50},mm	d_{95},mm	σ	U	Remarks
1	24.4	116	0.013	0.13	-	-	Clayey SILT
1	24.4	115	0.014	0.065	-	-	Clayey SILT
2	38.4	111	0.021	0.19	-	-	SILT
3	60.2	107	0.04	0.175	5.88	-	Sandy SILT
3	60.2	105	0.063	0.19	4.74	30.40	Sandy SILT
4	82.1	100	0.012	0.20	-	-	Clayey SILT
4	82.1	99	0.15	0.24	1.59	2.83	Fine SAND
4	82.1	98	0.17	0.32	4.60	23.75	Fine to medium SAND
5	101 to 102	124	0.018	0.51	-	-	Sandy Clayey SILT
5	101 to 102	123	0.017	0.26	-	-	Sandy Clayey SILT
5	101 to 102	122	0.014	0.27	-	-	Sandy Clayey SILT
6	104.0	92	0.01	0.30	-	-	Clayey SILT
6	104.0	91	0.0084	0.065	-	-	Clayey SILT
6	104.0	90	0.0034	0.042	-	-	Silty CLAY
7	113.0	89	0.016	0.17	-	-	SILT
7	113.0	88	0.027	0.20	-	-	SILT
8	116.5	85	0.52	10.0	6.23	5.0	Fine to coarse SAND
8	116.5	84	0.27	0.44	1.75	3.29	Fine SAND

TABLE 2. Particle Size Characteristics of the Bank Materials(cont.)

Reach No.	River Mile	Sample No.	d_{50},mm	d_{95},mm	σ	U	Remarks
8	116.5	83	0.008	0.19	-	-	Silty CLAY
9	121.4	80	0.75	13.0	5.14	4.31	Fine to coarse SAN0
9	121.4	79	2.40	36.0	7.07	16.07	Fine to coarse SAND & GRAVEL
12	142.5	68	0.035	0.12	2.63	-	Mottled Gray SILT
12	142.5	67	0.0073	0.14	-	-	Clayey SILT
12	142.5	66	0.013	0.49	-	-	Clayey SILT
13	150.0	64	0.0073	0.26	-	-	Clayey SILT
13	150.0	63	0.17	0.42	15.14	115.0	Silty fine to coarse SAND
13	150.0	62	0.032	0.40	17-83	-	Sandy SILT
14	154.0	60	0.14	0.24	2.98	15.0	Fine to medium SAND
14	154.0	59	0.04	0.20	8.04	-	Sandy SILT
14	154.0	58	0.05	0.15	6.10	-	Sandy SILT
15	180.0	53	0.26	5.0	4.48	40.0	Fine to coarse SAND
15	180.0	52	0.19	0.38	10.26	80.0	Silty fine to medium SAND
15	180.0	51	0.017	0.24	-	-	Clayey SILT
17	213.0	44	0.17	0.26	1.11	2.25	Fine SAND
17	213.0	43	0.042	0.23	12.40	-	Sandy SILT

Table 2. Particle Size Characteristics of the Bank Materials(cont.)

Reach No.	River Mile	Sample No.	d_{50},mm	d_{95},mm	σ	U	Remarks
18	227.5	39	0.29	0.94	2.56	34.0	Fine to coarse SAND
18	227.5	38	0.08	0.27	11.65	105.0	Silty fine SAND
18	227.5	37	0.12	0.27	10.19	80.0	Silty fine SAND
18	227.5	36	0.011	0.13	-	-	Clayey SILT
18	228.5	28	0.024	0.24	12.77	-	Sandy SILT
18	228.5	27	0.23	0.40	1.57	3.0	Fine to medium SAND
18	228.5	26	0.12	0.35	11.08	62.96	Silty fine to medium SAND
19	229.0	32	0.27	0.45	4.56	25.45	Fine to medium SAND
19	229.0	31	0.06	0.24	11.58	-	Sandy SILT
19	229.0	30	0.07	0.28	10.46	-	Fine to medium SAND
19	229.0	29	0.20	0.39	1.29	1.4	Fine SAND
20	228.9	35	0.08	8.0	25.0	-	Sandy SILT
20	228.9	34	0.29	0.57	1.67	3.16	Medium to fine SAND
20	228.9	33	0.39	0.53	1.44	2.15	Medium to fine SAND
22	262.0	18	0.02	0.18	-	-	Little clay and fine SAND
22	262.0	17	0.24	0.47	1.42	1.63	Fine to medium SAND
23	267.9	15	0.35	7.0	4.83	4.50	Fine to coarse SAND
23	267.9	14	2.0	-	30.13	427.27	Fine to coarse SAND
23	267.9	13	0.075	0.38	-	-	Silty fine to medium SAND
24	276.8	9	20.0	67.0	1667.92	-	Fine to coarse GRAVEL
24	276.8	7, 8	14.0	103.0	6.52	28.57	Sandy fine to coarse GRAVEL

below.

$$U = d_{60}/d_{10} \tag{2}$$

The numerical values of the standard deviation and the uniformity coefficient indicate a measure of the gradation of the particles. Higher values of σ and U will indicate a very well graded material, whereas a lower value of σ and U will demonstrate the uniformity of these particles. The last column in Table 2 gives the general nature of the bank materials.

In order to determine if the bank material particle sizes for different samples are similar, frequency distribution analyses of the d_{50} and d_{95} sizes were made. Figures 29 and 30 show the frequency distribution for d_{50} and d_{95} sizes, respectively. From Figure 29 it is obvious that 63 out of a total of 67 samples have their median diameter smaller than 2 mm. The insert in Figure 29 shows that out of this 63 samples, 38 of them have their d_{50} values less than 0.1 mm. The second insert in Figure 29 shows that 15 of the samples have their d_{50} sizes within the range of 0.01 to 0.02 mm indicating that these materials are in the clay to silty (Appendix B) ranges.

As shown in Figure 30, a total of 61 samples out of 66 samples have d_{95} values less than 11 mm. The first insert in Figure 30 indicates that 53 samples out of 61 samples have a d_{95} value of less than 1 mm. The second insert indicates that 20 of the samples have their d_{95} values in the range of 0.2 to 0.3 mm indicating that they are basically sandy materials.

Figure 31 shows the frequency distribution for σ and U. Although

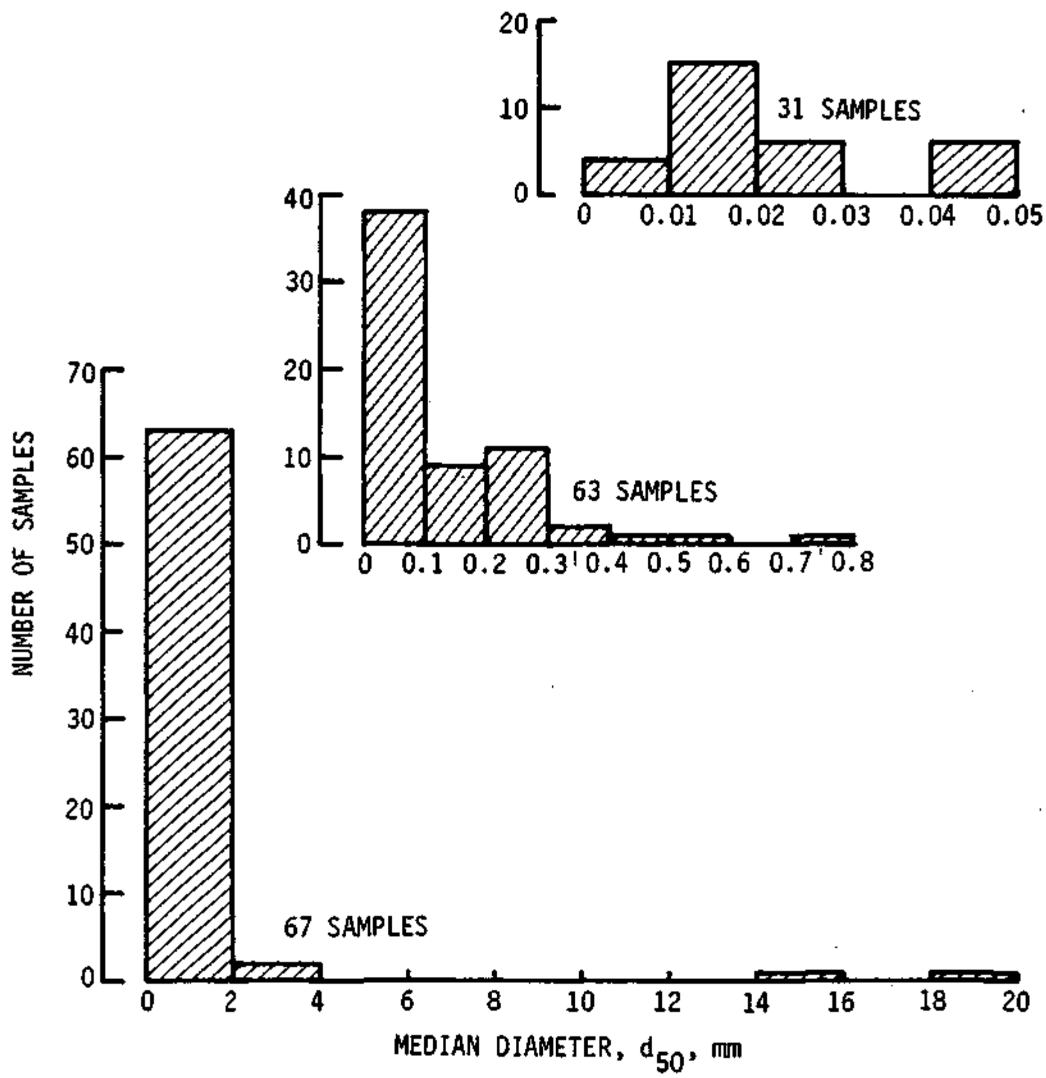


Figure 29. Frequency Distribution of the Median Diameter of the Bank Materials

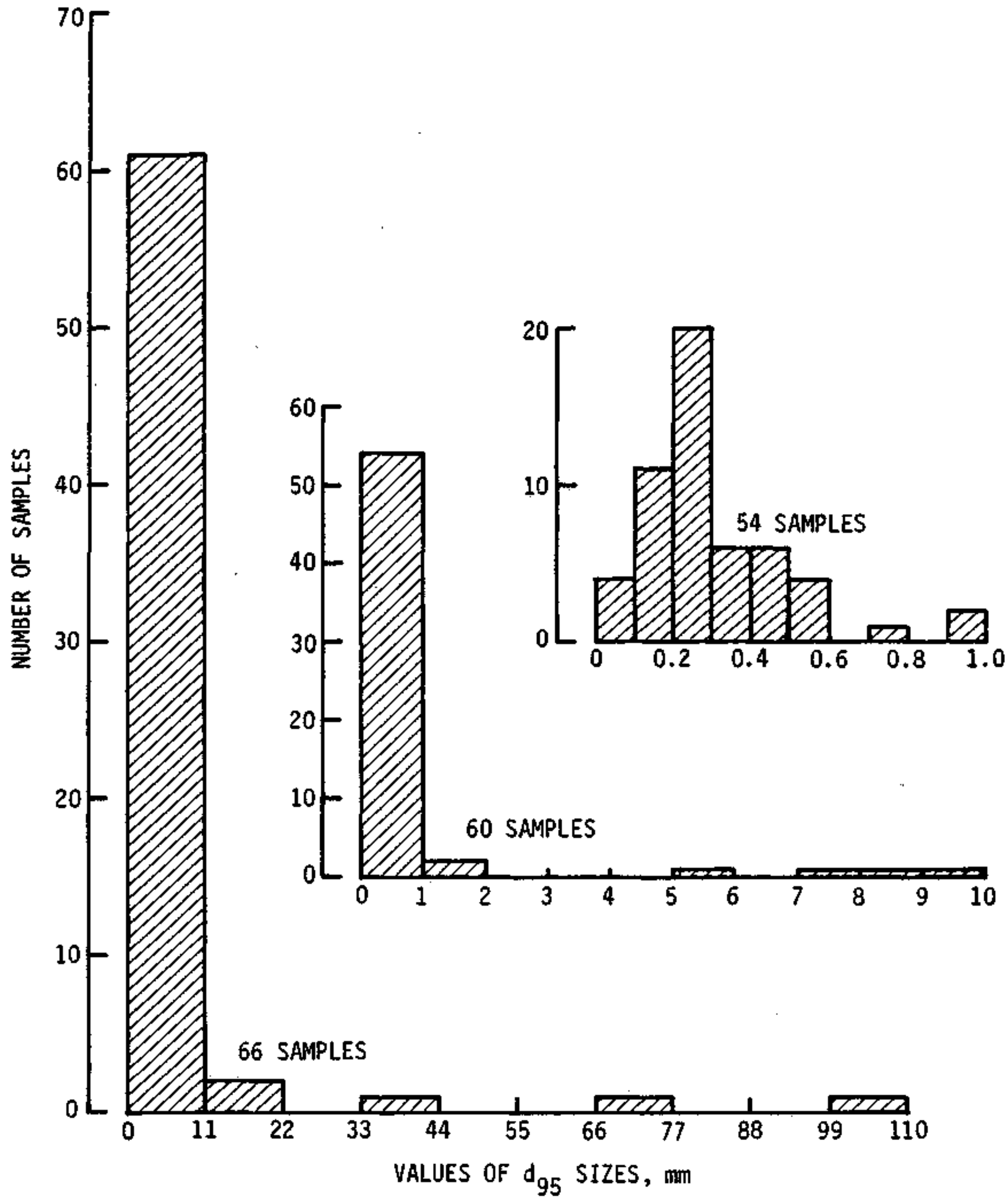


Figure 30. Frequency Distribution of the d_{95} Sizes of the Bank Materials

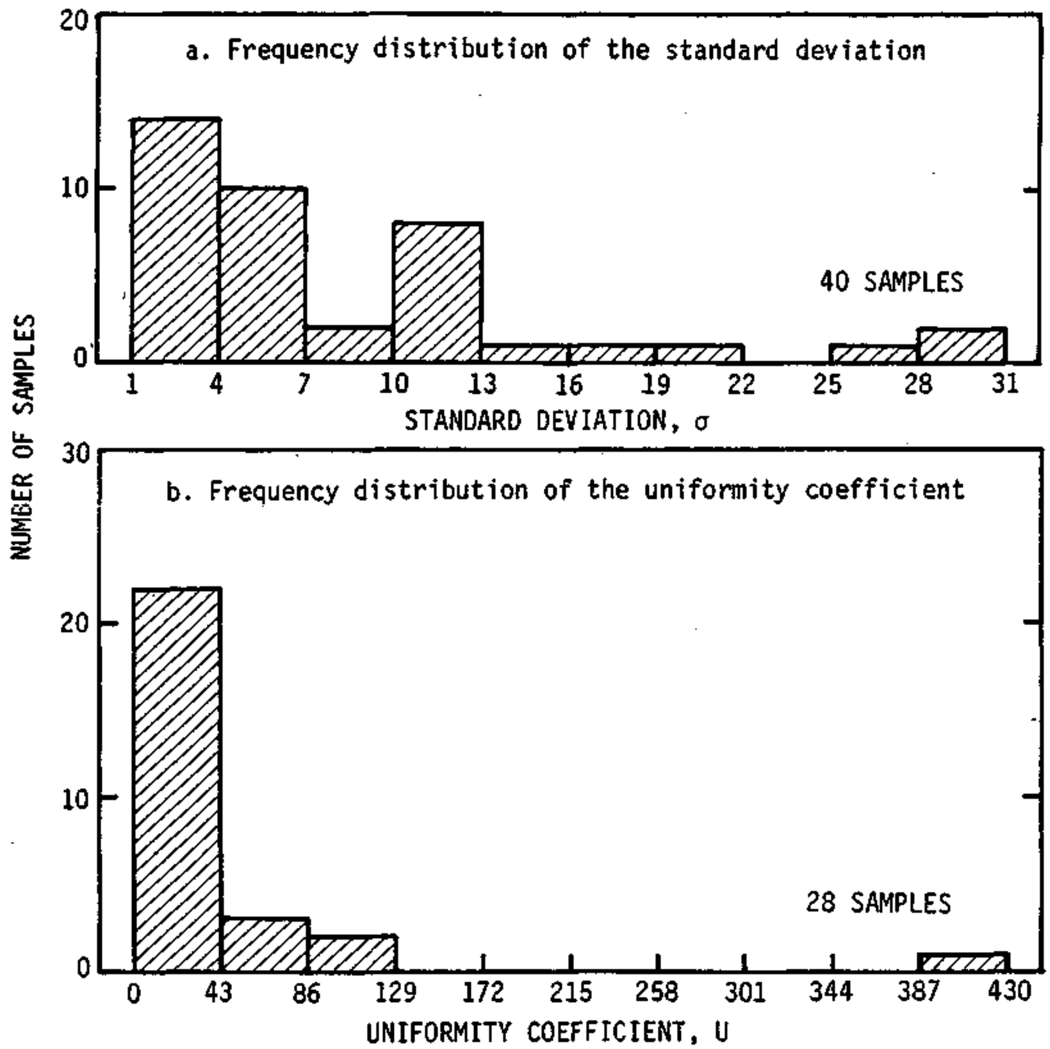


Figure 31. Frequency Distribution of Standard Deviation (σ) and Uniformity Coefficient (U).

no definitive statement can be made as to the uniformity characteristics of these materials, they are basically well graded materials, although some of the samples consist of uniform materials for almost 60 to 70 percent of their volumes.

Data analyzed for the bank materials definitely indicate that wherever serious bank erosion does exist on the Illinois River, the bank materials are usually composed of fine grained sands to silts having practically very little resistance against relatively high flow velocity and the onslaught of the waves generated either by wind or by waterway traffic. This may explain to some extent why severe bank erosion does exist on the Illinois River waterway wherever the bank lacks any natural or artificial protection.

Bed Material Sizes

A total of 54 bed material samples were collected and analyzed. Table 3 shows the values of d_{50}, d_{95}, σ, U and a description of the materials.

Appendix C shows the particle size distribution for all 54 bed material samples. Other information shown are river mile locations, dates of data collection, sample numbers and general comments as to the size distribution classification of materials.

Figure 32 shows the frequency distribution of the median diameter, d_{50}, of the bed materials. Out of 53 samples plotted, 49 had the d_{50} sizes less than 5 mm. However, the insert in the figure indicates that 14 of the 49 samples with d_{50} less than 5 mm,had d_{50} values less than 0.1 mm, whereas the rest of the d_{50} values follows a distribution

Table 3. Particle Size Characteristics of the Bed Materials

River Mile	Sample No.	d_{50},mm	d_{95},mm	σ	U	Remarks
8.0	121	-	0.014	-	-	CLAY
8.0	120	0.24	0.70	1.59	1.59	Fine to medium SAND
13.2	119	0.42	6.0	3.49	2.45	Fine to coarse SAND
17.0	118	0.23	32.0	8.0	46.67	Fine to medium SAND
22.8	117	0.019	0.070	-	-	SILT
28.9	114	0.33	0.65	1.49	1.85	Fine to medium SAND
33.0	113	0.024	0.49	-	-	Sandy SILT
41.4	110	0.37	1.4	1.56	1.78	Fine to coarse SAND
48.5	109	0.28	23.0	1.54	1.88	Fine to coarse SAND
54.2	108	0.47	1.0	1.48	2.13	Fine to coarse SAND
60.2	104	0.0125	0.32	-	-	SILT
65.8	103	0.35	0.52	1.56	2.62	Fine to medium SAND
69.3	102	0.30	1.0	1.60	1.79	Fine to medium SAND
76.0	101	0.33	0.61	1.40	1.68	Fine to medium SAND
82.1	97	0.40	0.80	1.43	1.91	Fine to medium SAND
88.2	96	0.38	0.75	1.54	2.15	Fine to medium SAND
92.0	95	0.38	1.0	1.54	2.0	Fine to coarse SAND
95.8	94	0.42	1.20	1.61	2.19	Fine to medium SAND
101.7	93	0.012	0.18	-	-	SILT
107.0	87	0.30	1.50	1.80	2.19	Fine to coarse SAND
112.6	86	0.32	1.10	1.71	2.25	Fine to coarse SAND
118.0	82	0.38	1.50	1.78	2.20	Fine to medium SAND
124.0	78	0.40	10.0	3.68	3.57	Fine to coarse SAND
129.9	74	0.090	0.30	1.45	1.28	Fine SAND
135.0	70	0.18	2.20	2.49	1.31	Fine to coarse SAND
140.0	59	0.36	1.70	1.66	2.10	Fine to coarse SAND
145.0	65	0.19	1.05	3.30	5.40	Fine to medium SAND

Table 3. Particle Size Characteristics of

the Bed Materials (cont.)

River Mile	Sample No.	d_{50},mm	d_{95},mm	σ	U	Remarks
150.0	61	0.43	1.50	2.15	3.57	Fine to medium SAND
154.4	57	0.013	0.45	-	-	SILT
160.2	56	20.0	55.0	6.38	31.94	Sandy SHELLS
161.0	125	0.045	0.25	5.10	-	Sandy SILT
161.0	126	0.17	0.46	2.17	3.50	Fine to medium SAND
166.0	55	0.0045	0.55	-	-	Clayey SILT
174.9	54	0.0054	0.52	-	-	Clayey SILT
180.0	50	0.30	0.62	1.54	2.0	Fine to medium SAND
186.4	49	0.025	0.20	5.77	-	Sandy SILT
196.4	48	27.0	60.0	1.96	103.33	Fine GRAVEL and SHELLS
206.0	45	0.32	0.80	1.33	1.38	Fine to medium SAND
213.0	42	0.36	1.80	1.83	1.91	Fine to coarse SAND
218.0	41	0.40	4.0	2.02	1.50	Fine to coarse SAND
222.0	40	0.33	1.15	1.46	1.23	Fine to medium SAND
229.0	25	0.35	3.0	2.05	2.05	Fine to coarse SAND
238.0	22	0.71	5.5	2.58	2.79	Fine to coarse SAND
242.9	21	30.0	66.0	1.80	3.50	Fine to coarse SAND
250.0	20	0.48	25.0	4.92	2.0	Fine to coarse SAND
263.4	16	0.51	32.0	26.24	2.26	Fine to coarse SAND
265.0	19	0.54	60.0	46.21	3.17	Fine to coarse SAND
269.0	12	0.38	2.0	1.63	1.83	Fine to coarse SAND
272.4	11	0.011	0.75	-	-	SILT
274.0	10	0.01	0.20	-	-	SILT
277.0	6	0.08	0.90	7.98	46.67	Silty SAND
279.4	5	50.0	65.0	4.72	33.33	Fine to coarse GRAVEL
282.3	4	0.275	0.75	1.86	2.41	Fine to medium SAND
286.9	1	0.024	0.40	7.13	26.92	Sandy SILT

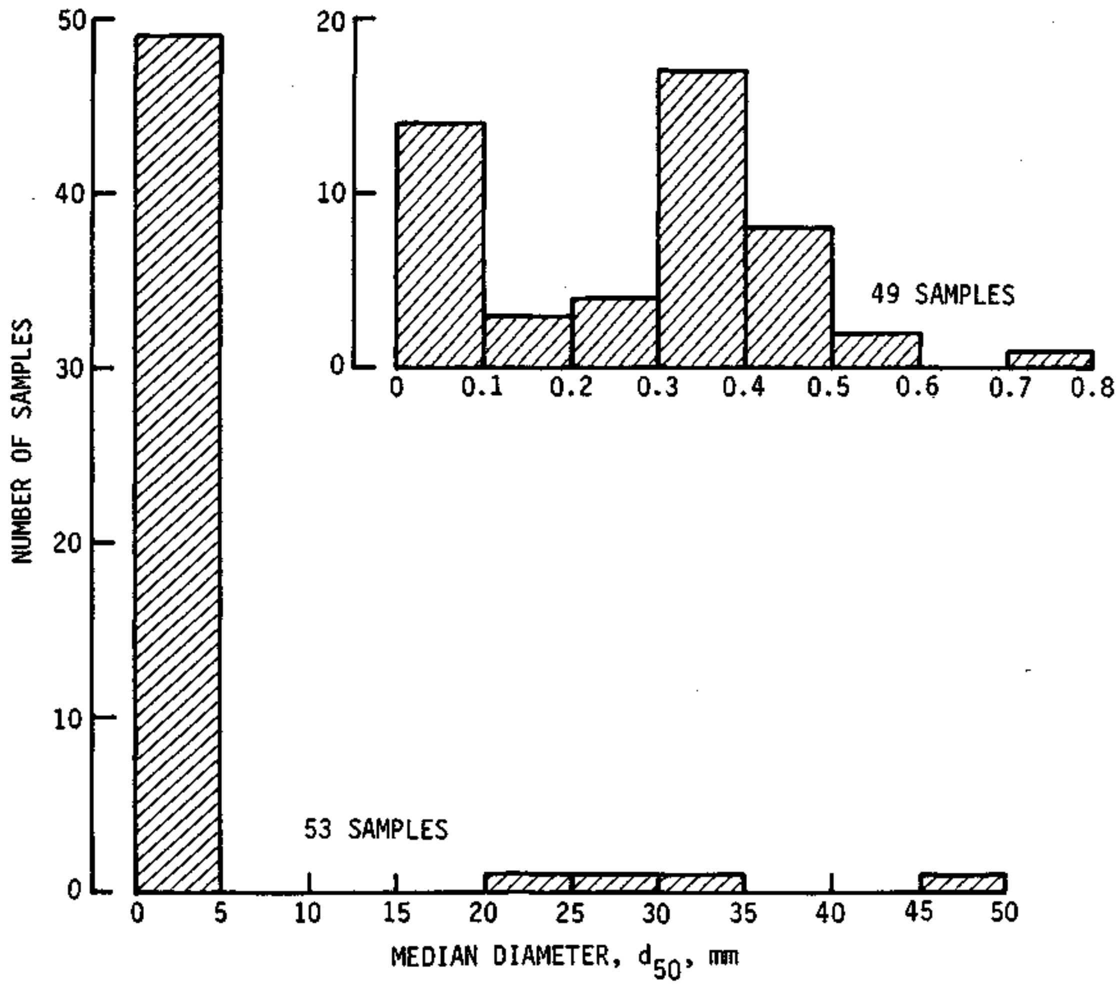


Figure 32. Frequency Distribution of the Median Diameter of the Bed Materials

similar to a normal distribution function with a mean value somewhere in the range of 0.3 and 0.4 mm. However, when all the samples are considered, it is obvious that the bed material of the Illinois River is basically composed of fine to medium sands (Appendix C) with the occasional presence of gravels and larger particles.

Figure 33, where the frequency distribution of the d_{95} sizes of the bed materials are shown, indicates that 44 of the 54 samples had d_{95} values less than 6.6 mm. The inserts indicate that most of these 44 samples have d_{95} values less than 1.2 mm.

The frequency distribution of the standard deviation, σ, and uniformity coefficient, U, are shown in Figure 34 and 35, respectively. They indicate that the bed materials of the Illinois River are basically well graded.

The bank and bed material data presented so far and the various parameters computed from the particle size distribution will be used later for the stability analysis of the banks. This set of data should be an excellent data base that could be used in the future for further hydraulic analysis of the Illinois River. Knowledge of the size distribution of the bed materials is needed in the study and investigation of sediment transport in any open channel flow problem. To the best of the knowledge of the authors, this is the first time that a comprehensive set of bed and bank material sample data from the Illinois River were collected and analyzed systematically.

Hydraulic Geometry of the River

In the stability analysis of the banks at various selected reaches,

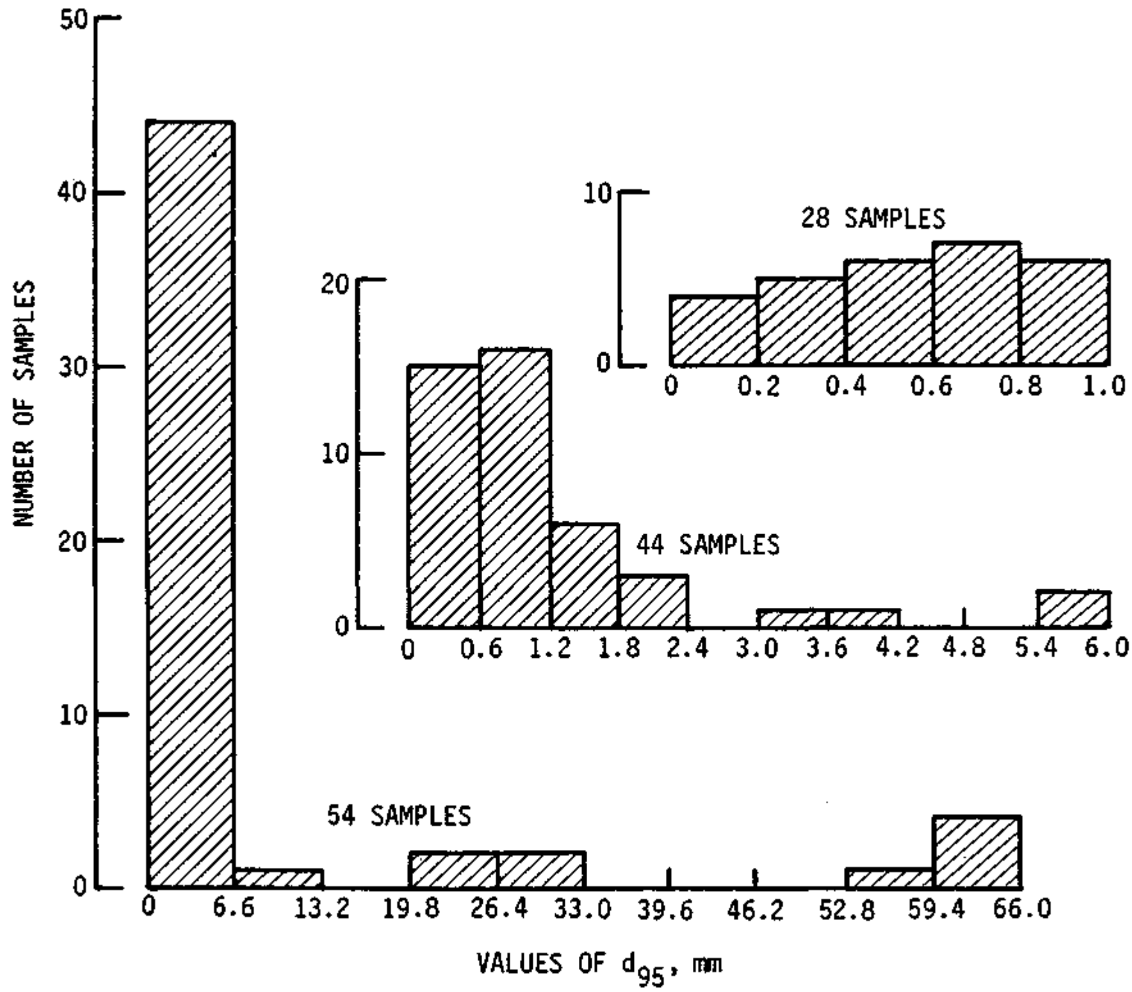


Figure 33. Frequency Distribution of the d_{95} Sizes of the Bed Materials

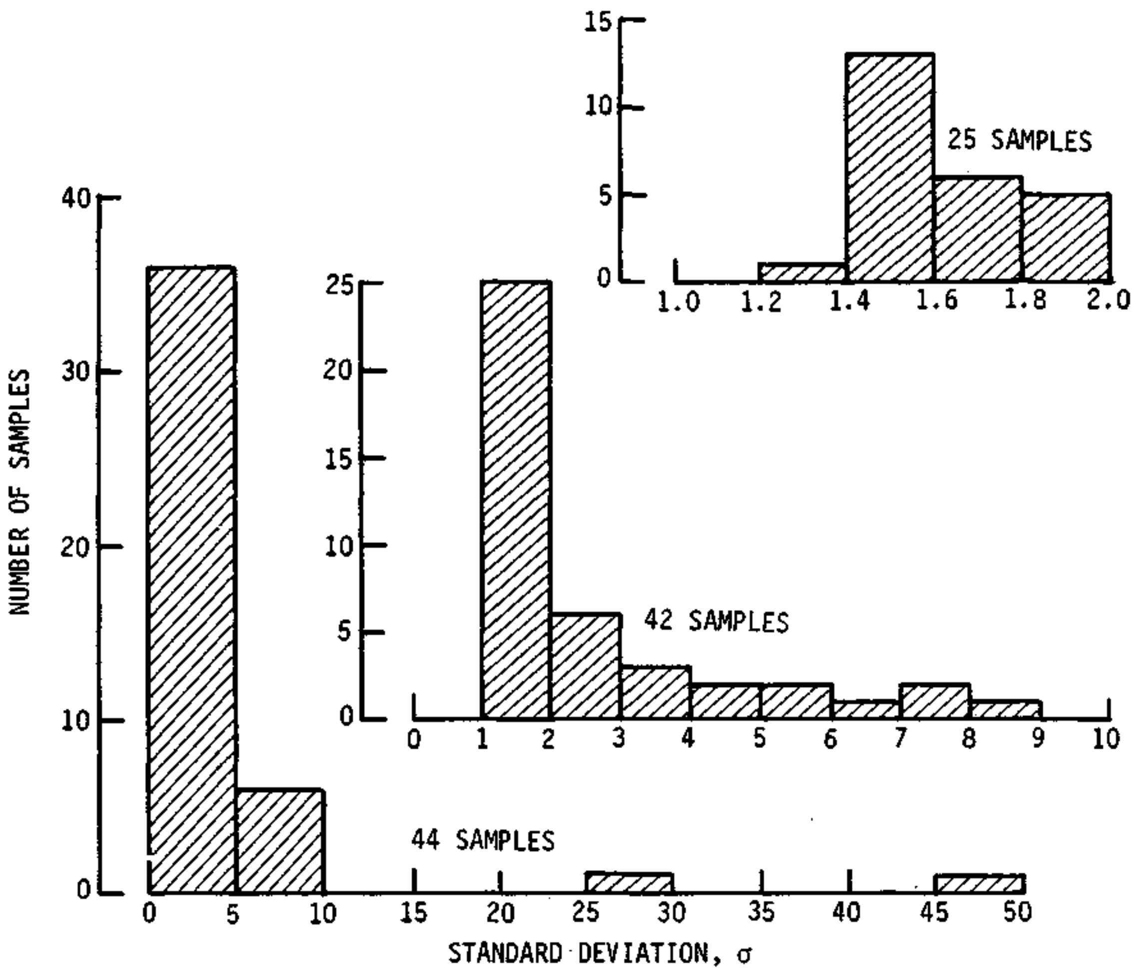


Figure 34. Frequency Distribution of the Standard Deviation (σ) of the Bed Materials

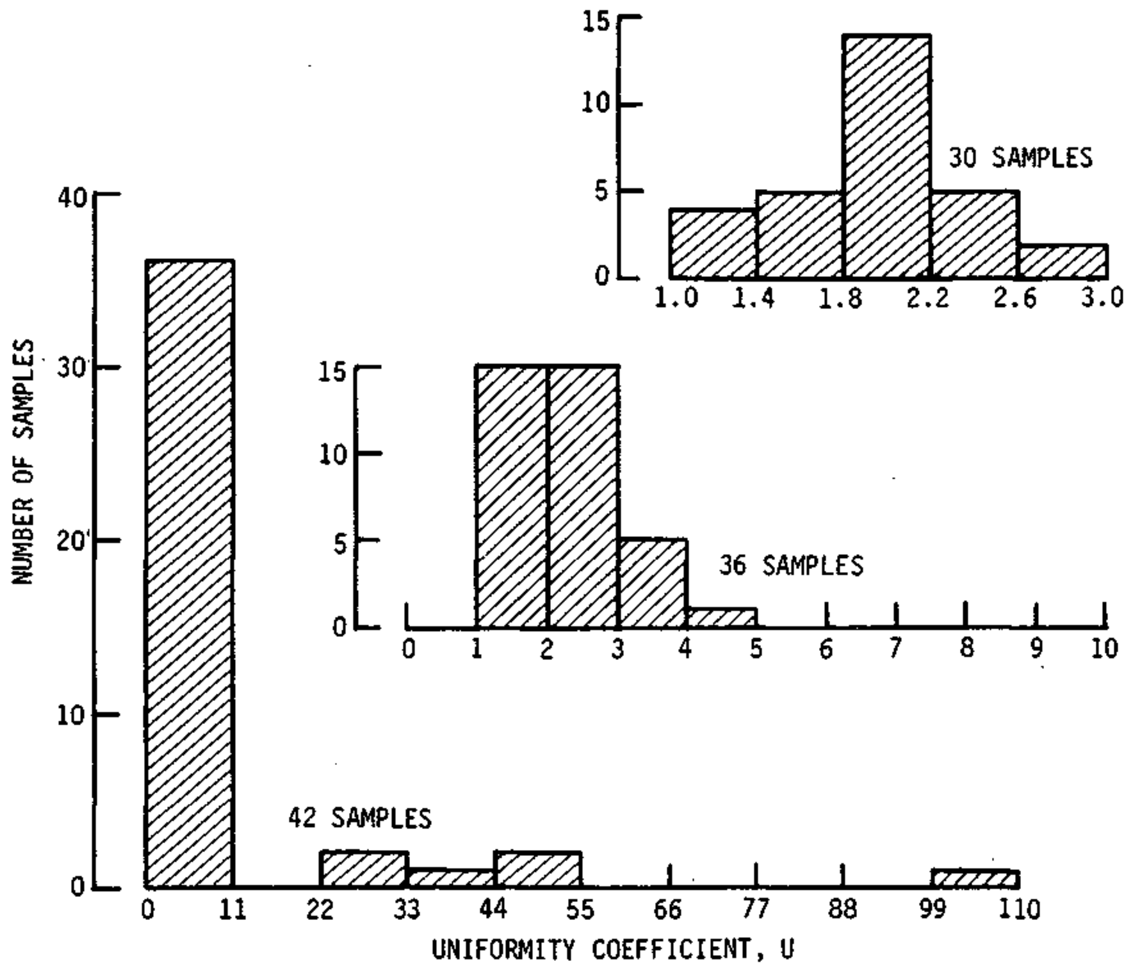


Figure 35. Frequency Distribution of the Uniformity Coefficient (U) of the Bed Materials

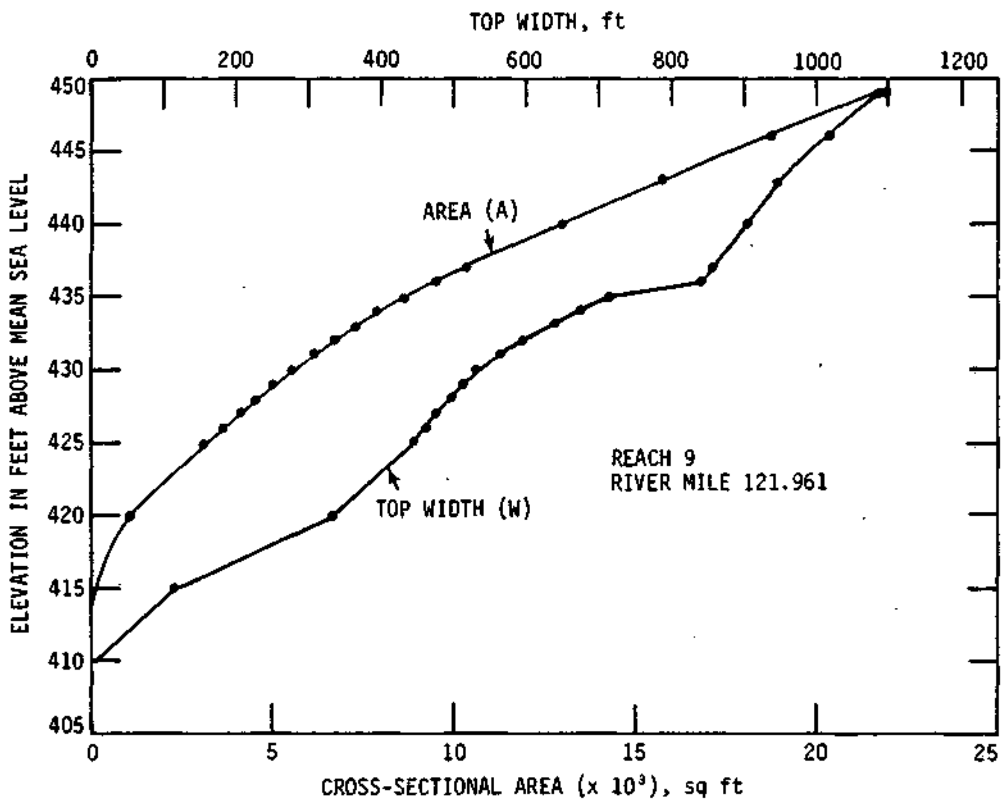
some hydraulic geometric parameters must be determined based on historical data. The parameters that are needed are, the discharge, Q for some specified frequency, the corresponding cross-sectional area, A, top width, W, depth, D, and the river stage. These data are needed for two different cases, e.g., with present diversion (3200 cfs) and with increased diversion discharges.

Most of the flow data that are needed for the stability analysis of the banks were supplied by the Corps of Engineers. The Corps of Engineers have supplied the plots showing the average daily stages and the average daily discharges versus time for the water years of 1971, 1973, and 1977. These data were given for the conditions based on present diversion practices and with the increased diversions. Data were available only for 17 locations along the whole length of the river. Since the 20 selected reaches were scattered along the river from Joliet to Grafton, quite a bit of interpolation had to be made to estimate the stage and discharge at or near anyone of these selected reaches.

The stability of any bank depends upon many hydraulic and geometric factors. But whenever the stage in the river is relatively high, it is suspected that the banks of the river will be vulnerable to the erosive action of the flow as compared to the low flow regime of the river. Therefore, in all subsequent analyses, it was assumed that the critical condition related to the bank erosion potential of the river will exist whenever the stage in the river is the highest. The stability of each reach was checked against this selected maximum stage and discharge for present diversion and increased diversion practices.

Two of the water years, 1971 and 1973, were the years with relatively high stage conditions. For these two years, the maximum stage and discharge at all selected reaches did not show any variation or changes between the conditions of present diversion and increased diversions to 6,600 cfs and 10,000 cfs. Therefore, for these two water years, the stability of the banks was tested for only one set of conditions. On the other hand, the water year 1977 was a relatively dry year. The maximum stages for the conditions of present diversion and diversions of 6,600 cfs and 10,000 cfs did show some changes at all selected locations. Consequently, the stability of the banks were tested for three different conditions, namely: present (3200 cfs) diversion, and increased diversions of 6,600 cfs and 10,000 cfs, respectively.

The values of A, D, and W for selected maximum stages for each reach were computed from the sounding data supplied by the Corps of Engineers. All the sounding data for each reach were plotted as elevations above mean sea level versus A and W. Figure 36 shows such relationships for Reach 9 for two cross-sections. Once the maximum stages for various conditions were selected, values of A and W were determined from plots similar to the plot in Figure 36. Whenever the sounding data were available at more than one cross-section in any reach, an average of the values of A and W were computed. With known discharge Q, cross sectional area A, top width W, the values of average depth D and average velocity V were computed.



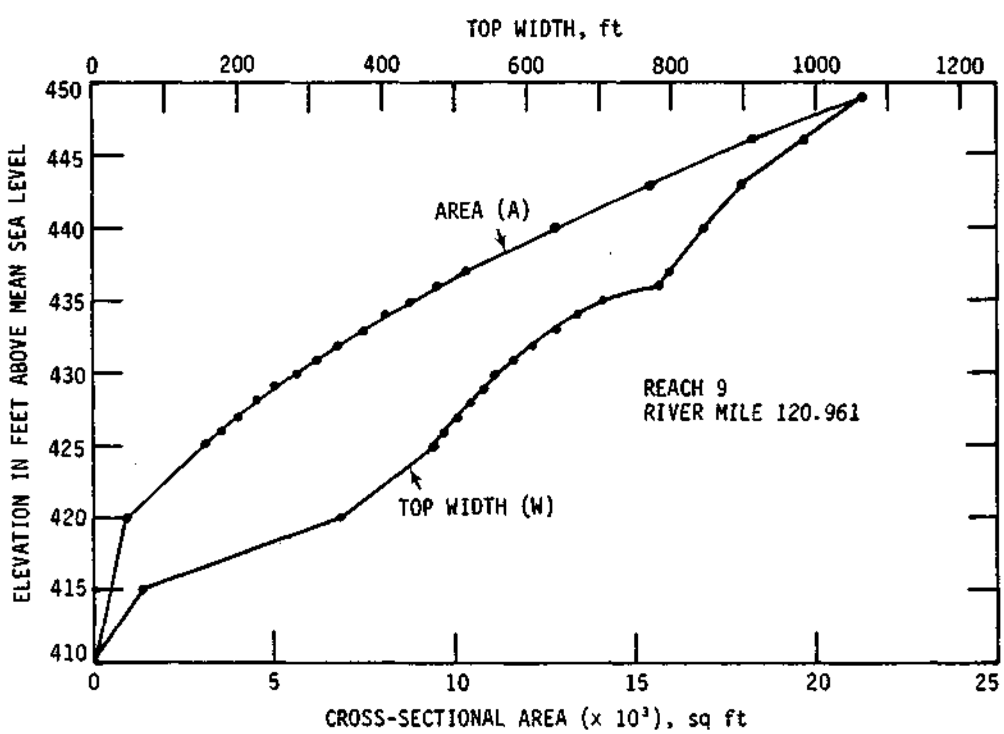


Figure 36. Typical Hydraulic Geometry Relationships for Reach 9

In some instances, the floodplain of the Illinois River is broad and wide. In such cases, it is probable that the floodplains are not fully effective in conveying an equal amount of discharge proportional to its cross-sectional areas (Bhowmik and Stall, 1979). Therefore, in a few instances the effective cross-sectional areas were modified and the values of W and A were computed based on this modified shape of the river. Figure 37 shows such a typical case for Reach 23 near River Mile 268. Here it was assumed that the effective cross-sectional area of the river varies similarly to the cross-sectional area shown by broken line. The relationships between elevations above msl in feet versus top width (W) and area (A) were developed based on this modified cross-sectional shape of the river at this location.

Stability Analysis

Based on the particle size distribution analysis presented thus far, the Illinois River essentially flows through alluvial materials composed of gravel to rock near its upper part to sand, silt and clay near its lower part. Most of the major rivers of the world also flow through alluvial materials with a sand bed. Streams and rivers flowing in a sand bed channel do undergo changes due to changing bed forms(Simons and Richardson, 1971). In some instances, changes in bed form can change the flow resistance and also the concentration of the suspended sediments dramatically. In some cases, increase in resistance to flow can increase the flow depths quite significantly.

In testing the stability of any river bank one must consider the various factors that may make a bank unstable. Among the various forces

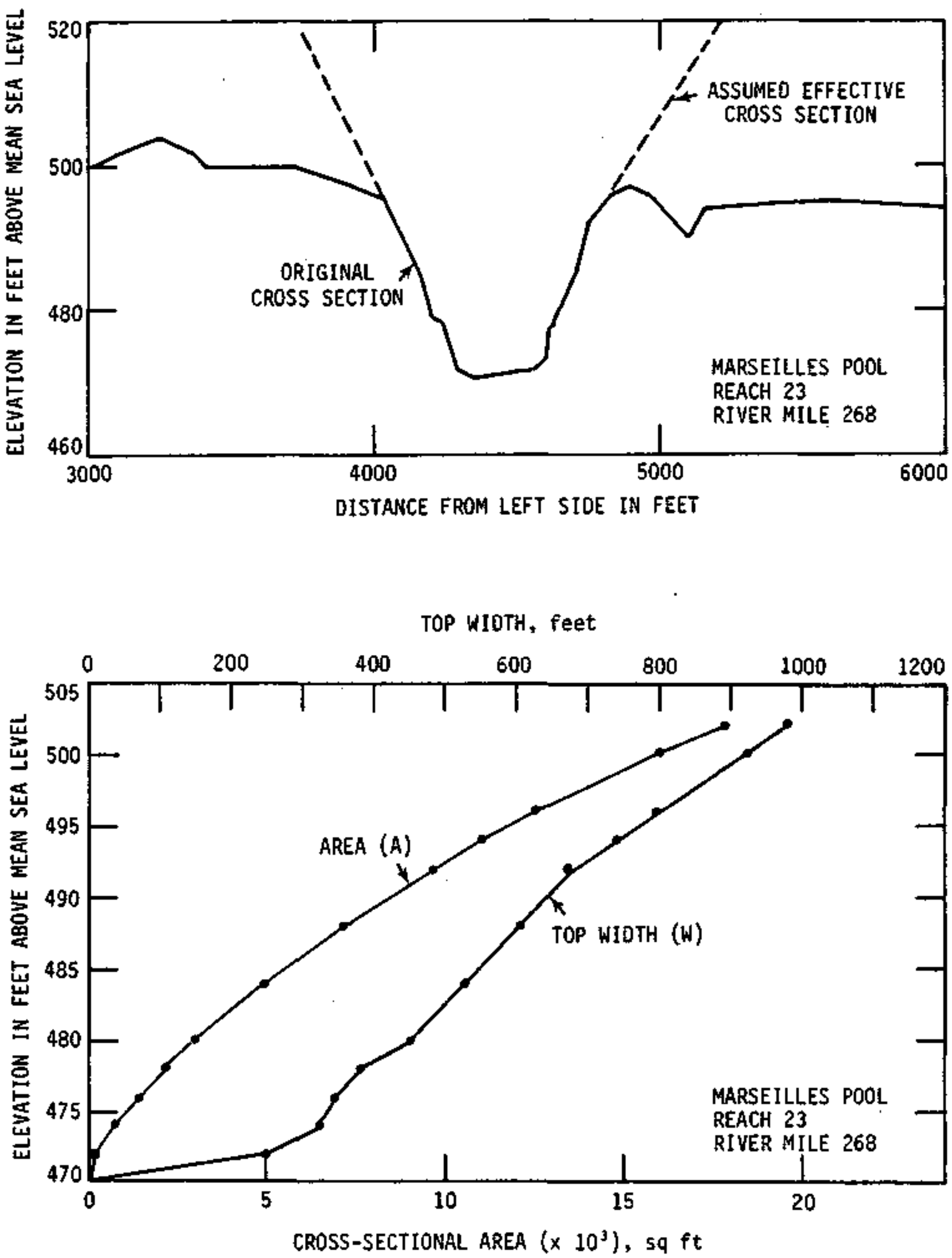


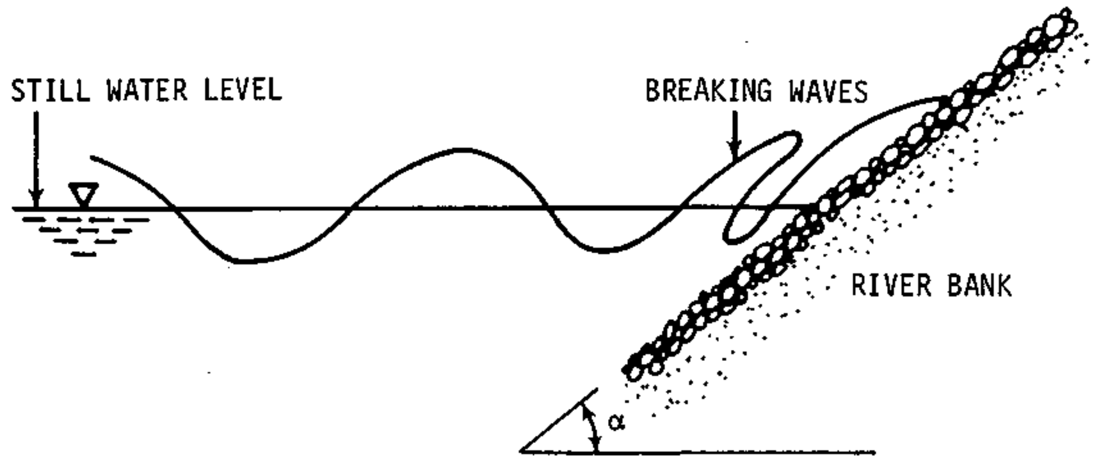
Figure 37. Typical Hydraulic Geometry Relationships for Reach 23

that can work on a bank and help to erode it are: the force developed by the flowing water and the action of waves generated by either the wind or waterway traffic. Among physical parameters that will effect the bank stability are: bank material sizes, the bank slope, natural or artificial protective measures, orientation of the exposed bank toward the prevailing wind direction, the proximity of the bank to the main waterway traffic, frequency and physical characteristics of the waterway traffic, climatic changes which may account for rapid changes in the viscosity of the water, and ice action.

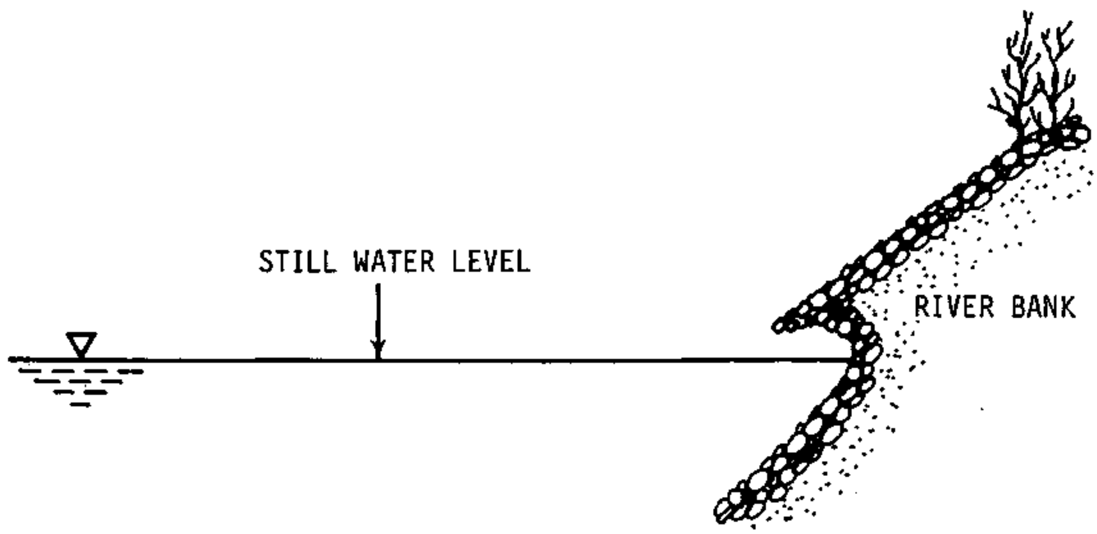
From a pure observational point of view, it appears that a combination of flow characteristics and the wave action are responsible for the bank erosion of the Illinois River. The segment or segments of the river banks that are being eroded consist of materials in the sandy to silty or clayey sizes. Unless these materials are on a very flat slope, their natural resistance against erosion in a high velocity stream is negligible. Moreover, wave action or flow may undercut the bank. The cantilivered bank will either fall because of its own weight or because of the effects of the next high flow. Figures 38a and 38b show such two hypothetical cases.

In many places along the Illinois River the banks are stable. Usually at all these places, either the bank materials consist of larger particles or dense vegetation or tree roots are well developed and is helping to protect the banks.

The stability analyses of the bank slopes for 20 selected reaches are shown in the next subsection. The bank stability was analyzed by a



a. Wave erosion of stream banks



b. Stream bank failure due to scouring of the toe

Figure 38. Initiation of Bank Erosion

number of different methods, namely, Lane's critical tractive force method(Lane 1955), the critical velocity or permissible velocity method for various bank material sizes (Lane 1955, Chow, 1959), and the Shields criteria (ASCE 1975). In addition to these methods, the stability of the banks was also tested against wave action generated by prevailing winds.

Theoretically the flow velocity in a confined waterway should increase during the passage of a large tow with barges. This will be true especially underneath a barge with a 9 foot draft. The increased flow velocity may accelerate the scour of the bed and the erosion of the banks.

Stability Analysis of the Individual Reaches

Tables 4 through 8 show all the parameters that were computed and or estimated to test the stability of the banks. Data are shown for the water years 1971, 1973, and 1977. The various parameters in Tables 4 through 8 are explained below.

The maximum discharge Q in cfs was estimated based on the maximum stage at all selected locations. Cross-sectional area A in square feet, top width W in feet, and the average depth D in feet were estimated from the sounding data supplied by the Corps of Engineers. In a few instances, such as, for Reaches 1, 2, 3, 12, 13, 14, 15, 22, and 23, the effective cross-sectional shape of the river was assumed to be different than that given by the actual sounding data similar to Figure 37 for Reach 23.

The average velocity V in fps was computed based on discharge Q and cross-sectional area A. The average bed slope S_o was computed based on

Table 4. Stability Analysis

Water Year 1977, Diverted flow = 3200 cfs

Reach No.	Maximum Discharge, Q cfs	Cross-sectional Area, A sq ft	Top Width, W ft	Average Depth, D ft	Average Velocity, V ft/sec	Bed Slope, S_0 ft/mile
1	38,800	11,300	895	12.6	3.4	0.0715
2	37,900	15,400	1,310	11.8	2.5	0.0715
3	36,400	14,500	1,200	12.1	2.5	0.0715
4	37,800	16,900	1,093	15.5	2.2	0.057
5	35,000	11,400	743	15.3	3.1	0.057
6	35,000	11,500	928	12.4	3.0	0.057
7	35,000	10,800	825	13.1	3.2	0.057
8	35,000	14,750	1,085	13.6	2.4	0.057
9	30,500	12,700	870	14.6	2.4	0.057
12	30,500	12,600	655	19.2	2.4	0.057
13	26,200	14,200	860	16.5	1.9	0.057
14	26,200	12,700	685	18.5	2.1	0.057
15	25,400	11,900	915	13.0	2.1	0.0107
17	27,300	14,650	1,380	10.6	1.9	0.0107
18	27,000	14,800	820	18.1	1.8	0.0107
19	27,000	14,800	820	18.1	1.8	0.0107
20	27,000	14,800	820	18.1	1.8	0.0107
22	39,700	13,300	675	19.7	3.0	0.155
23	30,300	13,600	840	16.2	2.2	0.155

Table 4. Stability Analysis (cont.)

Water Year 1977, Diverted flow = 3200 cfs

Reach No.	Bed Shear Stress, τ_o lb/sq ft	Shear Velocity, U_* ft/sec	Median Diameter of the Bank Material, d_{50} in	Boundary Reynolds No., R_*	Dimensionless Shear Stress, τ_*	Lane's Limiting Tractive force lb/sq ft	Maximum Permissible Velocity (Lane 1955) ft/sec
1	.011	.074	.0005	0.27	2.56	.048	5.5
2	.010	.072	.0008	0.42	1.46	.047	5.5
3	.010	.073	.002	1.08	0.58	.048	5.5
4	.010	.073	.0044	2.37	0.26	.044	3.0
5	.010	.073	.0006	0.32	1.94	.023	5.5
6	.008	.066	.0003	0.15	3.11	.042	5.5
7	.009	.067	.0009	0.44	1.17	.049	5.5
8	.009	.069	.010	5.09	0.10	.049	3.0
9	.010	.071	.062	32.5	0.019	.062	6.5
12	.013	.082	.0007	0.42	2.2	.044	5.5
13	.011	.076	.0028	1.57	0.46	.049	5.5
14	.012	.080	.003	1.77	0.47	.048	5.5
15	.002	.029	.0061	1.30	0.038	.049	3.0
17	.001	.026	.0042	0.81	0.028	.048	3.0
18	.002	.034	.0049	1.23	0.048	.048	3.0
19	.002	.034	.0059	1.48	0.039	.049	3.0
20	.002	.034	.010	2.51	0.023	.049	3.0
22	.036	.136	.0051	5.12	0.82	.042	3.0
23	.030	.124	.032	29.3	0.11	.058	3.0

Table 5. Stability Analysis

Water Year 1977, Diverted flow = 6,600 cfs.

Reach No.	Maximum Discharge, Q cfs	Cross-sectional Area, A sq ft	Top Width, W ft	Average Depth, D ft	Average Velocity, V ft/sec	Bed Slope, S_o ft/mile
1	41,700	12,300	940	13.1	3.4	0.0715
2	40,700	16,800	1,360	12.4	2.4	0.0715
3	39,000	16,000	1,260	12.7	2.4	0.0715
4	40,500	17,550	1,100	16.0	2.3	0.057
5	36,200	11,500	750	15.3	3.2	0.057
6	36,200	11,800	945	12.5	3.1	0.057
7	36,200	11,000	843	13.1	3.3	0.057
8	36,200	14,950	1,103	13.6	2.4	0.057
9	32,500	12,950	875	14.8	2.5	0.057
12	32,500	13,100	660	19.9	2.5	0.057
13	28,300	14,800	890	16.6	1.9	0.057
14	28,300	13,000	690	18.8	2.2	0.057
15	27,100	12,400	930	13.3	2.2	0.0107
17	28,500	15,500	1,470	10.5	1.8	0.0107
18	27,800	14,950	838	17.8	1.9	0.0107
19	27,800	14,950	838	17.8	1.9	0.0107
20	27,800	14,950	838	17.8	1.9	0.0107
22	39,700	13,300	675	19.7	3.0	0.155
23	30,300	13,600	840	16.2	2.2	0.155

Table 5. Stability Analysis (cont.)

Water Year 1977, Diverted flow = 6,600 cfs.

Reach No.	Bed Shear Stress, τ_o lb/sq ft	Shear Velocity, U_* ft/sec	Median Diameter of the Bank Material, d_{50} in	Boundary Reynolds No., R_*	Dimensionless Shear Stress, τ_*	Lane's Limiting Tractive force lb/sq ft	Maximum Permissible Velocity (Lane 1955) ft/sec
1	.011	.076	.0005	0.28	2.58	.048	5.5
2	.010	.074	.0008	0.43	1.53	.047	5.5
3	.011	.074	.002	1.10	0.63	.048	5.5
4	.011	.075	.0044	2.42	0.29	.044	3.0
5	.010	.073	.0006	0.32	2.0	.023	5.5
6	.008	.066	.0003	0.15	3.27	.042	5.5
7	.009	.067	.0009	0.45	1.14	.049	5.5
8	.009	.069	.010	5.07	0.11	.049	3.0
9	.010	.072	.062	32.80	0.019	.062	6.5
12	.013	.083	.0007	0.43	2.2	.044	5.5
13	.011	.076	.0028	1.57	0.47	.049	5.5
14	.013	.081	.003	1.79	0.49	.048	5.5
15	.0017	.029	.0061	1.33	0.032	.049	3.0
17	.0013	.026	.0042	0.81	0.037	.048	3.0
18	.0023	.034	.0049	1.23	0.054	.048	3.0
19	.0023	.034	.0059	1.48	0.044	.049	3.0
20	.0023	.034	.010	2.51	0.026	.049	3.0
22	.036	.136	.0051	5.13	0.82	.042	3.0
23	.030	.124	.032	29.20	0.11	.058	3.0

Table 6. Stability Analysis

Water Year 1977, Diverted flow = 10,000 cfs.

Reach No.	Maximum Discharge, Q cfs	Cross-sectional Area, A sq ft	Top Width, W ft	Average Depth, D ft	Average Velocity, V ft/sec	Bed Slope, S_o ft/mile
1	44,700	13,100	975	13.4	3.4	0.0715
2	43,600	18,100	1,400	12.9	2.4	0.0715
3	41,800	16,800	1,320	12.7	2.5	0.0715
4	43,300	18,200	1,113	16.4	2.4	0.057
5	38,800	12,000	783	15.3	3.2	0.057
6	38,800	12,350	935	13.2	3.1	0.057
7	38,800	11,550	878	13.2	3.4	0.057
8	38,800	15,750	1,125	14.0	2.5	0.057
9	35,200	13,600	888	15.3	2.6	0.057
12	35,200	13,600	670	20.3	2.6	0.057
13	30,800	15,500	940	16.5	2.0	0.057
14	30,800	13,600	695	19.6	2.3	0.057
15	29,300	13,200	950	13.9	2.2	0.0107
17	30,900	16,450	1,585	10.4	1.9	0.0107
18	29,700	15,400	855	18.0	1.9	0.0107
19	29,700	15,400	855	18.0	1.9	0.0107
20	29,700	15,400	855	18.0	1.9	0.0107
22	39,700	13,300	675	19.7	3.0	0.155
23	30,300	13,600	840	16.2	2.2	0.155

Table 6. Stability Analysis (cont.)

Water Year 1977, Diverted flow = 10,000 cfs.

Reach No.	Bed Shear Stress, τ_o lb/sq ft	Shear Velocity, U_* ft/sec	Median Diameter of the Bank Material, d_{50} in	Boundary Reynolds No., R_*	Dimensionless Shear Stress, τ_*	Lane's Limiting Tractive force lb/sq ft	Maximum Permissible Velocity (Lane 1955) ft/sec
1	.011	.076	.0005	0.28	2.64	.048	5.5
2	.011	.075	.0008	0.44	1.59	.047	5.5
3	.011	.074	.002	1.10	0.63	.048	5.5
4	.011	.076	.0044	2.45	0.29	.044	3.0
5	.010	.073	.0006	0.32	2.0	.023	5.5
6	.009	.068	.0003	0.15	3.45	.042	5.5
7	.009	.068	.0009	0.45	1.15	.049	5.5
8	.009	.070	.010	5.14	0.11	.049	3.0
9	.010	.073	.062	33.34	0.019	.062	6.5
12	.014	.084	.0007	0.43	2.28	.044	5.5
13	.011	.076	.0028	1.56	0.46	.049	5.5
14	.013	.083	.003	1.83	0.51	.048	5.5
15	.002	.030	.0061	1.35	0.034	.049	3.0
17	.001	.026	.0042	0.81	0.036	.048	3.0
18	.002	.034	.0049	1.24	0.054	.048	3.0
19	.002	.034	.0059	1.49	0.045	.049	3.0
20	.002	.034	.010	2.53	0.027	.049	3.0
22	.036	.136	.0051	5.13	0.82	.042	3.0
23	.030	.124	.032	29.00	0.108	.058	3.0

Table 7. Stability Analysis

Water Year 1971

Reach No.	Maximum Discharge, Q cfs	Cross-sectional Area, A sq ft	Top Width, W ft	Average Depth, D ft	Average Velocity, V ft/sec	Bed Slope, S_o ft/mile	Remarks
1	47,000	14,300	1,020	14.0	3.3	0.0715	Maximum Stages
2	46,900	19,600	1,455	13.5	2.4	0.0715	and Discharges
3	46,800	18,300	1,400	13.1	2.6	0.0715	Remained the same
4	44,300	15,150	1,048	14.5	2.9	0.057	for all Diversion
5	31,600	10,700	700	15.3	3.0	0.057	Cases (Data by
6	31,600	10,700	870	12.3	3.0	0.057	Corps of Engineers)
7	31,600	10,150	755	13.4	3.1	0.057	
8	31,600	13,850	1,015	13.7	2.3	0.057	
9	29,200	11,900	858	13.9	2.5	0.057	
12	29,200	12,300	650	18.9	2.4	0.057	
13	27,300	13,800	840	16.4	2.0	0.057	
14	27,300	12,900	690	18.7	2.1	0.057	
15	27,700	12,600	935	13.5	2.2	0.0107	
17	30,300	16,050	1,550	10.4	1.9	0.0107	
18	29,700	15,600	850	18.4	1.9	0.0107	
19	29,700	15,600	850	18.4	1.9	0.0107	
20	29,700	15,600	850	18.4	1.9	0.0107	
22	28,600	11,700	660	17.7	2.4	0.155	
23	23,400	10,100	700	14.4	2.3	0.155	

Table 7. Stability Analysis (cont.)

Water Year 1971

Reach No.	Bed Shear Stress, τ_o lb/sq ft	Shear Velocity, U_* ft/sec	Median Diameter of the Bank Material, d_{50} in	Boundary Reynolds No., R_*	Dimensionless Shear Stress, τ_*	Lane's Limiting Tractive force lb/sq ft	Maximum Permissible Velocity (Lane 1955) ft/sec
1	.012	.078	.0005	0.29	2.76	.048	5.5
2	.011	.077	.0008	0.45	1.66	.047	5.5
3	.011	.076	.002	1.11	0.64	.048	5.5
4	.010	.071	.0044	2.30	0.26	.044	3.0
5	.010	.073	.0006	0.32	2.0	.023	5.5
6	.008	.065	.0003	0.14	3.21	.042	5.5
7	.009	.068	.0009	0.45	1.17	.049	5.5
8	.009	.069	.010	5.09	0.11	.049	3.0
9	.009	.070	.062	31.8	0.018	.062	6.5
12	.013	.081	.0007	0.42	2.12	.044	5.5
13	.011	.076	.0028	1.56	0.46	.049	5.5
14	.013	.081	.003	1.78	0.49	.048	5.5
15	.002	.030	.0061	1.34	0.033	.049	3.0
17	.001	.026	.0042	0.81	0.036	.048	3.0
18	.002	.035	.0049	1.25	0.055	.048	3.0
19	.002	.035	.0059	1.51	0.046	.049	3.0
20	.002	.035	.010	2.56	0.027	.049	3.0
22	.032	.13	.0051	4.86	0.74	.042	3.0
23	.026	.12	.032	27.53	0.096	.058	3.0

Table 8. Stability Analysis

Water Year 1973

Reach No.	Maximum Discharge, Q cfs	Cross-sectional Area, A sq ft	Top Width, W ft	Average Depth, D ft	Average Velocity, V ft/sec	Bed Slope, S_Q ft/mile	Remarks
1	98,800	25,800	1,420	18.2	3.8	0.0715	Maximum Stages
2	97,900	35,500	1,940	18.3	2.8	0.0715	and Discharges
3	96,300	34,500	2,060	16.8	2.8	0.0715	Remained the same
4	98,300	29,850	1,215	24.6	3.3	0.057	for all Diversion
5	67,400	19,100	908	21.0	3.5	0.057	Cases. (Data
6	67,400	21,050	1,075	19.6	3.2	0.057	by Corps of
7	67,400	19,550	1,078	18.1	3.5	0.057	Engineers)
8	67,400	25,950	1,378	18.8	2.6	0.057	
9	65,000	21,650	1,075	20.1	3.0	0.057	
12	65,000	18,400	740	24.9	3.5	0.057	
13	55,000	22,800	1,110	20.5	2.4	0.057	
14	55,000	18,800	745	25.2	2.9	0.057	
15	51,400	19,600	1,120	17.5	2.6	0.0107	
17	56,700	27,200	2,880	9.4	2.1	0.0107	
18	51,200	21,400	1,088	19.7	2.4	0.0107	
19	51,200	21,400	1,088	19.7	2.4	0.0107	
20	51,200	21,400	1,088	19.7	2.4	0.0107	
22	77,800	16,600	715	23.2	4.7	0.155	
23	55,000	17,400	965	18.0	3.2	0.155	

Table 8. Stability Analysis (cont.)

Water Year 1973

Reach No.	Bed Shear Stress, τ_o lb/sq ft	Shear Velocity, U_* ft/sec	Median Diameter of the Bank Material, d_{50} in	Boundary Reynolds No., R_*	Dimensionless Shear Stress, τ_*	Lane's Limiting Tractive force lb/sq ft	Maximum Permissible Velocity (Lane 1955) ft/sec
1	.015	.089	.0005	0.33	3.58	.048	5.5
2	.015	.089	.0008	0.53	2.25	.047	5.5
3	.014	.086	.002	1.26	0.83	.048	5.5
4	.017	.092	.0044	3.00	0.44	.044	3.0
5	.014	.085	.0006	0.38	2.75	.023	5.5
6	.013	.083	.0003	0.18	5.13	.042	5.5
7	.012	.079	.0009	0.53	1.58	.049	5.5
8	.013	.081	.010	5.96	0.15	.049	3.0
9	.014	.084	.062	38.22	0.025	.062	6.5
12	.017	.093	.0007	0.48	2.79	.044	5.5
13	.014	.084	.0028	1.74	0.57	.049	5.5
14	.017	.094	.003	2.07	0.66	.048	5.5
15	.002	.034	.0061	1.52	0.042	.049	3.0
17	.001	.025	.0042	0.77	0.033	.048	3.0
18	.002	.036	.0049	1.30	0.059	.048	3.0
19	.002	.036	.0059	1.56	0.049	.049	3.0
20	.002	.036	.010	2.64	0.029	.049	3.0
22	.042	.15	.0051	5.57	0.97	.042	3.0
23	.032	.13	.032	30.78	0.12	.058	3.0

actual field data as described previously. The shear force, was computed by the equation given below

$$\tau_o = \gamma D S_o \qquad (3)$$

where γ is the unit weight of water in pounds per cubic feet and T_0 is in pounds per square feet. The shear velocity U_* was computed by

$$U_* = \sqrt{gDS_o} \qquad (4)$$

where g is the acceleration due to gravity in feet per sec^2 and U_* is in fps. The median diameter of the bank materials, d_{50} given in inches are the values obtained from Appendix B for the respective reaches. The boundary Reynolds Number R_* is defined by

$$R_* = U_* d_{50} / \nu \qquad (5)$$

where U_* is the shear velocity in fps, d_{50} is the median diameter of the bank materials in feet and υ is the kinematic velocity of water in square feet per sec. For the computations shown in Table 4 through 8, the values of υ are based on a water temperature equal to 65 degrees fahrenheit. The dimensionless shear stress, T_* was computed by the equation shown below

$$\tau_* = \tau_o / [(\gamma_s - \gamma)\ d_{50}] \qquad (6)$$

where γ_s is the unit weight of the bank materials assumed to be equal to 165 pounds per cubic foot, γ is the unit weight of water equal to 62.4 pounds per cubic foot. The values of Boundary Reynolds number R_* and dimensionless shear stress τ_* were needed to test the stability of banks based on Shields relationship (ASCE, 1975).

The Lanes tractive force (Lane 1955) shown as τ_L and the maximum permissible velocity shown as V_p were based on the relationships and tables given by Lane.

All the parameters discussed thus far are given in Tables 4 through 8 for 19 reaches. Computations are not shown for Reach No. 24. Because of the broad and wide exposure of Reach 24 to the water surface (Figure 14), it is obvious that the bank erosion at this location basically resulted from the wave action of the water.

If it is assumed that the Tractive Force on the bank is the dominant force against which the stability of the banks must be checked, then the values of τ_o must be less than the values of τ_L. The tabulated values shown in tables 4 through 8 indicate that in all cases, τ_o is less than the value of τ_L. Thus the banks at all locations should be stable as far as the tractive force is concerned.

On the other hand if we assume that the stability of the banks depends upon the allowable or the permissible velocity (V_p) that the bank materials can withstand, then the values of V should be less than the value of V_p. As shown in tables 4 through 8, this is found to be true for all cases except for Reach No. 22 for the water year 1973. For this reach, the permissible velocity is more than the computed average velocity. The permissible velocities were estimated depending upon the compostion of the existing bank materials (Lane 1955) at different locations.

The above comparison can be refined by estimating and using the bottom velocity V_b rather than the average velocity V. Further refinements can be made by taking into consideration the hydraulic effect of the river bend on flow velocity. Based on the results from research work done elsewhere (Bhowmik and Stall, 1978, 1979) it was observed that the value of the flow velocity at 0.5 foot above the bed can vary anywhere from 70 to 95 percent of the' average velocities in the individual verticals in a cross-section. The average of these values can be taken to be about 90 percent. Thus it is assumed that

$$V_b = 0.9 \; V_v \qquad (7)$$

where V_v is the average velocity in any vertical in a cross-section. On the other hand, the maximum average velocity in a vertical inside a bend was found to be about 28 percent more than the average velocity in the cross-section. These data were collected from the Kaskaskia River in Illinois. This river is smaller than tihe Illinois River. If it is assumed that the relationships developed for the Kaskaskia River are also valid for the Illinois River, then the average maximum bottom velocity in the Illinois River in a bend can be assumed to be equal to 15 percent more than the average velocity in the cross-section, i.e.

$$V_b = 0.9 \; V_v = (0.9) \; (1.28) \; V = 1.15 \; V \qquad (8)$$

Reach numbers 1, 4, 5, 6, 7, 8, 9, 12, 13, 16, 18, and 19 are either located on the outside bank of a bend or on the outside downstream bank of a bend. If the average velocity is increased by 15 percent at all these locations for all five conditions given in Tables 4 through 8, at only one location, Reach No. 22, will the maximum bottom velocity exceed the maximum permissible velocity. This was found to be true for the water year 1977 with diversions equal to 6,600 cfs and 10,000 cfs. Except for this location, in all other cases the banks should be stable as far as the maximum permissible velocities in the river for the existing bank material compositions are concerned.

When the stability of the banks were tested using the Shields (ASCE, 1975) relationship, it was observed that in few instances, the banks were shown to be unstable. In the Shields relationship the values of R_* and τ_* are computed from Equations 5 and 6, respectively, and these values are plotted in a figure similar to the one shown in Figure 39. However, it must be pointed out that the Shields diagram was developed for non-cohesive materials and that the value of the hydraulic gradient is needed to compute both the abscissa and the ordinate of Figure 39. In almost all cases, the plotted points were found to be clustered around the particular bed slope that was used in the computation of U_* and τ_o. Since in all the computations, bed slope was assumed to be equal to the hydraulic gradient and that field data are not available related to the magnitude of the hydraulic gradients, the stability analysis following Shields diagram may or may not be valid for the above cases.

The average velocity shown in Tables 4 through 8 were computed based on estimated stage, discharge, and the cross-sectional area of the river at respective reaches. In order to check whether or not these average computed velocities corresponding to certain discharges are anywhere close to the measured average velocities, the gaging data from the United States Geological Survey files were gathered and compared with the computed velocities. Data were gathered from the gaging stations at Kingston Mines, Meredosia, and Marseilles.

The discharge measurement data from Kingston Mines resulted in average velocities of 2.03, 1.97, 2.40, and 3.33 fps corresponding to discharges of 20,500, 26,800, 37,000 and 61,600 cfs, respectively.

The computed velocities for Reaches 12, 13, and 14 which are close to the Kingston Mines gage, varied from 1.9 to 3.5 fps for discharges of 26,200 and 65,000 cfs respectively.

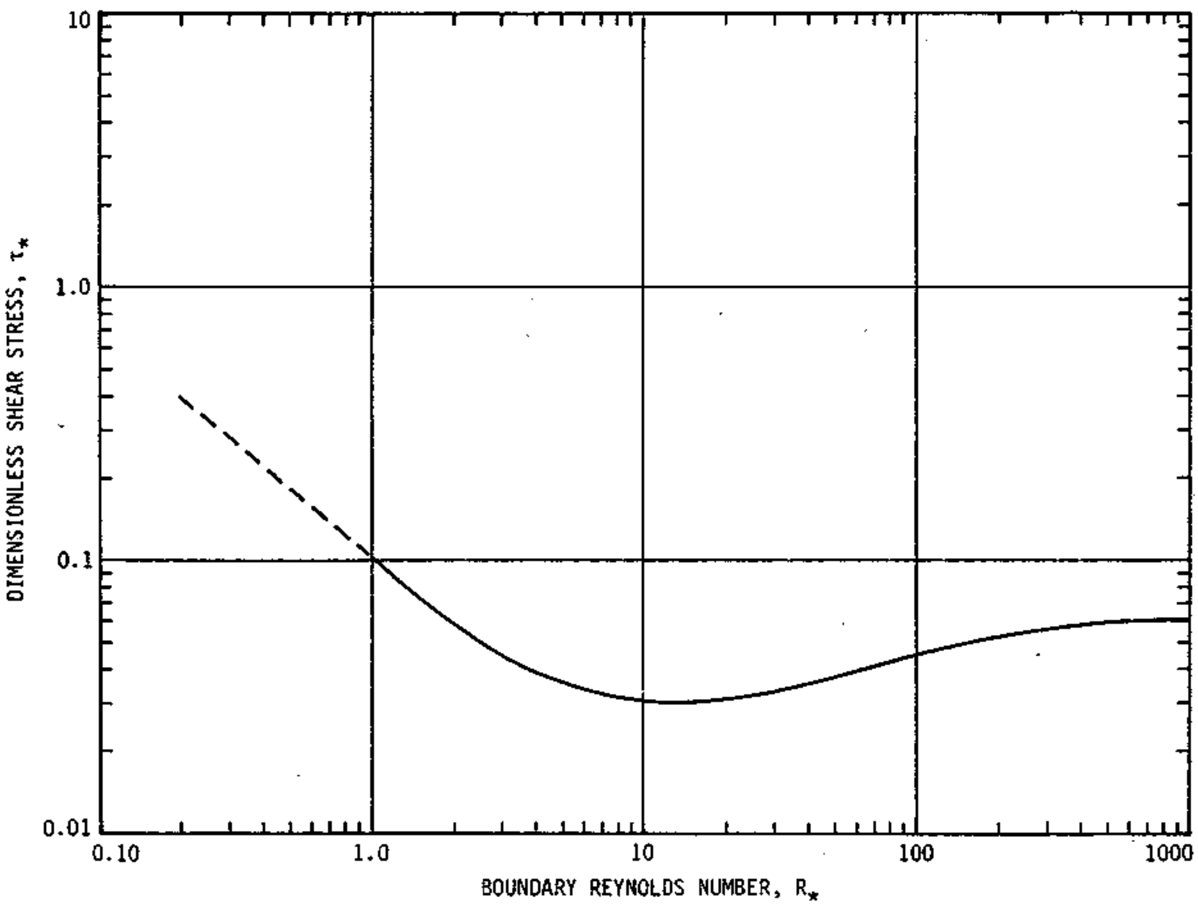


Figure 39. Shields Diagram, ASCE 1975

The discharge measurement data at the Meredosia gage resulted in average velocities of 2.04 and 2.47 fps for discharges of 29,200 and 70,300 cfs respectively. Computed velocities for Reaches 2, 3, and 4 which are in close proximity of the Meredosia gage, varied from 2.3 to 3.3 fps for discharges of 37,800 and 98,300 cfs, respectively.

The discharge measurement data at Marseilles gage resulted in average velocities of 3.11 and 4.20 fps for discharges of 11,100 and 39,600 cfs, respectively. The computed velocities for Reach 22, which is about 20 miles upstream of the gage varied from 2.4 to 4.7 fps for discharges of 28,600 and 77,800 cfs,respectively.

These computations indicated that the procedure followed in the analysis and estimation of different parameters shown in Tables 4 through 8, should yield reasonable approximation of the actual field condition for the anticipated flow condition in the river.

Stability of the Banks Against Wind-Generated Waves

Banks exposed to the direct action of waves will erode if they lack protection. To a certain degree, almost all the reaches of the Illinois River are exposed to wave action.

An analysis, using methodology given in detail by Bhowmik (19:76, 1978) was made to compute the wave height and the stable size of the bank materials.

The methodology suggested in the Shore Protection Manual by the Corps of Engineers (1977) can also be used to compute wave height and the stable size of the bank materials.

In the computation of the wave height, it was assumed that wind blowing for a duration of 6 hours having a return period of 50 year will be the critical wind velocity that may develop significant wave action. Historical data related to wind velocity and duration were analyzed by Bhowmik (1976, 1978) for 5 climatological stations in and around the State of Illinois. The design wind velocity was selected for each reach based on its proximity to the climatological station for which data have been analyzed. The wind data analyses also included the variability of the prevailing wind directions. Once the wind velocity and direction were selected, the maximum fetch, F, facing the exposed bank was measured from the Chart of the Illinois Waterways (1974). Here fetch, F, is defined as the maximum length of the water surface over which the wind blows before it is deflected by the bank. In any confined waterway, the maximum fetch is usually much larger than the width, W, of the waterway normal to the direction of the fetch. In all the theoretical relationships that have been developed by various researchers to compute the wave heights thus far, fetch is used as a parameter provided the value of the width of the waterway normal to the direction of the fetch is also as long as the fetch itself. In order to make corrections for the effects of the confined waterway, the following equation was utilized to compute the effective fetch, designated as F_e.

$$F_e = 1.054\ W^{0.6}\ F^{0.4} \qquad (9)$$

This equation is valid whenever the ratio of W/F is between 0.05 to 0.6. However, when the value of W/F is more than 0.6, the total length of the fetch was used to compute the wave height.

The significant wave height designated as H_s was computed by the following equation (Bhowmik, 1976).

$$gH_s/U^2 = 3.23 \times 10^{-3}\ (gF_e/U^2)^{0.435} \qquad (10)$$

Here H_s is in feet, g is in feet/sec^2 and U is the wind velocity in fps. The wave height exceeded by one-third of the waves in the wave profile is defined as the significant wave height, H_s. With the computed value of H , the measured value of bank slope, α, and an assumed value of the specific gravity, the median weight of the stable riprap particle, W_{50}, was computed by the following equation.

$$W_{50} = (0.388\ S_s H_s^{\ 3}) \ / \ (S_s - 1)^3 (\text{Cos}\alpha - \text{Sin}\alpha)^3 \qquad (11)$$

where W_{50} is the median weight of the riprap particle in lbs., S_s is the specific gravity of the particle and a is the bank slope. For all computations, the value of S_s was assumed to be equal to 2.65.

Two sets of computations based on the two methods to determine the fetch length were made to estimate the significant wave heights for each reach. Techniques for determining the fetch lengths for each method are shown in Figure 40. For the first computation,the fetch (a) was assumed to be the maximum length of the water surface over which the wind can blow based on the prevailing wind direction. Here, the measured fetch, F, was modified to estimate the effective fetch, F_e from equation 9 to account for the constricted nature of the waterway. This value of F_e was then used to compute H_s from Equation 10. In the computation of W_{50} from Equation 11, the bank slope α had to be modified to account for the directional orientation of the fetch, F.

For the second computation the wind and the fetch (b) was taken in a direction normal to the exposed bank. Here no correction was used to account for the constriction of the waterway.

The computational procedure outlined above was followed for each

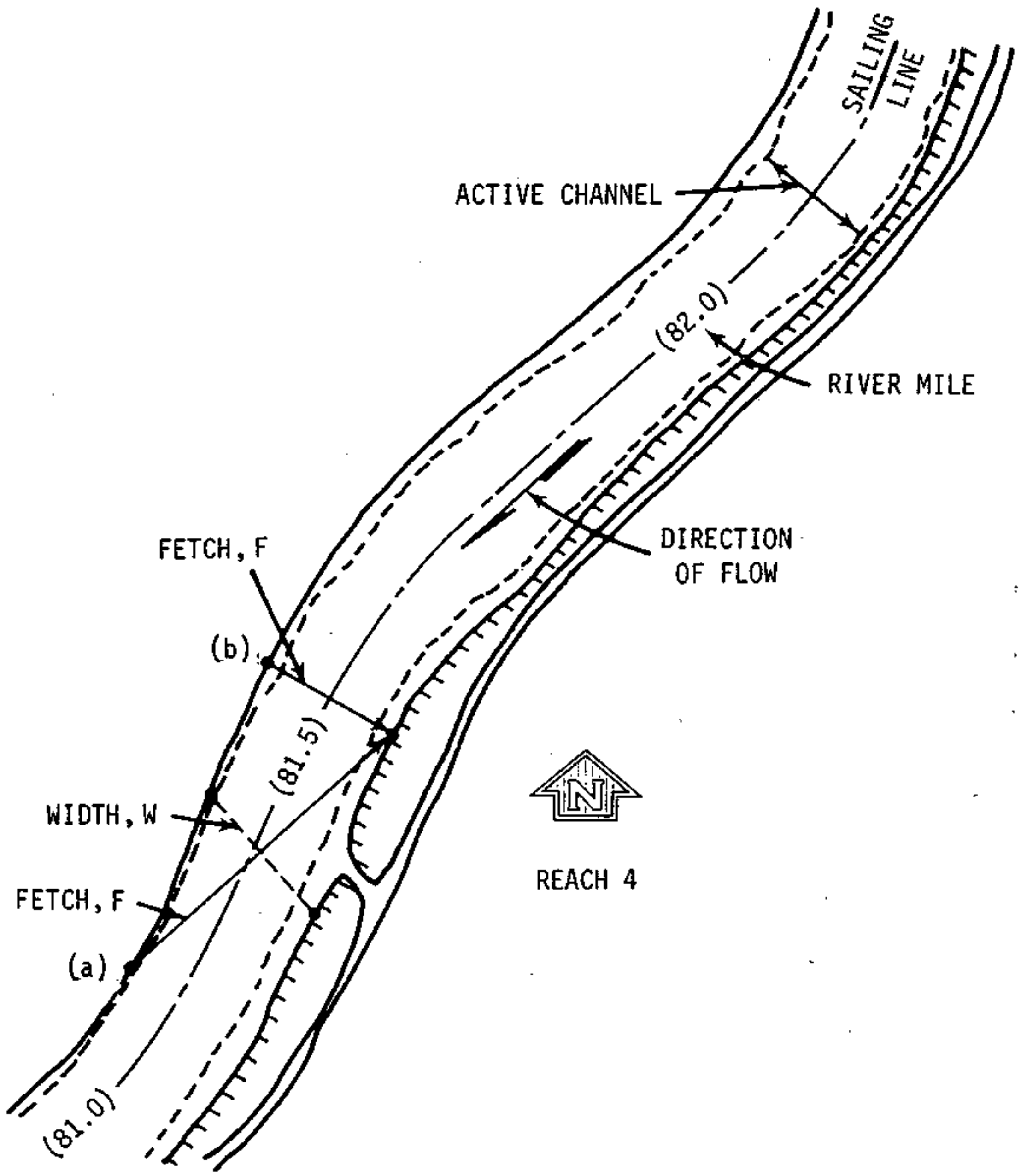


Figure 40. A Typical Reach Showing the Direction of Wind and Fetches Utilized to Compute the Wind-Generated Wave Height

reach of the river. For a detailed step by step procedure, the reader is referred to the original publication by Bhowmik (1976).

Utilizing the procedure outlined above, computations were made to estimate the stable size of the bank materials against an anticipated wave action. These results are given in Table 9. The computed values of the median diameter of the stable particles and the existing and measured median diameter of the bank materials are given in the last two columns. A comparison between these two sets of the sizes of the median diameters will show that in all instances, the estimated stable particle size is much higher than the existing size of the bank material.

Table 10 shows the computed values of the stable median diameter of the particles for selected reaches when the prevailing wind direction normal to the bank is considered. For these cases where the fetch is much smaller than for the case (a), (Figure 40) the estimated d_{50} is always higher than the existing d_{50}.

Bank materials along the Illinois River are basically sandy to silty with some clay content. Any material with clay will be cohesive and hence may be more stable than the purely non-cohesive materials. Therefore, in some cases, although the numerical differences between the computed and existing d_{50} sizes are very high, the effective size difference, considering the stability of the sand, silt and clay mixture, may not be that high. Even though we can assume that this clayey mixture is more stable than non-cohesive materials of fine to median size sands, still it is unmistakably clear that the stable sizes of the bank material must be much higher than the existing bank material at those selected 20 reaches of the Illinois River considering wind-generated wave action.

Table 9. Measured and Computed Median Diameter of the Bank Materials Considering Wind-Generated Wave Action

(Waves Generated in the direction of Maximum Fetch)

Reach No.	Wind Characteristics				Fetch in the Direction of Wind, F, ft	Width, Normal to the Direction of Fetch, ft
	Climatological Station	Month of the Year	Wind Velocity,* U, fps	Wind Direction		
1	St. Louis	March	67.42	40°SW	2700	580
2	St. Louis	March	67.42	30°SW	3800	900
3	Springfield	March	95.32	45°NW	1100	700
4	Springfield	March	95.32	45°SW	2000	850
5	Springfield	March	95.32	52°SW	5700	420
6	Springfield	March	95.32	0°W	6000	500
7	Springfield	March	95.32	0°W	1900	500
8	Springfield	March	95.32	30°SW	4850	600
9	Springfield	March	95.32	40°SW	4000	500
12	Springfield	March	95.32	50°SW	8200	600
13	Springfield	March	95.32	50°SW	3600	500
14	Springfield	March	95.32	30°SW	1100	550
15	Moline	May	84.01	30°SW	1300	700
17	Moline	May	84.01	60°SW	4800	900
18	Moline	May	84.01	75°SW	4000	570
19	Moline	May	84.01	60°SW	2800	680
20	Moline	May	84.01	80°SW	1800	650
22	Urbana	March	61.0	75°SW	2300	500
23	Urbana	March	61.0	75°SW	4000	550
24	Urbana	March	61.0	60°NW	2800	3000

* 6 hour duration and 50 year return period

Table 9. Measured and Computed Median Diameter of the Bank Materials Considering Wind-Generated Wave Action (cont.)

(Waves Generated in the direction of Maximum Fetch)

Reach No.	Effective Fetch, Fe, ft	Significant Wave Height, H_s, ft	Bank Slope along the Direction of Fetch, degrees	Median Weight of the Stable Riprap, W_{50} lbs	Equivalent Median Diameter of the Stable Riprap, d_{50} inches	Average Existing Median Diameter of the Bank Materials, d_{50} inches
1	1131	1.13	1.7	0.36	1.9	0.00053
2	1688	1.34	3.7	0.68	2.4	0.00083
3	884	1.50	3.8	0.95	2.7	0.0020
4	1262	1.75	3.0	1.45	3.1	0.0044
5	1256	1.75	6.4	1.77	3.3	0.00064
6	1424	1.84	3.2	1.71	3.2	0.00029
7	899	1.51	1.5	0.85	2.6	0.00085
8	1459	1.86	3.8	1.83	3.3	0.010
9	1211	1.72	2.6	1.33	3.0	0.062
12	1800	2.04	5.1	2.61	3.7	0.00072
13	1161	1.69	5.1	1.47	3.1	0.0027
14	765	1.41	4.2	0.81	2.5	0.0030
15	945	1.34	0.8	0.57	2.2	0.0061
17	1853	1.79	1.7	1.44	3.1	0.0042
18	1310	1.54	4.5	1.08	2.8	0.0051
19	1262	1.52	1.0	0.85	2.6	0.0056
20	1030	1.39	1.5	0.67	2.4	0.010
22	970	0.94	1.2	0.20	1.6	0.0051
23	1282	1.06	1.0	0.29	1.8	0.032
24	2800	1.49	9.5	1.38	3.0	0.67

TABLE 10. Measured and Computed Median Diameter of the Bank Materials Considering Wind-Generated Wave Action

Waves Generated in a Direction Normal to the Bank

Reach No.	WIND CHARACTERISTICS				Fetch in the Direction of Wind F ft
	Climatological Station	Month of the Year	Wind Velocity,* U fps	Wind Direction	
1	St. Louis	March	67.42	62°NW	580
2	St. Louis	March	67.42	73.5°NW	750
3	Springfield	March	95.32	71.5°SW	600
4	Springfield	March	95.32	63°NW	800
6	Springfield	March	95.32	30°SW	600
13	Springfield	March	95.32	30°SW	600
14	Springfield	March	95.32	80°NW	520
15	Moline	May	84.01	67°NW	700
18	Moline	May	84.01	30°SW	600
22	Urbana	March	61.0	0°S	550
24	Urbana	March	61.0	72°NW	1550

*6 hour duration and 50 year return period

Reach No.	Significant Wave Height, H_s ft	Bank Slope along the Direction of Fetch, degrees	Median Weight of the Stable Riprap, W_{50} lbs	Equivalent Median Diameter of the Stable Riprap, d_{50} inches	Average Existing Median Diameter of the Bank Materials, d_{50} inches
1	0.84	8.4	0.23	1.7	0.00053
2	0.94	10.4	0.37	2.0	0.00083
3	1.27	9.0	0.81	2.5	0.0020
4	1.43	7.7	1.08	2.8	0.0044
6	1.27	15.1	1.32	3.0	0.00029
13	1.27	7.5	0.72	2.4	0.0027
14	1.19	11.5	0.81	2.5	0.0030
15	1.17	4.5	0.48	2.1	0.0061
18	1.10	8.4	0.50	2.2	0.0051
22	0.74	6.4	0.13	1.4	0.0051
24	1.15	11.6	0.75	2.5	0.67

Waterway Traffic Generated Waves

Commercial or pleasure crafts traveling in any waterway may generate waves which may be detrimental to the banks of the waterway. The Illinois river is one of the major waterways of the Midwest and it carries a tremendous amount of barge traffic in addition to the normal pleasure crafts.

As far as it is known to the authors, no field data has been published related to the distribution and magnitudes of waves generated by barge traffic in a waterway. Some laboratory data has been reported by DAS (1969) and Sorenson (1973). Bhowmik (1976) collected a very limited amount of boat-generated wave data from a lake and has developed a relationship for computing the maximum wave height.

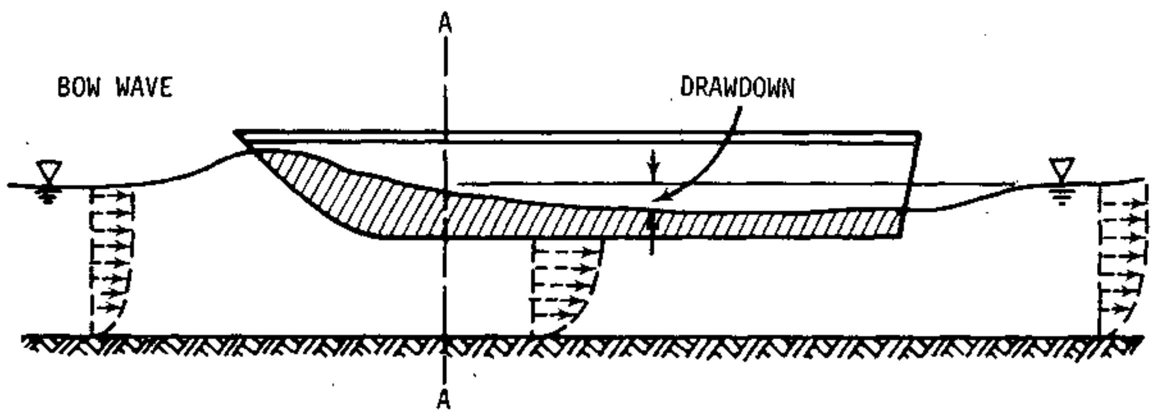
Karaki and Van Hoften (1974) described the various principles involved in the generation of waves by passing river traffic especially in the Illinois and Upper Mississippi Rivers. No theoretical analysis was made or no field data were collected for this report. A number of color aerial photographs were shown in this report depicting the pattern and the type of waves generated by waterway traffic.

Johnson (1976) and Karaki and Van Hoften (1974) discussed the effect of barge traffic on the resuspension of the sediment particles with an associated increase in turbidity and its effect on the dissolved oxygen concentrations in the Illinois and Upper Mississippi Rivers. Liou and Herbich (1977) developed a numerical model to study the sediment movement in a restricted waterway induced by a ship's propeller.

Figure 41 shows a sketch of a moving boat in a waterway indicating what occurs to the velocity distribution in a river just upstream, underneath and downstream of the moving boat. The hydraulic forces that a channel bank and bed must withstand during the passage of a barge are shown in Figure 42. There are three different cases depicted: for deep, normal and shallow channel depths. For shallow water flow, the lateral and longitudinal flow velocity underneath a moving barge must increase tremendously increasing the scour of the bed and the erosion of the banks. However, field data are needed before any definitive type of analysis or statements can be made regarding the potential of barge traffic on the scouring of the bed or erosiveness of the banks.

SUGGESTED MONITORING PROGRAM

It is suggested that a monitoring program be undertaken to document any future changes in bank erosion along the Illinois river. Locations recommended for monitoring are the 20 locations selected for the present analysis as shown in Figure 3. Bank erosion along these reaches has already been well documented with permanent concrete monuments installed. Base line data, such as plan view and bank slope, are available for 1978 conditions. These reaches also represent some of the more severely eroded banks of the Illinois river. The program recommended is as follows.



Water surface profile
along the side of a boat

(After Karaki and vanHoften, 1974)

Figure 41. Surface Disturbances Created by Boats

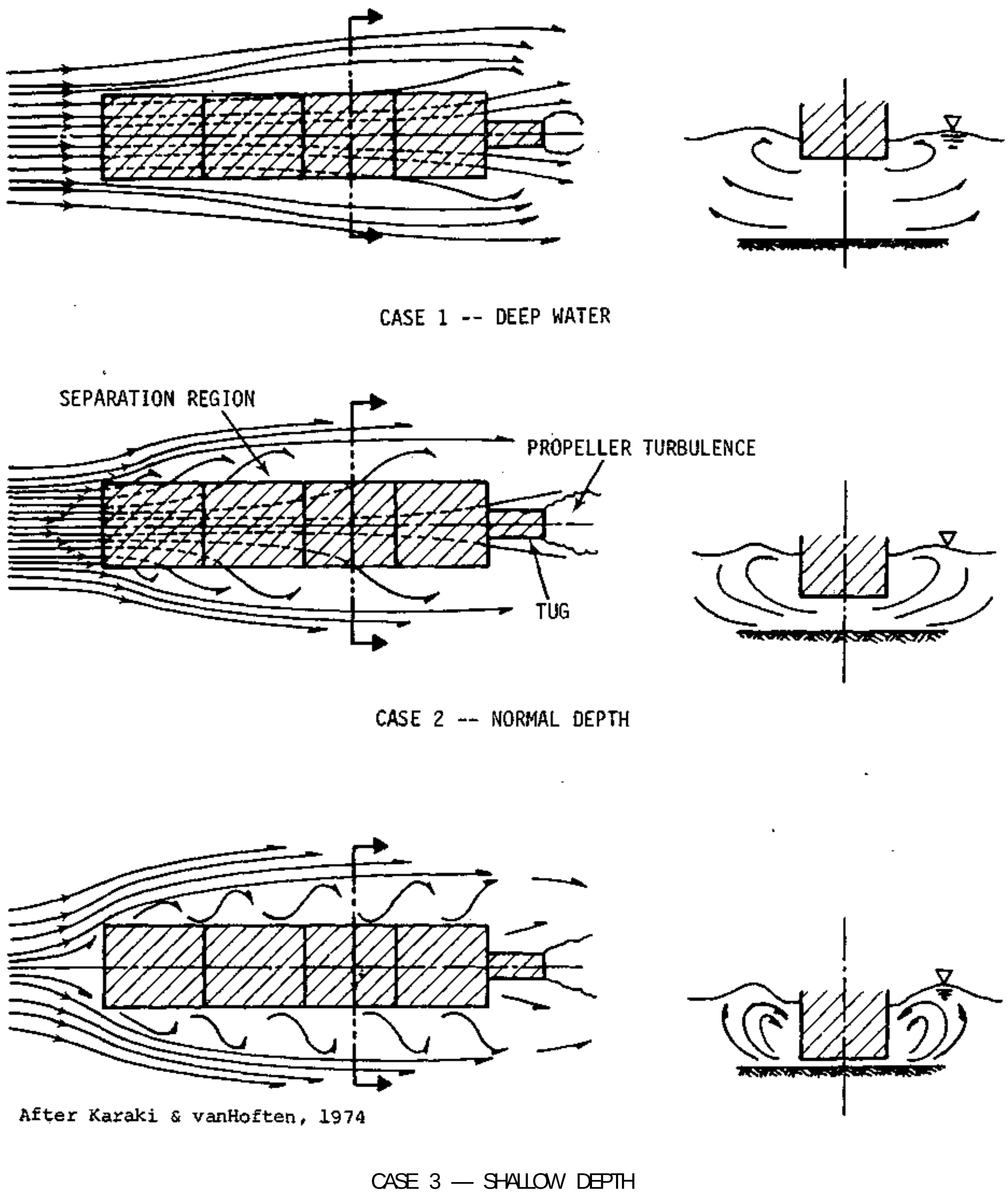


Figure 42. Acceleration of Flow and Turbulence Created by Tow Boats

a. Resurvey all 20 reaches selected for the present investigation. Determine the plan view and bank slopes for each reach. Collect representative bank material samples from each reach.

b. Compare the newly developed plan view and the measured bank slopes with the original set of data collected in 1978. Determine the rate of erosion. Compare the changes in the bank material composition to check for any changes or variations.

c. Reanalyse the stability of the banks at selected reaches for the changed circumstances.

d. Based on the original and the new set of data, make an attempt to postulate the probable changes in the rate or nature of bank erosion along the Illinois river.

e. If new information or data are available related to the characteristics and nature of waves generated by the waterway traffic, incorporate these data in the stability analyses.

It is estimated that the above monitoring program will cost about $40,000 per year.

FUTURE RESEARCH

The analysis presented thus far indicates that severe bank erosion occurs along the Illinois river. The normal flow characteristics of the river may or may not be responsible for the bank erosion of the river. The present analysis indicates that the wave action in the river may be the main cause of bank erosion. Waves in an inland waterway are generated by wind and waterway traffic. The nature and characteristics of the waves generated by these two factors are not necessarily the same.

An extensive literature search indicated that very little basic information exists regarding the waves generated by waterway traffic and its potential for river bank erosion. Moreover, the waves generated by wind in an inland stream, its interaction with the flow velocity, confinement of the waterway and the relative interdependence between these parameters are not well understood. With this background in mind, it is proposed to undertake a research investigation entitled:

"WAVES GENERATED BY RIVER TRAFFIC AND WINDS ON THE ILLINOIS RIVER"

The proposed research is described below.

a. Research Objectives: The two broad objectives of the research are:

A. To collect a set of data on waves generated by river traffic and winds on the Illinois River to answer questions such as, "What are the characteristics of tow, barge, or boat-generated waves in an inland waterway? What are the similarities and dissimilarities between these waves and those produced by natural effects such as wind?"

B. To determine the bank erosion potential of these waves and suggest some preventive measures to protect the banks against the destructive action of the traffic and wind-generated waves.

b. Research approach: Four representative reaches of the Illinois River will be selected for study. At each reach wave data will be collected and analyzed to determine amplitudes, periods, energy spectrum, and other relevant parameters. Correlations between the speed of the river traffic, distance of the sailing line from the bank, the width, length, and draft of the vessels, and wave parameters such as maximum wave height or significant wave height will be developed. From consideration of the wave characteristics, mechanics of flow in the river, sediment transport, nature of the bed and bank materials, geology and other pertinent parameters, a methodology will be suggested for protecting or preventing stream bank erosion.

c. Research Result Users: Federal, State, Private, Local and Regional agencies entrusted with maintaining the inland waterways of this nation would be the main beneficiaries of this research. The results of the analysis of the basic data will definitely have a broad spectrum of application related to waterway traffic generated waves in any inland waterway, intracoastal waterways, and in some cases in lakes.

d. Duration of the Project: This project will last for a period of two years. During the first year, basic field data will be collected. The second year will mostly be devoted to data analysis and interpretation. It is expected that the field personnel from the Corps of Engineers offices will be requested to assist in the data collection program and also in the surveillance of the field instrumentations.

The total estimated cost of this proposed research will be $70,000. Out of this amoung, $40,000 will be needed for the first fiscal year and $30,000 for the second year.

SUMMARY AND CONCLUSIONS

Erosion of the stream bank attracts public attention, reduces property value, results in permanent loss of real estate, increases the turbidity of the stream, and accelerates the silting of reservoirs or backwater lakes along the stream course. Banks of any stream or river flowing through non-cohesive or partly cohesive materials will erode if natural or artificial protection is lacking. Bank erosion does exist in the Illinois river ranging from negligible to severe. The normal flow characteristics, changes in the flow regime and water wave action in the river initiates and sustains the bank erosion.

The present investigation of bank erosion along the Illinois River was initiated to study the probable effects of increased di-verison from the Lake Michigan. A boat trip was taken to document and select some representative bank erosion areas of the Illinois river. A total of 67 bank material samples and 54bed material samples were collected and analysed to determine the particle size distribution of the materials. A total of 20 eroded reaches of the river were selected for study. Present plan view and bank slopes were surveyed and a permanent concrete monument was installed at each reach for future monitoring.

Based on present and anticipated flow condition, measured and estimated hydraulic parameters, bank stability analyses at each study reach were made following different accepted procedures. Stability analyses indicate that as far as the flow hydraulics are concerned, bank erosion along the Illinois river will not be affected by the proposed increase in diversion. In all probability, the main cause of the bank erosion of the Illinois river is the wave action caused by the wind and the waterway traffic.

A future monitoring program is proposed to document and monitor areas of bank erosion along the river at a few selected locations.

A research project is also suggested to investigate the effects of waves on the stability of the banks. The two types of waves that are to be studied are the wind-generated waves and the waves produced by waterway traffic.

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APPENDIX A

Surveying Method and

Monument Location Descriptions

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"ILLINOIS RIVER BANK EROSION PROJECT"

TIME: The survey was conducted between September 7, 1978 and October 6, 1978

METHOD OF SURVEY

I.. VERTICAL CONTROL

The vertical control was established by using existing Coast and Geodetic Survey bench marks and as built elevations at the LaGrange Lock and Dam and the Commonwealth Edison Plant at Morris, Illinois. The level crew used a Carl Zeiss Ni - 2 instrument to establish the elevations on the monuments points. Elevations were established on the brass plugs implanted in the concrete monuments at all reaches except 13, 14, 15, and 17. At these locations, the elevations were established on top of the protruding iron pin.

As the elevations were taken along each, they were either read directly (90° 00') or by reading a vertical angle and distance using a Wild T-2 Theodolite.

II. HORIZONTAL CONTROL

The horizontal control was established by using a Wild T-2 Theodolite and a graduated level rod. Angles were read to the nearest 05" on all points, except turning points at which time the angles were read to within 01". Distances were all read to the nearest 1.0 foot.

At each reach a solar observation was taken using a Roelofs Solar Prism and an Instar Solid State watch check against radio station WWV. Both the horizontal and vertical angles to the sun were read and the altitude method of calculation the bearing of the line of each reach was used. This method will give an accuracy of 30" +. Each solar observation was made a minimum of 4 times and a maximum of 6 times.

III. TIES

Each reach, except reach 13 and 24 were tied into existing lights or day markers, by either triangulation or reading a direct angle and distance to the light or day marker. At reach 13 the light or daymarker no. 149.4 could not be found; however the reach was tied into the Northern Potrochemical Company Loading Dock (formerly the Olin Mathieson Chemical Co.) At reach 24 the light and day marker are located on an island and the reach is a bend making it impossible to tie in.

Wherever possible physical ties were taken and are shown on the plan sheet. At all reaches except reach 13 and 24 a distance was either physically measured or computed from the light or day marker to the monument. These distances are measured along the side that the reach is on.

IV. PLOTTING

Each reach is plotted on a plan sheet using a scale of 1"=200'. A solid line indicates the top of the bank with a dashed line indicating the water's edge at that date. In some cases the top of the bank extends to the top of existing levees, in areas such as reach 2 and 15 where the reach is located on an island, the top of bank means the point at which the ground levels off.

Several typical cross-sections are shown plotted on cross-section paper. Along with this report each cross-section taked on every reach has been charted, starting at the monument or downstream and working upstream. The top of bank was used as O feet with the elevation of that point. Then each break in the ground slope is shown with elevation and distance from 0. The water's elevation for that day has been noted.

In some locations a bottom elevation is not shown. This is because of river conditions being impossible to control the boat long enough for the transit man to obtain the readings. Also some reaches have what looks like inconsistent water elevations. This is due to the level rod sinking into mud or wave action of barges and other traffic conditions.

V. MISCELLANEOUS

The bearings that are shown on the plans and reported are True North bearings. Reach N. 2-3-4-5-6-7-8- amd 13 were computed in error, however re-computed at at a latter date. Since the cross section and plans had been completed only the arrow was changed. At the bottom of the cross section reports the differance between the computed North and the actual True North is shown. To obtain True North bearings on these reaches add or subtract the difference. The bearings shown on the tie sheets are current to True North.

SUBMITTED THIS 23RD OP OCTOBER, 1978

R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

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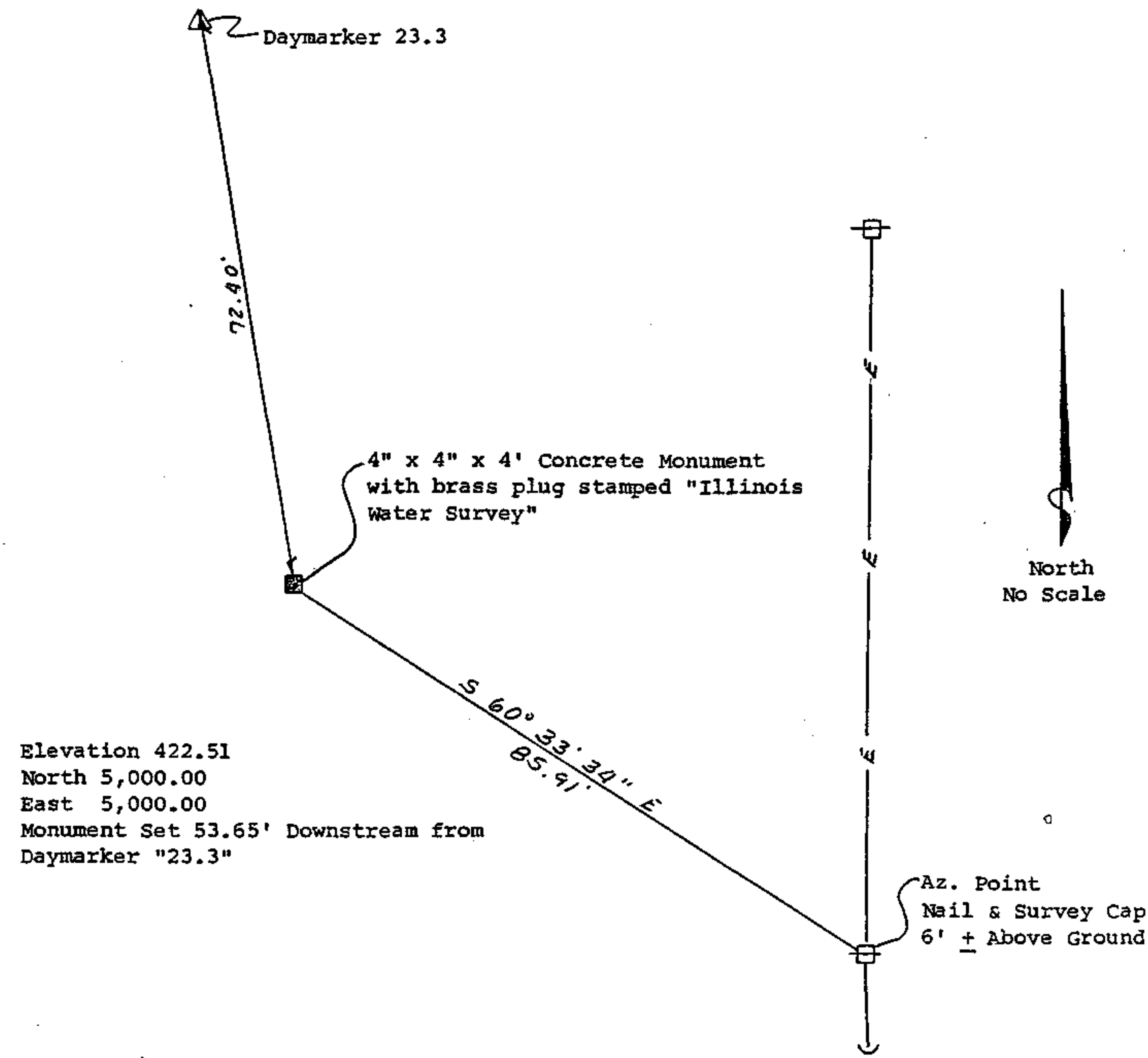
REACH I



R. Gregg Dodson

ILLINOIS REGISTERED LAND SURVEYOR #2010

Dodson - Van Wie
Engineering & Surveying, Ltd.
1213 Charleston Avenue
MATTOON, ILLINOIS 61938

PRESIDENT: Dean G. Van Wie. P. E.
V. PRESIDENT: R. Gregg Dodson, R.L.S.

ASSOCIATES:
Jim Fitzpatrick, P. E.
Terry Grass

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217-234-6459
217-234-6450

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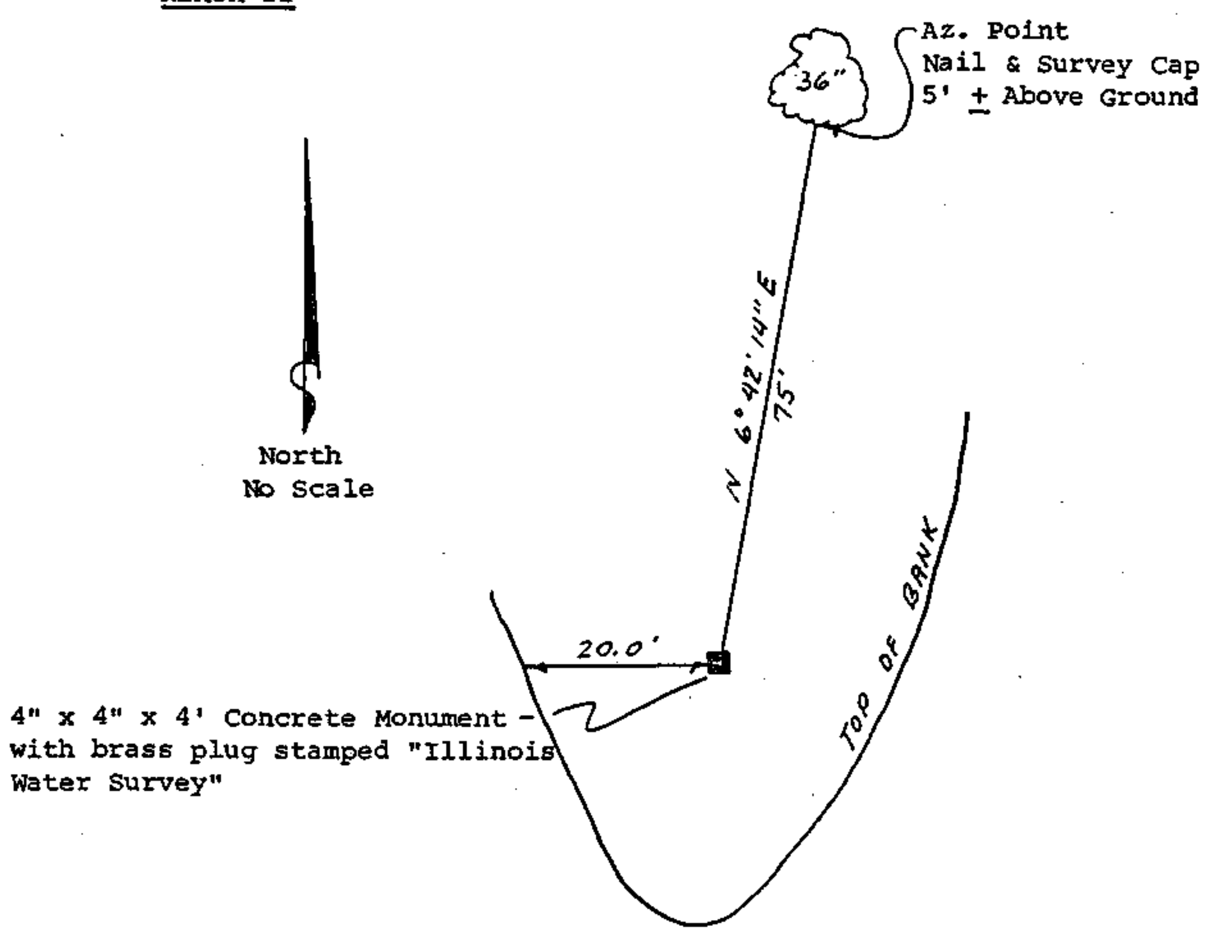
REACH II



Elevation 431-34'
North 5,000.00
East 5,000-00
Monument Set 3818.08'
Downstream from light "38.7"

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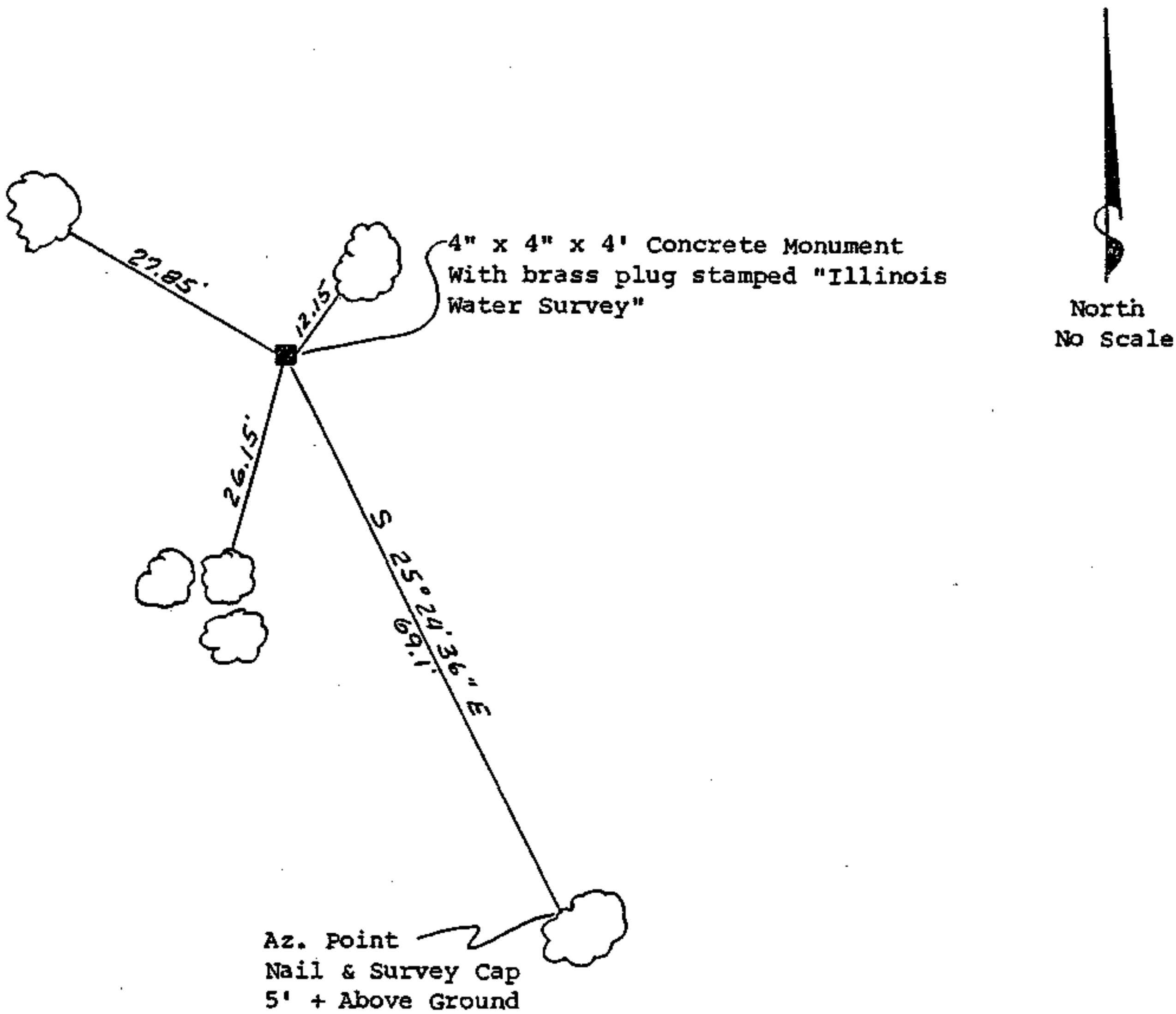
REACH III



Elevation 432.13
North 5,000.00
East 5,000.00
Monument Set 4697'
Downstream from Light
"60.8"

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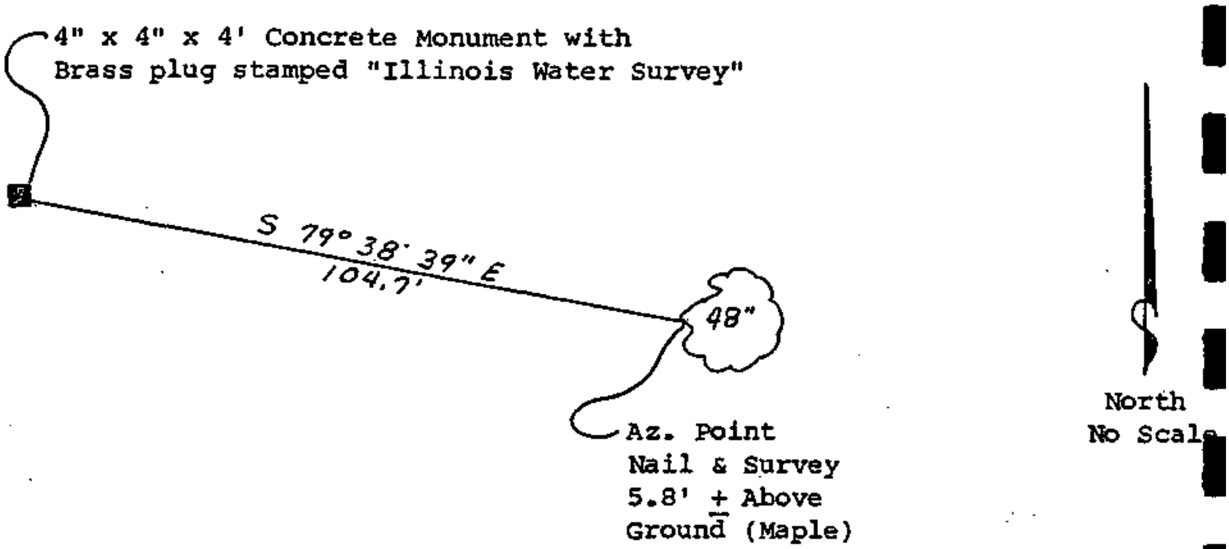
REACH IV



Elevation 434.35
North 5,000.00
East 5,000.00
Monument Set 3517.57'
Downstream from Light "82.3"

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Tarry Grass

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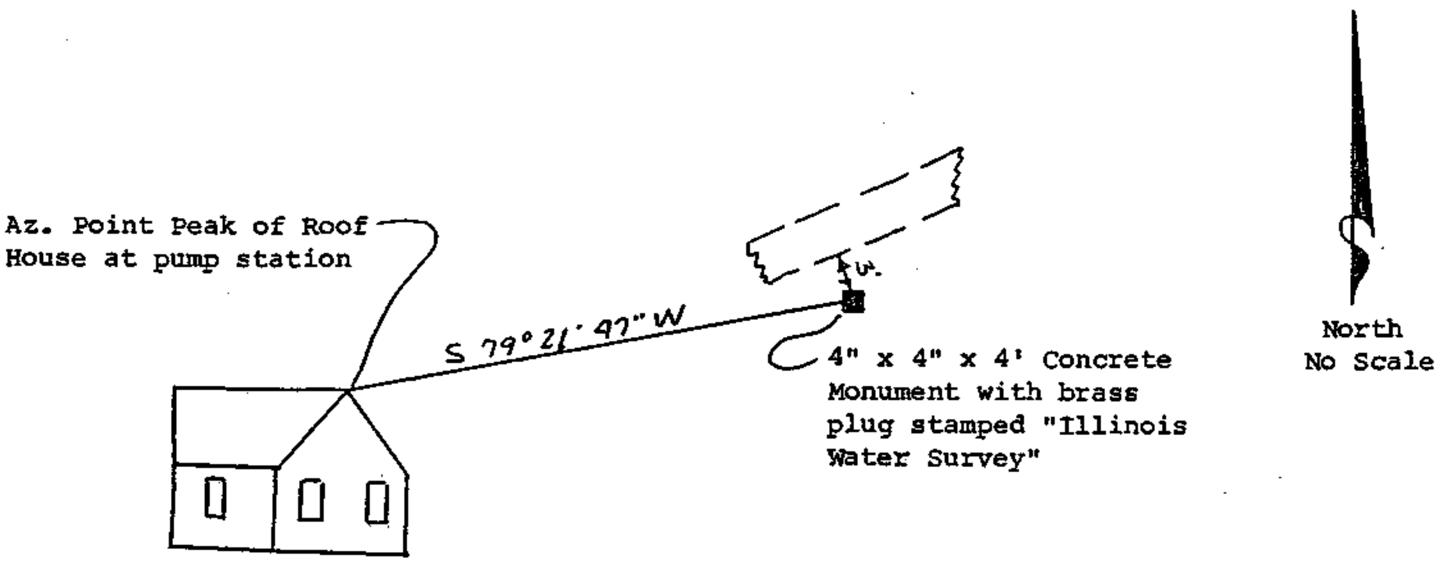
REACH V



Elevation 458.61
North 5,000.00
East 5,000.00
Monument set 1625.40'
Upstream from light "100.9"

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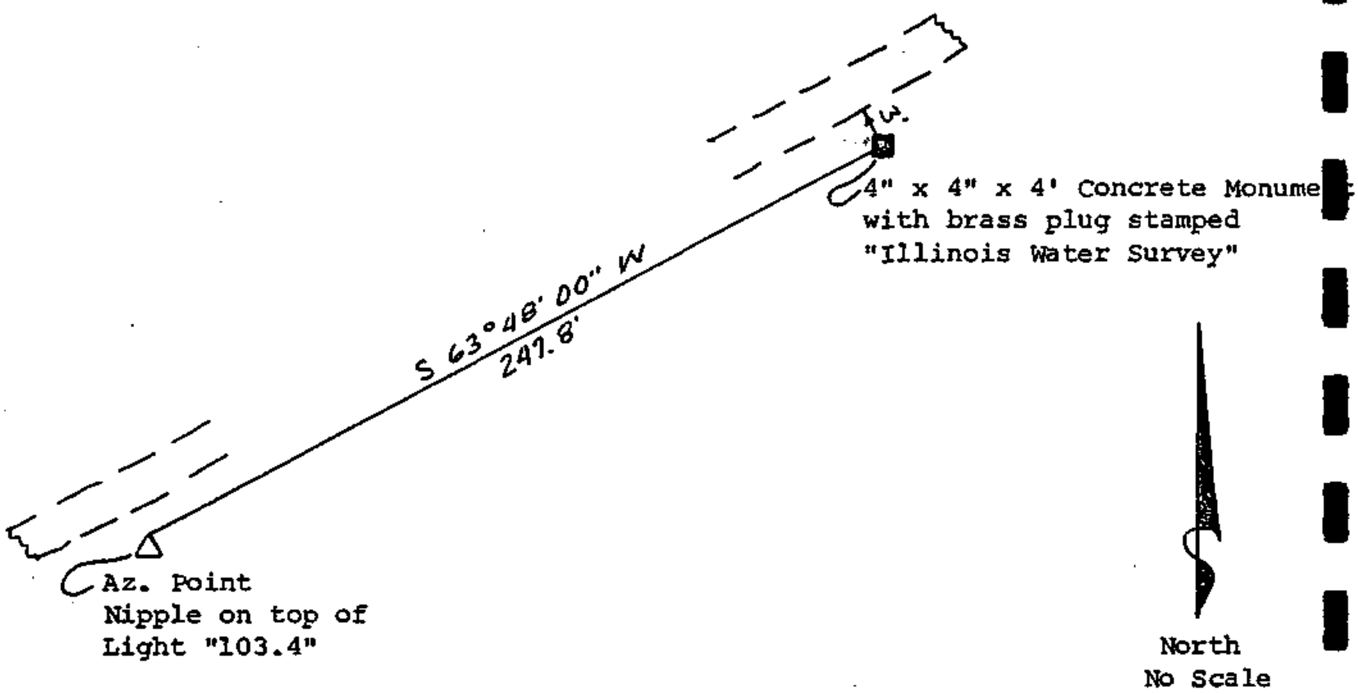
REACH VI



R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

Elevation 453.71
North 5,000-00
East 5,000.00
Monument set 247.68'
Upstream from light "103.4"

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217-234-6450

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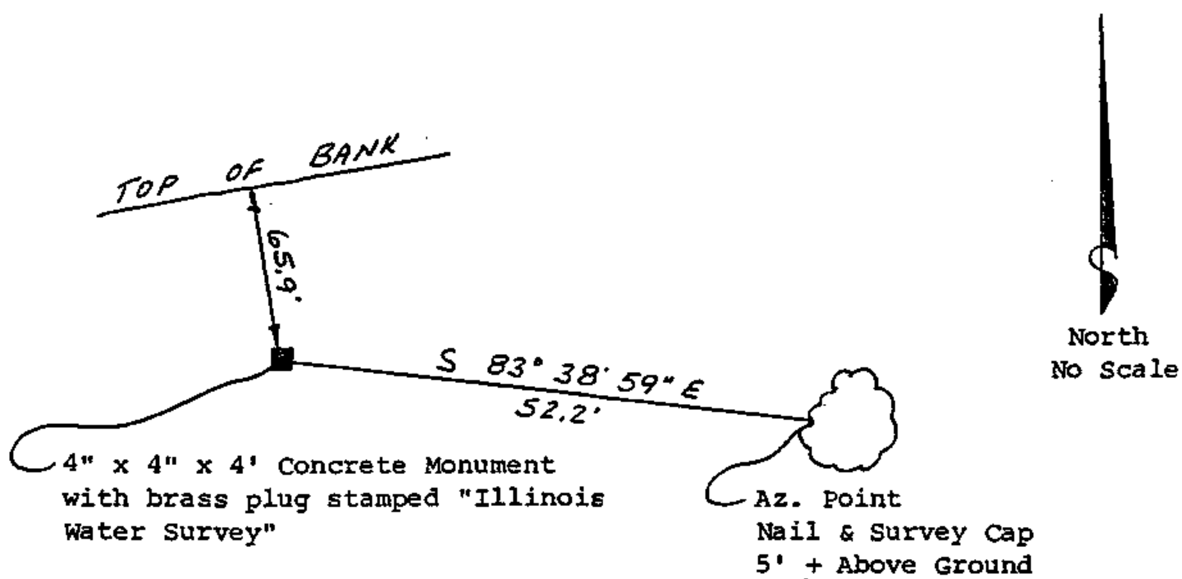
REACH VII



R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

Elevation 452.04
North 5,000.00
East 5,000.00
Monument Set 5718.00
Downstream From Light "113.3'

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217-234-6450

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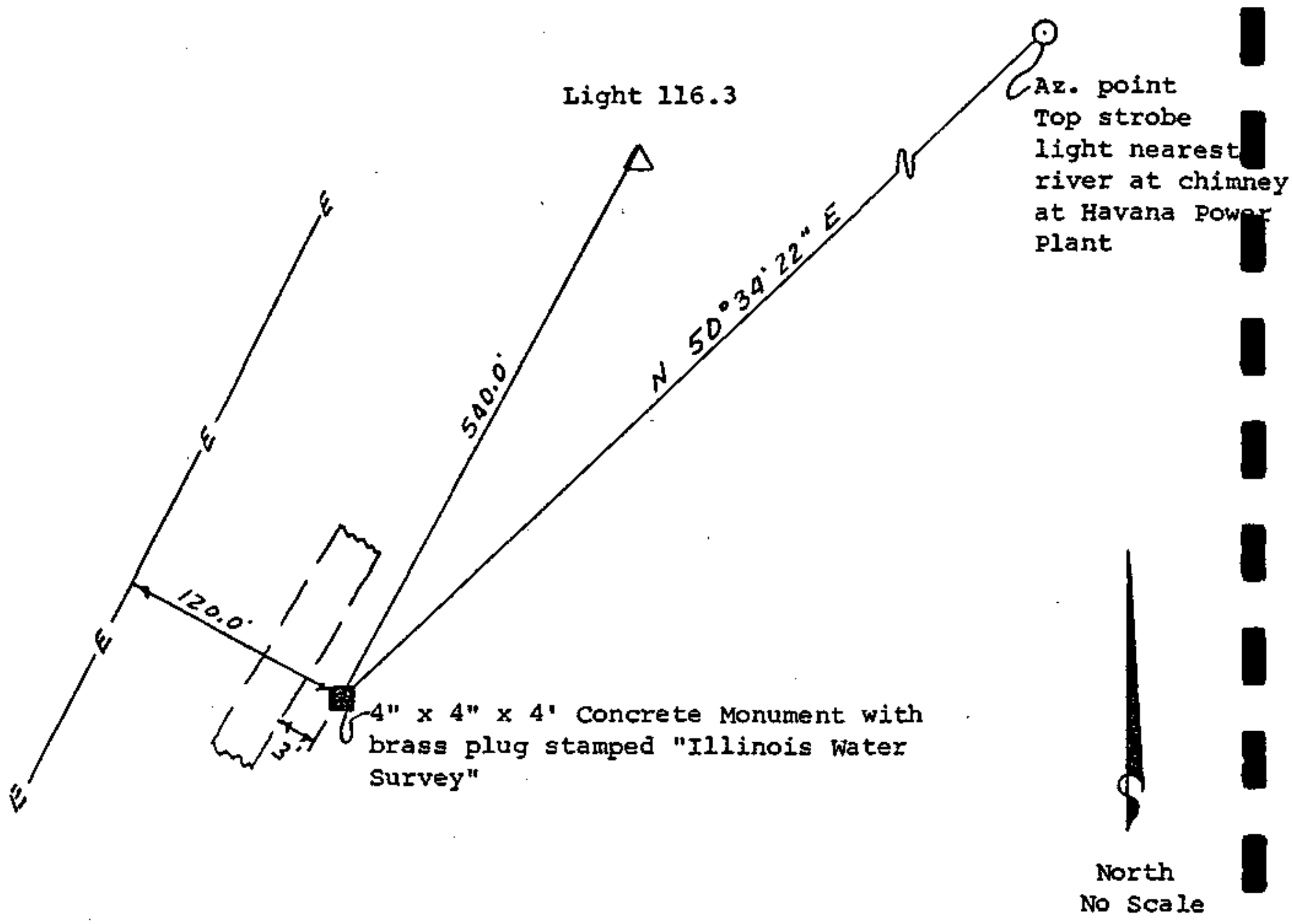
REACH VIII



R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

Elevation 469.33
North 5,000.00
East 5,000.00
Monument Set 540.00 Downstream
From Light "116.3"

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Terry Grass

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217-234-6450

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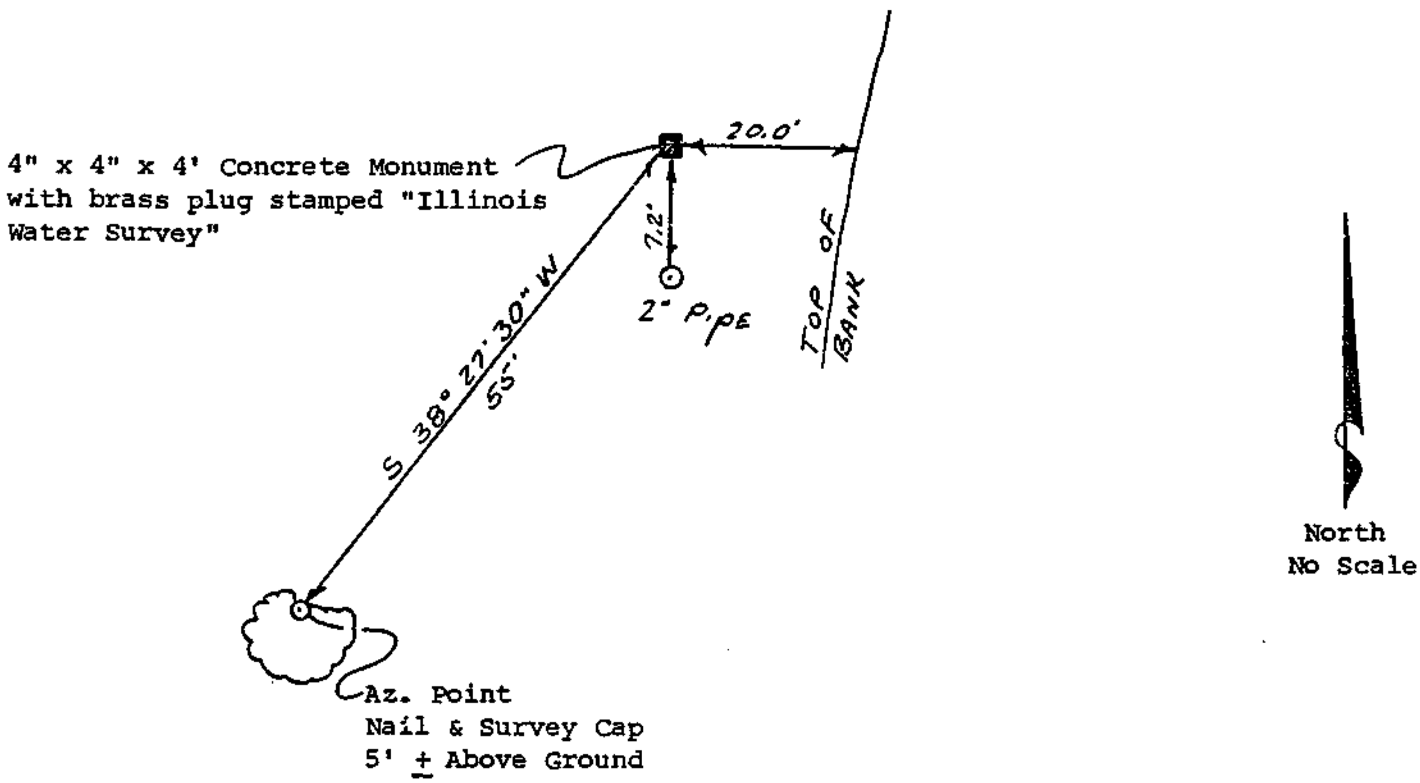
REACH IX



R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

Elevation 439.46'
North 5,000.00
East 5,000.00
Monument set 650.18' Downstream from Light "121.1"

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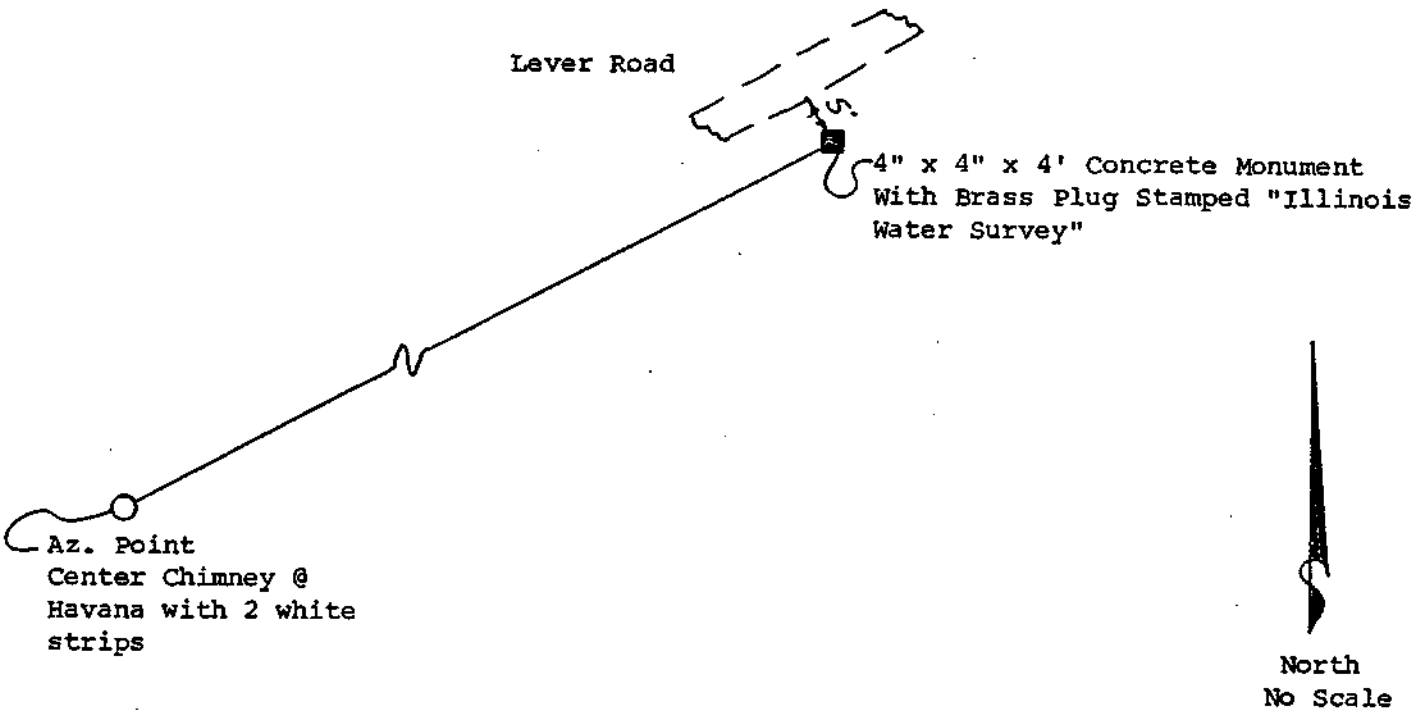
<u>REACH XII</u>



R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

Elevation 458.18
North 5,000.00
East 5,000.00
Monument Set 3041.27' Downstream
From Light "143.2"

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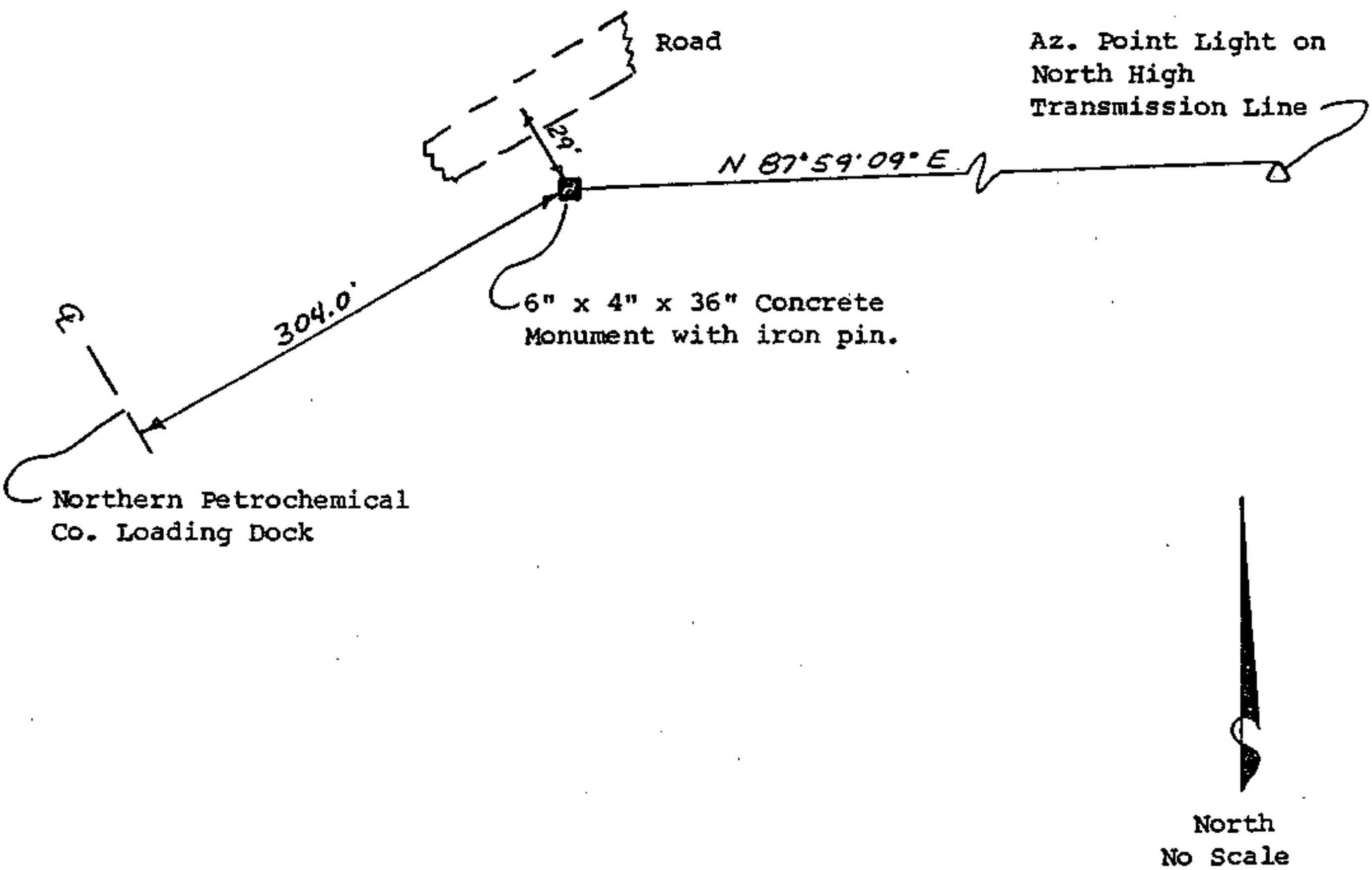
REACH XIII



R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

Elevation 445.17
North 5,000.00
East 5,000.00
Monument Set 304.0' Upstream
From Northern Petrochemical
Co. Loading Dock.

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Engineering & Surveying, Ltd.
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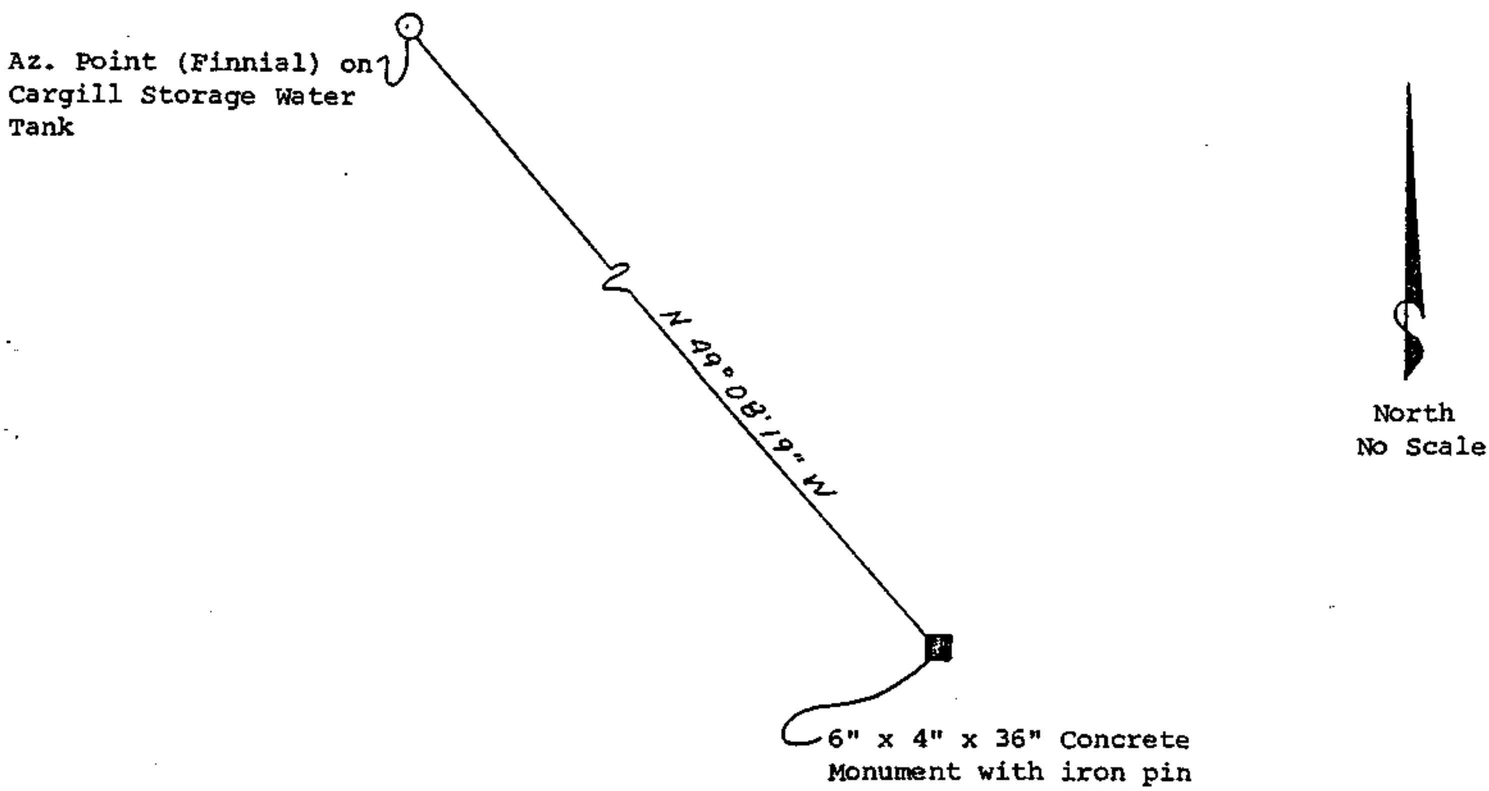
REACH XIV



R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

Elevation 453.00
North 5,000.00
East 5,000.00
Monument Set 1102.26' Upstream
From Light "153.5"

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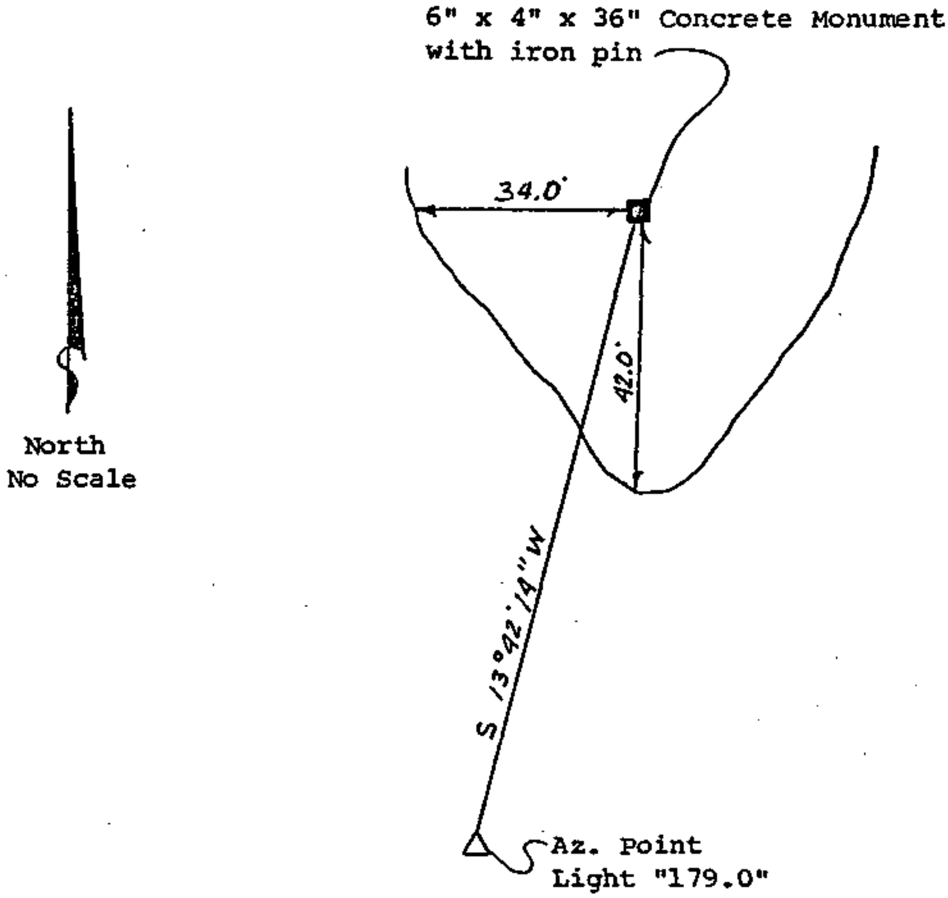
REACH XV



R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

Elevation 442.70
North 5,000.00
East 5,000.00
Monument Set 3439.18' Upstream
From Light "179.0"

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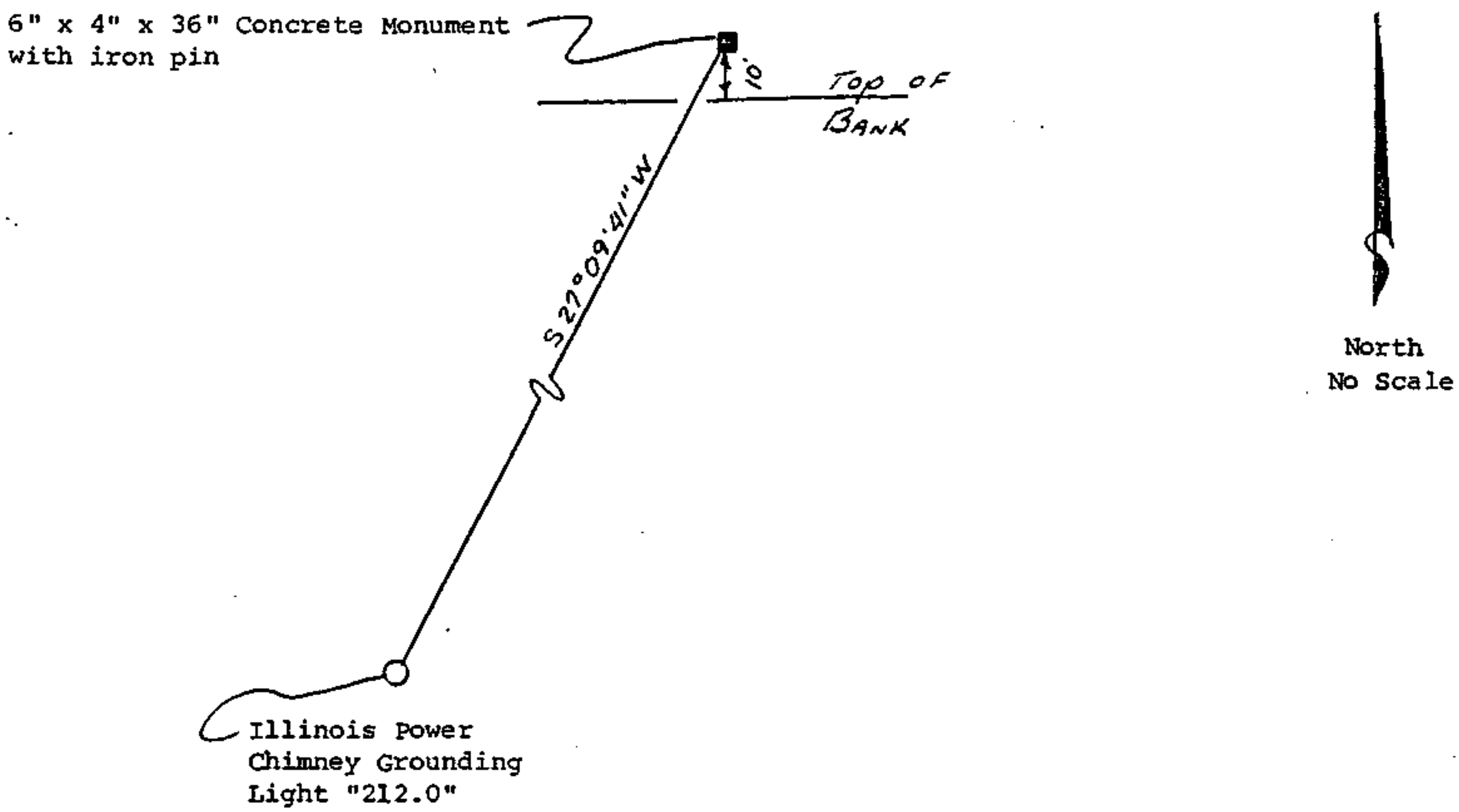
REACH XVII



R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

Elevation 455.76
North 5,000.00
East 5,000.00

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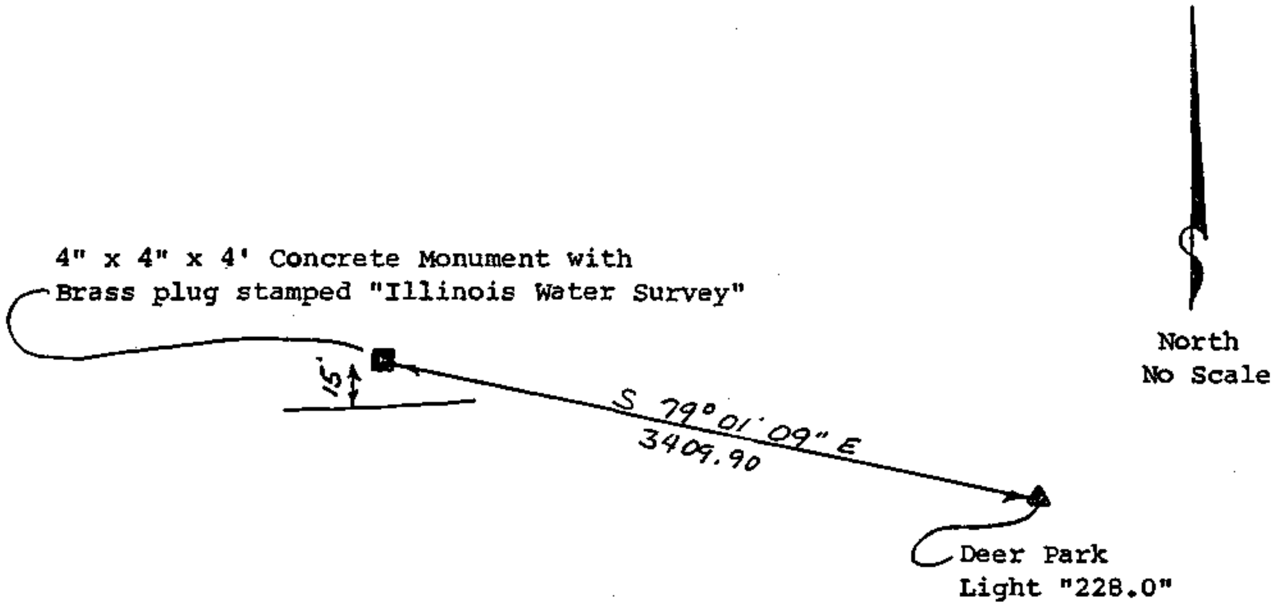
REACH XVIII



R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

Elevation 455.32
North 5,000.00
East 5,000.00
Monument Set 3409.90' Downstream
From Light "228.0"

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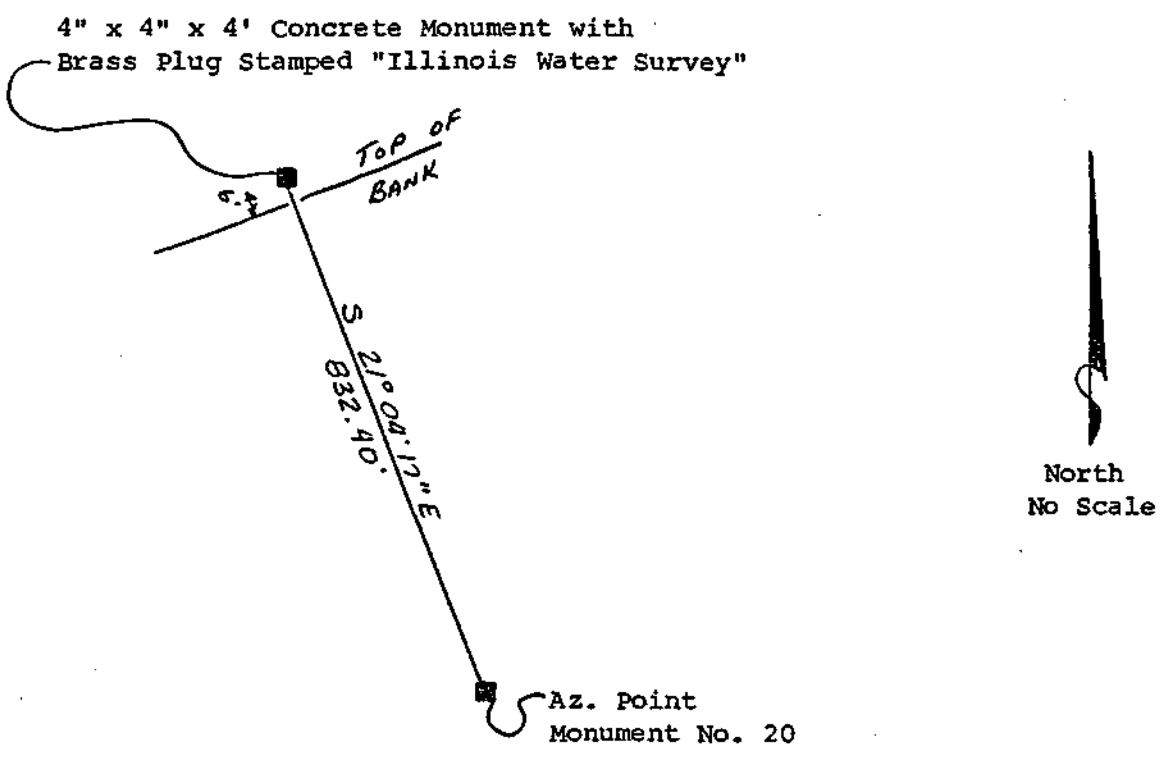
REACH XIX



R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

Elevation 456.30
North 5895.98
East 10726.90
Monument Set 2686.60' Upstream
From Light "228.0"

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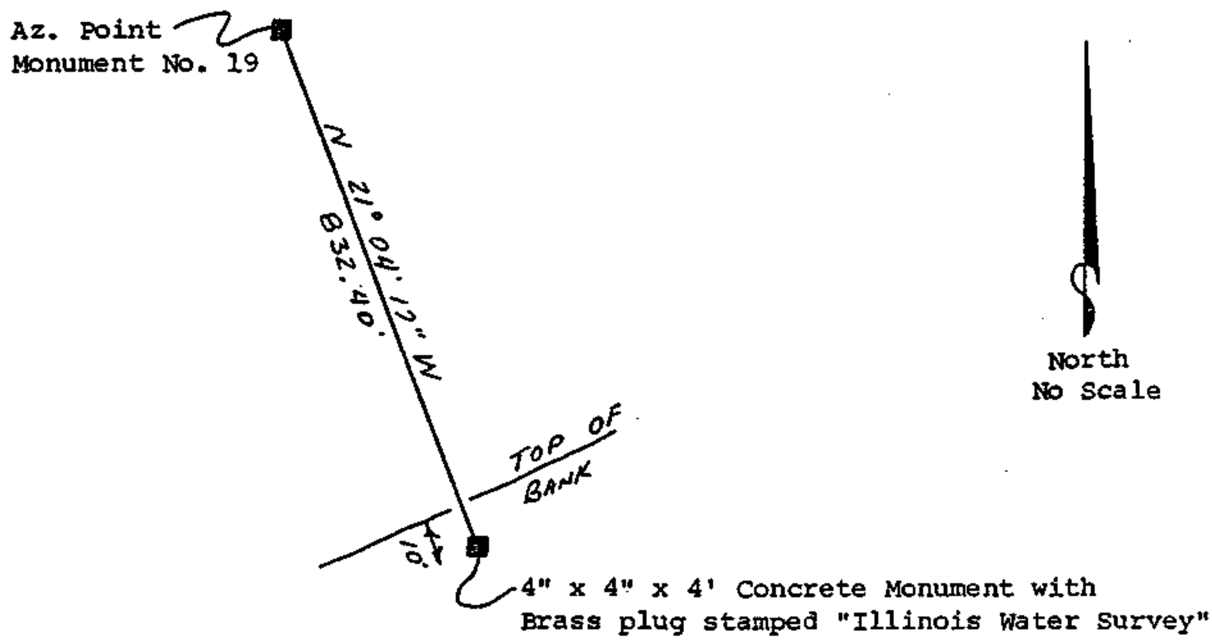
REACH XX



R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

Elevation 450.36'
North 5119.24
East 11026.18
Monument Set 2725.54' Upstream
From Light "228.0"

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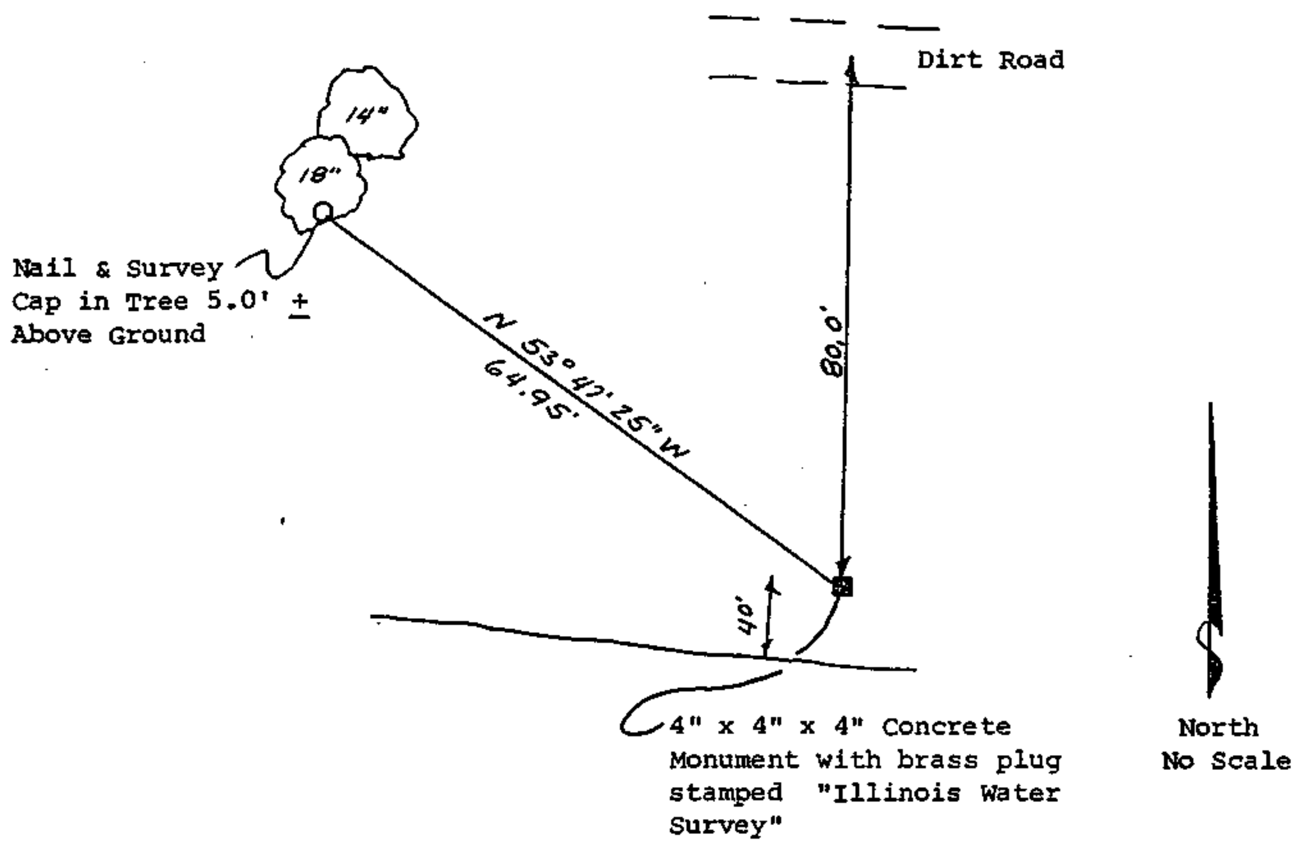
REACH XXII



R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

Elevation 494.45
North 5,000.00
East 5,000.00
Monument Set 4011.63' Downstream
From Light "262.6"

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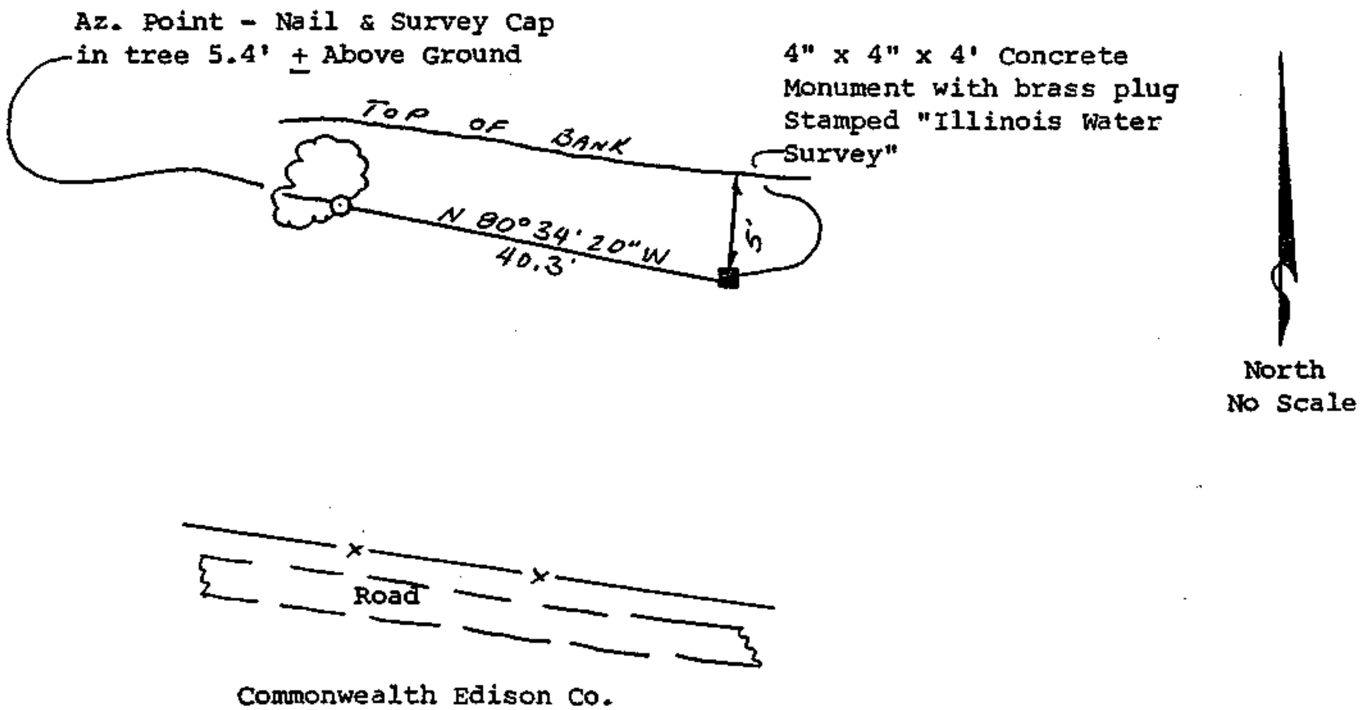
<u>REACH XXIII</u>



Elevation 498.80
North 5,000.00
East 5,000.00
Monument Set 1874.55' Upstream
From Light "267.2"

R. Gregg Dodson
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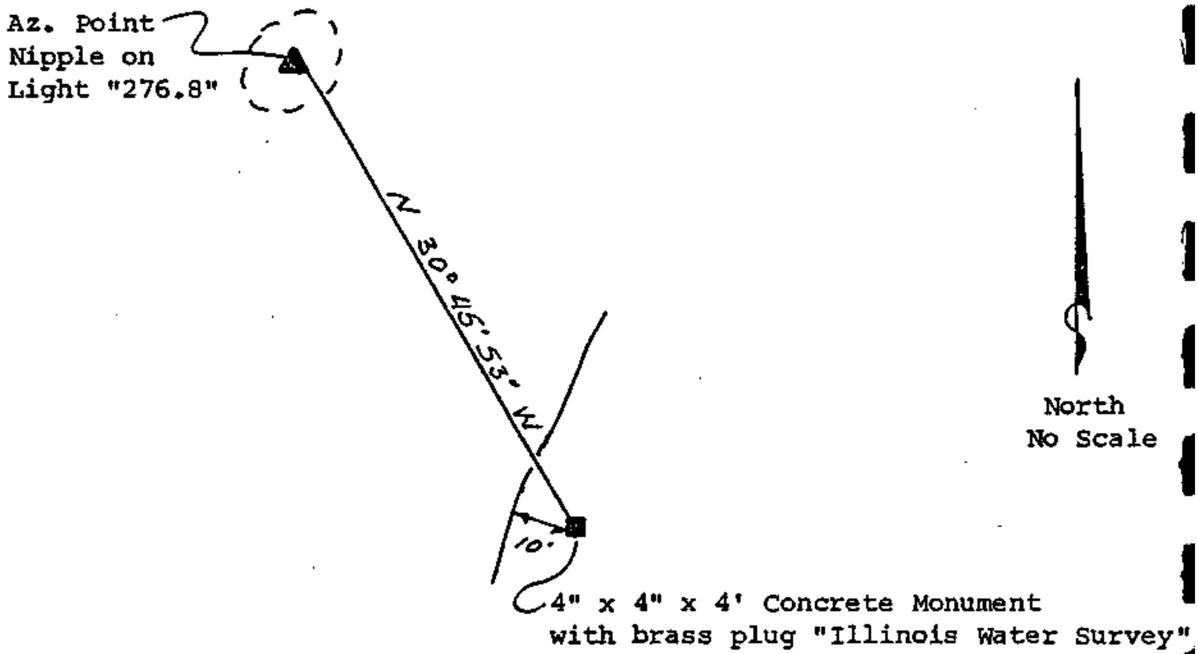
REACH XXIV



R. Gregg Dodson
ILLINOIS REGISTERED LAND SURVEYOR #2010

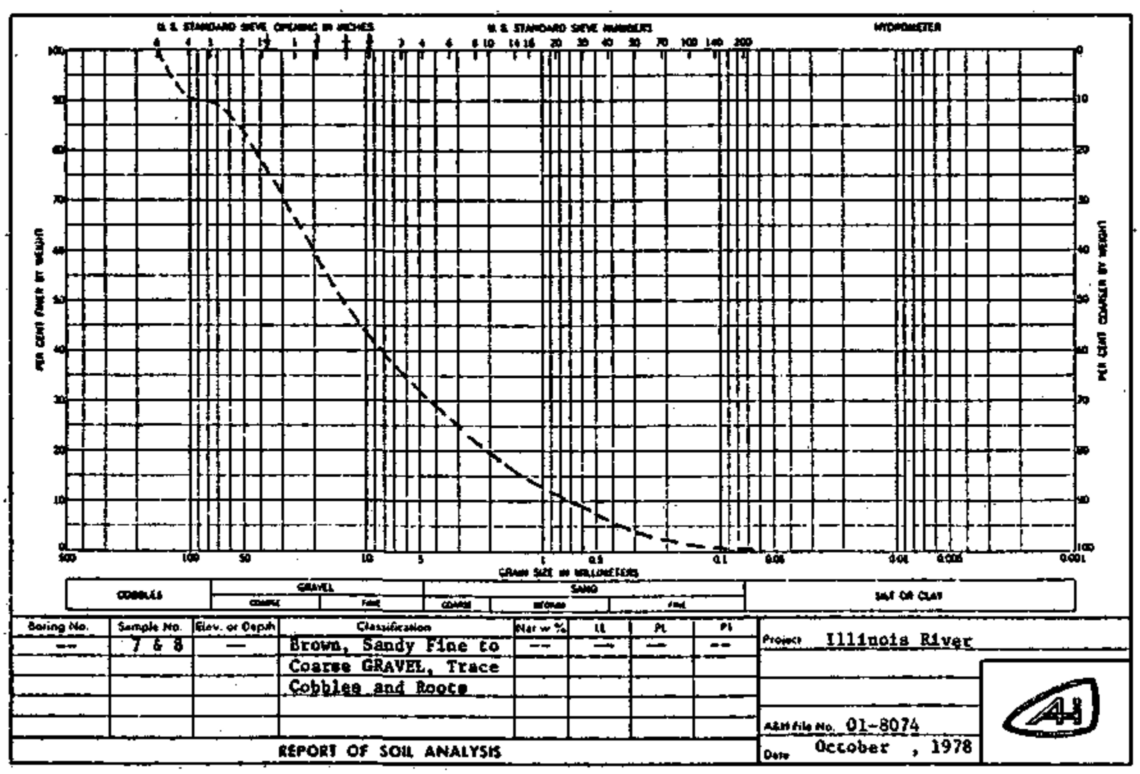
Elevation 508.41
North 5,000.00
East 5,000.00

APPENDIX B

Bank Material Particle Size Distribution

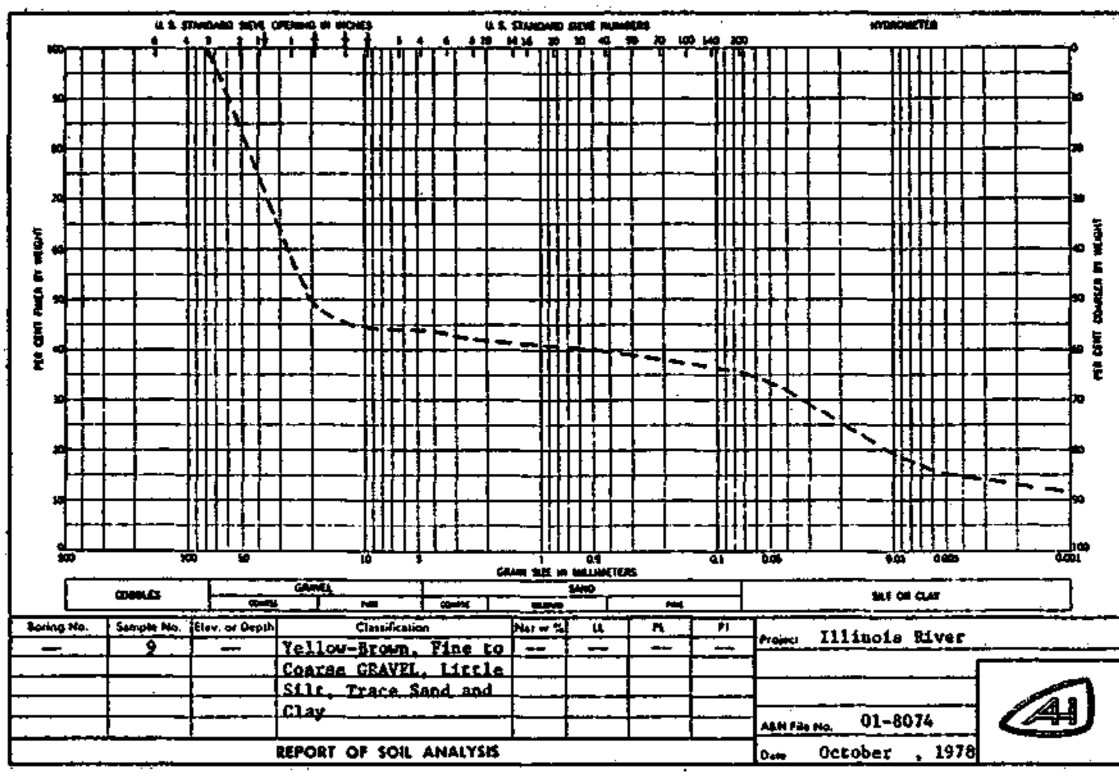
REACH NUMBER: 24
RIVER MILE: 276.8
LOCATION: Left hand side of the river at the water line; sample 8 is 20 to 30 feet upstream of sample 7
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 7 and 8 (Combined Sample)
CLASSIFICATION: Brown, Sandy Fine to Coarse GRAVEL, Trace Cobbles and Roots

GRAIN SIZE ANALYSIS:



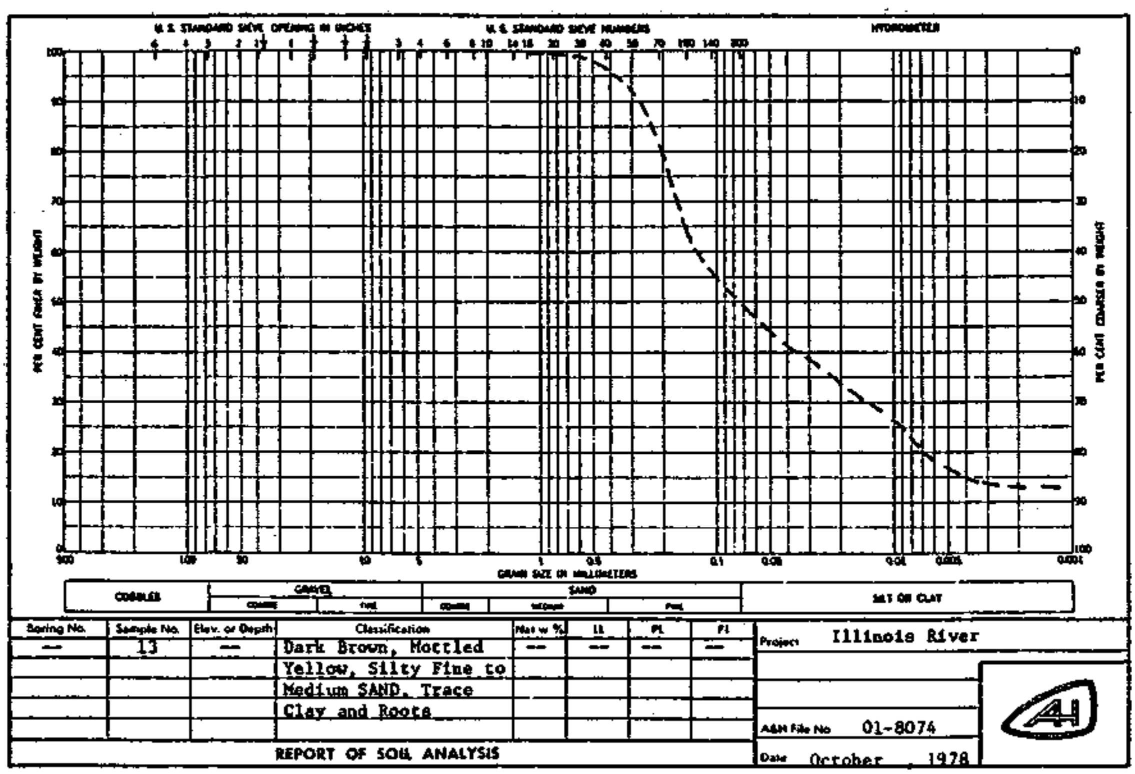
REACH NUMBER: 24
RIVER MILE: 276.8
LOCATION: Left hand side of the river, 25 feet from the water line in the river
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 9
CLASSIFICATION: Yellow-Brown, Fine to Coarse GRAVEL, Little Silt, Trace Sand and Clay

GRAIN SIZE ANALYSIS:



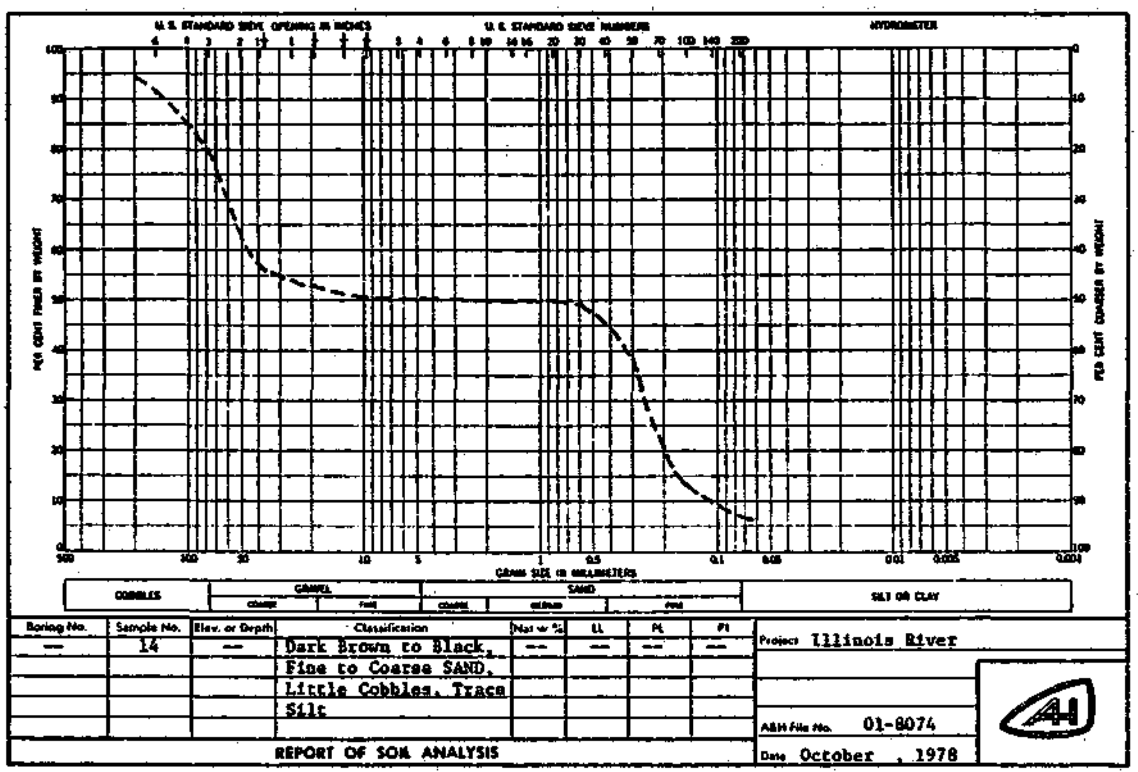
REACH NUMBER: 23
RIVER MILE: 267.9
LOCATION: Left hand side of the river at a bank erosion area
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 13
CLASSIFICATION: Dark Brown, Mottled Yellow, Silty Fine to Medium SAND, Trace Clay and Roots

GRAIN SIZE ANALYSIS:



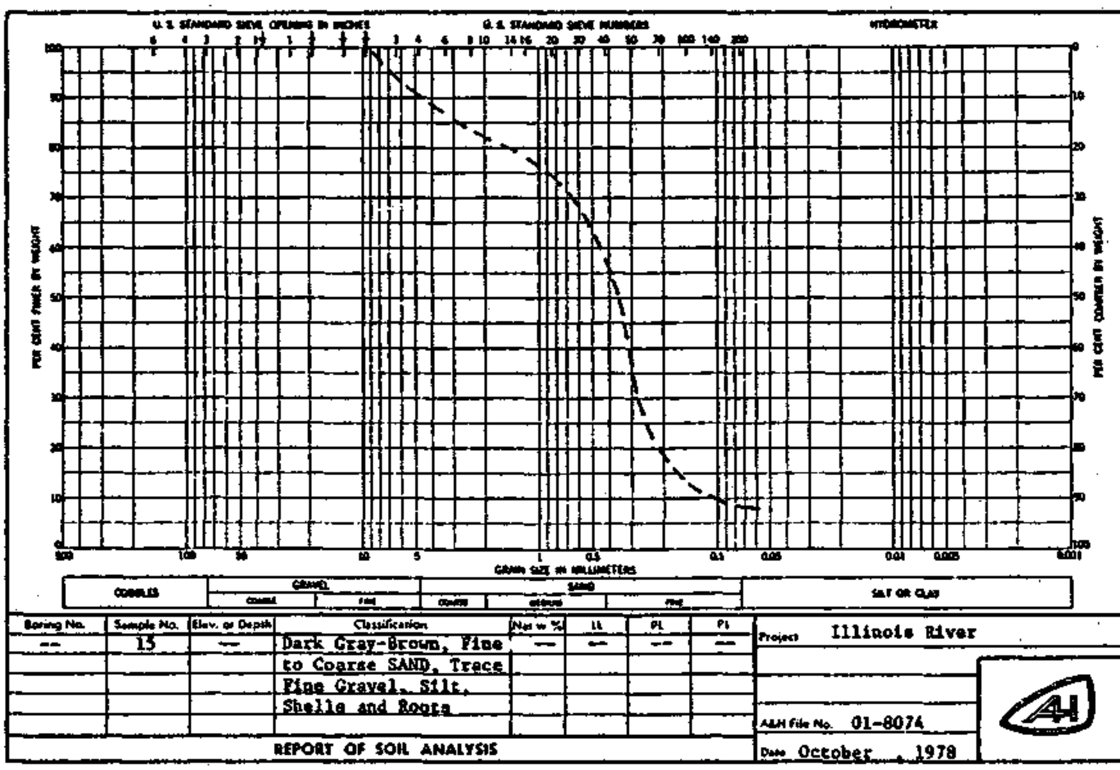
REACH NUMBER: 23
RIVER MILE: 267.9
LOCATION: Left hand side of the river, 1 to 2 feet from the water line in the river
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 14
CLASSIFICATION: Dark Brown to Black, Fine to Coarse SAND, Little Cobbles, Trace Silt

GRAIN SIZE ANALYSIS:



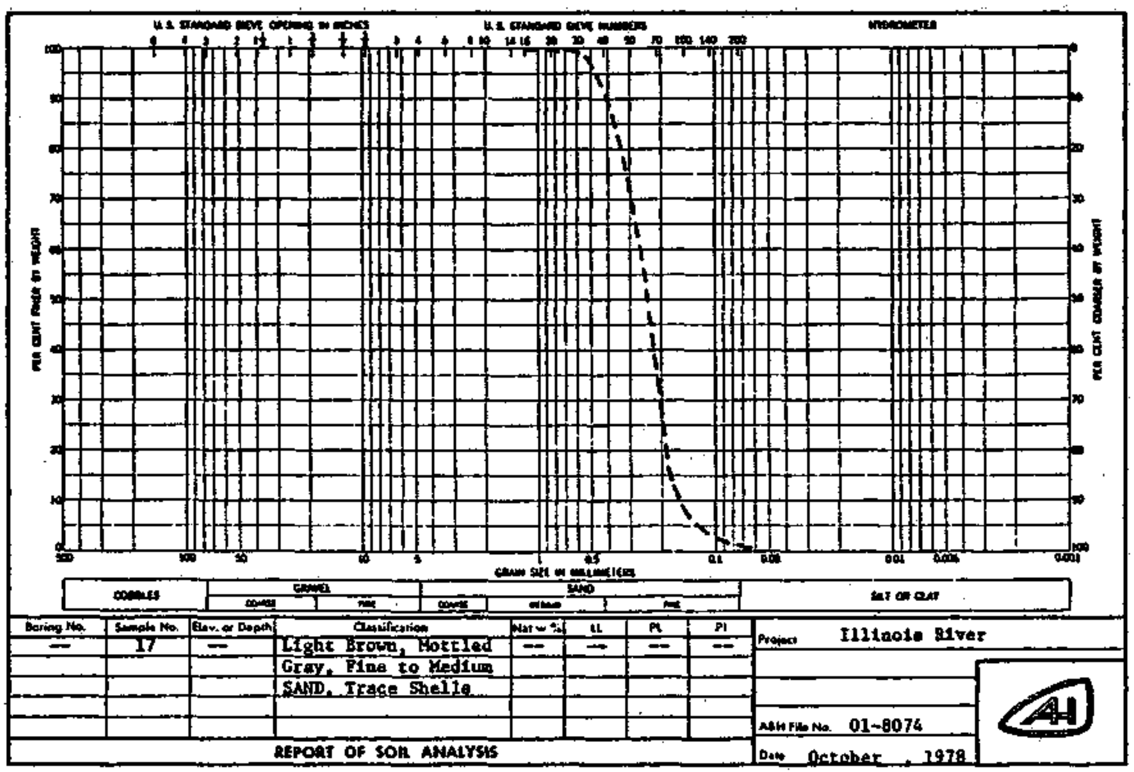
REACH NUMBER: 23
RIVER MILE: 267.9
LOCATION: Left hand side of the river, 30 feet from the water line in the river
DATE OF DATA COLLECTION July 17, 1978
SAMPLE NUMBER: 15
CLASSIFICATION: Dark Gray-Brown, Fine to Coarse SAND, Trace Fine Gravel, Silt, Shells and Roots

GRAIN SIZE ANALYSIS:



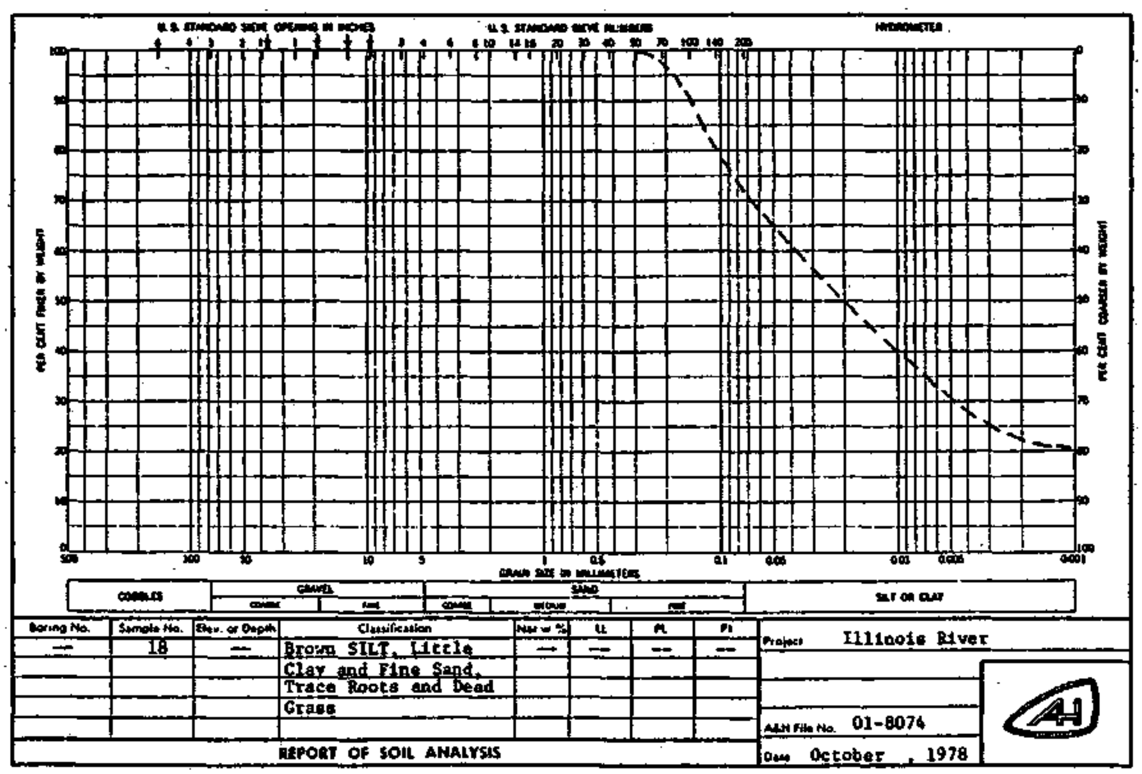
REACH NUMBER: 22
RIVER MILE: 262.0
LOCATION: Right hand side of the river at the water line at a bank erosion site
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 17
CLASSIFICATION: Light Brown, Mottled Gray, Fine to Medium SAND, Trace Shells

GRAIN SIZE ANALYSIS:



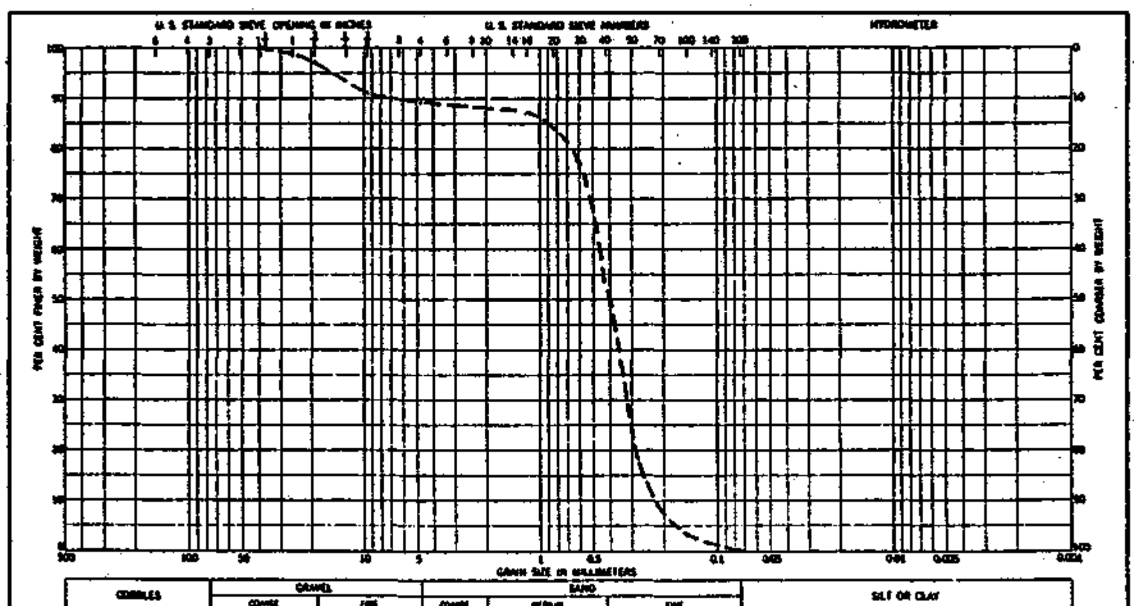
REACH NUMBER: 22
RIVER MILE: 262.0
LOCATION: Right hand side of the river, near the top of the bank
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 18
CLASSIFICATION: Brown SILT, Little Clay and Fine Sand, Trace Roots and Dead Grass

GRAIN SIZE ANALYSIS:



REACH NUMBER: 21
RIVER MILE: 235.6
LOCATION: Right hand side of the river near the water line
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 23
CLASSIFICATION: Yellow-Brown, Fine to Coarse SAND, Trace Gravel

GRAIN SIZE ANALYSIS:



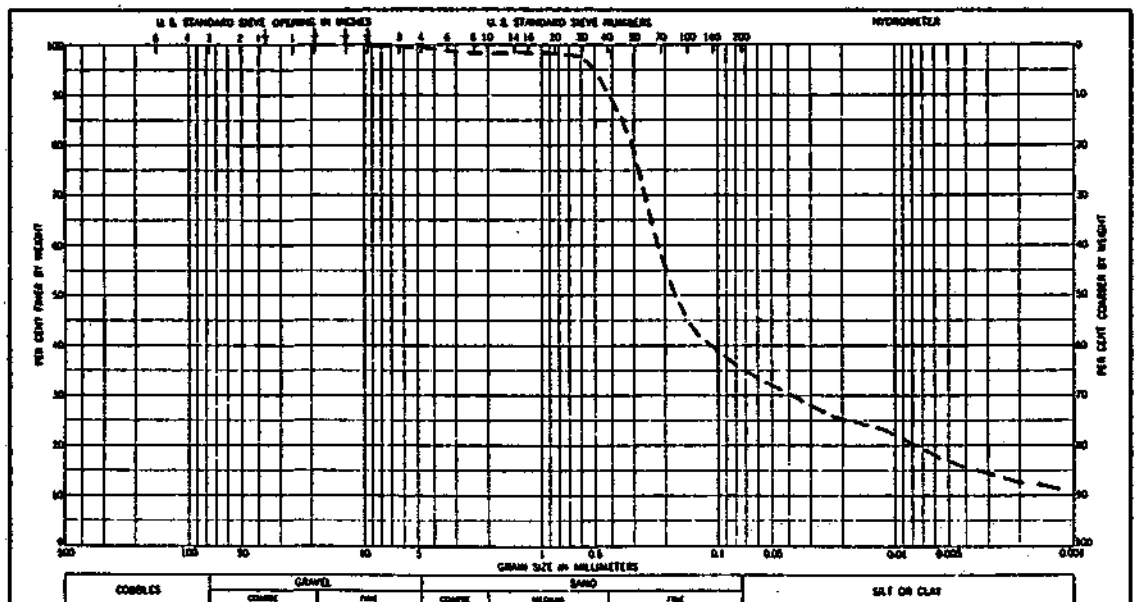
Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	23	--	Yellow-Brown, Fine to Coarse SAND, Trace Gravel	--	--	--	--

Project Illinois River
A&H File No. 01-8074
Date October , 1978

REPORT OF SOIL ANALYSIS

REACH NUMBER: 21
RIVER MILE: 235.6
LOCATION: Right hand side of the river at a vertical bank
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 24A
CLASSIFICATION: Brown, Mottled Yellow, Silty Fine to Coarse SAND, Trace Clay and Small Roots

GRAIN SIZE ANALYSIS:



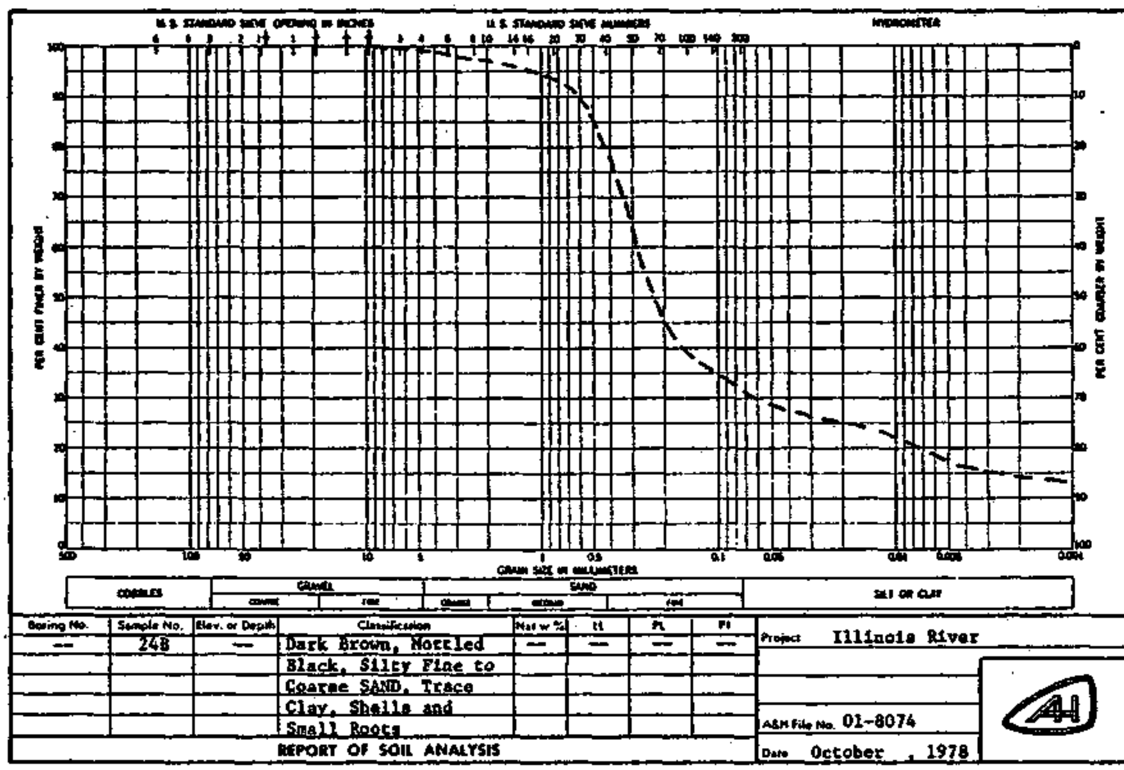
Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	24A	—	Brown, Mottled Yellow, Silty Fine to Coarse SAND, Trace Clay and Small Roots	—	—	—	—

REPORT OF SOIL ANALYSIS

Project Illinois River
A&H File No. 01-8074
Date October , 1978

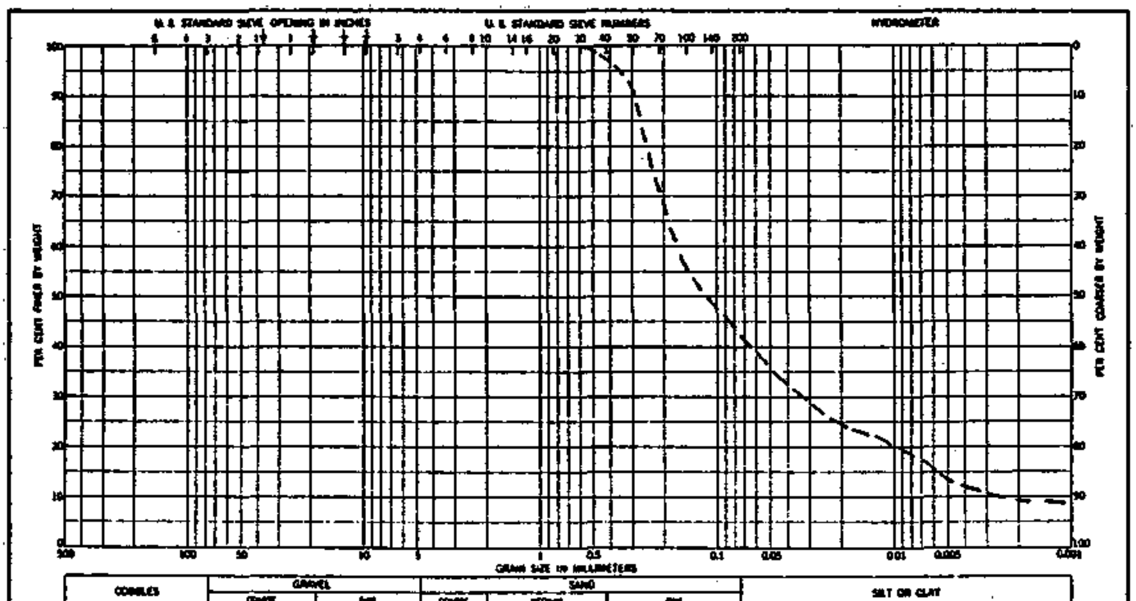
REACH NUMBER: 21
RIVER MILE: 235.6
LOCATION: Right hand side of the river at a vertical bank
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 24B
CLASSIFICATION: Dark Brown, Mottled Black, Silty Fine to Coarse SAND, Trace Clay, Shells and Small Roots

GRAIN SIZE ANALYSIS:



REACH NUMBER: 18
RIVER MILE: 228.5
LOCATION: Right hand side of the river, 15 feet from the water line on the upper bank
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 26
CLASSIFICATION: Dark Brown, Silty Fine to Medium SAND, Trace Clay and Small Roots

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	26	—	Dark Brown, Silty Fine to Medium SAND, Trace Clay and Small Roots	—	—	—	—

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REACH NUMBER: 18

RIVER MILE: 228.5

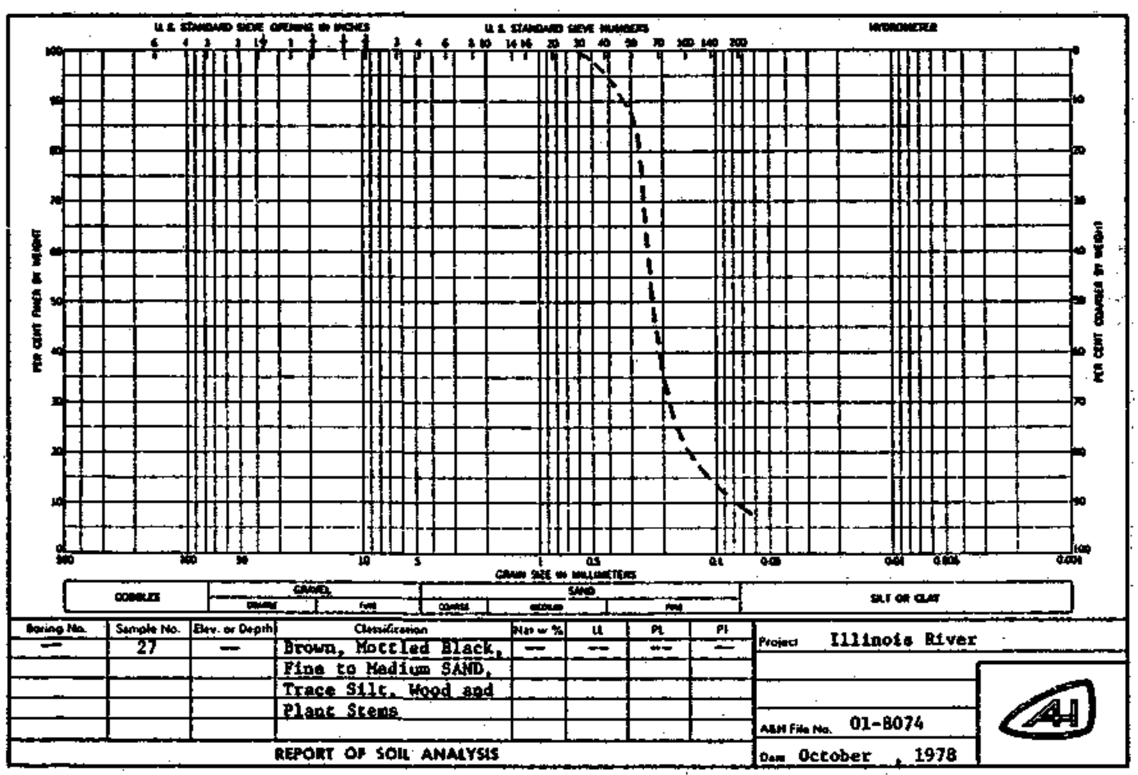
LOCATION: Right hand side of the river, 3 feet from the water line on the bank

DATE OF DATA COLLECTION: July 18, 1978

SAMPLE NUMBER: 27

CLASSIFICATION: Brown, Mottled Black, Fine to Medium SAND, Trace Silt, Wood and Plant Stems

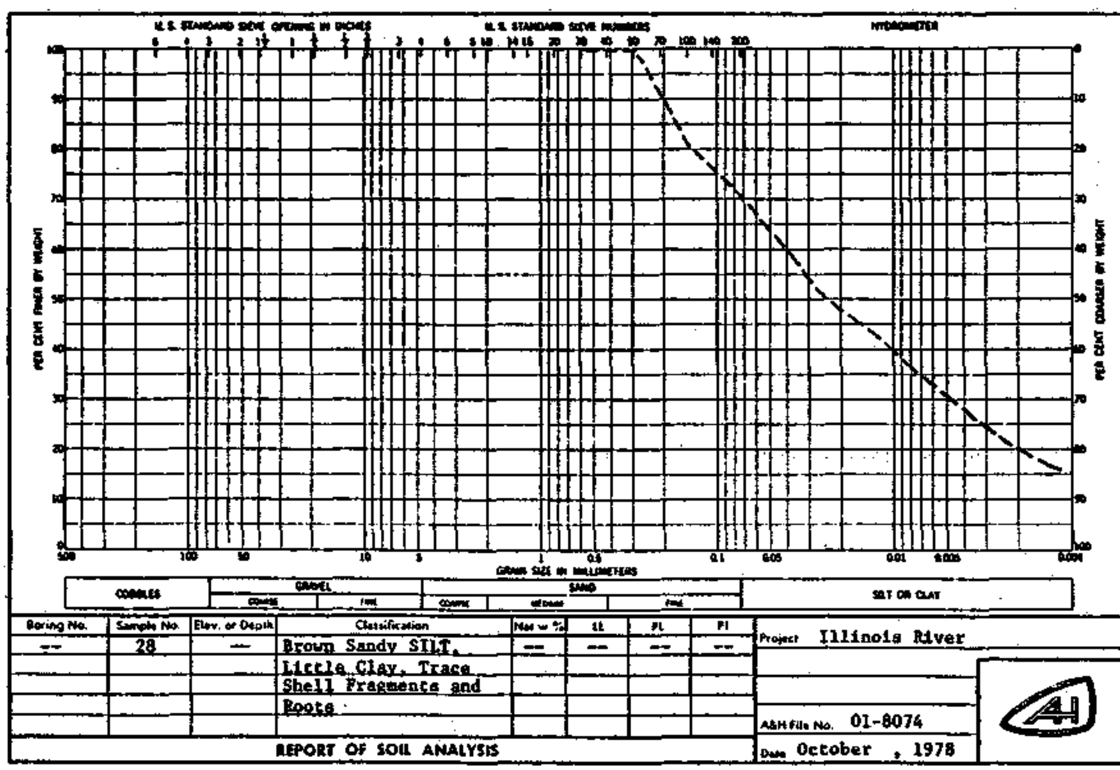
GRAIN SIZE ANALYSIS:



REACH NUMBER: 18
RIVER MILE: 228.5
LOCATION: Right hand side of the river, 15 to 20 feet from the water line, high up on the bank

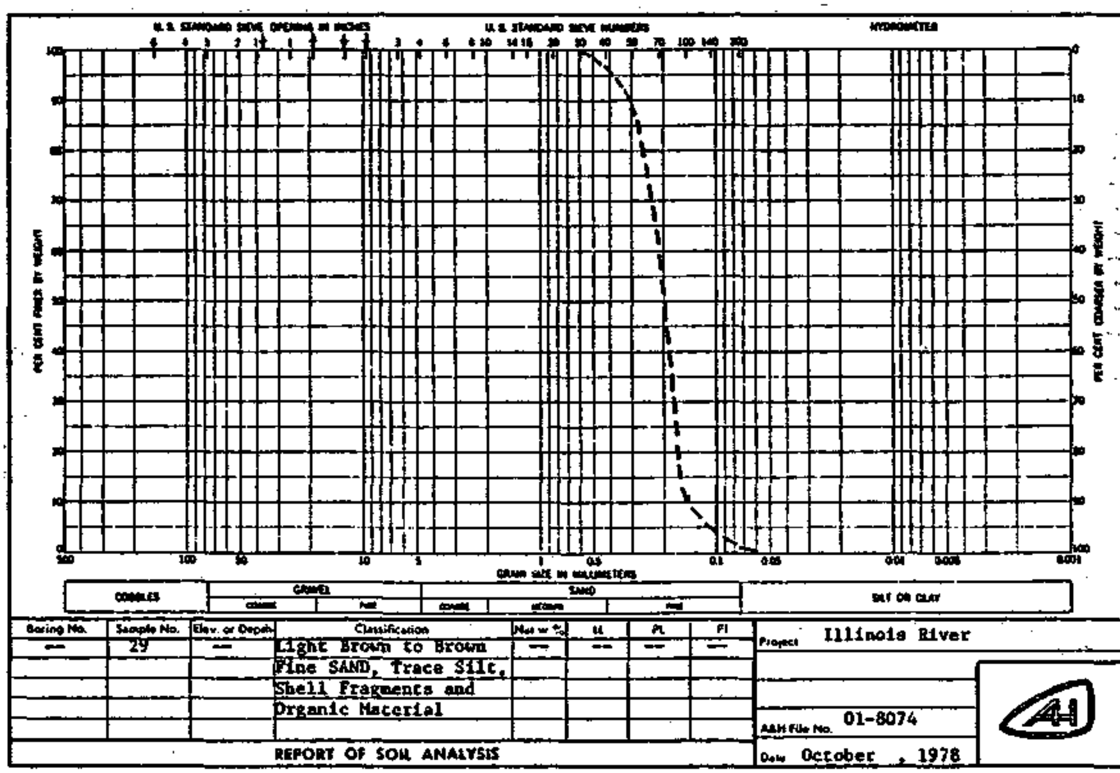
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 28
CLASSIFICATION: Brown Sandy SILT, Little Clay, Trace Shell Fragments and Roots

GRAIN SIZE ANALYSIS:



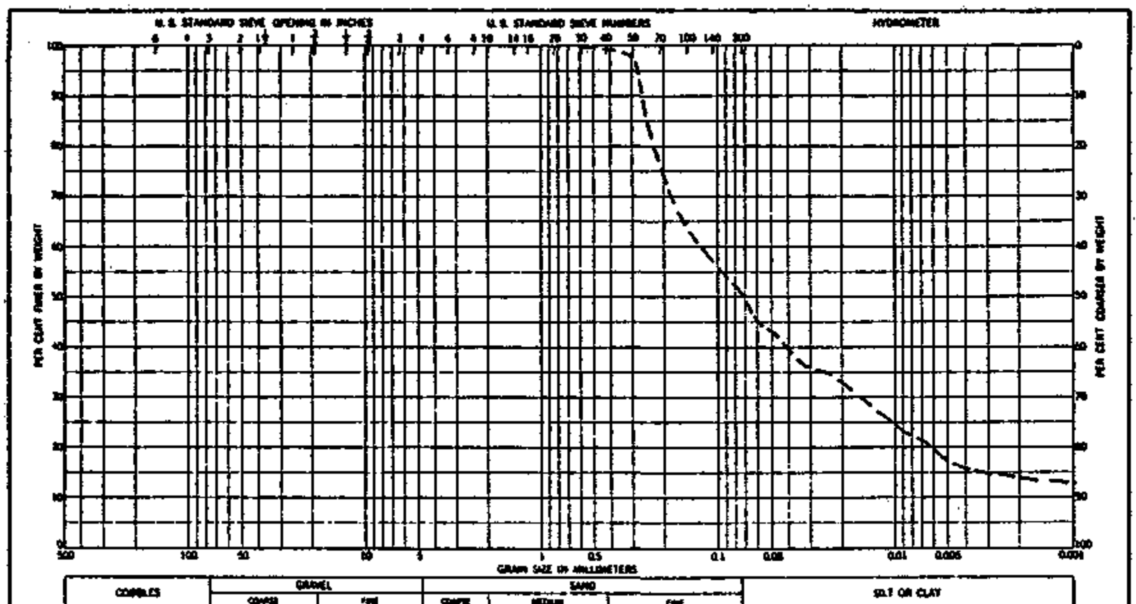
REACH NUMBER: 19
RIVER MILE: 229.0
LOCATION: Right hand side of the river, 3 feet from the water line on the bank
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 29
CLASSIFICATION: Light Brown to Brown Fine SAND, Trace Silt, Shell Fragments and Organic Material (Decayed Plant Stems, Wood and Small Roots)

GRAIN SIZE ANALYSIS:



REACH NUMBER: 19
RIVER MILE: 229
LOCATION: Right hand side of the river, 15 to 20 feet from the water line at the toe of eroded bluff
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 30
CLASSIFICATION: Brown Silty, Fine to Medium SAND, Trace Clay and Small Roots

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	30	—	Brown Silty, Fine to Medium SAND, Trace Clay and Small Roots	—	—	—	—

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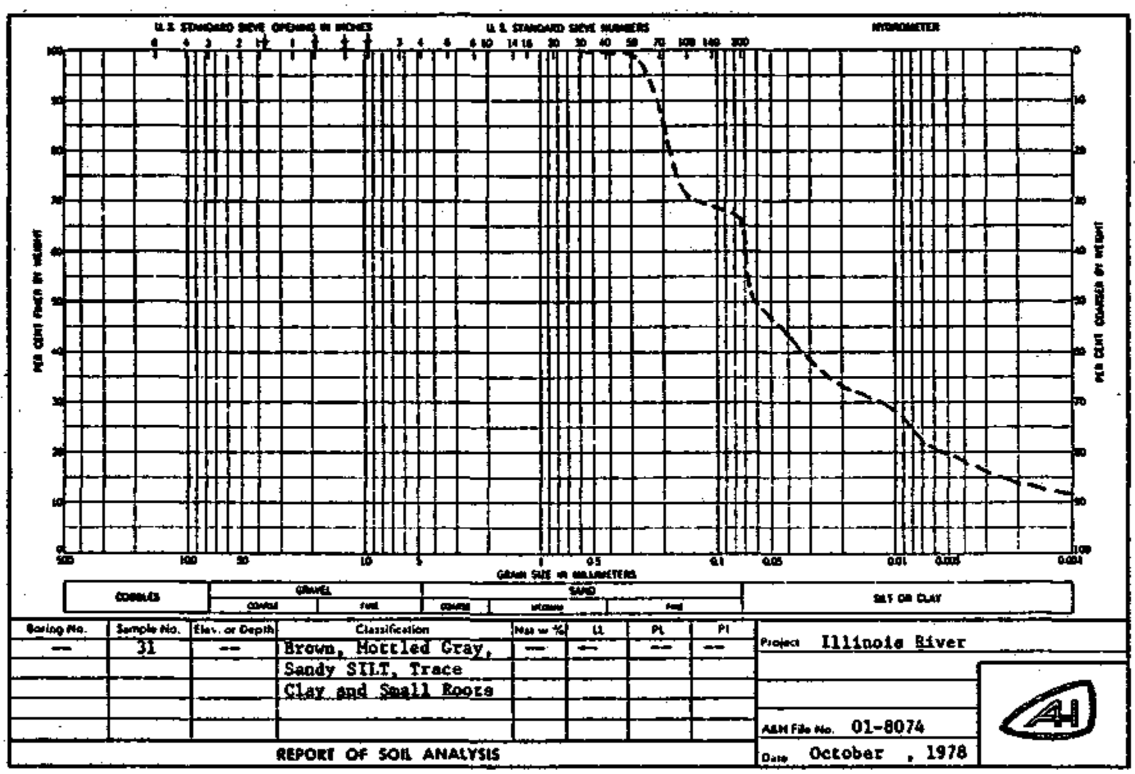
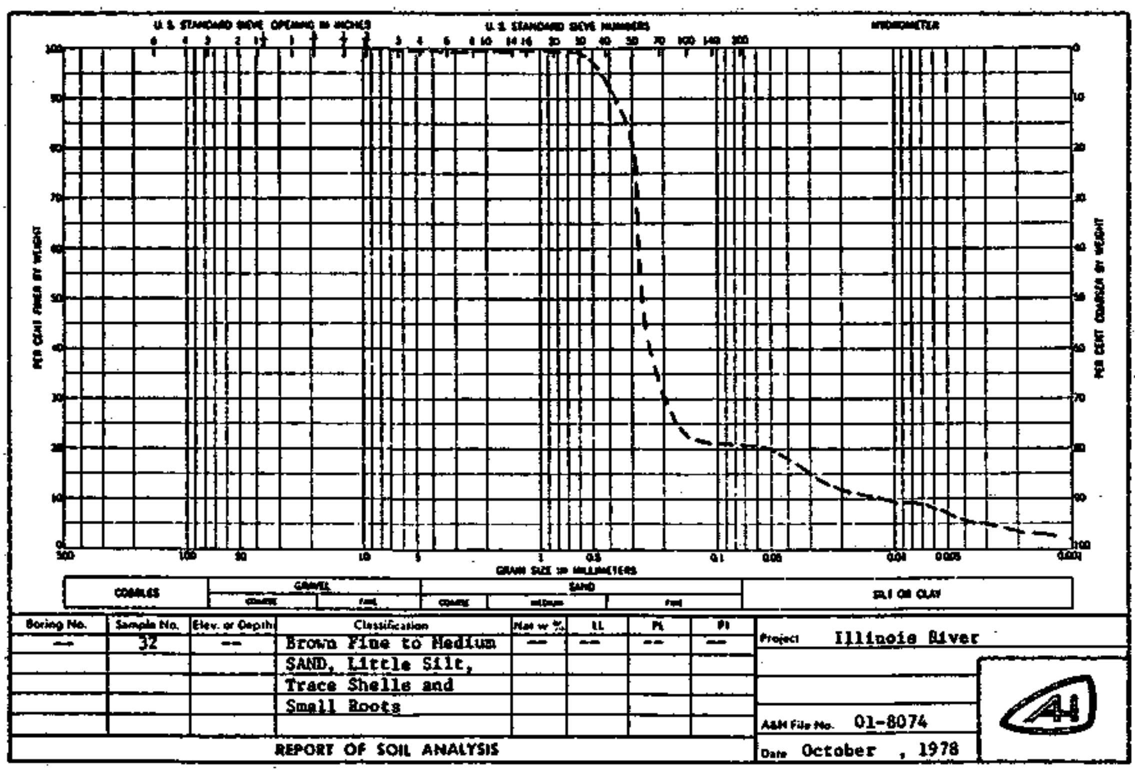
REACH NUMBER: 19
RIVER MILE: 229.0
LOCATION: Right hand side of the river, 2 feet from the water line
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 31
CLASSIFICATION: Brown, Mottled Gray, Sandy SILT, Trace Clay and Small Roots

GRAIN SIZE ANALYSIS:



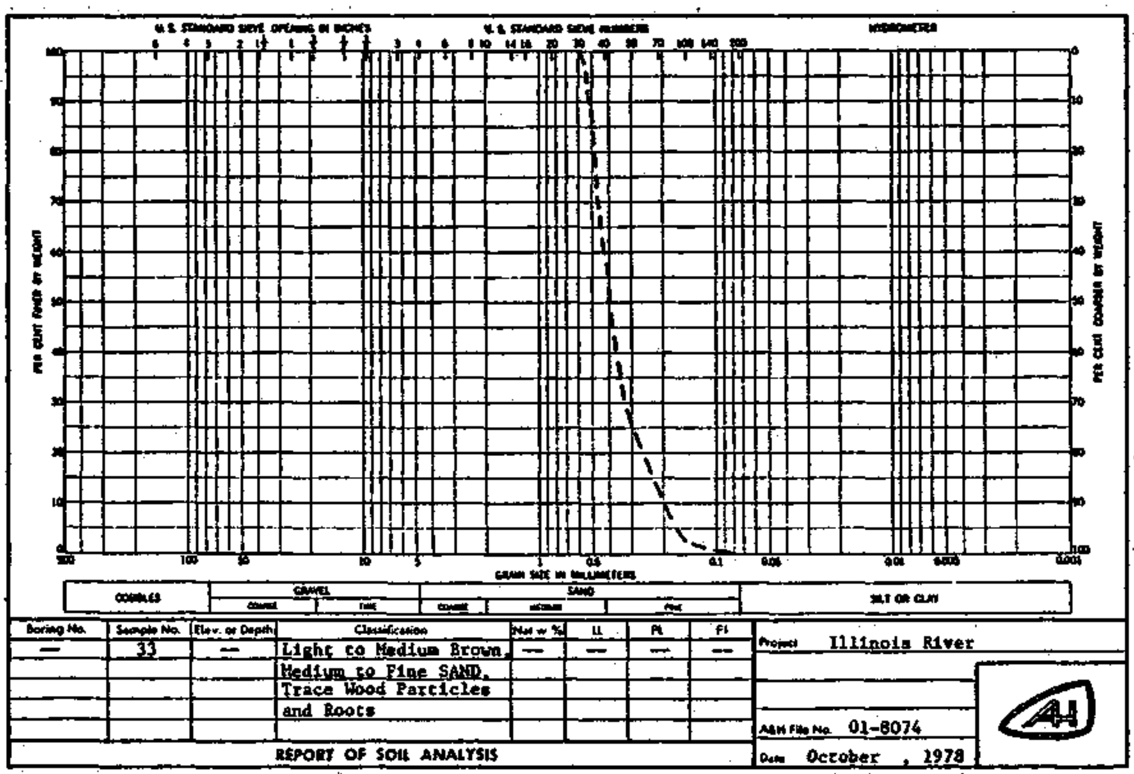
REACH NUMBER: 19
RIVER MILE: 229.0
LOCATION: Right hand side of the river, 40 feet from the water line in the river under 4 feet of water
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 32
CLASSIFICATION: Brown Fine to Medium SAND, Little Silt, Trace Shells and Small Roots

GRAIN SIZE ANALYSIS:



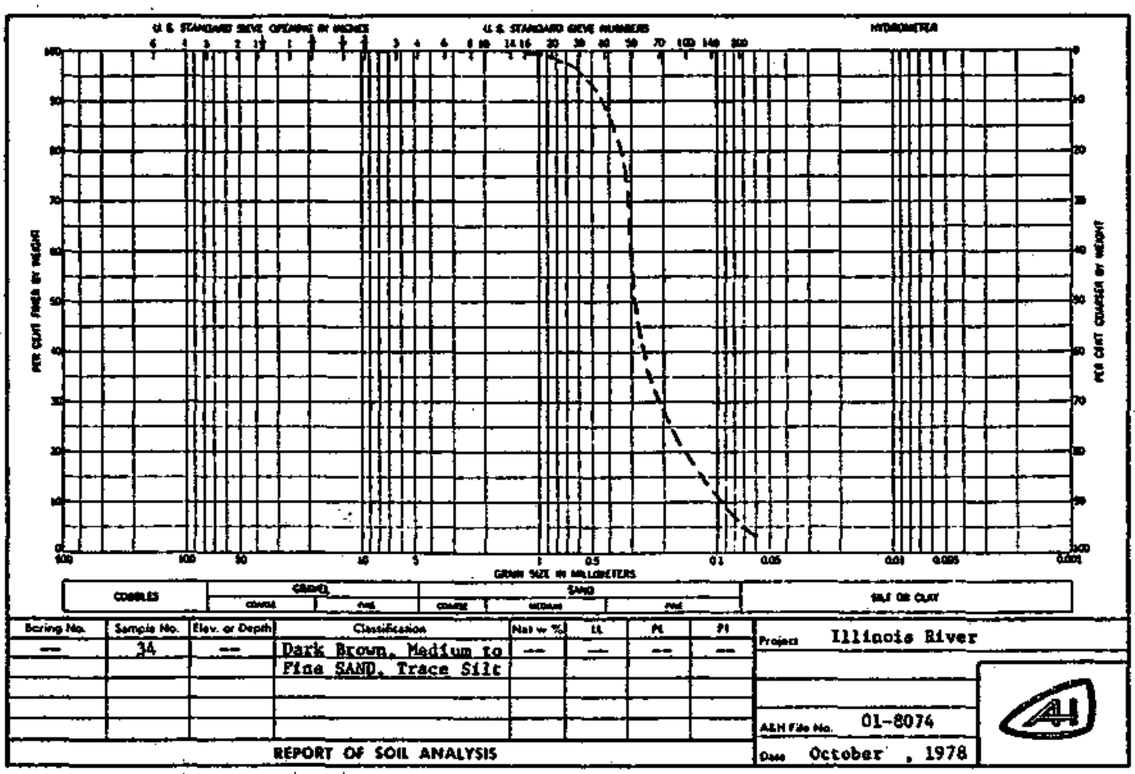
REACH NUMBER: 20
RIVER MILE: 228.9
LOCATION: Left hand side of the river, 20 feet up from the water line near the top of sand bank
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 33
CLASSIFICATION: Light to Medium Brown, Medium to Fine SAND, Trace Wood Particles and Roots

GRAIN SIZE ANALYSIS:



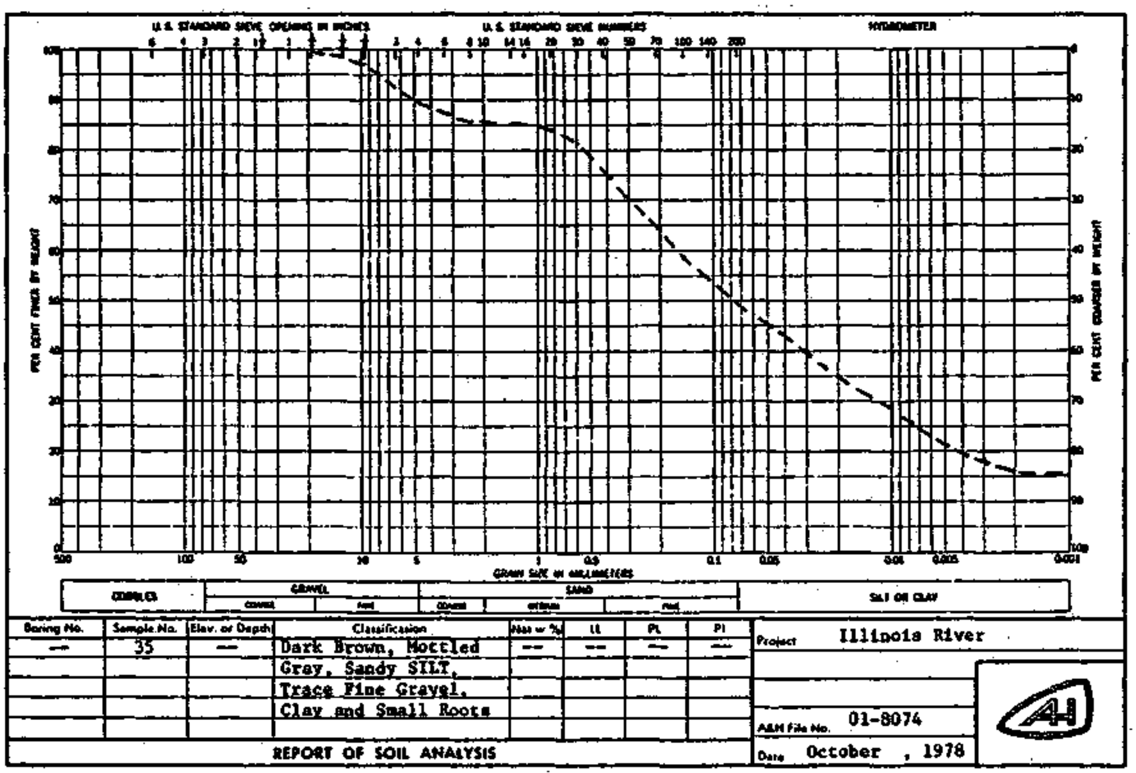
REACH NUMBER: 20
RIVER MILE: 228.9
LOCATION: Left hand side of river, 3 feet from the water line on the bank
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 34
CLASSIFICATION: Dark Brown, Medium to Fine SAND, Trace Silt

GRAIN SIZE ANALYSIS:



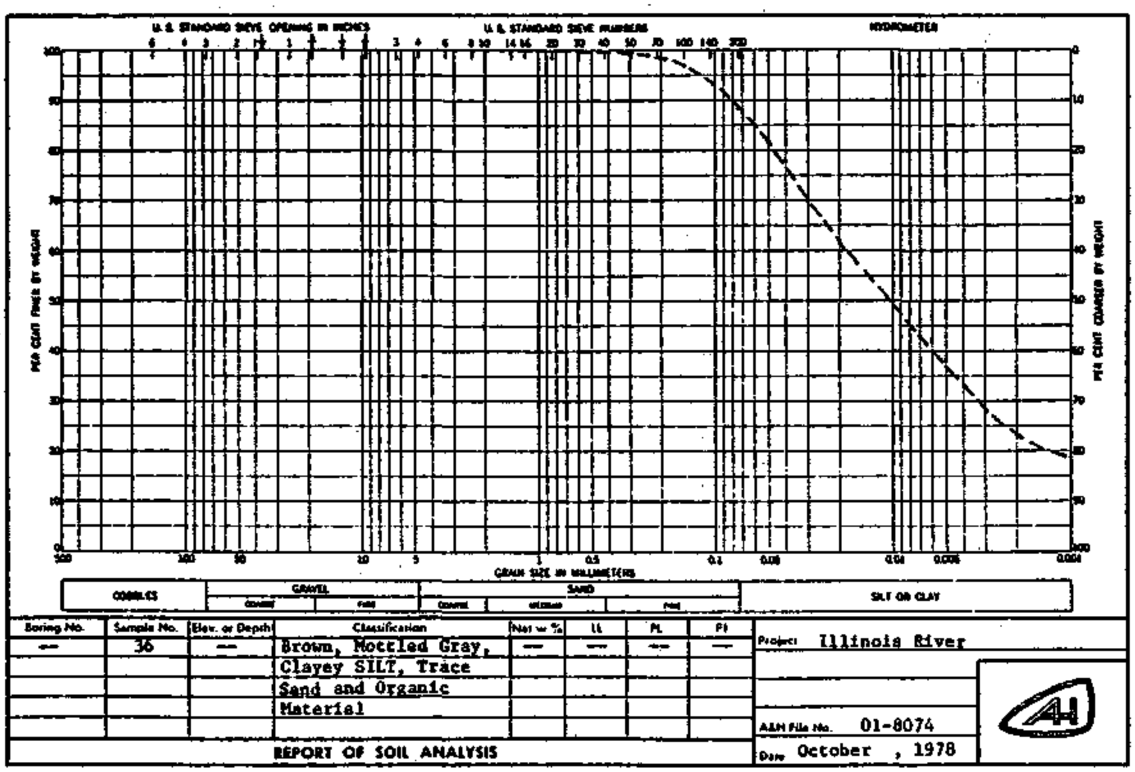
REACH NUMBER: 20
RIVER MILE: 228.9
LOCATION: Left hand side of the river, 25 to 30 feet from the water line in the river
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 35
CLASSIFICATION: Dark Brown, Mottled Gray, Sandy SILT, Trace Fine Gravel, Clay and Small Roots

GRAIN SIZE ANALYSIS:



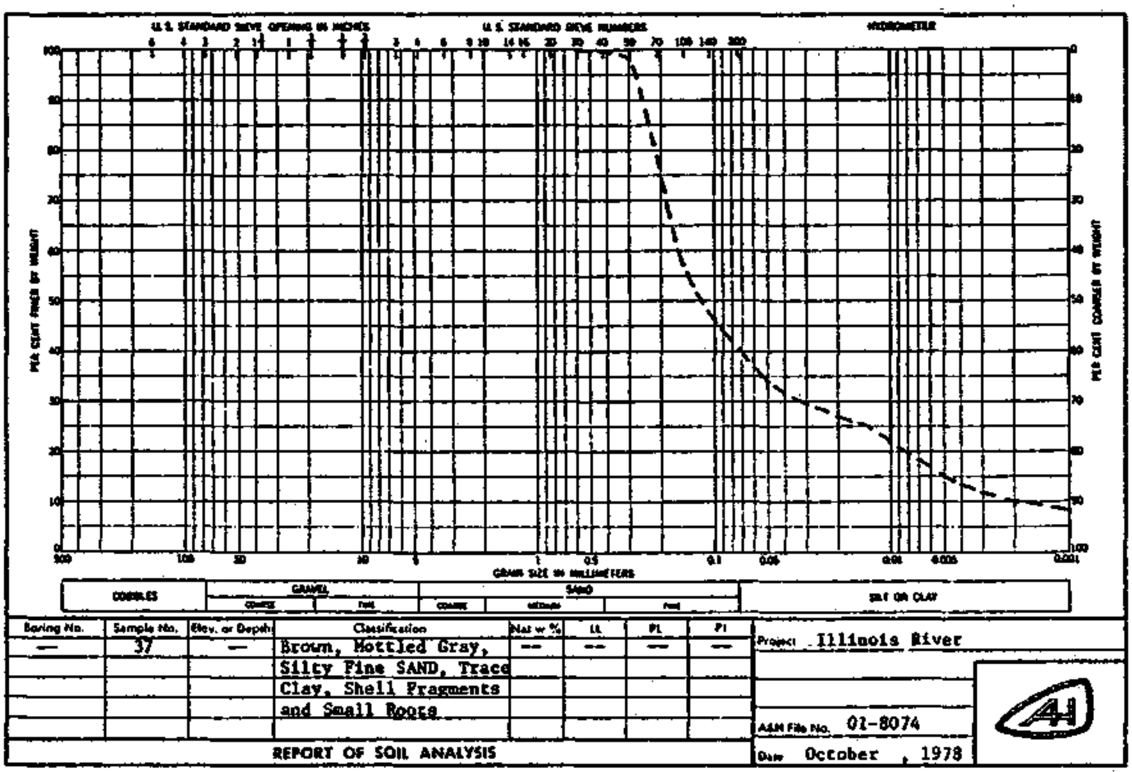
REACH NUMBER:	18
RIVER MILE:	227.5
LOCATION:	Right hand side of the river, 40 feet from the water line near the top of the bank by the vegetation line
DATE OF DATA COLLECTION:	July 18, 1978
SAMPLE NUMBER:	36
CLASSIFICATION:	Brown, Mottled Gray, Clayey SILT, Trace Sand and Organic Material (Dry Weeds, Roots, Leaves and Twigs)

GRAIN SIZE ANALYSIS:



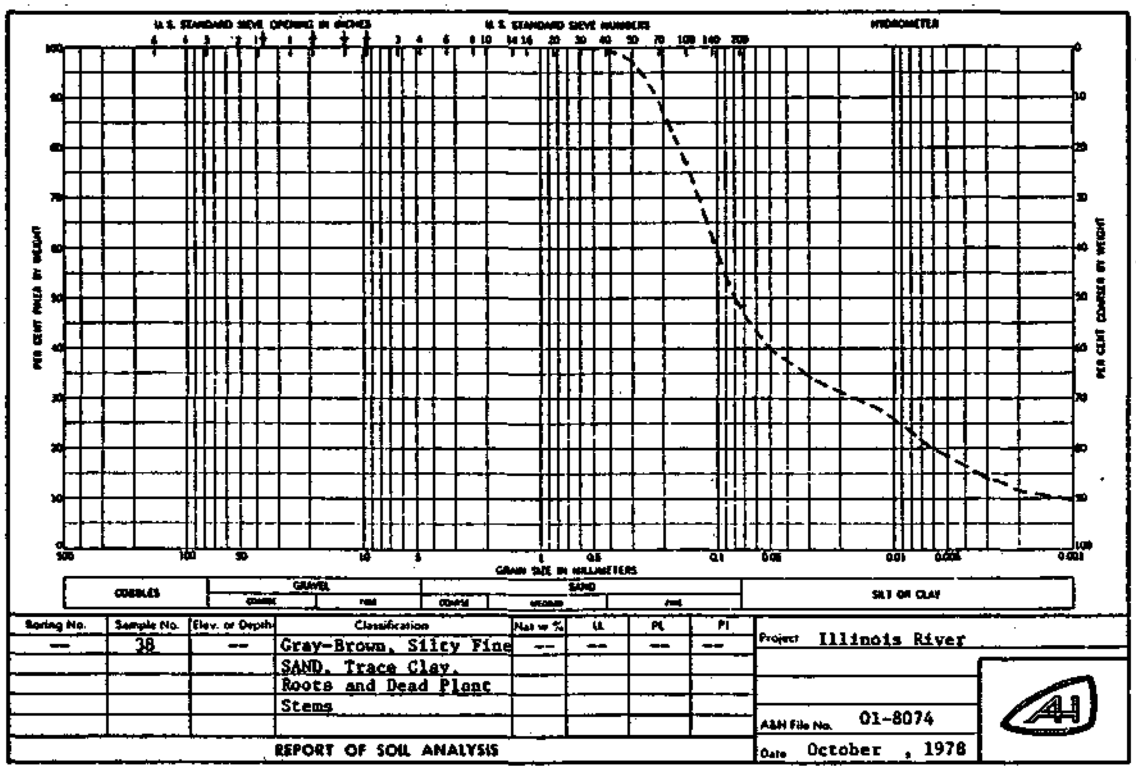
REACH NUMBER: 18
RIVER MILE: 227.5
LOCATION: Right hand side of the river at the middle of the bank area
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 37
CLASSIFICATION: Brown, Mottled Gray, Silty Fine SAND, Trace Clay, Shell Fragments and Small Roots

GRAIN SIZE ANALYSIS:



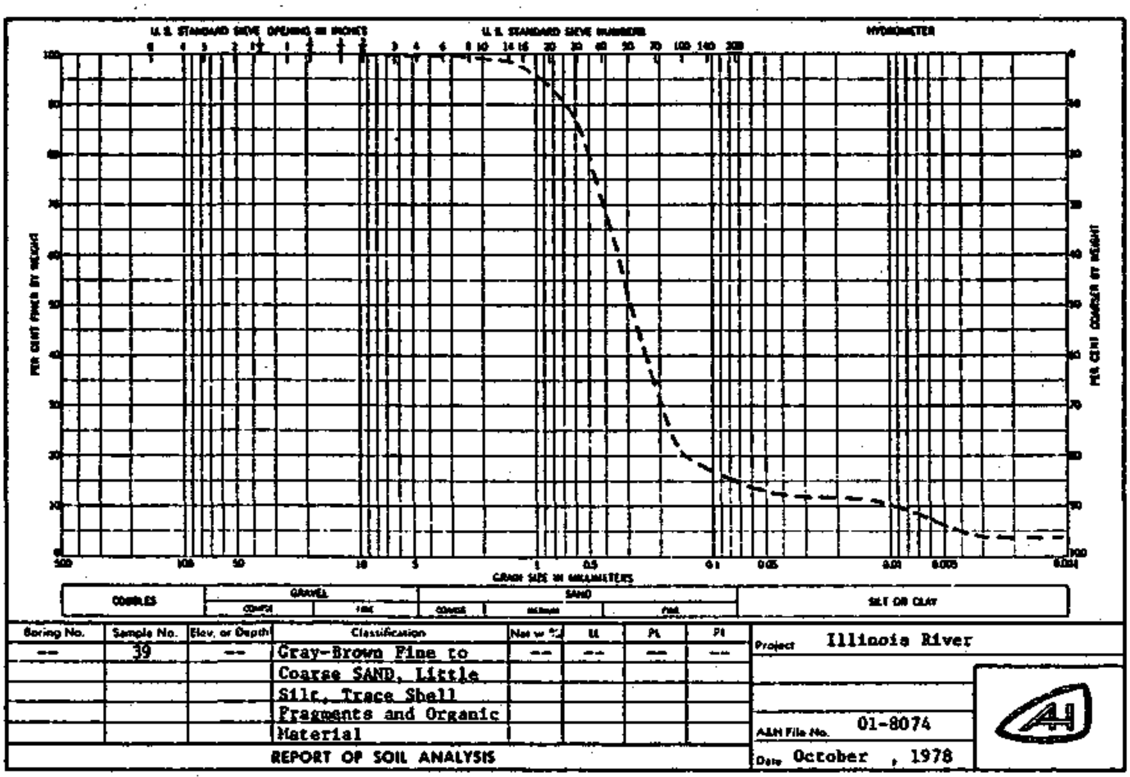
REACH NUMBER: 18
RIVER MILE: 227.5
LOCATION: Right hand side of the river, 5 feet from the water line on the bank
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 38
CLASSIFICATION: Gray-Brown, Silty Fine SAND, Trace Clay, Roots and Dead Plant Stems

GRAIN SIZE ANALYSIS:



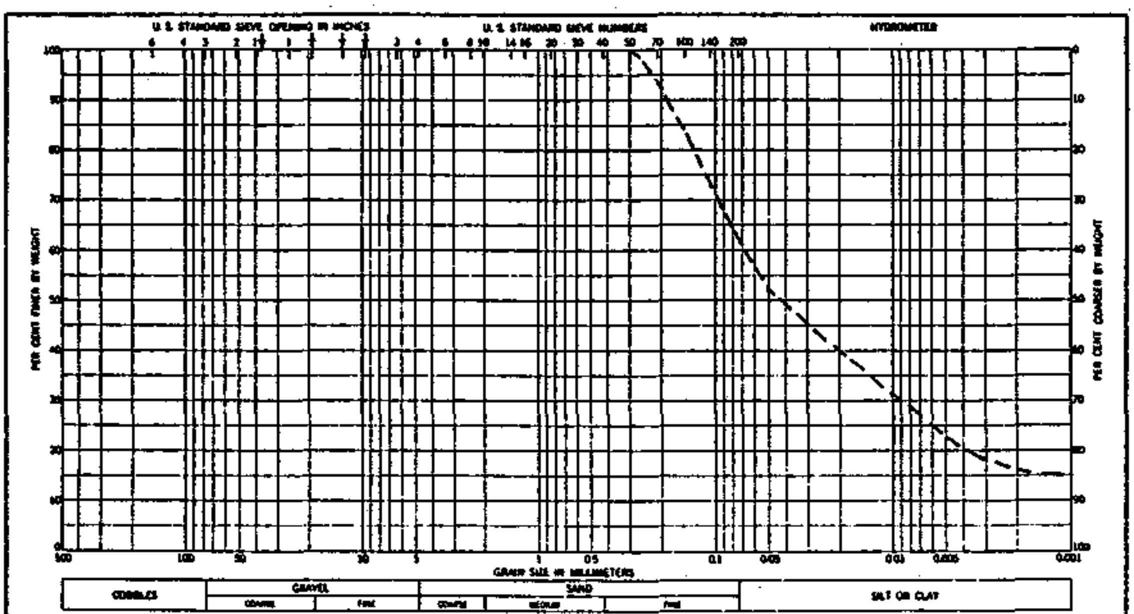
REACH NUMBER: 18
RIVER MILE: 227.5
LOCATION: Right hand side of the river, 40 feet from the water line in the river
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 39
CLASSIFICATION: Gray-Brown Fine to Coarse SAND, Little Silt, Trace Shell Fragments and Organic Material (Small Roots and Twigs)

GRAIN SIZE ANALYSIS:



REACH NUMBER:	17
RIVER MILE:	213.0
LOCATION:	Right hand side of the river near the top of the bank
DATE OF DATA COLLECTION:	July 18, 1978
SAMPLE NUMBER:	43
CLASSIFICATION:	Brown, Mottled Yellow, Sandy SILT, Trace Clay, Shell Fragments and Roots

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	43	—	Brown, Mottled Yellow, Sandy SILT, Trace Clay, Shell Fragments and Roots	—	—	—	—

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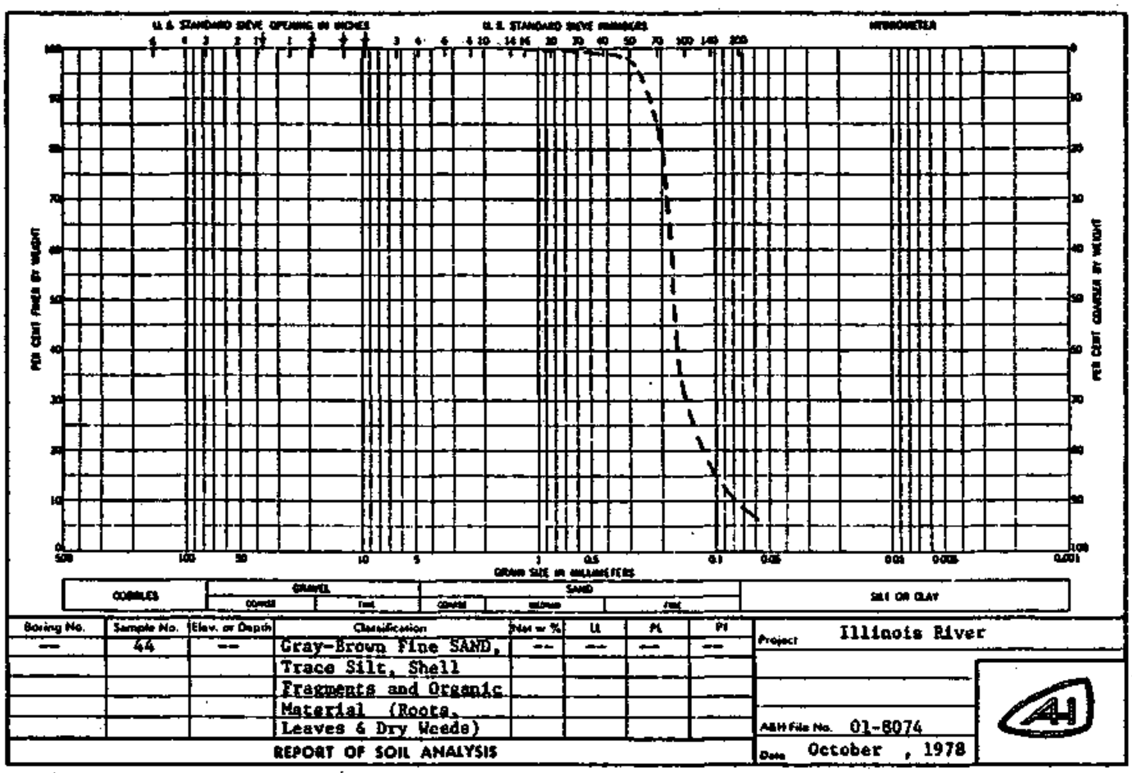
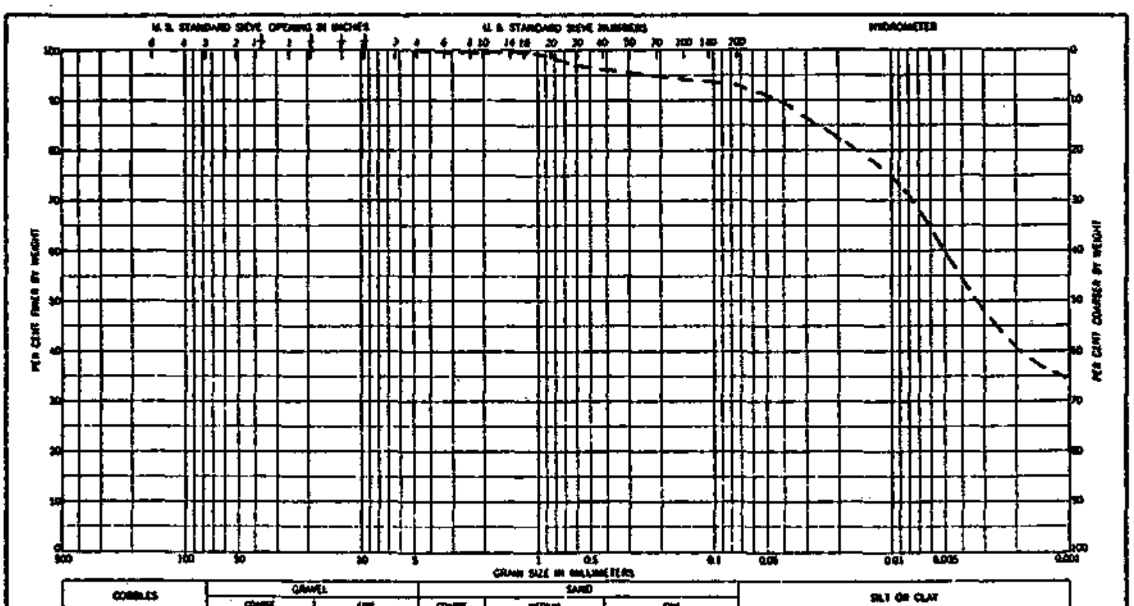
REACH NUMBER: 17
RIVER MILE: 213.0
LOCATION: Right hand side of river near the water line
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 44
CLASSIFICATION: Gray-Brown Fine SAND, Trace Silt, Shell Fragments and Organic Material (Roots, Leaves and Dry Weeds)

GRAIN SIZE ANALYSIS:



REACH NUMBER: 16
RIVER MILE: 204.5
LOCATION: Left hand side of the river; Hennepin Drainage and Levee District
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 46
CLASSIFICATION: Dark Brown, Mottled Gray, Clayey SILT, Trace Sand and Small Roots

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	46	--	Dark Brown, Mottled Gray, Clayey SILT, Trace Sand and Small Roots	--	--	--	--

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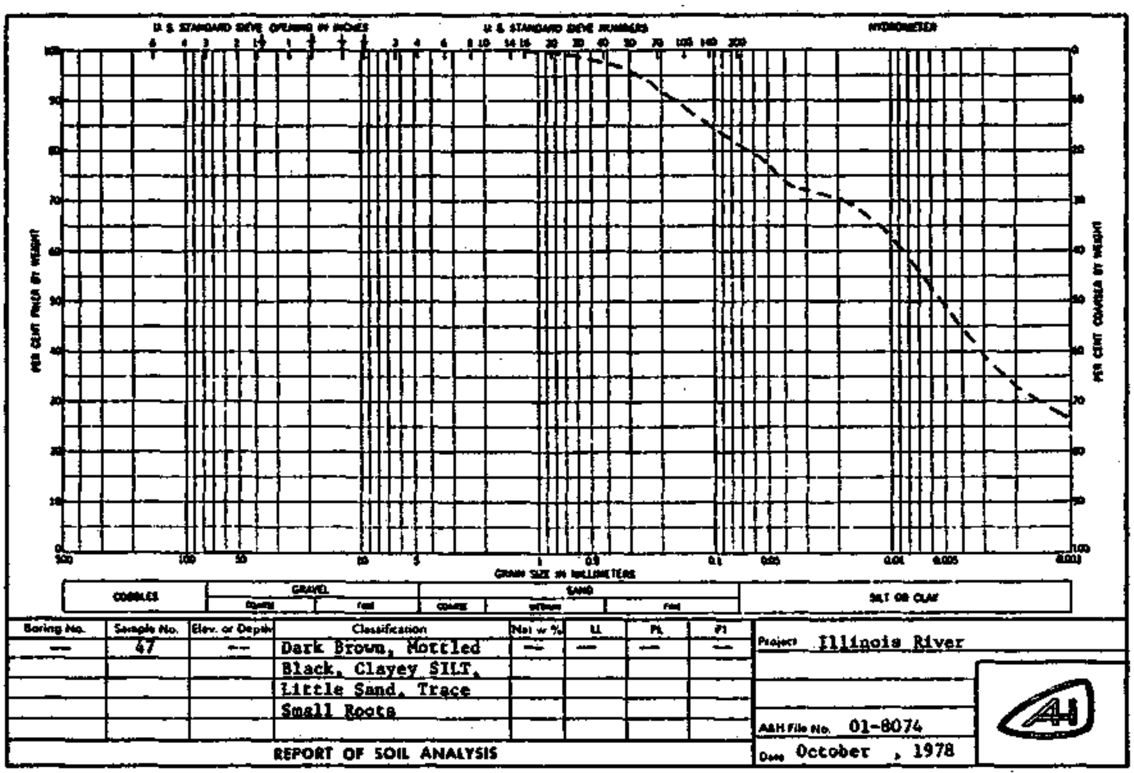
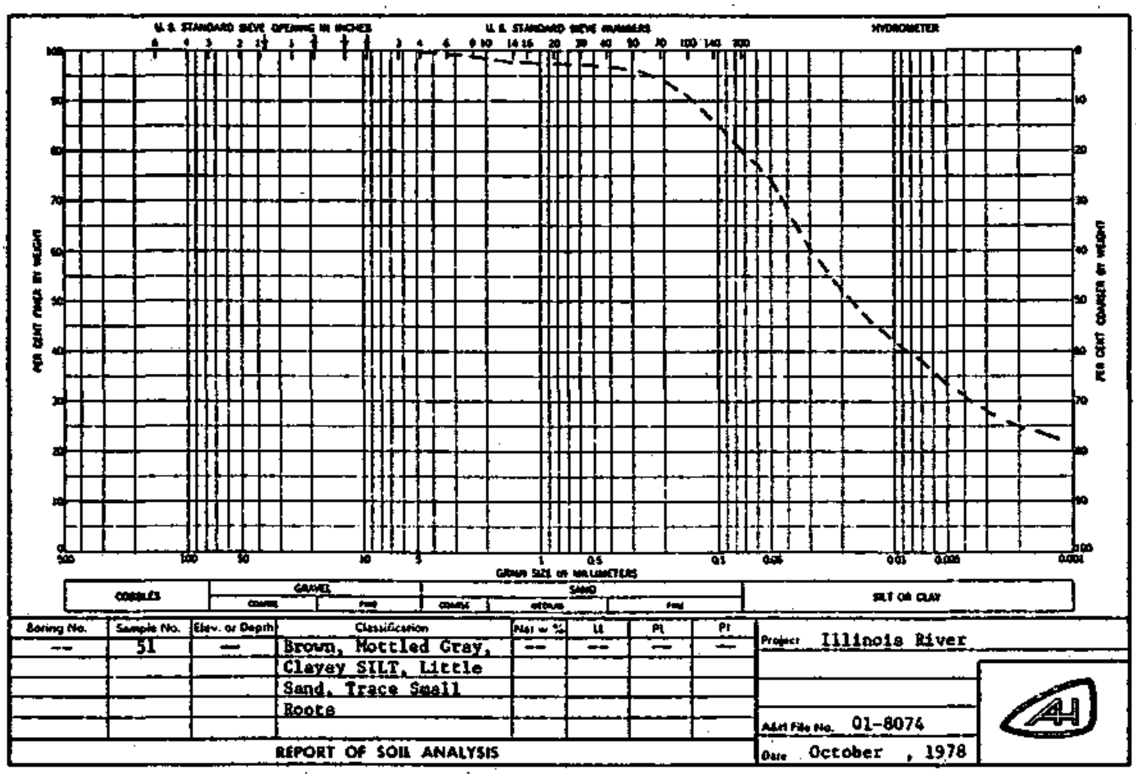
REACH NUMBER: 16
RIVER MILE: 204.0
LOCATION: Left hand side of the river; Hennepin Drainage and Levee District
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 47
CLASSIFICATION: Dark Brown, Mottled Black, Clayey SILT, Little Sand, Trace Small Roots

GRAIN SIZE ANALYSIS:



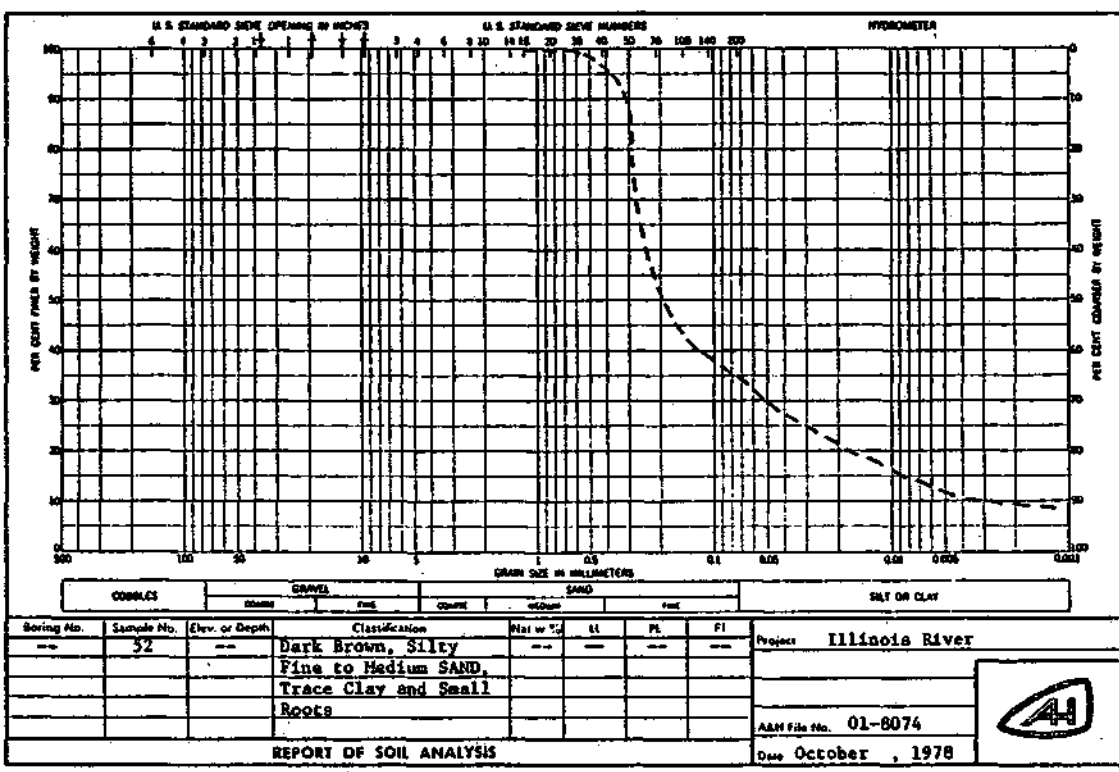
REACH NUMBER: 15
RIVER MILE: 180.0
LOCATION: Left hand side of the river
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 51
CLASSIFICATION: Brown, Mottled Gray, Clayey SILT, Little Sand, Trace Small Roots

GRAIN SIZE ANALYSIS:



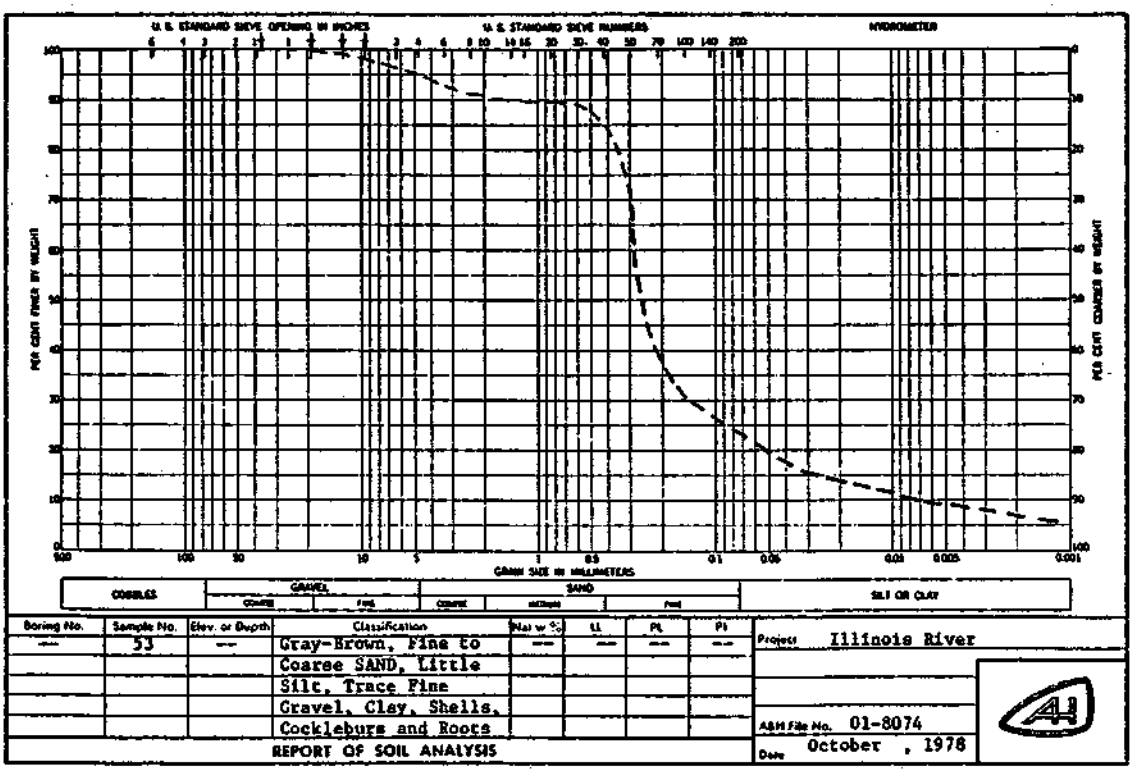
REACH NUMBER: 15
RIVER MILE: 180.0
LOCATION: Left hand side of the river across the small boat harbor at Chillicothe
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 52
CLASSIFICATION: Dark Brown, Silty Fine to Medium SAND, Trace Clay and Small Roots

GRAIN SIZE ANALYSIS:



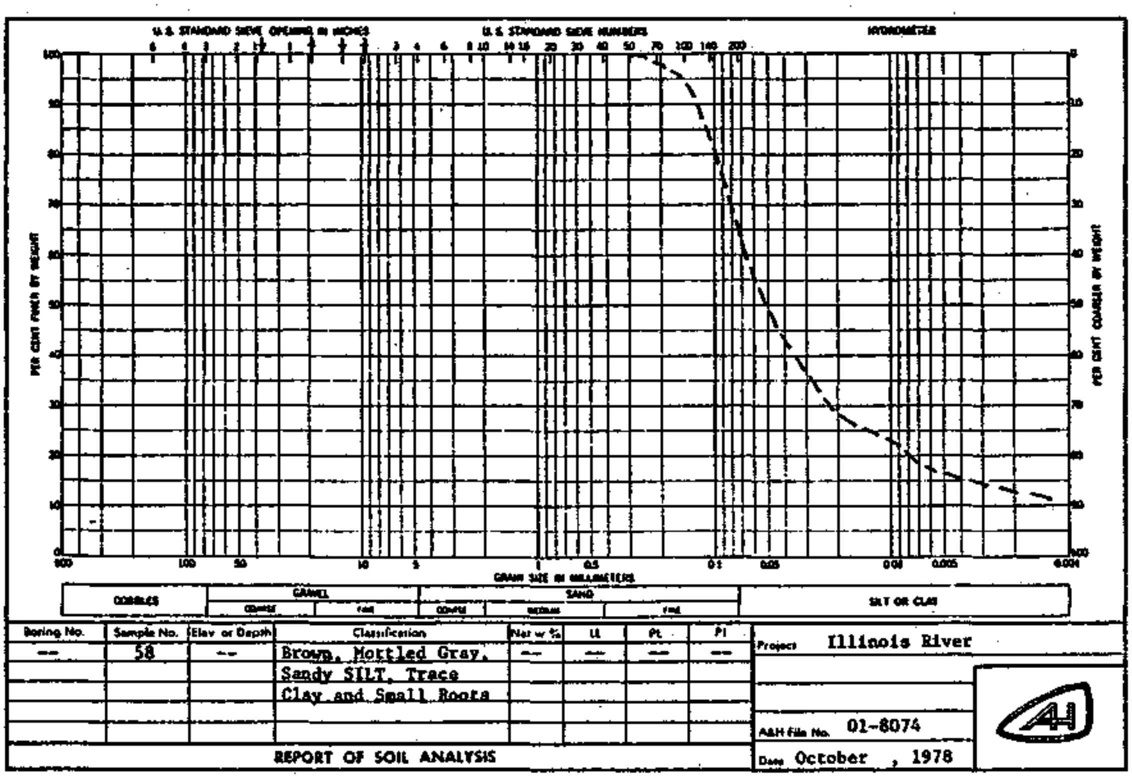
REACH NUMBER: 15
RIVER MILE: 180.0
LOCATION: Left hand side of the river, 50 feet from the water line in the river
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 53
CLASSIFICATION: Gray-Brown, Fine to Coarse SAND, Little Silt, Trace Fine Gravel, Clay, Shells, Cocklebures and Roots

GRAIN SIZE ANALYSIS:



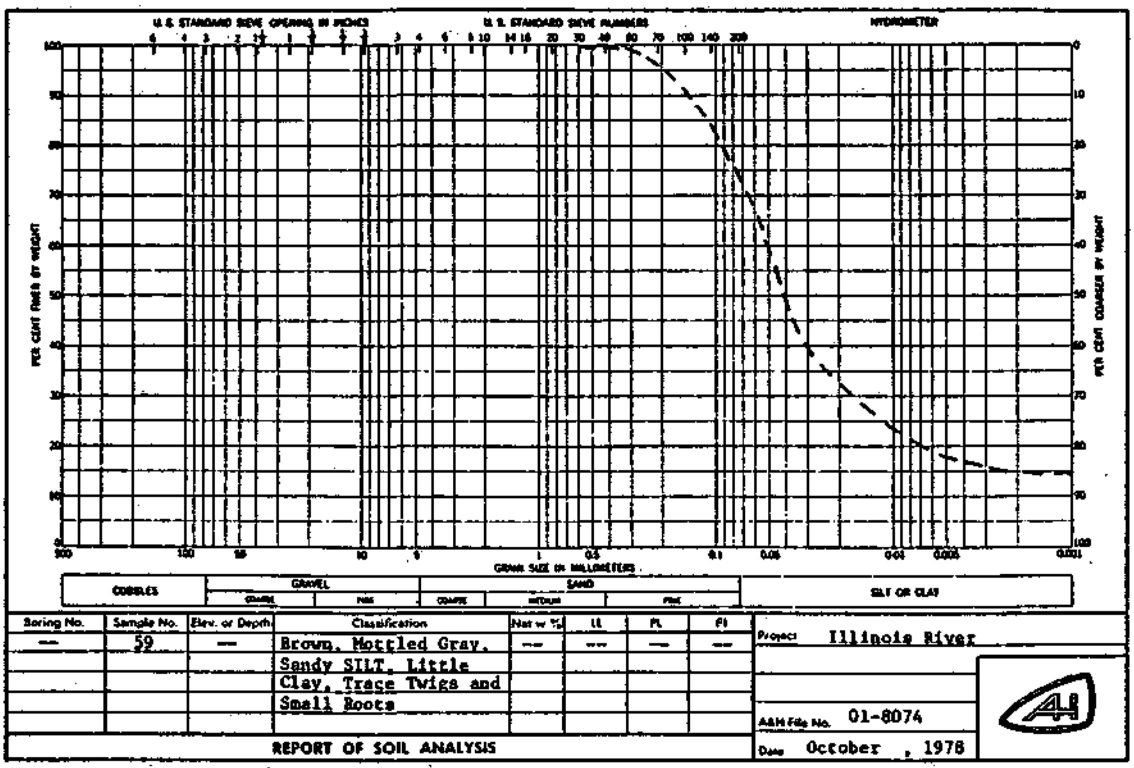
REACH NUMBER: 14
RIVER MILE: 154.0
LOCATION: Left hand side of the river, 15 feet from the water line on the bank
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 58
CLASSIFICATION: Brown, Mottled Gray, Sandy SILT, Trace Clay and Small Roots

GRAIN SIZE ANALYSIS:



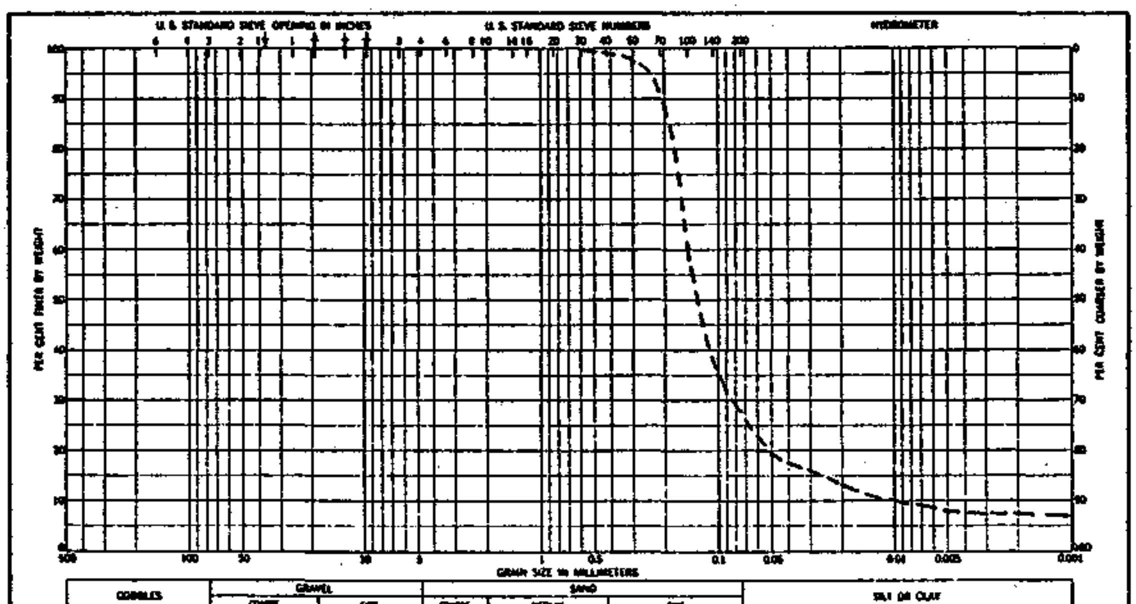
REACH NUMBER: 14
RIVER MILE: 154.0
LOCATION: Left hand side of the river at the water line
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 59
CLASSIFICATION: Brown, Mottled Gray, Sandy SILT, Little Clay, Trace Twigs and Small Roots

GRAIN SIZE ANALYSIS:



REACH NUMBER:	14
RIVER MILE:	154.0
LOCATION:	Left hand side of the river, 50 feet from the water line in the river
DATE OF DATA COLLECTION:	July 19, 1978
SAMPLE NUMBER:	60
CLASSIFICATION:	Gray-Brown, Fine to Medium SAND, Little Silt, Trace Shell Fragments and Twigs

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	60	--	Gray-Brown, Fine to Medium SAND, Little Silt, Trace Shell Fragments and Twigs	--	--	--	--

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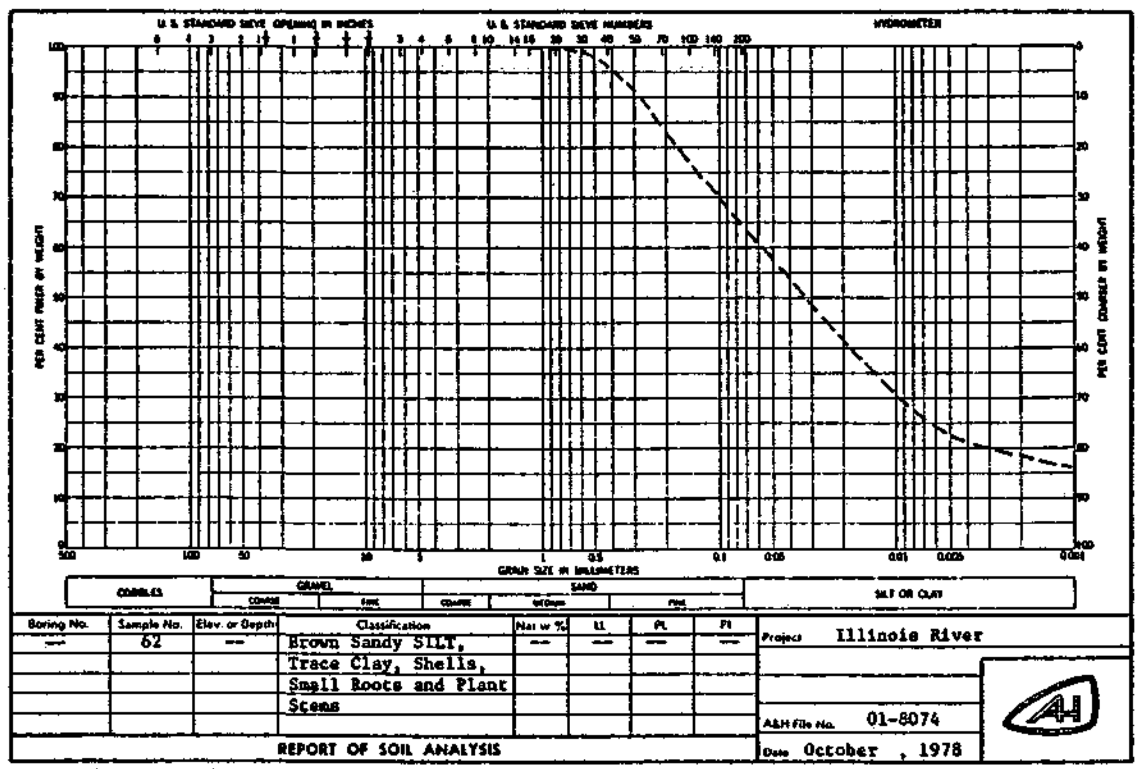
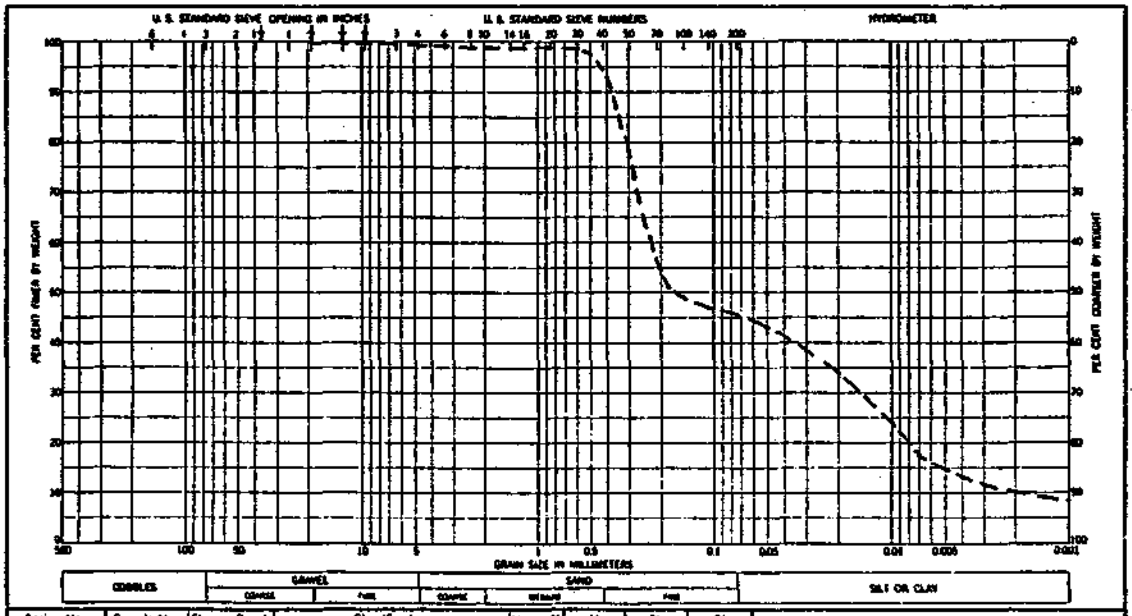
REACH NUMBER: 13
RIVER MILE: 150.0
LOCATION: Right hand side of the river, 15 feet from the water line on the bank
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 62
CLASSIFICATION: Brown Sandy SILT, Trace Clay, Shells, Small Roots and Plant Stems

GRAIN SIZE ANALYSIS:



REACH NUMBER:	13
RIVER MILE:	150.0
LOCATION:	Right hand side of the river near the water line
DATE OF DATA COLLECTION:	July 19, 1978
SAMPLE NUMBER:	63
CLASSIFICATION:	Gray-Brown, Mottled Black, Silty Fine to Coarse SAND, Trace Clay, Wood, Weed Particles and Twigs

GRAIN SIZE ANALYSIS;



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	63	—	Gray-Brown, Mottled Black, Silty Fine to Coarse SAND, Trace Clay, Wood, Weed Particles and Twigs	—	—	—	—

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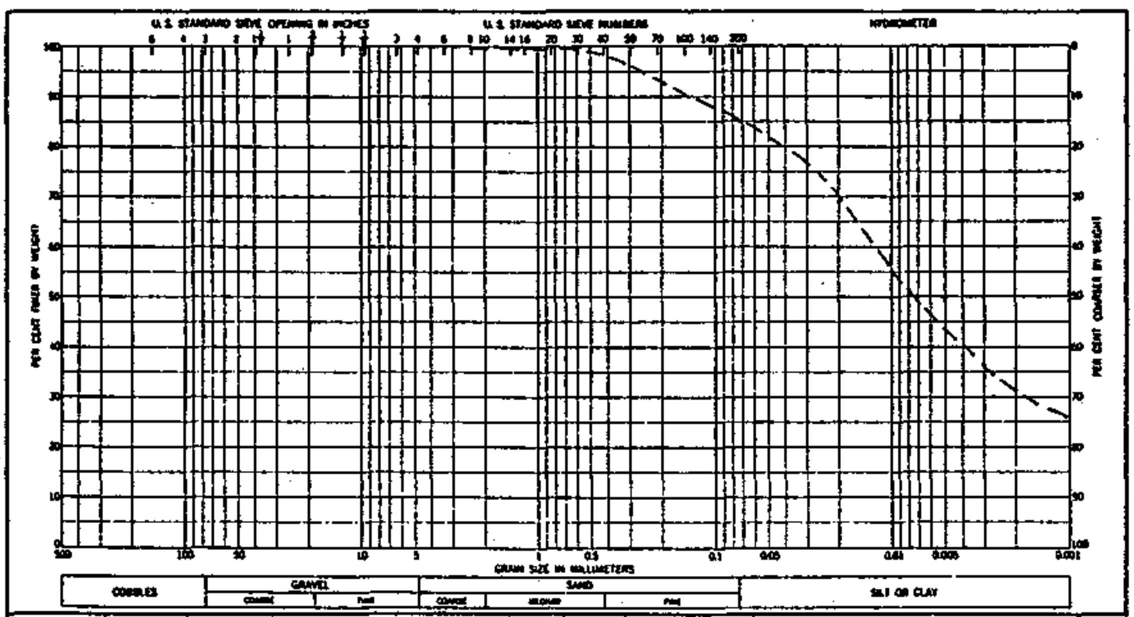
REACH NUMBER: 13
RIVER MILE: 150.0
LOCATION: Right hand side of the river, 50 feet from the water line in the river
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 64
CLASSIFICATION: Brown, Mottled Gray, Clayey SILT, Little Sand, Trace Shells, Roots and Wood

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	64	—	Brown, Mottled Gray Clayey SILT, Little Sand, Trace Shells, Roots and Wood	--	--	--	--

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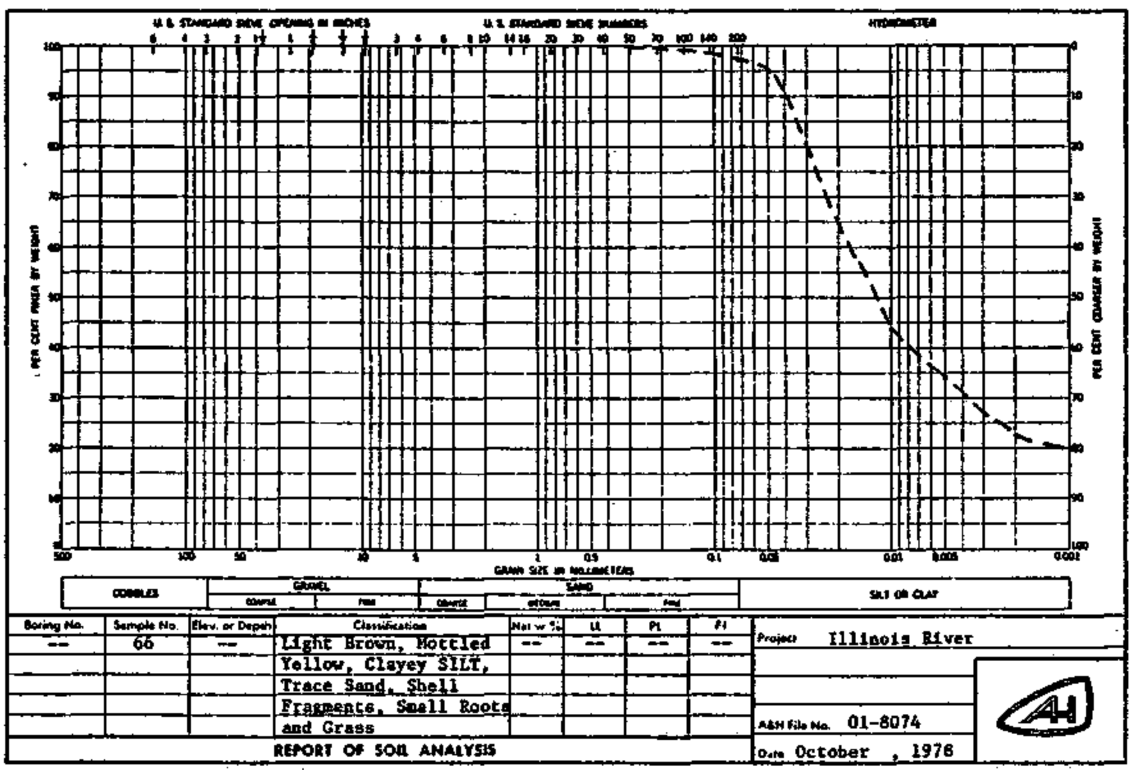
REPORT OF SOIL ANALYSIS

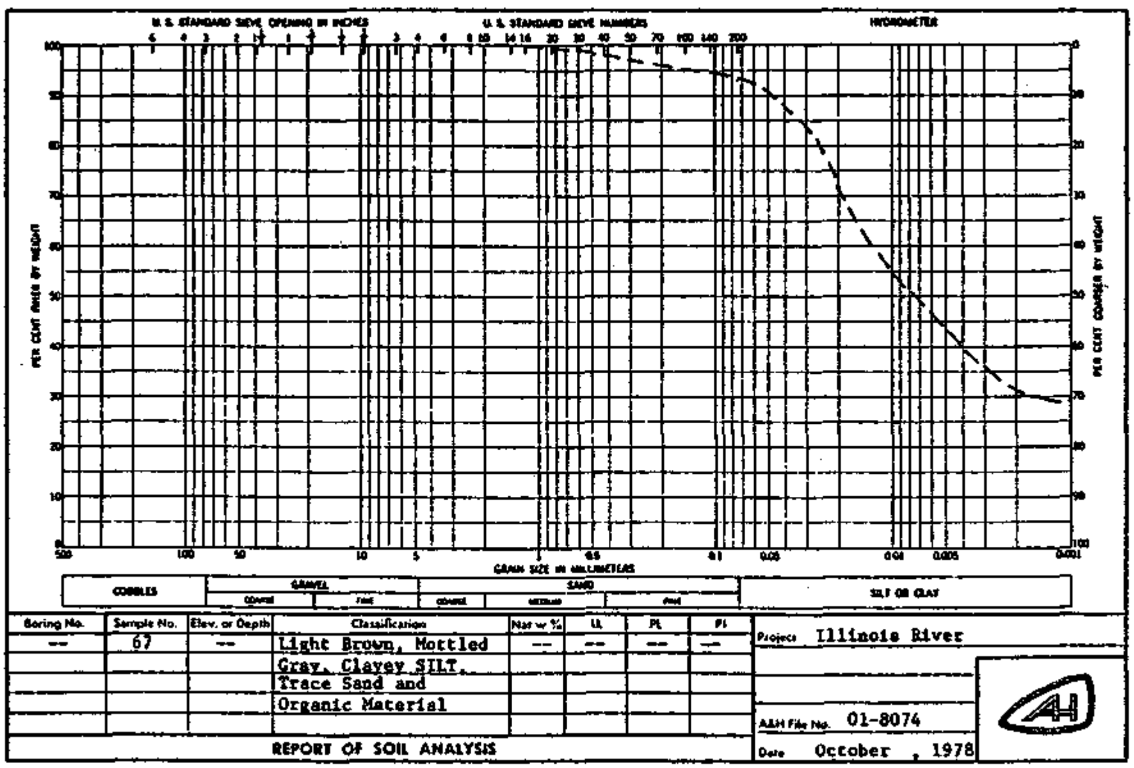
REACH NUMBER: 12
RIVER MILE: 142.5
LOCATION: Right hand side of the river; Banner Special Drainage and Levee District
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 66
CLASSIFICATION: Light Brown, Mottled Yellow, Clayey SILT, Trace Sand, Shell Fragments, Small Roots and Grass

GRAIN SIZE ANALYSIS:



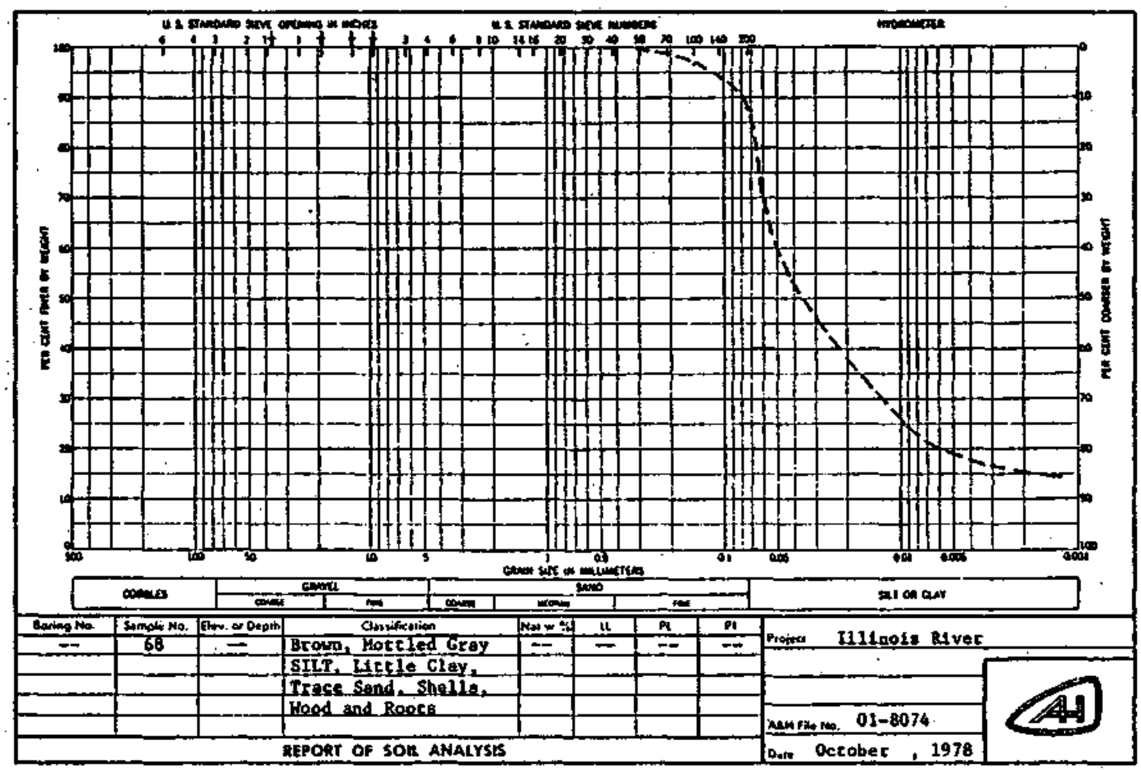
REACH NUMBER: 12
RIVER MILE: 142.5
LOCATION: Right hand side of the river near the water line; Banner Special Drainage and Levee District
DATE OF DATA COLLECTION; July 19, 1978
SAMPLE NUMBER: 67
CLASSIFICATION: Light Brown, Mottled Gray, Clayey SILT, Trace Sand and Organic Material (Small Roots and Grass Seed)

GRAIN SIZE ANALYSIS:



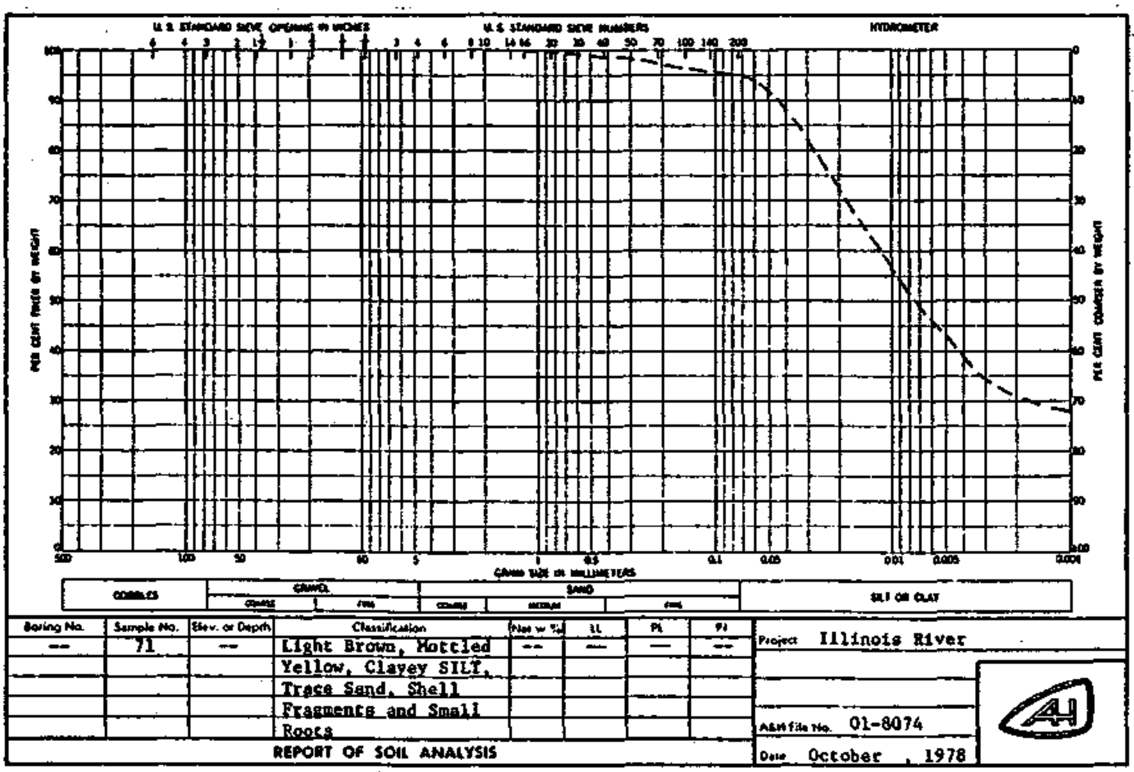
REACH NUMBER: 12
RIVER MILE: 142.5
LOCATION: Right hand side of the river, 50 feet from the water line in the river; Banner Special Drainage and Levee District
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 68
CLASSIFICATION: Brown, Mottled Gray SILT, Little Clay, Trace Sand, Shells, Wood and Roots

GRAIN SIZE ANALYSIS:



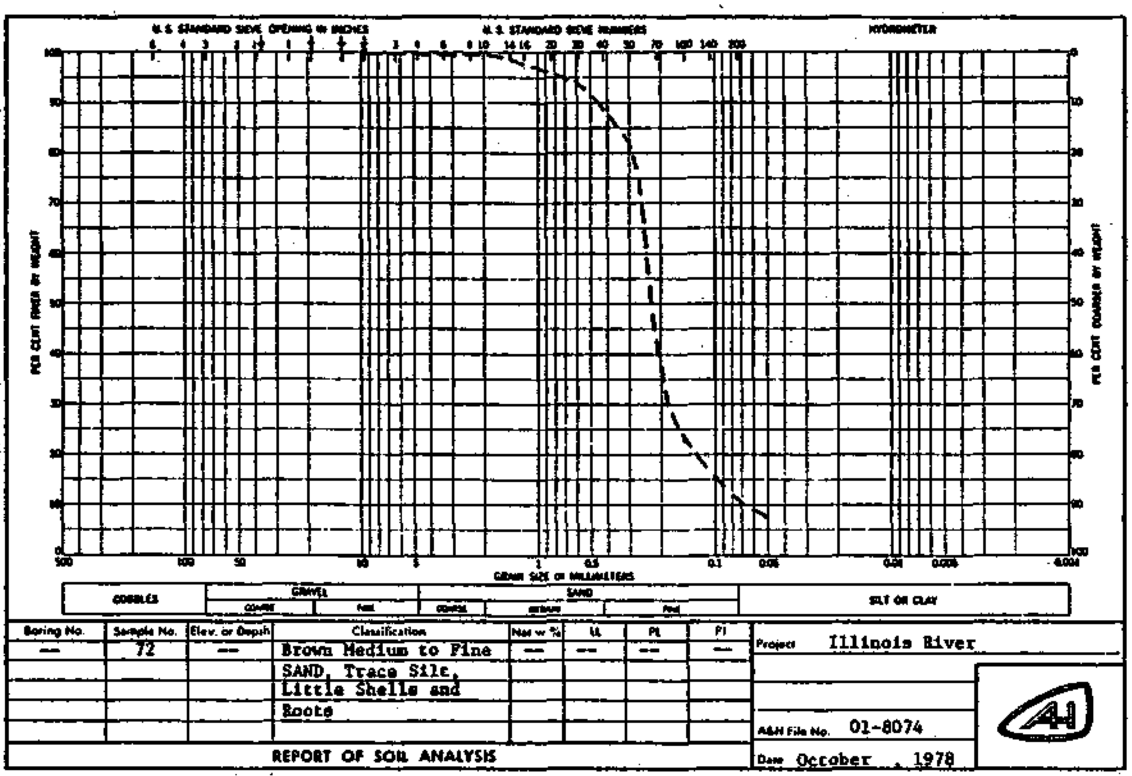
REACH NUMBER:	11
RIVER MILE:	134.0
LOCATION:	Left hand side of the river, 15 feet from the water line on the bank
DATE OF DATA COLLECTION:	July 19, 1978
SAMPLE NUMBER:	71
CLASSIFICATION:	Light Brown, Mottled Yellow, Clayey SILT, Trace Sand, Shell Fragments and Small Roots

GRAIN SIZE ANALYSIS:



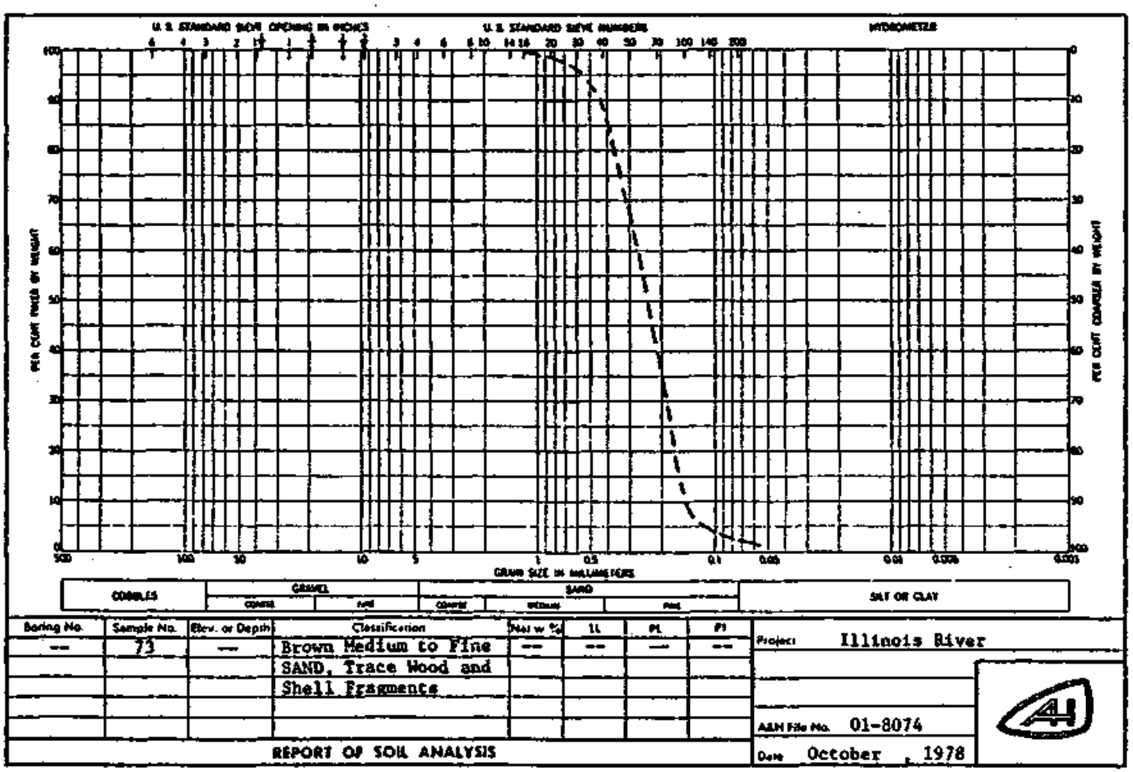
REACH NUMBER: 11
RIVER MILE: 134.0
LOCATION: Left hand side of the river near the water line
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 72
CLASSIFICATION: Brown to Medium to Fine SAND, Trace Silt, Little Shells and Roots

GRAIN SIZE ANALYSIS:



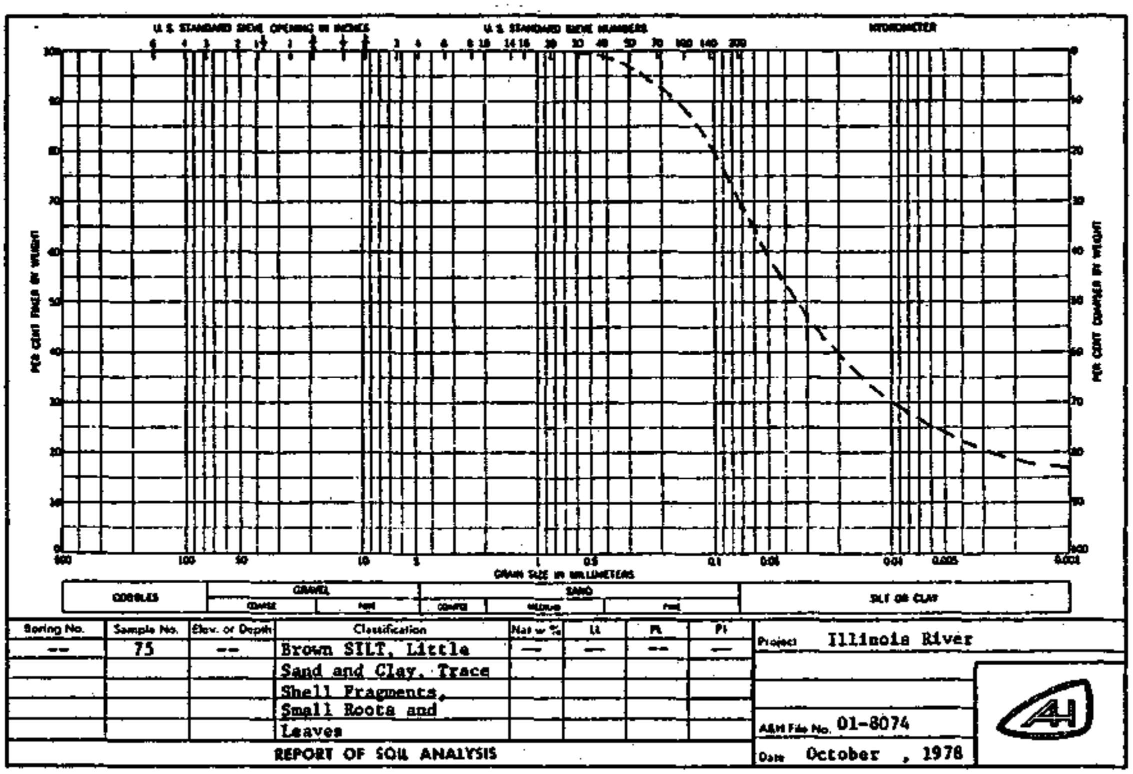
REACH NUMBER:	11
RIVER MILE:	134
LOCATION:	Left hand side of the river, 30 feet from the water line in the river
DATE OF DATA COLLECTION:	July 19, 1978
SAMPLE NUMBER:	73
CLASSIFICATION:	Brown Medium to Fine SAND, Trace Wood and Shell Fragments

GRAIN SIZE ANALYSIS:



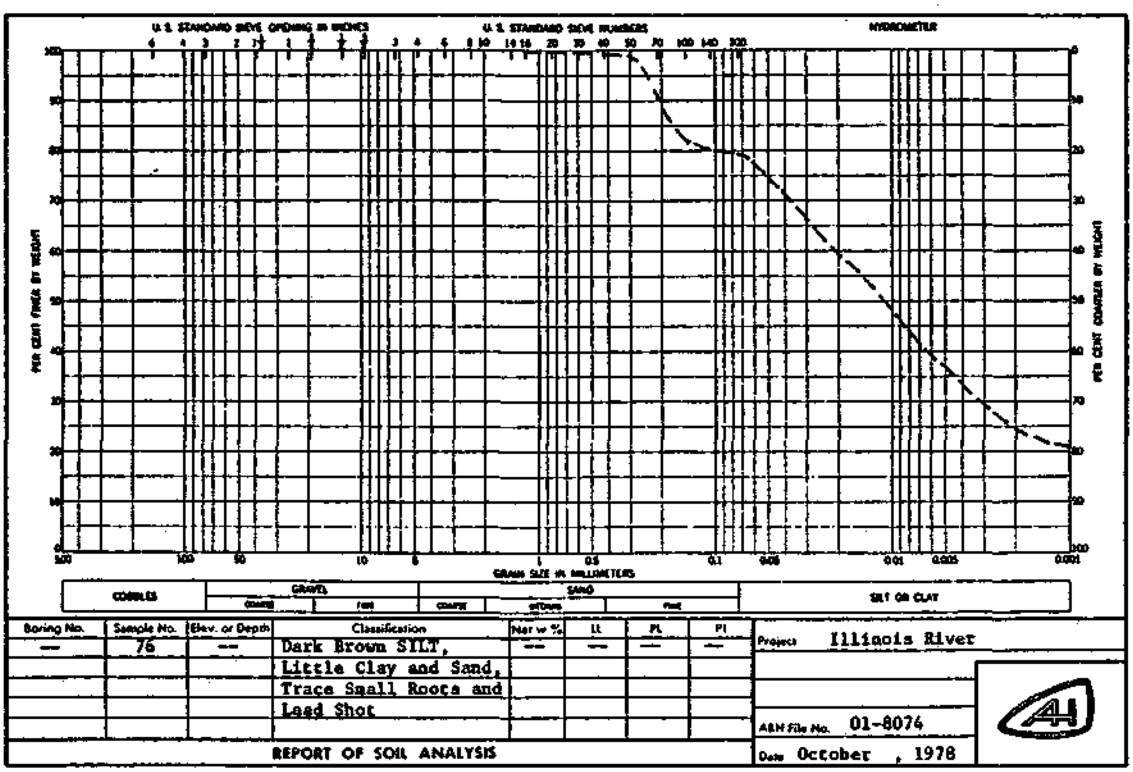
REACH NUMBER: 10
RIVER MILE: 126.0
LOCATION: Left hand side of the river at the top of the bank
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 75
CLASSIFICATION: Brown SILT,Little Sand and Clay, Trace Shell Fragments, Small Roots and Leaves

GRAIN SIZE ANALYSIS:



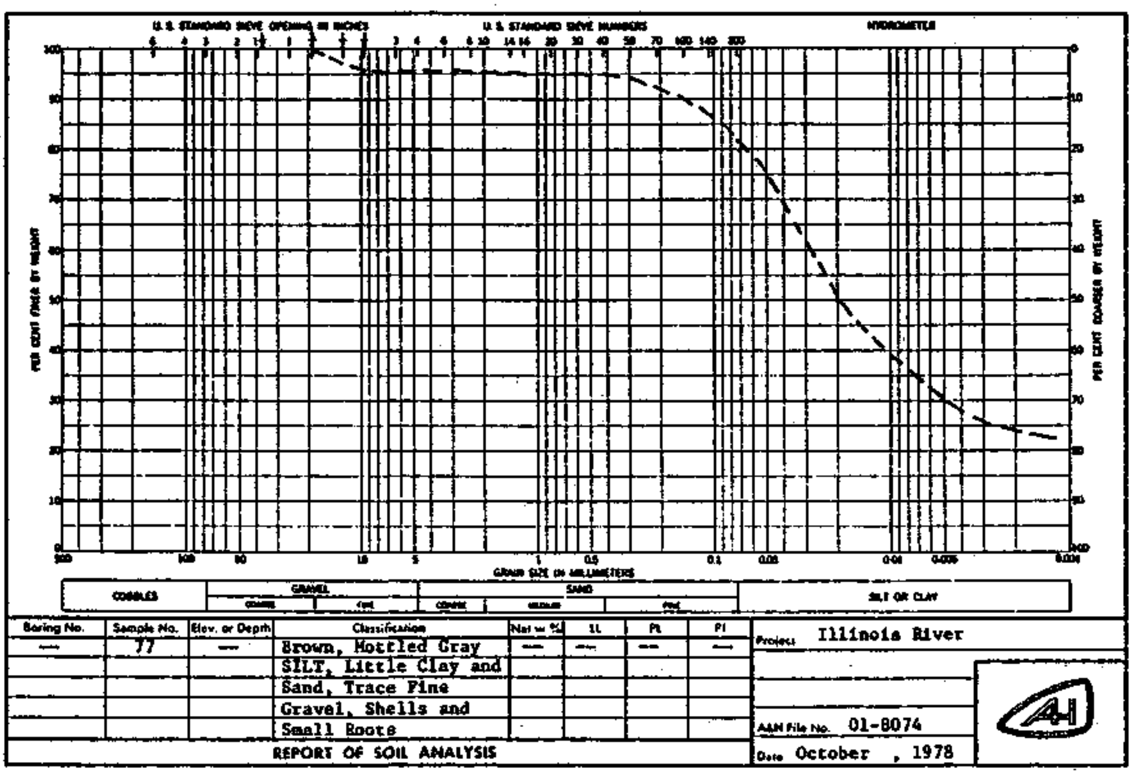
REACH NUMBER: 10
RIVER MILE: 126.0
LOCATION: Left hand side of the river near the water line
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 76
CLASSIFICATION: Dark Brown SILT, Little Clay and Sand, Trace Small Roots and Lead Shot

GRAIN SIZE ANALYSIS:



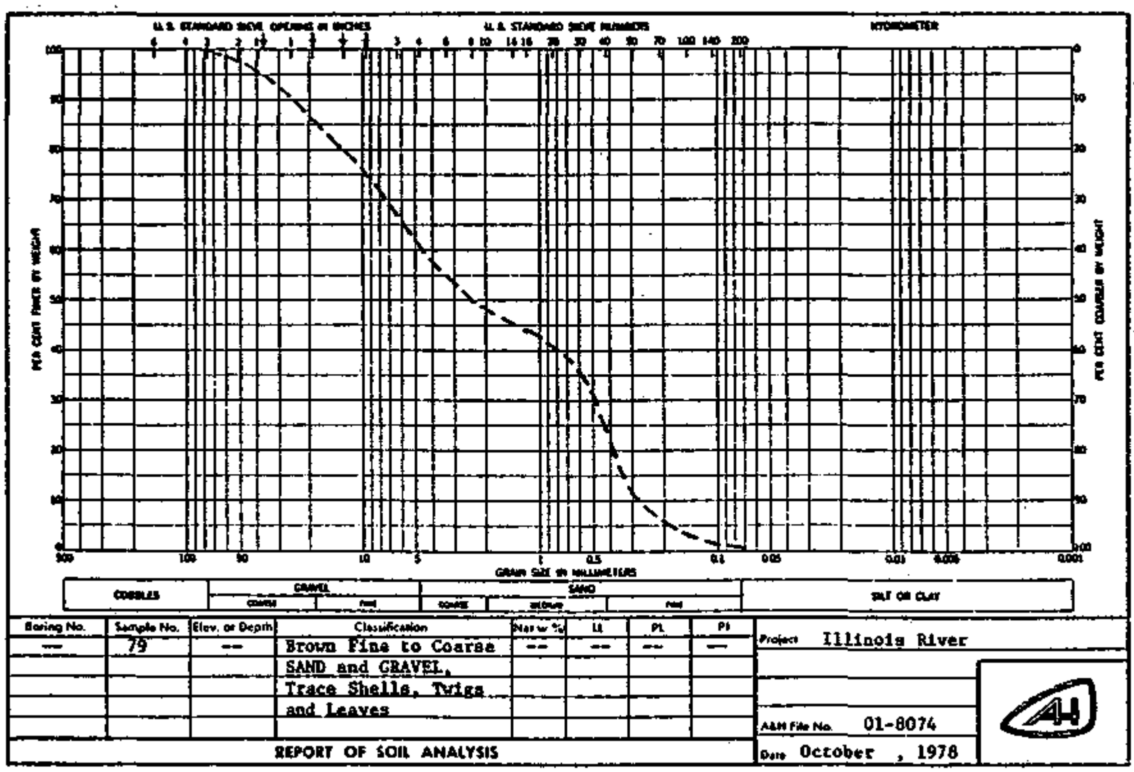
REACH NUMBER: 10
RIVER MILE: 126.0
LOCATION: Left hand side of the river, 50 feet from the water line in the river
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 77
CLASSIFICATION: Brown, Mottled Gray SILT, Little Clay and Sand, Trace Fine Gravel, Shells and Small Roots

GRAIN SIZE ANALYSIS:



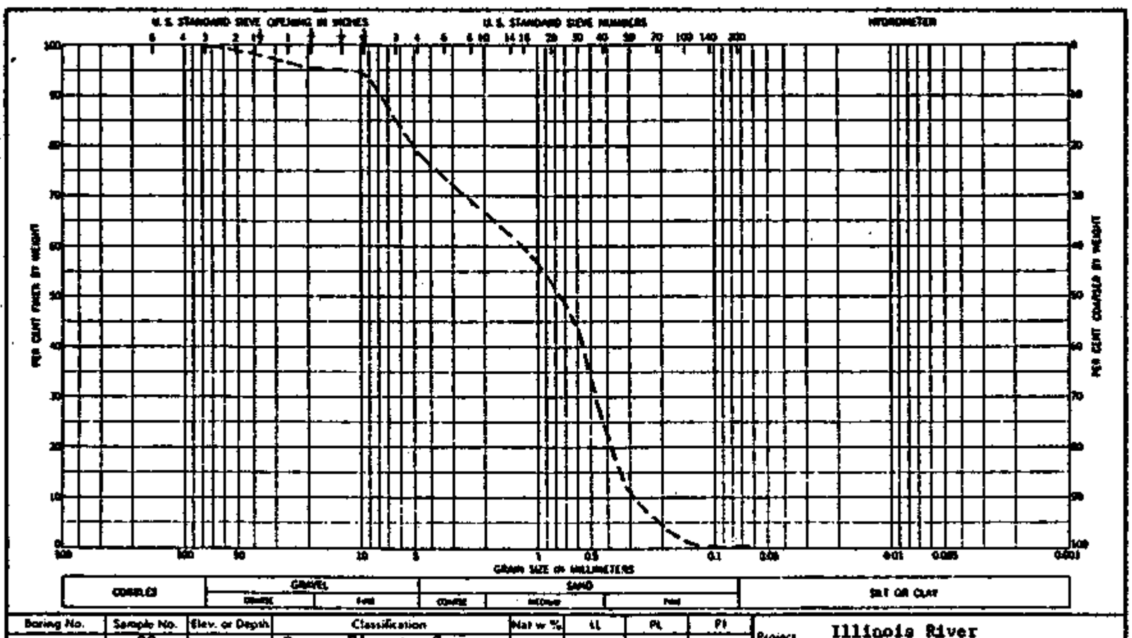
REACH NUMBER: 9
RIVER MILE: 121.4
LOCATION: Right hand side of the river near the water line; Thompson Lake Drainage and Levee District
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 79
CLASSIFICATION: Brown Fine to Coarse SAND and GRAVEL, Trace Shells, Twigs and Leaves

GRAIN SIZE ANALYSIS:



REACH NUMBER: 9
RIVER MILE: 121.4
LOCATION: Right hand side of the river, 50 feet from the water line on the Levee; Thompson Lake Drainage and Levee District
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 80
CLASSIFICATION: Brown Fine to Coarse SAND, Little Gravel, Trace Shells and Organic Material (Cockleburs, Roots, Maple Seed, Leaves and Wood)

GRAIN SIZE ANALYSIS:



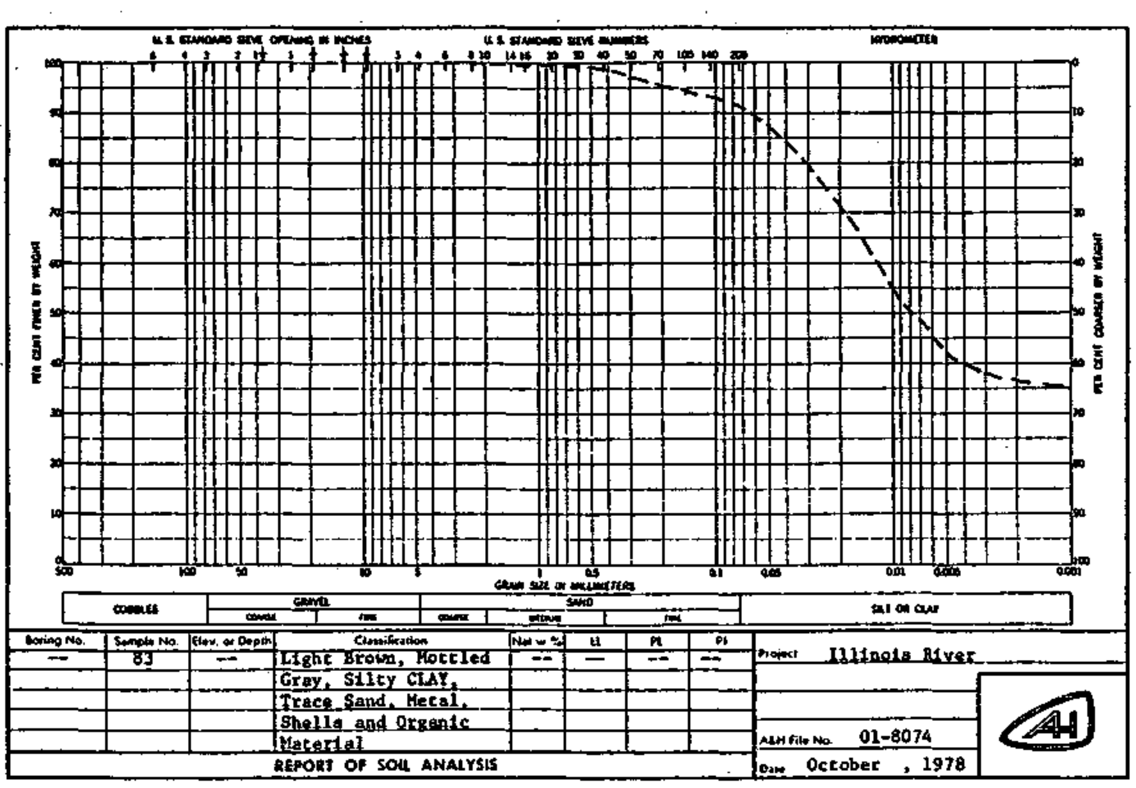
Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	80	—	Brown Fine to Coarse SAND, Little Gravel, Trace Shells and Organic Material	--	--	--	—

Project Illinois River
A&H File No. 01-8074
Date October , 1978

REPORT OF SOIL ANALYSIS

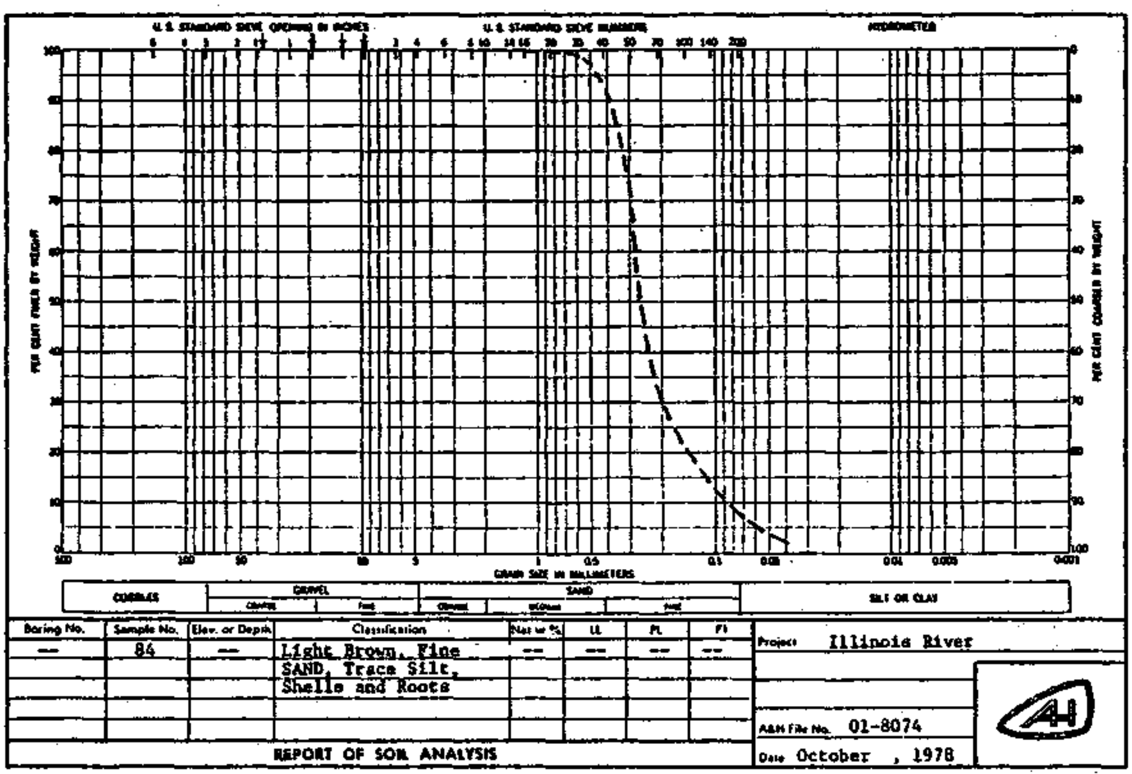
REACH NUMBER:	8
RIVER MILE:	116.5
LOCATION:	Right hand side of the river, 10 feet from the water line on the bank; Lacey, Langellier, West Matanzas and Kerton Valley Drainage and Levee District
DATE OF DATA COLLECTION:	July 19, 1978
SAMPLE NUMBER:	83
CLASSIFICATION:	Light Brown, Mottled Gray, Silty CLAY, Trace Sand, Metal, Shells and Organic Material (Leaves and Roots)

GRAIN SIZE ANALYSIS:



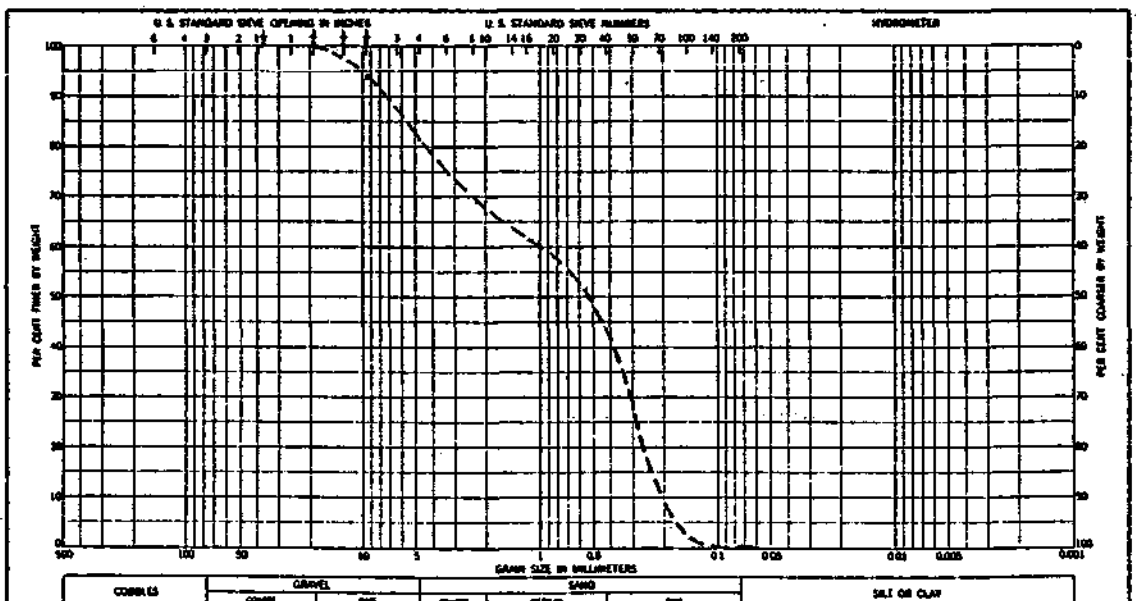
REACH NUMBER: 8
RIVER MILE: 116.5
LOCATION: Right hand side of the river near the water line in the same area as Sample 83
DATE OF COLLECTION: July 19, 1978
SAMPLE NUMBER: 84
CLASSIFICATION: Light Brown, Fine SAND, Trace Silt, Shells and Roots

GRAIN SIZE ANALYSIS:



REACH NUMBER:	8
RIVER MILE:	116.5
LOCATION:	Right hand side of the river, 50 feet from the water line in the river
DATE OF DATA COLLECTION:	July 19, 1978
SAMPLE NUMBER:	85
CLASSIFICATION:	Brown Fine to Coarse SAND, Little Fine Gravel and Trace Shells

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	85	—	Brown Fine to Coarse SAND, Little Fine Gravel and Trace Shells	—	—	—	—

Project Illinois River

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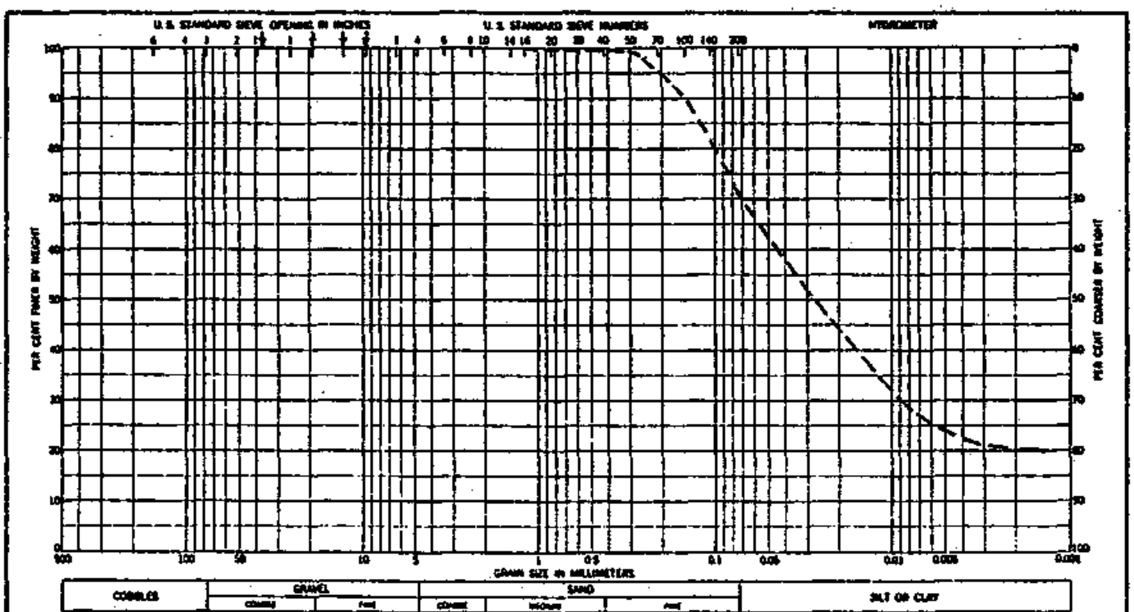
Date October , 1978

REPORT OF SOIL ANALYSIS

REACH NUMBER: 7
RIVER MILE: 113.0
LOCATION: Left hand side of the river on the bank
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 88
CLASSIFICATION: Brown, Mottled Gray SILT, Little Clay and Sand, Trace Moss, Small Roots and Twigs

GRAIN SIZE ANALYSIS:



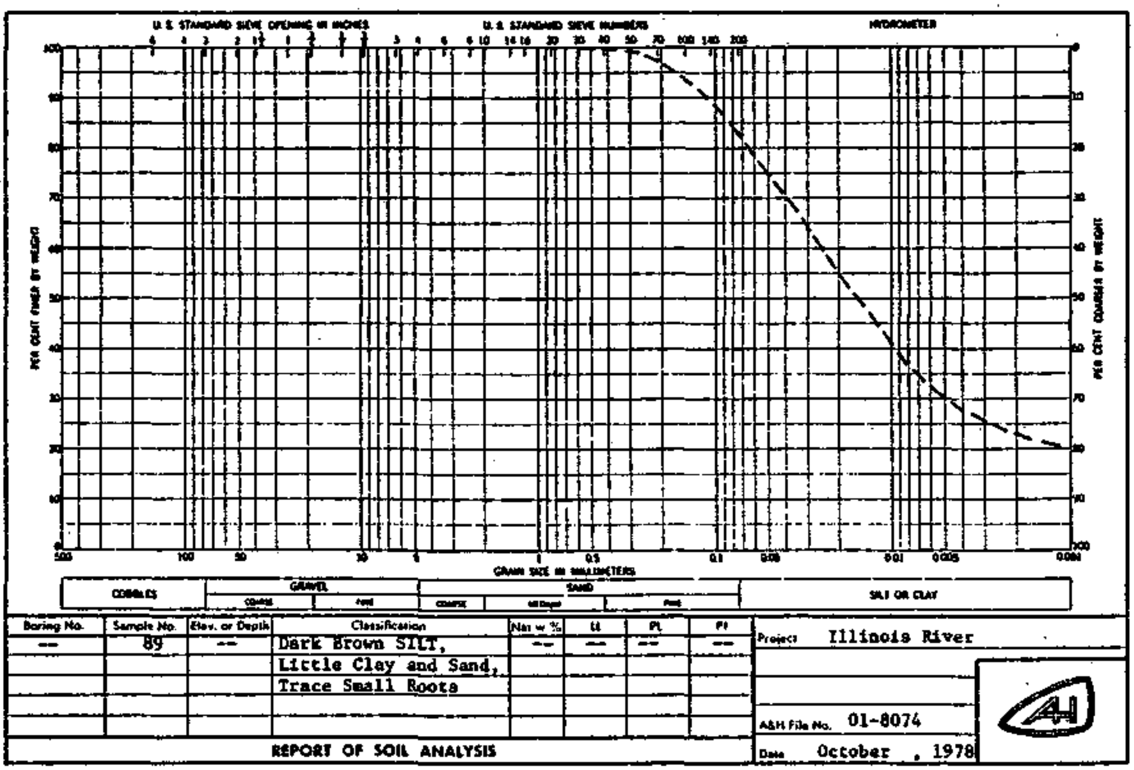
Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	88	--	Brown, Mottled Gray SILT, Little Clay and Sand, Trace Moss, Small Roots and Twigs	--	--	--	--

Project: Illinois River
A&H File No. 01-8074
Date October , 1978

REPORT OF SOIL ANALYSIS

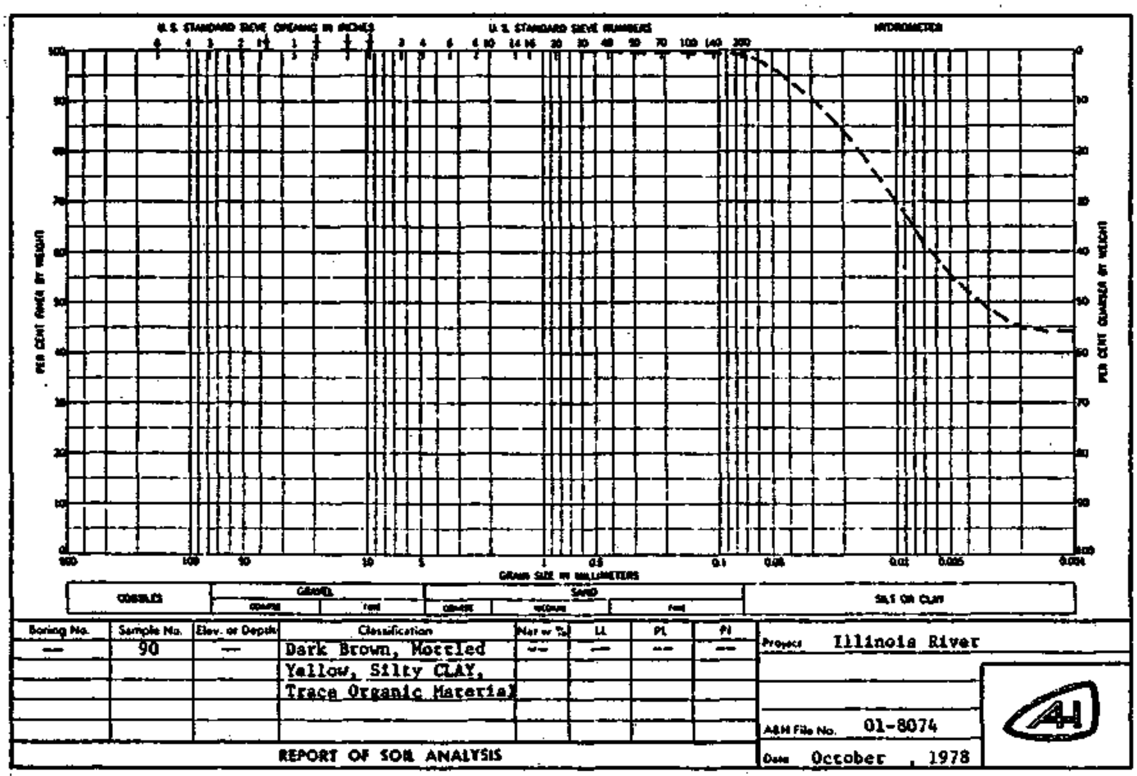
REACH NUMBER: 7
RIVER MILE: 113.0
LOCATION: Left hand side of the river, 50 feet from the water line in the river
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 89
CLASSIFICATION: Dark Brown SILT, Little Clay and Sand, Trace Small Roots

GRAIN SIZE ANALYSIS:



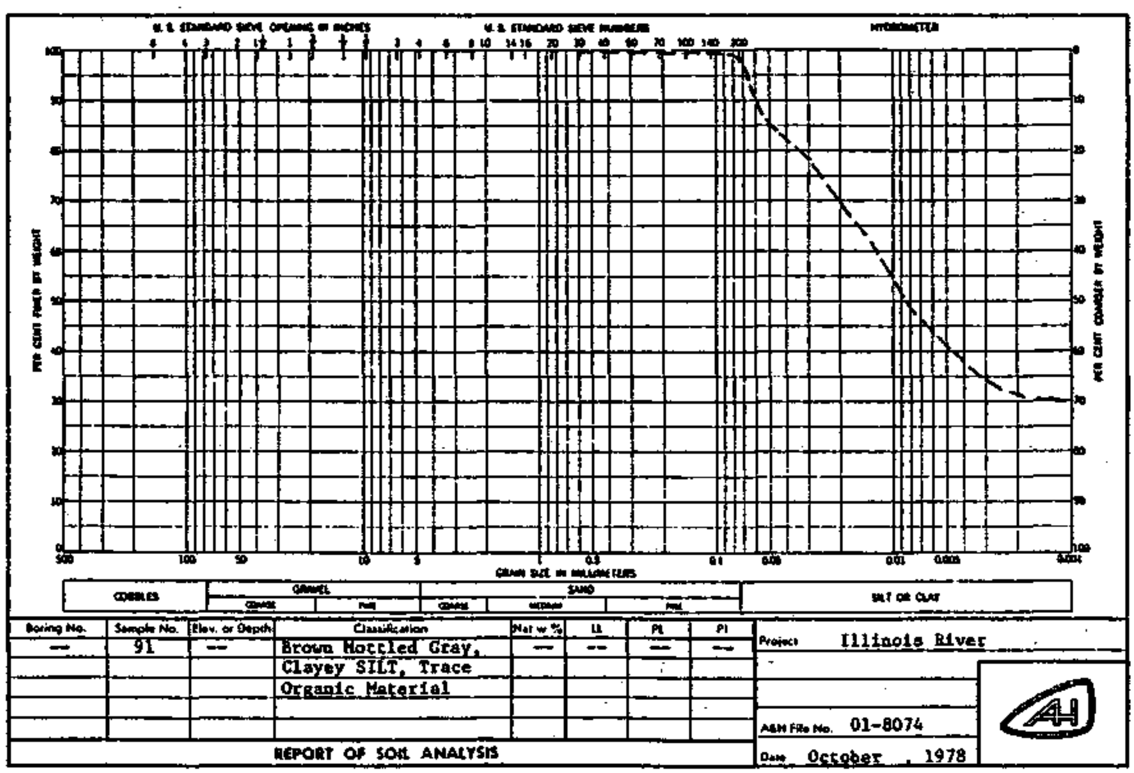
REACH NUMBER: 6
RIVER MILE: 104.0
LOCATION: Right hand side of the river at the top of the bank
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 90
CLASSIFICATION: Dark Brown, Mottled Yellow, Silty CLAY, Trace Organic Material (Roots, Leaves, Plant Stems, and Grass Seed)

GRAIN SIZE ANALYSIS:



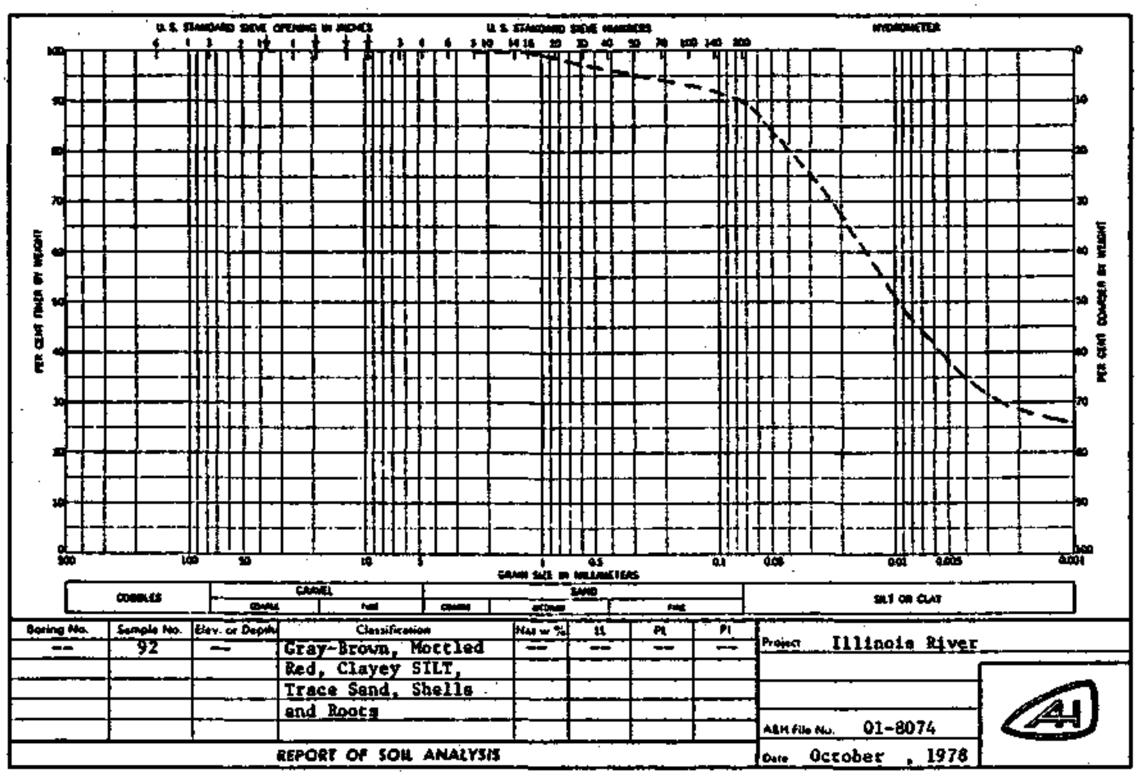
REACH NUMBER: 6
RIVER MILE: 104.0
LOCATION: Right hand side of the river near the water line
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 91
CLASSIFICATION: Brown Mottled Gray, Clayey SILT, Trace Organic Material (Twigs, Roots, Plant Stems and Grass Seed)

GRAIN SIZE ANALYSIS:



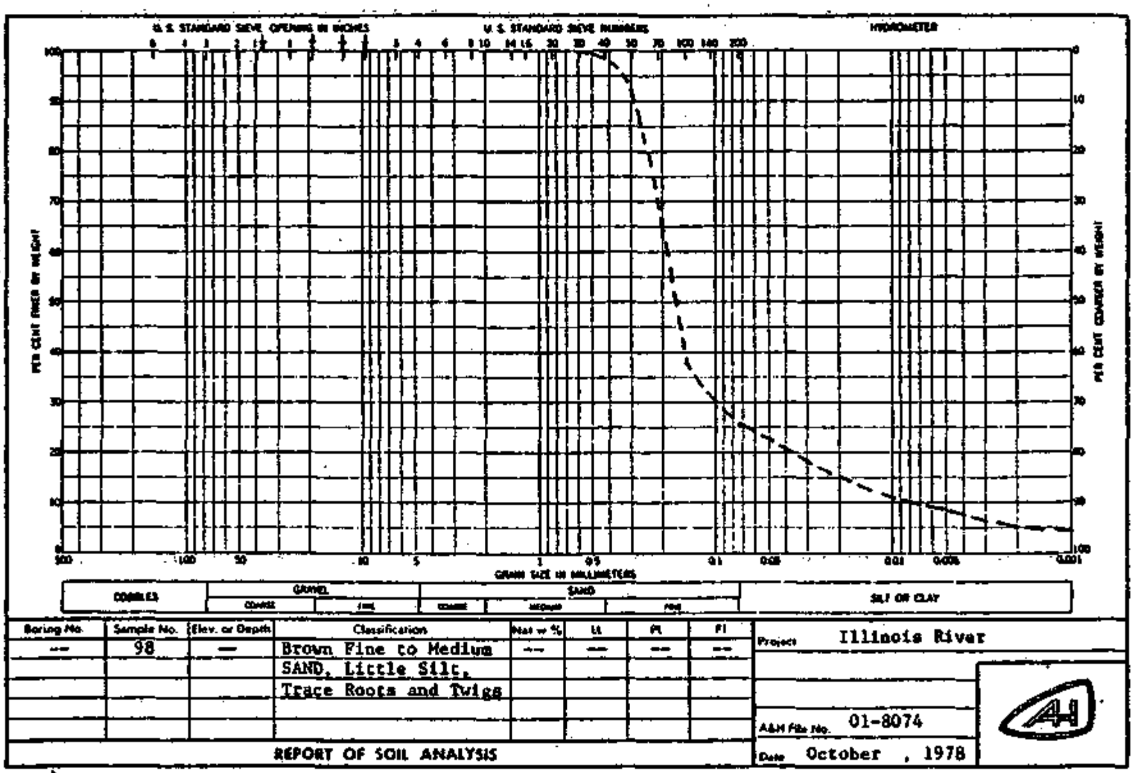
REACH NUMBER: 6
RIVER MILE: 104.0
LOCATION: Right hand side of the river, 50 feet from the water line in the river
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 92
CLASSIFICATION: Gray-Brown, Mottled Red, Clayey SILT, Trace Sand, Shells and Roots

GRAIN SIZE ANALYSIS:



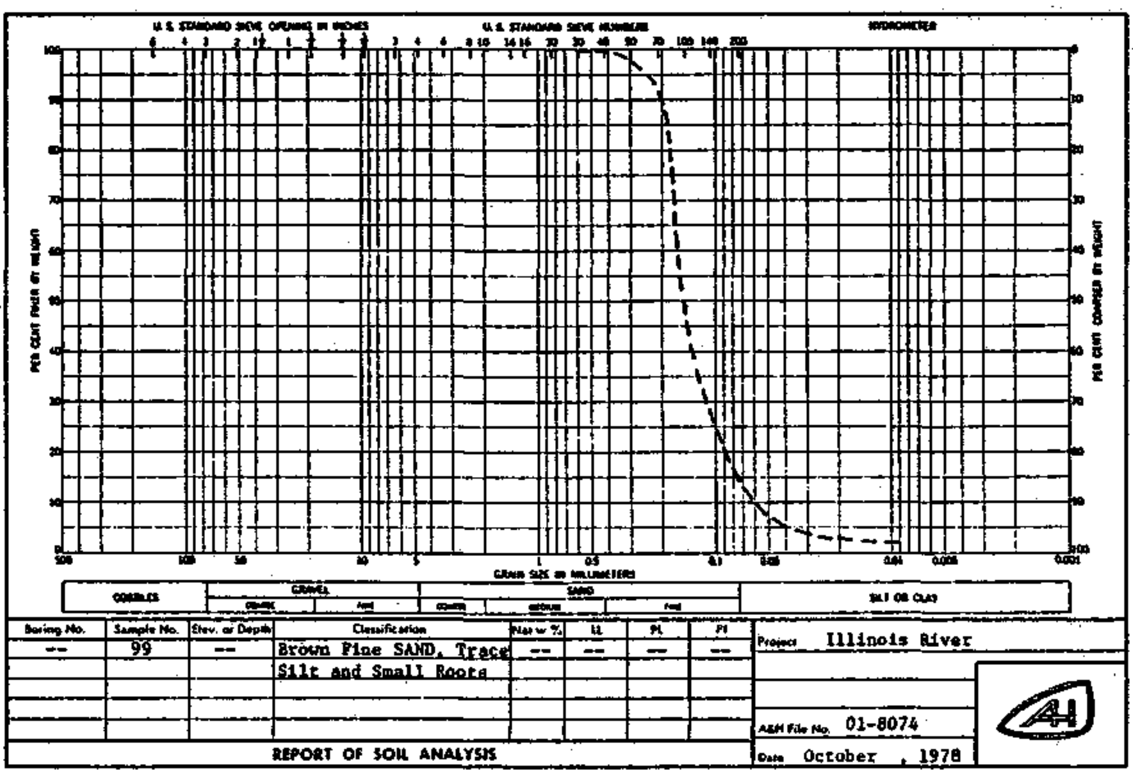
REACH NUMBER: 4
RIVER MILE: 82.1
LOCATION: Left hand side of the river on the bank
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 98
CLASSIFICATION: Brown Fine to Medium SAND, Little Silt, Trace Roots and Twigs

GRAIN SIZE ANALYSIS:



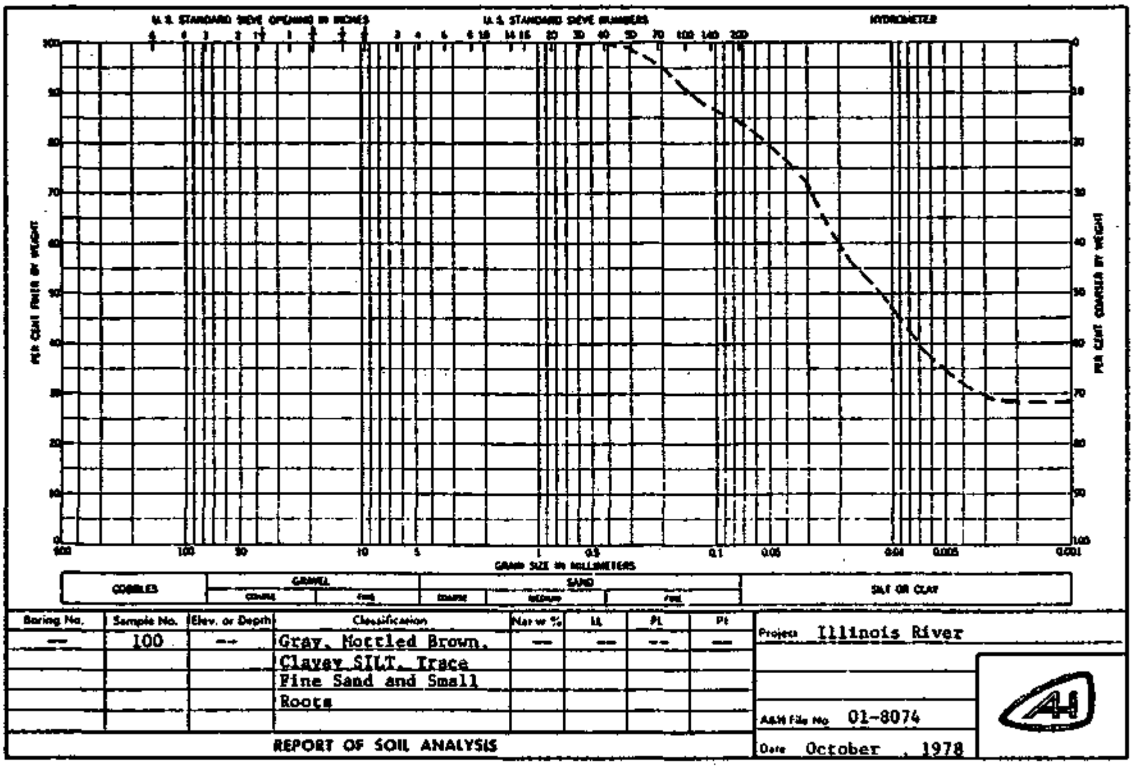
REACH NUMBER: 4
RIVER MILE: 82.1
LOCATION: Left hand side of the river near the water line
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER:. 99
CLASSIFICATION: Brown Fine SAND, Trace Silt and Small Roots

GRAIN SIZE ANALYSIS:



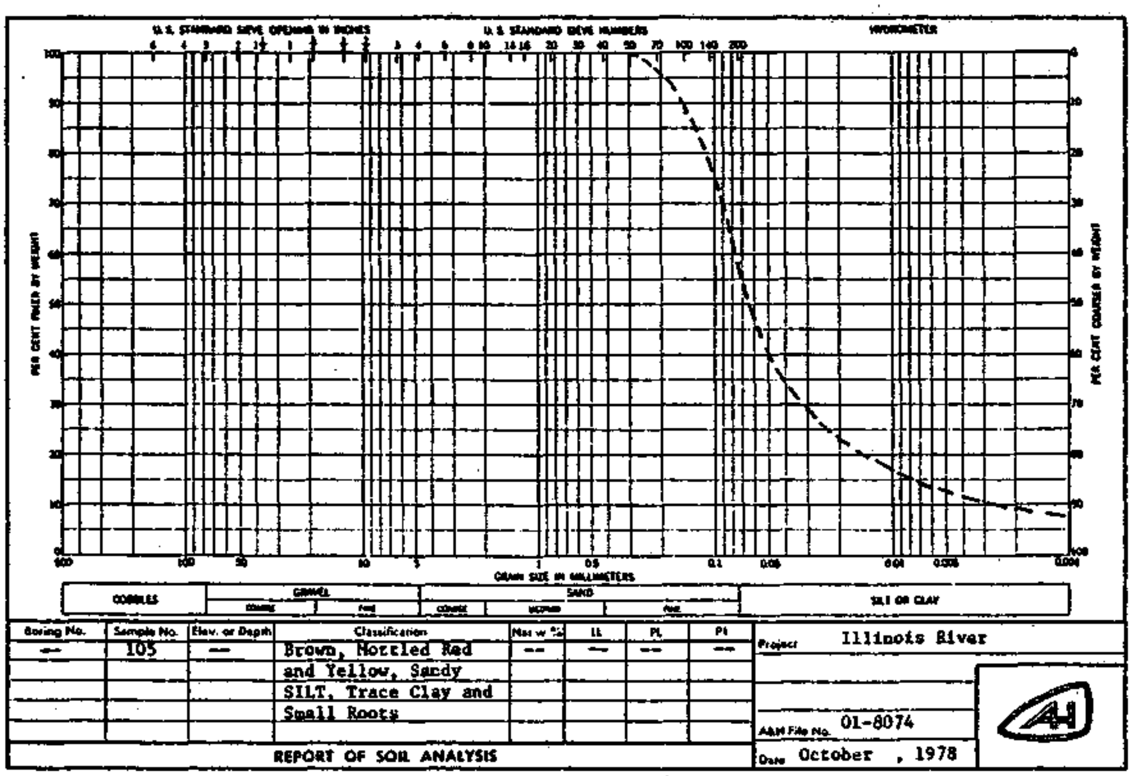
REACH NUMBER: 4
RIVER MILE: 82.1
LOCATION: Left hand side of the river, 50 feet from the water line in the river
DATE OF DATA COLLECTION; July 20, 1978
SAMPLE NUMBER: 100
CLASSIFICATION: Gray, Mottled Brown, Clayey SILT, Trace Fine Sand and Small Roots

GRAIN SIZE ANALYSIS:



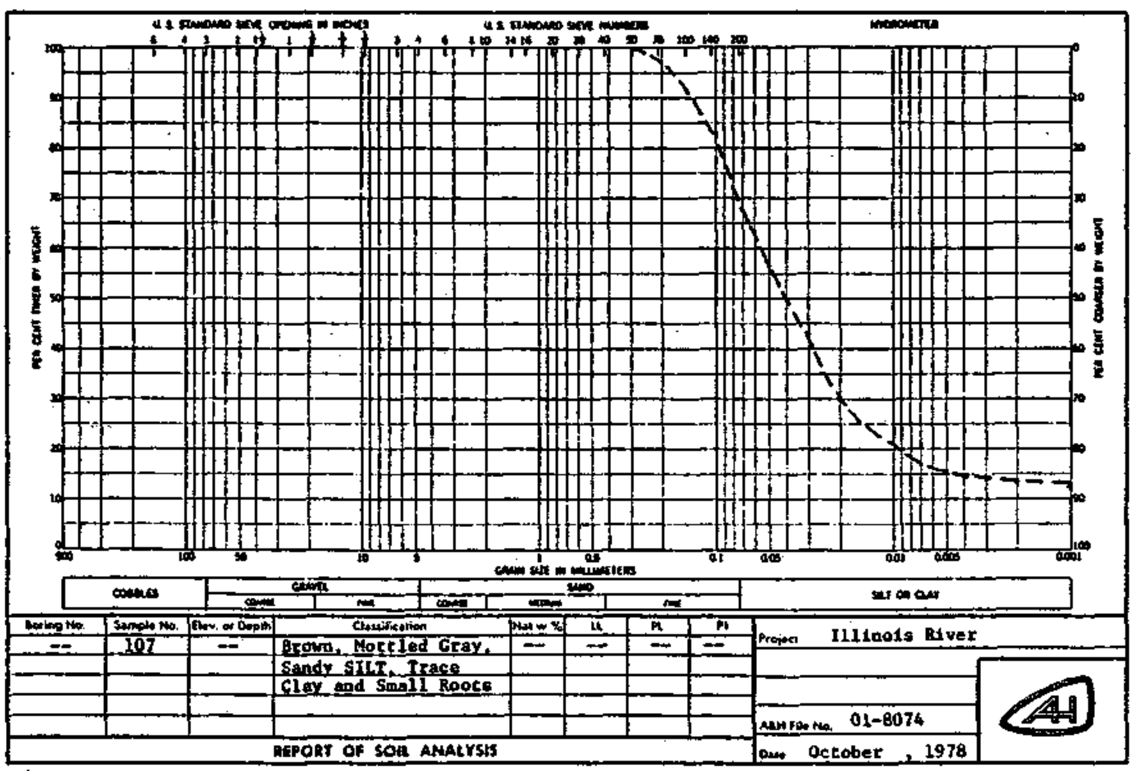
REACH NUMBER: 3
RIVER MILE: 60.2
LOCATION: Left hand side of the river on the bank
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 105
CLASSIFICATION: Brown, Mottled Red and Yellow, Sandy SILT, Trace Clay and Small Roots

GRAIN SIZE ANALYSIS:



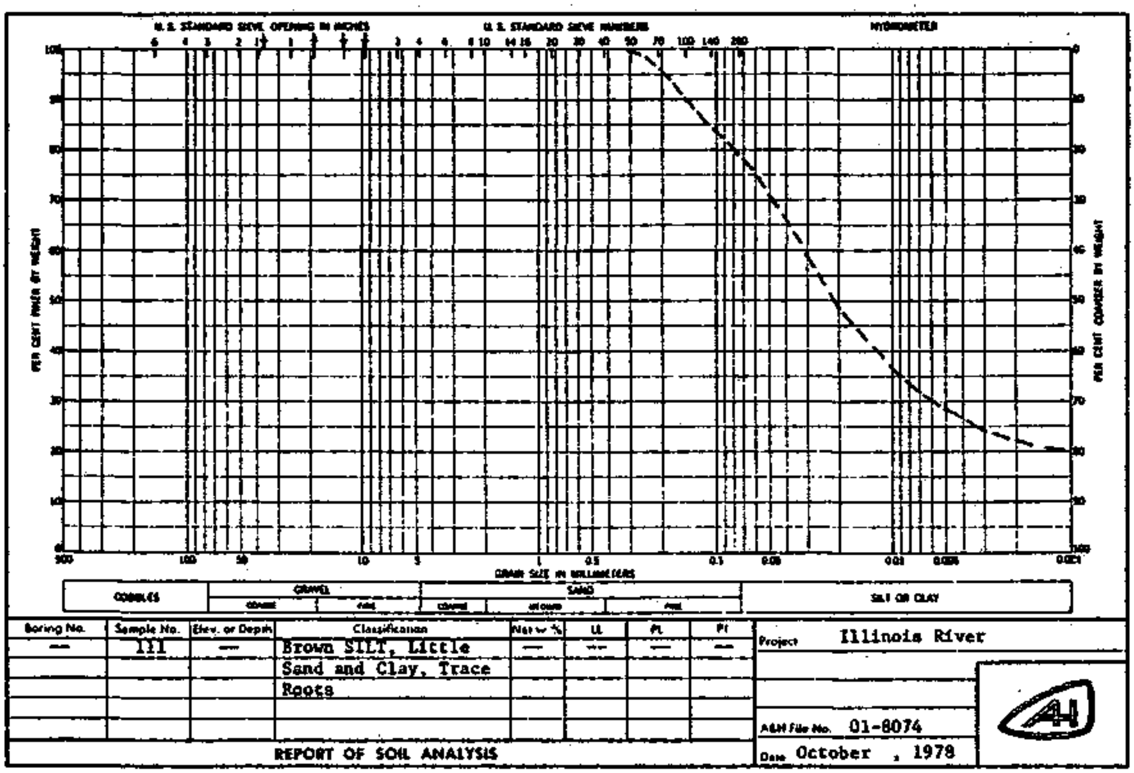
REACH NUMBER: 3
RIVER MILE: 60.2
LOCATION: Left hand side of the river; 50 feet from the water line in the river
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 107
CLASSIFICATION: Brown, Mottled Gray, Sandy SILT, Trace Clay and Small Roots

GRAIN SIZE ANALYSIS:



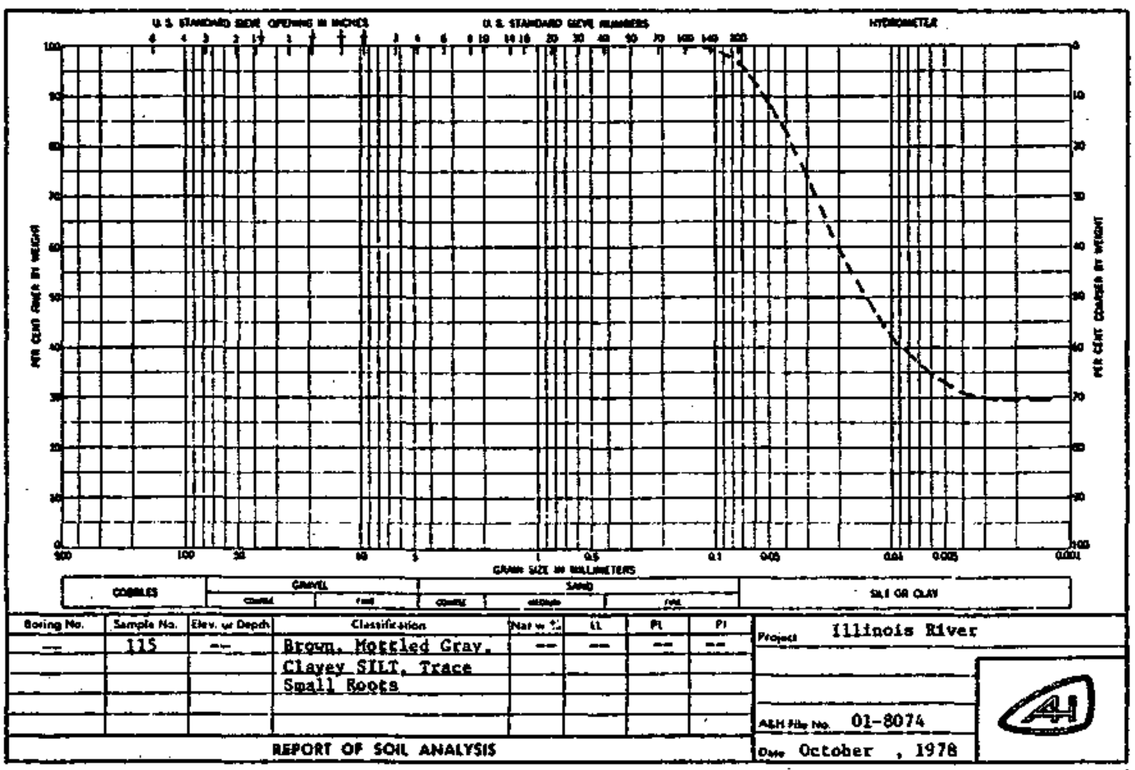
REACH NUMBER: 2
RIVER MILE: 38.4
LOCATION: Left hand side of the river on Fisher Island
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 111
CLASSIFICATION: Brown SILT, Little Sand and Clay, Trace Roots

GRAIN SIZE ANALYSIS:



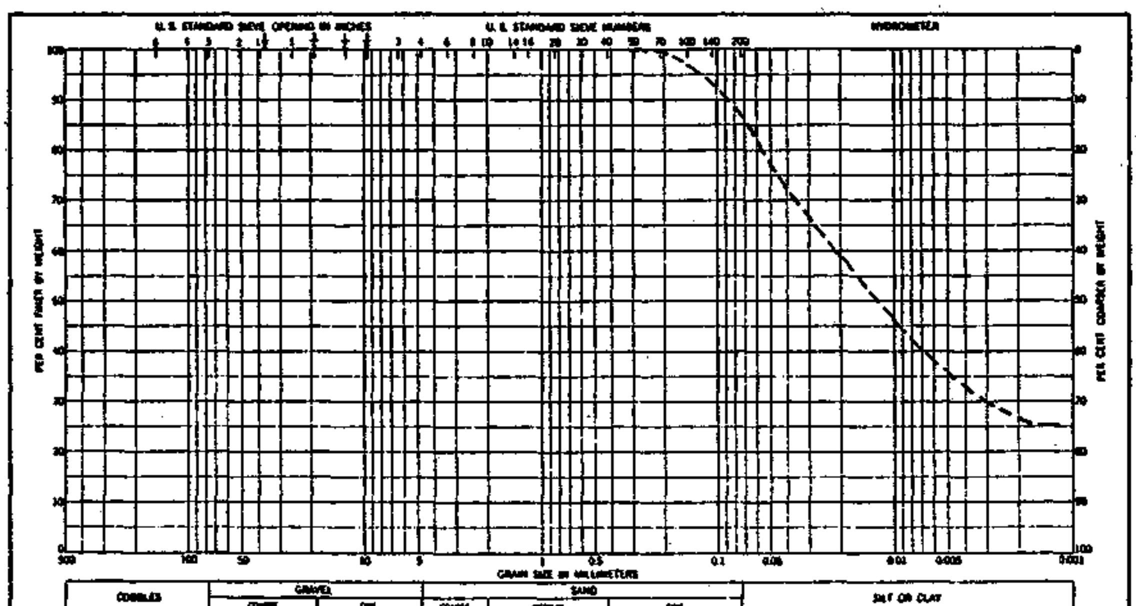
REACH NUMBER: 1
RIVER MILE: 24.4
LOCATION: Left hand side of the river on the bank
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 115
CLASSIFICATION: Brown, Mottled Gray, Clayey SILT, Trace Small Roots

GRAIN SIZE ANALYSIS:



REACH NUMBER: 1
RIVER MILE: 24.4
LOCATION: Left hand side of the river, 50 feet from the water line in the river
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 116
CLASSIFICATION: Gray, Mottled Brown, Clayey SILT, Trace Sand, Shells and Small Roots

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	116	—	Gray, Mottled Brown, Clayey SILT, Trace Sand, Shells and Small Roots	--	—	--	--

Project: Illinois River

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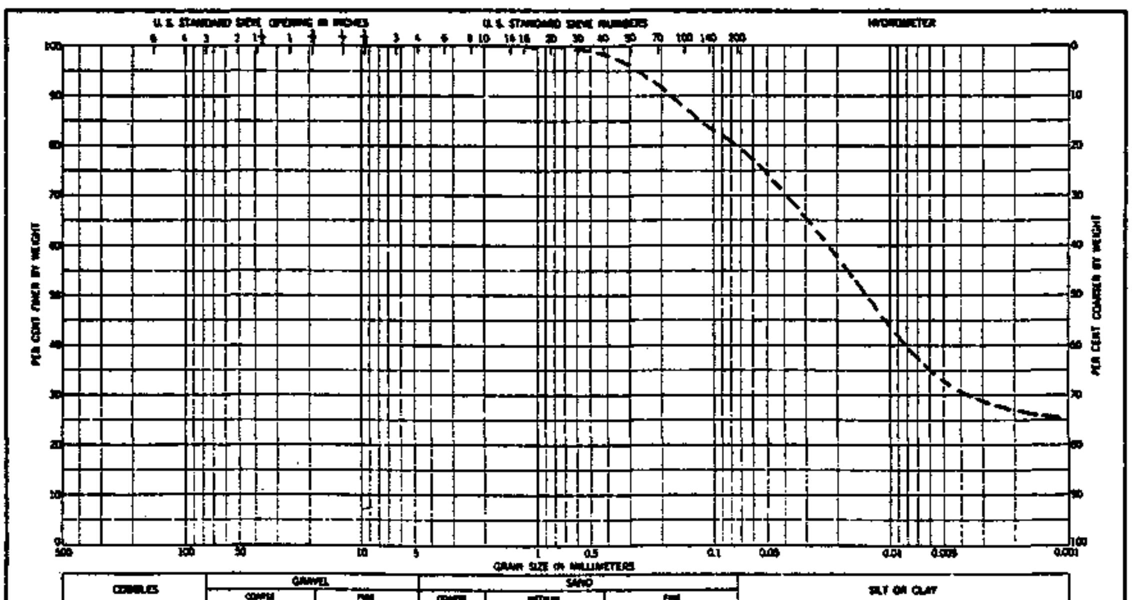
Date October , 1978

REPORT OF SOIL ANALYSIS

REACH NUMBER: 5
RIVER MILE: 101 to 102
LOCATION: Right hand side of the river, near the water line
DATE OF DATA COLLECTION: October 19, 1978
SAMPLE NUMBER: 122
CLASSIFICATION: Brown, Mottled Gray, Sandy Clayey SILT, Trace Shell Fragments and Organic Material (Roots and Leaves)

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	122	—	Brown, Mottled Gray, Sandy Clayey SILT, Trace Shell Fragments and Organic Material	—	—	—	—

Project: Illinois River

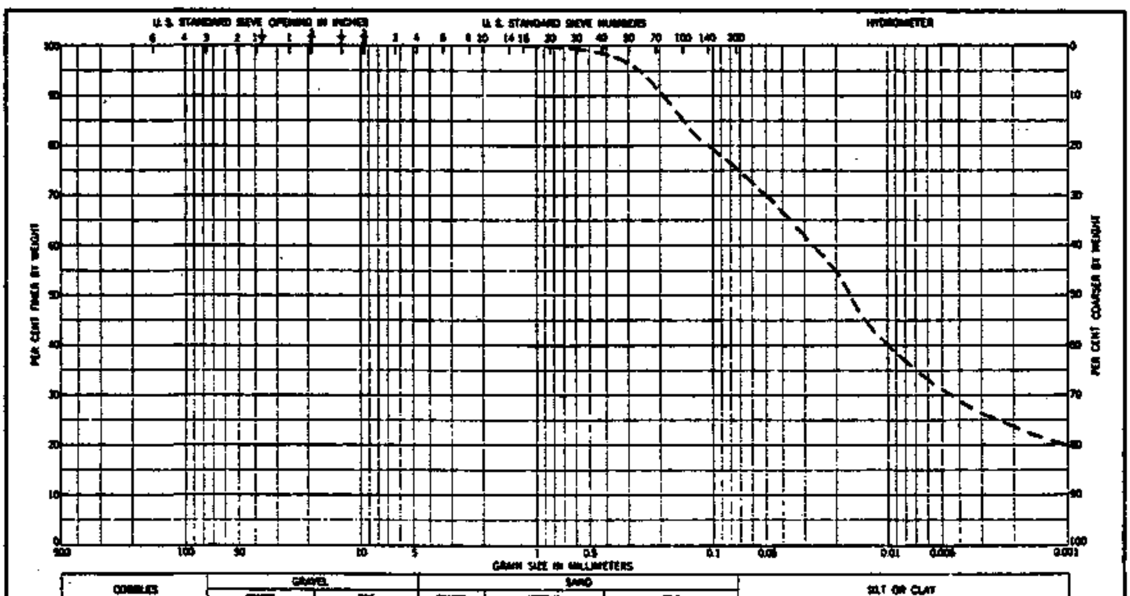
A&H File No. 01-8075

Date: October , 1978

REPORT OF SOIL ANALYSIS

REACH NUMBER: 5
RIVER MILE: 101 to 102
LOCATION: Right hand side of the river, near the water line
DATE OF DATA COLLECTION: October 19, 1978
SAMPLE NUMBER: 123
CLASSIFICATION: Brown, Mottled Gray, Sandy Clayey SILT, Trace Shell Fragments and Organic Material (Leaves)

GRAIN SIZE ANALYSIS:



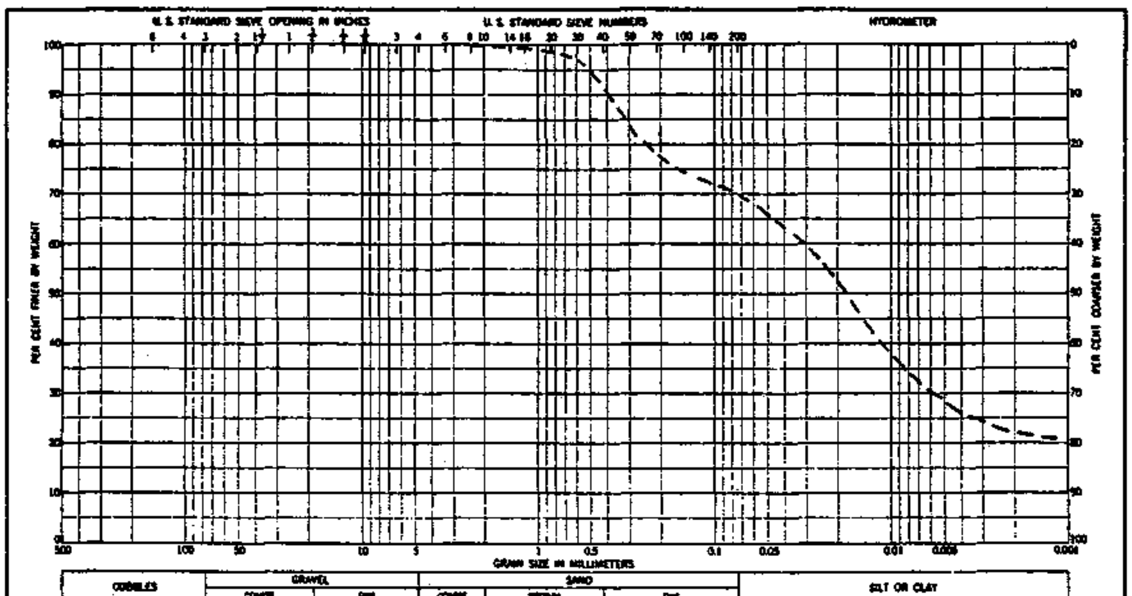
Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	123	--	Brown, Mottled Gray, Sandy Clayey SILT, Trace Shell Fragments and Organic Material	--	--	--	--

Project Illinois River
A&H File No. 01-8075
Date October , 1978

REPORT OF SOIL ANALYSIS

REACH NUMBER:	5
RIVER MILE:	101 to 102
LOCATION:	Right hand side of the river near the water line
DATE OF DATA COLLECTION:	October 19, 1978
SAMPLE NUMBER:	124
CLASSIFICATION:	Gray, Mottled Brown, Sandy Clayey SILT, Trace Shell Fragments and Organic Material (Leaves and Wood)

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	124	—	Gray, Mottled Brown, Sandy Clayey SILT, Trace Shell Fragments and Organic Material	—	—	—	—

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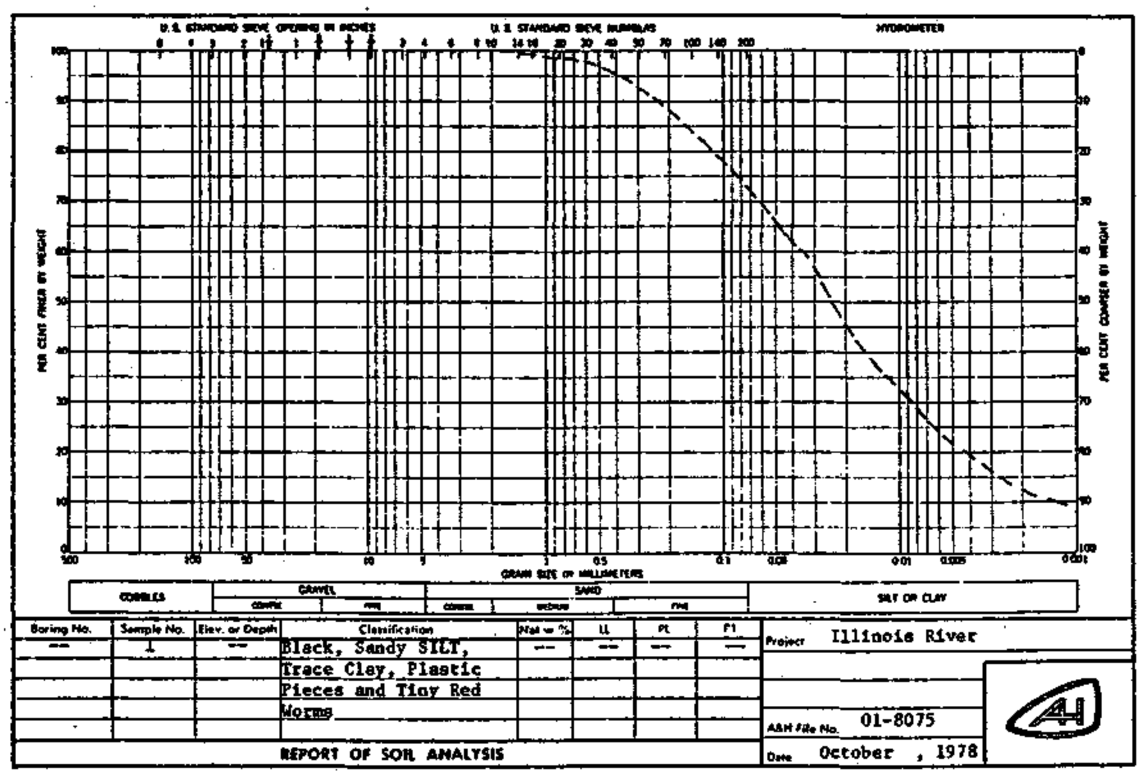
REPORT OF SOIL ANALYSIS

APPENDIX C

Bed Material Particle Size Distribution

RIVER MILE: 286.9
LOCATION: Right hand side of the river near Corps of Engineers Dock, near Joliet
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 1
CLASSIFICATION: Black, Sandy SILT, Trace Clay, Plastic Pieces and Tiny Red Worms

GRAIN SIZE ANALYSIS:



RIVER MILE: 282.3

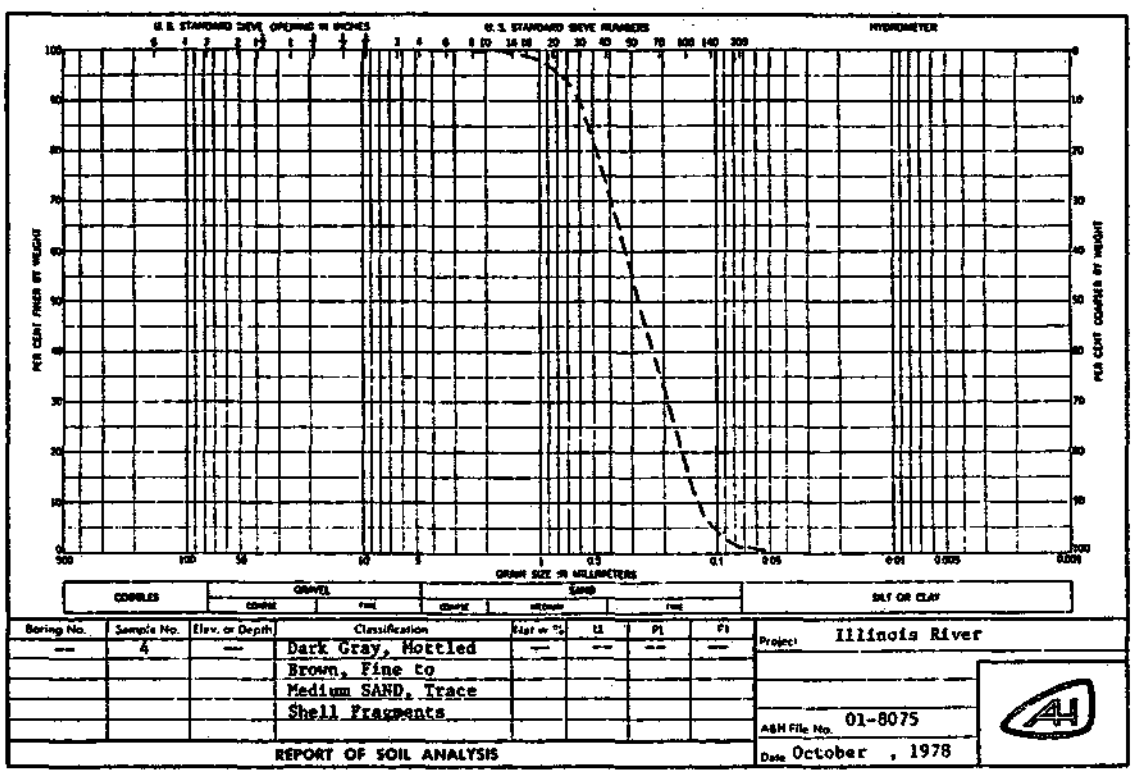
LOCATION: Left hand side of the river about 300 feet from Shoreline in the river

DATE OF DATA COLLECTION: July 17, 1978

SAMPLE NUMBER: 4

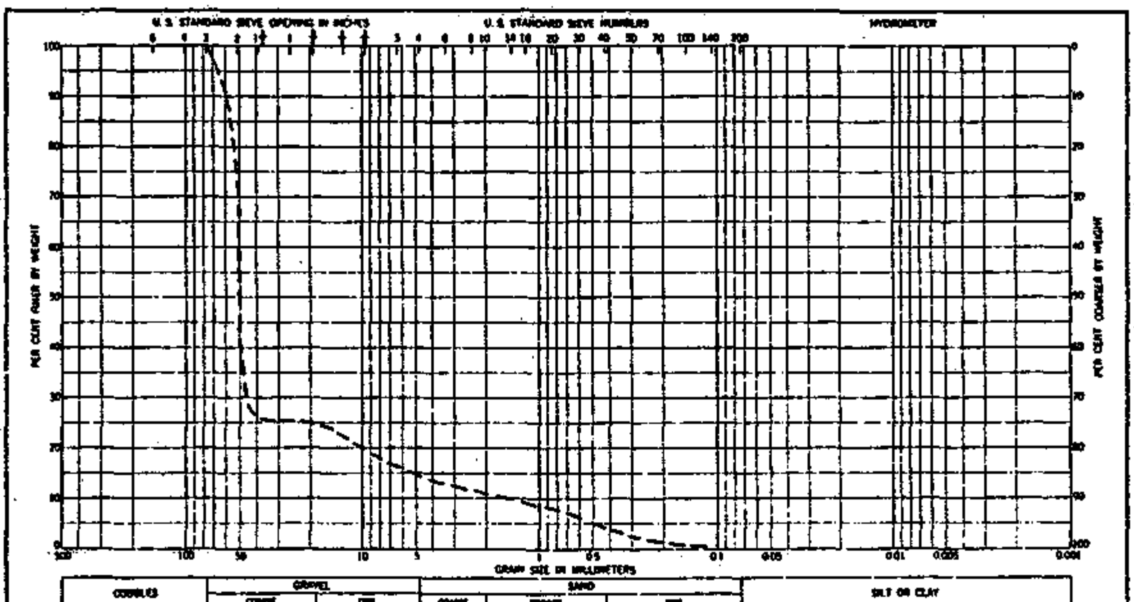
CLASSIFICATION: Dark Gray, Mottled Brown, Fine to Medium SAND, Trace Shell Fragments

GRAIN SIZE ANALYSIS:



RIVER MILE: 279.4
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 5
CLASSIFICATION: Brown Fine to Coarse GRAVEL, Little Sand

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	5	—	Brown Fine to Coarse GRAVEL, Little Sand	—	—	—	—

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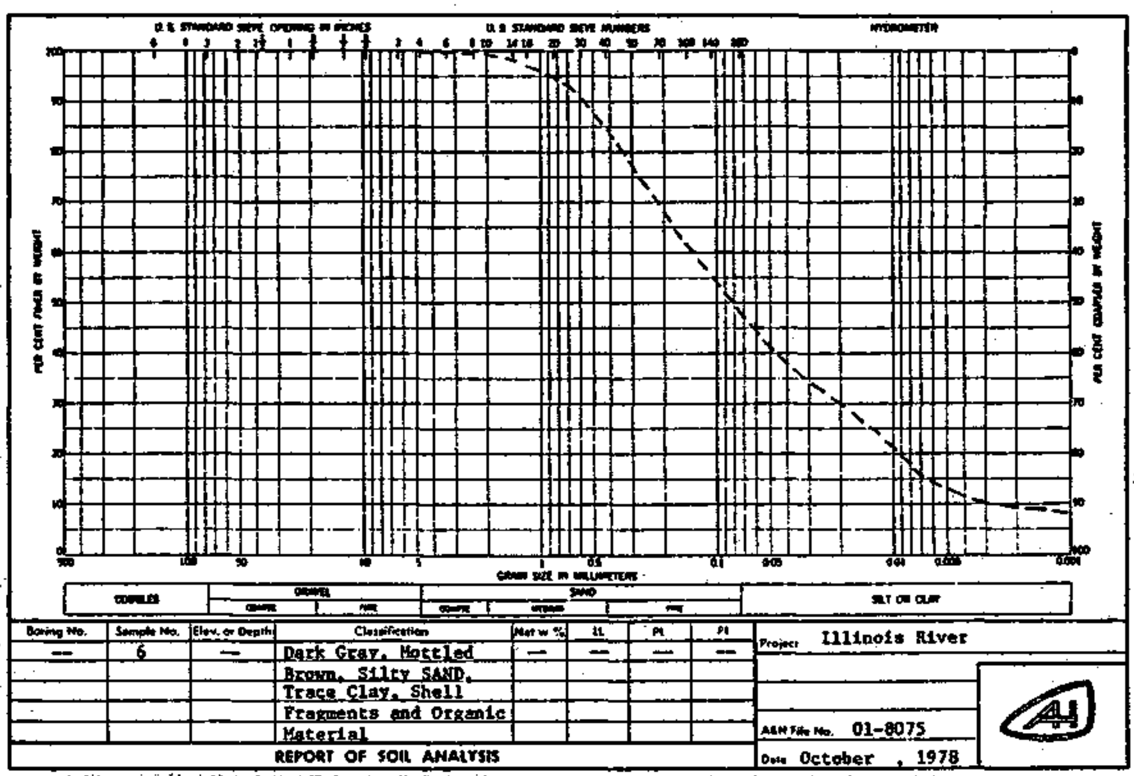
REPORT OF SOIL ANALYSIS

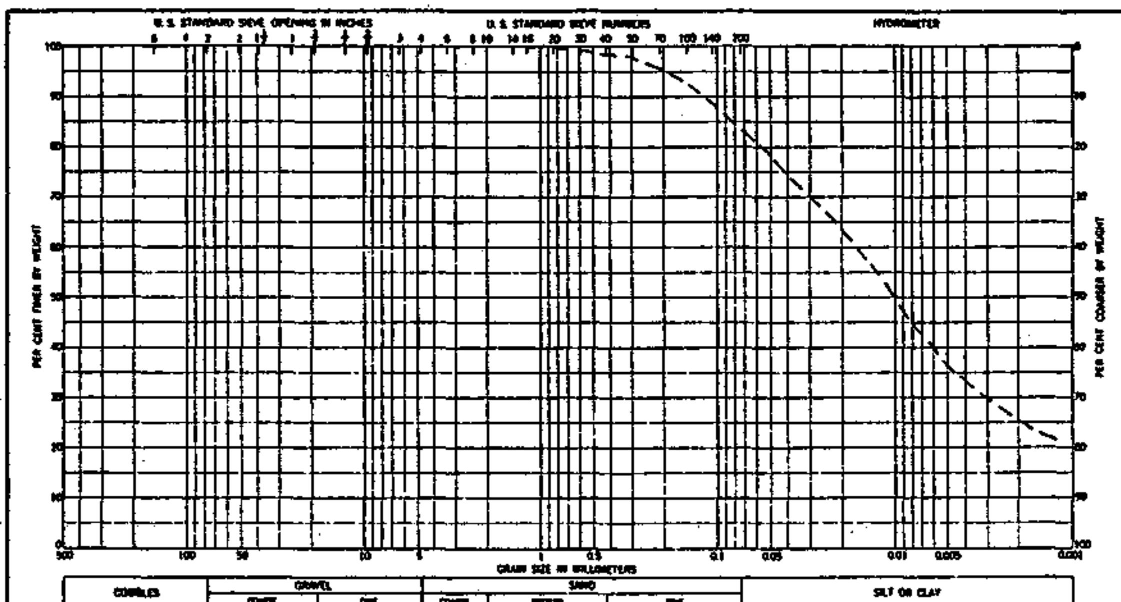
REACH NUMBER: 24
RIVER MILE: 277
LOCATION: 700 feet from the left shoreline in the river
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 6
CLASSIFICATION: Dark Gray, Mottled Brown, Silty SAND, Trace Clay, Shell Fragments and Organic Material (Roots)

GRAIN SIZE ANALYSIS:



RIVER MILE: 274
LOCATION: 400 feet from the left shoreline in the river
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 10
CLASSIFICATION: Gray, Mottled Brown SILT, Little Clay and Sand, Trace Shell Fragments and Organic Material (Roots)

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	10	--	Gray, Mottled Brown SILT, Little Clay and Sand, Trace Shell Fragments and Organic Material	--	--	--	--

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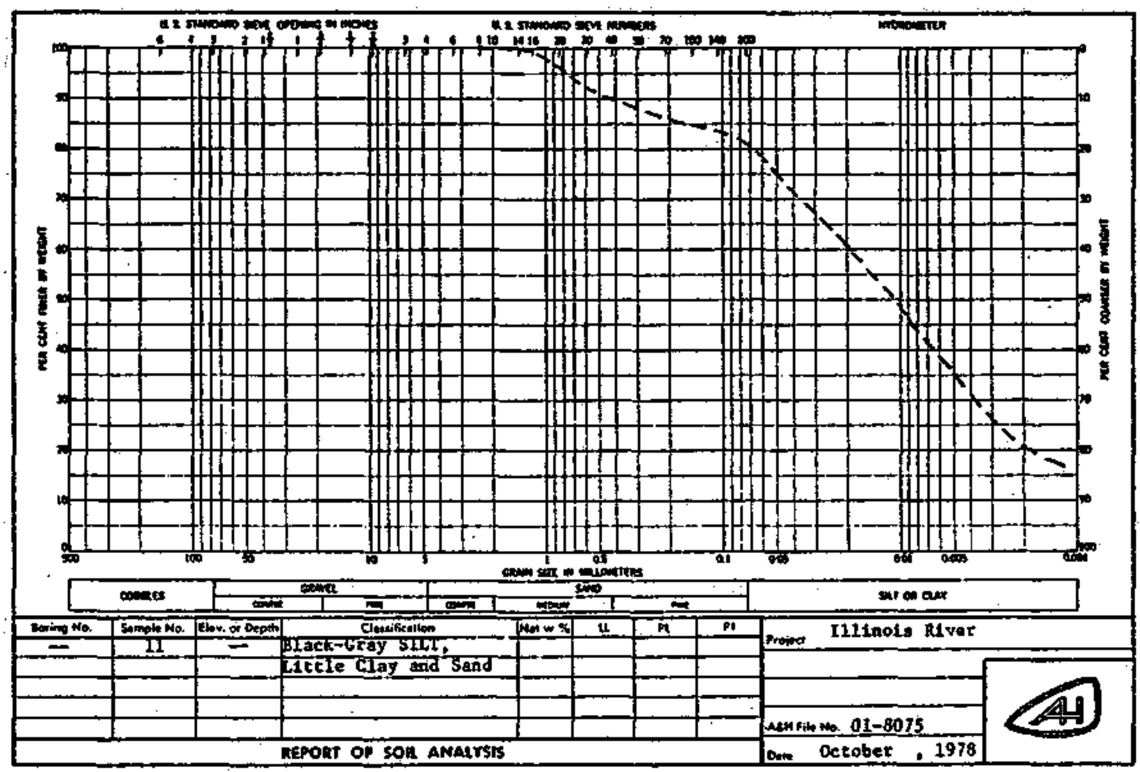
REPORT OF SOIL ANALYSIS

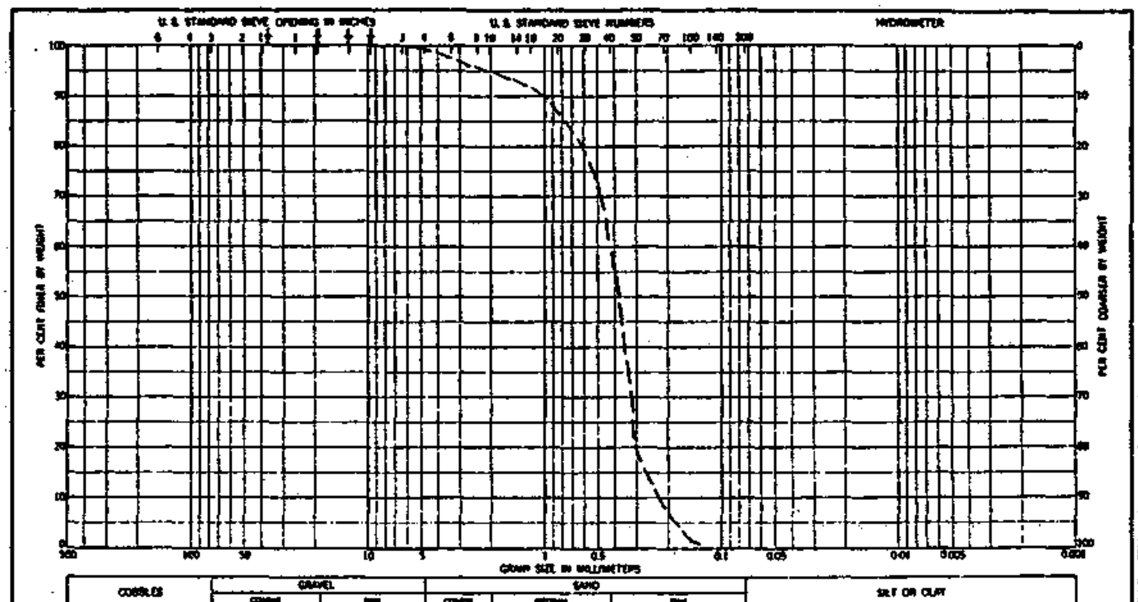
RIVER MILE: 272.4
LOCATION: Downstream of the junction of the Kankakee River with the Illinois River
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 11
CLASSIFICATION: Black-Gray SILT, Little Clay and Sand

GRAIN SIZE ANALYSIS:



REACH NUMBER: Upstream of 23
RIVER MILE: 269
LOCATION: At the Middle of the Channel
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 12
CLASSIFICATION: Brown Fine to Coarse SAND, Trace Shells, Shell Fragments and Organic Material (Roots)

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	12	—	Brown Fine to Coarse SAND, Trace Shells, Shell Fragments and Organic Material	—	—	—	—

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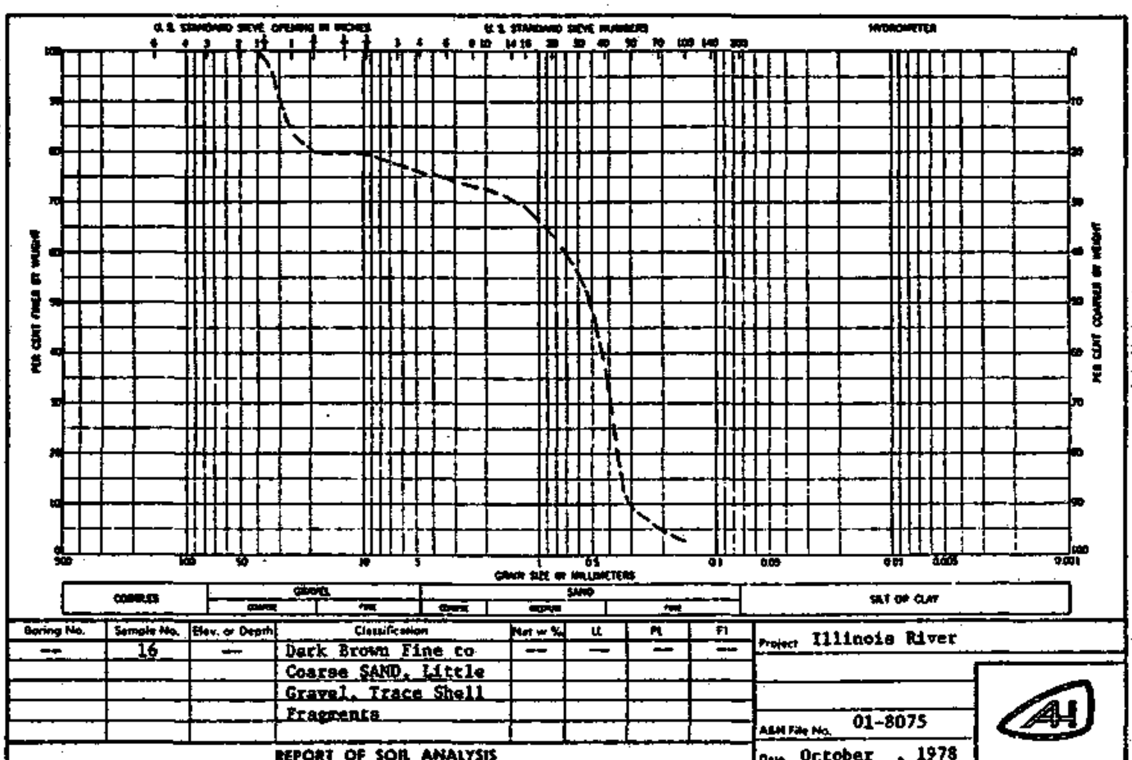
REPORT OF SOIL ANALYSIS

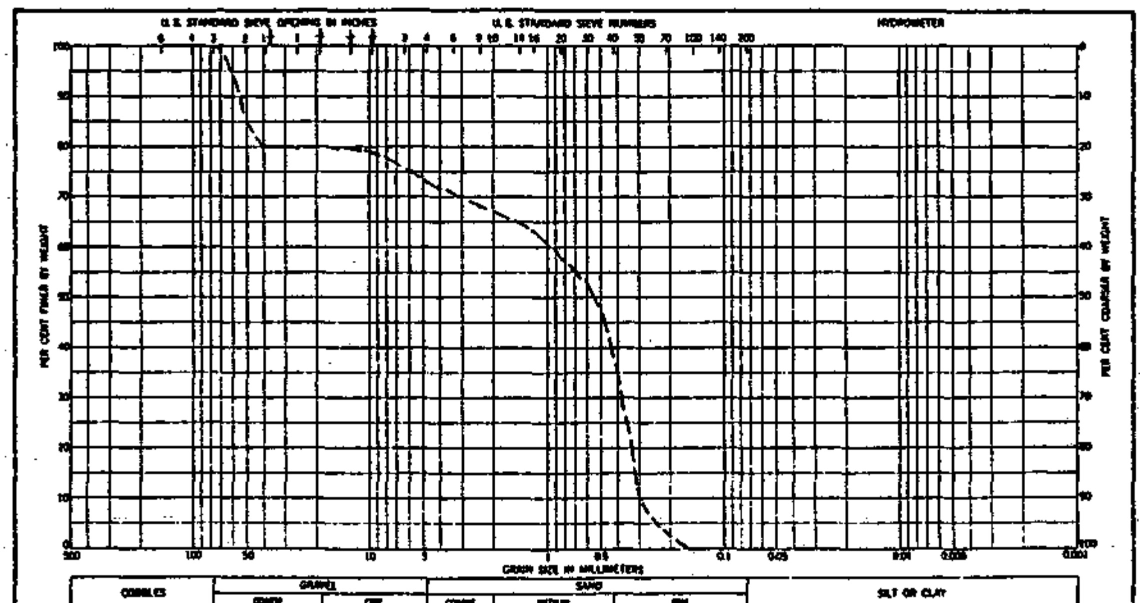
RIVER MILE:	263.4
LOCATION:	At Morris downstream of the highway bridge, at the middle of the channel
DATE OF DATA COLLECTION:	July 17, 1978
SAMPLE NUMBER:	16
CLASSIFICATION:	Dark Brown Fine to Coarse SAND, Little Gravel, Trace Shell Fragments

GRAIN SIZE ANALYSIS:



RIVER MILE: 265
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 19
CLASSIFICATION: Brown Fine to Coarse SAND, Little Gravel, Trace Shell Fregments

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	19	--	Brown Fine to Coarse SAND, Little Gravel, Trace Shell Fragments	--	--	--	--

REPORT OF SOIL ANALYSIS

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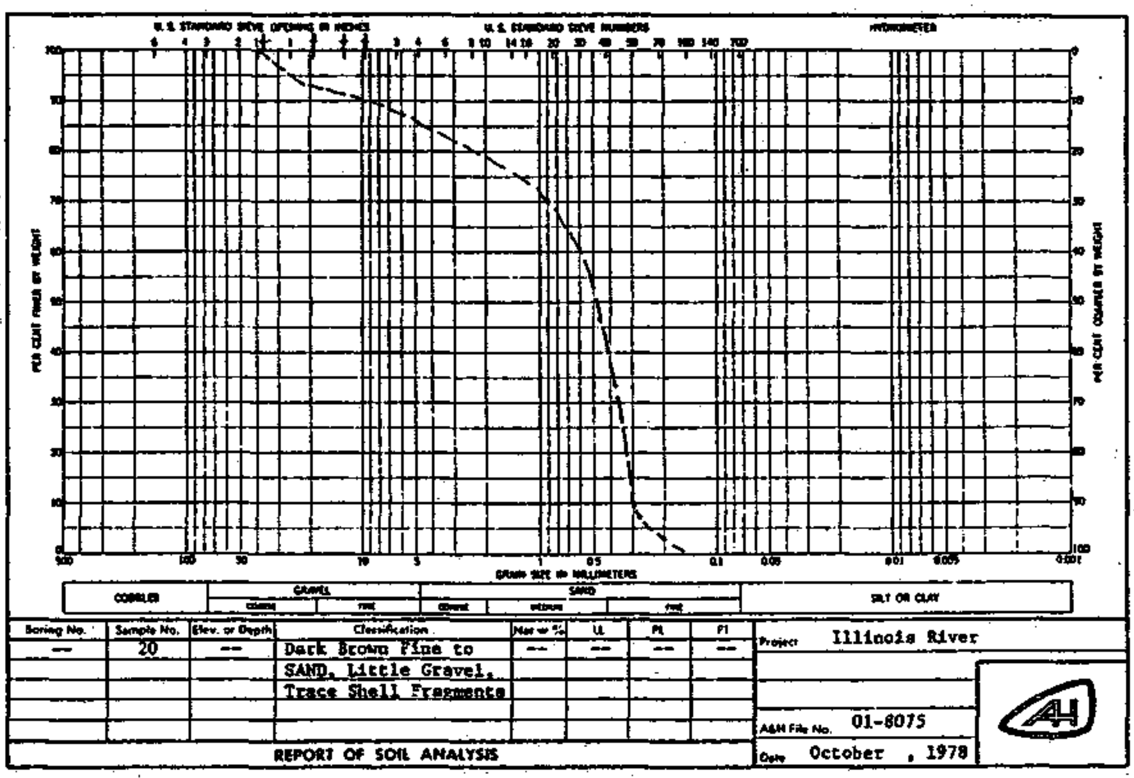
RIVER MILE: 250
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 20
CLASSIFICATION: Dark Brown Fine to Coarse SAND, Little Gravel, Trace Shell Fregments

GRAIN SIZE ANALYSIS:



RIVER MILE: 242.9

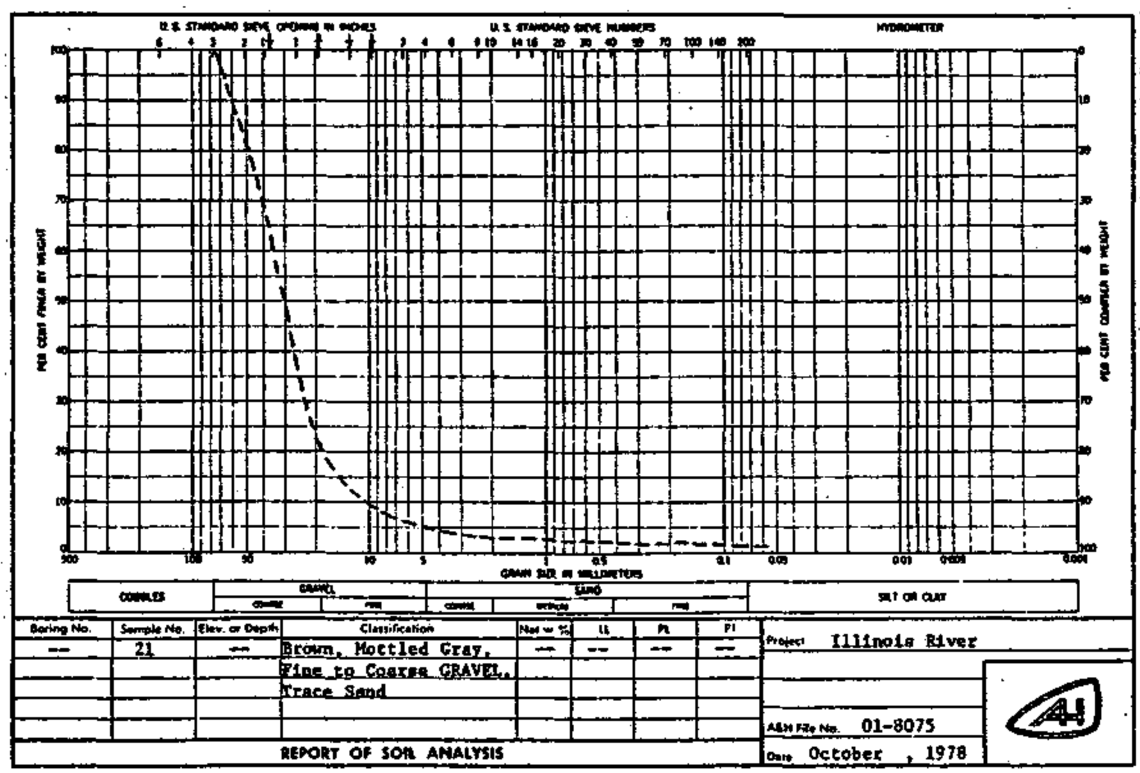
LOCATION: Upstream of Marseilles Lock at the middle of the channel

DATE OF DATA COLLECTION: July 17, 1978

SAMPLE NUMBER: 21

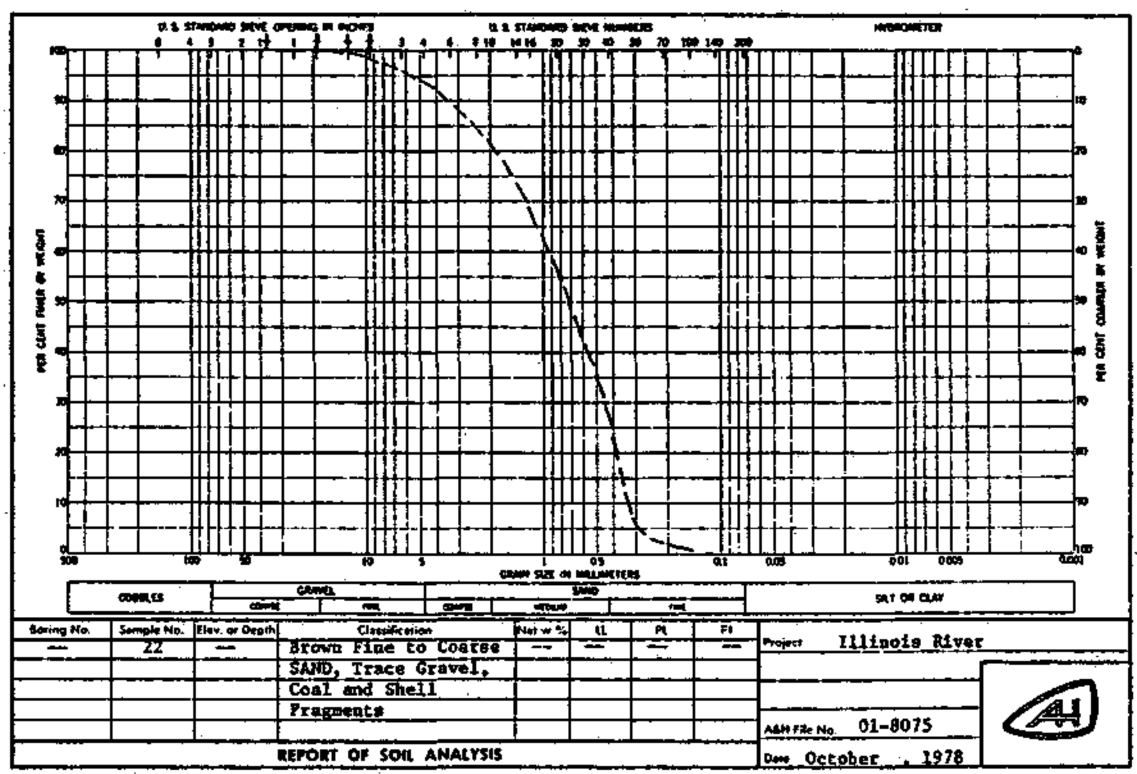
CLASSIFICATION: Brown, Mottled Gray, Fine to Coarse GRAVEL, Trace Sand

GRAIN SIZE ANALYSIS:



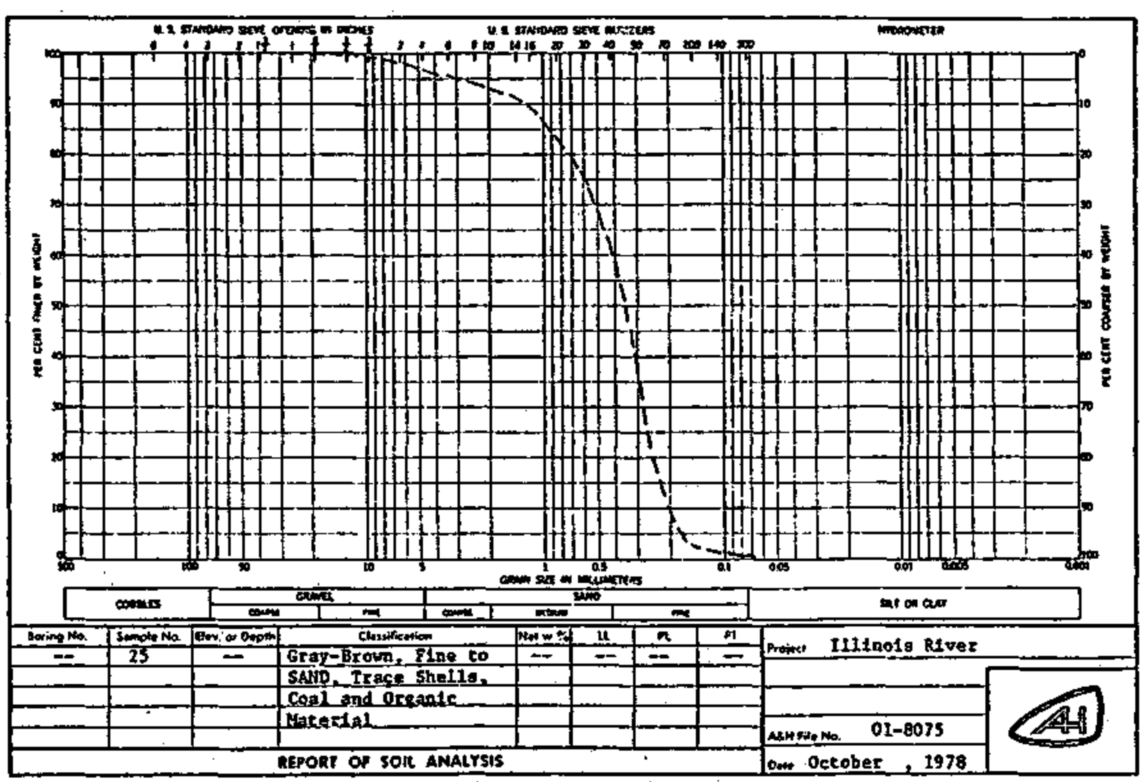
RIVER MILE: 238
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 17, 1978
SAMPLE NUMBER: 22
CLASSIFICATION: Brown Fine to Coarse SAND, Trace Gravel, Coal and Shell Fragments

GRAIN SIZE ANALYSIS:



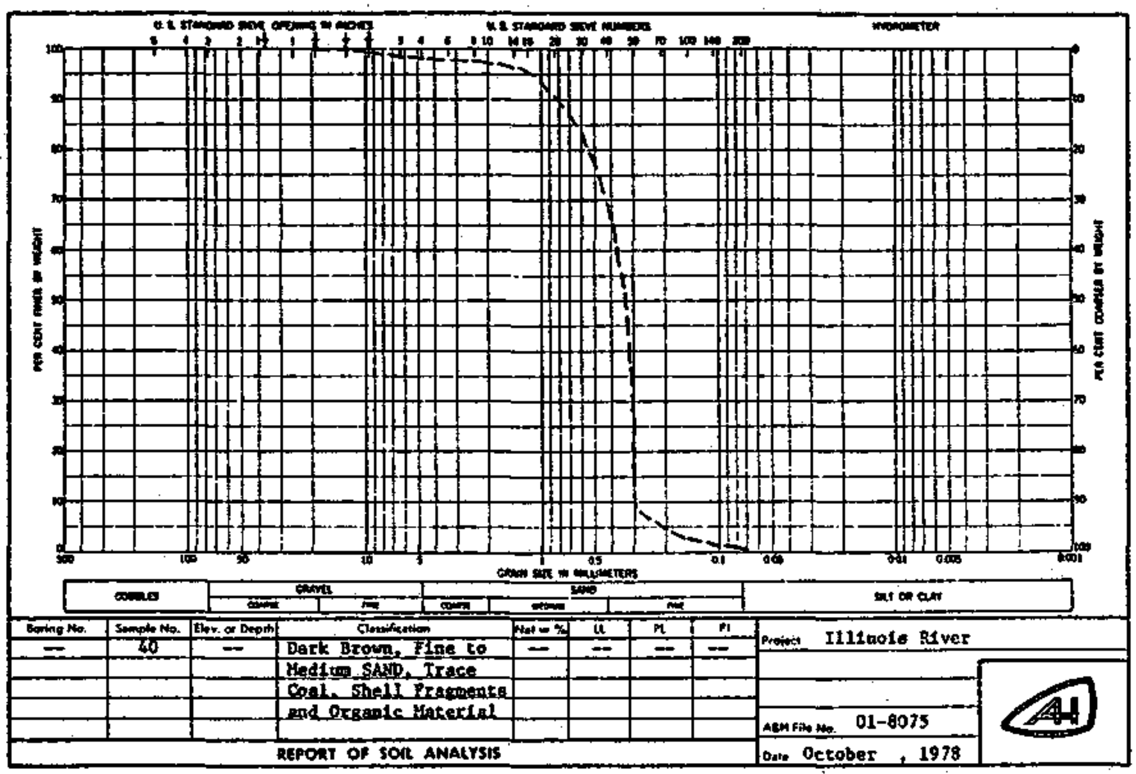
REACH NUMBER: 19
RIVER MILE: 229
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 25
CLASSIFICATION: Gray-Brown, Fine to Coarse SAND, Trace Shells, Coal and Organic Material (Wood)

GRAIN SIZE ANALYSIS:



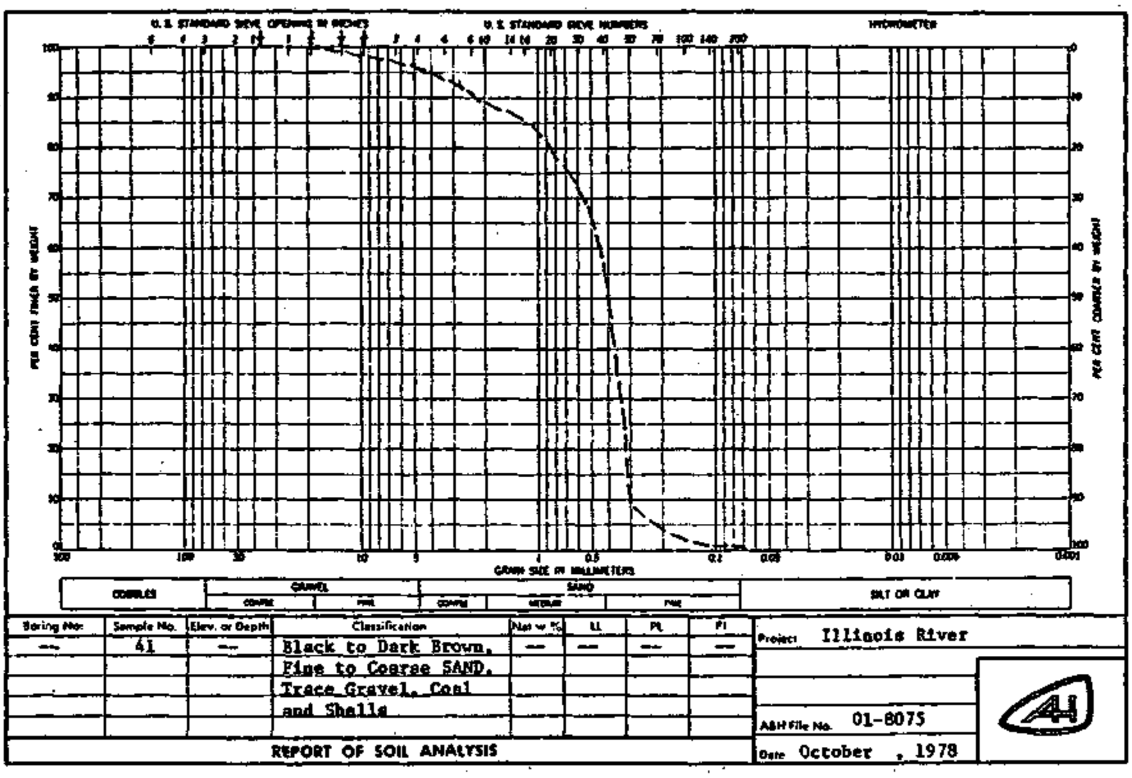
RIVER MILE: 222
LOCATION: Opposite to the South Shore Boat Club, at the middle of the channel
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 40
CLASSIFICATION: Dark Brown, Fine to Medium SAND, Trace Coal, Shell Fragments and Organic Material (Wood)

GRAIN SIZE ANALYSIS:



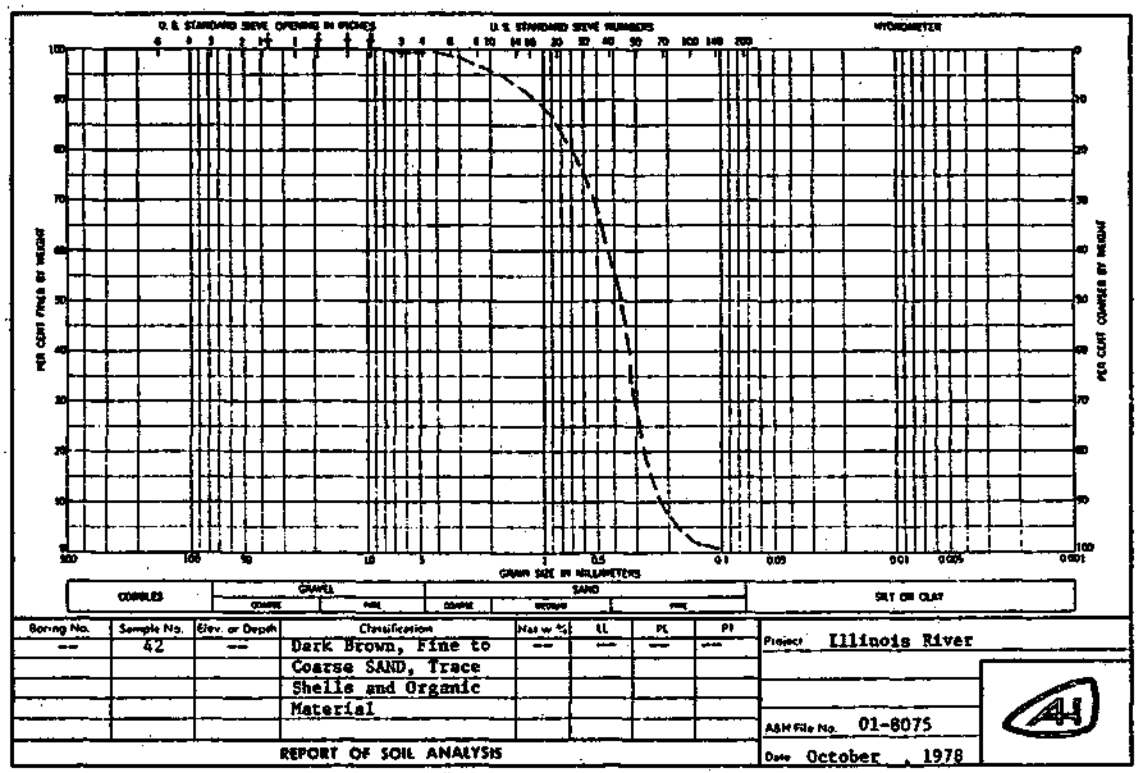
RIVER MILE: 218
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 41
CLASSIFICATION: Black to Dark Brown, Fine to Coarse SAND, Trace Gravel, Coal and Shells

GRAIN SIZE ANALYSIS:



REACH NUMBER: 17
RIVER MILE: 213
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 42
CLASSIFICATION: Dark Brown, Fine to Coarse SAND, Trace Shells and Organic Material (Burnt Wood)

GRAIN SIZE ANALYSIS:



RIVER MILE: 206

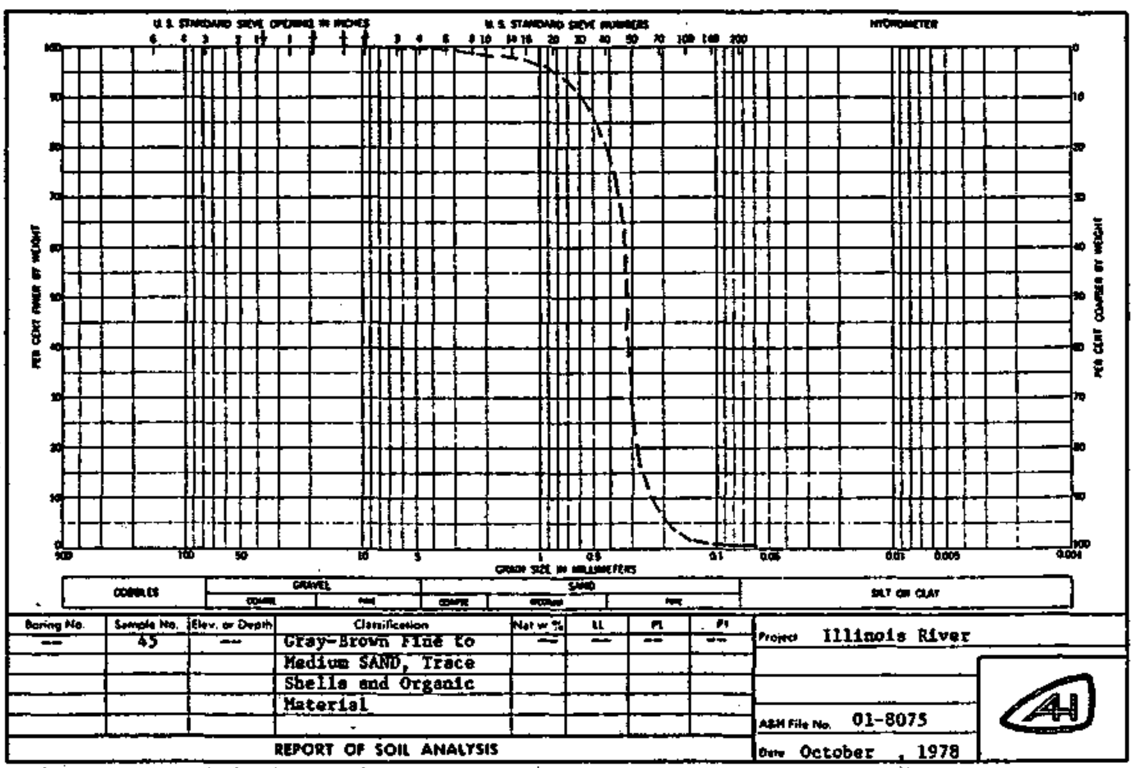
LOCATION: Along the Hennepin Levee District, at the middle of the channel

DATE OF DATA COLLECTION: July 18, 1978

SAMPLE NUMBER: 45

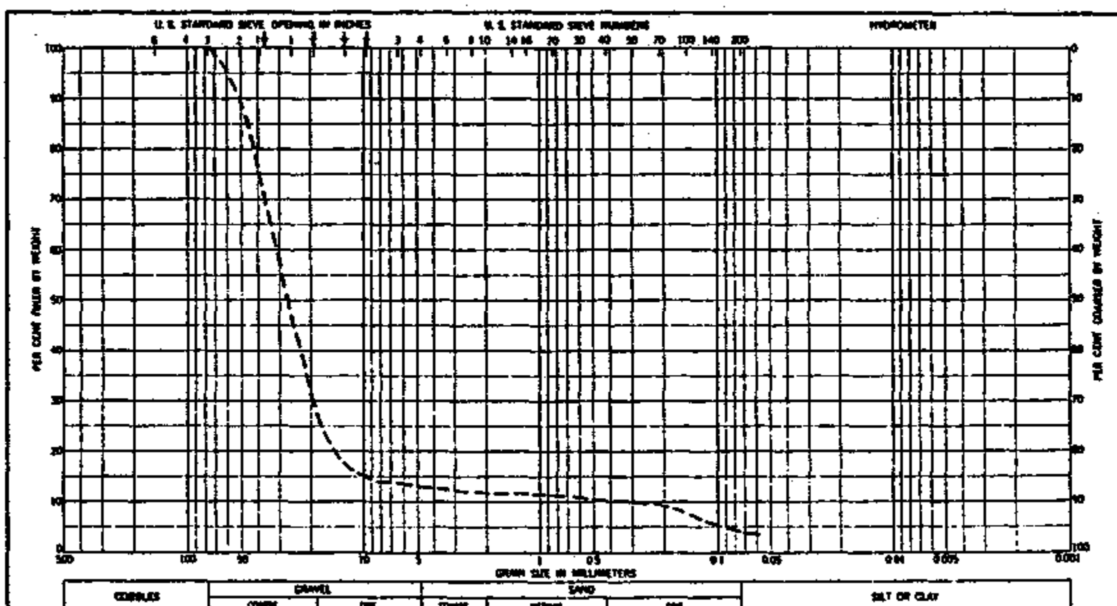
CLASSIFICATION: Gray-Brown, Fine to Medium SAND, Trace Shells and Organic Material (Small Roots and Wood Pieces)

GRAIN SIZE ANALYSIS:



RIVER MILE: 196.4
LOCATION: Upstream of the bridge at Hennepin
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 48
CLASSIFICATION: Brown, Mottled Gray, Fine GRAVEL and SHELLS

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	48	—	Brown, Mottled Gray, Fine GRAVEL and SHELLS	—	—	—	—

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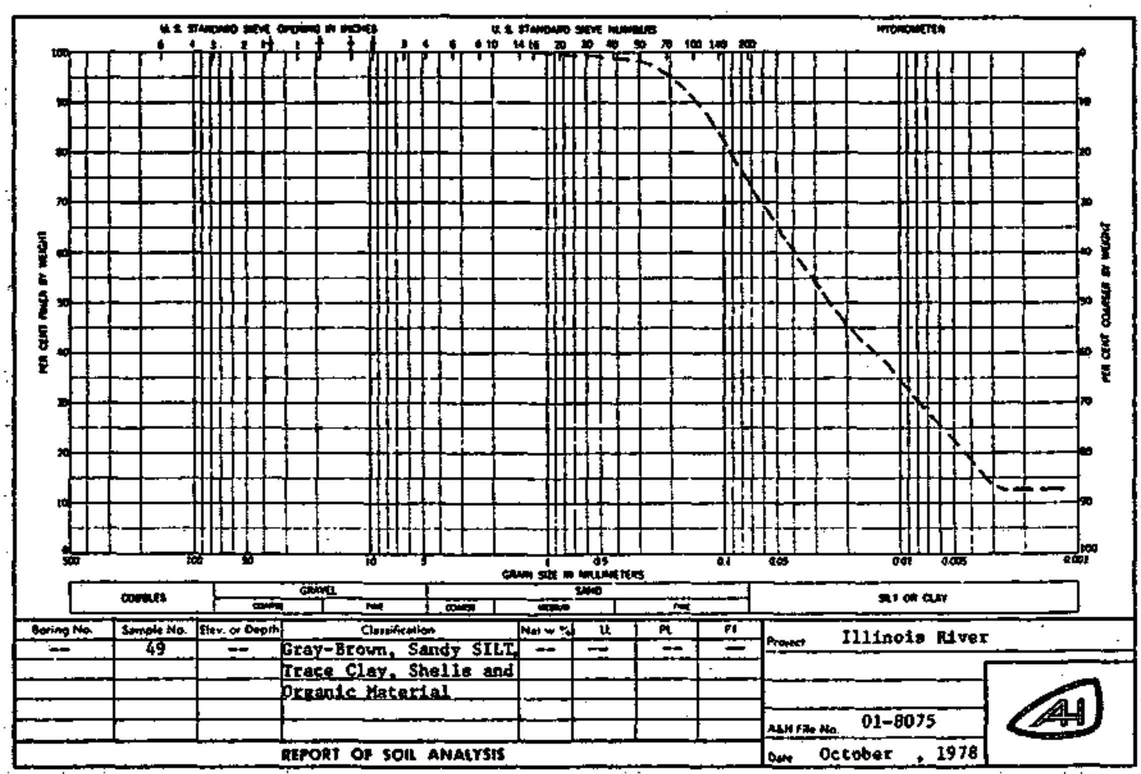
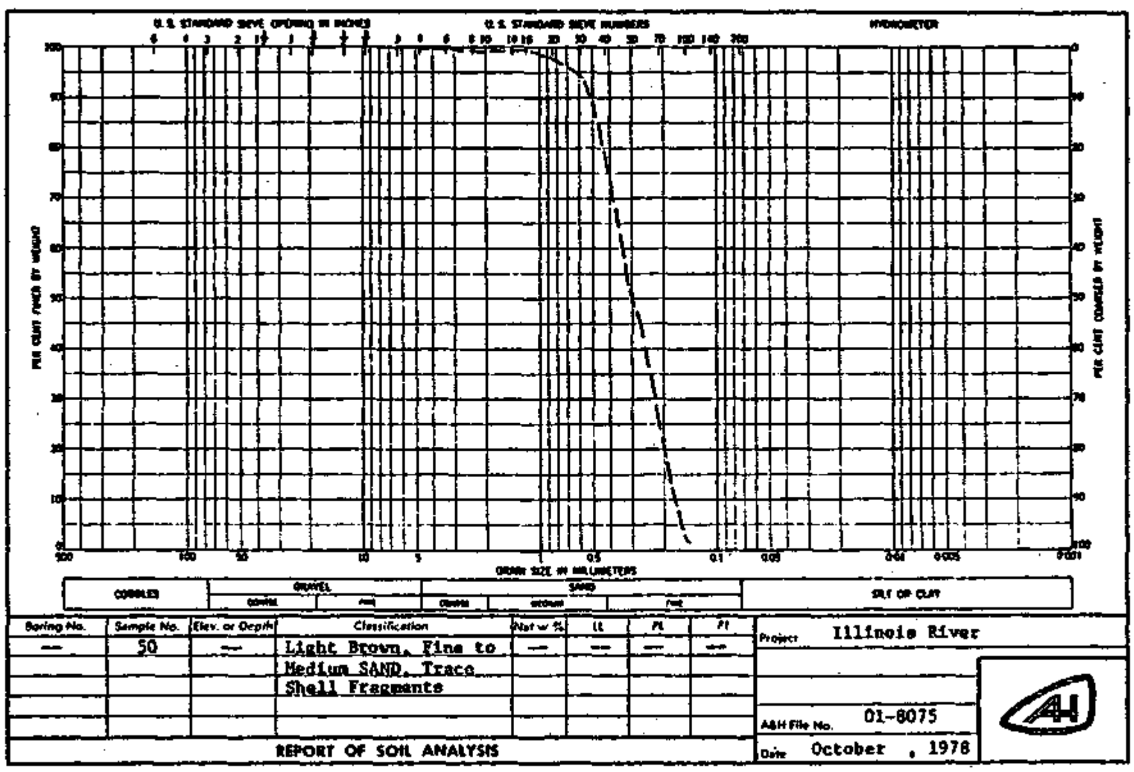
RIVER MILES:	186.4
LOCATION:	At the middle of the channel
DATE OF DATA COLLECTION:	July 18, 1978
SAMPLE NUMBER:	49
CLASSIFICATION:	Gray-Brown, Sandy SILT, Trace Clay, Shells and Organic Material (Roots)

GRAIN SIZE ANALYSIS:



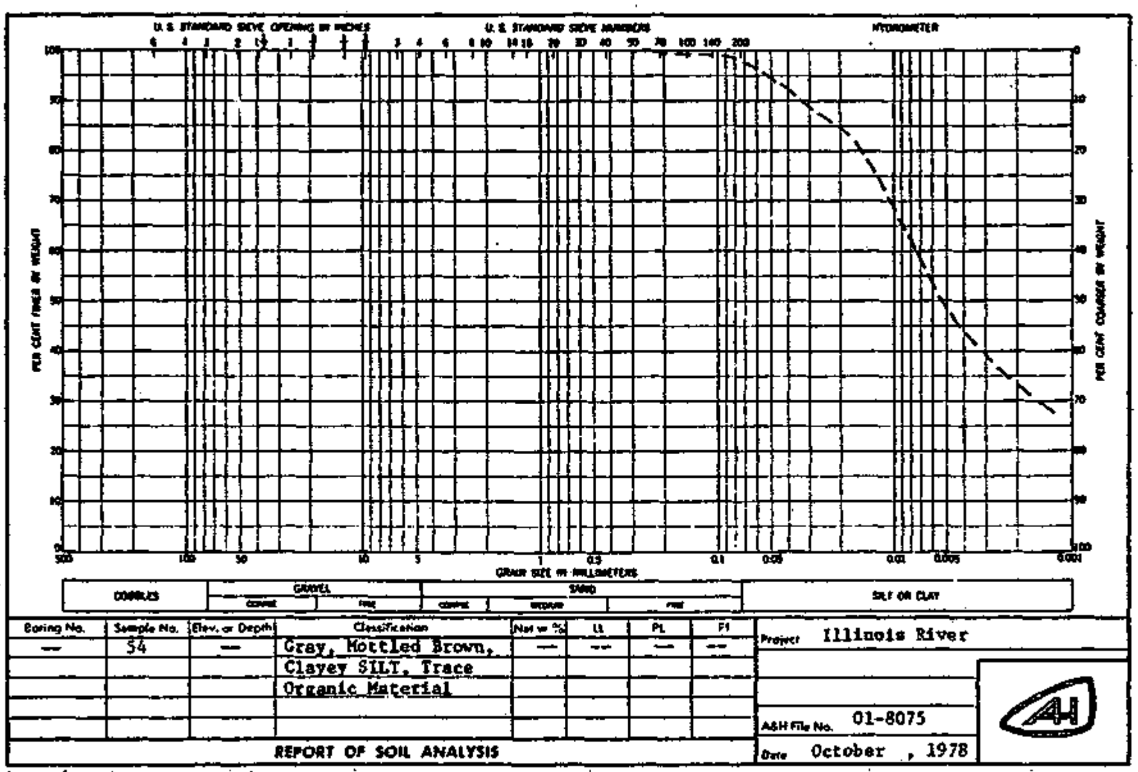
REACH NUMBER: 15
RIVER MILE: 180
LOCATION: Across from the harbor at Chillicothe, at the middle of the channel
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 50
CLASSIFICATION: Light Brown, Fine to Medium SAND, Trace Shell Fragments

GRAIN SIZE ANALYSIS:



RIVER MILE: 174.9
LOCATION: At the Peoria Pool, at the middle of the channel
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 54
CLASSIFICATION: Gray, Mottled Brown, Clayey SILT, Trace Organic Material (Small Roots)

GRAIN SIZE ANALYSIS:



RIVER MILE: 166

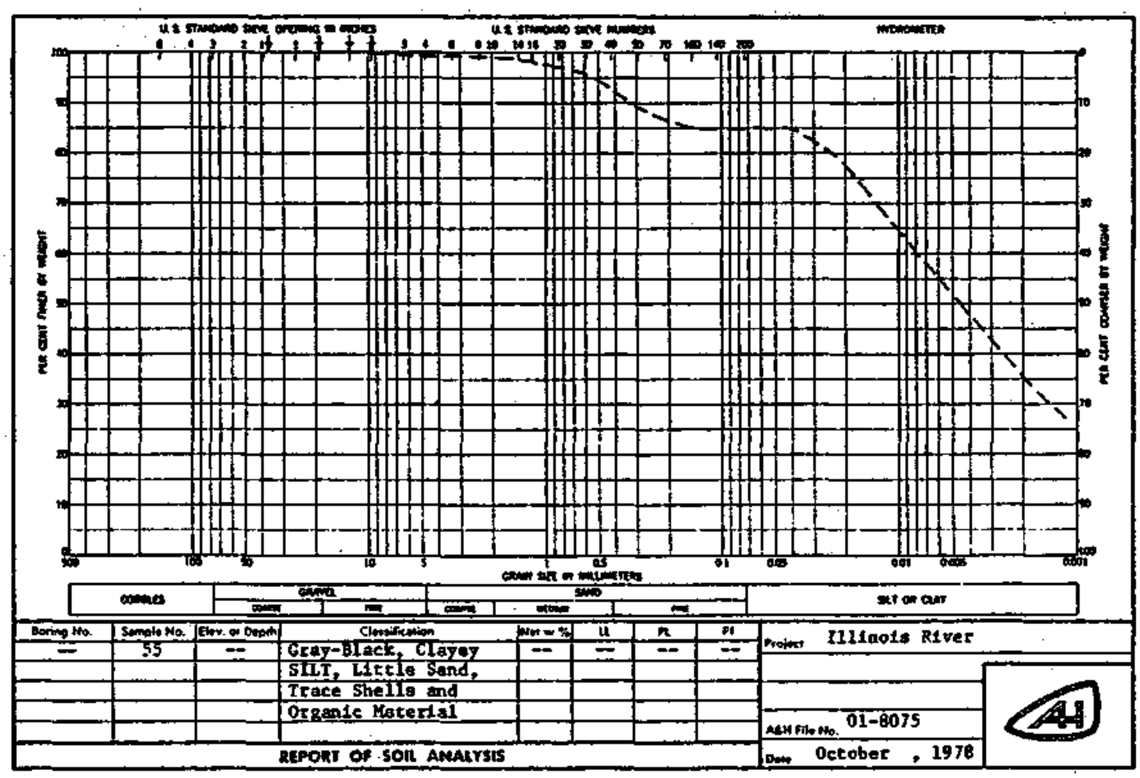
LOCATION: Upstream of the bridge at Peoria, at the middle of the channel

DATE OF DATA COLLECTION: July 18, 1978

SAMPLE NUMBER: 55

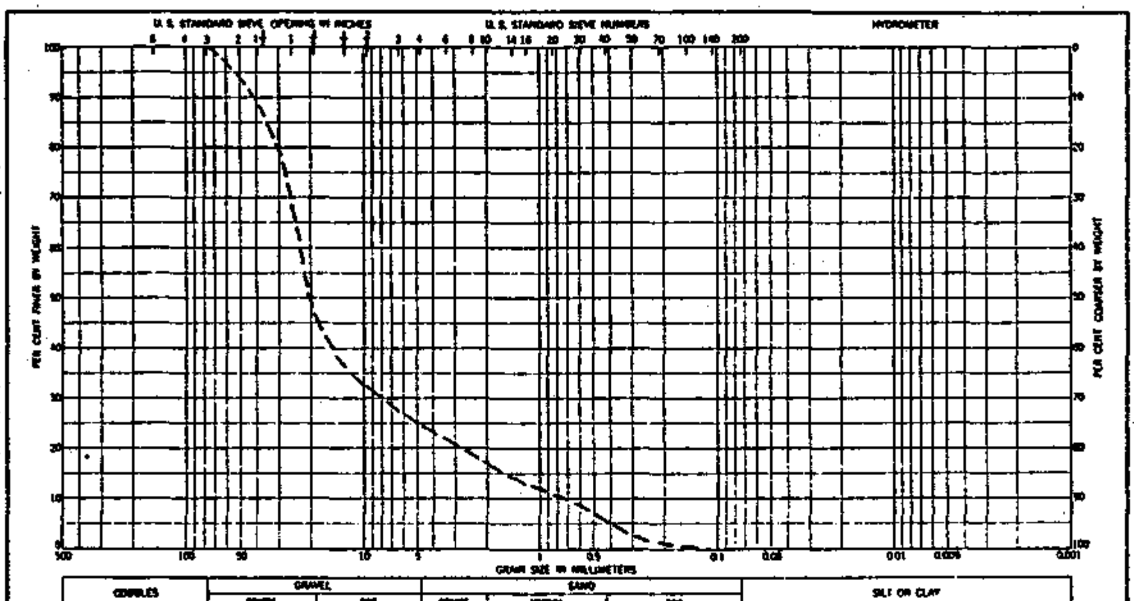
CLASSIFICATION: Gray-Black, Clayey SILT, Little Sand, Trace Shells and Organic Material (Roots)

GRAIN SIZE ANALYSIS:



RIVER MILE: 160.2
LOCATION: At Peoria, at the middle of the channel
DATE OF DATA COLLECTION: July 18, 1978
SAMPLE NUMBER: 56
CLASSIFICATION: Brown Medium to Coarse, Sandy SHELLS (53% coarser than or equal to 3/4") Trace Fine Gravel, Cinders and Organic Material (Roots)

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	56	--	Brown Medium to Coarse Sandy SHELLS, Trace Fine Gravel, Cinders and Organic Material	--	--	--	--

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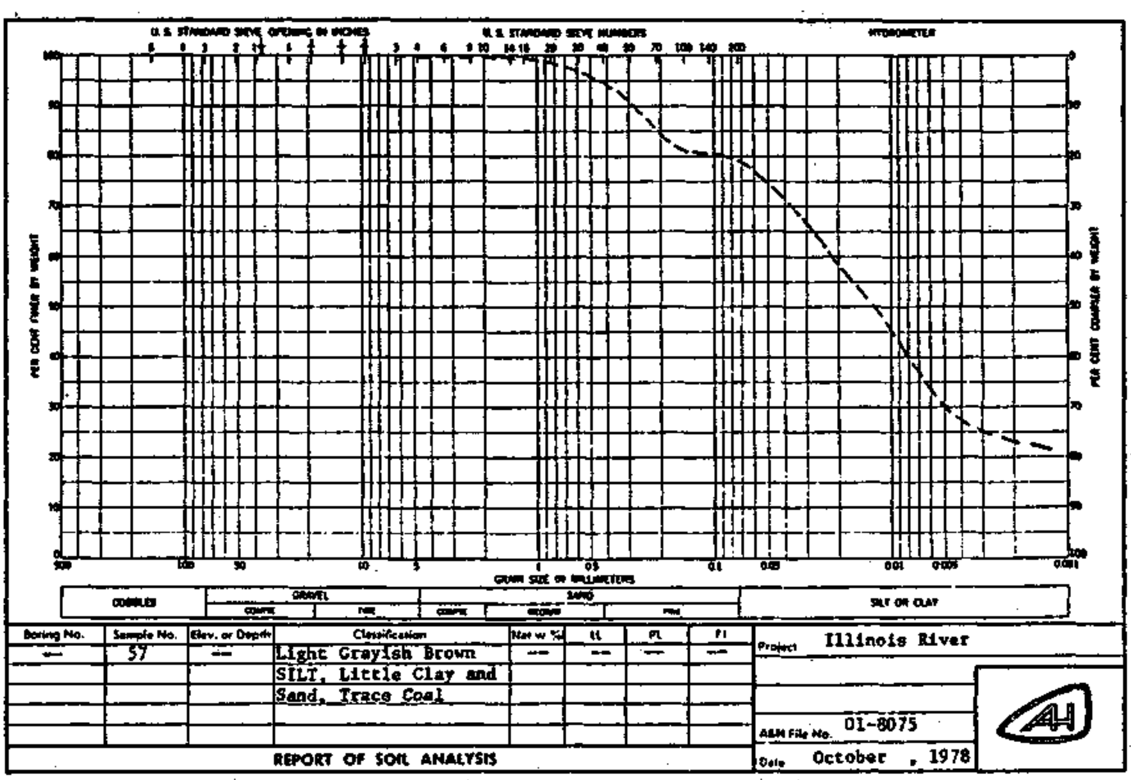
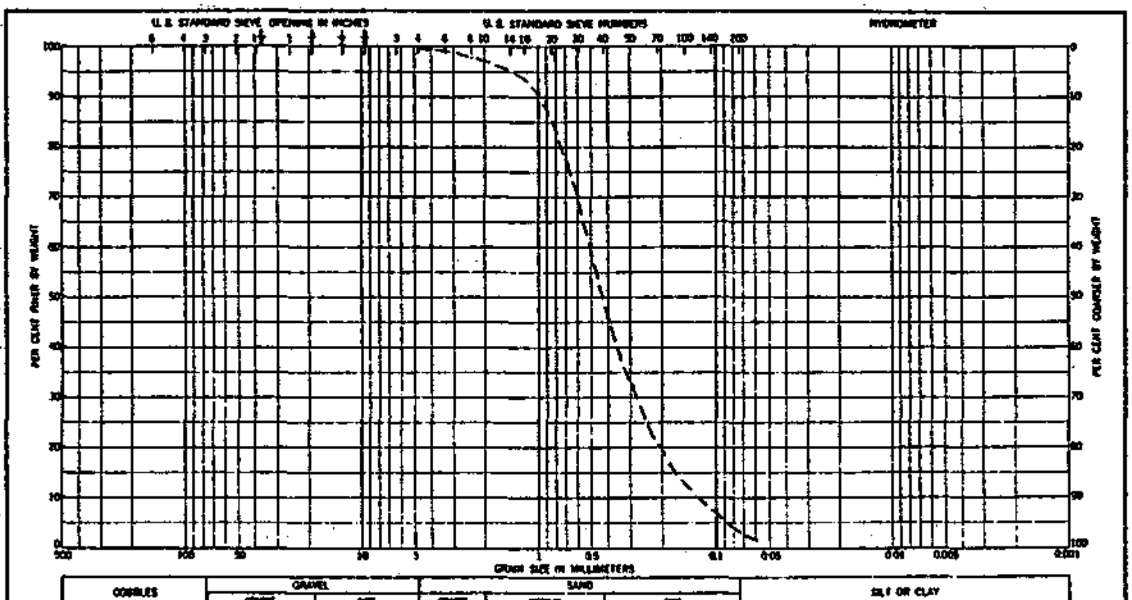
REACH NUMBER: 14
RIVER MILE: 154.4
LOCATION: At Peoria, at the middle of the channel
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 57
CLASSIFICATION: Light Grayish Brown SILT, Little Clay and Sand, Trace Coal

GRAIN SIZE ANALYSIS:



REACH NUMBER:	13
RIVER MILE:	150
DATE OF DATA COLLECTION:	July 19, 1978
SAMPLE NUMBER:	61
CLASSIFICATION:	Brown Fine to Medium SAND, Trace Shell Fragments and Organic Material (Plant Stems and Roots)

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	61	—	Brown Fine to Medium SAND, Trace Shell Fragments and Organic Material	—	—	—	—

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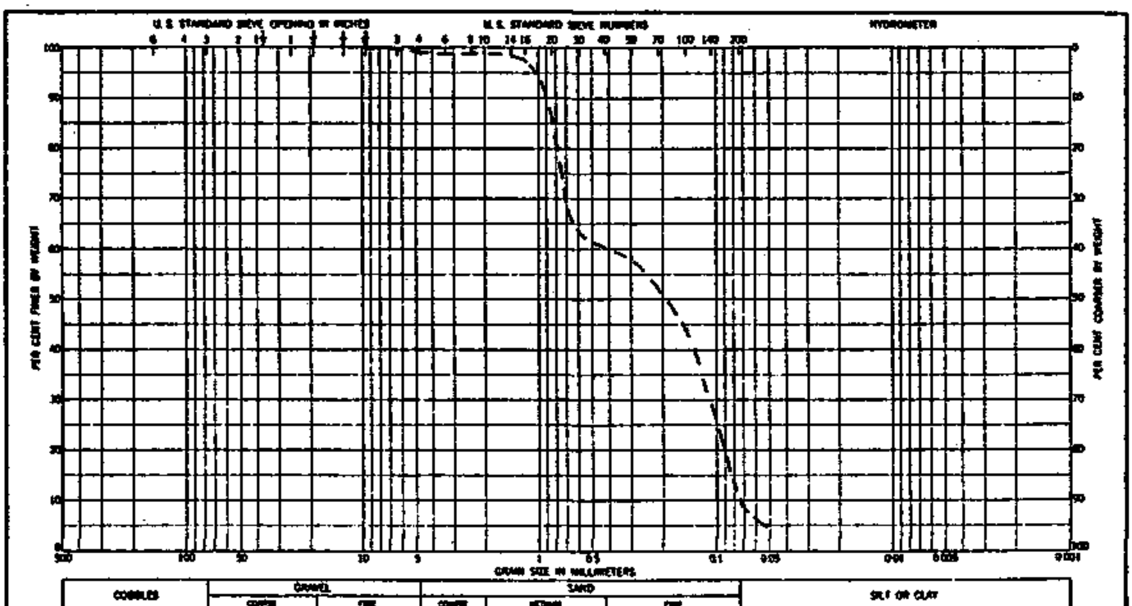
RIVER MILE: 145
LOCATION: At Kingston Mines at the middle of the channel
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 65
CLASSIFICATION: Brown Fine to Medium SAND, Trace Shells and Organic Material (Small Roots)

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	65	--	Brown Fine to Medium SAND, Trace Shells and Organic Material	--	--	--	--

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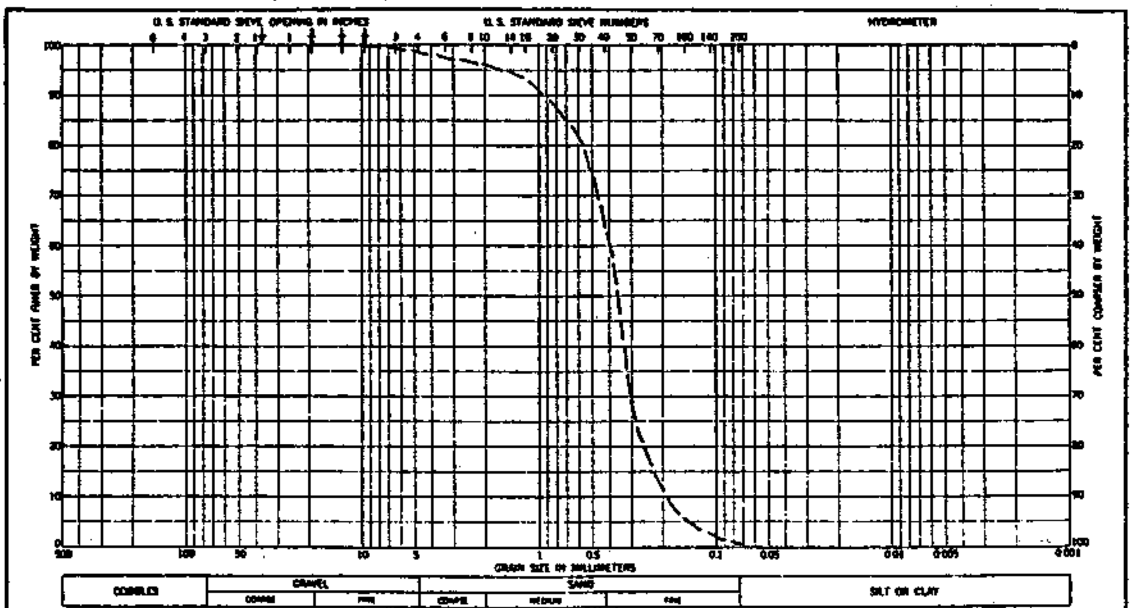
RIVER MILE: 140
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 69
CLASSIFICATION: Brown Fine to Coarse SAND, Trace Shells and Organic Material (Roots)

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	69	—	Brown Fine to Coarse SAND, Trace Shells and Organic Material	—	—	—	—

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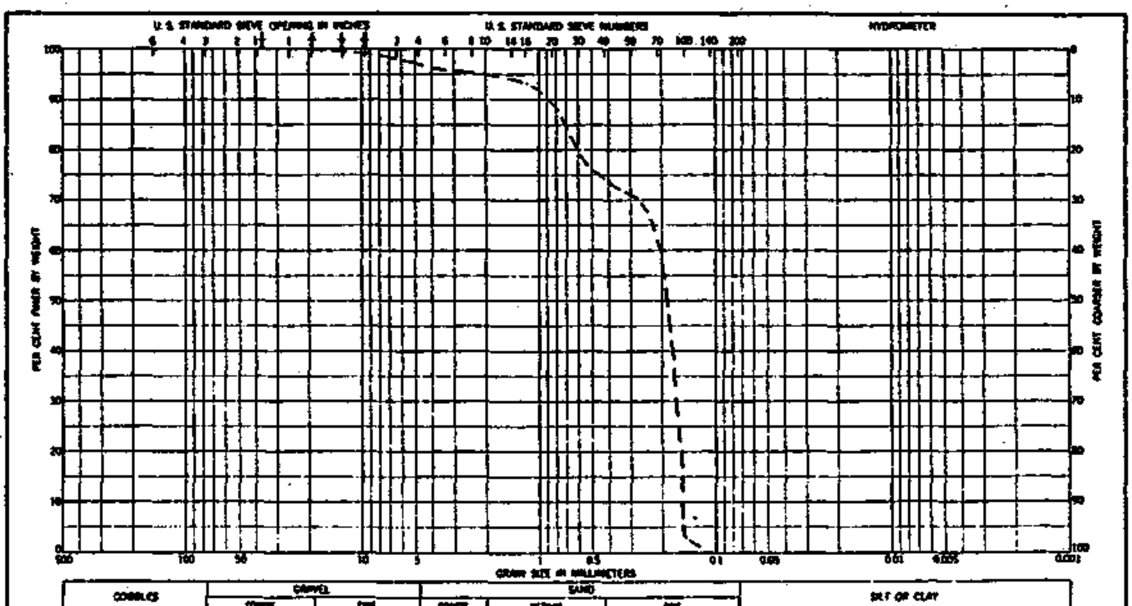
REACH NUMBER: 11
RIVER MILE: 135
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 70
CLASSIFICATION: Light Brown, Fine to Coarse SAND, Trace Shells and Shell Fragments

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	70	—	Light Brown, Fine to Medium SAND, Trace Shells and Shell Fragments	—	—	—	—

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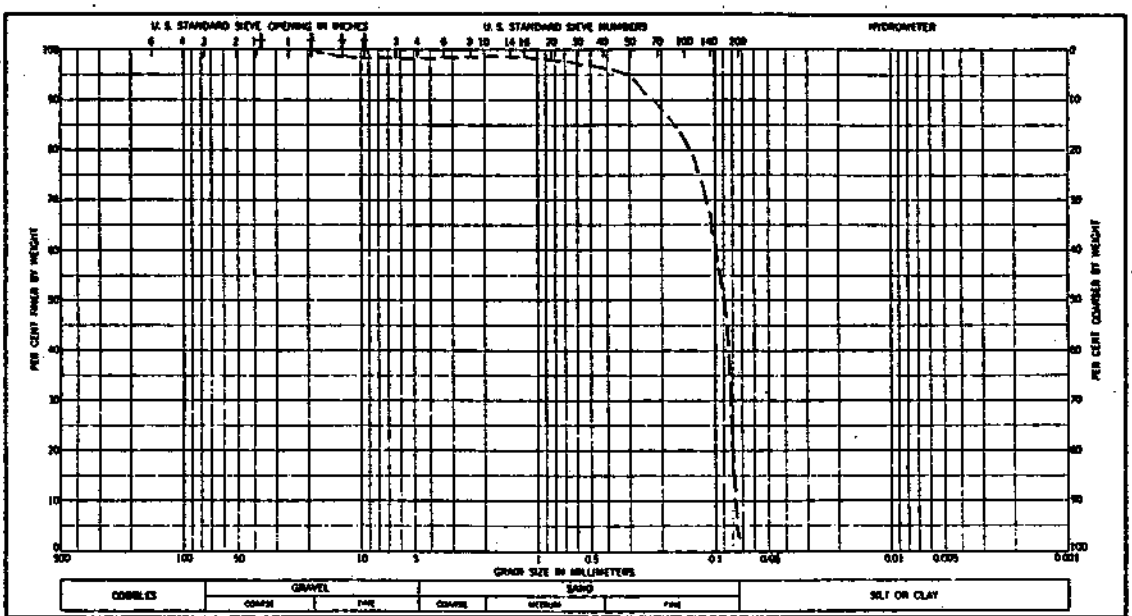
RIVER MILE: 129.9
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 74
CLASSIFICATION: Brown Fine SAND, Trace Shells, Shell Fragments and Organic Materials (Wood)

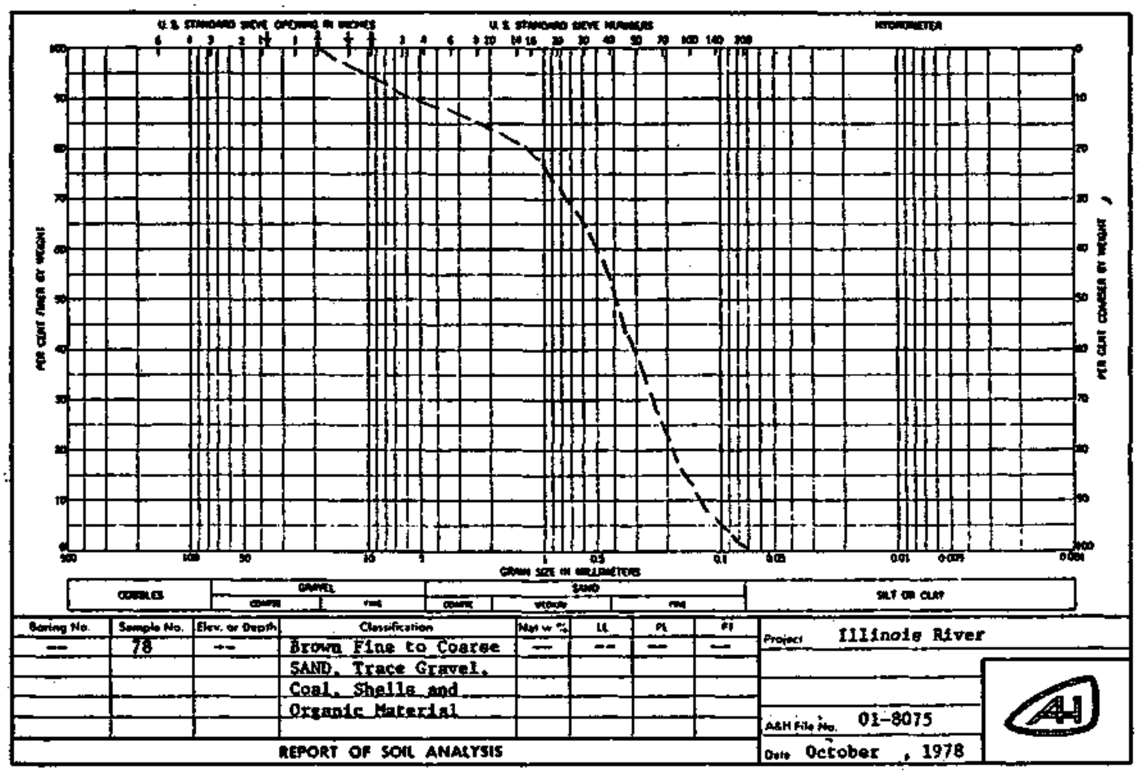
GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	74	--	Brown Fine SAND, Trace Shells, Shell Fragments and Organic Material	--	--	--	--

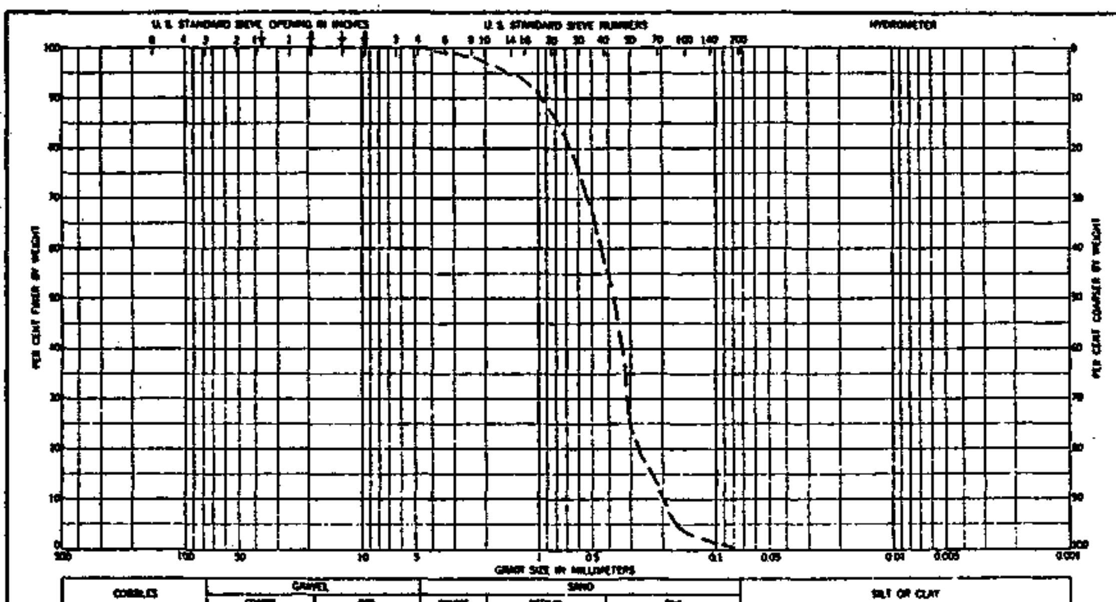
RIVER MILE: 124
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 78
CLASSIFICATION: Brown Fine to Coarse SAND, Trace Gravel, Coal, Shells and Organic Material (Wood and Tree Roots)

GRAIN SIZE ANALYSIS:



RIVER MILE:	118
LOCATION:	At the middle of the channel
DATE OF DATA COLLECTION:	July 19, 1978
SAMPLE NUMBER:	82
CLASSIFICATION:	Light Brown, Fine to Medium SAND, Trace Coal, Shell Fragments and Organic Material (Wood)

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	82	—	Light Brown, Fine to Medium SAND, Trace Coal, Shell Fragments and Organic Material	—	—	—	--

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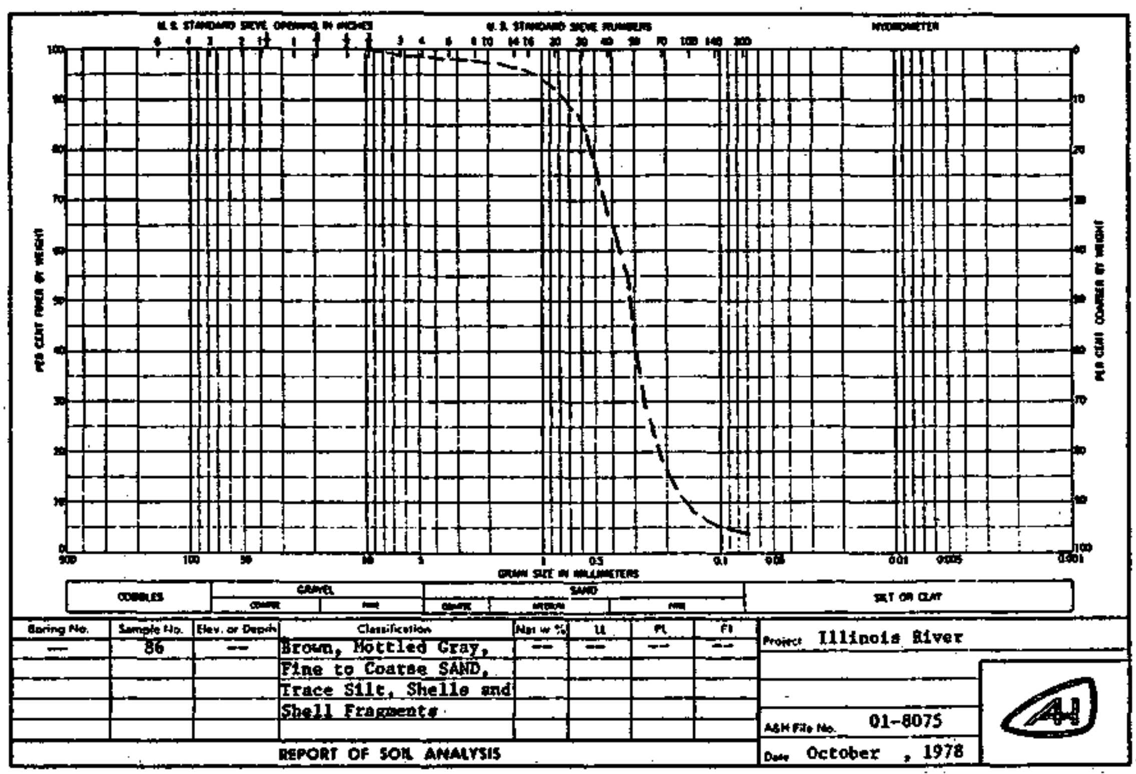
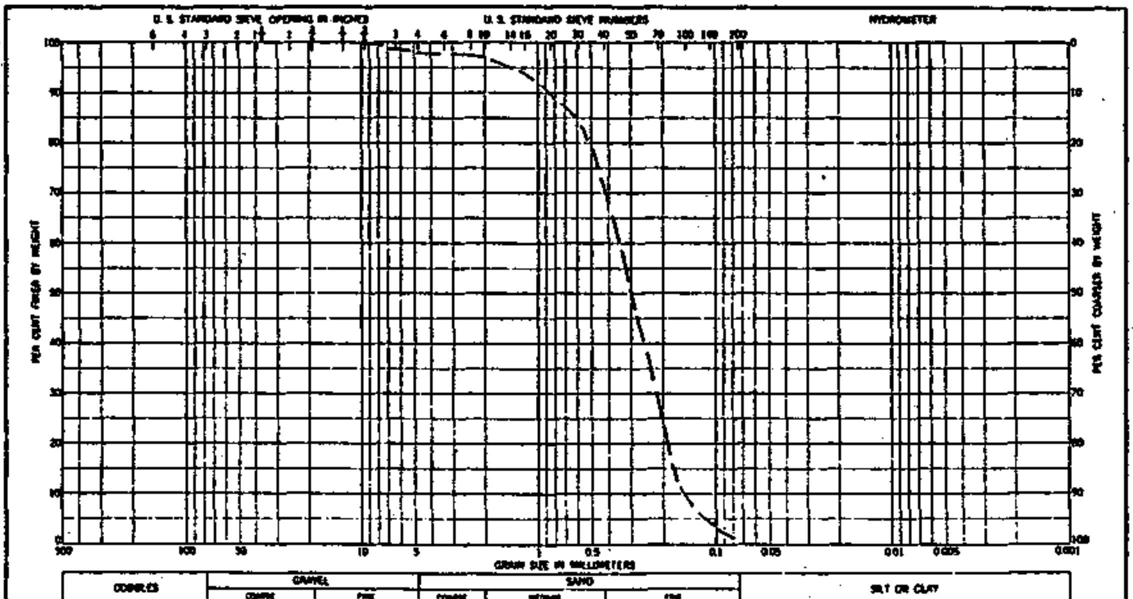
REACH NUMBER: 7
RIVER MILE: 112.6
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 19, 1978
SAMPLE NUMBER: 86
CLASSIFICATION: Brown, Mottled Gray, Fine to Coarse SAND, Trace Silt, Shells and Shell Fragments

GRAIN SIZE ANALYSIS:



RIVER MILE:	107
LOCATION:	At the middle of the channel
DATE OF DATA COLLECTION:	July 19, 1978
SAMPLE NUMBER:	87
CLASSIFICATION:	Gray-Brown, Fine to Coarse SAND, Trace Coal, Shells, Shell Fragments and Organic Material (Twigs)

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	87	--	Gray-Brown, Fine to Coarse SAND, Trace Coal, Shells, Shell Fragments and Organic Material	--	--	--	--

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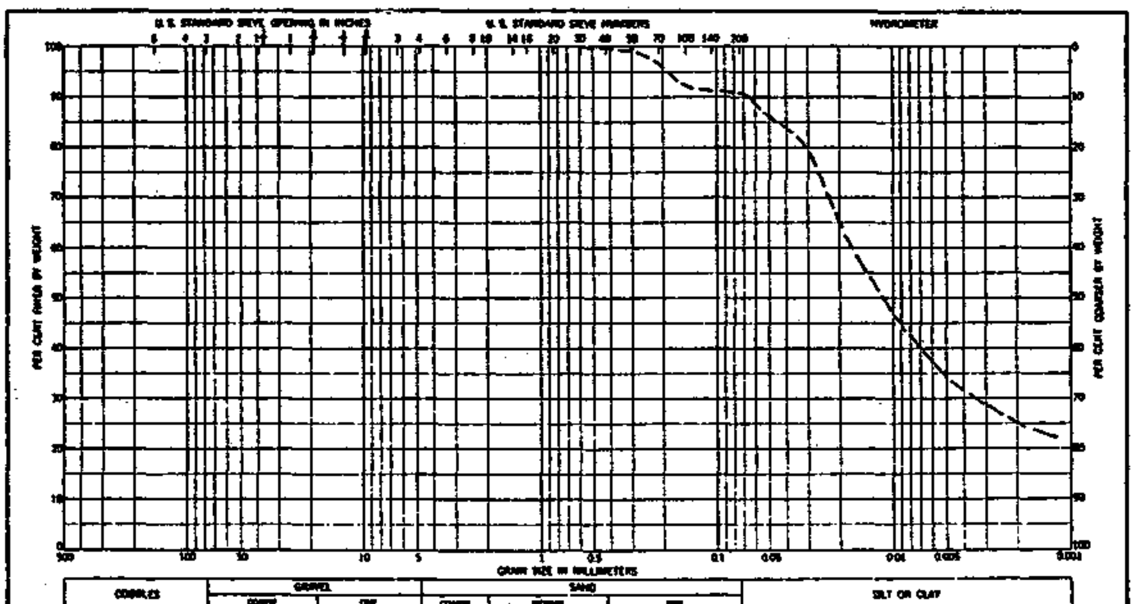
REACH NUMBER: 5
RIVER MILE: 101.7
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 93
CLASSIFICATION: Dark Gray SILT, Little Clay, Trace Sand and Organic Material (Plant Stems and Small Roots)

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	93	--	Dark Gray SILT, Little Clay, Trace Sand and Organic Material	--	--	--	--

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RIVER MILE: 95.8

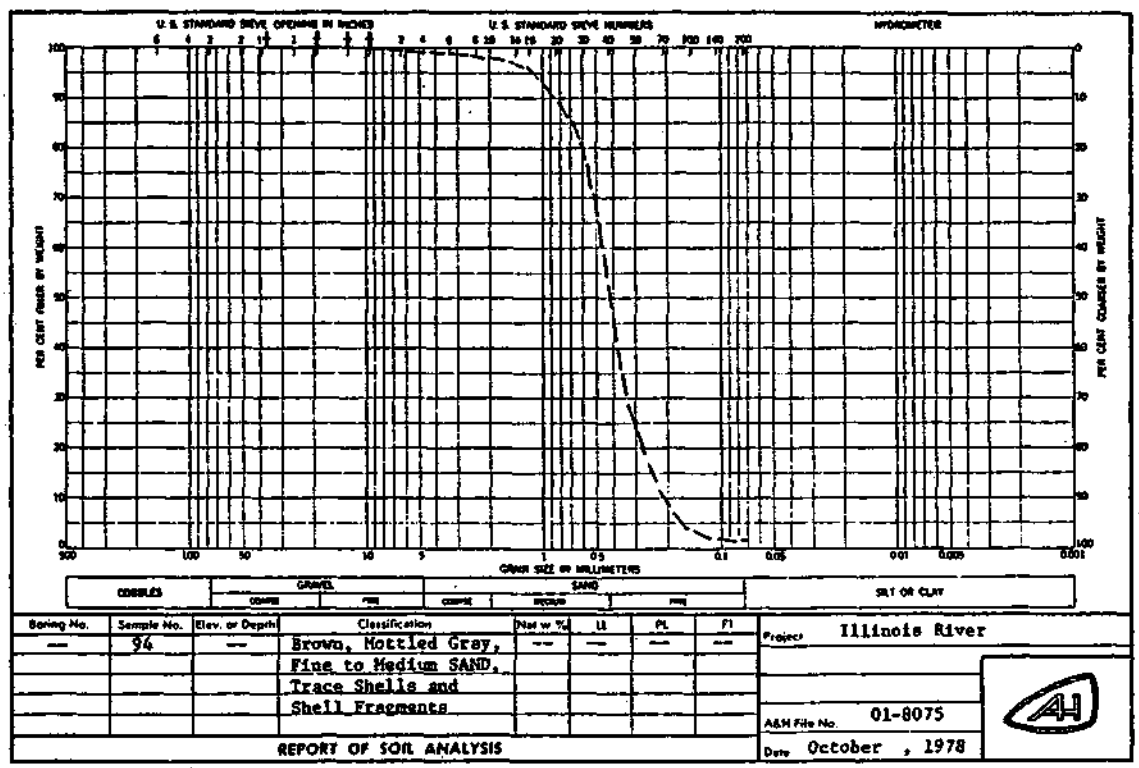
LOCATION: At the middle of the channel

DATE OF DATA COLLECTION: July 20, 1978

SAMPLE NUMBER: 94

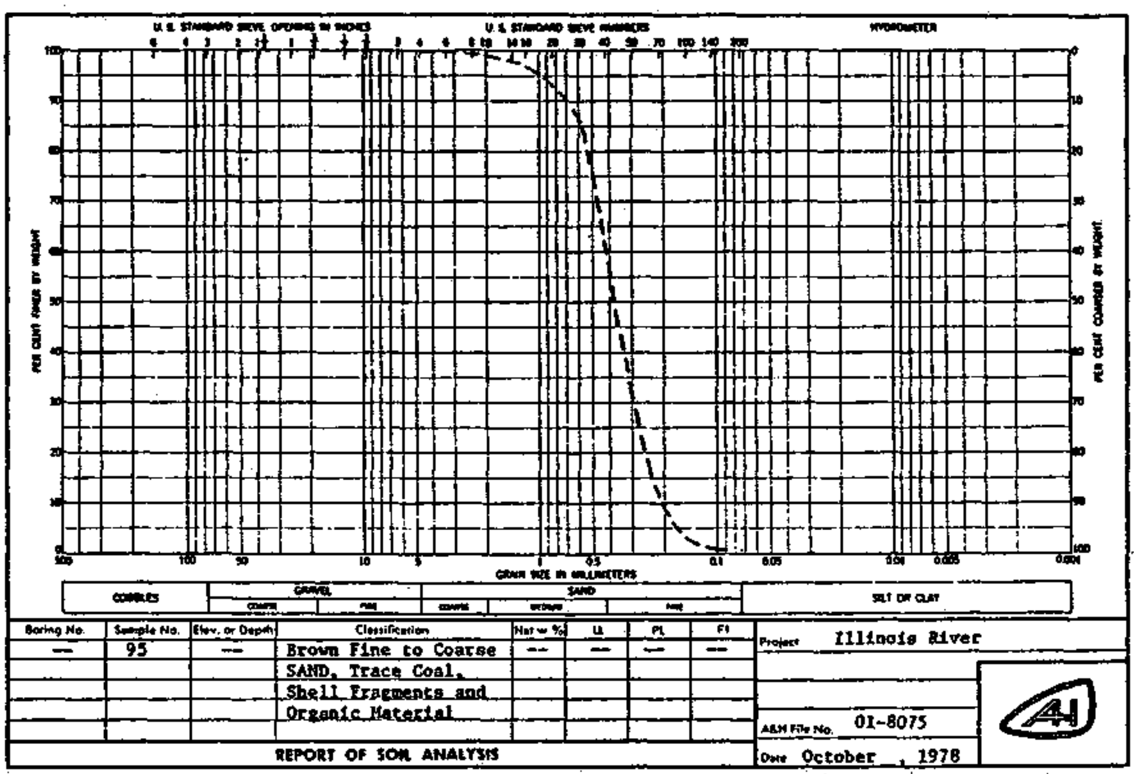
CLASSIFICATION: Brown, Mottled Gray, Fine to Medium SAND, Trace Shells and Shell Fragments

GRAIN SIZE ANALYSIS:



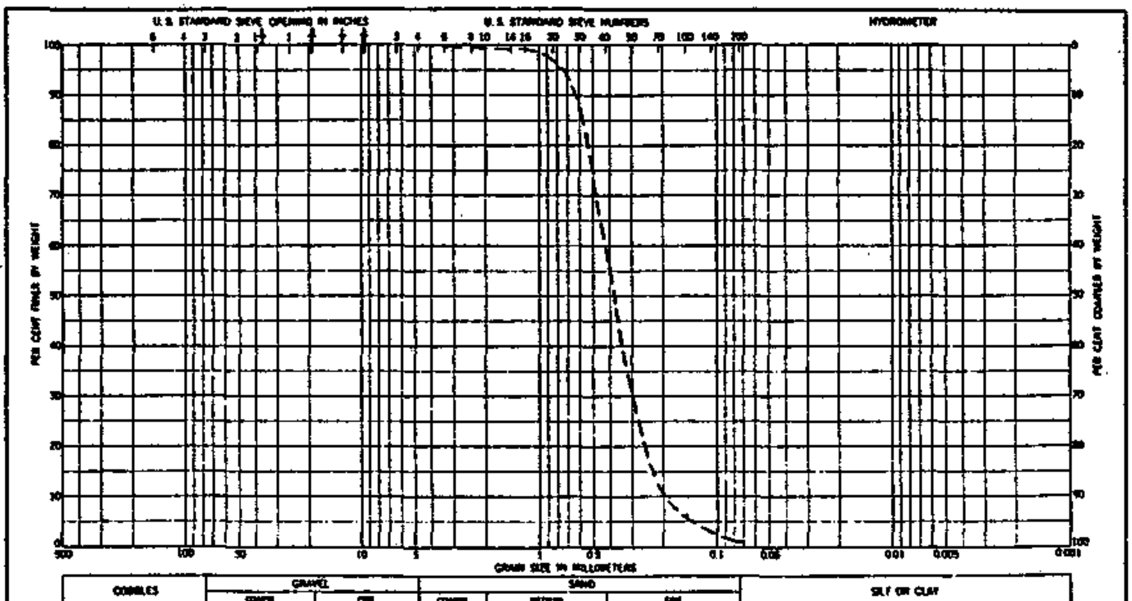
RIVER MILE: 92
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 95
CLASSIFICATION: Brown Fine to Coarse SAND, Trace Coal, Shell Fragments and Organic Material (Wood)

GRAIN SIZE ANALYSIS:



RIVER MILE: 88.2
LOCATION: At Beardstown, at the middle of the channel
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 96
CLASSIFICATION: Dark Brown, Fine to Medium SAND, Trace Shells, Shell Fragments and Organic Material (Small Roots)

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	96	—	Dark Brown, Fine to Medium SAND, Trace Shells, Shell Fragments and Organic Material	--	--	--	--

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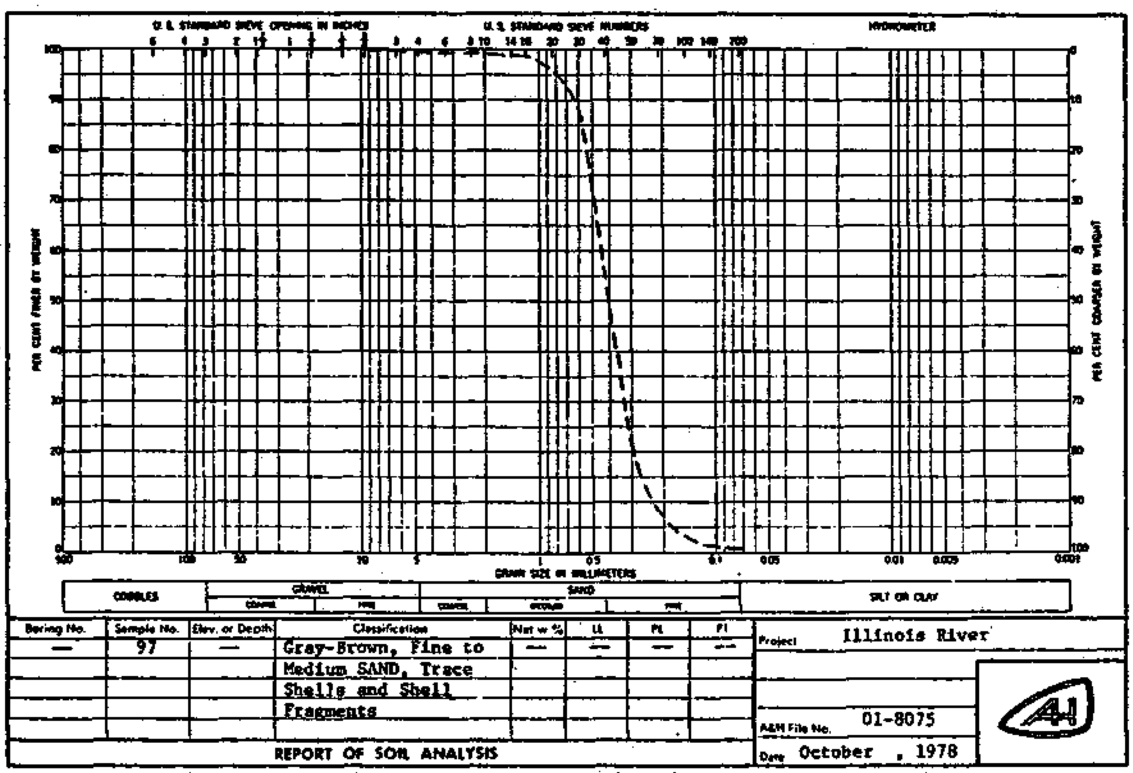
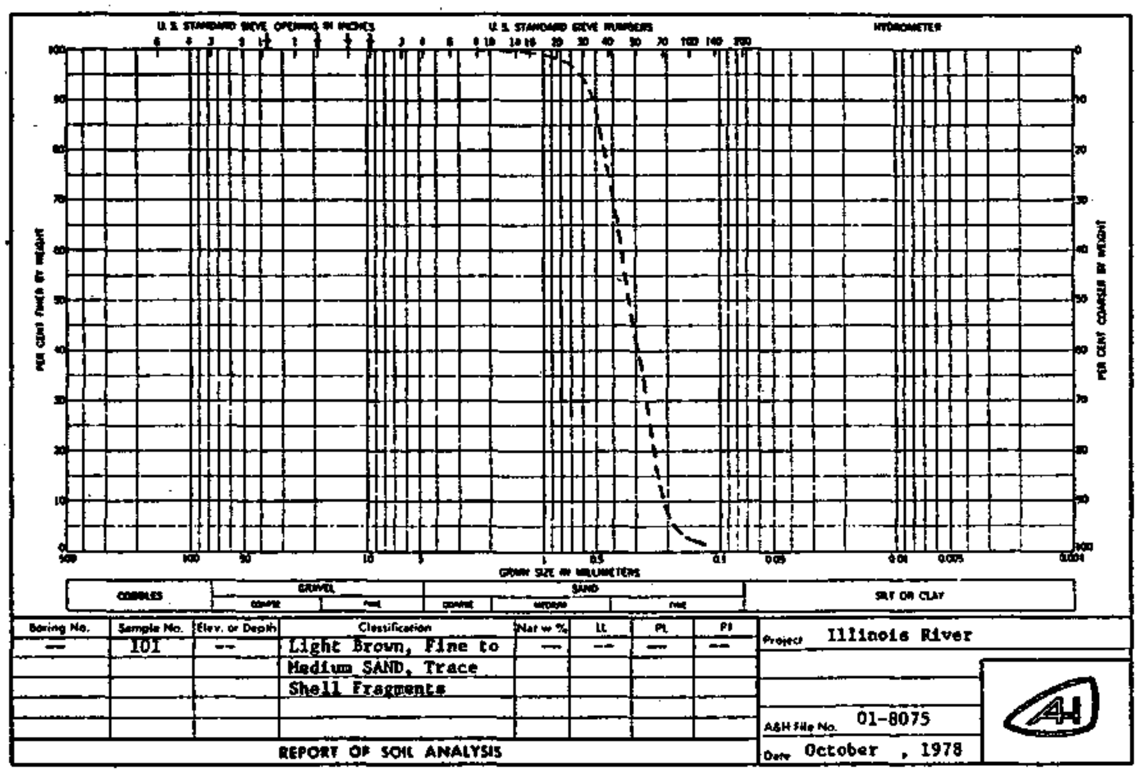
REACH NUMBER: 4
RIVER MILE: 82.1
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 97
CLASSIFICATION: Gray-Brown, Fine to Medium SAND, Trace Shells and Shell Fragments

GRAIN SIZE ANALYSIS:



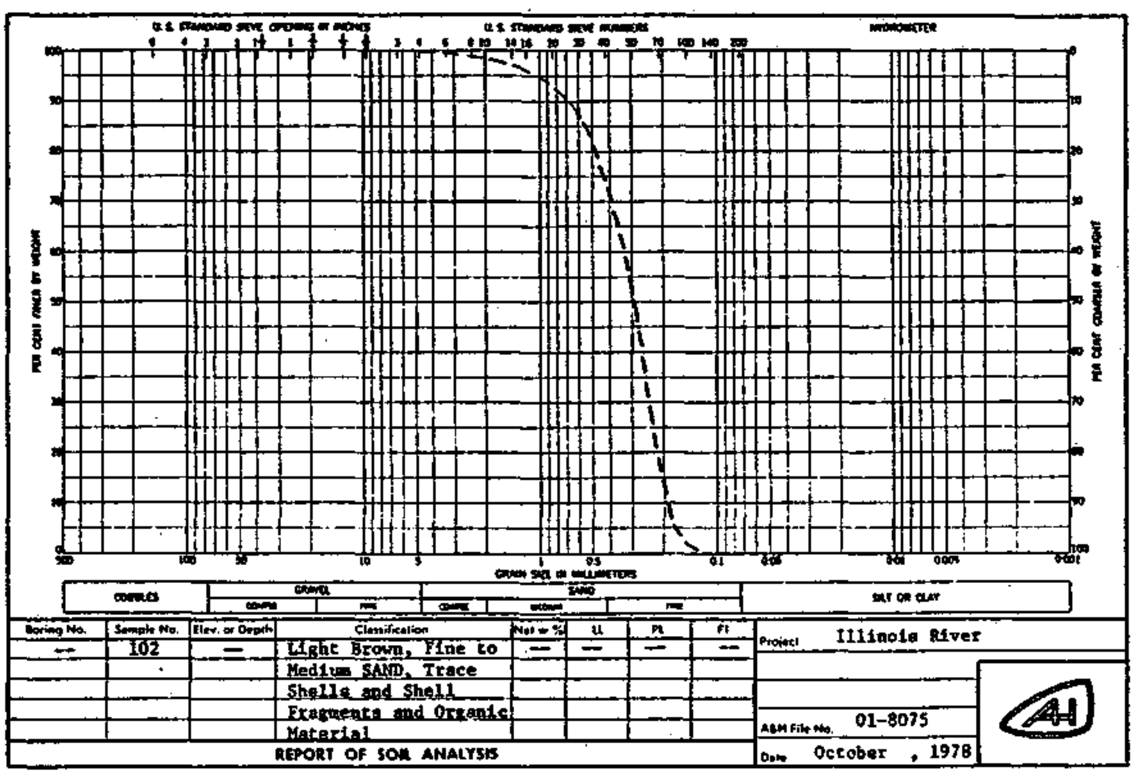
RIVER MILE: 76
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 101
CLASSIFICATION: Light Brown, Fine to Medium SAND, Trace Shell Fragments

GRAIN SIZE ANALYSIS:



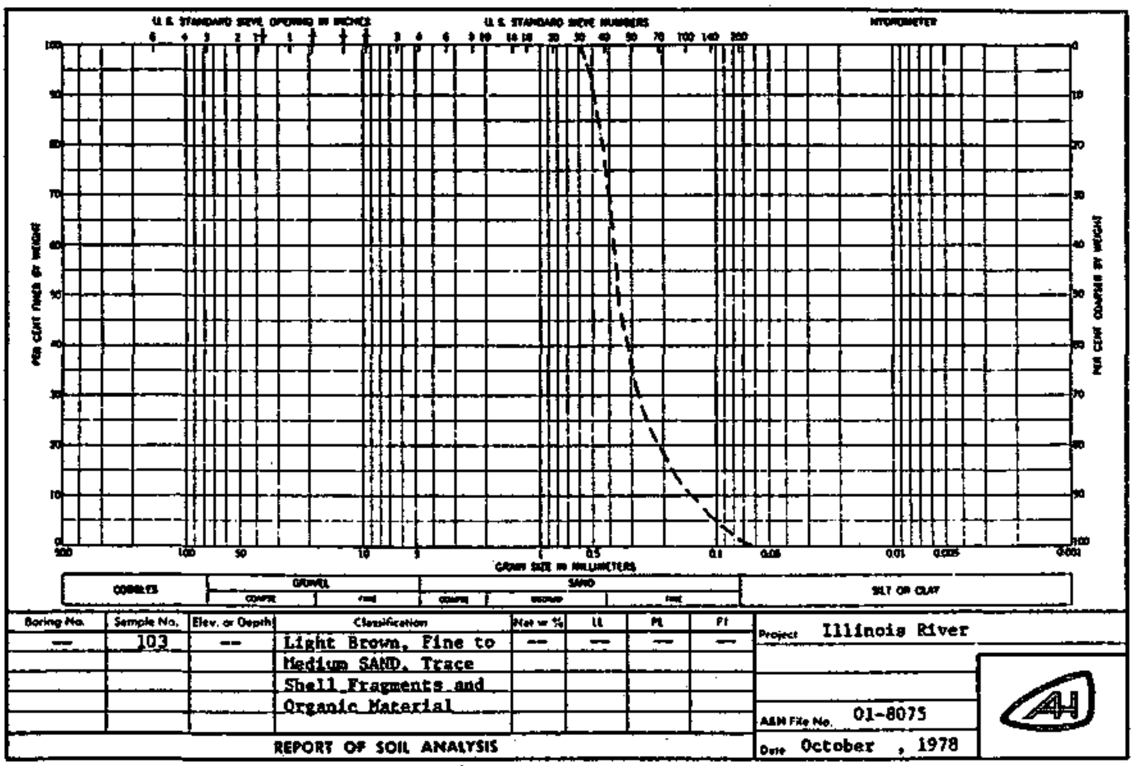
RIVER MILE:	69.3
DATE OF DATA COLLECTION:	July 20, 1978
SAMPLE NUMBER:	102
CLASSIFICATION:	Light Brown, Fine to Medium SAND, Trace Shells, Shell Fragments and Organic Material (Wood)

GRAIN SIZE ANALYSIS:



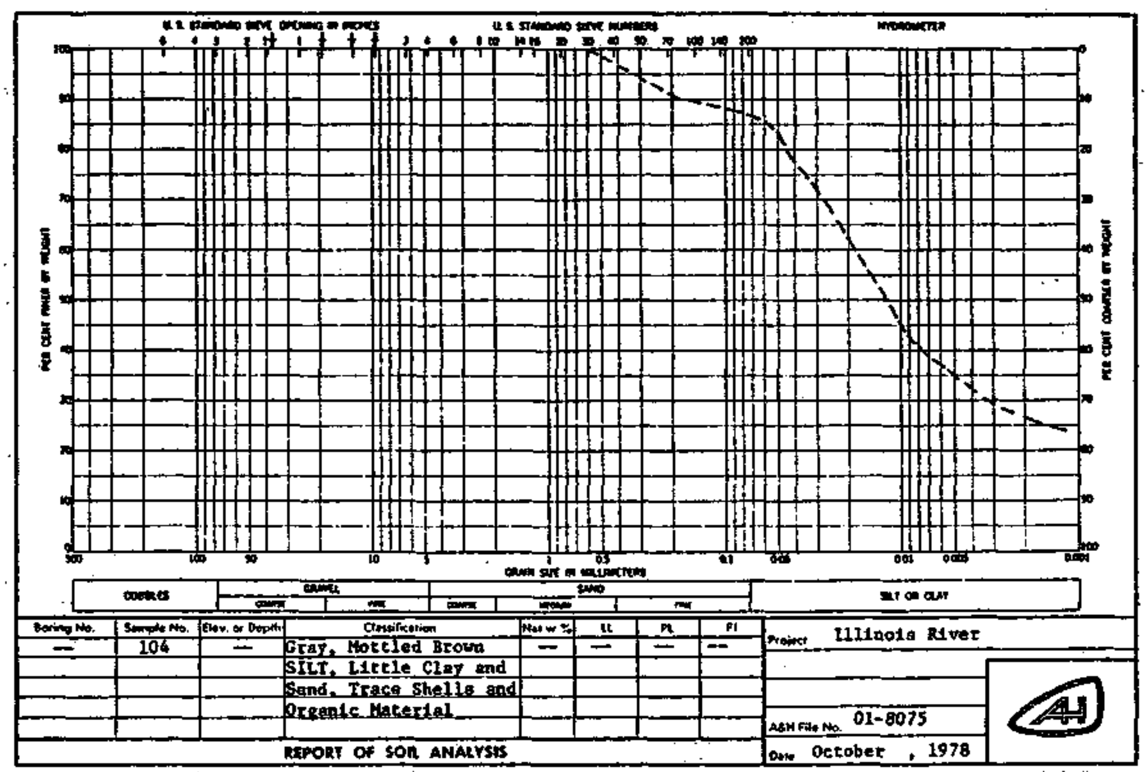
RIVER MILE: 65.8
LOCATION: Near Nables at the middle of the channel
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 103
CLASSIFICATION: Light Brown, Fine to Medium SAND, Trace Shell Fragments and Organic Material (Twigs)

GRAIN SIZE ANALYSIS:



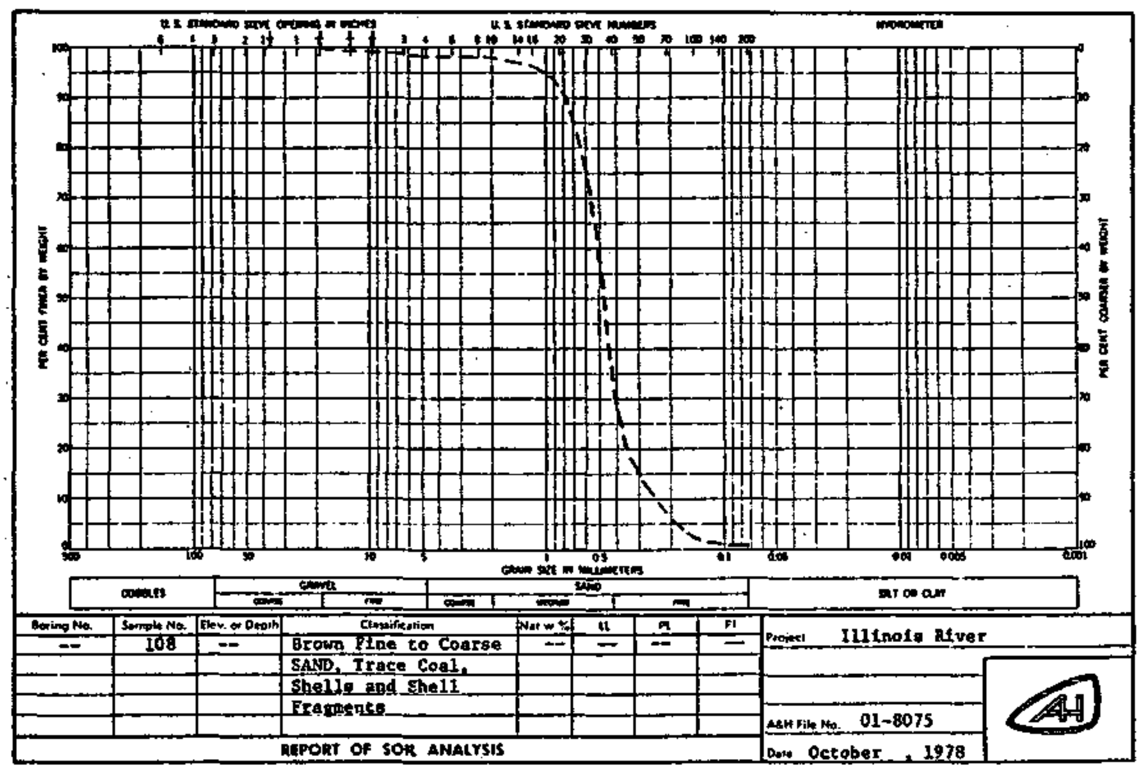
REACH NUMBER: 3
RIVER MILE: 60.2
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 104
CLASSIFICATION: Gray, Mottled Brown SILT, Little Clay and Sand, Trace Shells and Organic Material (Small Roots)

GRAIN SIZE ANALYSIS:



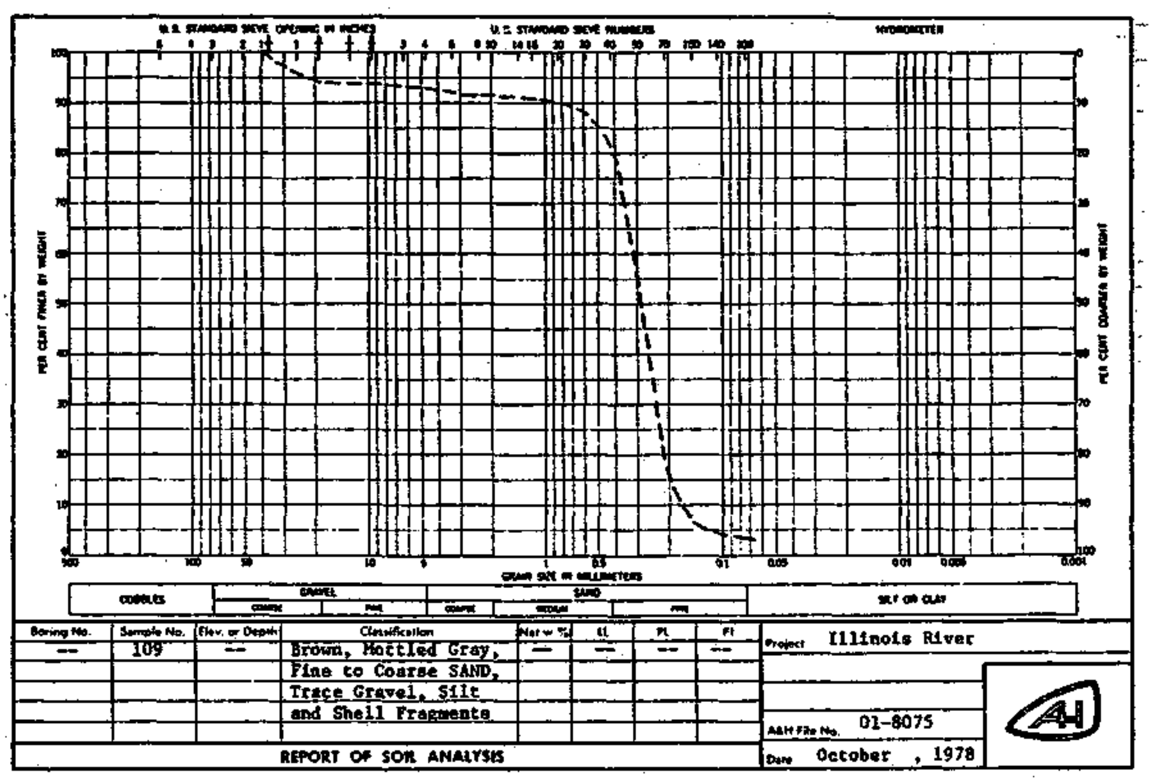
RIVER MILE: 54.2
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 108
CLASSIFICATION: Brown Fine to Coarse SAND, Trace Coal, Shells and Shell Fragments

GRAIN SIZE ANALYSIS:



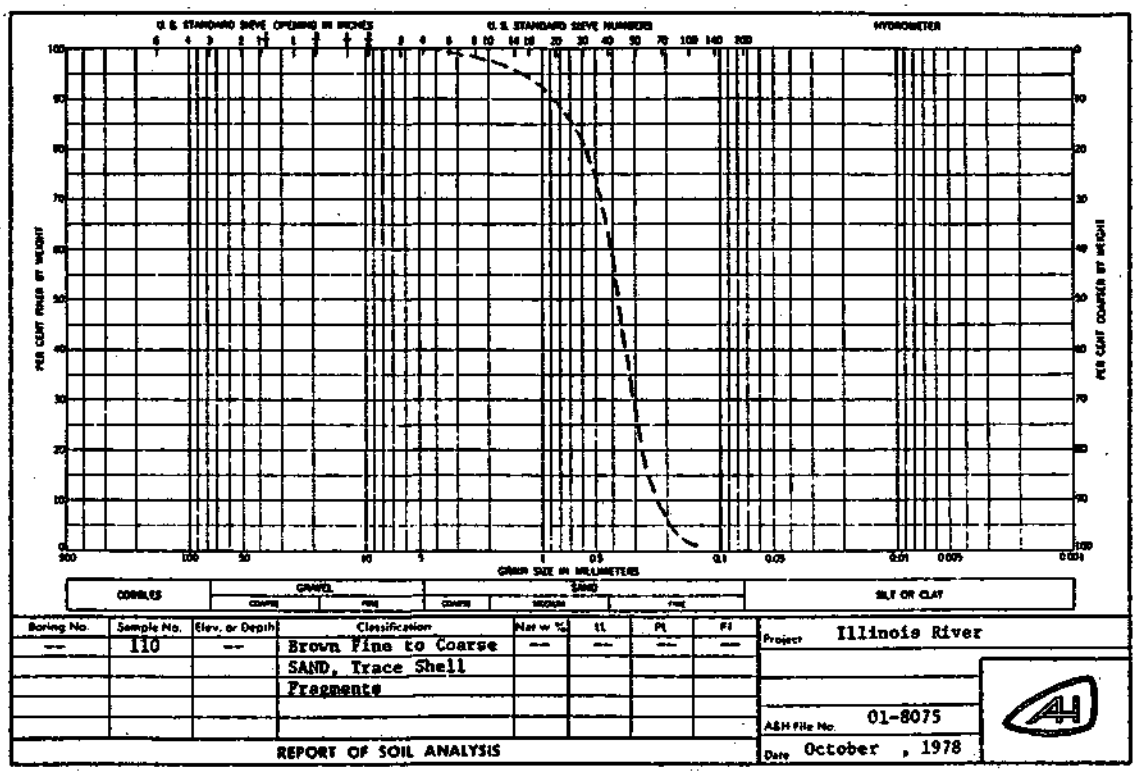
RIVER MILE:	48.5
LOCATION:	At the middle of the channel
DATE OF DATA COLLECTION:	July 20, 1978
SAMPLE NUMBER:	109
CLASSIFICATION:	Brown, Mottled Gray, Fine to Coarse SAND, Trace Gravel, Silt and Shell Fragments

GRAIN SIZE ANALYSIS:



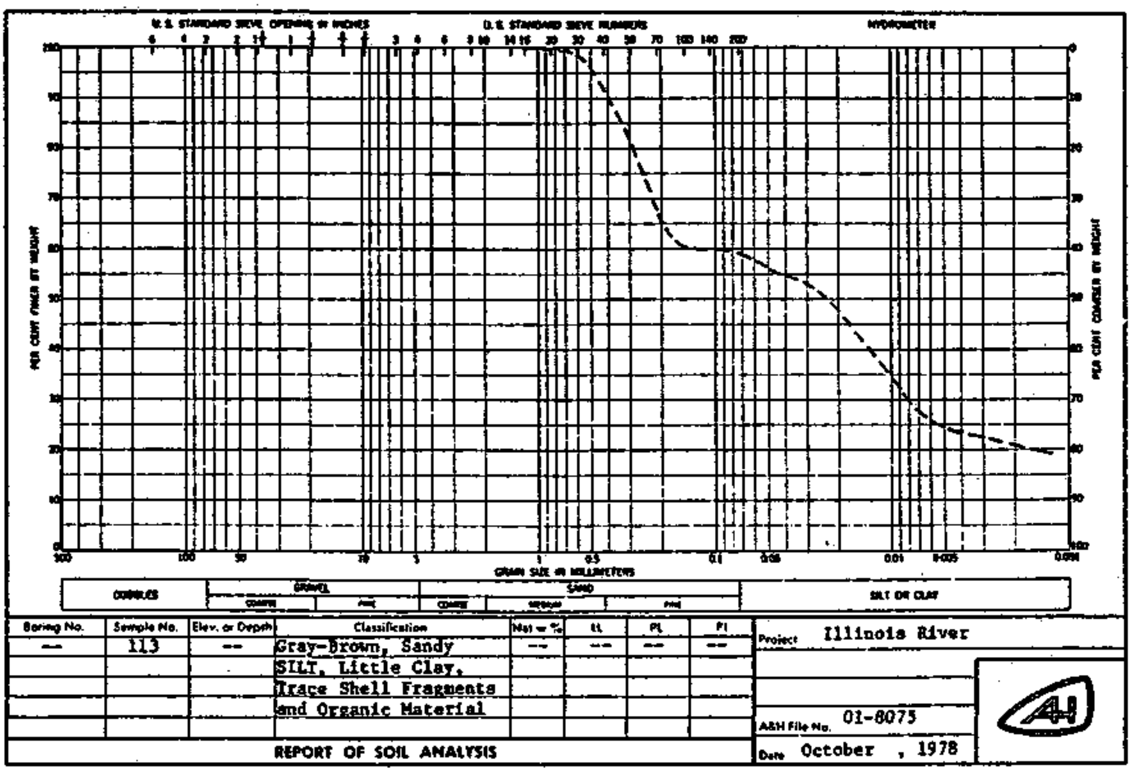
RIVER MILE: 41.4
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 110
CLASSIFICATION: Brown Fine to Coarse SAND, Trace Shell Fragments

GRAIN SIZE ANALYSIS:



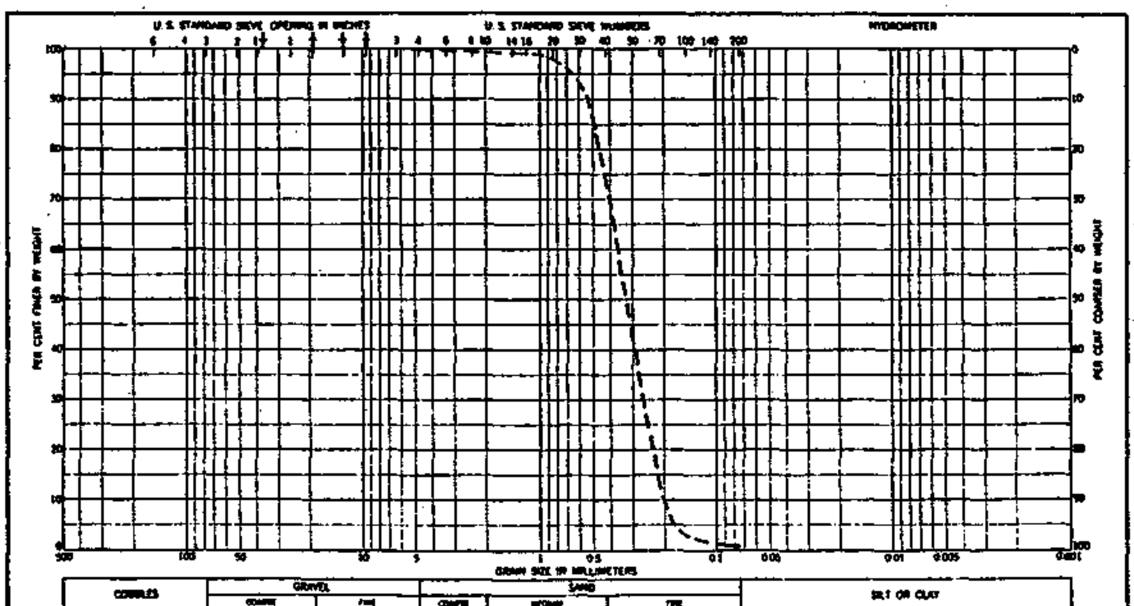
RIVER MILE: 33
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 113
CLASSIFICATION: Gray-Brown, Sandy SILT, Little Clay, Trace Shell Fragments and Organic Materials (Roots)

GRAIN SIZE ANALYSIS:



RIVER MILE:	28.9
LOCATION:	At the middle of the channel
DATE OF DATA COLLECTION:	July 20, 1978
SAMPLE NUMBER:	114
CLASSIFICATION:	Brown, Mottled Gray, Fine to Medium SAND, Trace Shells and Shell Fragments

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	114	—	Brown, Mottled Gray, Fine to Medium SAND, Trace Shells and Shell Fragments	—	—	—	—

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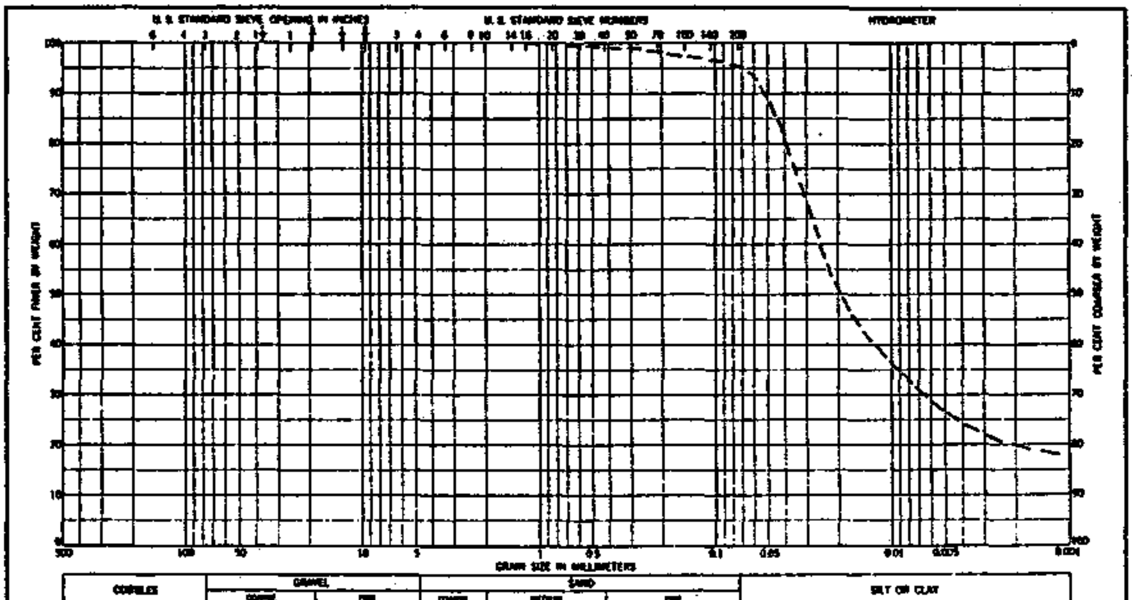
RIVER MILE:	22.8
LOCATION:	At the middle of the channel
DATE OF DATA COLLECTION:	July 20, 1978
SAMPLE NUMBER:	117
CLASSIFICATION:	Gray SILT, Little Clay, Trace Sand and Organic Material (Small Roots)

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
—	117	—	Gray SILT, Little Clay, Trace Sand and Organic Material	—	—	—	—

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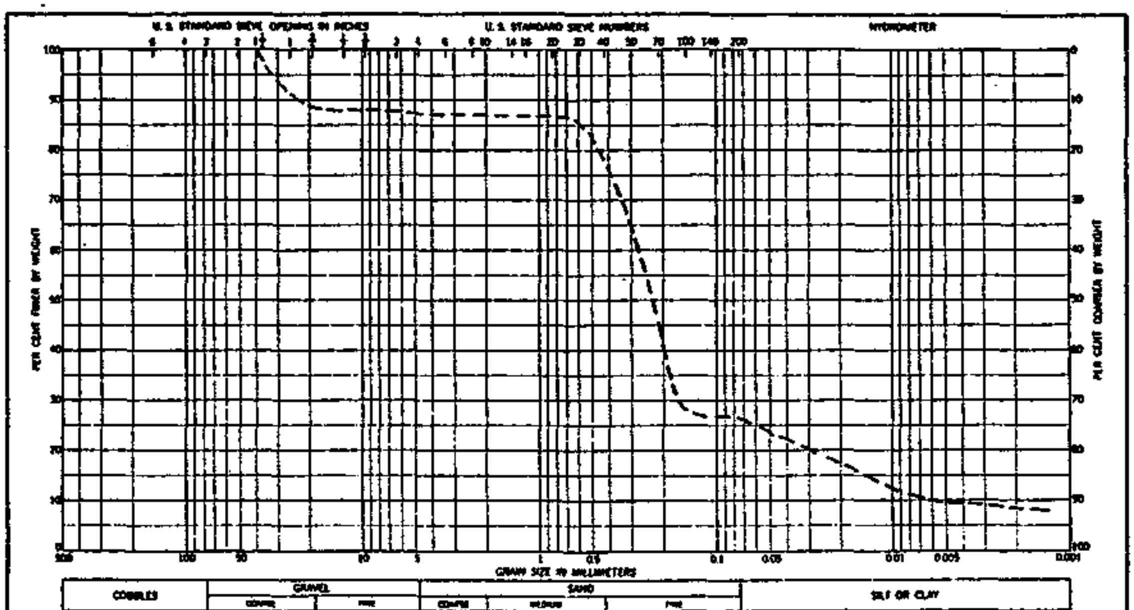
RIVER MILE: 17.0
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 118
CLASSIFICATION: Gray-Brown, Fine to Medium SAND, Little Silt, Trace Gravel, Clay and Shell Fragments

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	118	--	Gray-Brown, Fine to Medium SAND, Little Silt, Trace Gravel, Clay and Shell Fragments	--	--	--	--

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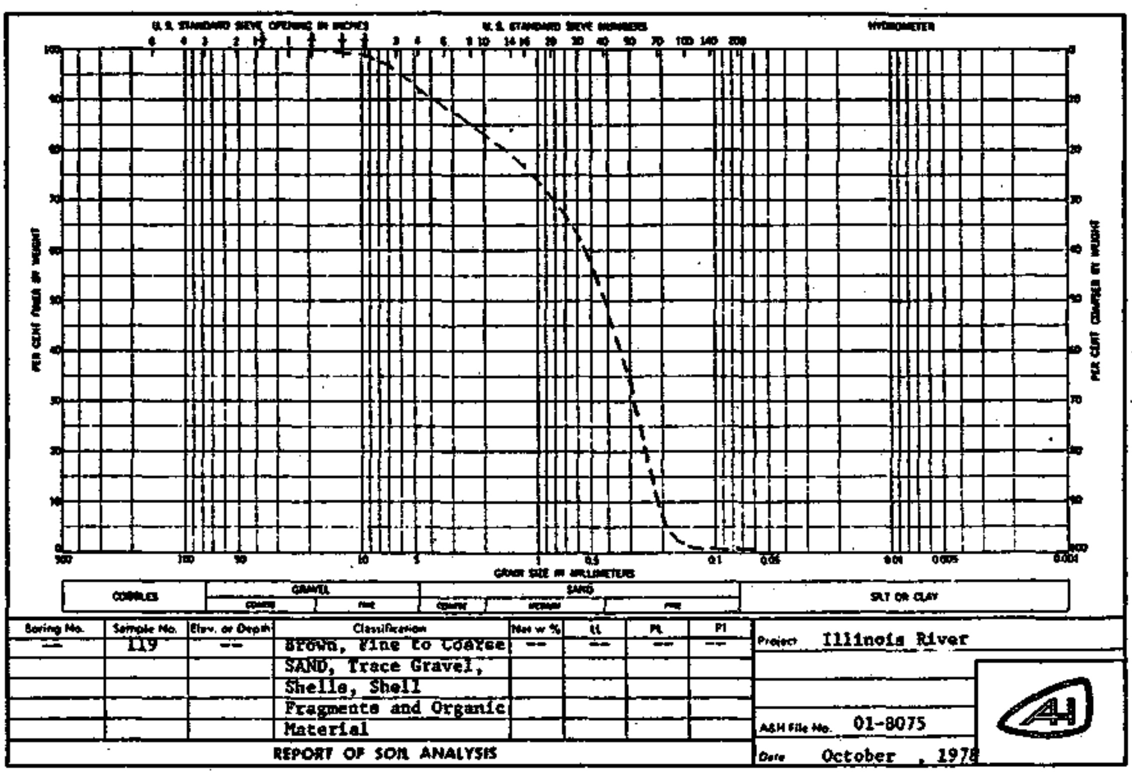
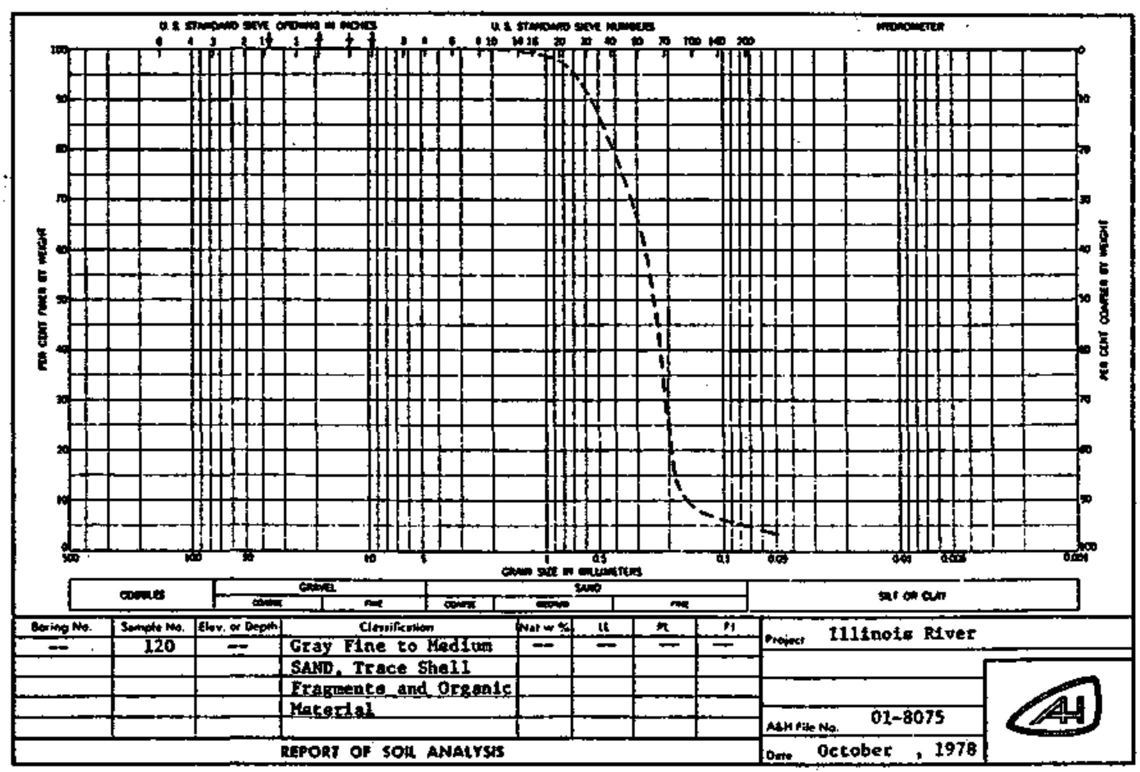
RIVER MILE:	13„2
DATE OF DATA COLLECTION:	July 20,1978
SAMPLE NUMBER:	119
CLASSIFICATION:	Brown, Fine to Coarse SAND, Trace Gravel, Shells, Shell Fragments and Organic Material (Wood, Bark, Roots)

GRAIN SIZE ANALYSIS:



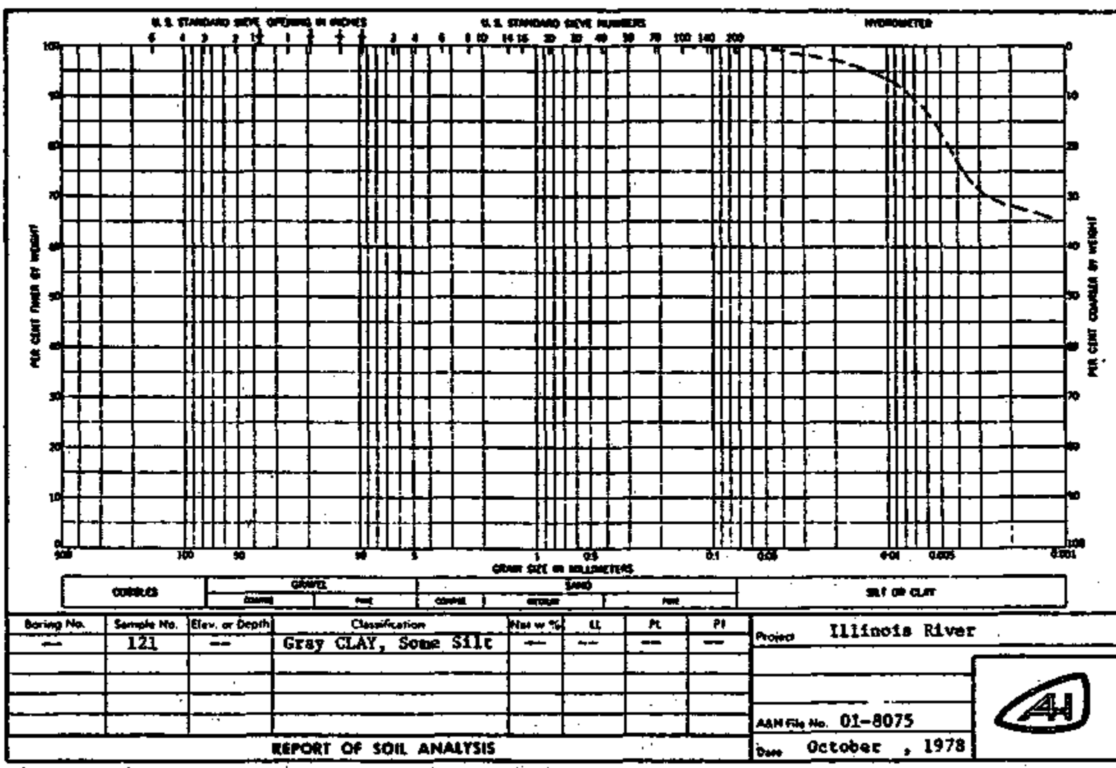
RIVER MILE: 8
LOCATION: At the middle of the channel
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 120
CLASSIFICATION: Gray Fine to Medium SAND, Trace Shell Fragments and Organic Material (Roots)

GRAIN SIZE ANALYSIS:



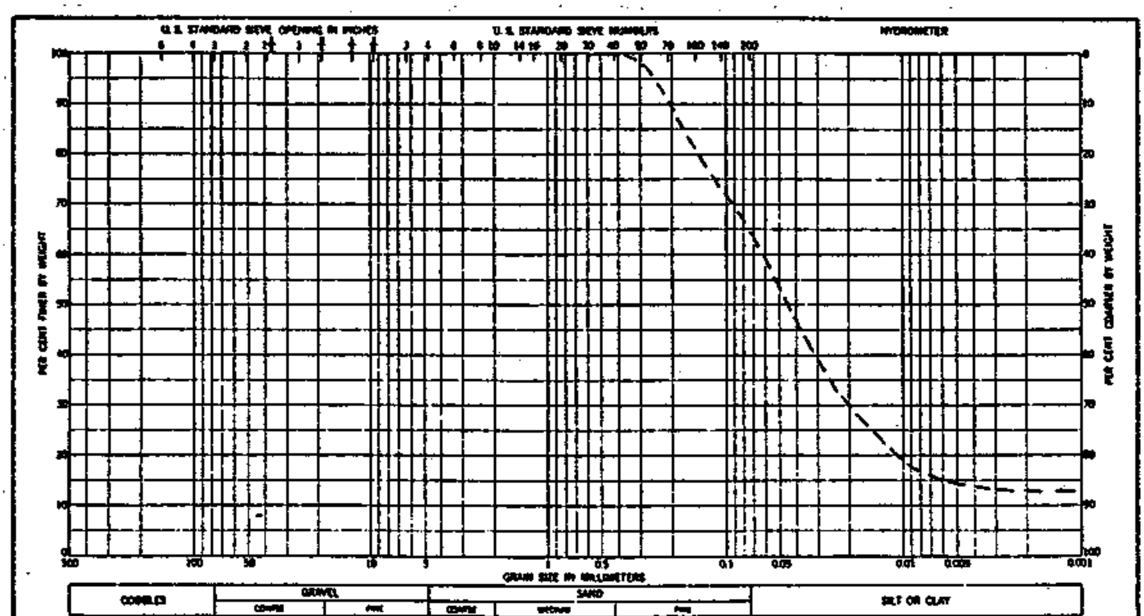
RIVER MILE: 8.0
LOCATION: Left hand side of the river 70 feet from the water line in the river
DATE OF DATA COLLECTION: July 20, 1978
SAMPLE NUMBER: 121
CLASSIFICATION: Gray CLAY, Some Silt

GRAIN SIZE ANALYSIS:



RIVER MILE: 161
LOCATION: Near Valley City in the river depth of water about 10 feet
DATE OF DATA COLLECTION: October, 1977
SAMPLE NUMBER: 125
CLASSIFICATION: Gray-Brown, Sandy SILT, Trace Clay

GRAIN SIZE ANALYSIS:



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
--	125	--	Gray-Brown, Sandy SILT, Trace Clay	--	--	--	--

Project: Illinois River
A&H File No. 01-8075
Date: October , 1978

REPORT OF SOIL ANALYSIS

RIVER MILE:	161
LOCATION:	Near Valley City in the river, depth of water about 12 feet
DATE OF DATA COLLECTION:	October, 1977
SAMPLE NUMBER:	126
CLASSIFICATION:	Light Brown, Fine to Medium SAND, Trace Silt, Shell Fragments and Organic Material (Small Roots)

GRAIN SIZE ANALYSIS: