7-1972

Hydraulic and Sediment Transport Studies in Relation to River Sediment Control and Solid Waste Pollution and Economic Use of the By-Products

Bruce R. Moore
University of Kentucky

Michael R. Short
University of Kentucky

Repository Citation

Moore, Bruce R. and Short, Michael R., "Hydraulic and Sediment Transport Studies in Relation to River Sediment Control and Solid Waste Pollution and Economic Use of the By-Products" (1972). *KWRRI Research Reports*. 136.
https://uknowledge.uky.edu/kwrri_reports/136

Research Report No. 59

HYDRAULIC AND SEDIMENT TRANSPORT STUDIES IN RELATION TO RIVER SEDIMENT CONTROL AND SOLID WASTE POLLUTION AND ECONOMIC USE OF THE BY-PRODUCTS

Dr. Bruce R. Moore
Principal Investigator

Graduate Student Assistant: Michael R. Short

Project Number A-034-KY (Completion Report)
Agreement No. 14-31-0001-3217
Period of Project - January 1970 - June 1972

University of Kentucky Water Resources Institute
Lexington, Kentucky

The work on which this report is based was supported by funds provided by the Office of Water Resources Research, United States Department of the Interior, as authorized under the Water Resources Research Act of 1964

July 1972

TABLE OF CONTENTS

Page

CHAPTER

I. Introduction

II. Research Procedures

III. Data and Results

Flume Results:

TABLE OF CONTENTS, continued

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The distribution of sediments and conditions of transport were studied in the Kentucky, Big Sandy and Ohio Rivers. The sand and coal were in transport at different flow velocities for the rivers and the deposition of these sediments was a direct function of the flow conditions at a particular locality.

The flow conditions of transport of the sediments were studied in flumes as were the hydraulic conditions in model dredge holes to determine the feasibility of trapping sediment. The conditions of scour and fill were also established and compared with known conditions in a dredge hole in the Ohio River. Flow records from gaging stations were analyzed to determine the periods of sediment transport.

The results indicate that solid waste pollutants can be trapped in dredge holes in certain conditions of flow. The principal source of the coal appears to be natural erosion.

Key Words

Sediment Transport, Scour, Dredging

ACKNOWLEDGMENTS

The author wishes to acknowledge the help of Michael R. Short in field and laboratory work and the assistance of Dr. Billy Barfield of the University of Kentucky in the design and execution of flume experiments. Mrs. Judy Cutler assisted in data analysis and manuscript preparation. Dr. John Thrailkill freely gave advice and time in discussion.

CHAPTER I

INTRODUCTION

Objectives

(a) To establish that a dredge hole in a river can act as a sediment trap to collect coal and sand using the vortex action of the river.

(b) To delineate the parameters of flow and the dimensions of such a hole to trap particular sized particles at given conditions of flow.

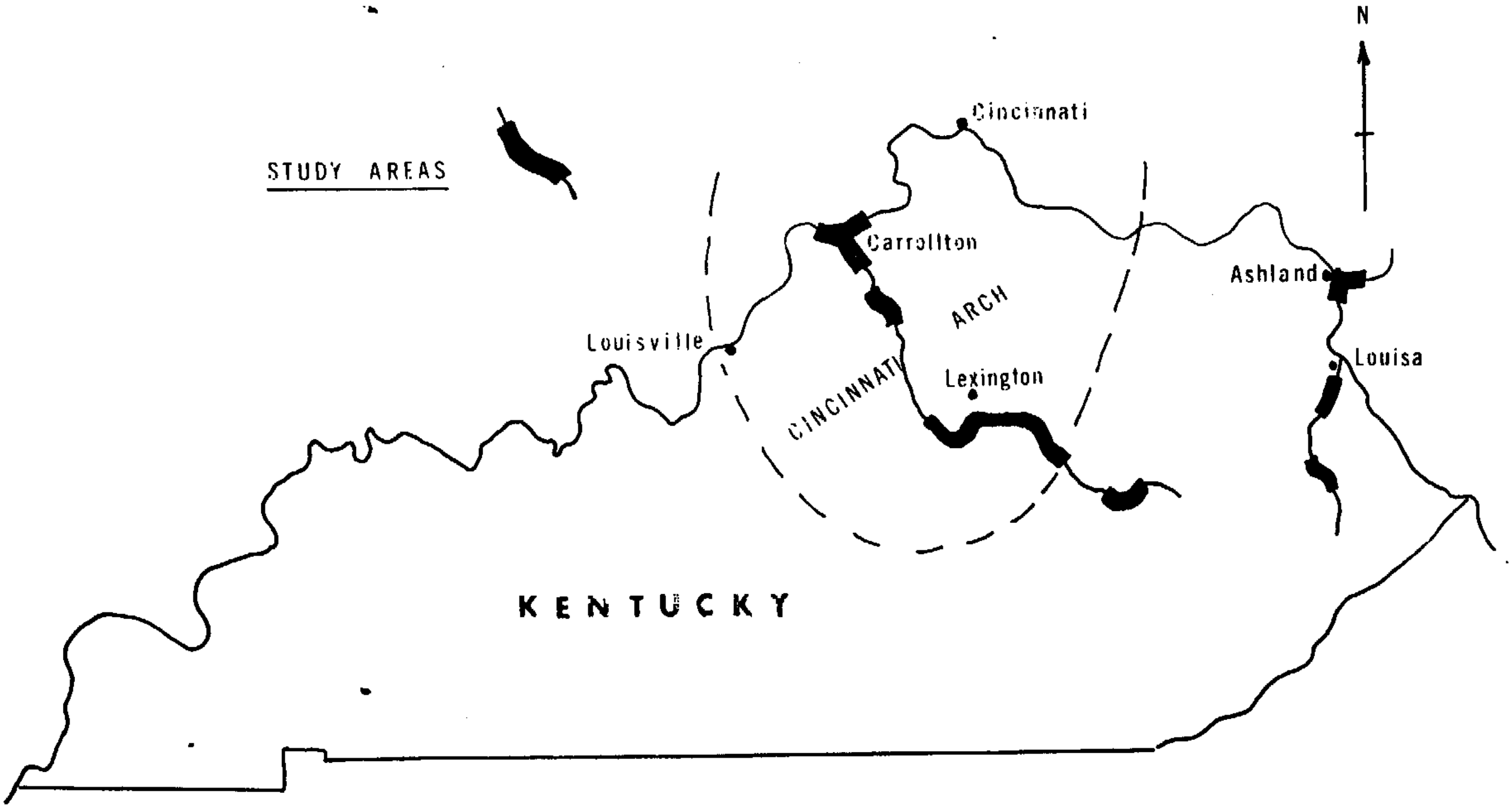
(c) To examine the feasibility of controlling sedimentation by use of a dredge hole and of extracting sediment and solid waste from streams using such a sediment trap.

(d) To establish the pattern of distribution of sediments in the study area.

Background

The streams draining Eastern Kentucky were chosen for the study since they traverse a wide variety of geologic strata in deriving their sediment load. The study was principally concentrated on the Kentucky River but included the Big Sandy River and the Ohio River. This gave a range of stream discharge from a small to a very large river. All the rivers are important for water supply and removal of sewage effluent and the Ohio and Kentucky Rivers have a system of commercially navigable locks.

The study area lies on the eastern flank of the geologic structure known as the Cincinnati Arch, with strata dipping outward to the east, south and west from Lexington. This broad structure has dips of



LOCATION MAP OF CINCINNATI ARCH

FIG. 1

approximately 20 ft. per mile. The sediment load of the streams is derived from sandstones, siltstones, shale, coal beds and limestones. There are no igneous rocks of any significance in the catchment areas of the streams and any metamorphic or igneous rock fragments are derived from the Pleistocene age glacial deposits, themselves originating to the north in Canada.

The Eastern coalfield of Kentucky is located within the catchment areas of the Kentucky and Big Sandy Rivers and contributes sediment and coal material to these two rivers. In the Eastern coalfield the Pennsylvanian age coal is interbedded with terrigenous clastic sediments such as sandstone, siltstone and shale. Towards the center of the Cincinnati Arch the sediments are principally carbonates, such as limestone and dolomites with some shale. The sediments on the Arch are Ordovician age in the Lexington area and become successively younger to the east, south and west, being Pennsylvanian age in the coalfields.

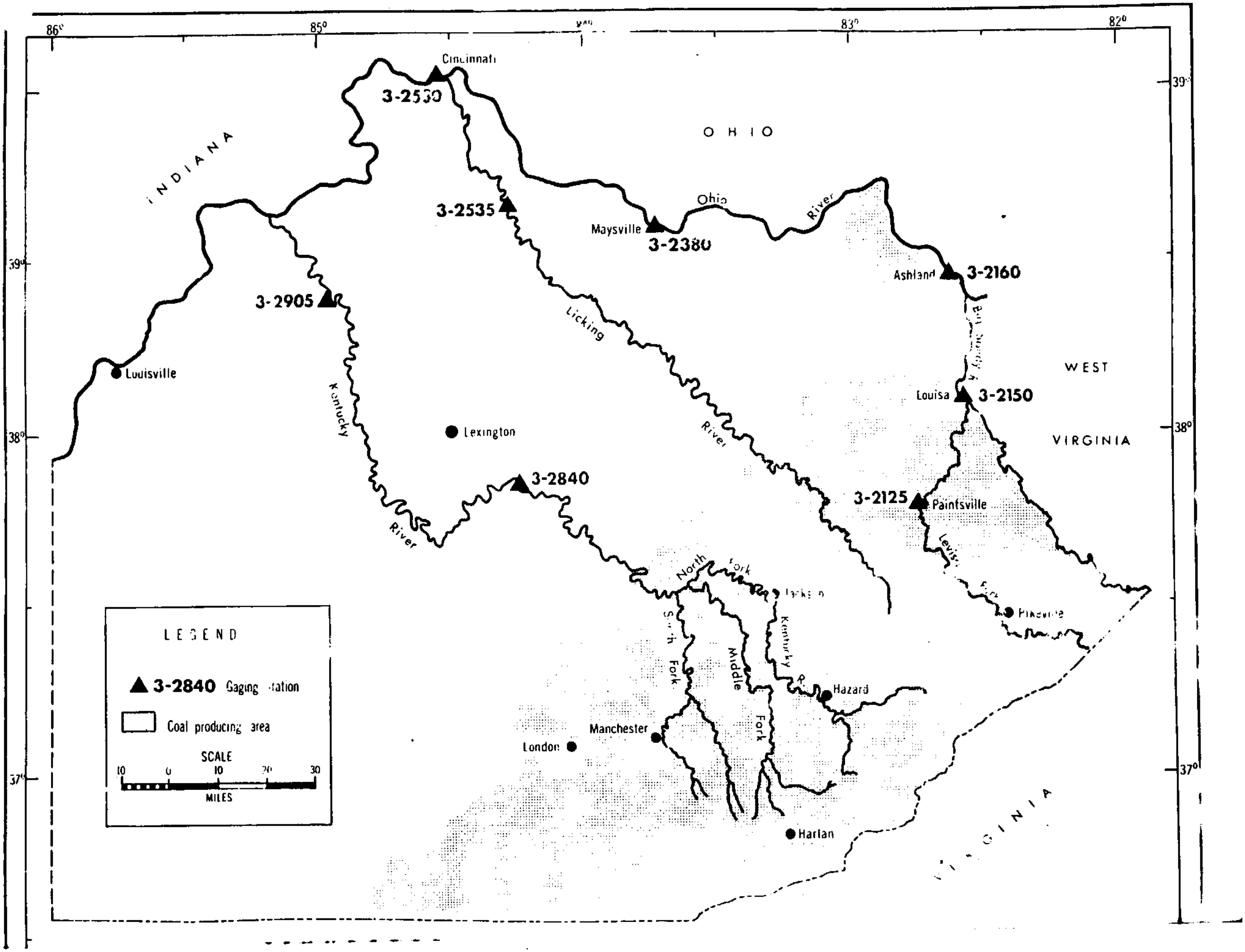
Coal is mined in the Eastern coalfield by underground and strip mining methods. Coal distribution had previously been studied in flood plain sediments, Moore (1971), at Louisville. This present study was directed to the source, transport and possible removal methods for coal and other sediment from the actual river channels rather than the banks. The origins of the coal prior to the study were thought to be:

(1) natural erosion of coal seams;

(2) coal washing and loading operations and spillage during transport;

(3) run-off from strip mining operations;

the latter two having received the bulk of the publicity.


86°
85°
84°
83°
82°
39°
38°
37°
INDIANA
OHIO
WEST VIRGINIA
VIRGINIA
Cincinnati
3-2530
3-2535
Maysville
3-2380
Ohio River
Ashland
3-2160
Big Sandy R.
Louisa
3-2150
3-2905
Louisville
Kentucky River
Lexington
Licking River
3-2840
3-2125
Paintsville
Levisa Fork
Pikeville
North Fork
Jackson
South Fork
Middle Fork
Kentucky R.
Hazard
Manchester
London
Harlan
LEGEND
3-2840 Gaging station
Coal producing area
SCALE
10
0
10
20
30
MILES

The concept of a dredge hole trap for sediment to assist in sediment dispersal was developed by the author from previous studies of dredging operations in the Ohio River, Moore (1970). These studies were extended in the present project to more clearly explain the hydraulics of trap efficiency and dispersal of sediments in dredge holes. The dredge hole originally studied at Louisville has remained in the river since 1966 and is still largely unaltered up to the latest measurements during this project work in 1972. A vortex action over the hole scours it free of sand during periods of high water and contributes to the deposition of sand between the hole and the bank (see details later). In the present study the flow conditions to fill and scour the hole were determined in models and compared to the known flow conditions of the river.

CHAPTER II

RESEARCH PROCEDURES

(a) River Sampling

General

The samples were taken from the river bottom using a Petterson Dredge from an 18 foot boat. The stations were marked on the bank and the samples taken across the width of the stream. The numbers of samples taken at each station varied from one to five depending on the width of the stream. The depth at each station, the gage reading for the pool and the width of the stream were recorded. Most material to coarse gravel could be recovered using the dredge but cobble sized material was more conveniently recovered using scuba equipment. Coarse sized coal up to 18" was collected from sand bars after high water had receded.

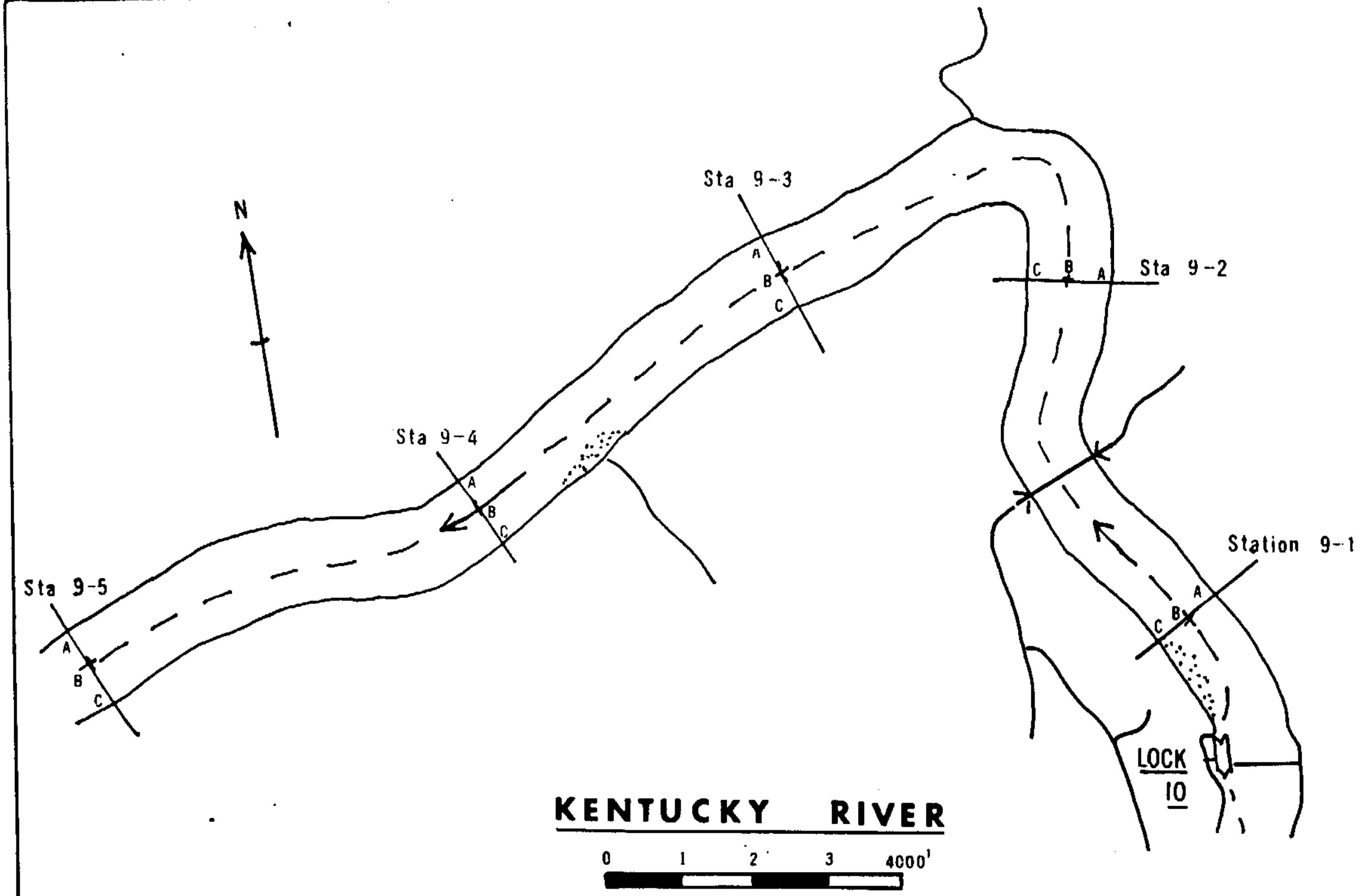
The position of the thalweg and maximum flow velocity was usually indicated at a station by the coarsest sediment. Flow velocity was recorded using a propellor type flowmeter with a direct readout.

The Ohio and Kentucky Rivers are controlled by a series of navigation locks and dams and at low flow conditions become almost stationary pools. At high water the flow continues almost uninterrupted over the top of the dam and in the Kentucky River even the locks are submerged.

The influence of the dams on sediment distribution was also considered.

Kentucky River Sampling

The river is controlled by 14 locks and dams over 258 miles from its junction with the Ohio River at Carrollton to the junction of the North



SAMPLE OF NAVIGATION CHARTS AND SAMPLE STATIONS FIG.3

and Middle Forks above Beattyville. The South Fork also joins the river at Beattyville. The pools above Locks 2, 9, 10 and 14 were chosen for the study and also the river below Lock 1 to the Ohio River. Lock 2 is located at Lockport, Ky., Lock 9 at Valley View, Lock 10 at Boonesboro, and Lock 14 at Beattyville, (see map, fig. 2). The choice of pools was made to study the contributions of the Red River in Pool 10 and the Middle, North and South Forks in Pool 14. Pool 2 was chosen to compare coal samples which must have originated above Lock 10. Commercial barge traffic at present only goes upstream to Lock 4 at Frankfort and sand is the principal cargo. No coal has been barged on the Kentucky River during the past 15 years.

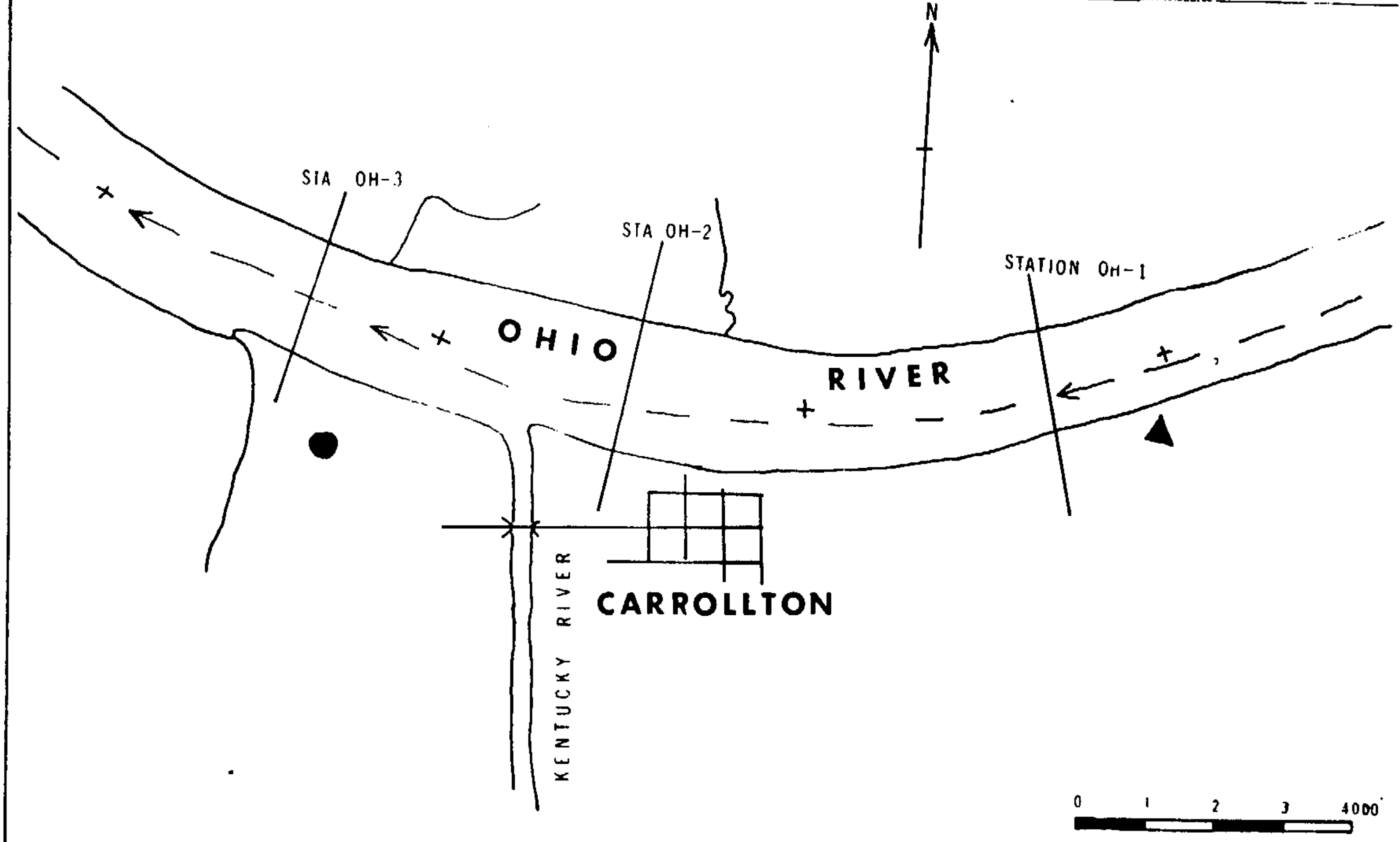
Sample stations were located at mile points indicated on U.S. Army Engineers Navigation Charts (1972). Three samples across the river were taken at each station.

The river gradients in the various pools are different and appear to influence sediment transport. The gradients were calculated from levels given in the Navigation Charts.

Sediments were dried, wet sieved, dried, weighed and examined for shape and roundness, relationships possibly indicating the transport history, particularly in the case of the coal. A typical chart of sample locations is given, fig. 3.

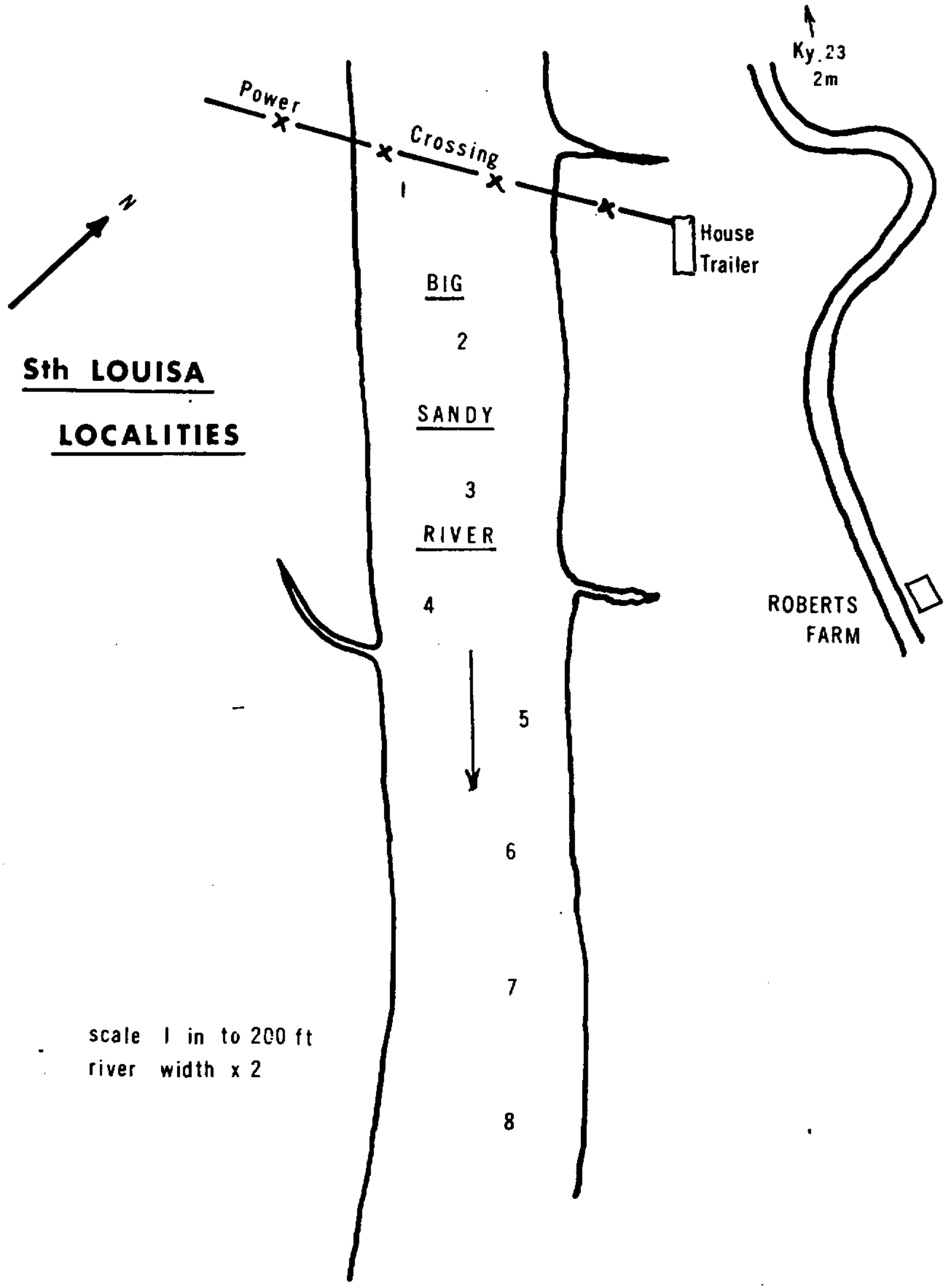
Ohio River Samples

The Ohio River was sampled at Louisville, Carrollton and Ashland. At the confluence of the Kentucky and Ohio Rivers at Carrollton, the Ohio was sampled above and below the junction and in the mouth of the Kentucky

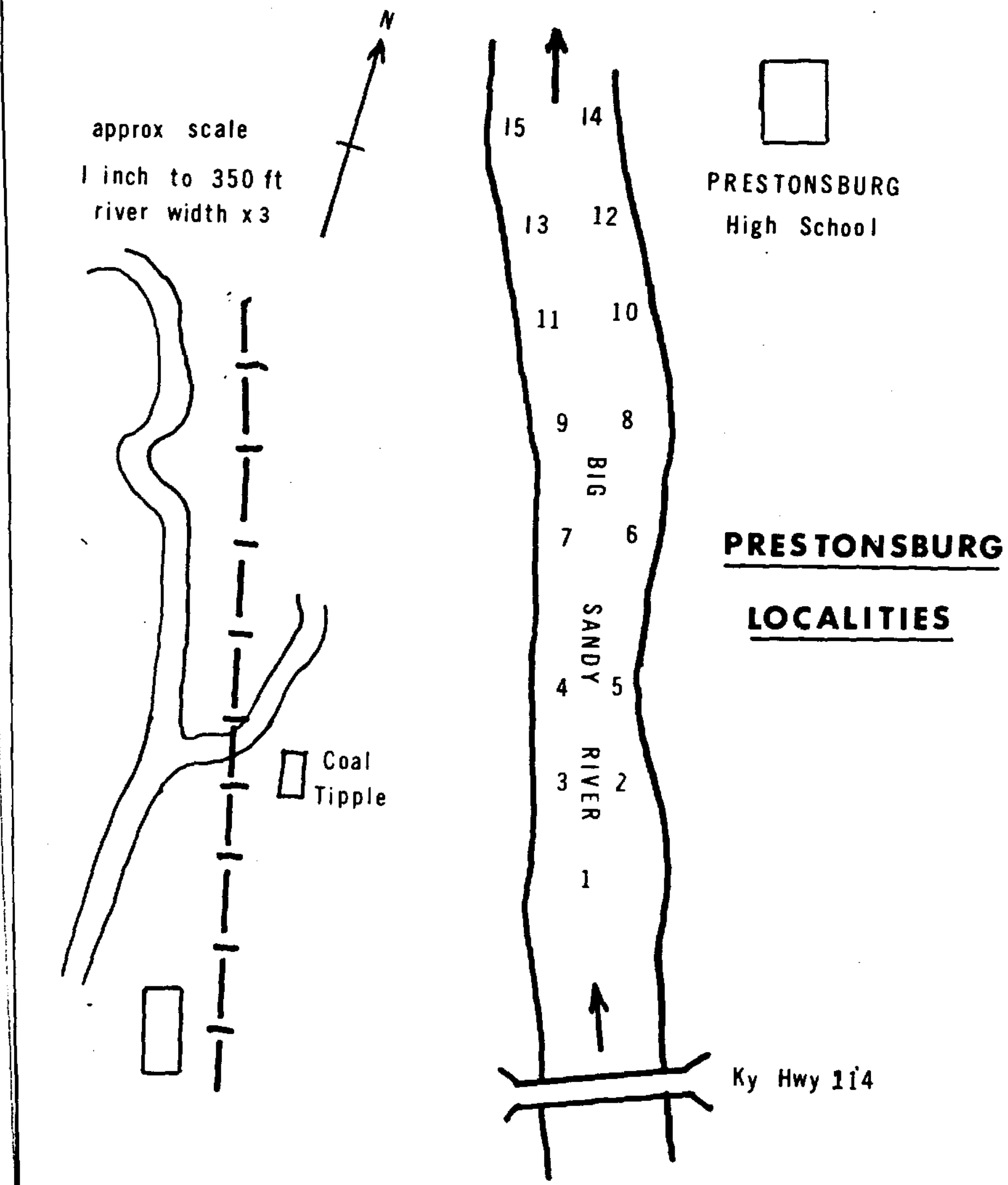


OHIO RIVER CHART AT CARROLLTON

FIG 4



BIG SANDY RIVER SAMPLE LOCATIONS AT LOUISA FIG.5



BIG SANDY RIVER LOCATIONS AT PRESTONSBURG

FIG.6

River. At Ashland, where the Big Sandy River joins the Ohio, a similar sample pattern was adopted to determine the sediment contribution of the Big Sandy River. The samples taken at Louisville were to compare the coal shape after transport some 50 miles below the mouth of the Kentucky River and for further data on the coal distribution pattern.

Big Sandy River Samples

Two locations on the Levisa Fork of the Big Sandy River were selected since the river is closed to general navigation and accessibility is a problem. The Big Sandy River originally had four navigation locks but all are now inoperable and the dams destroyed so that the river is running in open flow. A 12 ft. boat and outboard motor were used for the work. One location was at Prestonsburg and the other adjacent to the farm of Mr. Roberts approximately 7 1/2 miles south of Levisa on Hwy. 23 reached by a track to the east one mile. See figure 5. The mouth of the Big Sandy was sampled at one mile intervals for a distance of ten miles from the Ohio River.

(b) Flume Studies

Threshold of Particular Transport

When the flow of a fluid over a flat surface of loose grains is gradually increased a condition is reached where a few grains here and there begin to move with the fluid owing to the forces enacted by the fluid flow. The critical shear stress to produce this condition is a complex function of fluid density, particle density, velocity of flow, bottom roughness and many other factors. For more than two centuries workers in the field have attempted to formulate the conditions of incipient motion and the results are still not well understood.

A commonly used approach is that of Shields (1936) modified by Vanoni (1964) in which experimental results in terms of an entrainment function $\frac{r_c}{(S_s-1)d}$ plotted against the Reynolds number. Where r_c is the critical shear stress, S_s is the specific gravity of the solids, the specific weight of water and d is the particle diameter. Experimental results in flumes with materials of different density such as sand, coal, amber and barite yielded results closely approximating the Shields curve.

Critical velocity and shear values vary considerably from the Shields curve for the wide variety of coal particle shapes found in the river, hence these values were determined for this project in the flume.

In the present study it was necessary to know the range of critical conditions for transport of coal and sand in order to estimate the flow conditions for differential transport of these two solids in the river. The range of velocities when transport begins is very much a function of particle size, shape, bottom composition, slope and roughness, etc. Experimental conditions were set up in the flume to establish the critical velocity for transport of different sized coal particles on rock and sand material of different sizes. These results of necessity must be only an approximation to the conditions in a river and results provide a range of critical velocities.

The tests were conducted in an 8 ft. x 8" flume and the runs were made on coal of different screen sizes and shapes. The sizes varied from 40 mesh up to 3" and the bottom material varied from sand to gravel.

Hydraulic Theory of Sediment Movement in Dredge Holes

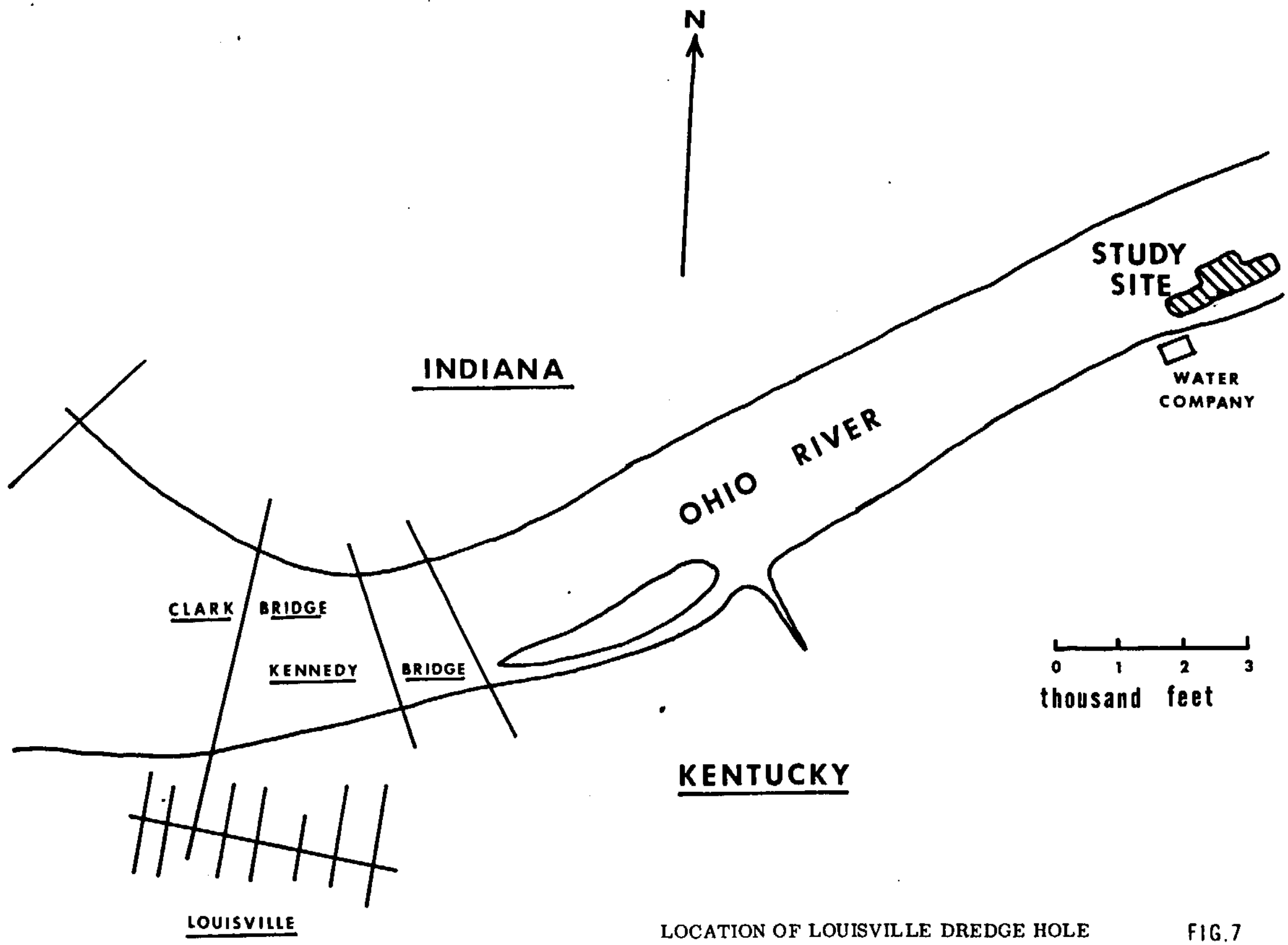
Study of sediment transport in a deep river hole began by the author in 1966 when such a hole was excavated in the Ohio River by suction dredging to produce fill for highway construction at Louisville, Kentucky.

The hole was located 2 miles upstream of McAlpine Dam near the Louisville Water Company pumping station. The hole was 1500 ft. long, a maximum of 500 ft. wide and had an average depth of 25 ft. below river bottom, (fig. 7).

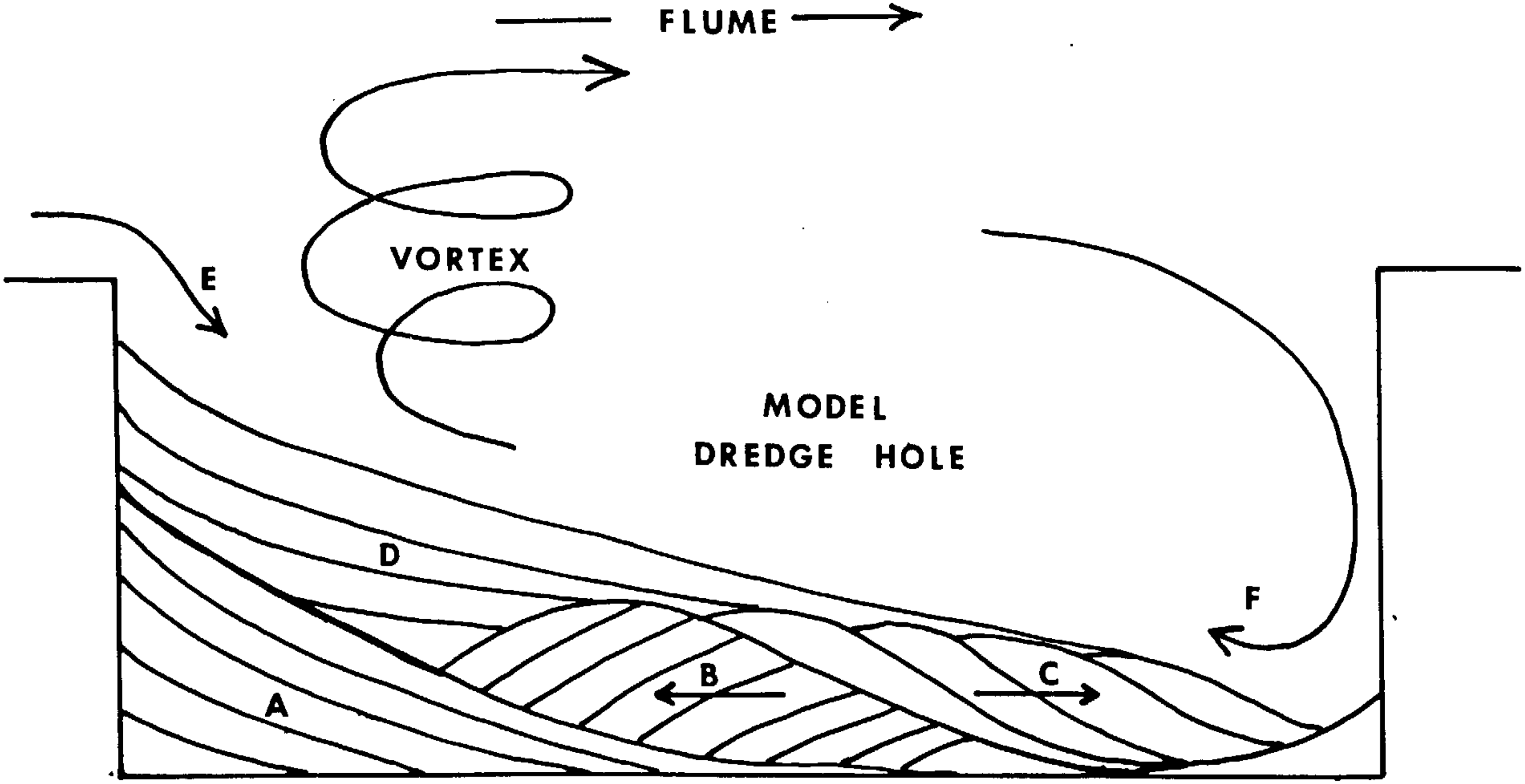
The original study was planned to measure the hole before and after high water periods to determine the rate of sediment fill. The hole did not fill as expected but rather caused the sand to deposit between the hole and the bank and on the bank during high water. The hole was studied during 1966-70 and again in this project in 1971 and 1972. It still has not refilled.

Hydraulic model studies, Moore (1970), revealed that there was a combination of scour and fill processes keeping the hole free of sediment. During a cycle of high water the hole first began to fill, then scour by the action of a vortex and refill during the falling cycle of the river. See diagrams, (figs. 8 and 18). The result was that under low conditions of flow the hole acted as a trap for sand and at higher velocities the vortex action of the hole removes the sand and places it on or near the bank.

The difference in densities of coal (1.3) and sand (2.6) opened the possibility of the two solids being in transport under different flow conditions. The theoretical aim of the present study was to establish whether the hole would trap the coal under low flow conditions and trap



LOCATION OF LOUISVILLE DREDGE HOLE FIG.7



SEQUENCES IN THE MODEL DREDGE HOLE

FIG.8

and vortex the sand under higher flow conditions preserving the hole. To this end a series of experiments were set up using mixtures of coal and sand of different sizes in a model of plexiglass hole in the 8 ft. flume under differing flow conditions. The experiments were designed to test whether the coal and sand may be differentially sorted within the dredge hole.

Experiments with Model Dredge Hole Parameters

A series of experiments was designed to test the effect on flow conditions caused by varying the depth and position and dimensions of a model dredge hole in the flume. See diagram 9, p. 19. A 40 ft. x 18" recirculating plexiglass flume was used for the tests. The flume has a section with a hole 6' x 3" x 18" in the base of the flume. By constructing boxes of plexiglass, the large hole could be shut off to any desired size and the position of the hole changed with respect to the dimensions of the flume. The velocity of the main flow and the velocity at the center bottom of each model hole was measured with a pitot tube. A pressure transducer coupled to the pitot tube gave an amplified voltage output, having been previously standardized. The Froude number was varied for each configuration. See figure 9, p. 19, for the hole configuration. The bottom roughness of each hole was constant and created by cementing 4 mm. diameter glass beads to a false bottom of plexiglass placed in the hole. The relative depths of flow of the main flume to depth of the hole were varied in the tests by changing the depth of flow in the main flume.

The experimental procedure was designed after a similitude analysis of the model and conformed to the laws of similitude. The directions of flow in each test were observed by introducing potassium permanganate into the hole for each test. The general pattern of flow of the water was thus observed in each hole.

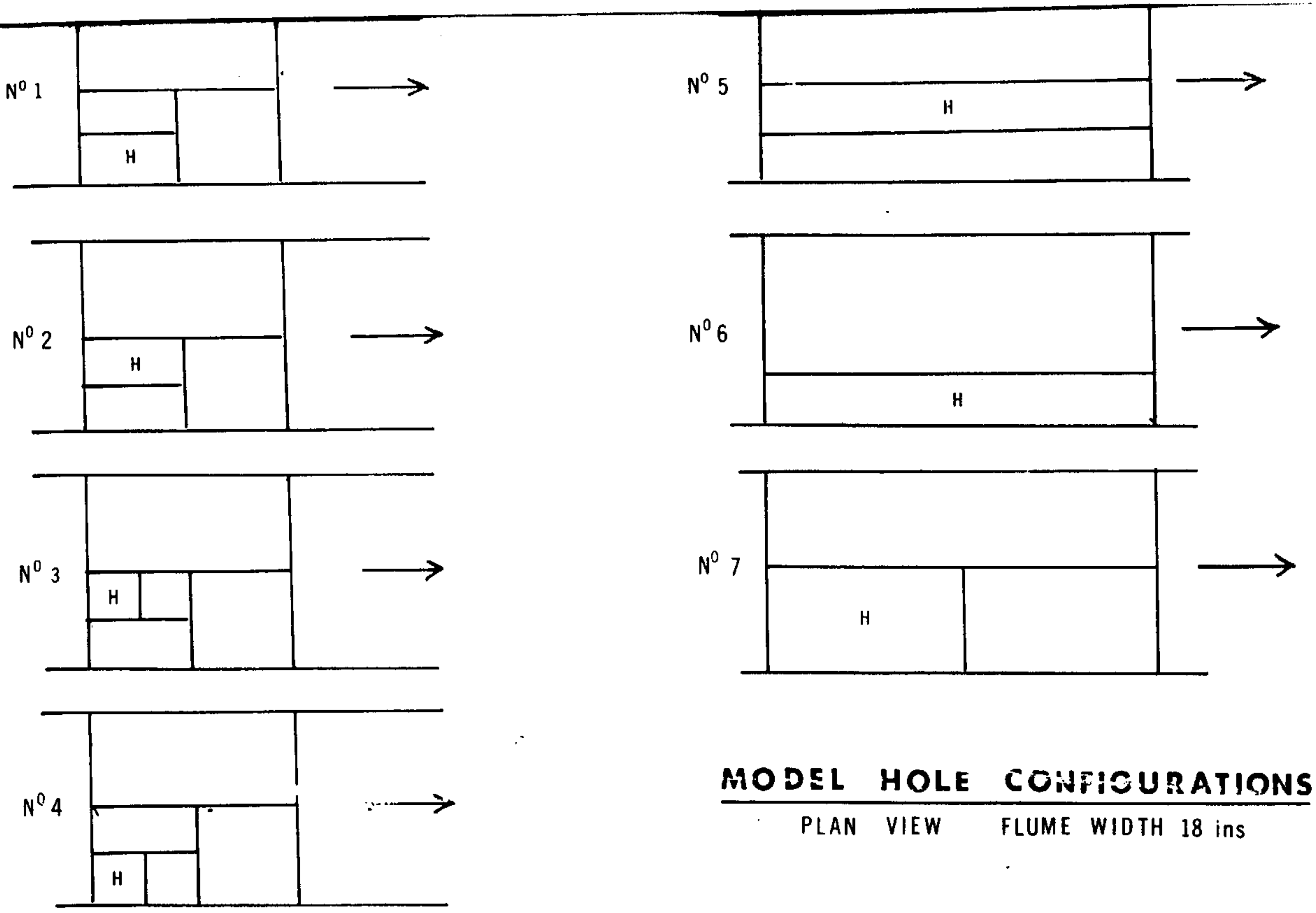
Graphical plot of the ratio of depth of hole to depth of flow against velocity of flow in the bottom of the model hole is given in fig. 17, p. 42. The dimensions of the hole, position of hole in the flow, relative depths of flume and the hole were varied furing runs of different flume velocity to establish the most efficient trap conditions.

Analysis of Flow Conditions in the River

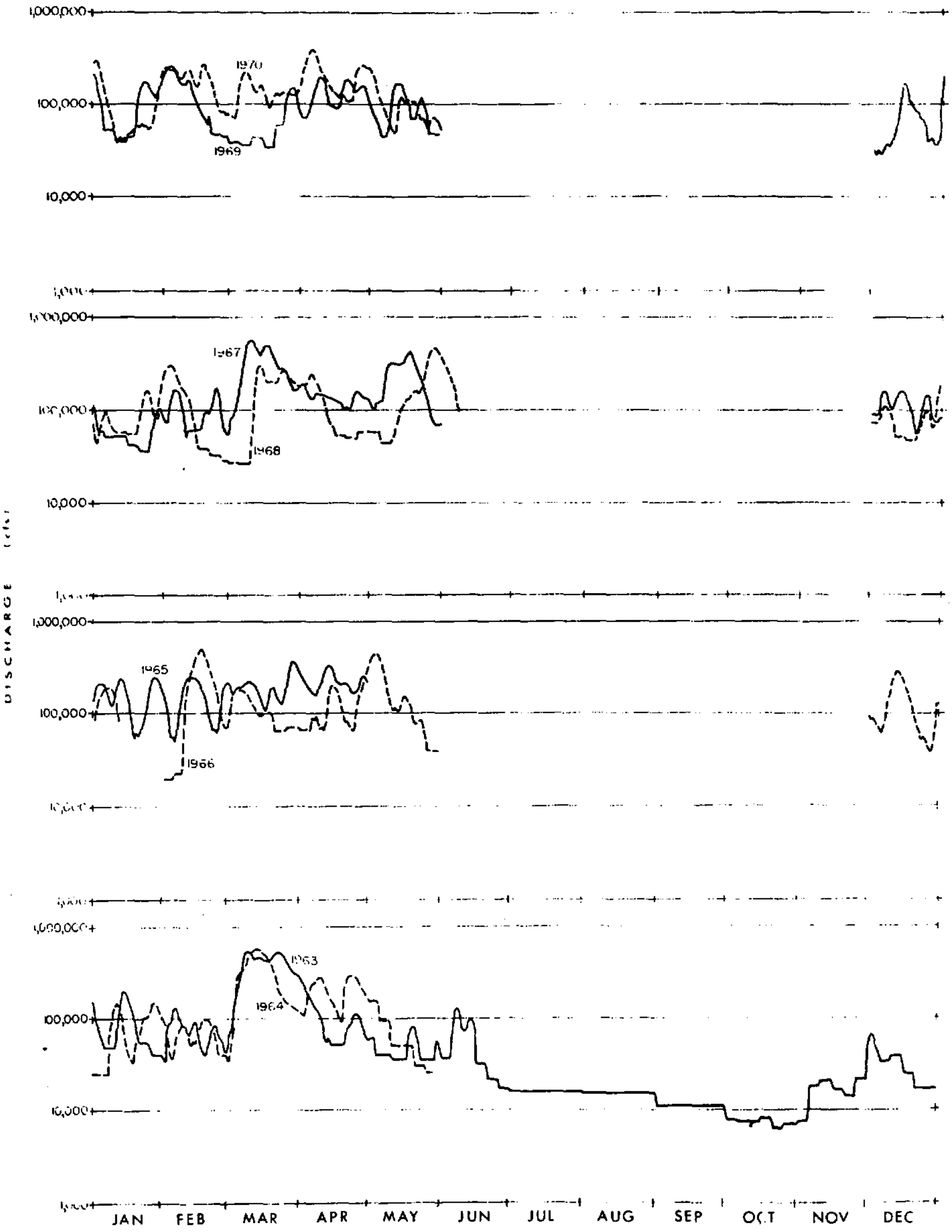
To achieve the main aim of relating coal and sand transport conditions measured in flumes to similar conditions in the rivers, the analysis of flow conditions in the rivers became vital. Actual flow velocities can only be measured with a current meter for low flow conditions. As the rivers rise the physical problems of measuring velocity such as floating debris, dangerous boating conditions, etc., make it necessary to extrapolate these values from existing gaging stations.

During low flow conditions the velocity profile and mean velocity of the river could be measured from an anchored boat at the station using a propellor type flow meter mounted on a metal rod. The rod and meter were lowered from the boat and the velocity given by a direct readout on the boat. For very low flow conditions the digital counter built into the meter was used and had been standardized for number of revolutions against velocity and gave consistent readings.

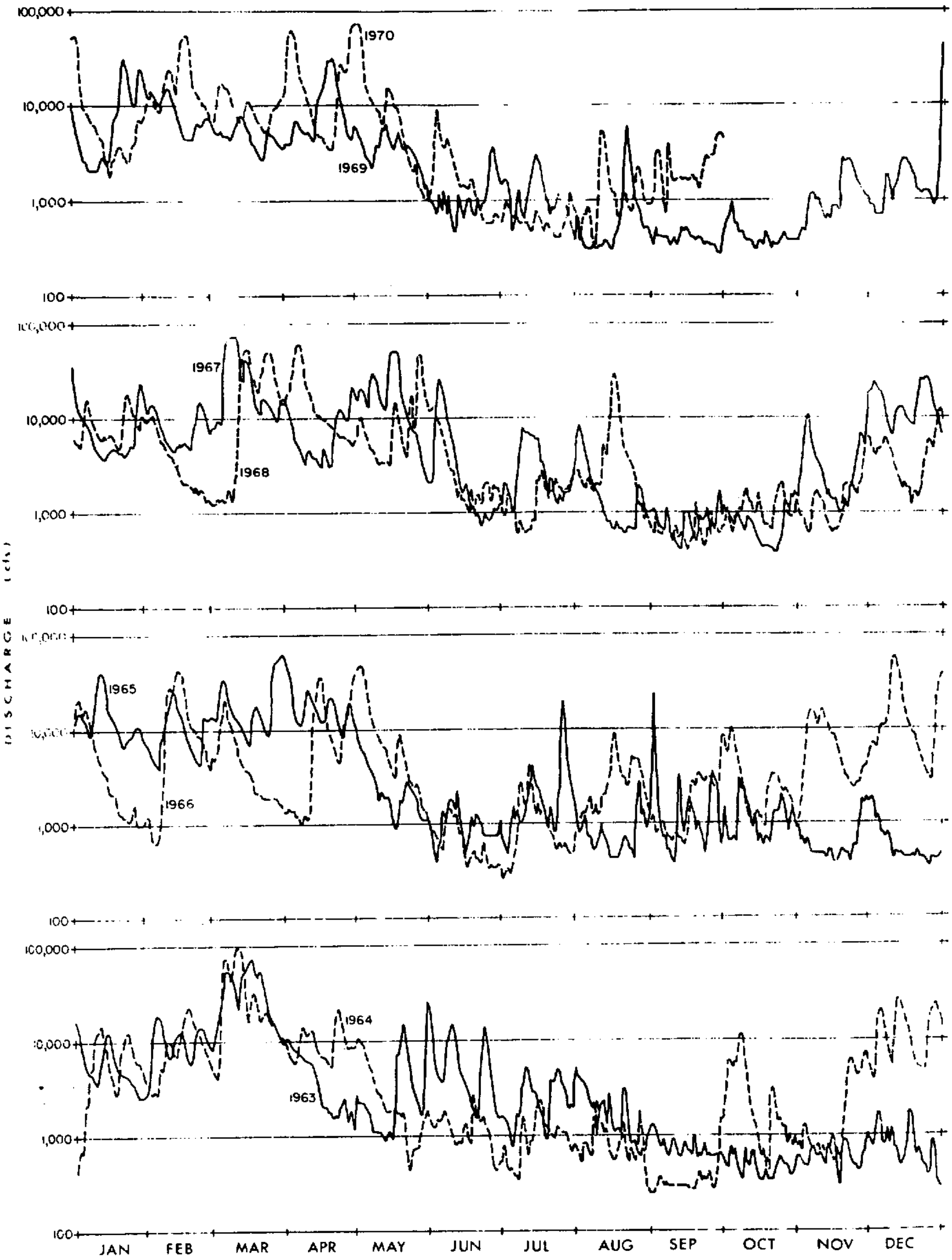
For high flow conditions, and to obtain a continuous record of flow, the readings from U.S.G.S. gaging stations for the years 1963 to 1970.



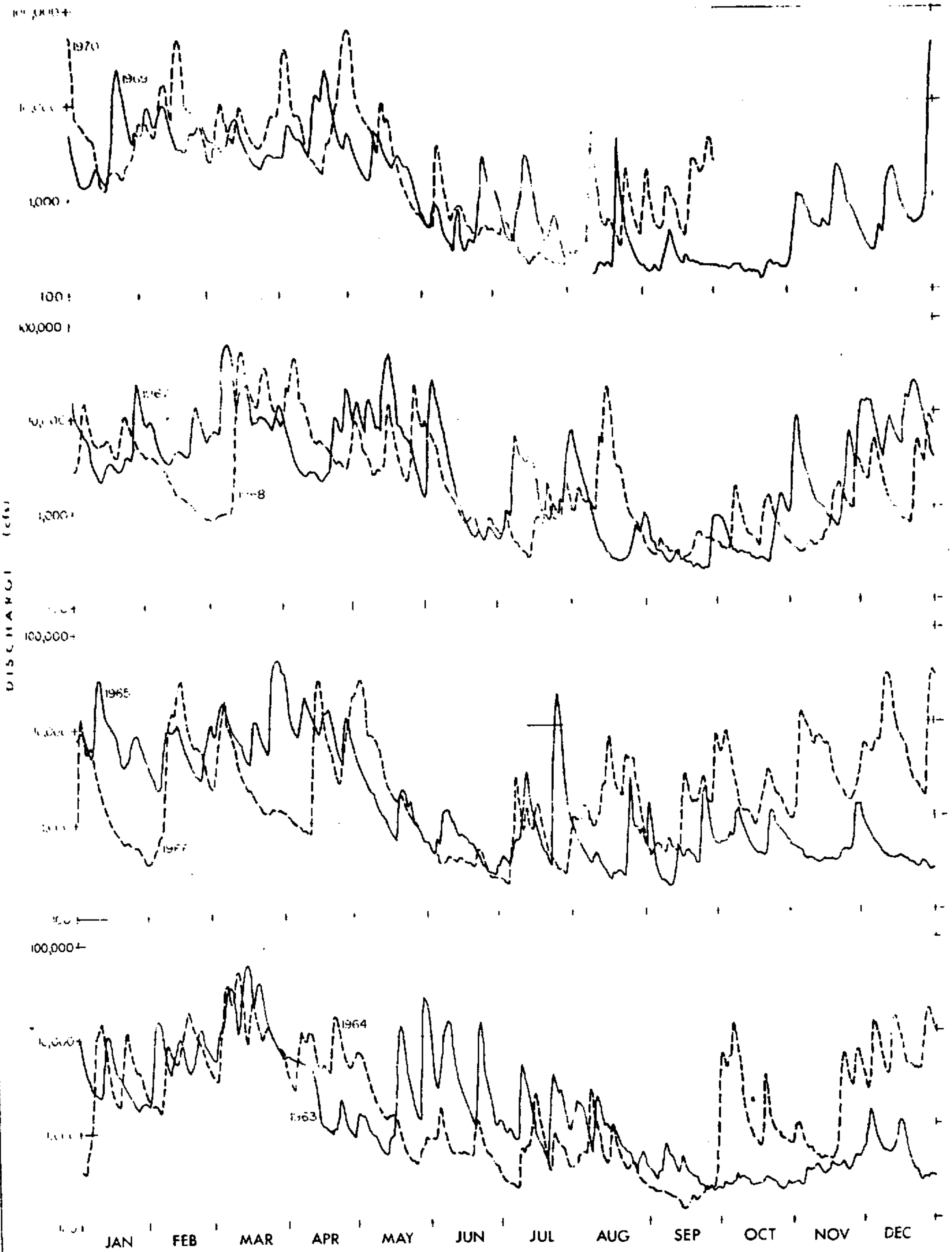
MODEL HOLE CONFIGURATION IN THE FLUME FIG.9



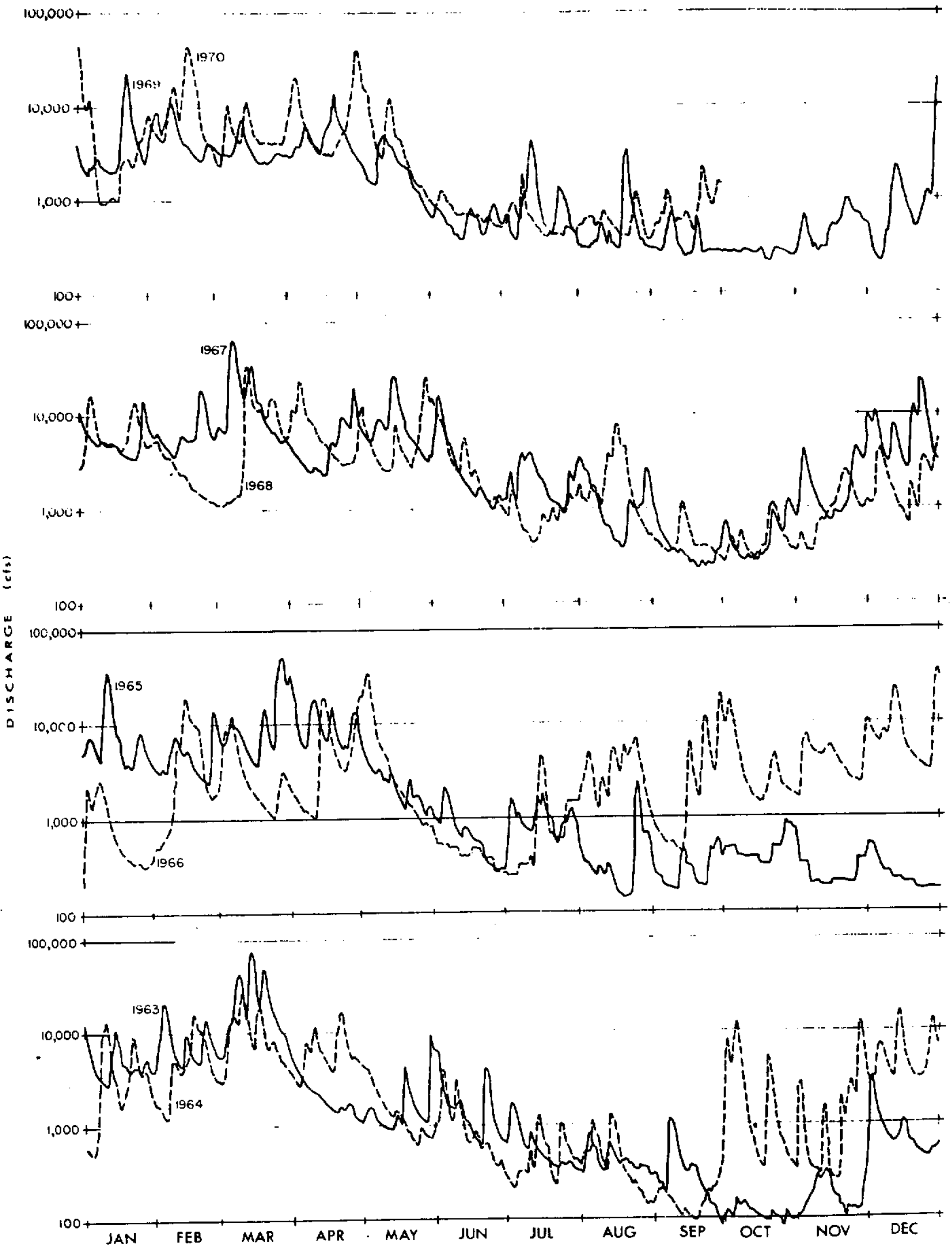
Station 3-2380 Ohio River at Maysville, Ky. FIG.10



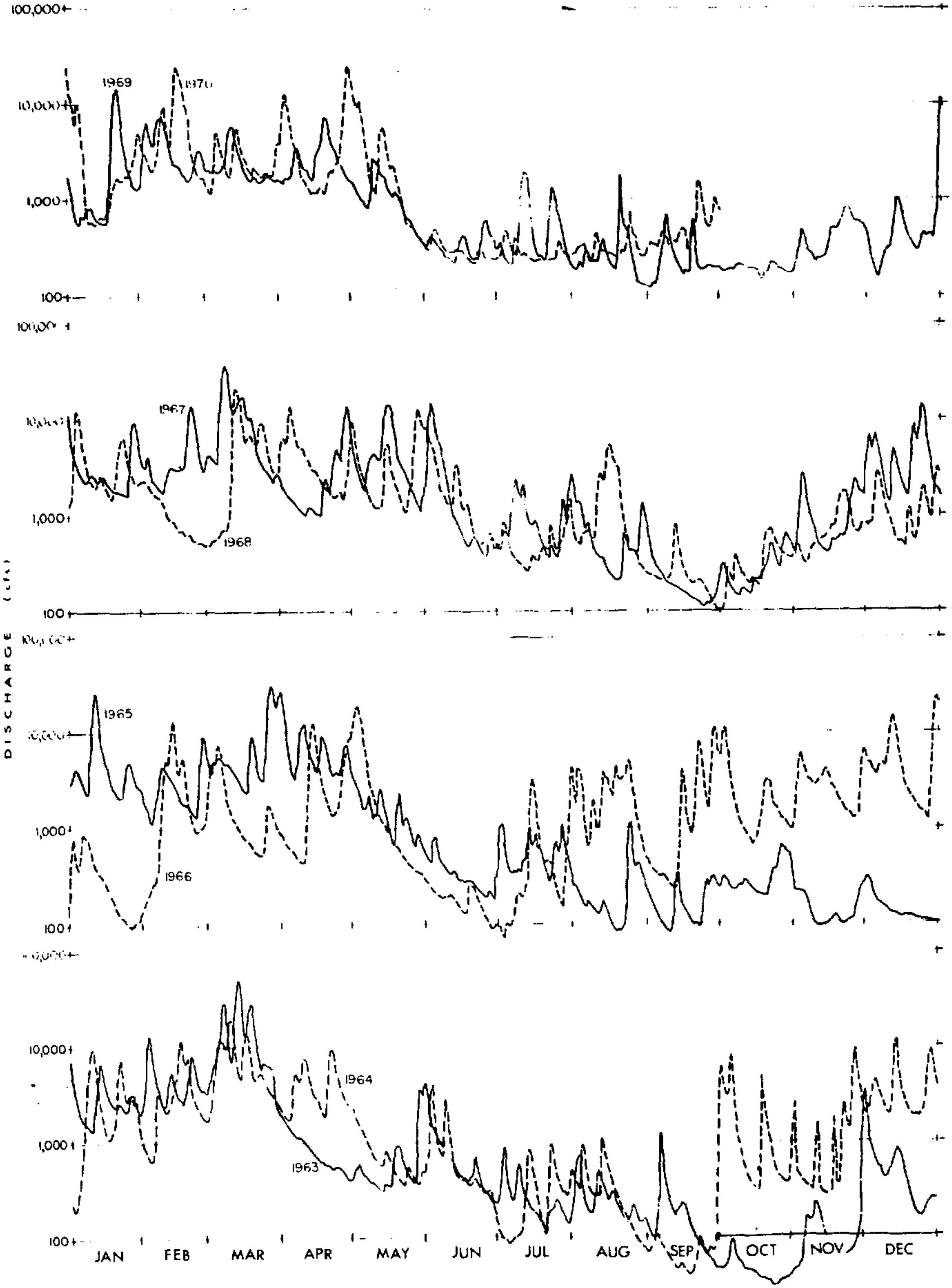
Station 3-2905 Kentucky River at lock 2, at Lockport, Ky. FIG. 11



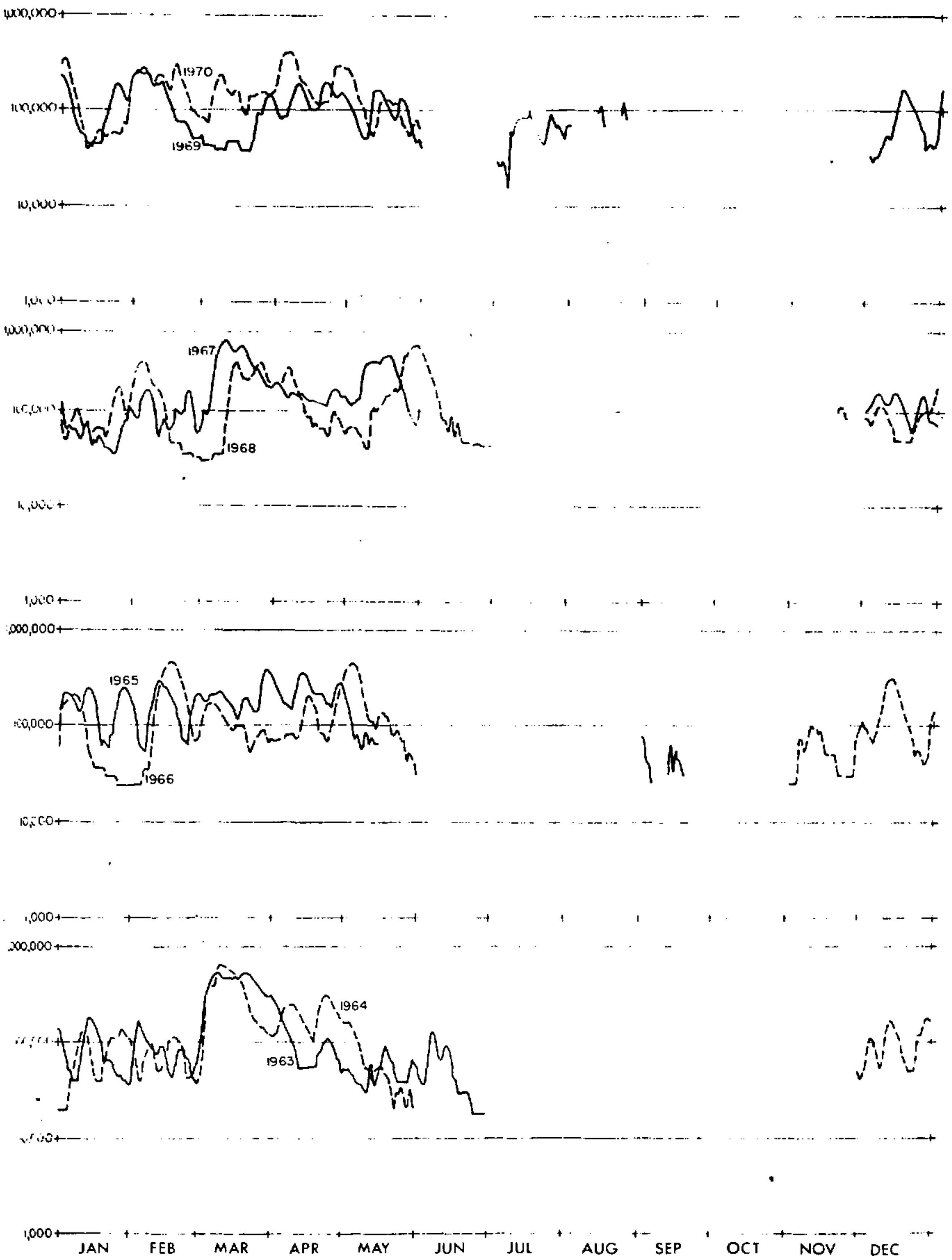
Station 3-2840 Kentucky River at lock 10, near Winchester, Ky. FIG.12



Station 3-2150 Big Sandy River at Louisa, Ky. FIG. 13



Station 3-2125 Levisa Fork at Paintsville, Ky. FIG. 14



Station 3-2550 Ohio River at Cincinnati, Ohio FIG.15

were analyzed. The values were fed into a computer plotter to establish the curves of discharge against time. See figs. 10-15, p. 20. The standardization rating curve for each station was used to establish the mean velocity for a particular discharge, the rating curve being an expression of the cross sectional area of the stream at the gaging station for various discharges. From the discharge - time plots and the known range of mean velocity - particle size relations shape for different shaped coal particles in the flume, it was possible to calculate the number of days per year that coal would be in transport in the river. Also from the measured flume velocities of sand and gravel transport in the flume the number of days when coal alone moves without sand can be computed. This is important to determine the effectiveness of a dredge hole as a trap for coal alone. From previous experiments, Moore (1970), the mean velocity conditions in which the hole will fill with sand before scouring clean due to vortex action are known.

Existing Coal and Sand Extraction Operations

The removal of commercial sand from the rivers has been successful for many years and is the principal source of supply in Kentucky. Extraction is achieved by bucket or suction dredging utilizing river transport. The Ohio River is the principal source of sand and gravel.

Limited successful attempts have been made to extract coal commercially. The largest plant was operated by the Pennsylvania Power and Water Co. at Safe Harbor, Pa., on the Susquehanna River. The coal is used to fuel the company's Holtwood generating station and is reclaimed from river deposits behind the dam serving the hydroelectric plant. The plant produces about 570,000 tons per year of anthracite. The operation extracts both coal and sand from the river and the coal is subsequently separated in a sophisticated plant.

Smaller operations have functioned on some of the minor tributaries of the Ohio River and an example is that of the Guyan River Co. on the Guyandotte River at Midkiff, West Va. The output of approximately 20,000 tons per year of coal is a by-product of the company's principal business of supplying sand for local consumption. A six inch sand pump conveys the coal, sand and water mixture by pipeline to a simple separation plant on the bank. Similar small scale operations were inspected at Allen, Ky., on the Levisa Fork of the Big Sandy River and at Beattyville, Ky., on the Kentucky River. All plants only utilize one pumping location.

CHAPTER III

DATA AND RESULTS

RIVER SAMPLING

The river sampling showed a number of associations of different sized sediment and a very variable distribution of coal particles with other sediment. As expected, the sediment distribution patterns in Kentucky, Ohio and Big Sandy Rivers showed major differences. Sediment size in clastic rock and rock derived particles varied from clay to silt, fine sand, sand, gravel and cobble sizes. Very little coal finer than #20 mesh was collected but all coarser sizes up to cobble size were represented. Isolated examples of boulder size coal up to 2 cu. ft. in volume were collected on river bars after high water in the Kentucky River.

Several sediment regimes or associations could be identified:

(A) Cobble sized rock particles with some gravel. This association was restricted to the line of maximum current flow in the rivers, following the thalweg.

(B) Gravel and coal. The coal particles are from fine to coarse gravel size and minor amounts of sand are associated.

(C) Sand with minor amounts of silt but no coal.

(D) Sand with coal. This was the most common association in which the coal occurred. Coal particles varied from #20 mesh to 1-2 inch sizes.

(E) Clay with minor amounts of silt and usually containing abundant organic matter such as sticks, leaves, etc. This association was almost always a capping to coarser sediment beneath and is apparently the deposit of very low water conditions when the river returns to pool level.

Kentucky River
Pool #2

TABLE 1

Station #	Mile Point	Position in Channel Facing Downstream		
		Right Side	Centre	Left Side
		A	B	C
2-1	42	Coal Sand	Sand	Coal Sand
2-2	41	Clay Sand Cobbles	Sand	Coal Gravel Sand
2-3	40	Sand	Coral Sand Gravel	Clay Fine Sand
2-4	39	No Sample	Cobbles Gravel sand	No Rock Sample
2-5	38	Sand & Some Clay	Coal, Gravel Sand	Clay & Fine Sand
2-6	37	Clay	Gravel Cobbles	Sand
2-7	36	Clay Sand & Cobbles		Sand
2-8	36	No Sample (Rock)	Coal Sand Gravel	Clay
2-9	35	Clay	Sand	San
2-10	34	Clay & Fine Sand	Coal, Gravel Sand	Clay
2-11	33	Clay & Fine Sand	Little Coal Sand	No Sample (Rock)

Kentucky River
Pool #9

Sample #	Mile Post	Position in Channel Looking Downstream		
		Right Side	Center	Left Side
		A	B	C
9-1	176	No Sample	Coal, Sand	Coal, Sand
9-2	175	Clay & Sand	Coal Sand Gravel	Cobble
9-3	174	No Sample (Rock)	Sand, Gravel	Sand
9-4	173	Rock	Coal, Sand Gravel	Clay & Sand
9-5	172	Clay Some Sand	Cobble	Sand, Fine Sand
9-6	171	Clay	Coal Sand Gravel	Clay
9-7	170	Clay	Coal, Sand	Cobble
9-8	169	Sand	Cobble	Sand & Clay
9-9	168	Sand	Cobble	Sand
9-10	167	Cobble	Coal, Sand	Sand
9-11	166	Clay	Sand	No Sample (Rock)
9-12	165	Sand & Clay	Coal, Sand	Sand
9-13	164	Sand	Cobble	Clay
9-14	163	Clay & Sand	Coal Sand Gravel	Sand & Clay
9-15	162	Sand	Coal Sand Gravel	Clay
9-16	161	Sand	Coal, Sand	Clay
9-17	160	Clay	No Sample	Clay
9-18	159	Clay	Clay	Clay
9-19	158	Clay	Clay	Clay

Kentucky River
Pool #10

Sample #	Mile Point	Position Channel Facing Downstream		
		Left Side A	Center B	Right Side C
10-1	177	Sand, Some Clay	Sand, Some Clay	Sand
10-2	178	Clay, some Sand	Clay & Sand	Clay + Cobble
10-3	179	Clay	Sand	Clay
10-4	180	Clay	Sand	Sand
10-5	181	Clay, fine sand	Clay, gravel	Sand
10-6	182	Clay	Sand	Clay
10-7	183	Clay	Coal, Sand	Clay
10-8	184	Clay	Gravel, Sand	Cobbles
10-9	185	Clay, Sand	Clay	Clay
10-10	186	Sand, Clay Cobbles, Gravel	Sand	Clay
10-11	187	Clay	Coal, Sand	Sand & Clay
10-12	188	No Sample	Sand	Sand
10-13	189	Clay, Sand	Sand	Clay & Cobble
10-14	190	Sand	Coal, Sand	Sand, Clay
10-15	191	Sand, Organics	Cobble	Cobble + Clay
10-16	192	Small Coal Gravel Sand	Small Coal & Sand	Small Coal & Sand
10-17	193	Clay	Coal Sand	Clay
10-18	194	Sand	Coal, Sand	Cobble
10-19	195	Sand	Sand	Sand
10-20	196	Cobbles	Coal, Sand	Sand
10-21	197	No Sample	Cobbles, Gravel	Sand
10-22	198	No Sample	Sand	Sand
10-23	199	Clay, Fine Sand	Sand	Cobble
10-24	200	Sand	Cobbles	Cobble
10-25	201	Sand	Cobbles	No (Cobble) Sample
10-26	202	Cobbles	Cobbles	Cobble + Clay

Kentucky River
Pool #14

Sample #	Mile Point	Position in Channel Facing Downstream		
		Left Side	Center	Right Side
		A	B	C
14-1	249.2	Clay	Coal, Sand	Clay, Coal
14-2	250	Clay	Coal, Sand	Clay
14-3	251	Clay + Coal	Coal, Sand	Sand
14-4	252	Clay + Fine Sand	Coal Sand Gravel	Clay
14-5	253	Clay	Coal Sand	Clay
14-6	254	Clay + Sand	Coal, Sand	Sand + Clay
14-7	255	Coal, Sand	Coal, Sand	Sand
14-8	256	Sand	Coal, Sand	Coal, Sand
14-9	257	NO SAMPLES HERE DREDGING		
14-10	258	Coal + Sand	Coal, Sand	Coal, Sand
NORTH FORK BY RIVER				
N14-0	0	Clay	Sand, Coal	
N14-1	1	Coal, Sand	Sand, Coal	
N14-2	2	Coal Sand Gravel	Coal Sand Gravel	
SOUTH FORK				
S14-1	0	Clay	Fine Sand Coal Gravel	
S14-2	1	Clay Coal Fine Sand	No sample	
S14-3	2	Clay Five Sand	Clay	
MIDDLE FORK, KY RIVER				
M14-1	0	Coal Gravel Sand	Taken in Middle of Stream (UKX Narrow)	
M14-2	1	Coal Sand		

Ohio River at Carrolton

Sample #	Mile Point	Position in Channel Facing Downstream				
		Right Side				Left Side
		A	B	C	D	E
Oh-1	544	Sand	Sand	Gravel Sand	Gravel	
OH-2		Sand Gravel + Cobble	Sand Gravel	Sand	Gravel Coal Sand	
OH-3		Sand	Sand	Sand Gravel	Cobble	Gravel Cobble
OH-4		Cobble Gravel	Cobble Gravel	Sand Clay	Gravel Sand	Sand Coal
OH-5	546.5	Clay	Sand Gravel	Sand Gravel	Sand	Sand

Kentucky River

The distribution of the various sediment associations A, C, D, E in the Kentucky River appear to be closely related to the meandering of the thalweg or line of maximum flow. Association B of gravel and coal was not found on any sample locations in the river. The position of the thalweg in Pools 9 and 10 was always marked by Association A of cobble sized rock particles with some gravel. The maximum coal occurs in Association D of sand and coal and Association C of almost pure sand is widely distributed. The occurrence of coal and sand at locations close to those with pure sand seems due to a subtle gradation of flow conditions laterally in the flow. The clay and organic matter Association E does not accumulate along the thalweg but usually caps the underlying coarser sediment to each side of the thalweg during low flow conditions. See sample details (Table 1 , p. 29). Most of the Kentucky River coal appears to be carried by the North Fork rather than the South and Middle Forks. The Red River makes a significant coal contribution even though it drains an area of very little coal mining activity.

The quantities of coal in the river vary longitudinally down the course. The maximum coal occurs in Pool 14 above Beattyville with values from 30%-75% by weight. Pools 9 and 10 have the least coal from 5%-30% and Pool 2 had considerable quantities from 15%-45%. The scarcity of coal in the middle portion of the river course at Pools 9 and 10 is attributed to the rockbound nature of the channel in this region giving a smaller cross sectional area and faster flow conditions which do not allow the coal to deposit. The positions of locks and dams do not appear to influence the sediment distribution pattern and coal and other sediment freely flows over these structures when the river is above pool stage.

A study of the roundness of coal indicated little difference in roundness between coal in Pool 14 and that in Pools 9, 10 or 2. All the coal in the river was much more rounded than any left at coal tipples or mining dumps along the river. The indication is that maximum rounding occurs between erosion from the source to the point where the coal enters the main river for transport. The significance of this will be further discussed under the source and origin of the river coal.

At the confluence of both the Big Sandy and Kentucky Rivers with the Ohio River there was a noticeable build-up of clay and silt deposits in the tributaries, presumably due to the damming effect on them by the Ohio River.

Big Sandy River

The river is generally shallow with depths ranging from 1-10 feet. No clay of sediment Association E was encountered and bottom is generally sand of Association C or D with coal and sand. Cobble and gravel sized particles of Association A are present at the broad shallow stretches. Abundant coal occurs at the sample localities at Prestonsburg and Louisa with values of 30%-65% by weight. Samples with 25%-30% coal were taken within six miles of the confluence of the Big Sandy and the Ohio with a thin capping of clay. Lateral distribution of coal is variable and appears to be a function of the meandering of the thalweg. Flow data analysis shows that coal is in transport at some locations in the Big Sandy River as many as 260 days per year. See table 2 , p. 38.

Ohio River

The sediments are coarser in the Ohio River than the other streams and the coal most commonly occurs in Association B of coal and gravel in the form of gravel bars. The pure sand Association C is common but the clay Association E was not encountered. Coal was sampled in sediment upstream of the Big Sandy confluence with the Ohio indicating a source of supply other than the Big Sandy River. Sediment with 30%-35% coal was sampled as far downstream as Louisville. Generally no coal was obtained in the thalweg of the river. The existing commercial sand operations are located in sediment of Association C and those of Association B have been rejected for commercial sand.

Source of the Coal in the Kentucky River

The project took into account the three possible sources:

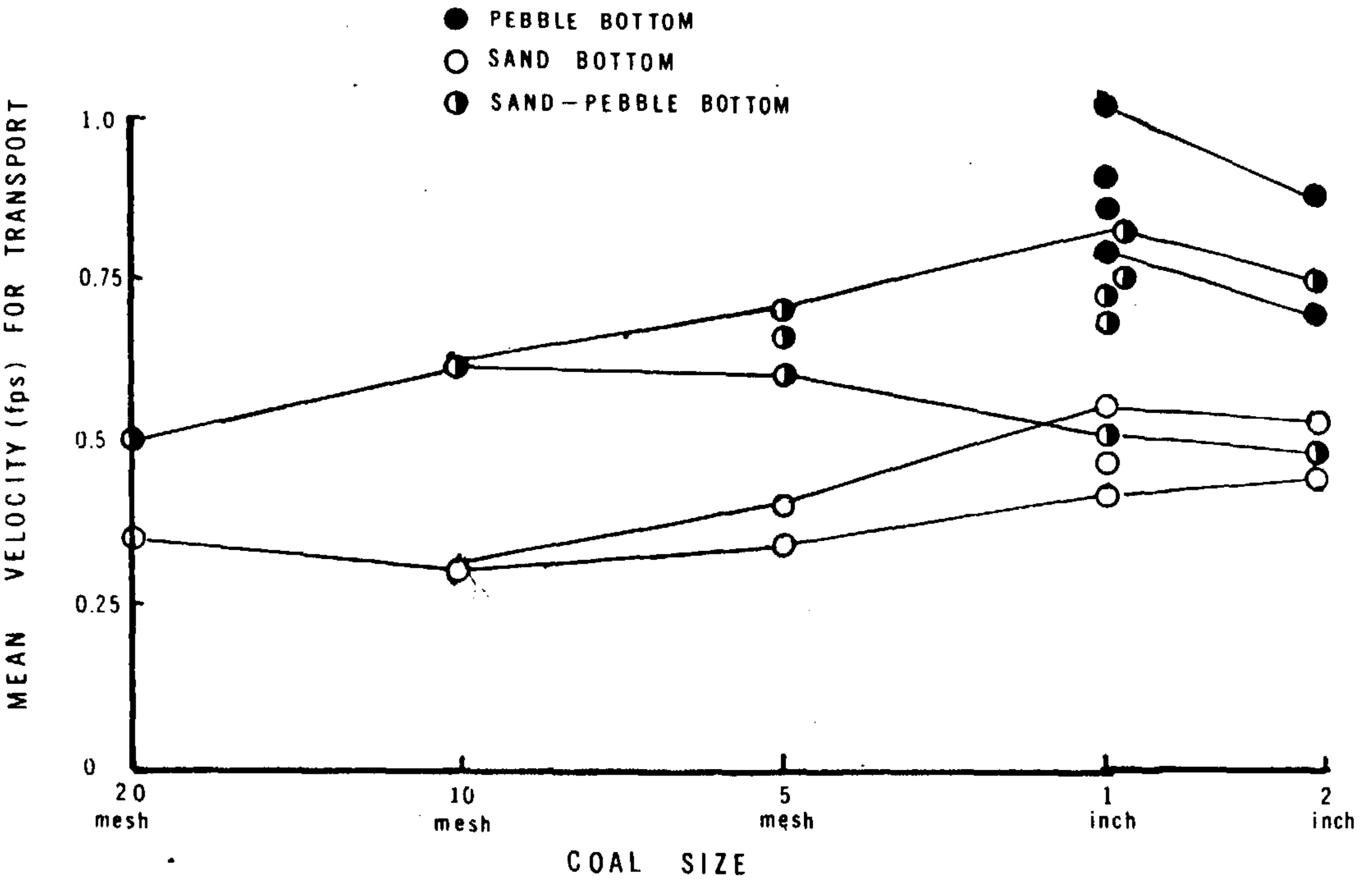
(a) coal mining and washing operations

(b) spillage from barge and rail loading

(c) natural erosion

No coal has been barged on the Kentucky River in the last twelve years and this tends to rule out this source. Coal from mining and washing operations is angular on refuse piles even to the water's edge and no appreciable quantity of angular coal was found even in the upper reaches of the river. Also the coal released from coal washing operations is less than #40 mesh and this size constitutes only a minute fraction of the coal found in the river, hence natural erosion was investigated.

Several geological quadrangles in the catchment area of the Kentucky River were investigated to determine the tonnage of coal eroded from the number of line miles of outcrop using published rates of erosion for the area. The calculation yielded a conservative annual contribution from



GRAPH OF THRESHOLD TRANSPORT RESULTS FOR FLUME FIG 16

TABLE 2

YEAR	STATION NO.	TOTAL DAYS DATA AVAILABLE	DAYS NO COAL MOVED	DAYS ALL SIZES TO 2" COAL MOVED
68		365	33	238
69		365	84	196
70		273	29	181
62	32550 Ohio River			
63	At Cincinnati	180	0	174
64		181	0	173
65		144	0	144
66		211	0	211
67		181	0	181
68		215	0	215
69		217	0	216
70		150	0	150
63	32840 Kentucky	365	111	117
64	River at Lock 10	365	83	158
65	Near Winchester	365	123	128
66		365	62	134
67		365	66	198
68		365	72	149
69		365	139	114
70		273	64	119
63	32905 Kentucky	365	68	169
64	River at Lock 2	365	64	184
65	At Lockport	365	69	156
66		365	33	210
67		365	23	229
68		365	20	186
69		365	89	170
70		273	27	169

YEAR	STATION NO.	TOTAL DAYS DATA AVAILABLE	DAYS NO COAL MOVED	DAYS ALL SIZES TO 2" COAL TRANSPORT
63	32125 Levisa Fork	365	0	286
64	At Paintsville	365	0	314
65		365	0	287
66		365	0	331
67		365	0	347
68		365	0	357
69		365	0	354
70		273	0	273
63	32150 Big Sandy	365	21	184
64	At Louisa	365	6	220
65		365	0	180
66		365	0	266
67		365	0	292
68		365	0	265
69		365	0	180
70		273	0	172
63	32160 Ohio River	164	0	160
64	At Ashland	159	0	151
65		119	0	119
67		181	0	181
68		192	0	176
69		195	0	191
70		150	0	149

YEAR	STATION NO.	TOTAL DAYS DATA AVAILABLE	DAYS NO COAL TRANSPORTED	DAYS ALL COAL SIZES TO 2" TRANSPORTED
63	32380 Ohio River	365	133	103
64	At Maysville	152	0	107
65		119	0	114
66		158	0	139
67		181	0	156
68		188	0	131
69		181	0	113
70		150	0	133

erosion of the order of 500,000 tons which would far exceed the contribution from other sources. Also most of the coal recovered is in the 13,000 BTU range, low on ash and sulphur, and therefore not waste material.

A study of localities in the Red River, a tributary of the Kentucky River in Pool 10, indicates more coal being transported per volume of sediment than the Kentucky River above their junction. This further supports natural erosion as the principal source of the coal since little or no coal mining activity exists on the Red River.

FLUME RESULTS

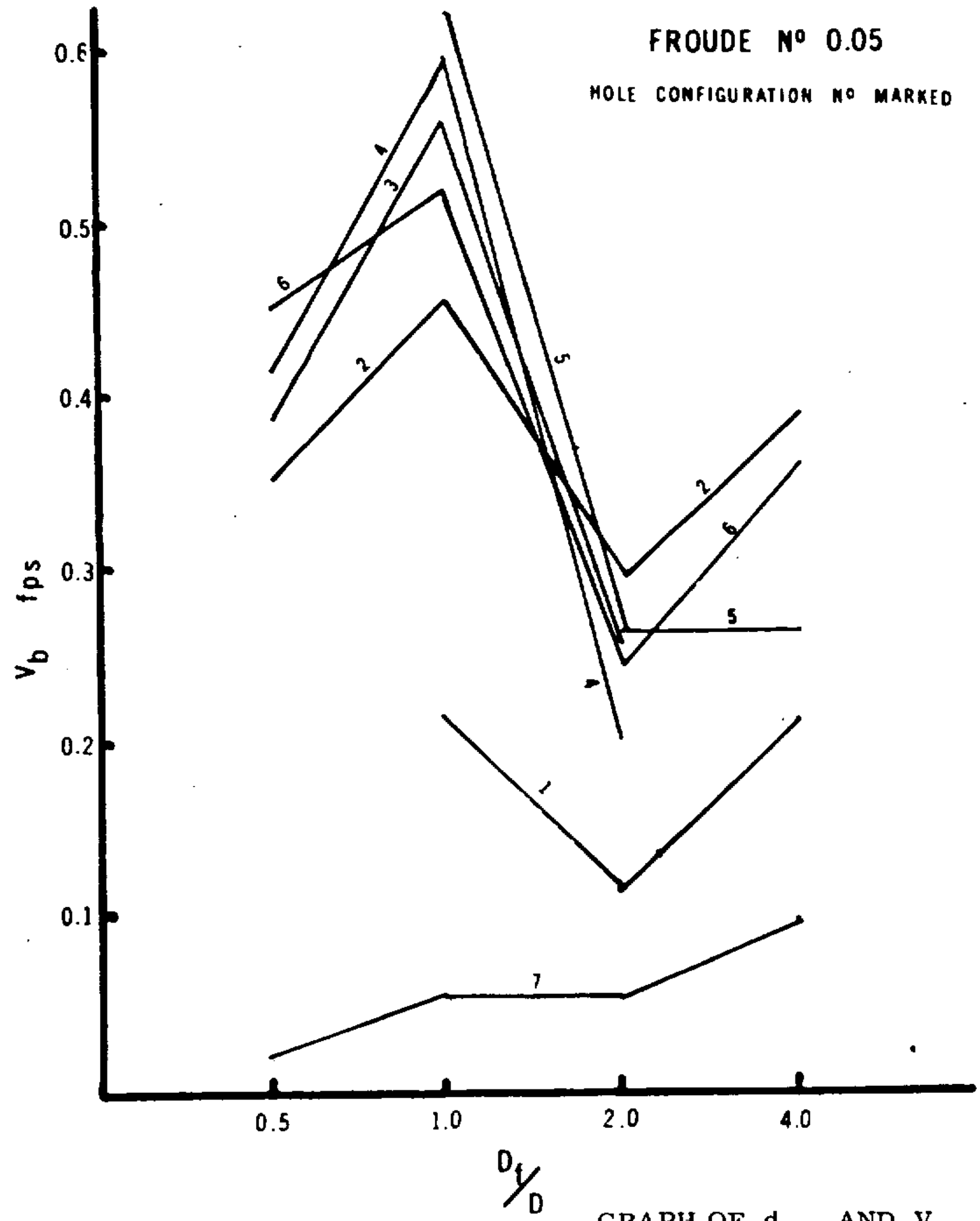
(a) Estimation of Threshold Velocity of Transport

Experiments used coal of sizes 10-20 mesh, 10-5 mesh and 1" size all of varying shapes on differing bottom mixtures. The bottom compositions were river sand, pebbles of 1/2" average size and a river sand and pebble mixture. Results are shown in figure 16 , p. 37 , and are the averages of several runs. The velocities were recorded when a particular coal size showed general movement.

On a sand bottom, the shape of the 1" sizes gave a considerable spread of velocity values due to the position of a particularly shaped particle in the boundary layer and velocity profile. On a pebble bottom the smaller sizes penetrated the spaces between the pebbles and only the 1" size moved.

In general, the transport of the fine coal begins at approximately 0.3 fps and most shapes to 2" size are in transport at 0.7 fps. At this velocity pure coal will be trapped in a dredge hole.

When the velocity of the flume reaches approximately 1.0 fps sand and coal accumulate in the hole and above 1.2 fps vortex action removes



GRAPH OF $d_{f/d}$ AND V_f FIG.17

the coal leaving mainly sand. When the mean velocity exceeds 1.8 fps the vortex action in all the model holes was sufficient to remove all the sand from the hole. Hence the models indicate a period of flow when pure coal collects, then sand and coal, then pure sand before the hole scours clean.

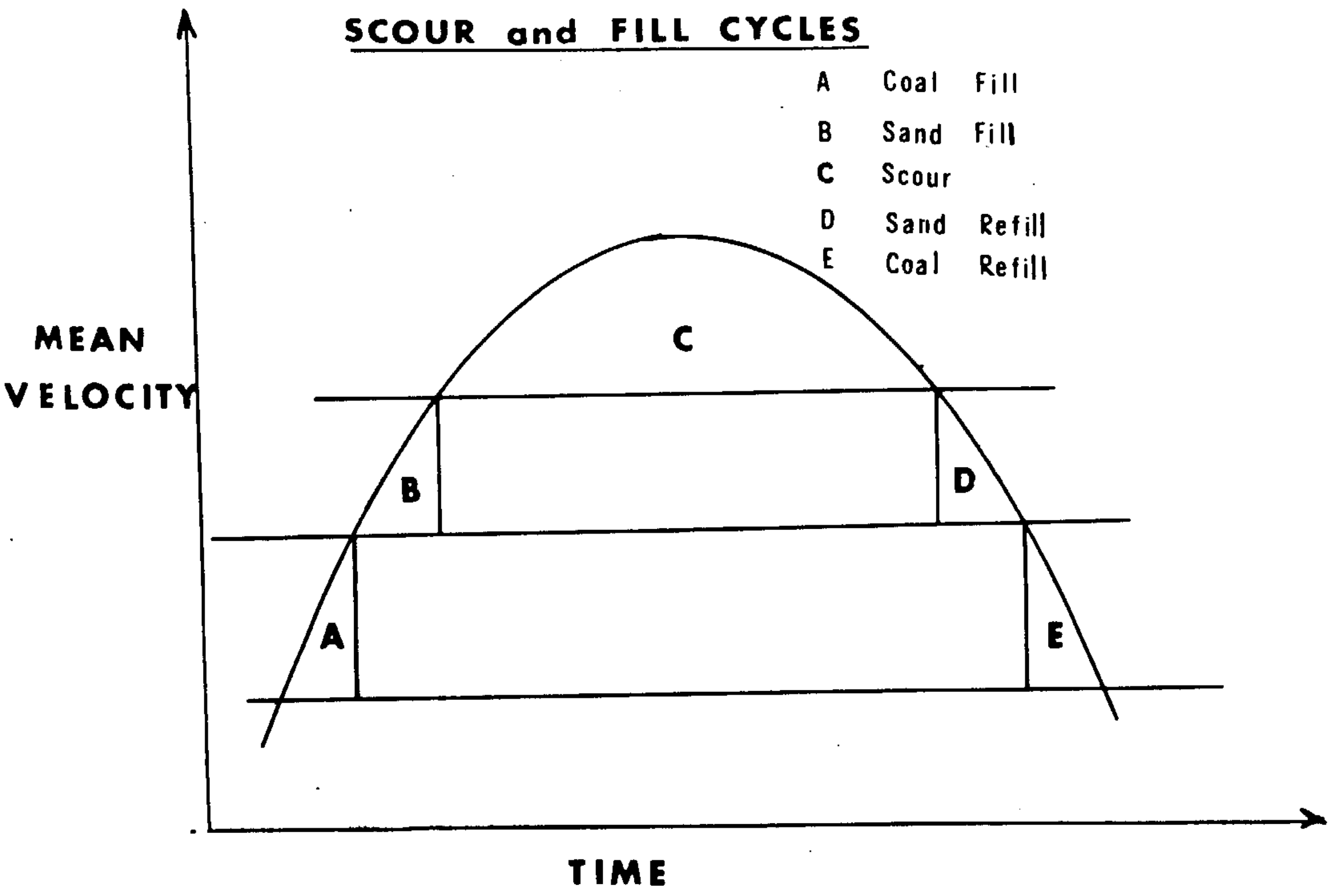
These velocities should approximate those corresponding for the river.

(b) Evaluation of Shape, Size, Flow Conditions and Trap Efficiency of Model Holes

The ratio of depth of flume flow to the depth of the hole was made 4.0, 2.0, 1.0 and 0.5 in flume runs using a Froude N° of 0.05. The dimensions of the model holes and their position in the flow were varied according to the configuration diagram, figure 9, p. 19. The velocity at the center bottom of the hole was compared to flume velocity. The bottom velocity is plotted against the depth ratio $d_{f/d}$ in figure 17, p. 42, where d_f is the depth of flow in the flume and d is the depth of the hole. Maximum trap efficiency occurs when the depth of the flume is twice that of the hole and maximum scour conditions occurs when hole and flume depths are approximately equal. Hole configurations #2 through #6 all appear to be efficient traps with the smaller sizes more economical to construct and maintain.

Analysis of Flow Records

Previous observations on the movement of river sand in flume experiments, Moore (1970), indicated that 0.175 mm river sand began movement at 0.8 fps. The small coal sizes in the flume began movement at 0.3 fps in the flume. These values are both considerably lower than the calculated values for the Ohio River of 1.38 fps for sand and 0.56 fps



FLOW CONDITIONS FOR SEDIMENT TRANSPORT FIG 18 for coal.

Both the flume and calculated river values indicate a period of flow with mean velocity between 0.3 fps and 0.8 fps for coal in the flume for which coal alone will be moving. If the coal can be trapped during this period of flow then coal alone will fill the hole. Above 0.8 fps in the flume the hole fills with a coal and sand mixture and then scour clean of sand and coal above 1.8 fps due to vortex action, Moore (1970). The operation of this vortex action in the river has been observed in the Ohio River at 2.0 fps, the indication being that mean velocity values will be higher in the river than in the flume.

An analysis of flow conditions above 0.7 fps at the gaging stations to estimate the number of days a year coal sizes up to 2" would be moving. The results are shown in table 2, p. 38.

Technical difficulties of bottom load measurement in the rivers will have to be overcome before these results can be confirmed in the rivers.

CONCLUSIONS

1. Significant quantities of coal occur in the rivers studied but their distribution is irregular and is a function of the flow conditions in the river.

2. The coal is in transport at much lower velocities than the sand and other material.

3. Coal and sand mixtures are already being extracted on an economic scale and separated into the two components.

4. A dredge hole trap designed for the particular flow conditions of a location can improve the efficiency of extraction of both coal and

sand. Due to differential sorting and transport pure coal, coal and sand mixtures, and pure sand can be extracted from the trap during different conditions of flow.

5. The dredge hole can be designed to scour clean during conditions of high water as the original study hole at Louisville has done.

6. Five major sediment associations with coal, sand and mud were encountered and described. These associations are the result of hydraulic conditions at a particular location.

7. The efficiency of a dredge hole trap is a function of the ratio of depth of flow in the channel to the length and depth of the hole. The most efficient trap should have a ratio of 2 for flow depth to hole depth.

8. The origin of the coal is primarily from natural erosion and secondarily due to mining and transport activities.

BIBLIOGRAPHY

Moore, Bruce R., 1970, Scour and Fill Process in a Deep River Hole, Ohio River, Louisville, Kentucky. Jour. Sed. Pet., vol. 40, p. 449-456.

_____, 1971, The Distribution of Pennsylvanian Age Coal Particles in Recent River Sediments, Ohio River, Kentucky as Age and Sediment Rate Indicators. Sedimentology, vol. 17, p. 135-139.

U.S. Army Corps of Engineers, 1972a, Navigation Charts for Ohio River.

U.S. Army Corps of Engineers, 1972b, Navigation Charts for Kentucky River.

Vanoni, V. A., 1964, Measurements of Critical Shear Stress for Entraining Fine Sediments in a Boundary Layer. Cal. Tech. Rep. N°KH-R-7. 47 p.