The Deep Channel and Alluvial Deposits of the Ohio Valley in Kentucky

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CONTENTS

ILLUSTRATIONS

[All plates in pocket]

THE DEEP CHANNEL AND ALLUVIAL DEPOSITS OF THE OHIO VALLEY IN KENTUCKY

By Eugene H. Walker

ABSTRACT

The alluvial deposits of Pleistocene age in the Ohio Valley form a ground-water reservoir of large storage capacity and yield. In this region it is the only source of large supplies of water that are both cool and of good quality the year round. The reservoir is heavily drawn upon, yet has very large potentialities for future development because of the favorable conditions for both natural and artificially induced infiltration of water from the river into the alluvial deposits.

The principal features of the Ohio Valley were formed during the Pleistocene, or glacial, epoch. The drainage area upriver from Cincinnati was added when ice first advanced south, blocked rivers draining northwestward off the Appalachians, and diverted their waters southwest into the headwaters of the early Ohio River. A deep channel, the bottom of which is at a lower altitude than the present river bed, was excavated before the third (Illinoian) glacial stage. The thick body of sand and gravel that now lies in the deep channel was deposited by floods of melt water as the ice sheet of the Wisconsin stage melted away from the Ohio basin.

The vertical distance between river pool level and the base of the old channel increases from 25 feet at Ashland, Ky., to 110 feet at the mouth of the river, for the old channel has a steeper gradient than the present river. The width of the bedrock valley ranges from half a mile at one point near Cincinnati to almost 10 miles near Uniontown, Ky. Where the valley is narrow, the flat-floored deep channel extends from one side of the valley to the other. Where the valley is wide, the deep channel occupies only part of the width of the valley, the rest being underlain by rock benches mantled with alluvium.

The alluvium consists of a sheet of sand and gravel overlain by a thinner layer of silt and clay. The sheet of sand and gravel is continuous across and up and down the valley, and at most places along the valley it is exposed in part of the river channel. The gravel is coarse and cobbly near Cincinnati but finer downstream, and near Paducah most of it is no larger than pea size. The thickness of water-saturated sand and gravel increases downvalley in the same way as does the distance between river level and the base of the old channel, roughly from 25 to 110 feet. The storage coefficient is likely to average about 0.2, or 1.5 gallons of water per cubic foot of sand and gravel.

INTRODUCTION

This report describes the old deep channel of the Ohio River and the alluvial deposits that fill it, along the section of the Ohio Valley that borders Kentucky from West Virginia to the Mississippi River. The coarse-grained alluvial deposits, of glacial origin, are permeable and water bearing and form a ground-water reservoir that ranks as one of the most important in the United States in terms of its present use and future potentialities. The storage capacity of the alluvial deposits is large; at Louisville, where the pumpage in 1951 averaged more than 32 million gallons a day (mgd), the storage coefficient has been determined to be about 0.2, which equals 1. 5 gallons of water per cubic foot of saturated alluvium. The amount of water in storage is enormous; by a rough calculation it is more than a trillion gallons in the stretch of the valley adjacent to Kentucky. Moreover, the supply is virtually inexhaustible, at least to wells near the Ohio River, so long as water flows in the river. Water moves from the river into the alluvium during periods of high river stage and wherever pumping from wells lowers the level of ground water below river level. More water is pumped from the alluvium every year, principally for air conditioning and industrial cooling, though the water is also used in many other ways. In summer the water from the Ohio River reaches temperatures above 80°F, but the temperature of ground water, even from wells close to the river, seldom rises above 65°F. Other advantages of ground water are its freedom from the turbidity and rapid changes in chemical quality, taste, and odor that here characterize river water, and frequently the lower cost of developing a supply.

This report is one of a series on the ground-water reservoirs and resources of the State of Kentucky made by the United States Geological Survey, through agreement with the Agricultural and Industrial Development Board of Kentucky. The State of Kentucky and the Federal Government jointly financed the work. The index map, figure 1, shows the area covered by this report and by other reports already published or in preparation. The present report differs from the others of the series in that it describes the extent, the thickness, and the nature of the water-bearing formation (in this case river alluvium) but does not give information on the yields of wells, the quality of water, and usage. The report gives an overall view of the alluvial ground-water reservoir for preliminary planning of ground-water development. Other reports indicated on figure 1 present detailed information on all large ground-water supplies developed on the Kentucky side of the valley. A report by Klaer (1948) describes the ground-water potentialities of the alluvium in the Cincinnati area, Ohio. Elsewhere along the north and west sides of the valley large supplies of water are known to be derived from the valley alluvium (see, for example, Kazmann, 1947), but the information on them has not been systematically gathered and published.

Geologic investigations along the Ohio Valley include those concerned purely with geologic history, those made for ground-water studies or studies of other mineral resources, and groups of exploratory borings made in planning heavy structures, mostly

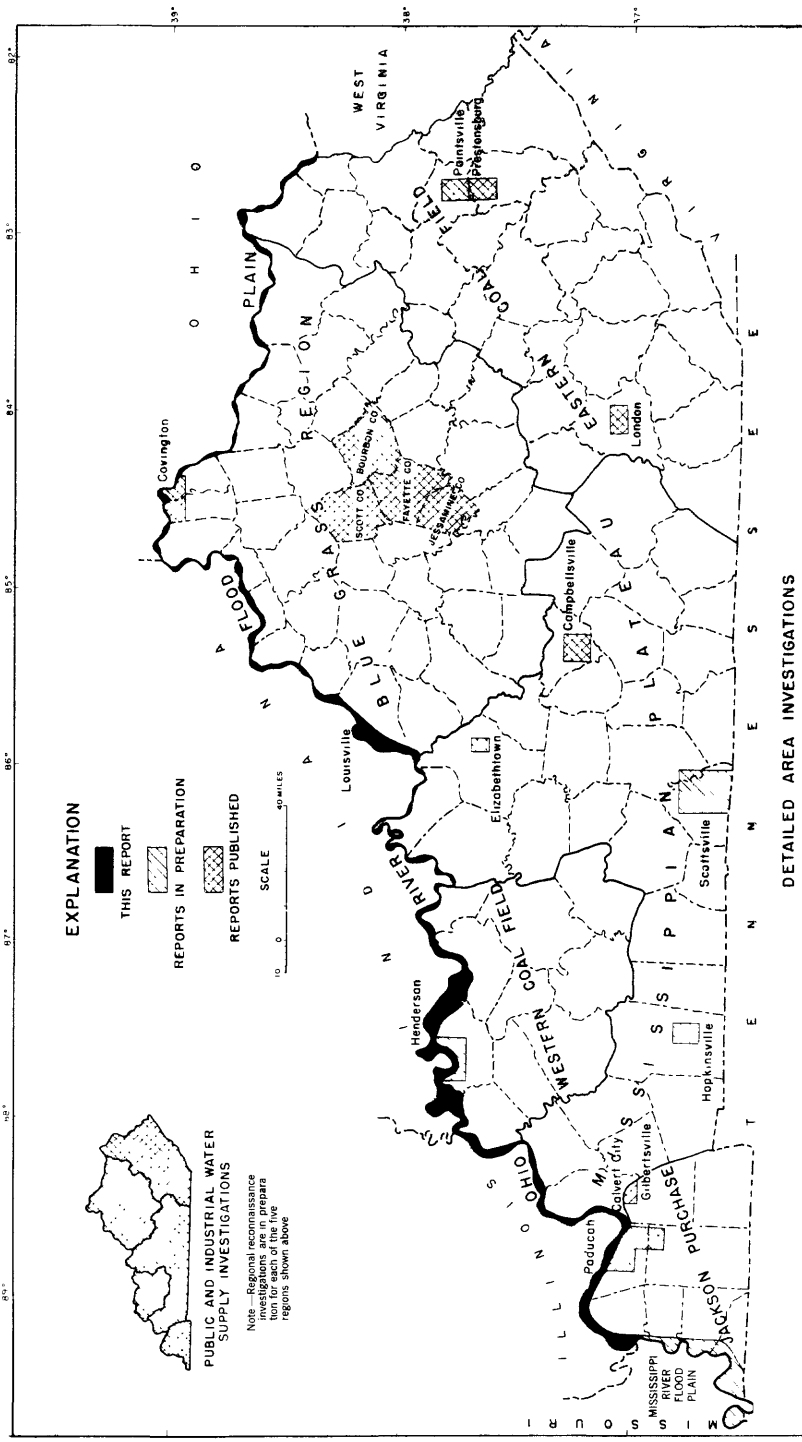

Figure 1. — Index map of Kentucky showing progress of ground-water investigations.

bridges. The last two of these give information on areas that are very small compared to the stretch of valley covered by the present report, and one purpose of the report is to coordinate this scattered information. The Pleistocene history of the valley is given to help the reader understand the features shown on the maps, sections, and profiles, or features that new borings may reveal.

The curious and interesting geologic history of the Ohio Valley during the Pleistocene, or glacial, epoch has stimulated the preparation of many scientific papers. The noted glacial geologist Frank Leverett made the principal contributions to this subject in his publications of 1902 and 1929 and those interested in earlier papers will find full and critical reference to them in these two publications. Leverett was interested mainly in the surface features and their bearing on the glacial history of the valley, and gathered little information on the buried channel and the deposits in it. McFarlan (1943) also provides a summary of the history of the valley, and an exhaustive bibliography of geologic literature on Kentucky.

Published reports on ground-water investigations at Louisville, Covington, and Cincinnati (see Selected references) provide much local detail on the deep channel and alluvial deposits. Valuable information has been provided at Henderson and Paducah by the local ground-water investigations now in progress. Some general information on the alluvial valley and water wells in it is to be found in the U. S. Geological Survey Circulars describing public and industrial supplies in the several regions of Kentucky (see Selected references).

The exploratory borings made prior to building bridges across the Ohio River constitute a valuable source of data. Lines of such borings reaching all or part of the way across the valley are the basis for most of the sections (pls. 4, 5, and 6) that show the form and elevation of the bedrock channel and the nature of the alluvium. Thanks are due the Kentucky Department of Highways, especially E. D. Smith, Director of Bridges, for providing copies of the logs of test borings for several of the Ohio River highway bridges and for giving information on sources of other sets of borings.

The following organizations and individuals contributed data on bridge borings used in this report:

Cairo Bridge Commission, Ray Williams, Chairman.

The Chesapeake and Ohio Railway Co., L. T. Nuckols, Chief Engineer.

Chicago, Burlington & Quincy Railroad Co., F. H. Cramer, Bridge Engineer.

Fullerton-Portsmouth Bridge Co., William H. Fowler, President.

Illinois Central Railroad, M. Block, Engineer of Bridges.

Indiana State Toll Bridge Commission, W. G. Koch, Chairman.

State Highway Commission of Indiana, J. R. Cooper, Engineer of Bridges.

Modjeski and Masters, Consulting Engineers.

Sverdrup and Parcel, Consulting Engineers.

In the course of planning for floodwalls and levees at many cities and towns in the valley, the Corps of Engineers, United States Army, has drilled numerous holes. Records of many holes were examined by the writer. The lines of drilling are generally parallel to the river edge and rarely provide data for sections entirely across the valley. Consequently these data, though locally of much value, are not given in this report.

The numerous borings for water in the alluvium, and those made in search of oil and gas in the underlying rocks, supply much valuable information. At Louisville (Hamilton, 1944; Rorabaugh, 1946) and at Henderson (Harvey, 1956) enough of these data have been gathered to permit the drawing of contour maps showing the position and shape of the surface of the bedrock channel. None of the isolated borings that have been examined show a lower elevation of the bedrock channel than does the adjacent section of the profile (pl. 3), which was constructed from the data provided by the sections.

Data for two important geologic sections (pl. 6), one across the Ohio Valley near Mound City, Ill. (sec. 15), the other across the old abandoned valley of the Ohio River at Ullin, Ill. (sec. 14), came from a report by Fisk (1944) on the alluvial valley of the lower Mississippi River.

HISTORY OF THE VALLEY

The course and size of the present Ohio River, and the deep channel filled with alluvial deposits resulted from processes at work during the Pleistocene epoch, which is considered to have begun about a million years or so ago, when ice sheets repeatedly advanced southward from Canada and then melted away. The advancing ice dammed old rivers and diverted their flow to new courses beyond the margin of the ice; in this fashion the preglacial Ohio was much enlarged and altered. The deep channel and its alluvial fill are the result of changes in level of land and sea during the glacial epoch, and of changes in the volume of the river and in the load of sediment the river has carried.

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The table and the text that follows provide a view of the main events leading to the development of the present valley with its

Development of the Ohio Valley in Kentucky

[After Leverett (1929) and others]

Geologic time units		Events in Ohio Valley
Recent		Erosion and reworking of part of valley alluvium. Local minor deposition of alluvium by major floods.
Wisconsin glacial stage	Mankato glacial substage Two Creeks interval of Flint (1947) Cary glacial substage	Advances and withdrawals of ice, outside the Ohio Basin, caused alternate cutting and filling by the Mississippi and correspondingly by the Ohio River. Ohio River diverted from Cache Valley to present course. Withdrawal of ice and rise of sea level caused alluviation along the Mississippi Valley, deposition of upper silt and clay in Ohio Valley.
	Tazewell-Cary interval	Withdrawal of ice from basin of Ohio; deposition of sand and gravel outwash in valley.
	Tazewell glacial substage Tazewell-Iowan interval Iowan glacial substage	Major advances of ice into United States; the principal advance into the Ohio Basin in the Tazewell substage. Lowering of sea level and erosion of alluvial fill of Illinoian age.
Sangamon interglacial stage		Partial erosion of Illinoian fill.
Illinoian glacial stage		Advance of ice diverted Ohio River from course north of Cincinnati to present course. Deposition of valley fill as ice withdrew.
Yarmouth interglacial stage		Bedrock channel cut to about its present level and valley much widened.
Kansan glacial stage		Advance of ice into Ohio River basin and northern Kentucky in one or both glacial stages. Enlargement of primitive Ohio River as waters of north-flowing streams were dammed and diverted westward.
Aftonian interglacial stage		
Nebraskan glacial stage		

buried channel and alluvial fill. The maps of plate 1 and the diagrams of figure 2 illustrate principal stages in the development of the valley. The actual sequence of events during the Pleistocene epoch, with its several glacial and interglacial stages, is far more complex than that set forth here. Reports listed on page 24 describe in detail what is currently known of the Pleistocene history of the valley and review various controversies.

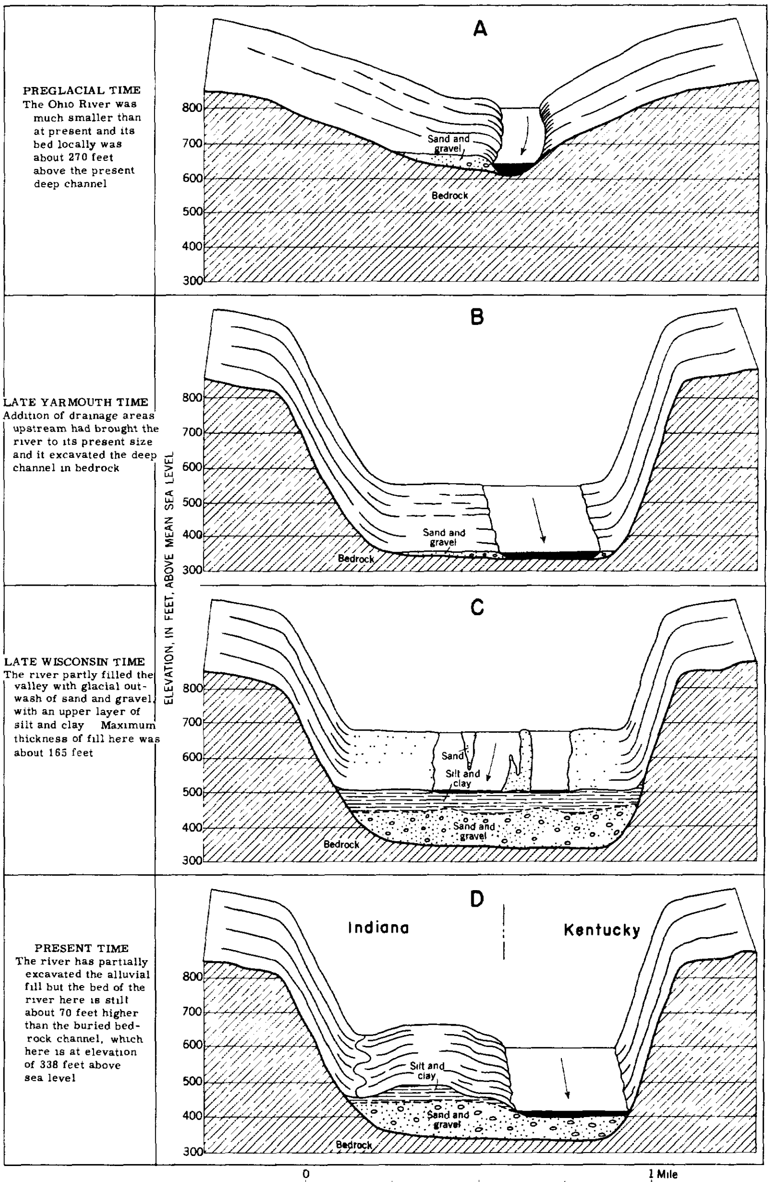

Figure 2.—Diagrams illustrating stages in development of the Ohio Valley near Madison, Ind.

DRAINAGE CHANGES OF EARLY PLEISTOCENE TIME

The Ohio River of preglacial time headed in the Cincinnati region, and the river basin was enlarged to its present size when the flow of rivers draining regions to the east and north was diverted across a divide into a tributary of the preglacial Ohio. This tributary headed near the site of the town of Manchester, Ohio, in the valley of the present river and flowed toward Cincinnati at about the course of the present river; it joined the ancestral Licking River north of the present site of Cincinnati. The stream so formed then joined the ancestral Miami River near Hamilton, Ohio, and flowed south and west along the present course of the Miami and into the Ohio River. The drainage pattern of this time is shown in plate 1*A*. The channel of this ancient river is preserved at places along the margins of the present valley, 200–220 feet above the level of the present river. The approximate profile of this old channel is shown on plate 3. Diagram *A*, figure 2, depicts the general aspect of the valley of that time in the vicinity of Madison, Ind.

An abandoned valley, conspicuous on the topographic map of the Sciotoville quadrangle, Ohio, turns northward from the present Ohio Valley 6 miles east of Portsmouth, Ohio, and shows that here at some time a river fed by a large drainage area flowed northward. This ancient river has been called the "old Kanawha." About 40 miles north of Portsmouth the abandoned valley disappears beneath a cover of glacial deposits, but can be traced, by well-log information, north and then west through Ohio, Indiana, and Illinois (Horberg, 1945) where it is known variously as the Teays and the Mahomet valley.

The old bedrock floor of the valley, mantled with reddish sand and gravel, underlies the Flatwood bench south of Ashland, Ky., at an elevation of 630 feet; stands at 625 feet near Portsmouth, Ohio, and 40 miles north of Portsmouth has declined in elevation to about 600 feet.

The divide that was overtopped between the drainage basins of "old Kanawha" and the old Ohio lay near the site of Manchester, Ohio. Above Manchester, along the present river, the ancient tributaries point upstream; below Manchester they point downstream (pl. 2). The upland near this point is higher than it is to the east or west, suggesting that a divide existed here, and the valley is more youthful in appearance, narrower, and walled with steeper bluffs than it is above or below.

The ice that advanced southward into this region in an early stage of the glacial period dammed the "old Kanawha River," backing up water in the valleys of that time until it spilled over the divide at Manchester into the old upper Ohio. At about the same time the flow was diverted across a divide that existed just east of Portsmouth (pl. 1*A*). The waters of the "old Kanawha River" kept to the new course after the ice melted away, for the valley leading to the north was left buried under glacial deposits.

It was, no doubt, ice of this early stage that diverted into the "old Kanawha River" the waters of other rivers draining westerly off the Appalachians from as far north as New York. In this fashion, as Leverett (1902) shows, the drainage from about 70,000 square miles was added to the primitive Ohio.

Fowke (1898) and, more recently, Wayne (1952) maintain that the preglacial Ohio River headed near Madison, Ind. (pl. 1). According to these authors the Kentucky River of preglacial time flowed northeast along the course of the present Ohio River, from Madison to join the Licking River near Hamilton, and the combined stream flowed northward. The main indications of this are the narrowness of the Ohio Valley at Madison, Ind., suggesting an old divide, and the northerly courses of the Kentucky and Licking Rivers. The pattern of drainage postulated by these authors may have existed in the remote past before the development of the channel that lies about 200 feet above the present river through this stretch. This high channel is almost surely preglacial, and it seems to slope down the present valley. Furthermore, as Leverett (1929) notes, the stretches of the old high valley up the Ohio Valley from the mouth of the Kentucky River seem too small to have been the downvalley extension of the Kentucky River.

It is generally assumed that the major advance of ice which caused the drainage changes occurred in the first or Nebraskan stage of glaciation (Flint, 1947), but there is no proof that it did not occur until the second or Kansan stage. The record of early glacial events in this region is very obscure. For example, the drainage changes in themselves provide the strongest evidence of early glaciation, for it is improbable that any other geological agent could have caused such changes. The only confirming evidence of early glaciation of this region consists of a few boulders of granite and gneiss, rocks of Canadian type, that Jillson (1924) found in northern Kentucky. The positions of the two largest boulders are shown on plate 1*A*. The larger of the two is estimated to weigh 16 tons and lies at an elevation of 986 feet. The other weighs about 4 tons, and, though it now lies at 700 feet, it probably was higher at one time. The boulders lie far south of the deposits of the ice sheets of the Illinoian and Wisconsin stages and testify to an earlier and farther reaching advance of ice.

EXCAVATION OF THE DEEP CHANNEL

The river dug its bedrock channel down to or very close to the level of the present bedrock profile in the long period of time between the major drainage changes and the advance of ice in the Illinoian stage. Comparison of the upper and lower profiles of plate 3, or of the diagrams *A* and *B*, figure 2, shows that the downcutting amounted to about 275 feet. This downcutting probably indicates that the region was uplifted several hundred feet in the time interval mentioned. The great increase in the flow of the river that resulted from the added drainage area must have enabled the river to deepen and widen its valley.

The deep channel of pre-Illinoian time takes the same course that the river does at present except, as shown on plate 1*A* and plate 2, in the vicinity of Cincinnati and at the lower end of the river. A few miles east of Cincinnati the river of pre-Illinoian time turned northward and flows almost to the site of Hamilton, Ohio, where it turned southwest along the present course of the Miami River and joined the present course of the Ohio a short distance upstream from Lawrenceburg, Ind. A few miles below Dam 51, at about river mile 908, below Pittsburgh the river of pre-Illinoian time turned westward through the valley in southern Illinois that the Cache River now follows. Both these old courses are indicated by broad abandoned valleys at the surface and by borings that show bedrock elevations conformable with those in adjacent sections of the deep channel.

The deep channel is known to have been developed by the time of the Illinoian glaciation, for Fenneman (1916) and Leverett (1929) identified as Illinoian the glacial deposits that lie in the abandoned channel passing northward around Cincinnati and near the floor of the present valley a few miles upstream from Cincinnati.

DEVELOPMENT OF COURSE SOUTH OF CINCINNATI

The Ohio River acquired its present course southward around Cincinnati during the Illinoian stage of glaciation. When the front of the ice sheet advanced south of Hamilton, Ohio, it dammed the Ohio Valley. Water rose in the Ohio and Licking valleys until it spilled over a divide between the valley of the Licking River and the valley of a creek that flows west to the Ohio. Leverett (1929) believes that at about the same time the Ohio acquired its present course across a divide between the Ohio and Licking valleys, just east of Newport, Ky. (pl. 2). Both divides that the river overflowed at this time were probably low, for in pre-Illinoian time the streams were running at lower elevations than they are now.

The ice advanced southward and crossed the river onto the Kentucky uplands along a broad front that extended, as Leverett (1929) shows, from 20 miles east of Cincinnati down to Louisville. A long, sprawling lake was backed up in the Ohio Valley east of Cincinnati, and a number of smaller lakes occupied the valleys of the Licking River, the Kentucky River, and other smaller streams that flow northward out of Kentucky. The waters of these lakes probably spilled across a succession of divides into the valley of the Salt River, and thus back into the lower Ohio Valley. When the Illinoian ice melted back far enough to expose the newly developed valley south of Cincinnati immense amounts of water from the lake upvalley and from melting ice quickly sluiced away any glacial deposits that the ice may have deposited in the valley.

ALLUVIAL FILLING AND DRAINAGE CHANGES OF WISCONSIN TIME

In the Ohio Valley the chief results of the growth and melting of the ice sheets of Wisconsin time are the deposits of river-laid alluvium and one important drainage change. The events of the Wisconsin stage of glaciation can be described in more detail than the events of the earlier stages because subsequent erosion and deposition have had less time to obscure the records. Four substages of the Wisconsin stage are recognized. (See table p. 6.)

Downcutting was no doubt the principal activity of the Ohio River during the first part of the Wisconsin stage. During the first (Iowan) substage of the Wisconsin, the ice sheet reached its maximum extent, though not in Kentucky, and sea level was lowered 200 feet or more (Flint, 1947). The Ohio River cut downward and removed most of the glacial outwash deposited in late Illinoian time, until it ran on or close to the deep bedrock channel. The bedrock channel in the section of valley newly developed in Illinoian time (from Cincinnati westward to the Miami River) was cut down to the grade of the channel above and below.

Some recession of ice and rising of sea level at the end of the Iowan substage interrupted erosion by the river, but the advance of ice and lowering of sea level in the Tazewell substage again set the river to deepening its channel. The farthest advance of ice into the Ohio basin in the Wisconsin stage was made in the Tazewell substage; one lobe of the ice sheet spread to what is now the northern part of Cincinnati (pl. 1*B*).

The coarse-grained alluvium of the Ohio Valley was probably deposited during the melting from the Ohio basin of the ice lobe of Tazewell time. The melting ice sheet furnished floods of water, which picked up and dumped into the Ohio Valley a vast load of sediment ranging in size from the finest clay to immense boulders. The principal outwash channels in this region are shown in plate 1B. Others were farther upriver. The river transported most of the fine-grained material such as the clay, silt, and fine sand far downstream, but it was unable to remove all the coarser material. The river spread, and sorted boulders, cobbles, pebbles, and sand, during floods, and gradually this coarse material accumulated and raised the level of the valley floor. The mass of coarse-grained alluvium seemingly represents one unbroken period of deposition, for it is relatively homogeneous and is interrupted in few places by layers of silt or clay indicating quiet water deposition.

The deposition of coarse-grained alluvium ended when the ice sheet of Tazewell time melted from the basin of the Ohio River, leaving no more floods of melt water to transport coarse-grained material in the Ohio Valley.

As the sections in plates 4–6 show, the upper surface of the body of coarse-grained alluvium is irregular enough to suggest that some erosion and channeling of these deposits took place after they were deposited. Probably most of this erosion occurred during the readvance of ice in the Cary substage, when sea and river levels were somewhat lowered. This advance barely carried ice into the headwaters of the Ohio River. Consequently little or no coarse glacial outwash was deposited in the Ohio Valley as ice of the Cary substage melted.

The level of the Ohio River was lowered moderately during the advance of ice in the Mankato substage. The ice front of this substage barely spread into the northernmost headwaters of the Ohio system of drainage, hence the river received little melt water and glacial outwash sediment during the melting away of the ice. The Mississippi Valley, however, was a major sluiceway for melt water and outwash during much of late Mankato time (pl. 1C).

A thick sheet of fine-grained alluvium was laid upon the coarse-grained glacial outwash during the final melting away of the Wisconsin ice sheet in post-Mankato time. Figure 3C illustrates a section of the valley at the close of the episode of filling. The silt and clay of the fine-grained alluvium represents the normal, nonglacial sediment brought to the Ohio River by its tributaries. This material was deposited because the rising water along the Mississippi River backed up the Ohio River and produced slack-water conditions. The rise of water planes along the Mississippi River resulted from late glacial rise in sea level and from deposition of sediment by the river. Sea level rose probably 200 feet in post-Mankato time as the ice front melted back about 1,000 miles, and the bulk of the water that had been stored on land since the early part of the Wisconsin stage returned to the sea. During part of the period of deglaciation, the floor of the Mississippi Valley was elevated by the deposition of heavy loads of glacial outwash. As Malott (1922) noted, during all of late glacial time the rapid building forward of the delta of the Mississippi, with the heavy load of sediment the river carried, contributed to elevate the profile of the river farther upvalley.

The valleys of all substantial streams that join the Ohio contain alluvial fill below present stream level, for these streams cut downward and rose, filling their valleys, at the time similar action affected the Ohio River. Valleys from the north, such as the Wabash, that carried glacial melt water and outwash, contain an alluvial fill of sand and gravel, in most places overlain by more or less fine-grained material. Some of the valleys on the north side of the Ohio and all valleys on the south side carried no glacial melt water; as a result, there is little or no gravel in most of these valleys, and most of the alluvium is no coarser than fine-grained sand. An exception is the valley of the Tennessee River, in which there is a thick sheet of sand and gravel (Pree and Walker, 1952).

As Shaw (1911) pointed out, many of the valleys on both sides of the Ohio Valley, particularly in western Kentucky and southern Indiana, contained lakes during part of the glacial period. The principal evidence for these lakes are the flat bottoms of many valleys, underlain by laminated silt and clay deposited in the still waters of the lakes. Thornbury (1950) shows that these lakes existed in valleys tributary to glacial sluiceways, where water was backed up behind the quickly rising glacial fill in the sluiceways.

Fossil remains in the alluvium of the Ohio and tributary valleys reveal that when the alluvium was being deposited the climate was colder and wetter than it is now. The mastodons and hairy mammoths whose teeth, tusks, and bones have been unearthed at a number of places along the Ohio Valley lived in cold damp forests and grasslands. A famous locality for the remains of these and other animals is Big Bone Lick (Kindle, 1931), about 3 miles up Big Bone Creek from the Ohio River, some 25 miles southwest of Cincinnati. Throughout a long period of time various animals became mired in this lick, where salt water oozed up through alluvial silt and mud. The remains of muskox and caribou, animals of the boreal forest and tundra, lie at greater depth than remains of the bison, showing that the climate grew warmer and drier as the period of alluviation closed.

The diversion of the lower part of the Ohio River from its old course through the Cache Valley to its present route past Paducah probably occurred late in the Wisconsin stage, during the period of maximum alluviation. The old pattern of drainage shown in plate 1*A*, which Fisk (1944) deduces, has the Tennessee and Cumberland Rivers turning north to join the Ohio River. It is equally possible that the Tennessee and Cumberland Rivers, after joining, took the course that the Ohio now does, and that a divide existed between the Cumberland and the Ohio. Regardless of its position, the old divide was doubtless low in this region of low relief, and was easily overtopped at some period of exceptionally high water. The present course has the advantage over the old one of being considerably shorter. The old route served as a spillway for some of the waters of the record-breaking Ohio River flood of 1937.

In the narrow and meandering section of river valley between miles 675 and 700, at least two meanders have been cut off, leaving short segments of abandoned valley. The depth of the abandoned segments shows that the cutoffs occurred fairly late in the glacial epoch, probably in the Wisconsin stage.

POSTGLACIAL EROSION

Downcutting by the Ohio River and removal of much of the Wisconsin alluvial fill are the principal features of postglacial history, resulting in conditions such as are illustrated in figure 3*D*. Along the course of the valley the bed of the Ohio River now lies 75 to 115 feet below the original level of the Wisconsin fill. In meandering from side to side during the lowering, the river eroded the alluvium throughout most parts of the valley, so that only at a few places is alluvium left as high as its original upper level.

In its natural state, before the construction of locks and dams for navigation, the profile of the river probably had attained a condition of near-equilibrium. There is no strong evidence that the river was either aggrading or degrading its bed. The main activity of the river was the gradual shifting of the channel, in which cutting on one side was partly compensated by deposition on the other.

At present floodwaters spread over part of the bottom land each year leaving behind a thin layer of sand, silt, and clay. However, the surface is not necessarily raised by the thickness of the flood deposit, for a considerable amount of scour accompanies the early stages of flooding. The flood of 1937 attained levels 3 to 10 feet higher in Kentucky than any previously recorded and spread over areas that probably had not been flooded in the past few thousand years, but the deposits in the flooded area averaged less than one-eighth of an inch in thickness (Mansfield, 1938).

The long-run effect of the navigation dams on the profile of the bed of the river is not known and is subject to some dispute. It seems indisputable, however, that sediment gathers above the dams when they are closed during the season of low water. It also seems highly probable that such accumulations are largely scoured away when the dams are open during the winter season of high water.

THE DEEP CHANNEL

The deep channel at lower elevation than the present river bed is a most important factor in the existence of a major aquifer along the valley. Alluvium extending down only to the base of the present channel—even if much thicker than now exists in the valley—would yield small amounts of water compared with that available from the deposits in the deep channel, below water level in the river. Under natural conditions the water level in the alluvium stands at or somewhat above river level and the saturated thickness below represents year-round storage. Wells can be pumped to lower the water level below the level of water in the river, thereby setting up gradients which induce river water to enter the alluvium and flow toward the wells.

LONG PROFILE

The profile of the deepest part of the buried channel (pl. 3) connects points where the minimum elevation of the channel bed is thought to be known within 5 feet. Points in the vicinity of Louisville and of Henderson are taken from contour maps of bedrock at these places, prepared from many well records (Rorabaugh, 1946, 1956; Harvey, 1956). The other points are derived from the geologic sections on plates 4, 5, and 6 that either cross the valley from side to side, or cross enough of the valley to show the level of the old stream bed descending and then beginning to rise toward the other side.

Many cross sections of the valley are based on borings hundreds of feet apart, which only by accident could reveal the lowest point of the channel along the section line. The borings made especially to explore the old channel at Ullin, Ill. (sec. 14, pl. 6), failed to show the true depth, which fortunately was shown by an unrelated boring nearby. The 4 borings of section 15 also fail, it is thought, to show the full depth of the channel. However, most of the other sections across the valley give points reliable within a few feet, for the base of the old channel is not very irregular, to judge from the few places where information is provided by closely spaced borings.

The segment of the profile from Henderson downstream rests on the channel elevation determined in the abandoned course of the Ohio River at Ullin, Ill., because none of the 4 sections across the present valley below mile 908 provide satisfactory data. All 4 sections are across the stretch of valley that is floored with unconsolidated sand and clay of the Coastal Plain. In the logs available these formations cannot readily be distinguished from the river alluvium; consequently the position of the base of the alluvium, marking the bottom of the old channel, is not certain. However, section 13 at mile 944 and section 16 at mile 977.7 show gravel, probably of river origin, down to elevations of 190 and 168 feet, respectively. These elevations are in accord with the elevations, at similar mileages, of the buried channel along the Cache Valley route. Therefore, it appears that, after the diversion from the Cache Valley, the Ohio River excavated its new valley to the depth of the old one, aided by the circumstance that urconsolidated material and not hard rock lay under the new valley.

From Ashland, Ky., to the Mississippi River, the old channel has an average gradient of about 0.46 foot per mile, for in these 658 river miles the channel declines about 306 feet, from an elevation of 471 to 165 feet above sea level. During low water and before construction of the navigation dams, the Ohio River had a drop of 211 feet, and a gradient of about 0.32 foot per mile, over this same stretch. For further comparison, the slope of the alluvial fill of Wisconsin age, judging from the remnants at high levels, was about 0.38 foot per mile.

The great vertical exaggeration of the profile, 4,224 times, clearly reveals how the old channel consists of two segments of gentle slope, interrupted by a distinct step at Louisville. For some tens of miles above Louisville the old channel has a gradient of less than one-tenth of a foot per mile. Below Louisville, in the vicinity of mile 620, the gradient for a few miles is more than 4 feet per mile. This break shows that in pre-Illinoian time, when the deep channel was carved out, rapids existed where the river crossed the belt of outcrop of the resistant limestones of Late Silurian and Early Devonian age. During a long period of downcutting to a level controlled by the level of the Mississippi River and the sea, the lower part of the Ohio River brought the bedrock channel to a gently sloping profile. The resistant formations at and for some distance downvalley from Louisville slowed the rate of downcutting locally so that a stretch of steep profile developed downvalley on the softer rocks there. Just upstream from the rocks that slowed the downcutting the river developed a stretch of very gentle slope; farther upstream, a moderately sloping profile was developed.

WIDTH AND SHAPE

As shown on plate 2, the width of the Ohio Valley ranges greatly, from about half a mile just southwest of Cincinnati to about 10 miles near Uniontown, Ky. In general the valley grows wider downstream as the stream grows larger by the addition of tributaries. Measurements by the U. S. Geological Survey show that the flow of the river averages 83,550 cubic feet per second (cfs) at Ashland, Ky., and 272,600 cfs at Metropolis, Ill., 37 miles upriver from Cairo, Ill. The valley is wider or narrower in places, in response to the differing degrees of resistance to lateral erosion of the valley walls. Some variations in valley width are the results of the drainage changes that caused the assembling of valleys of unequal age and development into a new, continuous valley.

The valley from Ashland down to within a few miles of Louisville is narrow in comparison with the valley downstream. This upper segment across a series of shaly limestone beds of rather uniform resistance to erosion, and the more obvious changes in valley width from place to place reflect the geologic history. The valley is narrowest where divides existed in the past, near Manchester, Ohio, and in the stretch just southwest of Cincinnati. The valley is widest where considerable rivers have been flowing longest; that is, in the stretch east of Manchester which in preglacial time drained northward, and the stretch downstream from the mouth of Miami River.

A few miles upstream from Louisville the valley widens notably as it enters a broad lowland developed on soft shales of Late Devonian and early Mississippian age. This wide stretch ends a few miles downstream from the town of West Point, where the valley first crosses the thick massive limestone of middle Mississippian age which supports a plateau about 400 feet above river level. The valley remains narrow for about 90 river miles, first across the Mississippian limestone and sandstone formations, and then across the thick sandstone strata that occur at the base of the Pennsylvanian system.

Near Hawesville the valley broadens conspicuously as it passes onto soft shale and thin sandstone beds of Pennsylvanian age. The valley is at least 6 miles wide from Owensboro to Uniontown, a distance of about 90 miles along the river. About 10 miles downstream from Shawneetown the valley narrows as it again crosses the strong sandstone beds at the base of the Pennsylvanian system and then the massive limestone of Mississippian age.

The valley broadens again only where it leaves the hard rocks behind, near the mouth of the Cumberland River, and crosses the unconsolidated formations of sand and clay of the Mississippi Gulf Embayment of the Coastal Plain. Along much of this stretch of the valley the bordering land is so low that no definite boundary to the alluvial valley can be drawn.

The valley in general has the shape of a trench with steep walls and a flat bottom, and in most places is very shallow in comparison to its width. Along the narrow stretches of the valley where the river has always tended to work against the bases of the slopes, the valley walls are precipitous, and even clifflike where the rocks are strong. In the wider parts of the valley the valley walls are more worn and subdued, except at a few points where the river is now cutting against the edge of the valley or has done so in the recent past. The relief on the valley floor consists of shallow sloughs, low steps between flat benches or terraces, and by the shallow trench in which the river is confined in normal water stages.

The shape of the buried valley, along the stretches where the entire valley is narrow, usually resembles a simple trough with steep walls and a flat bottom. Section 6 (pl. 4) at Madison, Ind., is representative. Although two borings that indicate a flat-bottomed channel here are several hundred feet apart, there is little reason to believe that closer control would reveal much more irregularity than is shown.

Where the valley is several miles wide, the river was unable to plane off bedrock to flatness all the way across, and all the sections across wide parts of the valley show irregularities. The deepest part of the buried channel may be found anywhere under the present valley, not necessarily beneath the middle of the valley, and only by coincidence beneath the present river channel.

Rock benches thinly covered with alluvium are known to exist at several places, and probably are to be expected in any complete section across a wide part of the valley. Section 11 (pl. 5), at Shawneetown, shows such a bench, mantled by about 30 feet of alluvium and apparently occupying about half the width of the valley; beneath the other half the deep channel probably holds 125 feet of alluvium. In the Henderson area (Harvey, 1956) a rock bench of similar type underlies part of the city of Henderson, and the deep channel lies a couple of miles farther north. The Falls of the Ohio at Louisville are due to a bench of bedrock on the north side of the valley. The Ohio River, meandering from one side of the valley to the other during the postglacial period of downcutting in alluvium, was lowered by chance onto this rock bench hidden beneath alluvium, rather than into the thick alluvial deposits in the main deep channel beneath the city of Louisville. The break in stream profile at the falls, due to superimposition of the stream on an obstacle, differs in origin from the break in the profile of the bedrock channel in this vicinity, which is the result of marked differences in the resistance of bedrock within a short distance along the channel.

At some wide places in the valley the buried channel divides around islands of rock. The most obvious example is just west of Owensboro (pl. 2), where the Bon Harbor Hills of bedrock rise prominently above the valley fill that surrounds them. The channels both north and south of these hills lie deep, but it is not known which is deeper. Contour maps of the bedrock at Louisville and at Henderson show the deep channel dividing around low islands of bedrock buried under alluvium.

The sections of plates 4–6 show other deviations from flatness of the old valley bottom. At Evansville (sec. 10, pl. 5), for example, the surface of the bedrock declines gently toward its lowest elevation. The data available for section 14 (pl. 6) at Ullin, Ill., apparently indicate a rather steep-walled trench cut into a small part of the valley, and a similar trench must exist at Metropolis (sec. 15, pl. 6) if the deep channel extends through this stretch.

THE ALLUVIAL FILL

The thickness of alluvial fill deposited during the Wisconsin stage is represented by the interval between the reconstructed profile of the top of the fill and the profile of the bedrock channel (pl. 3). The fill thickened from about 130 feet at Ashland, Ky., to 185 feet at the mouth of the river. The original maximum thickness exists at a few points along the valley, for the fill exists to its original height only in protected places along the valley margin, whereas the lowest part of the buried valley generally lies some distance from the valley wall.

Under natural conditions the maximum thickness of alluvium likely to be saturated by water is represented by the difference in altitude between river level and the base of the deep channel. At Ashland the deep channel lies about 25 feet below river pool level; at the mouth of the river the difference is about 110 feet.

One of the most significant features of the alluvium is its division into a sheet of sand and gravel and an overlying sheet consisting mainly of silt. As described on pages 11–14, the coarse-grained material is glacial outwash; the fine-grained is that deposited in slack water after ice had melted from the basin of the Ohio River.

COARSE-GRAINED ALLUVIUM

All available sets of borings show that the body of coarse-grained alluvium extends entirely across the valley. The upper surface of the sand and gravel deposit, irregular beneath the cover of silt and clay, generally rises toward the margins of the valley. The greatest known thickness of sand and gravel is 150 feet.

Erosion by the river exposed sand and gravel at least part way across the channel at almost every point. This connection between the permeable sand and gravel, and the river bed, permits water to move from the sand and gravel to the river, or in the opposite direction, depending upon the local hydraulic gradient at a particular time.

At most places along the course of the river a blanket or lip of clay, formed by recent cutting and filling by the river, extends down the river bank and some distance across the stream bed on top of the sand and gravel. As Rorabaugh (1946) shows, such a clay lip may seriously interfere with the development of water supplies by infiltration, by placing the area of intake a considerable distance from the river bank and the wells.

The coarse-grained alluvium contains few beds or lenses of silt and clay. However, the materials are not uniform throughout; the many sand and gravel pits in the valley reveal alternate beds of sand and gravel. Rorabaugh (1956) gives evidence from pumping tests at Louisville which show clearly that some beds are more permeable and transmit water more readily than others.

The particles that compose the coarse alluvium range in size from clay to enormous boulders, but the bulk of the material is sand and gravel. The coarsest material is generally near the base of the channel. In general, the average coarseness decreases downstream, away from the source of the material.

The deposits are exceptionally coarse in the valley at Cincinnati and for some distance downstream, because in this locality a lobe of the ice sheet reached within a few miles of the river and disgorged vast amounts of water and sediment while melting. Boulders up to 3 or 4 feet in diameter have been reported. Consequently it is important that exploratory borings to determine the position of bedrock penetrate several feet of solid rock.

At Louisville the average size of particles no doubt is less, but cobbles up to 8 inches in diameter have been recorded, and much of the material is more than 2.5 inches in diameter and is classed as cobbles rather than gravel. A report on investigations in the southwestern part of Louisville by Rorabaugh (1956) gives the results of particle-size analyses of the alluvium, and many more are in the files of the Geological Survey at Louisville.

In the vicinity of Paducah, about 300 miles down the river from Louisville, cobbles up to 3 inches in diameter have been recorded at the base of the channel, but they make up a very small part of the alluvium. Almost all the gravel recorded in logs is "pea gravel," probably having an average diameter of less than one-third of an inch.

The sand fraction of the coarse alluvium consists almost entirely of the sharp-edged quartz grains characteristic of most river sands. The pebbles, cobbles, and boulders, most of them well rounded, are made up of the various types of rocks that occur along the valley or to the north in the regions scoured by the ice sheet. Sandstone, limestone, chert, and hard crystalline rocks such as quartzite and granite from Canada are all represented. Probably it would be possible to show that the percentage of pebbles and cobbles of soft rock such as limestone decrease downstream, owing to grinding and wearing during transport.

A high percentage of the particles larger than sand are composed of fresh rocks that had been subjected to little weathering and chemical attack at the surface, but that were broken during glacial erosion and transport.

FINE-GRAINED ALLUVIUM

Almost everywhere along the valley a sheet of fine-grained alluvium covers the coarser basal deposits. Generally, the trench occupied by the present river is cut lower than the base of the fine-grained alluvium, so that, unlike the underlying body of sand and gravel, this sheet is not continuous across the valley.

At a few places, the fine-grained deposits are as much as 75 feet thick; elsewhere on the flood plain they may thin almost to nothing. Their thickness ranges greatly from place to place, depending on the irregularities of both the underlying surface of the sand and gravel and the eroded land surface. The average thickness is probably 25 or 30 feet, for most wells and borings penetrate a few tens of feet of such material before entering the basal coarse-grained deposits.

The upper sheet of alluvium consists of clay, silt, sand, and in places a little gravel, but the fine-grained constituents are so dominant that the deposits are very distinct from the underlying alluvium. In natural exposures along banks, and in excavations, the material seems to be a clayey silt containing some sand. Drillers usually refer to it as clay, but actually only a small fraction consists of particles less than 0.0002 inch (0.005 mm) in diameter. Generally, enough clay is present to make the material somewhat plastic. However, some layers of fine sand lack plasticity and run freely, causing cave-ins.

At some exposures bedding may be lacking or not obvious; at others, lamination of sandy silt and clayey silt can be seen. Beds of sand several feet thick occur sporadically; generally they are narrow lenses filling channels.

Silty fine-grained alluvium is yellow. Where much clay is present the alluvium is various shades of gray, verging on black where the content of organic matter is high. The odor of marsh grass is very noticeable at some places where dark sediment containing much organic matter is being excavated.

The upper sheet of alluvium does not supply large amounts of water to wells, because water moves slowly through such fine-grained material. A few wells may obtain water from the "stray" lenses of sand, but such lenses will be encountered only by chance and will not give large sustained yields.

Although the movement is slow, significant amounts of water from precipitation and floods pass down through the fine-grained alluvium into the sand and gravel aquifer. From water-level observations at Louisville, Rorabaugh (1946) calculated that in 1945 about 6 inches of water, or 12 percent of the annual precipitation, seeped down from the surface to recharge the supply in the coarse-grained alluvial deposits. Precipitation in 1945 was 49.81 inches, 115 percent of normal, so the recharge during years of normal precipitation would be less than 6 inches. During the 1937 flood, which covered nearly all the alluvial bottom lands, so much water was added to the alluvium that several years passed before water levels receded to a lower, and more normal, position.

The presence of relatively impermeable silt and clay over the permeable sand and gravel results in artesian conditions in parts of the alluvial area during the winter season of high water. Water rising in the sand and gravel finds a barrier to further unimpeded rising at the base of the fine-grained alluvium causing pressure to develop. Such conditions exist most commonly in the zone along the river when the river rises above the base of the fine-grained alluvium.

CONCLUSION

The great alluvial aquifer along the Ohio Valley ranks as one of the principal natural resources of the region. The large sustained yields of ground water, together with the raw materials of the region and factors of location and transportation, will continue to attract industrial development. It also seems probable that the availability of ground water for supplemental irrigation will gradually change the pattern and increase the intensity of bottomland agriculture.

It must be borne in mind that there are limits to the amount of ground water that can be developed at even the most favorable locations. In the long run, the rate at which water can move from the river, the prime source of replenishment, determines the amount that can be developed by infiltration at a given location. This relation was demonstrated on a large scale at Louisville during World War II, when pumping locally exceeded the rate of inflow, and lowering water levels gave notice of impending shortage of cooling water for the chemical industries. The condition was remedied by the recharge through wells of water purchased from the city water company, in winter when the river water was cool and the water company was in a position to charge low rates. Artificial recharge of sediment-free river water through wells, or of raw river water through pits, doubtless will be resorted to in the future at a number of places along the valley.

Much of the usefulness of the ground water depends on its good chemical quality and cool temperature. Both characteristics can be altered for the worse quite readily in a relatively shallow aquifer such as this. Cases are on record of increased water temperature due to nearby recharge of heated water, and of contamination due to incautious disposal of saline and chemical wastes on the surface or into pits. Such undesirable characteristics may persist for a long time in a given locality, because of slow movement of the water.

The foregoing, points to the conclusion that the successful development of large supplies depends on adequate knowledge of the local geologic and hydrologic properties of the aquifer. The most important of these properties, the coefficients of storage and transmissibility, and the distance to the point of recharge from the river, ordinarily can be obtained only by test drilling and pumping. The costs of such preliminary investigations amount to but a small fraction of the total cost of any large development. Papers by Kazmann (1947) and by Rorabaugh (1956) reveal how closely the safe maximum yields at given localities can be predicted after the local properties of the aquifer have been determined.

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INDEX

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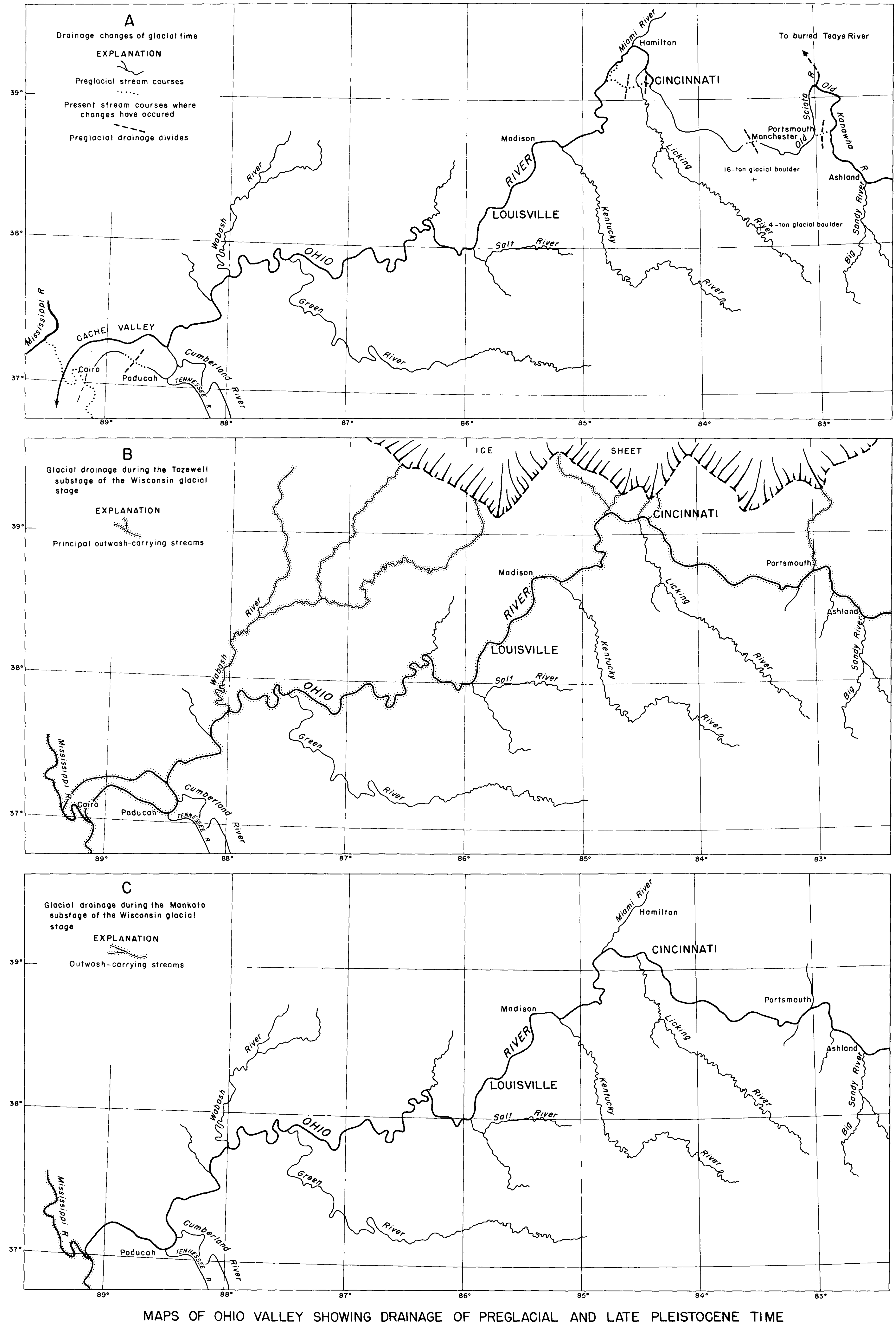

MAPS OF OHIO VALLEY SHOWING DRAINAGE OF PREGLACIAL AND LATE PLEISTOCENE TIME

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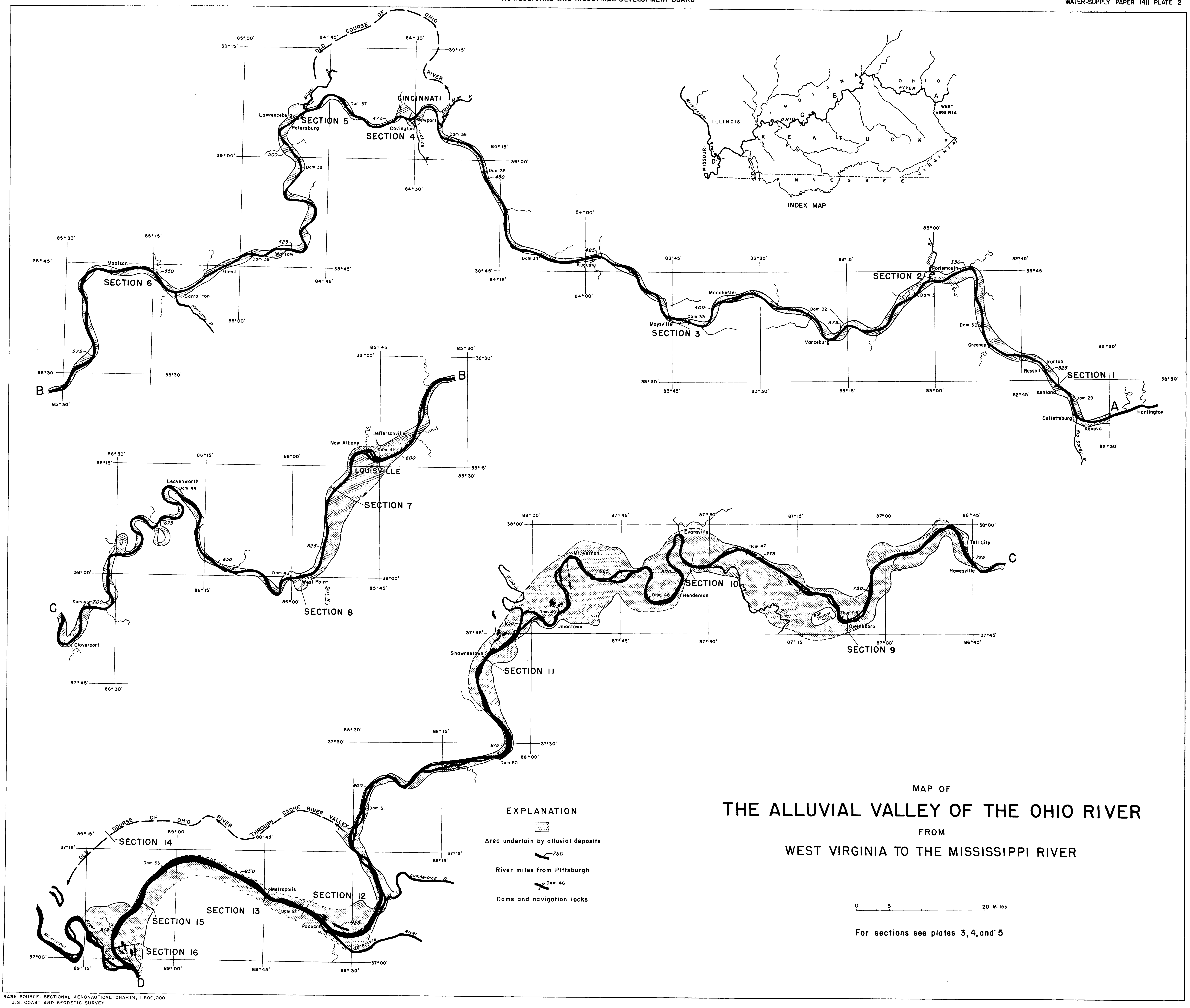
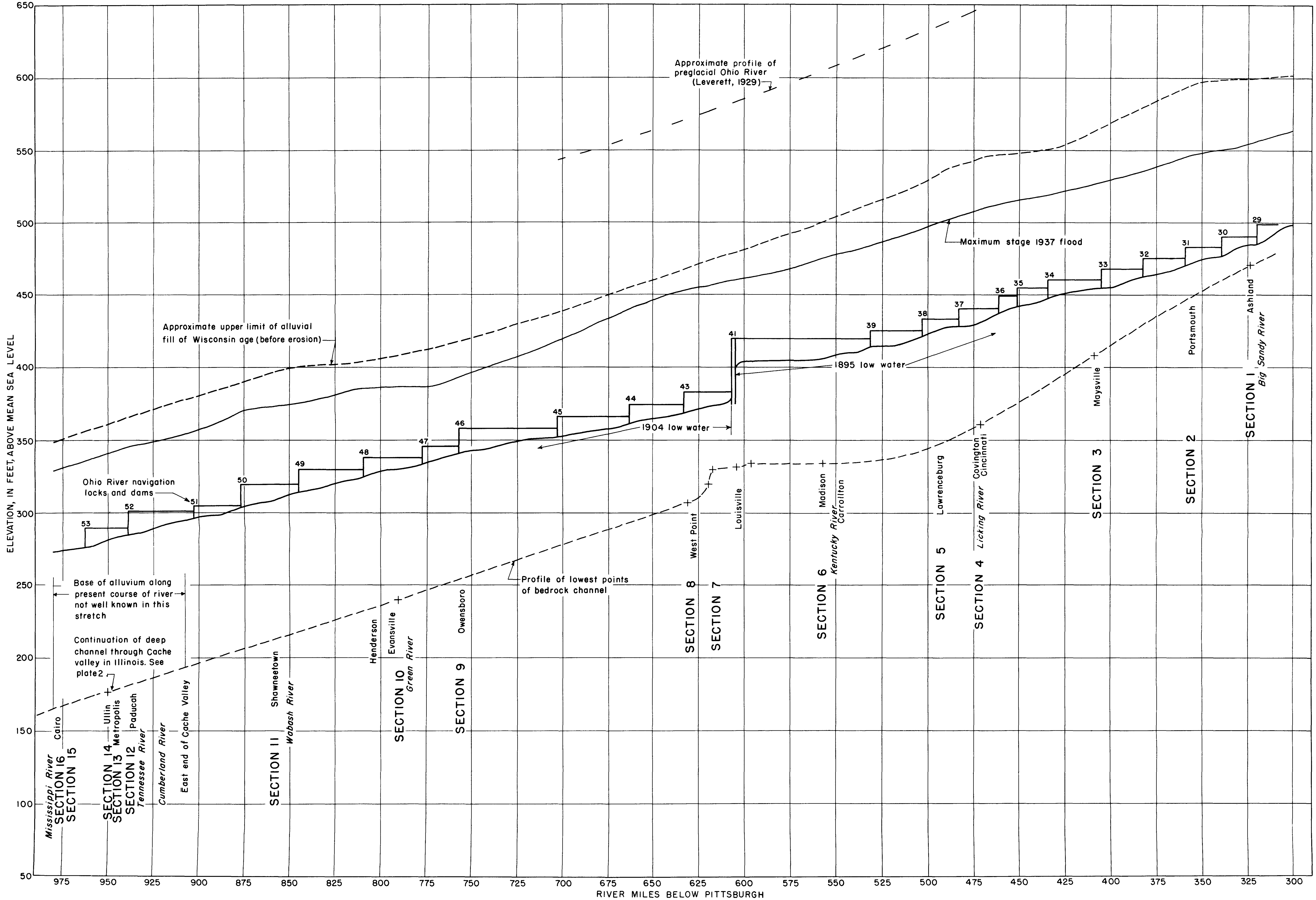


MAP OF
THE ALLUVIAL VALLEY OF THE OHIO RIVER
FROM
WEST VIRGINIA TO THE MISSISSIPPI RIVER

BASE SOURCE: SECTIONAL AERONAUTICAL CHARTS, 1:500,000
U.S. COAST AND GEODETIC SURVEY.



PROFILES OF THE OHIO RIVER FROM WEST VIRGINIA TO THE MISSISSIPPI RIVER SHOWING ELEVATIONS OF THE BEDROCK CHANNEL, POOL LEVELS, AND FORMER RIVER LEVELS

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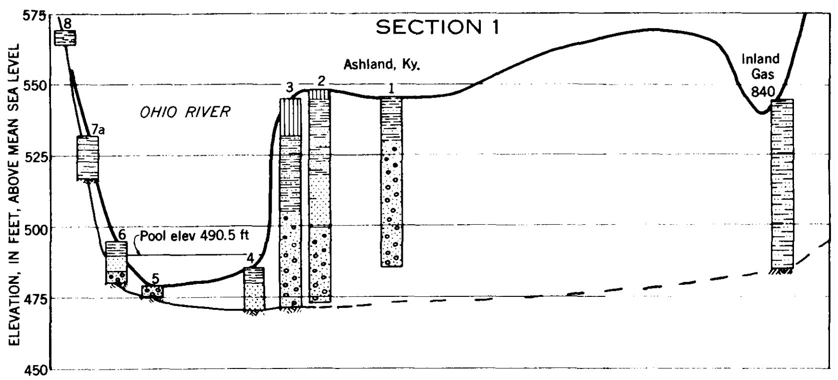
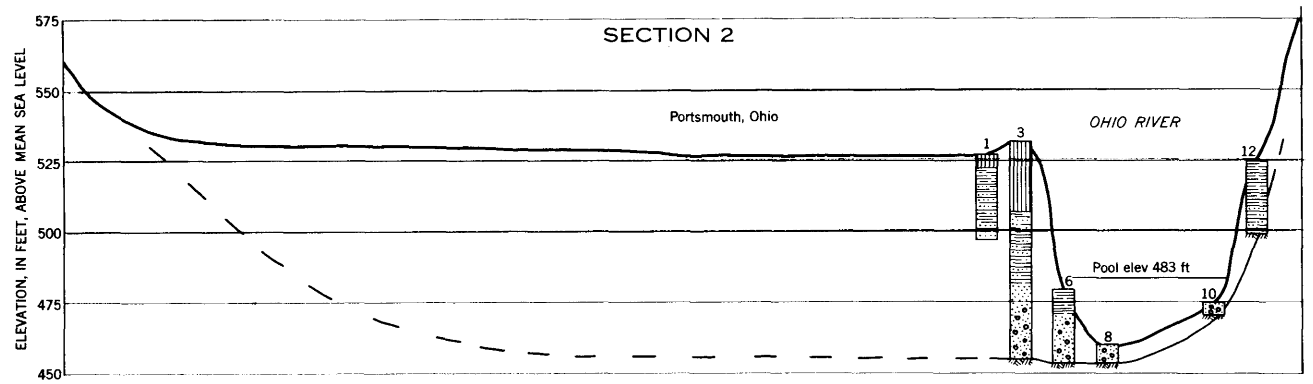
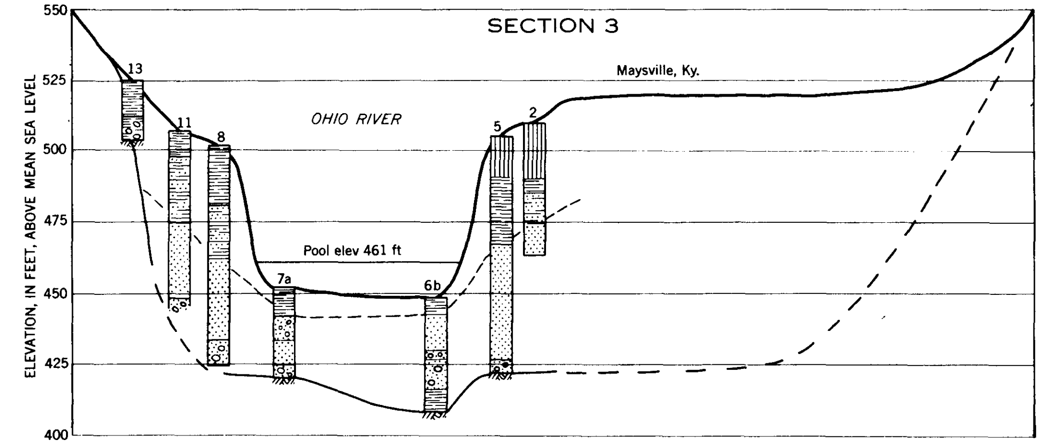


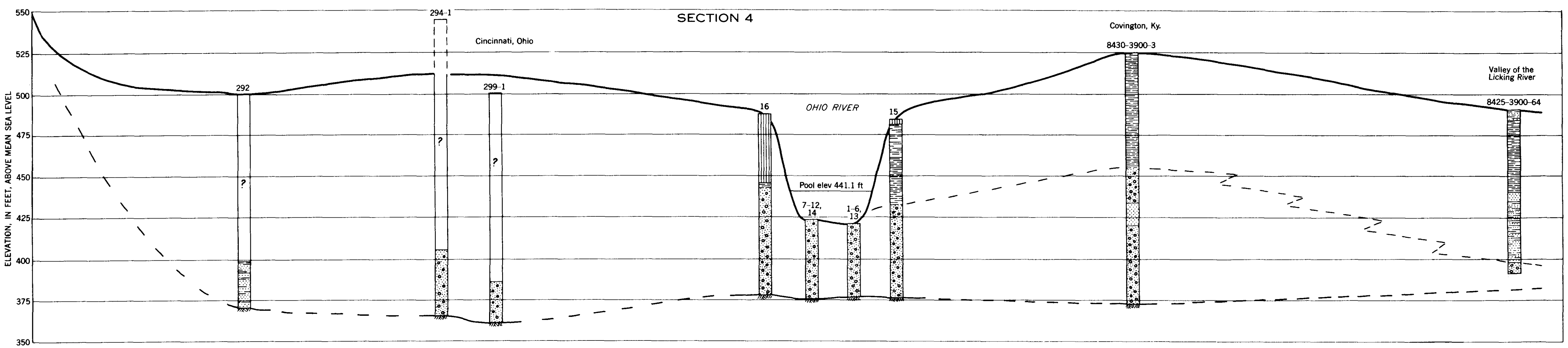
BORINGS FOR ASHLAND-COAL GROVE HIGHWAY BRIDGE AT RIVER MILE 322.8



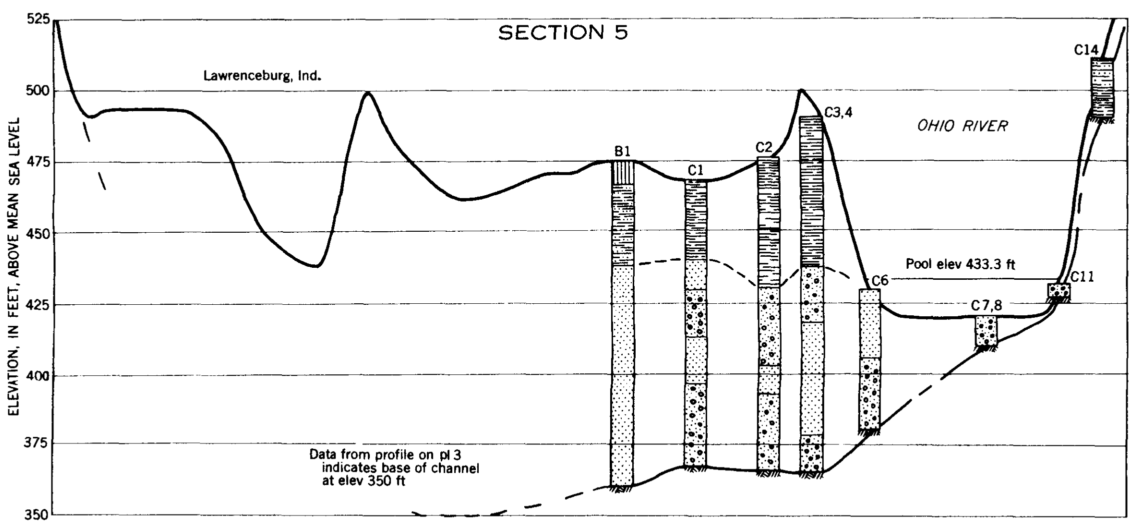
BORINGS FOR PORTSMOUTH, OHIO, HIGHWAY BRIDGE AT RIVER MILE 355.6



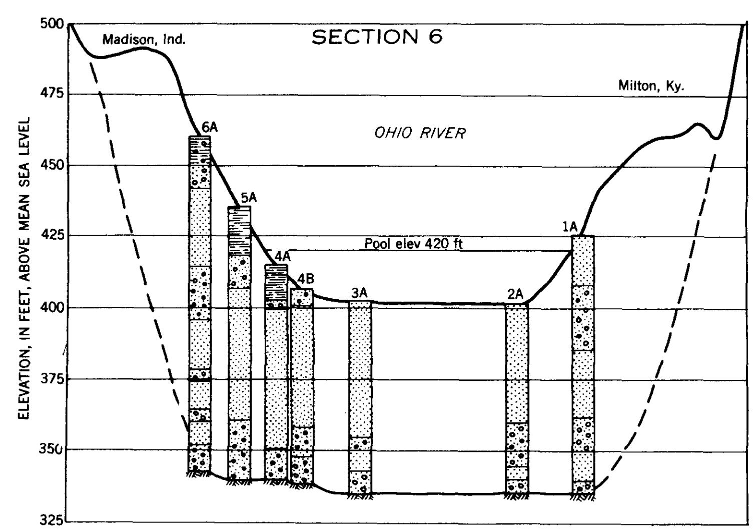
BORINGS FOR ABERDEEN-MAYSVILLE HIGHWAY BRIDGE AT RIVER MILE 408.4



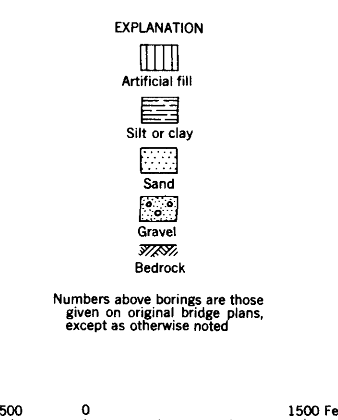
BORINGS FOR CHESAPEAKE AND OHIO RAILWAY CO. BRIDGE AT RIVER MILE 471 AND WELL LOGS IN CINCINNATI, OHIO, AND COVINGTON, KY.



BORINGS FOR PROPOSED LAWRENCEBURG, IND., HIGHWAY BRIDGE AT RIVER MILE 493



BORINGS FOR MADISON, IND., HIGHWAY BRIDGE AT RIVER MILE 557.3



GEOLOGIC SECTIONS OF THE OHIO VALLEY, ASHLAND, KENTUCKY, TO MADISON, INDIANA

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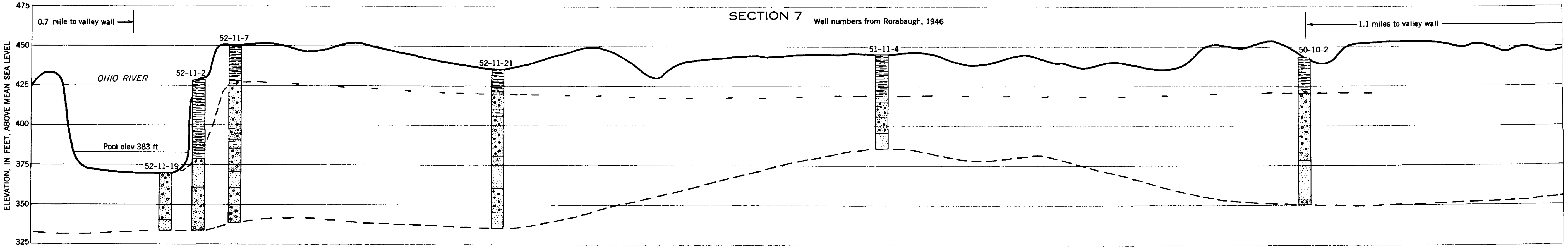
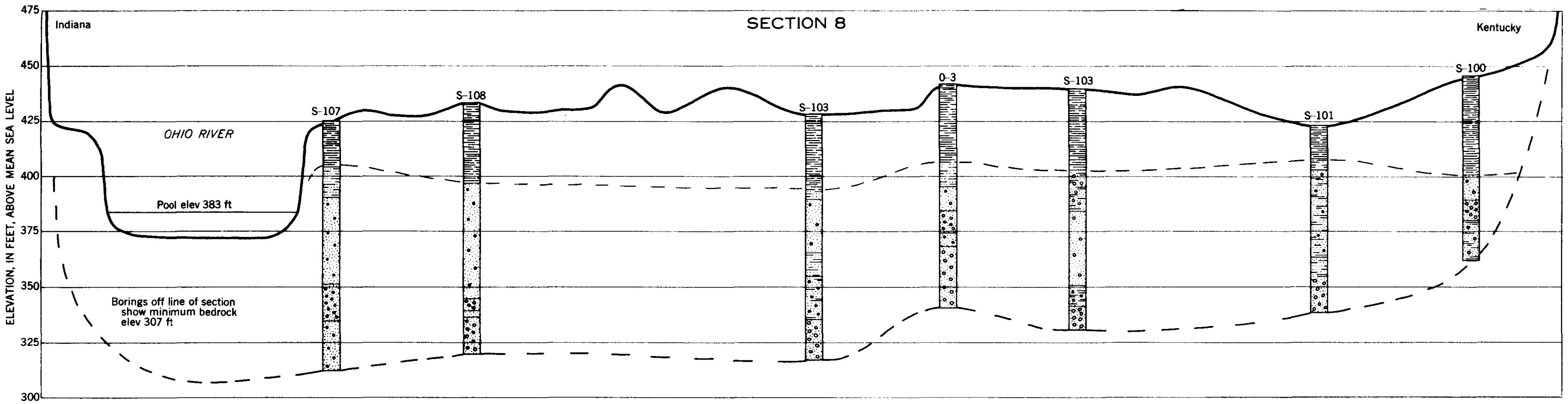
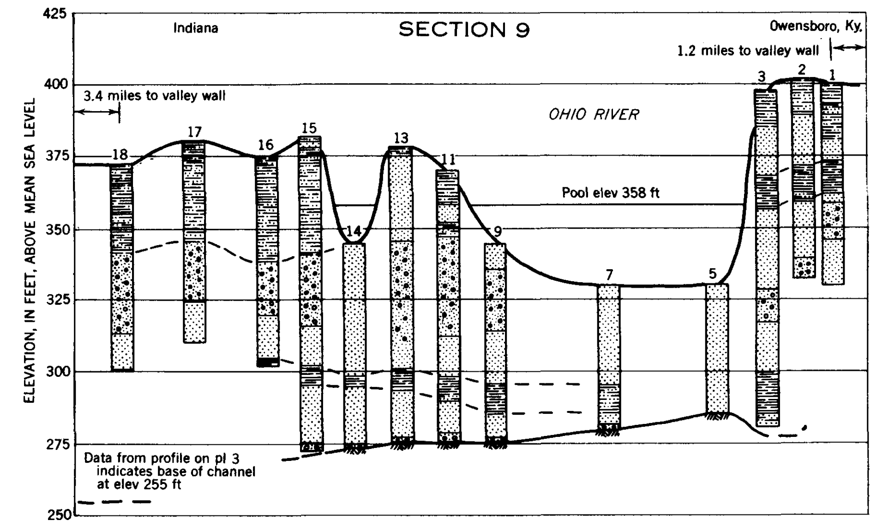


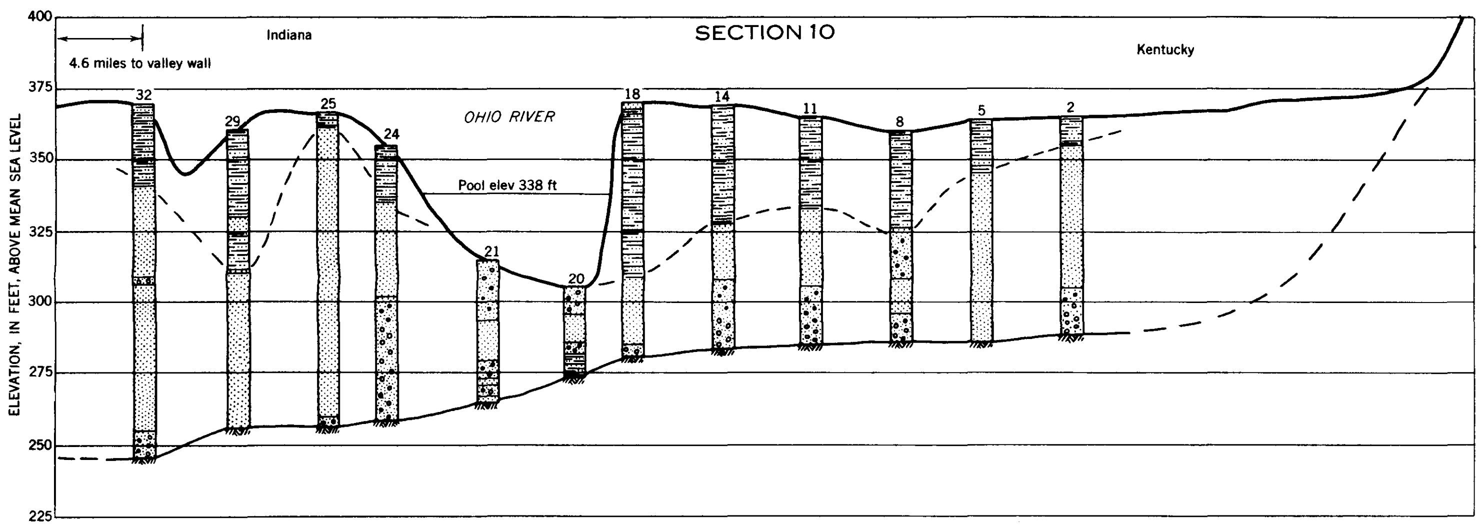
BORINGS AT LOUISVILLE, KY., RIVER MILE 615



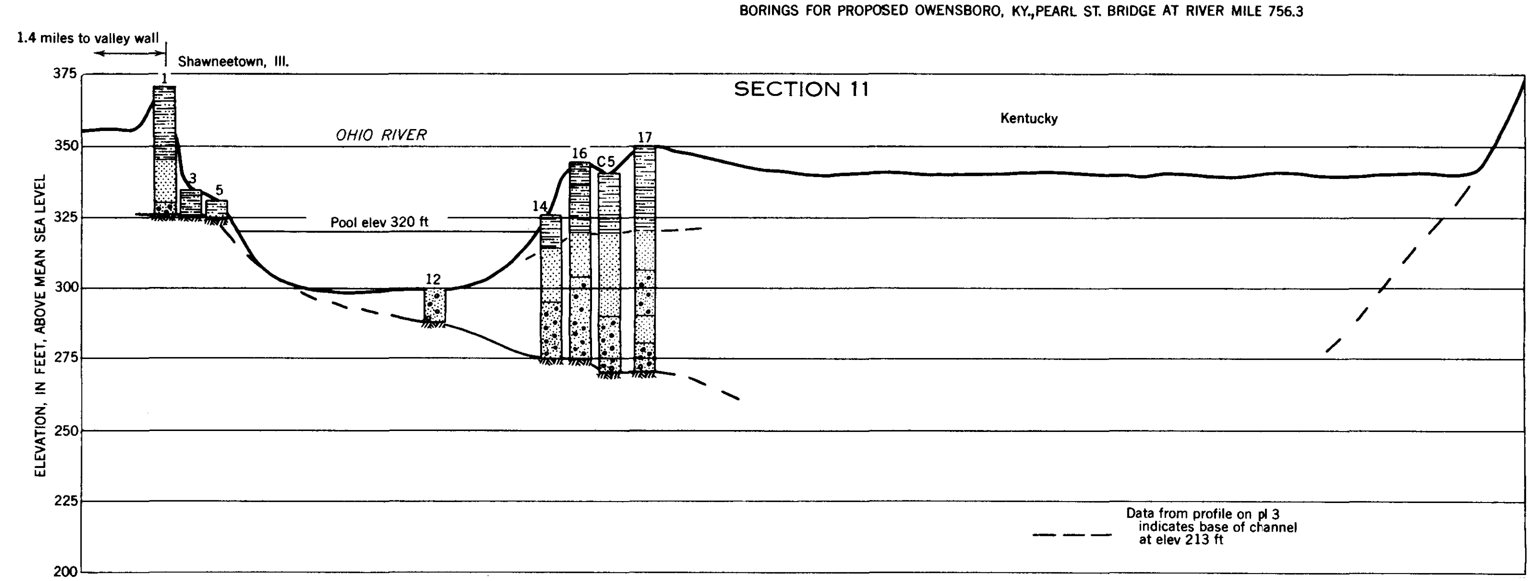
BORINGS AT FORT KNOX, KY., WELL FIELD, RIVER MILE 631



BORINGS FOR PROPOSED OWENSBORO, KY., PEARL ST. BRIDGE AT RIVER MILE 756.3



BORINGS FOR KENTUCKY-INDIANA HIGHWAY BRIDGE AT RIVER MILE 786.8



BORINGS FOR PROPOSED SHAWNEETOWN-THE ROCKS ROAD BRIDGE AT RIVER MILE 858

EXPLANATION

Silt and clay — Sand — Gravel — Bedrock

Numbers above borings are those given on original bridge plans, except as otherwise noted

GEOLOGIC SECTIONS OF THE OHIO VALLEY, LOUISVILLE, KENTUCKY, TO SHAWNEETOWN, ILLINOIS

500 0 1500 Feet

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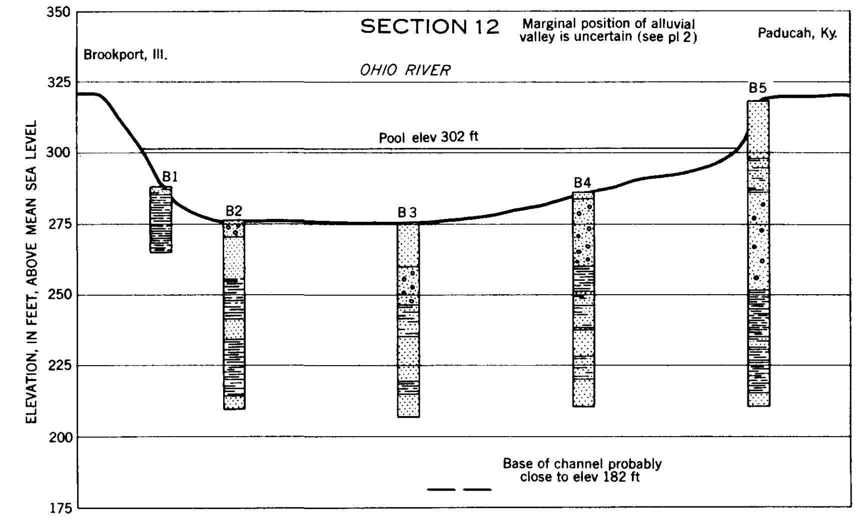
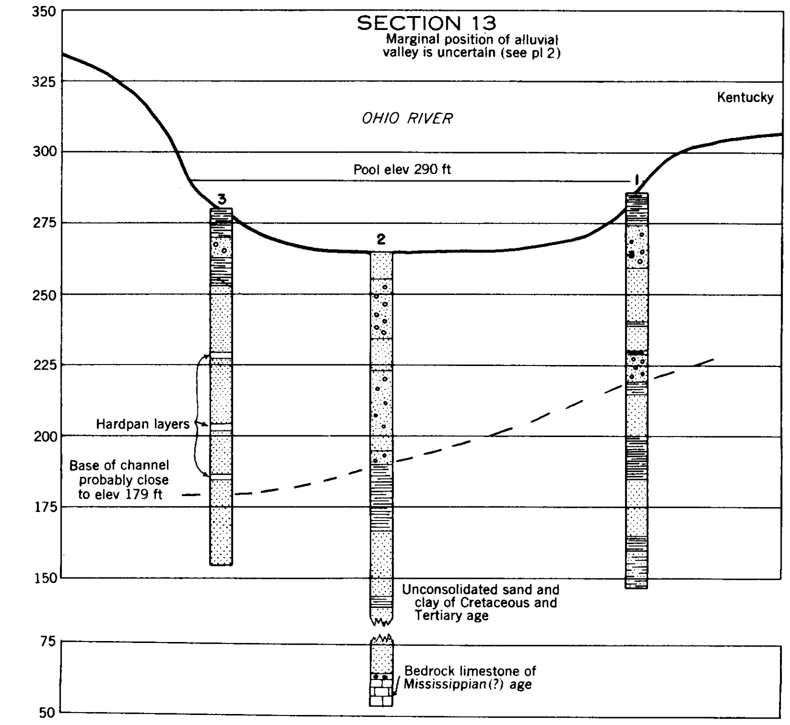
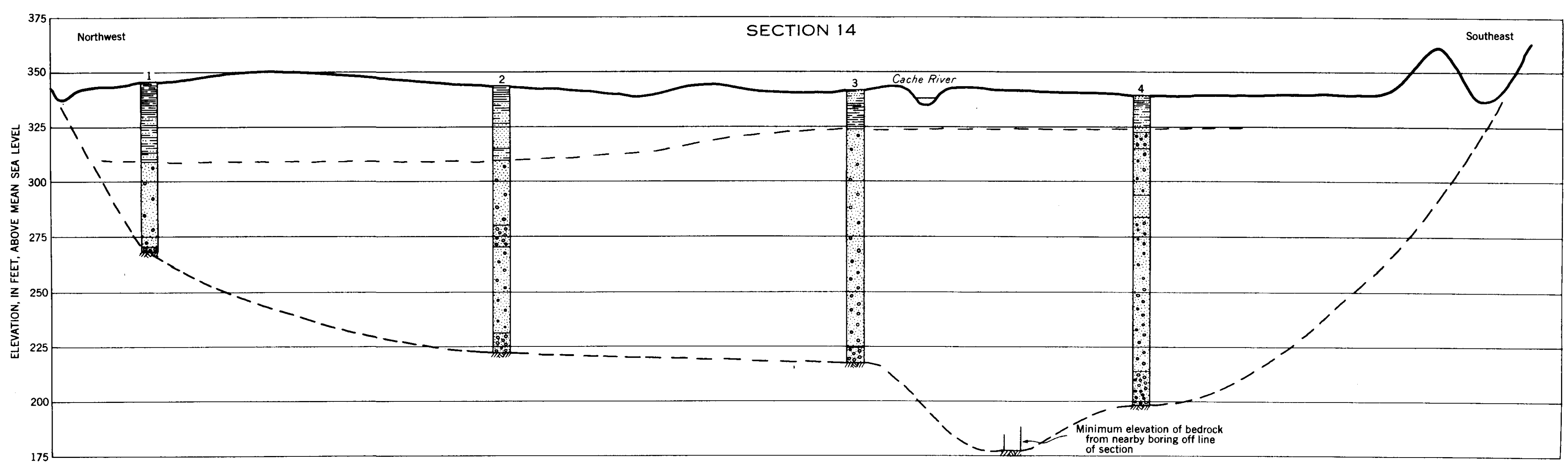


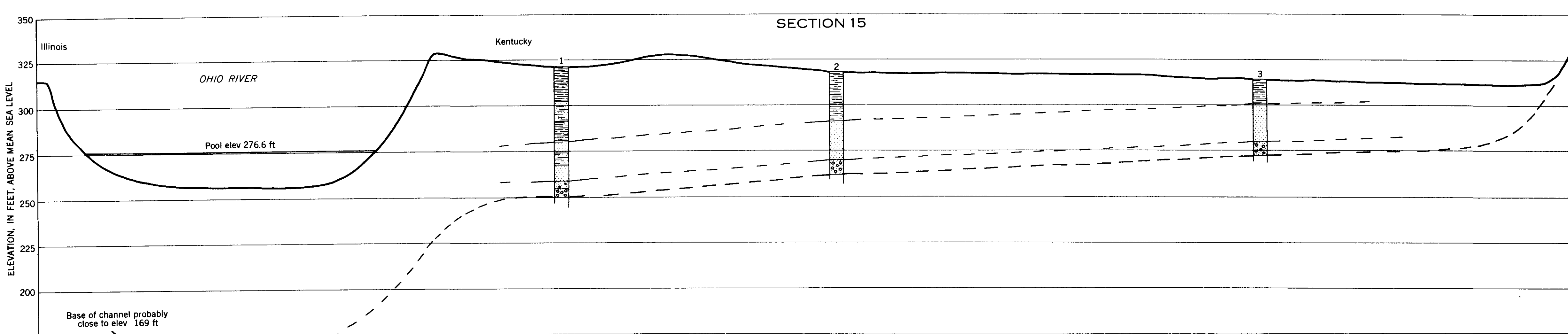
BORINGS FOR PADUCAH-BROOKPORT BRIDGE AT RIVER MILE 937.3



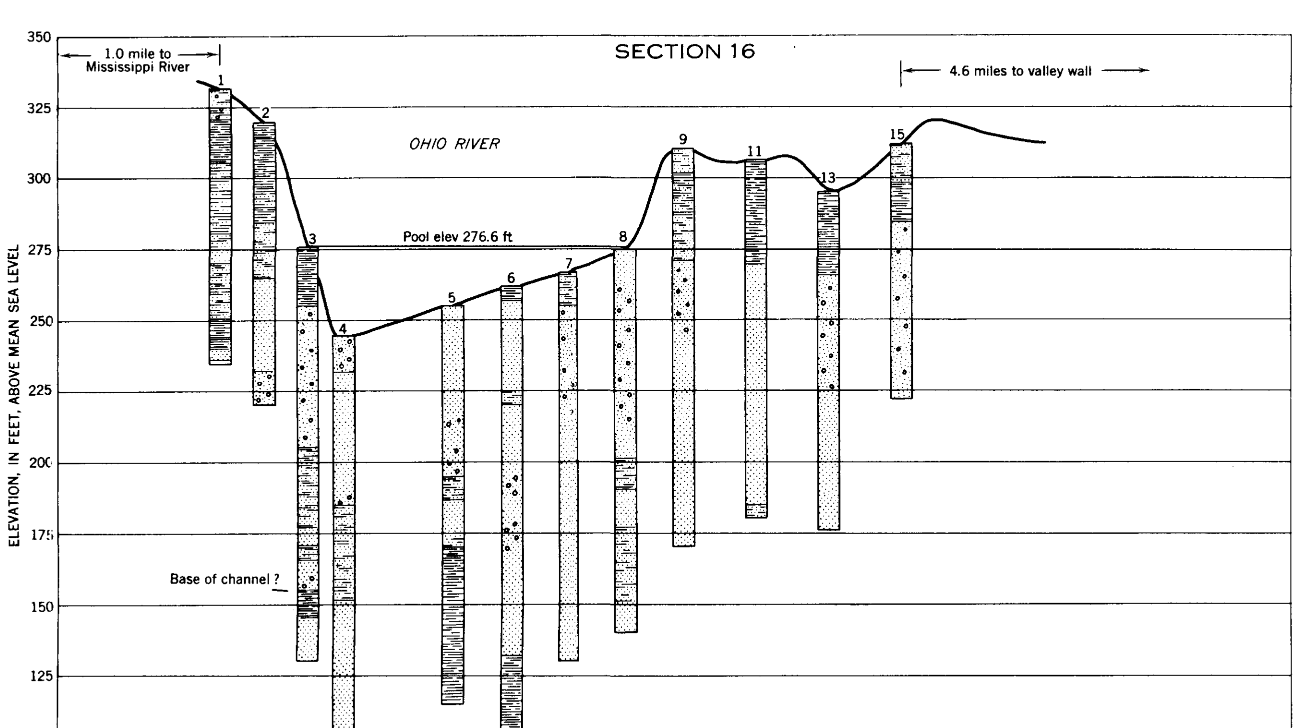
BORINGS FOR PADUCAH-ILLINOIS CENTRAL RAILROAD BRIDGE AT RIVER MILE 944



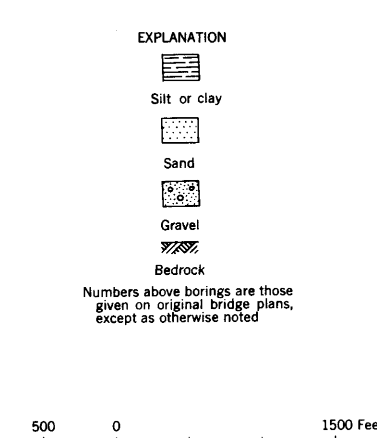
BORINGS BY FISK (1944) IN THE CACHE RIVER VALLEY NEAR ULLIN, ILL., AT RIVER MILE 951, MEASURED ALONG THE COURSE OF CACHE RIVER VALLEY



BORINGS BY FISK (1944) AT RIVER MILE 969



BORINGS FOR ILLINOIS CENTRAL RAILROAD BRIDGE AT RIVER MILE 977.7



GEOLOGIC SECTIONS OF THE OHIO VALLEY, PADUCAH, KENTUCKY, TO CAIRO, ILLINOIS

418817 O - 57 (In pocket)