

**Kansas Interim Joint Committee on Energy and Natural Resources
IMPACTS OF SAND AND GRAVEL DREDGING IN KANSAS RIVERS**

(Testimony to; and Supporting Materials Presented by the Kansas Geological Survey)

by

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Testimony of Dr. Lee Gerhard, Director and State Geologist, Kansas Geological Survey, to the Interim Joint Committee on Natural Resources, September 12, 1995.

Sand and Gravel Mining from River Systems in Kansas

My name is Lee Gerhard, State Geologist and Director of the Kansas Geological Survey, located at the University of Kansas, Lawrence. With me today are Larry Brady, Deputy Director, and David Grisafe, minerals specialist. Together we hope we can answer questions you may have about the occurrence, extraction, and use of sand and gravel resources from Kansas rivers. There are two attachments to my statement, supplied by Mr. Brady and Mr. Grisafe, that we will refer to as we discuss the topic.

I hope to make several points about sand and gravel resources, and then open the discussion to questions from the committee.

Sand and gravel are not romantic geologic resources, such as gold and diamonds. But, unlike their more famous cousins, they are absolutely critical to society. These minerals are not pretty, but our homes, our highways, our streets, and shopping centers - most of the physical community "infrastructure" we commonly talk about, absolutely require large supplies of sand and gravel.

If it's made of concrete or mortar, someone mined sand and gravel. Sand and gravel are regarded as common minerals, but where they are not present, costs-of-living tend to be high. I once lived on the island of St. Croix, in the U.S. Virgin Islands, where there was no sand suitable for concrete, but there were lots of termites. Consequently, sand was imported from Puerto Rico by shipload to construct homes. In 1972, concrete was \$75 per cubic yard.

Twenty-three years later, concrete cost in Lawrence is about \$56.50 per yard.

Sand and gravel occur where geological processes placed them, not necessarily where we would like them to occur. The major geological processes involved are erosion, river transportation, and deposition from the flowing river as it slows. Pleistocene glaciers were one of the major geological forces that formed much of

our present sand and gravel resource. Reworked glacial deposits and meltwater flowing from the main continental glaciers north of Kansas and the mountain glaciers of the Rockies supplied great quantities of rock debris to the Kansas River system. Locally derived gravel was deposited in the Neosho.

Although the Kansas river system is capable during flood of transporting additional multi-size sand and some gravel downstream to replenish supplies being extracted, modern dams and reservoirs block most such movement. On the Kansas River, Tuttle Creek, Milford, and Perry reservoirs intercept any coarse sediment that would otherwise flow to the Missouri. Only in times of high flood does the Kansas system now transport significantly large sediment through unobstructed reaches.

The sources of additional sand and gravel for the Kansas River are few. Some sediment is eroded from the Kansas landscape, both rural and developed, but most of this sediment is very fine-grained, and is transported as suspended load. Tributaries to the Kansas that drain areas where the Dakota Sandstone is exposed will supply fine sand, some may come from erosion of the Ogallala, but most of the sand that is transported through the system appears to be of Pleistocene origin. That is, much sand and gravel was deposited in the river during the last great glaciation, and now is exhumed occasionally by large floods, and re-transported further downstream.

We have no control of where these deposits may occur - the energy of the river at the place and at the time the deposit was formed determines the quality and type of sand or gravel to be found. Thirty Kansas Counties produce no sand and gravel according to our records, mostly in southeastern Kansas and east-central Kansas south of the Kansas River border counties.

The value (and thus the price for the resource) of any mineral deposit is determined by the costs of extraction, processing and transportation coupled to its rarity.

We geologists refer to minerals as being of high "unit value" or high "place value." By this we mean that some minerals are intrinsically very valuable, such as native gold, and thus can be mined by expensive methods and transported long

distances economically, thus, high "unit" value - \$300 per ounce is clearly a high "unit value."

Sand and gravel, on the other hand, have low unit values, \$5 per ton in Lawrence, but a very high place value. It costs about \$.20 per ton-mile to transport sand and gravel, and huge quantities are needed for most projects. Therefore, the closer the source of the sand and gravel to the place it is needed, the better. Since the resource is of low "unit value," any cost increase in processing, such as overburden stripping or pit reclamation, really impacts the price of the resource, and the costs to the community. Thus, sand and gravel have a very high "place value."

In the Kansas River system area, the most accessible sand and gravel is in the river itself, where there is little cost to removing overburden and access to the glacial sands is easy. Prime farmland is not lost, and the river itself helps rearrange the scars of mining when mining is finished.

Please now refer to the first attachment "Sand and Gravel Production in the State of Kansas" by Dr. David Grisafe, who has compiled a summary of sand and gravel production and usage for your reference. Please note on Table 1 that six counties produced sand and gravel from the Kansas River in 1992. Table 2 shows the tonnage from Kansas River dredges and the revenues to the state. A change in revenues through royalty increase and a drop in production coincide in 1990.

Royalty rates dropped in 1992 and production resumed, but at a lower volume on average. Table 3 shows per capita consumption of sand and gravel. A point to be made here is that we use a lot of sand and gravel in Kansas, over 5 tons per person in 1994. Construction of highways and large urban development, such as in Johnson County, requires huge amounts of sand and gravel for concrete, foundations, fill, and masonry.

The locations of significant sand and gravel extraction operations in river floodplains in Kansas is Figure 1. Figure 2 shows the location of river dredging operations along the Kansas River.

Attachment 2 is a bit more technical and is presented for background. Dr. Lawrence Brady has prepared a synopsis of the occurrence of sand and gravel along the Kansas River through the means of cross-sections showing the location of favorable deposits, highly generalized, but from drill-hole data done by the Kansas Geological Survey.

Figure 1 and 2 are generalized diagrams showing how erosion and deposition occur in river systems, and Figures 3-5 are cross sections along the Kansas River.

This has been a brief introduction to river erosion and sedimentation, and to the issue of supplying a necessary geological resource to Kansas for its development. We appreciate being invited to make this presentation. We will try to answer any questions you may have. Thank you.

Oct. 3, 1995
REVISION

SAND AND GRAVEL PRODUCTION IN KANSAS

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for

House Energy and Natural Resources Committee

SAND AND GRAVEL PRODUCTION IN THE STATE OF KANSAS

Sand and gravel production is an important part of the state's mineral production. The U.S. Bureau of Mines estimates that 1994 production amounted to 13.5 million tons at a value of \$37.1 million, equivalent to \$2.75/ton. The widespread use of this mineral commodity for construction, notably concrete, is why sand and gravel are so important. There are three basic methods of producing sand and gravel: river dredges, pit or lake dredges, and dry pits. All are used in Kansas.

RIVER DREDGES

The most economical method for producing sand and gravel is river dredging where the sand is sucked up from the bed of the river and subsequently screened into desired size fractions. The quality of the sand can vary greatly and one producer commented that every time the dredge is moved to a new position along an arc in the river, the quality changes. In addition, the top few feet may contain trash such as trees, brush, and foreign objects. Dredges are designed to eliminate most debris from being drawn into the sand slurry being removed. Details of 1992 production are listed in Table 1 while Table 2 shows the revenue generated by the mineral tax and calculated fiscal year tonnages for the Kansas River dredges since 1980. Current locations of all river dredges in Kansas are in the Kansas River (see map).

TABLE 1

1992 KANSAS RIVER DREDGE PRODUCTION OF SAND AND GRAVEL
Production and value supplied by U.S. Bureau of Mines

RIVER DREDGES	TONS	DOLLAR VALUE
Douglas	440,707	987,347
Johnson	905,800	2,361,650
Pottawatomie	84,800	227,900
Riley	143,949	236,076
Wyandotte	443,500	1,038,600
Shawnee	560,686	1,242,997
TOTALS	2,579,442	6,094,570

Tonnage represents 23.7% of total production in Kansas during 1992. Value represents 22.3% of 1992 Kansas total production value. Average value is \$2.36/ton compared to \$2.51/ton for state total.

TABLE 2

SAND AND GRAVEL REVENUE TO KANSAS FROM RIVER DREDGES AND
CALCULATED TONNAGE BASED ON FISCAL YEAR RESULTS

YEAR	REVENUES (FY)	TONNAGE
1980	73,500	3,675,000
1981	55,000	2,750,000
1982	40,600	2,030,000
1983	48,800	2,440,000
1984	57,673	2,883,650
1985	75,892	3,794,600
1986	87,586	4,379,300
1987	79,451	3,972,550
1988	78,434	3,921,700
1989	65,485	3,274,250
1990*	169,164	1,127,760
1991	180,641	2,258,012
1992	159,625	1,995,312
1993	159,168	1,989,600
1994	203,278	2,540,975
1995**	273,242	3,415,525

1995 includes one dredge on the Missouri River.

MINERAL TAX RATES FOR SAND AND GRAVEL

FY 1980 THROUGH 1989	\$0.02/TON
*FY 1990:	\$0.15/TON
FY 1991 TO DATE:	\$0.08/TON

FISCAL YEAR 1994 RIVER DREDGE PRODUCTION

During 1994, there were no longer river dredges in Pottawatomie and Riley Counties. The improved business climate, and new operations (including one on the Missouri River on the Kansas side) boosted taxable river dredge production to a little more than 3.4 million tons. Actual tonnage from the Kansas River was about 2.4 million tons. The value for 1994 production is unknown. The latter tonnage represents about 16.2% of the U.S.B.M. estimated total Kansas sand and gravel production for 1994. Although prices vary considerably with geographical area and end use of the product, the

price for concrete sand in Lawrence as of September 11, 1995 was about \$5.00/ton.

DREDGE PRODUCTION LIMITS ON THE KANSAS RIVER

In February, 1991, the U.S. Army Corps of Engineers imposed production limits on the Kansas River dredge operations. This had a major impact on these producers because some operations had been producing about 1 million tons per dredge. Some of the producers, while initially opposed to these restrictions, now comment that the Corps of Engineers probably did everyone a favor despite the added expense to producers. The Corps limits have apparently eliminated potential problems associated with lowering the bed of the river and have to date allowed adequate recharge to support present dredge activities. Whether this holds true over the long term is uncertain.

PIT/LAKE DREDGES ALONG THE FLOODPLAINS OF KANSAS RIVERS

Pit or lake dredges are located along the floodplains of the river where sand and gravel has been deposited during the past. This method of production is generally much more expensive because it requires removal of overburden (mostly silt and soil) before reaching the depth where the sand is located. The quality of the sand can vary greatly. Unlike river dredging where there is continual recharge of the sand, the pit or lake dredge has a limited lifetime. In addition, the pit dredge generally removes some of the most productive farmland the state has to offer.

CALENDAR YEAR 1994 PIT/LAKE (ALLUVIAL) DREDGE PRODUCTION

Locations and tonnages were provided by Conservation Commission. There were over 60 sites with a combined production of 4,436,012 tons. Values are unknown for 1994 production. The tonnage represents 29.8% of the U.S.B.M. estimated total Kansas production for 1994. The attached map shows the locations of these operations in 1995.

DRY PITS

Dry pit production in Kansas occurs primarily in the western portion of the state where present river deposited sand is limited or non-existent. The quality is quite variable at these pits and they are often limited in reserves. Generally smaller in size and output than dredge operations, there are large numbers (about 300) of such operations and their total output represents about 50% of the state's total sand

and gravel production. Some concern has been expressed that known resources in the northwestern portion of the state are limited.

PER CAPITA CONSUMPTION

The per capita consumption figures for Kansas are given in Table 3. Not surprisingly, the figures show considerable variation reflecting the business cycle. Overall, the per capita figures vary from 3.85 to 6.42 tons. The figures for 1994 indicate that per capita consumption of sand and gravel from Kansas River dredges is 1 ton per person.

TABLE 3

PER CAPITA CONSUMPTION OF SAND AND GRAVEL

<u>YEAR</u>	TONNAGE (USBM)	POPULATION (THOUSANDS)	PER CAPITA USAGE (TONS PER PERSON)
1970	12,968	2,249	5.77
1980	12,124	2,364	5.13
1981*	10,500	2,390	4.39
1982	9,720	2,410	4.03
1983*	12,400	2,416	5.13
1984	11,796	2,424	4.87
1985*	13,200	2,427	5.44
1986	15,609	2,433	6.42
1987*	15,600	2,445	6.38
1988	10,760	2,462	4.37
1989*	13,000	2,473	5.26
1990	10,737	2,478	4.33
1991*	9,600	2,491	3.85
1992	11,934	2,515	4.75
1993*	13,090	2,531	5.17
1994	14,850	2,554	5.81

* DENOTES ESTIMATED AMOUNTS BY U.S. BUREAU OF MINES DURING ODD NUMBERED YEARS.

TRANSPORTATION COSTS

The Kansas Aggregate Producers Association estimates that the current transportation costs are about \$0.20/ton mile. Thus, a 50,000

lb. or 25 ton truckload costs the buyer an additional \$5.00/mile. Obviously, hauling distance is an important factor in holding down construction costs. In view of such transportation costs coupled with the relatively high growth along the Topeka-Kansas City corridor, Kansas River sand and gravel operations assume special importance to the economy of the state.

Information for the hearing on "Study of the impacts of sand and gravel dredging in Kansas rivers, including a review of sand royalties", before the House Energy and Natural Resources Committee,---Tuesday September 12, 1995.

by
Lawrence L. Brady
Kansas Geological Survey

Sand and gravel is the most widespread non-fuel mineral resource in Kansas. Production of this commodity in commercial quantities is derived from at least 75 counties. The southeast and east-central areas south of the counties that border on the Kansas River are the areas of the state with very limited sand and gravel production. In the western part of the state, outside of the area along the Arkansas River, sand and gravel are derived from dry pits in the Ogallala Formation and equivalent-aged units formed of river-derived materials carried by rivers from late Tertiary (Miocene) uplift of the Rocky Mountain area and deposited on the high plains. The sand and gravel deposits associated with the rivers in the western areas of the state represent deposits of recent age, but they also contain deposits of older late Tertiary deposits. Deposits of recent sand and gravel are mainly derived from the erosion of terrace deposits of the older late Tertiary deposits. In the Arkansas River area, the sand and gravel is derived from stream erosion in the Rocky Mountains in recent times and from erosion of late Tertiary deposits on the plains. Underlying these recent sand and gravels are also stream deposits of the late Tertiary age.

In eastern Kansas two additional source areas provide different types of materials to deposits in those areas. Along the Neosho River is considerable chert gravel deposits that are derived from chert- and flint-rich lower Permian-age limestone rock that make up the Flint Hills area of eastern Kansas. Streams flowing eastward from the general area of the Flint Hills carried the resistant chert and flint gravels and deposited them as high terrace gravels in southeastern Kansas, and in stream valleys especially along the present Neosho River area.

In northeast Kansas, glaciers had a strong effect on the presence of important sand and gravel deposits in that area. The area in northeast Kansas that had a strong glacial influence is outlined on the geologic map of the state. The period of time of large continental glaciation in North America is referred to as the Pleistocene Period. Substantial amounts of the sand and gravel in the lower portion of the rivers in northeastern Kansas including the Kansas and Missouri rivers, was derived from outwash from the glaciers. Streams flowing into northeastern Kansas from the west also carried large amounts of materials derived from the late Tertiary deposits present in the high plains. The sand and gravel presently being transported by the northeast Kansas rivers was derived mainly from these late Tertiary deposits in the high plains.

Along the meanders of streams are the active processes of erosion and deposition of sediments by the stream. This action results in constant changes within the channel itself. Some of these changes are shown in the generalized diagram of Figure 1, showing the widening and deepening of the valley floor, and in Figure 2 is illustrated the general location of erosion and deposition of sediments within a meander of a stream.

Large amounts of sand and gravel are obtained from the rivers and floodplains of the rivers by dredging or pumping especially in the northeast part of the state. The alluvium of the Kansas River represents a very important source of sand and gravel that is used primarily for construction activity in this populous part of the state. This material is derived primarily from the channel of the river, but it can also be obtained by dredging from the floodplain of the river. However, variation in quality and the presence of thick amounts of silts and clays from overbank deposits during floods can make this a more risky operation. Dredging of the sand and gravel from the channel is providing a relatively inexpensive source of this material. This dredged material represents the deposits recently transported by the river, and also the relatively stable underlying sand and gravel deposits deposited during the glacial times. Similar materials of Recent and Pleistocene age exist in the floodplain of the Kansas River below the silts and clays of the overbank deposits.

Cross-sections of the Kansas River floodplain are shown on the accompanying pages. These cross-sections represent areas near recent dredging or proposed dredging at Topeka (Fig. 3; Section B-B'), a proposed permit area west of Lawrence (Fig. 4; Section D-D'), and an area east of Bonner Springs (Fig. 5; Section C-C'). For each of these three areas, a topographic map of the area, and a general cross-section of the valley is shown, all at the same scale. Test boring information for each cross section is also provided to show the type of material present at each boring location across the valley. With the same scale for each map and section direct comparison can be made of each area for depth and width of the floodplain. Each of the sections were obtained from publications of the Kansas Geological Survey.

Comparison of the floodplain sections show considerable differences in the width of the floodplain at each location, from 3.5 miles at the Lawrence section to 1.5 miles wide at the east Bonner Springs section, and about 2.5 miles wide at Topeka. Note in the Lawrence section, the old oxbow lake that makes up the Lake View Lake that was the active river channel about 100 years ago. Sand and gravel deposits in the area of the oxbow lake (test hole #2) appears to contain a much greater thickness of sand than the area north of the present river location (test holes #3 and 4). Test borings #1 and #6 in Lawrence section D-D' (Fig. 4) are in terrace deposits above the floodplain that are composed mainly of silts and clays.

The floodplain north of the river in section C-C' (Bonner Springs area, Fig. 5) appears to have considerable gravel from approximately 20-30 feet depth to the bedrock as shown by borings #153-158. The Topeka section (B-B', Fig. 3) seems to have quality material in the central part of the channel floodplain with much larger amounts of silt and clay on the outer portion of the floodplain.

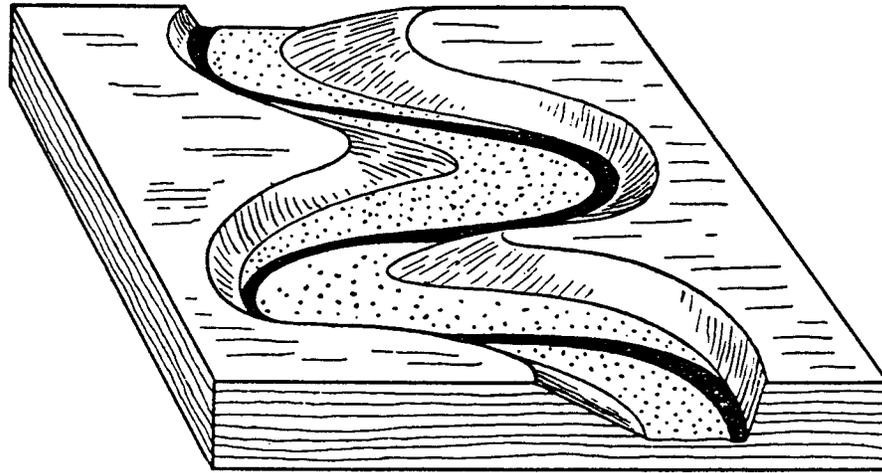


Figure 1. Generalized diagram to show widening and deepening of a valley floor by oblique erosion (vertical and lateral) on the outside of river bends combined with the downstream migration of the bends(meanders). Downstream erosion of the stream will remove the spurs and slip-slopes as shown. Modified from Holmes (1965, p. 533).

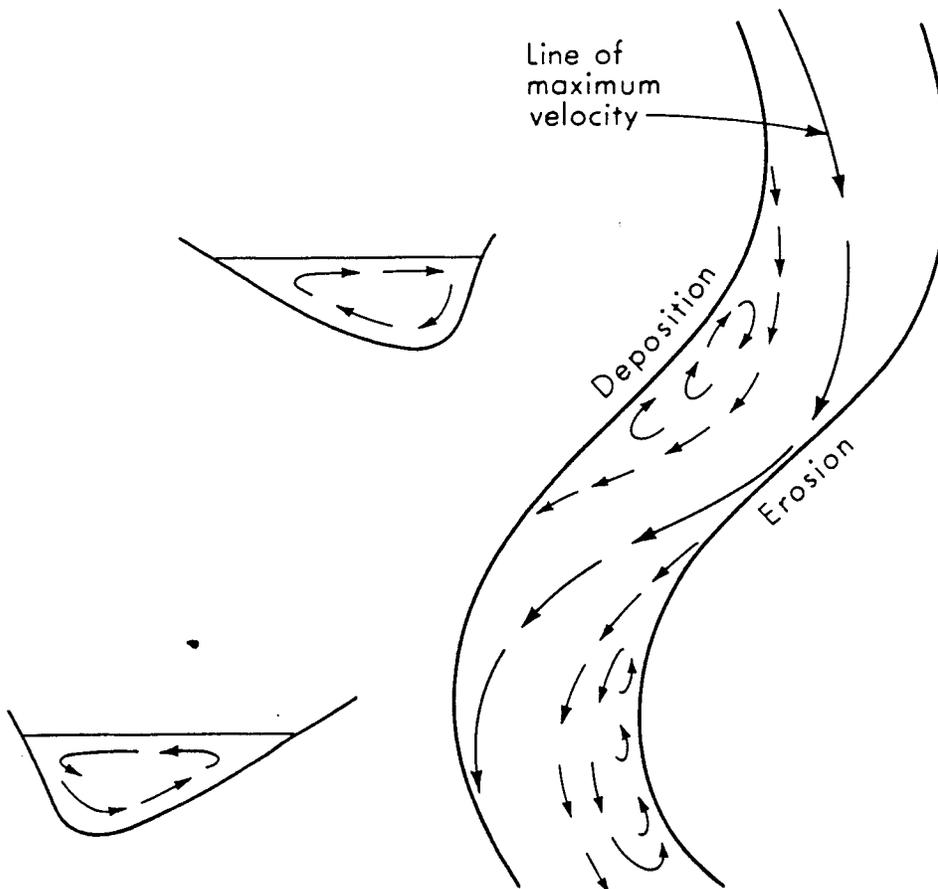


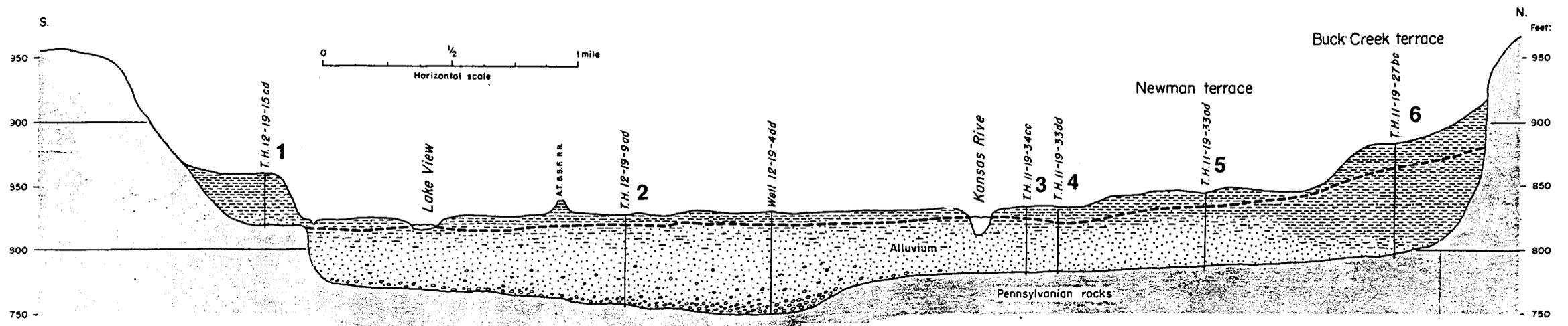
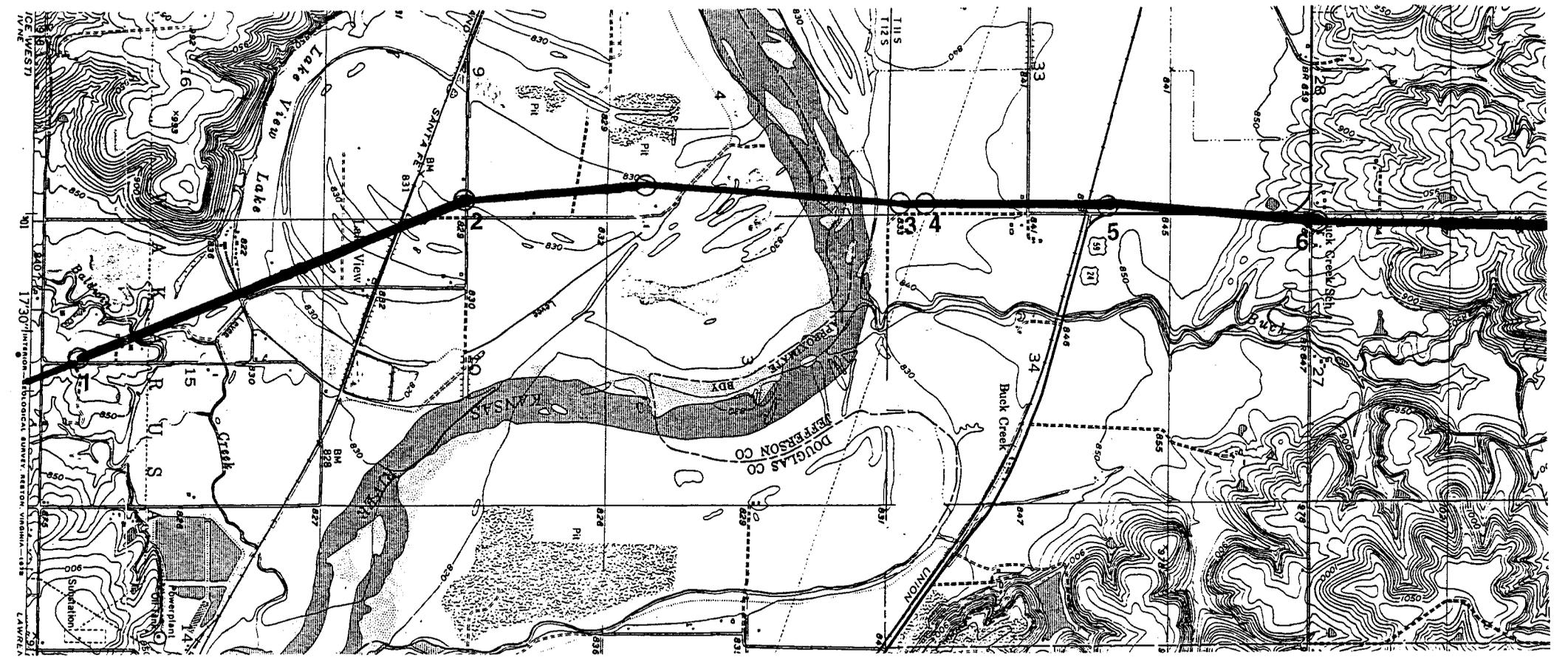
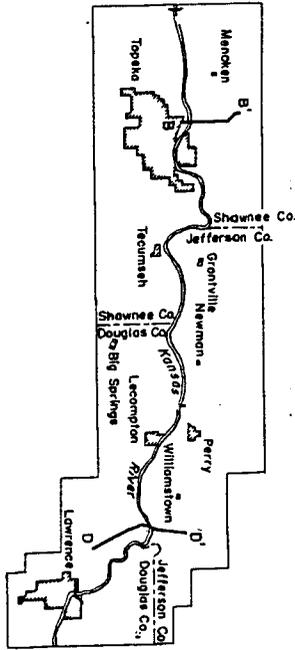
Figure 2. Generalized diagram of a portion of a meander showing the line of maximum velocity and separation of flow that produce areas of deposition and erosion. Transverse sketches show the lateral movement of water at the bends. Modified from Morisawa (1968, p. 139).

LOGS OF TEST HOLES USED IN CROSS-SECTION B-B' ACROSS THE KANSAS RIVER IN THE TOPEKA AREA.

1	<p>11-15-25bb. Sample log of test hole in the SE$\frac{1}{4}$ NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 25, T. 11 S., R. 15 E., Shawnee County; drilled 1950. Surface elevation, 883 feet.</p>
	<p>Thickness, Depth, feet feet</p>
	<p>QUATERNARY—Late Pleistocene to Recent</p>
	<p>Alluvium</p>
	<p>Silt, coarse, brown; contains some sand 4 4</p>
	<p>Silt, clayey, dark-brown; contains some sand and caliche nodules 4 8</p>
	<p>Silt, clayey; contains abundant sticks, leaves, and twigs 2 10</p>
	<p>Sand, medium, layers of clay, and silt toward bottom 18 28</p>
	<p>Granules; contains some sand and gravel 8 36</p>
	<p>Log, rotten 0.5 36.5</p>
	<p>Sand, coarse 7.5 44</p>
	<p>Gravel; contains some sand 4 48</p>
2	<p>11-15-24bc. Sample log of test hole near the SE cor. SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 24, T. 11 S., R. 15 E., Shawnee County; drilled 1950. Surface elevation, 884.6 feet.</p>
	<p>Thickness, Depth, feet feet</p>
	<p>QUATERNARY—Late Pleistocene to Recent</p>
	<p>Alluvium</p>
	<p>Clay, silty, brown 8.5 8.5</p>
	<p>Sand, medium, quartz and feldspar 6.5 15</p>
	<p>Clay, silty, light-brown 0.5 15.5</p>
	<p>Granules; contains some sand and gravel 29.5 45</p>
	<p>Gravel, coarse; contains many boulders of limestone 4 49</p>
	<p>PENNSYLVANIAN—Virgilian</p>
	<p>Limestone, light-gray 1 50</p>
	<p>Shale, calcareous, gray 0.5 50.5</p>
	<p>Shale, silty, blue 3 53.5</p>
3	<p>11-15-13cd. Sample log of test hole in the NW$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 13, T. 11 S., R. 15 E., Shawnee County; drilled 1950. Surface elevation, 890.2 feet.</p>
	<p>Thickness, Depth, feet feet</p>
	<p>QUATERNARY—Late Pleistocene to Recent</p>
	<p>Alluvium</p>
	<p>Silt, dark-brown 5 5</p>
	<p>Clay, silty, brown 8 13</p>
	<p>Sand, very fine 9 22</p>
	<p>Sand, coarse; contains some granules 22 44</p>
	<p>Gravel; contains granite, quartz, chert, and some limestone 7 51</p>
	<p>Sand, coarse; contains some gravel 15 66</p>
	<p>Gravel; contains some granules 13 79</p>
	<p>PENNSYLVANIAN—Virgilian</p>
	<p>Limestone, shaly, gray-white 1 80</p>
	<p>Siltstone, yellow-brown 3.5 83.5</p>
	<p>Shale, blue 1 84.5</p>
4	<p>11-15-13cb. Drillers log of Goodyear test hole No. 6 in the SW$\frac{1}{4}$ NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 13, T. 11 S., R. 15 E., Shawnee County; drilled 1944. Surface elevation, about 892 feet.</p>
	<p>Thickness, Depth, feet feet</p>
	<p>QUATERNARY—Late Pleistocene to Recent</p>
	<p>Alluvium</p>
	<p>Soil 1 1</p>
	<p>Clay 19 20</p>
	<p>Fine sand 4 23</p>
	<p>Sand, medium-coarse, brown 20 43</p>
	<p>Sand, gravel, and some clay balls 32 75</p>
	<p>Sand, gravel, and boulders 15.5 87.5</p>
	<p>PENNSYLVANIAN—Virgilian</p>
	<p>Rock 0 87.5</p>
5	<p>11-15-12cc. Sample log of test hole in the SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 12, T. 11 S., R. 15 E., Shawnee County; drilled 1950. Surface elevation, 885.0 feet.</p>
	<p>Thickness, Depth, feet feet</p>
	<p>QUATERNARY—Pleistocene to Recent</p>
	<p>Alluvium</p>
	<p>Clay, silty, dark-brown 5 5</p>
	<p>Silt, coarse, brown 13.5 18.5</p>
	<p>Sand, fine, tan; contains coarse silt 6 24.5</p>
	<p>Sand, coarse; contains some pebbles 9.5 34</p>
	<p>PENNSYLVANIAN—Virgilian</p>
	<p>Shale, silty, blue 1 35</p>
	<p>Limestone, white 1 36</p>

LOGS OF TEST HOLES USED IN CROSS-SECTION D-D' ACROSS THE KANSAS RIVER IN THE LAWRENCE AREA.

1	12-19-15cd. Sample log of test hole in the SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 15, T. 12 S., R. 19 E., Douglas County; drilled 1950. Surface elevation, 860 feet.	Thickness, feet	Depth, feet
	QUATERNARY—Pleistocene		
	Sanborn formation		
	Soil, clayey, black	3	3
	Silt and clay, brown	4	7
	Silt, clayey, red	33	40
	Silt, clayey, red, with some fine sand	12	52
	Sand, medium, to gravel	1	53
	PENNSYLVANIAN—Virgilian		
	Shale, blue-gray	1	54
2	12-19-9ad. Sample log of test hole in the SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 9, T. 12 S., R. 19 E., Douglas County; drilled 1950. Surface elevation, 828 feet.	Thickness, feet	Depth, feet
	QUATERNARY—Pleistocene		
	Alluvium		
	Sand, fine to coarse, composed of quartz and feldspar	8	8
	Sand, medium to coarse; contains snail shells	12	20
	Sand, coarse, quartzitic	10	30
	Sand, coarse, and granules of feldspar	18	48
	Sand, coarse, and gravel containing limestone fragments	12	60
	Gravel, coarse, and granules of quartz and feldspar with weathered shale	8	68
	PENNSYLVANIAN—Virgilian		
	Shale, blue-gray	2	70
3	11-19-34cc. Sample log of test hole in the SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 34, T. 11 S., R. 19 E., Jefferson County; drilled 1950. Surface elevation, 833 feet.	Thickness, feet	Depth, feet
	QUATERNARY—Pleistocene		
	Alluvium		
	Silt, clayey, dark-brown	3	3
	Clay, silty, brown	13	16
	Clay, blue-gray, some silt	4	20
	Silt, fine, and sand	13	33
	Sand, coarse, and gravel of feldspar and quartz	7	40
	Sand, fine to medium, quartz and feldspar	8	48
	PENNSYLVANIAN—Virgilian		
	Limestone, white	1	49
4	11-19-33dd. Sample log of test hole in the SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 33, T. 11 S., R. 19 E., Jefferson County; drilled 1950. Surface elevation, 834 feet.	Thickness, feet	Depth, feet
	QUATERNARY—Pleistocene		
	Alluvium		
	Road fill of fine gravel	1.5	1.5
	Clay, silty, dark-gray	3.5	5
	Clay, silty, dark-brown	9.5	14.5
	Sand, silty, fine, with feldspar and quartz	21.5	36
	Sand, coarse, and granules of feldspar and quartz	13	49
	PENNSYLVANIAN—Virgilian		
	Limestone	2.5	51.5
5	11-19-33ad. Sample log of test hole in the SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 33, T. 11 S., R. 19 E., Jefferson County; drilled 1950. Surface elevation, 843 feet.	Thickness, feet	Depth, feet
	QUATERNARY—Pleistocene		
	Alluvium		
	Silt, clayey, fine, dark-brown	6	6
	Silt, light to medium brown, with some clay	8.5	14.5
	Clay, silty, light-brown	10.5	25
	Clay, silty, brownish-gray with plant remains	8	33
	Sand, quartzite, and granules of feldspar	7	40
	Sand, coarse, quartzite	5	45
	Sand, coarse, quartzitic, and gravels of feldspar	15	60
	PENNSYLVANIAN—Virgilian		
	Shale, blue	2	62
6	11-19-27bc. Sample log of test hole in the SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 27, T. 11 S., R. 19 E., Jefferson County; drilled 1950. Surface elevation, 887 feet.	Thickness, feet	Depth, feet
	QUATERNARY—Pleistocene		
	Sanborn formation		
	Soil, black	2	2
	Silt, clayey, red, sometimes gritty with caliche	38	40
	Clay, silty, red, gritty with caliche	10	50
	Clay and silt, reddish-brown	12	62
	Clay and silt, red, with a few shale pebbles	28	90
	PENNSYLVANIAN—Virgilian		
	Shale, gray	7	97



D-D' Figure 4. Cross-Section of the Kansas River (D-D') northwest of Lawrence, Kansas. Modified from Davis and Carlson, 1952, KGS Bull. 96, Part 5.

Modified from USGS 7.5' Williamstown Quadrangle.

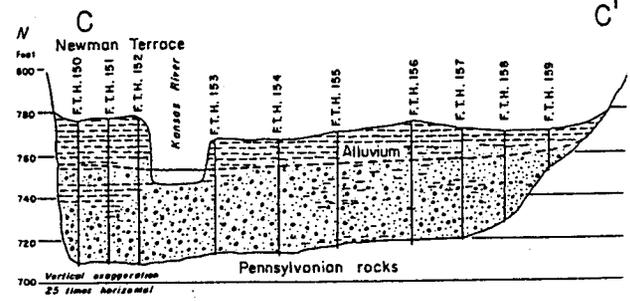
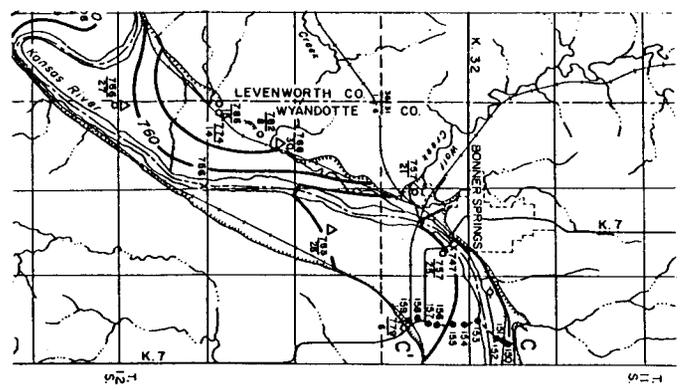
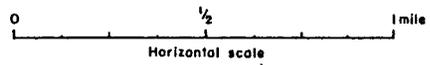
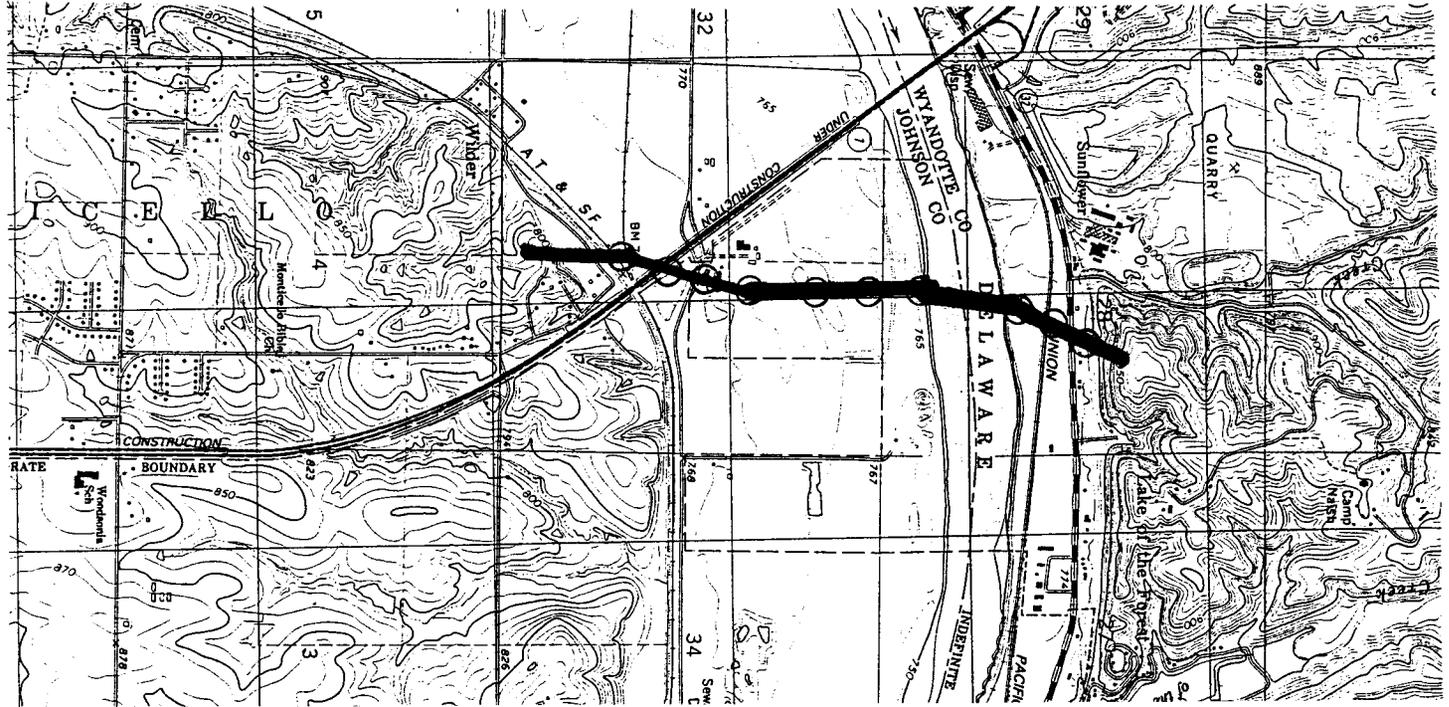


Figure 5. Cross-Section of the Kansas River (C-C') just east of Bonner Springs, Kansas. Modified from Dufford, 1958, KGS Bull. 130, Part 1.

LOGS OF TEST HOLES USED IN CROSS-SECTION C-C' ACROSS THE KANSAS RIVER IN THE BONNER SPRINGS AREA.

150

11-23-28dab—Log of test hole 150 (Fishel) in the NW¼ NE¼ SE¼ sec. 28, T. 11 S., R. 23 E., 78 feet south and 3 feet east of center of intersection of lane with highway, Wyandotte County, drilled by Kansas Geological Survey, 1944. Surface altitude, 776.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Upper Pleistocene to Recent		
Alluvium		
Silt, clayey, dark gray	8	8
Silt, soft, yellow gray	17	25
Sand, coarse to fine, and silt, gray to yellow gray	5	30
Silt, clayey, blue gray, medium sand, and medium gravel	10	40
Sand, coarse to fine, some medium gravel and clayey, blue-gray silt	10	50
Gravel, medium to fine, and medium sand, greenish to brown	18	68
PENNSYLVANIAN—Missourian		
Limestone, very hard, gray white	1	69

151

11-23-28dba—Log of test hole 151 (Fishel) in the NE¼ NW¼ SE¼ sec. 28, T. 11 S., R. 23 E., on west side of lane running south from highway, 63 feet south and 15 feet west of center of railroad crossing, Wyandotte County, drilled by Kansas Geological Survey, 1944. Surface altitude, 777.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Upper Pleistocene to Recent		
Alluvium		
Silt, partly clayey, yellow gray downward to gray	12	12
Silt, soft, buff	14	26
Sand, coarse to fine, and some fine gravel	5	31
Silt, clayey, blue gray	13	44
Silt, clayey, blue gray; contains some medium to fine sand	4	48
Gravel, coarse to fine, and sand, brown	20	68
PENNSYLVANIAN—Missourian		
Limestone, hard, gray white	1	69

152

11-23-28dbd—Log of test hole 152 (Fishel) in the SE¼ NW¼ SE¼ sec. 28, T. 11 S., R. 23 E., on west side of lane running south from highway, 12 feet north of river and 6 feet west of center of lane, Wyandotte County, drilled by Kansas Geological Survey, 1944. Surface altitude, 779.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Upper Pleistocene to Recent		
Alluvium		
Silt, dark yellow gray; contains much fine sand	22	22
Sand, coarse to fine, and some fine gravel	9	31
Sand, coarse to fine, silt, clayey, blue gray, and some medium gravel	7	38
Gravel, medium to fine, medium sand, and some clay, greenish gray	17	55
Gravel, coarse to fine, and coarse sand	5	60
Gravel, coarse to fine, and some coarse sand	11	71
PENNSYLVANIAN—Missourian		
Limestone, very hard, white	1	72

153

11-23-28dcc—Log of test hole 153 (Fishel) in the SW¼ SW¼ SE¼ sec. 28, T. 11 S., R. 23 E., on south bank of river and just northwest of curve of lane, Johnson County, drilled by Kansas Geological Survey, 1944. Surface altitude, 767.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Upper Pleistocene to Recent		
Alluvium		
Silt, light buff; contains much medium to fine sand	17	17
Silt, blue gray, fine gravel, and medium sand	3	20
Gravel, fine to medium, and medium sand; contains some blue-gray silt at depth of 34 feet	20	40
Gravel, medium to fine, and medium sand	10	50
Gravel, coarse to fine, and medium sand	5	55
PENNSYLVANIAN—Missourian		
Limestone, hard, white and light brown	1	56

154

11-23-33abb—Log of test hole 154 (Fishel) in the NW¼ NW¼ NE¼ sec. 33, T. 11 S., R. 23 E., 10 feet east of center of lane, 0.15 mile south of river, and 0.45 mile north of highway, Johnson County, drilled by Kansas Geological Survey, 1944. Surface altitude, 766.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Upper Pleistocene to Recent		
Alluvium		
Silt, gray brown and gray buff	6	6
Sand, medium to fine, brown, and some light-gray-buff silt	4	10
Sand, coarse to fine, brown	9	19
Gravel, fine to medium, and medium sand	11	30
Gravel, coarse to fine, medium sand, and some silt, gray green	10	40
Gravel, coarse to fine, and medium sand	10	50
Gravel, coarse to fine	3	53
PENNSYLVANIAN—Missourian		
Limestone, hard, buff and pink	0.5	53.5
Shale, hard, calcareous, fossiliferous, yellow to buff	1.5	55

11-23-33abc—Log of test hole 155 (Fishel) in the SW¼ NW¼ NE¼ sec. 33, T. 11 S., R. 23 E., on east side of lane, 3 feet west and 6 feet south of corner fence post, 0.25 mile south of river and 0.35 mile north of highway, Johnson County, drilled by Kansas Geological Survey, 1944. Surface altitude, 769.9 feet.

155

	Thickness, feet	Depth, feet
QUATERNARY—Upper Pleistocene to Recent		
Alluvium		
Silt, dark gray	2	2
Silt, gray buff to light gray	8	10
Silt, soft, light gray	5	15
Sand, medium to fine, and some fine gravel	5	20
Gravel, medium, medium sand, and silt, gray	10	30
Gravel, medium to fine, medium sand, and much silt, gray	10	40
Gravel, medium to fine	8.5	48.5
Boulders, consisting of limestone, pink quartzite, and coarse gravel	1.5	50
Clay, blue gray, yellow, and buff; contains some gravel and sand	3	53
PENNSYLVANIAN—Missourian		
Limestone, fairly hard, light buff and brown	2	55

11-23-33acb—Log of test hole 156 (Fishel) in the NW¼ SW¼ NE¼ sec. 33, T. 11 S., R. 23 E., 15 feet east of center of lane, 0.45 mile south of river, and 0.15 mile north of highway, Johnson County, drilled by Kansas Geological Survey, 1944. Surface altitude, 774.9 feet.

156

	Thickness, feet	Depth, feet
QUATERNARY—Upper Pleistocene to Recent		
Alluvium		
Silt, gray buff; contains much medium sand	8	8
Sand, medium to fine, interbedded with silt, blue gray	11	19
Sand, coarse to fine, some medium to fine gravel, and some silt	11	30
Gravel, medium to fine, and medium sand	2	32
Gravel, medium to fine, medium sand, and silt, blue gray	4	36
Gravel, medium to fine, and medium sand	14	50
Gravel, coarse to fine, and medium sand	6	56
PENNSYLVANIAN—Missourian		
Limestone, hard, light buff and brown; some blue-gray shale	2	58

11-23-33acc—Log of test hole 157 (Fishel) in the SW¼ SW¼ NE¼ sec. 33, T. 11 S., R. 23 E., 8 feet east of center of road, 0.55 mile south of river, and 0.05 mile north of highway, Johnson County, drilled by Kansas Geological Survey, 1944. Surface altitude, 770.6 feet.

157

	Thickness, feet	Depth, feet
QUATERNARY—Upper Pleistocene to Recent		
Alluvium		
Silt, gray buff; contains much sand	7	7
Sand, coarse to fine, and some medium gravel	18	25
Gravel, coarse to fine, medium sand, and some silt, blue gray	5	30
Gravel, medium to fine, medium sand, and some pebbles	10	40
Gravel, coarse to fine, and coarse sand	11	51
PENNSYLVANIAN—Missourian		
Limestone, hard, light gray	1	52

11-23-33dbb—Log of test hole 158 (Fishel) in the NW¼ NW¼ SE¼ sec. 33, T. 11 S., R. 23 E., on west side of highway, 0.65 mile south of river and 0.05 mile south of turn in highway, 66 feet north and 6 feet west of telephone pole, Johnson County, drilled by Kansas Geological Survey, 1944. Surface altitude, 768.8 feet.

158

	Thickness, feet	Depth, feet
QUATERNARY—Upper Pleistocene to Recent		
Alluvium		
Silt, gray and light buff	6	6
Sand, coarse to fine	7	13
Sand, coarse to fine, and some fine gravel	7	20
Gravel, fine, and medium sand	10	30
Gravel, medium to fine, and medium sand	11.5	41.5
PENNSYLVANIAN—Missourian		
Limestone, hard, gray white	0.5	42

11-23-33dbc—Log of test hole 159 (Fishel) in the SW¼ NW¼ SE¼ sec. 33, T. 11 S., R. 23 E., 0.15 mile south of turn in highway, 75 feet west and 30 feet north of center of south railroad crossing, Johnson County, drilled by Kansas Geological Survey, 1944. Surface altitude, 769.9 feet.

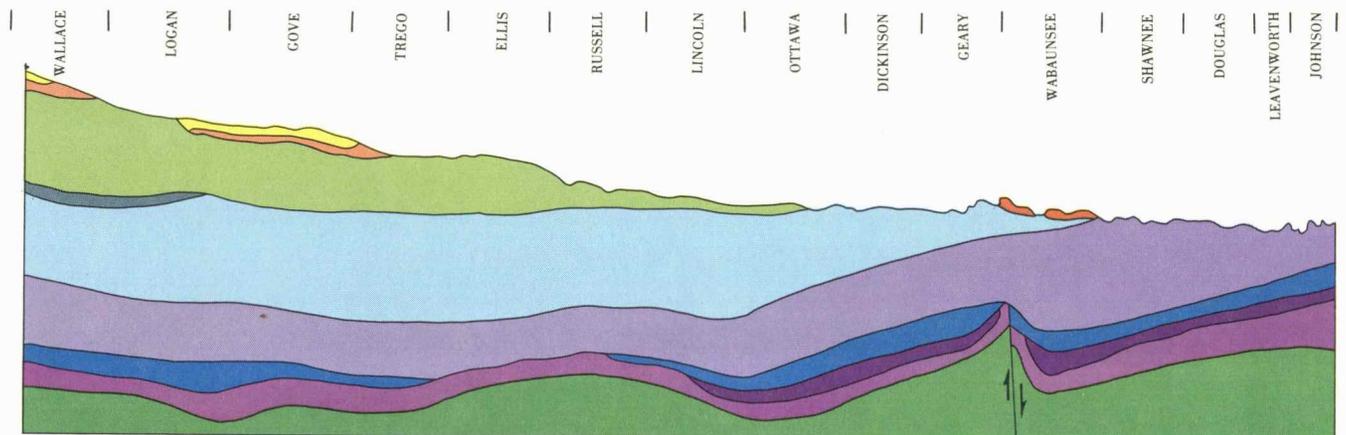
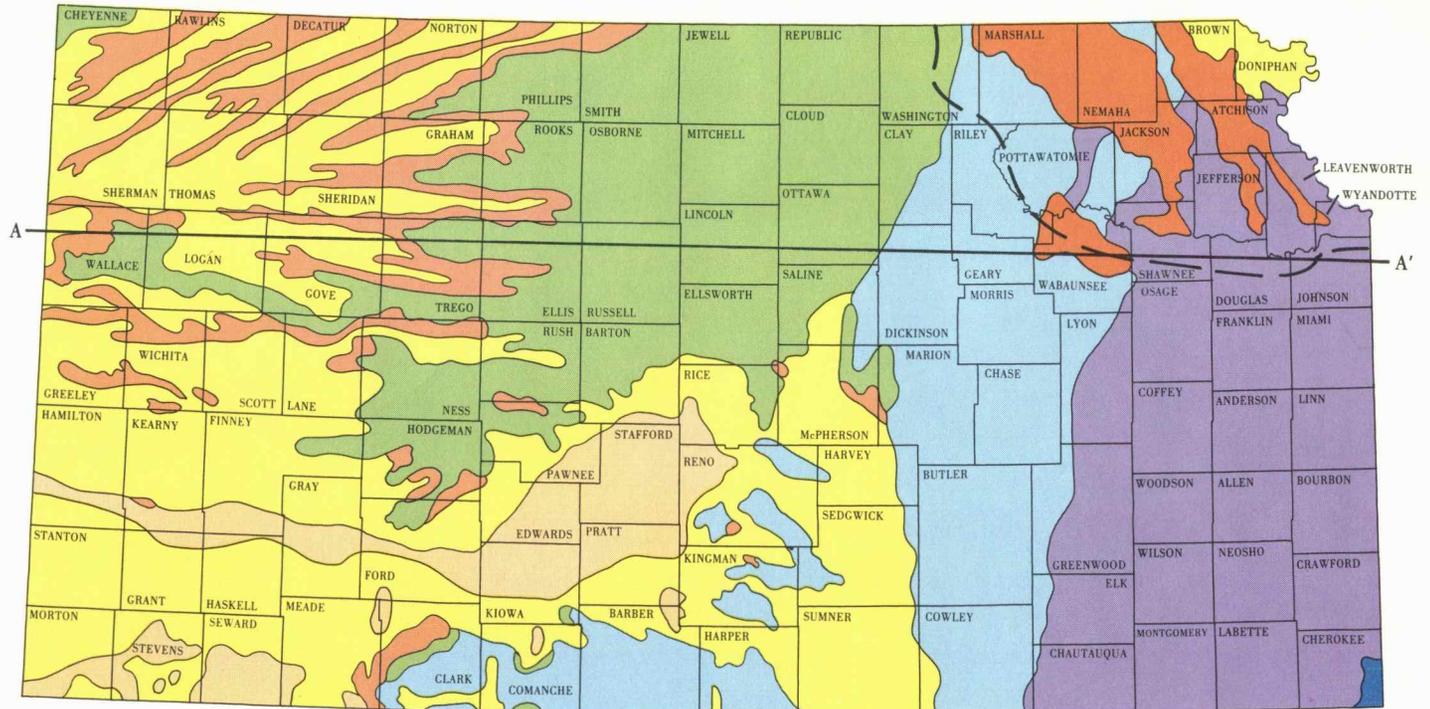
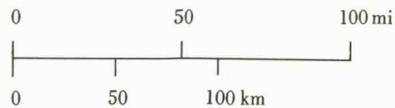
159

	Thickness, feet	Depth, feet
QUATERNARY—Upper Pleistocene to Recent		
Alluvium		
Silt, gray and buff	8	8
Sand, medium to fine	2	10
Sand, coarse to fine, some medium gravel, and many concretions of sand-limonite	5	15
Limestone block	0.5	15.5
Gravel, coarse to medium	1	16.5
PENNSYLVANIAN—Missourian		
Limestone, very hard, light gray	0.5	17
Shale, yellow buff	1	18

Generalized Geologic Map of Kansas

EXPLANATION

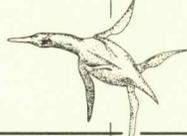
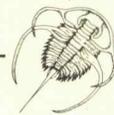
- QUATERNARY SYSTEM
Loess and river valley deposits
- Sand dunes
- Glacial drift deposits
- Limit of Kansan Glacier
- TERTIARY SYSTEM
- CRETACEOUS SYSTEM
- JURASSIC SYSTEM
- PERMIAN SYSTEM
- PENNSYLVANIAN SYSTEM
- MISSISSIPPIAN SYSTEM
- SILURIAN-DEVONIAN SYSTEMS
- CAMBRIAN-ORDOVICIAN SYSTEMS
- PRECAMBRIAN SYSTEM
- A—A' Line of cross section



Geologic cross section below I-70

KANSAS GEOLOGIC TIMETABLE

(Not scaled for geologic time or thickness of deposits)

ERAS	PERIODS	EPOCHS	EST. LENGTH (YEARS) *	DESCRIPTION		
CENOZOIC	QUATERNARY	HOLOCENE	 10,000+	Early, the land was stable with some erosion. Glaciers moved into the northeast at least twice. Later the climate was dry. Sand dunes were formed by wind in the west. Volcanic ash was blown in from California, New Mexico, and Wyoming.	1.6	
		PLEISTOCENE	1,590,000			
	TERTIARY		PLIOCENE	3,700,000	Rocks found are part of the Ogallala Formation (sand, gravel, and porous rock), which contains a large quantity of ground water and occurs only in the western third of the state. No rocks were formed in eastern Kansas.	
			 MIOCENE	18,400,000		
			OLIGOCENE	12,900,000		
			EOCENE	21,200,000		
PALEOCENE			8,600,000			
MESOZOIC	CRETACEOUS		77,600,000	Much of the western half was covered by seas. Limestone, sandstone, and chalk formed from sea deposits. Fossils can be found in these rocks, which crop out in central and western Kansas.	66.4	
	JURASSIC		64,000,000	Most rock in Kansas is underground in the west. A few small outcrops are found in the southwest corner.	144	
	TRIASSIC		37,000,000	No rocks have been found in Kansas.	208	
PALEOZOIC	PERMIAN		41,000,000	Much of Kansas was covered by several seas. As they rose and fell, limestone, shale, and chert were deposited. The Flint Hills were formed. When the seas dried up, salt and gypsum were left behind. Salt, now underground, is mined in central Kansas. The Red Hills were formed from deposits of shale, siltstone, sandstone, gypsum, and dolomite.	245	
	PENNSYLVANIAN		34,000,000	For much of the period the land was flat. Seas and swamps came and went; coal formed in swamps from dead plants. Shale, limestone, sandstone, chert, and conglomerates were deposited. Two ridges of hills, the Nemaha uplift and the Central Kansas uplift, appeared; both are now buried. Pennsylvanian rocks are found at the surface in eastern Kansas.	286	
	MISSISSIPPIAN		40,000,000	Repeated layers of limestone, shale, and sandstone indicate that seas rose and fell. Mississippian rocks are the oldest found at the surface and are in the southeast corner; elsewhere these rocks are only underground.	320	
	DEVONIAN		48,000,000	Seas covered Kansas during much of the period. Limestone, shale, and sandstone deposits are only underground.	360	
	SILURIAN		30,000,000	Land was uplifted and seas disappeared. Limestone deposits are found only underground.	408	
	ORDOVICIAN		67,000,000	Seas covered parts of Kansas during much of the period. Dolomite and sandstone are only underground.	438	
	CAMBRIAN		65,000,000	Early, the climate was dry and many rocks eroded. Later, parts of Kansas were covered by seas. Dolomite, sandstone, limestone, and shale are now underground.	505	
PRECAMBRIAN			3,930,000,000	These rocks are the oldest on earth. In Kansas, they are only found deep below the surface and not much is known about them. Many are igneous and metamorphic and have gone through many changes.	570	
					4,500?	

MILLION YEARS PAST

Eons not shown

* Decade of North American Geology 1983 Geology Time Scale, Geological Society of America