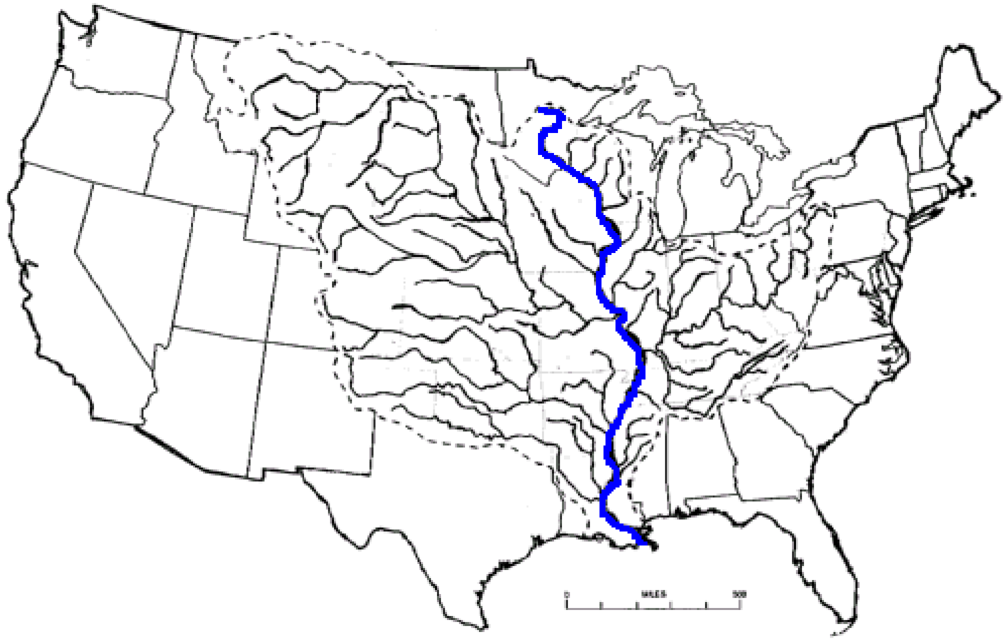
The Mississippi

Heartland River of the Nation

John C. Kammerer

1996

THE MISSISSIPPI—
Heartland River of the Nation



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THE MISSISSIPPI—

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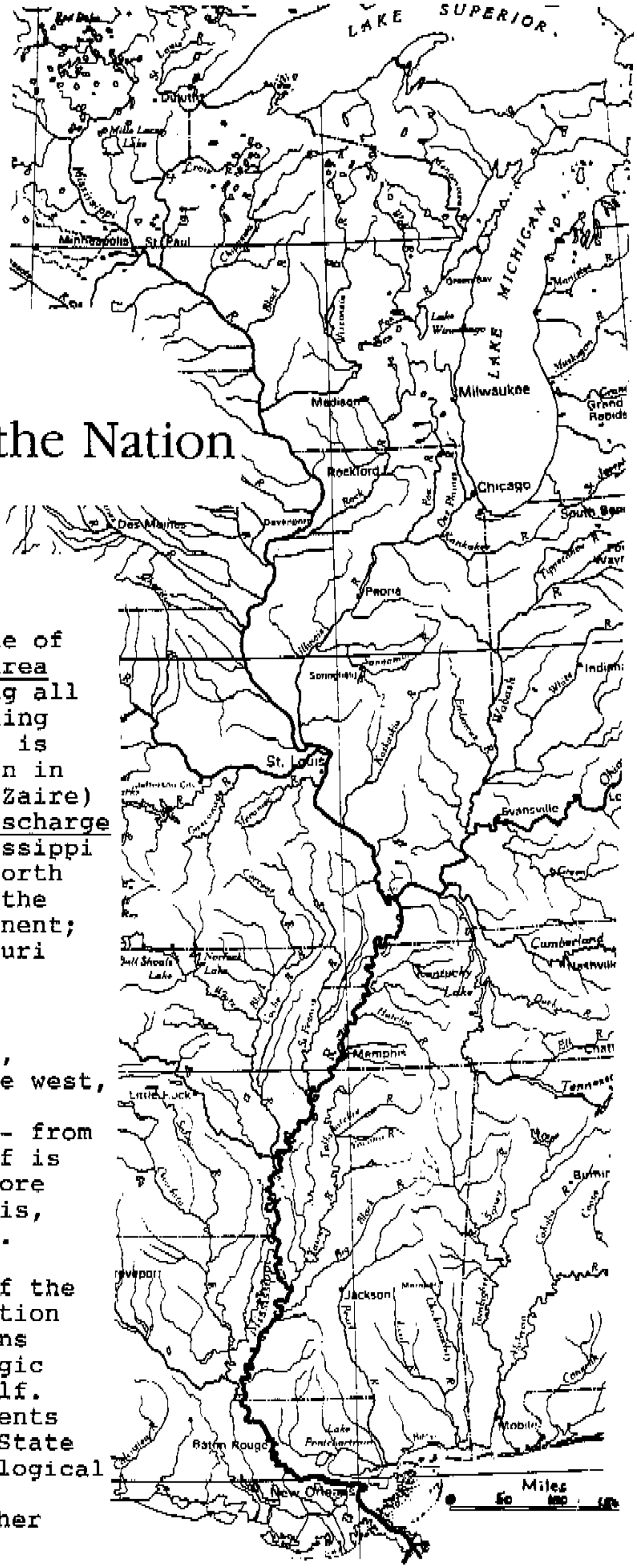

INTRODUCTION

The Mississippi River is one of the world's great rivers. The <u>area</u> of its drainage basin, comprising all or parts of 31 States and adjoining parts of two Canadian Provinces, is exceeded only by the Amazon basin in South America and by the Congo (Zaire) basin in Africa. The average <u>discharge</u> (flow) at the mouth of the Mississippi River is by far the largest in North America, and the Mississippi is the third longest river on the continent; only the Mackenzie and the Missouri Rivers are longer.

Major tributaries of the Mississippi include the Missouri, Arkansas, and Red Rivers from the west, and the Ohio River -- with its tributary, the Tennessee River -- from the east. The Mississippi itself is a major navigable waterway for more than 1,800 miles, from Minneapolis, Minnesota, to the Gulf of Mexico.

After a brief description of the river basin and of early exploration of the river, this report contains primarily geographic and hydrologic information about the river itself. Many of the numbers are measurements and computations by Federal and State agencies, including the U.S. Geological Survey, the U.S. Army Corps of Engineers, and the National Weather Service.

[MISINTRO]

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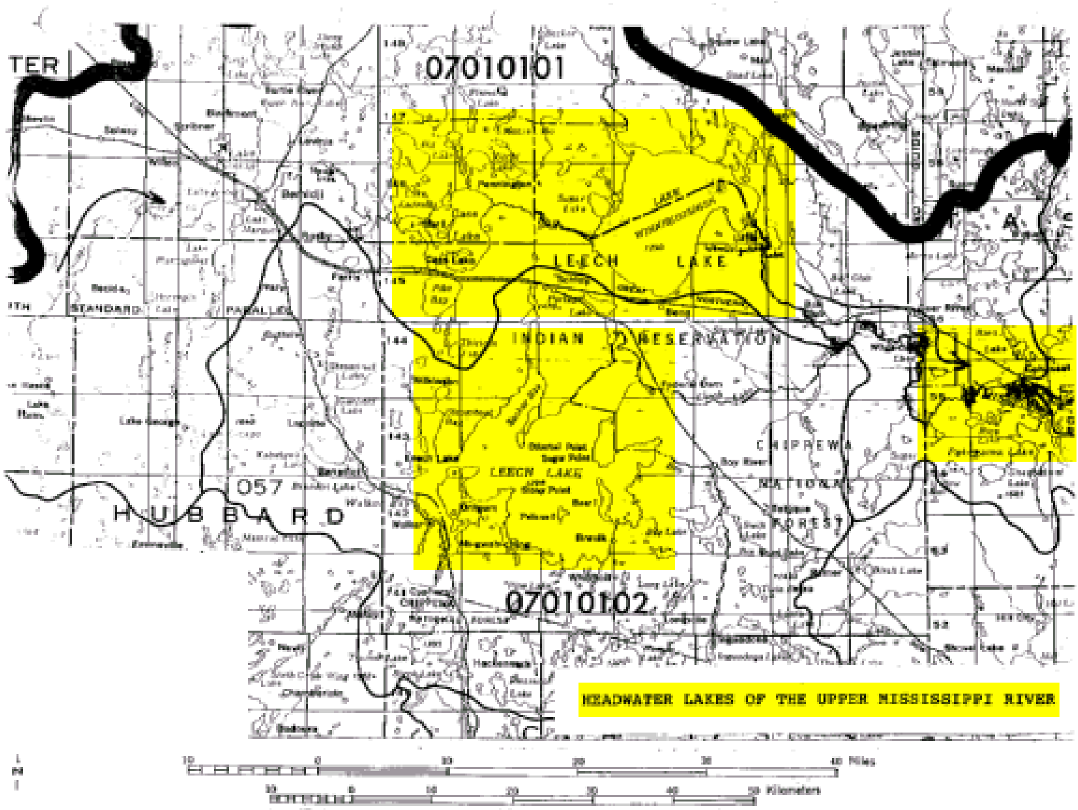
07010101
LEECH LAKE
INDIAN RESERVATION
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HEADWATER LAKES OF THE UPPER MISSISSIPPI RIVER
Miles
Kilometers

THE SOURCE

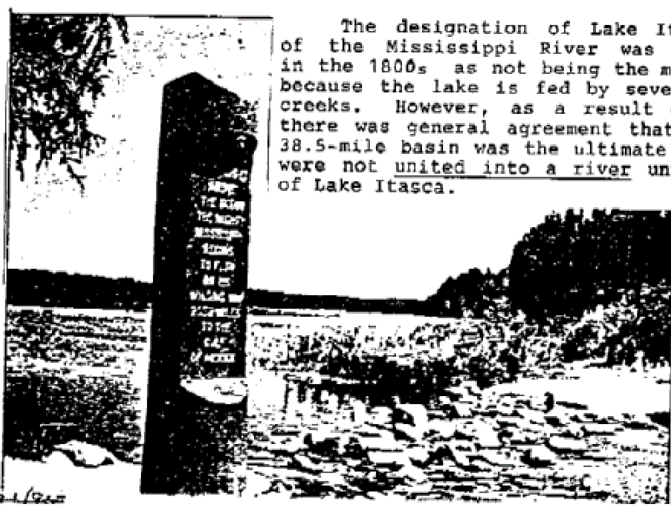
Amid the woodlands, marshes, and lakes of northern Minnesota, in Clearwater County, a ten-foot-high signpost (tree-trunk of Norway pine) contains the words carved many years ago: HERE 1475 FT. ABOVE THE OCEAN THE MIGHTY MISSISSIPPI BEGINS TO FLOW ON ITS WINDING WAY 2552 MILES TO THE GULF OF MEXICO. The site is the outlet of 1,200-acre Lake Itasca.

The lake was identified as the source in 1832 by a government expedition led by frontiersman and Indian linguist Henry R. Schoolcraft and aided by an Indian guide aware of the <u>north</u>ward flow from the outlet. Fur traders knew the <u>lake</u> by the French name, Lac la Biche, which means Elk Lake (now the name of a small lake feeding into Lake Itasca). The Chippewa/Ojibway Indians called the lake Omoshkos Sagaigon.

Schoolcraft named the lake "Itasca," a shortened spelling of the combined Latin words ver<u>itas</u> and <u>ca</u>put, meaning "true head." The infant Mississippi, initially about 12 feet wide and less than 2 feet deep, meanders in a general north and east direction through many forested lakes and shrub and grass wetlands on its way to Grand Rapids, Minnesota. The larger of these headwater lakes, in downstream order, are Bemidji, Cass, Winnibigoshish, and Pokegama. The straight-line distance from the Lake Itasca outlet to Grand Rapids is 80 miles, whereas the Mississippi River winds its way 186 miles between these two points.

The present <u>total</u> length of the river is now about 2,340 miles. This distance is more than 200 miles shorter than that shown on the Lake Itasca headwater marker. The reduction has resulted from man-made and natural cutoffs of river meanders and from other channel straightening during the past century at various locations between Minneapolis, Minnesota, and the Gulf of Mexico.

The designation of Lake Itasca as the source of the Mississippi River was challenged by some in the 1800s as not being the most upstream source, because the lake is fed by several small lakes and creeks. However, as a result of several surveys, there was general agreement that although the <u>whole</u> 38.5-mile basin was the ultimate source, the waters were not <u>united into a river</u> until they flowed out of Lake Itasca.



Principal Mississippi River headwater lakes from Lake Itasca to Grand Rapids, Minnesota

Lake [county]	Distance downstream from Lake Itasca	Area of water surface	Elevation of water surface above mean sea level	Maximum depth
	(miles)	(acres)	(feet)	(feet)
Itasca [Clearwater Co.]	0 (at outlet)	1,088	1,467	40
Bemidji [Beltrami Co.]	65.0 (at outlet)	6,920	1,339	70
Cass [Beltrami Co., [Cass Co.]	90.1 (at outlet)	29,775	1,301	115
Winnibigoshish [Cass Co., Itasca Co.]	118.2 (at outlet dam)	69,821	1,299	50
Pokegama [Itasca Co.]	182.6 (at outlet dam)	16,891 (includes four small connected lakes)	1,273	100

The waters of Leech Lake flow into the Mississippi River via Leech Lake River:

Leech [Cass Co., Hubbard Co.]	142.5 (mouth of Leech Lake River)	109,415	1,298	

Note: Bemidji Lake is a privately owned power reservoir.
Cass, Winnibigoshish, Pokegama, and Lech Lakes are Federal reservoirs operated by the U.S. Army Corps of Engineers for improvement of navigation on the Mississippi River and for other purposes.

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PRIMARY SUBDIVISIONS AND LENGTH OF THE RIVER

The Mississippi River is often described with reference to its "upper" and "lower" parts, corresponding in large measure to areas of regulatory responsibility of the U.S. Army Corps of Engineers with respect to river navigation and flood control. The upper Mississippi is that part north of the mouth of the Ohio River near Cairo, Illinois, whereas the lower Mississippi is downstream from Cape Girardeau, Missouri. There are 29 locks and dams for navigation on the upper river between Minneapolis, Minnesota, and St. Louis, Missouri; and none below St. Louis. There are hundreds of miles of flood-mitigation levees along the Mississippi River, especially between St. Louis and the Gulf of Mexico.

The length of the river and its changes by nature and man have been documented and mapped by the Corps of Engineers and its associated federal agency, the Mississippi River Commission, for more than a century. River mile numbers and locations between Minneapolis and the Gulf of Mexico are also shown on topographic maps of the U.S. Geological Survey, and referred to in "Light List" reports of the U.S. Coast Guard.

The present total length of the Mississippi River consists of the following components:

	Miles
Outlet of Lake Itasca to Minneapolis, Minn.	513
Minneapolis to mouth of Ohio River near Cairo, Ill. (River mile "0" at mouth of Ohio River, to river mile "853" at Minneapolis, 0.3 mile upstream from the Washington Avenue Highway Bridge).	853
Mouth of Ohio River to Head of Passes, Louisiana, south of New Orleans, La. (River mile "0" at Head of Passes, to river mile "954" at mouth of Ohio River)	954
Head of Passes to mouth of Mississippi River at South West Pass, Louisiana. (River mile "0" at Head of Passes, to river mile "20" at South West Pass and Gulf of Mexico)	20
Total length of Mississippi River.	2,340

[MS-LENGX]
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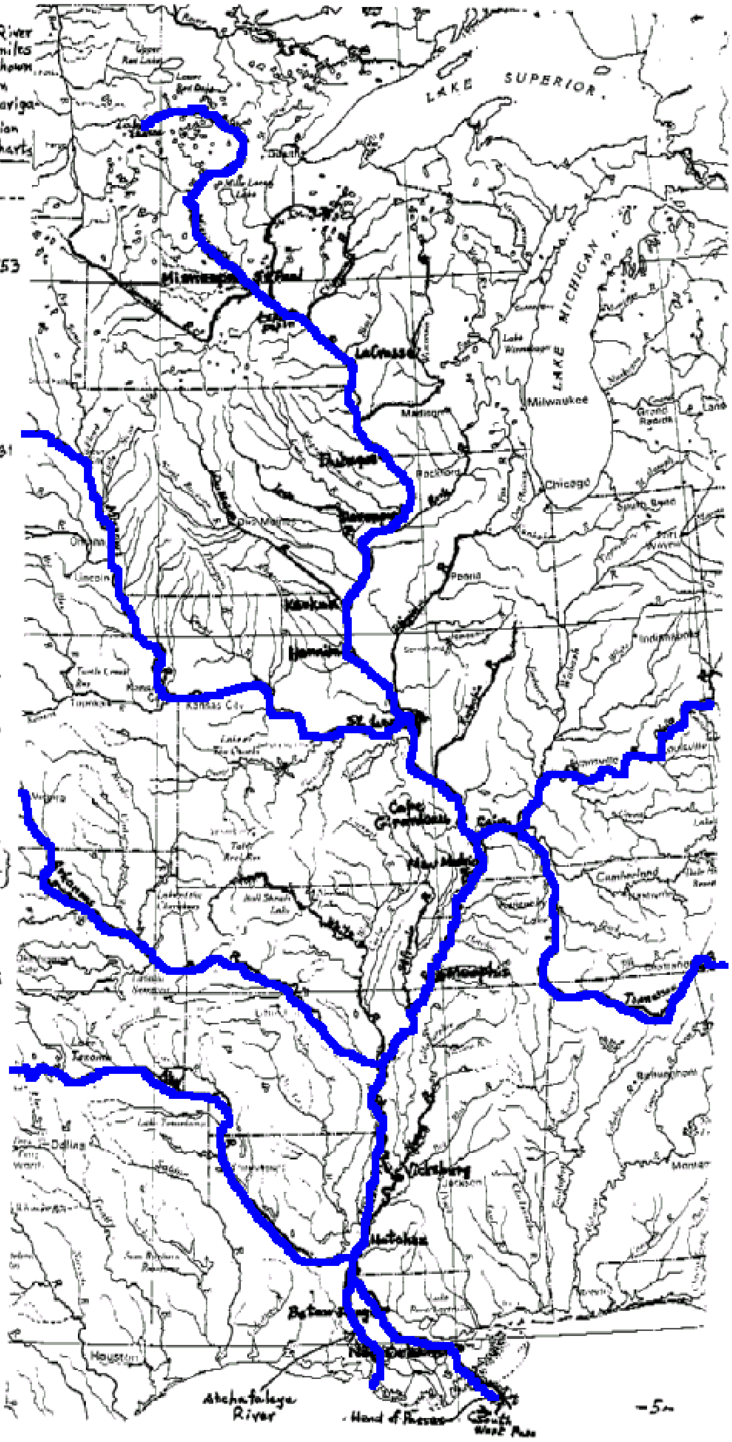
	River miles downstream from Lake Itasca	River miles shown on navigation charts
Lake Itasca	0 ↓	---
Minneapolis...	513	853
Mouth of Wisconsin River......	735	631
Mouth of Missouri River......	1,171	195
St. Louis, Eads Bridge..	1,186	180
Mouth of Ohio River..	1,366	{ ↑ 0 / 954 }
Memphis...	1,584	736
Vicksburg..	1,883	437
New Orleans..	2,225	95
Head of Passes...	2,320	{ ↑ 0 ↓ }
Mouth of Southwest Pass......	2,340	20



THE "BIG" PICTURE -- THE RIVER BASIN

The more than two hundred tributaries of the Mississippi River receive the runoff from precipitation -- rain, sleet, and snow -- that falls on the river basin. The area of the basin or watershed is 1,250,000 square miles (3,238 square kilometers). The area includes all or parts of 31 States and adjoining southern parts of the Canadian Provinces of Alberta and Saskatchewan. The river basin in the United States is 41 percent of the area of the "lower 48" States.

Mississippi River basin States

Entirely within basin (* or almost entirely)		States partly within the basin		
Arkansas	Missouri	Alabama	Minnesota	Ohio
Illinois(*)	Nebraska	Colorado	Mississippi	Pennsylvania
Iowa	Oklahoma	Georgia	Montana	Texas
Kansas	South Dakota(*)	Indiana	New Mexico	Virginia
Kentucky	Tennessee(*)	Louisiana	New York	West Virginia
		Maryland	North Carolina	Wisconsin
		Michigan	North Dakota	Wyoming

Precipitation and Runoff

Long-term average annual precipitation ranges geographically from less than 8 inches in some western parts of the basin to more than 60 inches in the Southeast. Corresponding totals of runoff (streamflow, including ground-water flow into streams) range from less than 1 inch, especially in the Dakotas and eastern Montana, to more than 30 inches per year in parts of the East.

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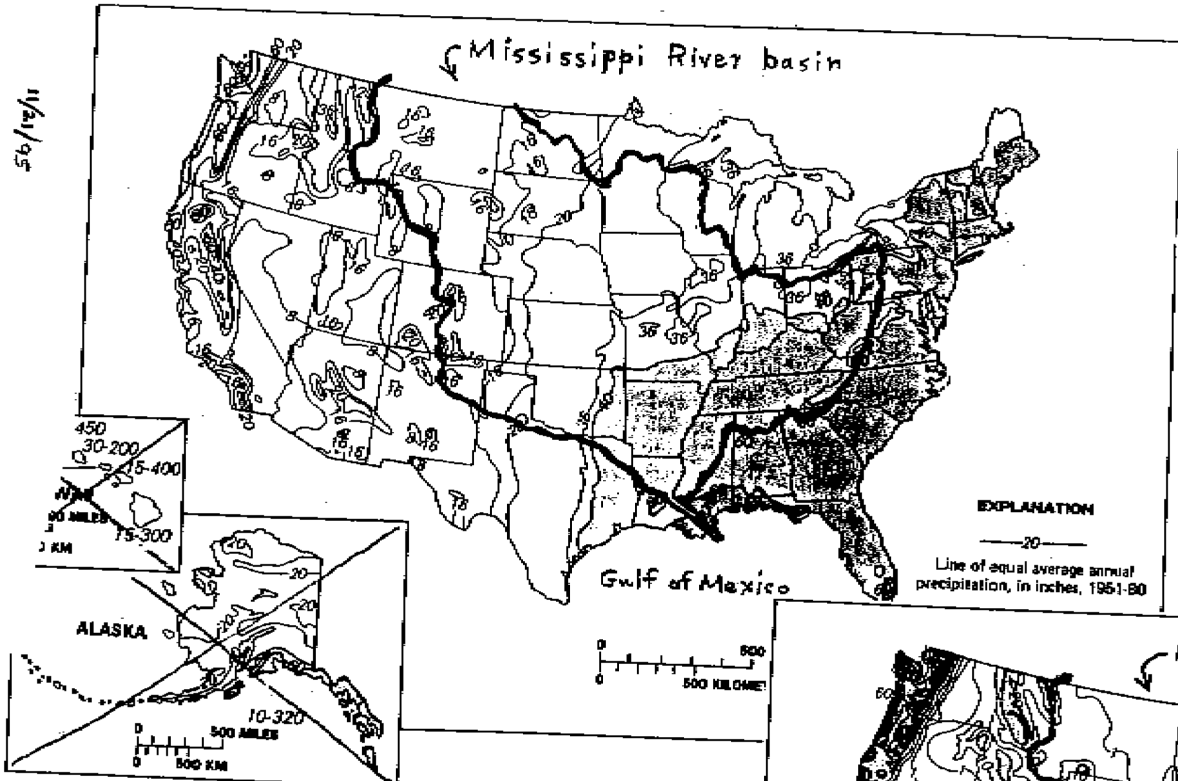
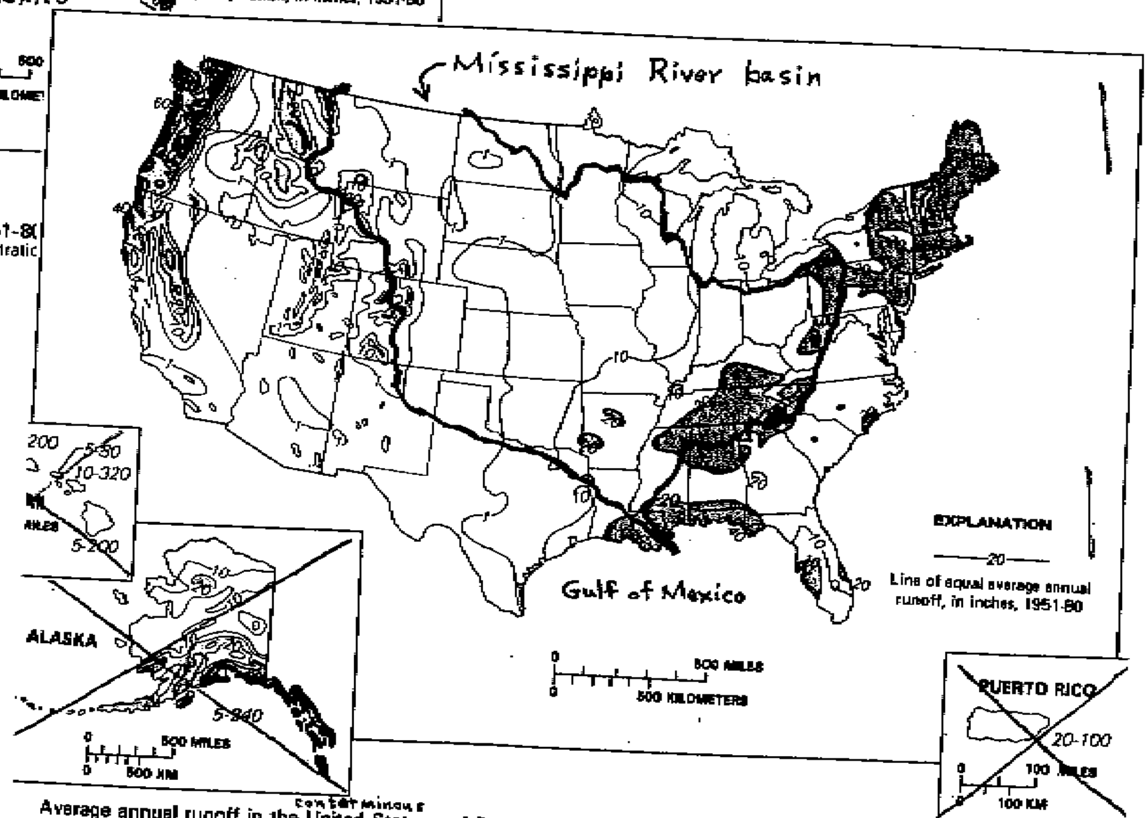
PRECIPITATION



~~Figure 27~~. Average annual precipitation in the conterminous United States ~~and Puerto Rico~~, 1951-8(
from unpublished map compiled by D. A. Olson, National Oceanic and Atmospheric Administratic

RUNOFF



Average annual runoff in the conterminous United States ~~and Puerto Rico~~, 1951-80. (Source: Gebert and others, 1985.)

Major Tributaries

The Ohio River is by far the largest tributary of the Mississippi River in terms of average stream discharge, contributing 43 percent of the flow of the Mississippi. The Ohio River basin at its mouth includes the Tennessee River basin, and both of these rivers drain humid eastern parts of the United States. By contrast, the Missouri River basin contributes an average of only 12 percent of the Mississippi's water even though the drainage area of the Missouri River basin is more than twice that of the Ohio River basin. Note in the table below that just six tributaries of the Mississippi River account respectively for nearly 84 percent of its drainage area and 78 percent of its average stream discharge.

Major Mississippi River tributaries

River	Percent of total drainage area	Percent of average discharge
Illinois	2.3	3.6
Missouri	42.5	11.7
Ohio	16.3	43.2
White	2.2	4.8
Arkansas	12.9	6.3
Red	7.5	8.6
Others	16.3	21.8

Major tributaries, in downstream order
(drainage areas, in square miles)

Streams from the west

Minnesota River (16,800)
Iowa River (12,600)
Des Moines River (14,400)
Missouri River (529,000)
(including Milk River, Yellowstone River, Cheyenne River, Niobrara River, James (Dakota) River, Platte River, Kansas River, and Osage River)
St. Francis River (9,040)
White River (27,610)
Arkansas River (161,000)
Red River (93,200)
(including Ouachita River)

Streams from the east

St. Croix River (7,750)
Chippewa River (9,750)
Wisconsin River (11,900)
Rock River (10,900)
Illinois River (28,600)
Kaskaskia River (5,700)
Ohio River (203,000)
(including Allegheny River, Monongahela River, Muskingum River, Kanawha River, Kentucky River, Green River, Wabash River Cumberland River, and Tennessee River)
Yazoo River (13,500)

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Mississippi River Basin, including principal tributaries, major dams on the tributaries, and navigation locks and dams along the upper Mississippi River

Regional Subdivisions of the Mississippi River Basin

The Mississippi River basin comprises 6 of the 21 water-resources regions of the United States as shown on the map below:

- Ohio Region (excludes the Tennessee River basin)
- Tennessee Region
- Upper Mississippi Region
- Lower Mississippi Region
- Missouri Region
- Arkansas-White-Red Region

The regions, consisting of groups of river basins, are subdivided into a standardized system of subregions and smaller units, to improve the effectiveness of water-data collection, use, and dissemination among Federal and State agencies. The U.S. Geological Survey publishes State Hydrologic Unit Maps, scale 1:500,000, showing boundaries and code numbers of each unit.

[MS-REGN1]
3/6/96

The tables below show one kind of water data -- namely, water use -- that applies the hydrologic unit system to organize and compile data. Note that all six of the regions comprising the Mississippi River basin are included. Among the largest water-using regions in the United States are two tributary regions of the Mississippi River -- the Missouri Region and the Ohio Region. By far the largest category of fresh-water withdrawal in the Missouri Region is irrigation, and in the Ohio Region is thermoelectric power (primarily generation of electric power with energy from coal). On a <u>per-square-mile</u> basis, the Tennessee <u>Region</u> withdraws more fresh water than the Ohio and Missouri <u>Regions</u> combined.

Table Total offstream water use by water-resources region, 1990

[Figures may not add to totals because of independent rounding. Mgal/d = million gallons per day; gal/d = gallons per day]

REGION	POPULATION, in thousands	PER CAPITA USE, fresh-water, in gal/d	WITHDRAWALS, in Mgal/d (includes irrigation conveyance losses): By source and type: Ground water: Fresh	Ground water: Saline	Ground water: Total	Surface water: Fresh	Surface water: Saline	Surface water: Total	Total: Fresh	Total: Saline	Total: Total	RECLAIMED WASTE-WATER, in Mgal/d	CONVEYANCE LOSSES, in Mgal/d	CONSUMPTIVE USE, fresh-water, in Mgal/d
Ohio	21,882	1,390	2,650	22	2,670	27,800	.8	27,800	30,400	22	30,500	.3	.5	2,110
Tennessee	3,911	2,350	305	0	305	8,900	0	8,900	9,200	0	9,200	.4	0	321
Upper Mississippi	21,270	977	2,620	4.2	2,630	18,200	0	18,200	20,800	4.2	20,800	0	.1	1,960
Lower Mississippi	7,167	2,510	8,340	.6	8,340	9,630	1,120	10,800	18,000	1,120	19,100	.7	600	6,970
~~Souris-Red-Rainy~~	~~[illegible]~~	~~[illegible]~~	~~120~~	~~0~~	~~120~~	~~166~~	~~0~~	~~166~~	~~295~~	~~0~~	~~295~~	~~0~~	~~1.1~~	~~144~~
Missouri Basin	10,048	3,730	8,490	37	8,530	29,000	0	29,000	37,500	37	37,500	3.0	9,010	12,100
Arkansas-White-Red	8,250	1,870	7,420	291	7,710	7,980	0	7,990	15,400	291	15,700	11	794	7,870

Table Total water withdrawals by water-use category and water-resources region, 1990

[Figures may not add to totals because of independent rounding. All values in million gallons per day]

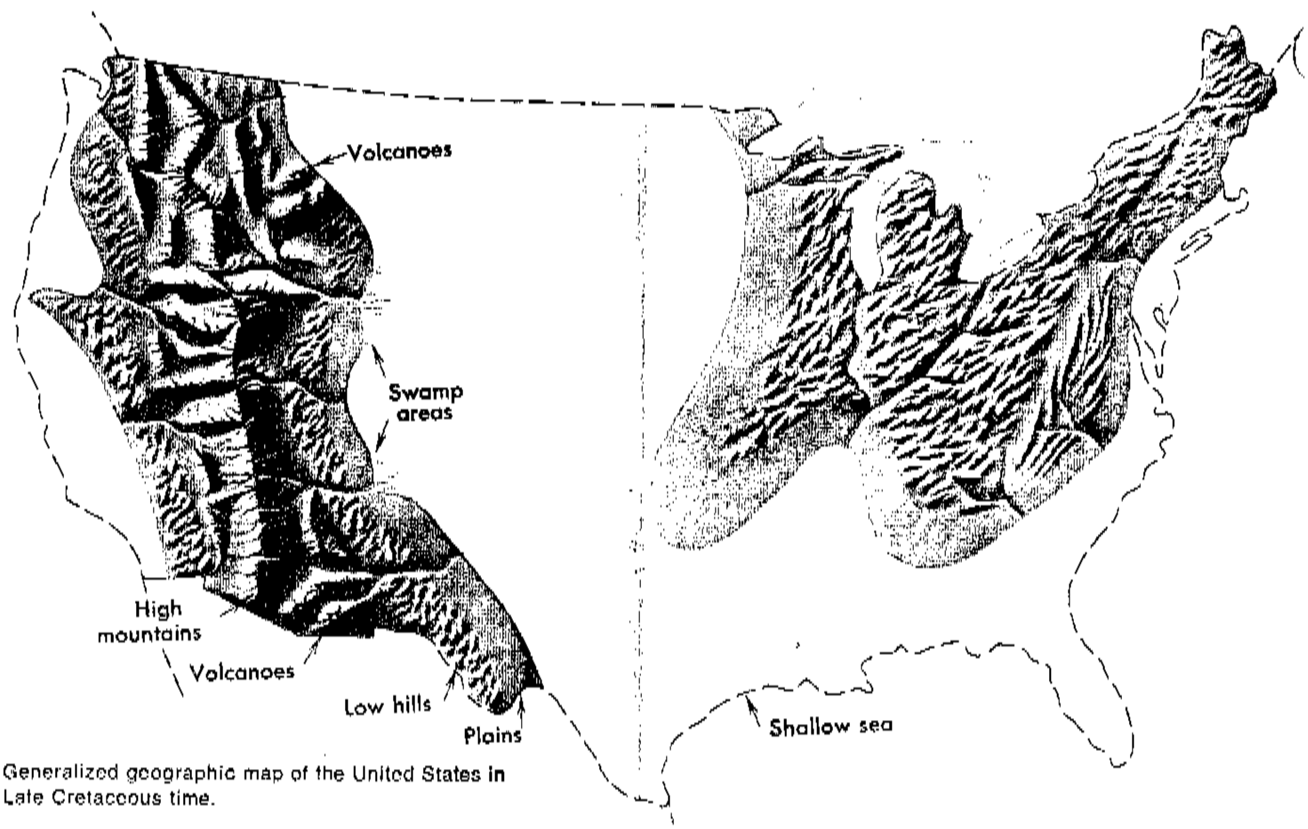
REGION	PUBLIC SUPPLY: Fresh	DOMESTIC: Fresh	COMMERCIAL: Fresh	IRRIGATION: Fresh	LIVESTOCK: Fresh	INDUSTRIAL: Fresh	INDUSTRIAL: Saline	MINING: Fresh	MINING: Saline	THERMOELECTRIC: Fresh	THERMOELECTRIC: Saline	TOTAL: Fresh	TOTAL: Saline
Ohio	2,530	360	89	68	132	2,370	0	1,000	22	23,900	0	30,400	22
Tennessee	511	86	56	27	201	1,190	0	92	0	7,070	0	9,200	0
Upper Mississippi	1,890	371	260	392	269	967	0	154	4.2	16,500	0	20,800	4.2
Lower Mississippi	1,040	90	92	7,380	1,070	2,620	67	40	0	5,640	1,060	18,000	1,120
~~Souris-Red-Rainy~~	~~72~~	~~22~~	~~8~~	~~[illegible]~~	~~21~~	~~43~~	~~0~~	~~8.2~~	~~0~~	~~26~~	~~0~~	~~[illegible]~~	~~0~~
Missouri Basin	1,620	139	40	24,800	415	171	0	279	37	10,000	0	37,500	37
Arkansas-White-Red	1,400	118	165	8,390	359	368	0	74	291	4,530	0	15,400	291

[MS-WOSEI]
3/6/96

ANCIENT BEGINNINGS AND THE CONSEQUENT MISSISSIPPI

The general location of the present-day Mississippi River from source to mouth, evolved during millions of years of geologic time, and especially during the glacial epochs of one million to 50,000 years ago. In terms of today's geographic subdivisions (provinces) of the United States, the upper Mississippi River is mainly in the central or interior lowland province. The lower Mississippi flows across its alluvial plain in the southern part of the coastal plain province.

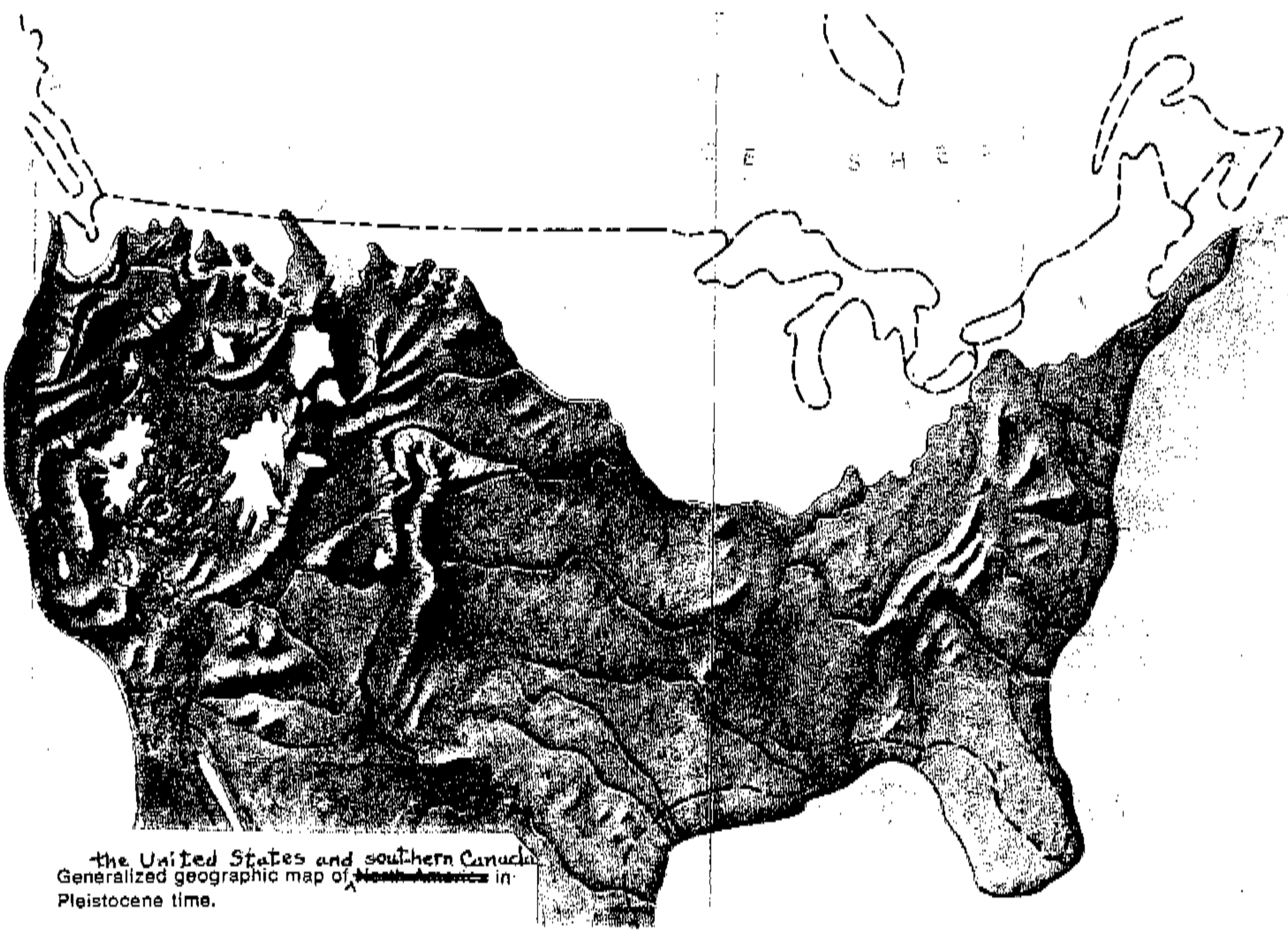
In the geologic past, much of the southern part of the nation has been covered and uncovered repeatedly by shallow seas as rising waters advanced northward and falling waters retreated southward. For example, about the time of the dinosaurs eighty million years ago (in "Cretaceous" time), the mouth of the ancient Mississippi River may have been as far north as present-day Cairo, Illinois, before the seas again retreated southward. Throughout most of these extremely long periods of time, streams eroded rocks from mountains and other highland areas and deposited the eroded particles of clay, silt, sand, and gravel in lowlands and seas to the south.



Generalized geographic map of the United States in Late Cretaceous time.

During glacial or "Pleistocene" time, the present major characteristics of the Mississippi River took shape. The Pleistocene ice sheet covered much of Canada and north-central and northeastern United States. As the ice sheet grew and spread outward during frigid climatic conditions. it scarred and scoured the land beneath it and added rock debris to its load. Sometimes blocks of ice were deposited in scoured depressions in the land. When the ice sheet and its glaciers melted, great quantities of water and disgorged rock debris dug a trench (river channel) southward for hundreds of miles. Then, as the momentum of these giant floods decreased, the waters gradually deposited their load of rocks and sediments, followed by repeated cycles of erosion and deposition, across a wide floodplain.

Today's headwater lakes and connective, meandering streams resulted mainly from depressions in the land surface that had been beneath the ice sheet. The "trench" of the Mississippi River extends from Minneapolis, Minnesota, to Commerce, Missouri (40 miles north of Cairo, Ill.). Finally, to the south there is the wide, nearly flat alluvial plain upon which the Mississippi River has meandered for thousands of years.



Generalized geographic map of ~~North America~~ the United States and southern Canada in Pleistocene time.

[MS-ABCMC]
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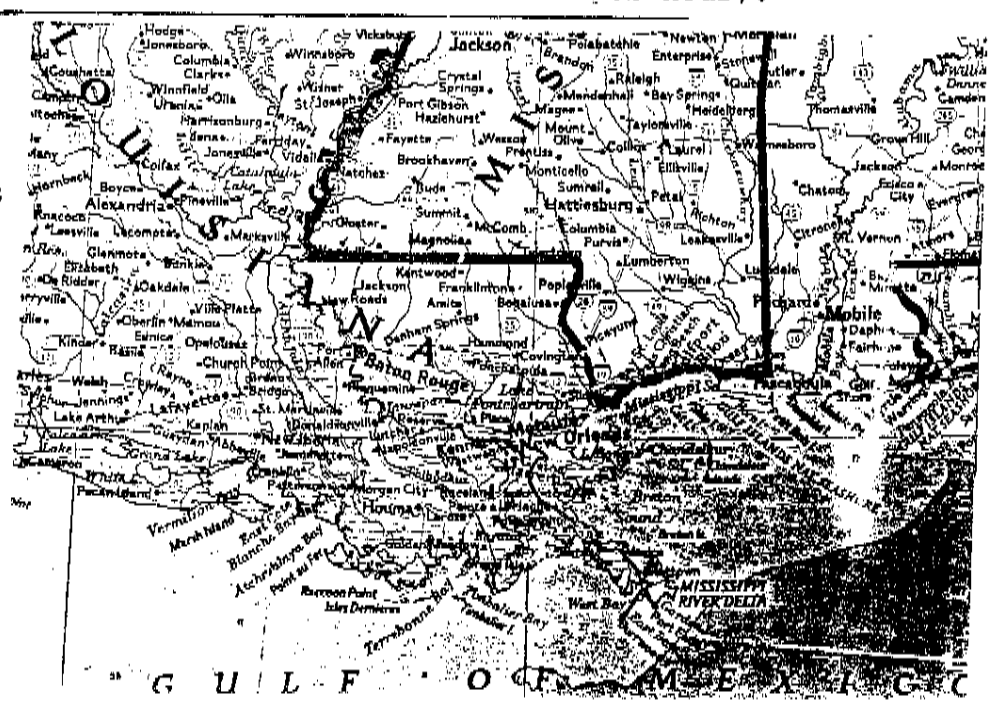
The Mississippi delta is the landward limit of deposition in the Mississippi valley, but these deposits continue outward beneath the Gulf of Mexico for as much as 300 miles. The depth to the bottom of the glacial deposits in the New Orleans-Baton Rouge area is 1,000-2,000 feet. The waters of the Mississippi enter the Gulf through mouths ("passes") in the delta. In modern times the South West Pass has superseded the South Pass in being designated the mouth of the river.

The result of the massive movements of water and sediment during and since glacial times is a river valley some 1,300 miles long (straight-line distance), and for the most part, gently sloping. The average slope from Lake Itasca to the mouth of the Missouri River is slightly less than one foot per river mile. From the Missouri to the Gulf, the average slope is about one-third of a foot per mile. Meanders are common, especially in the headwaters region in Minnesota and in much of the lower Mississippi, from Cairo, Illinois, to New Orleans, Louisiana. The only natural waterfall along the course of the river is St. Anthony Falls at Minneapolis, Minnesota, 18 feet high (in 1832); total fall, including rapids above and below falls, 80 feet (1832). South of the Twin Cities, the only natural lake that occurs in the river is the local widening known as Lake Pepin, on the Minnesota-Wisconsin border 68 river miles south of Minneapolis. The lake is 2-3 miles wide and 27 miles long (1861). The natural dam responsible for the ponding that became Lake Pepin, is a delta built by the Chippewa River when loaded with coarse gravel from the Pleistocene glacier to the northeast.

The average width of the river in the 1800s (prior to construction of dams, locks, and levees) was about 600-1,200 feet in the Twin Cities area of Minnesota; roughly 5,000 feet from La Crosse, Wisconsin, to the mouth of the Missouri River; and decreased to about 4,500 feet from Cairo, Illinois, to Memphis, Tennessee. Farther downstream, widths averaged about 4,000 feet at Natchez, Mississippi, and about 3,000 feet at Baton Rouge, Louisiana. The velocity of the Mississippi River at times other than flooding or high water, is generally between $2\frac{1}{2}$ and 6 feet per second (= between 2 and 4 miles per hour).



Mississippi River delta, 50-80 miles southeast of New Orleans; mouth is at South West Pass and Gulf, 5 miles southwest of Burrwood. (Scale of map, 1 inch= 72 miles.)

EARLIEST NATIVE INHABITANTS

North American Indians described as "mound builders" are perhaps the first known inhabitants of the Mississippi valley, pre-dating European discovery and settlement -- sometimes by hundreds or thousands of years. The mounds were burial places. At some locations, platforms were built on top of the mounds, to hold temples and the houses of chiefs. The larger mounds consist of several hundred tons of dirt, stone, and other materials, all transported by the Indians without the help of animals and vehicles.

The Hopewell Indians were the most advanced culture of the burial mound era, lasting from about 200 B.C. to 500 A.D., and centered in southern Ohio and Illinois. They cultivated corn, squash, and other crops. They were also extensive traders, obtaining shells, shark teeth, volcanic glass, and silver from great distances, and used some of these materials to make gifts to bury with their dead.

The Mississippian culture of mound-building Indians was dominant in the temple mound era, 700 to 1700 A.D. They built larger earth mounds than previous cultures. Their largest mound, at Cahokia, Illinois (10 miles east of present-day St. Louis, Mo.), was 1,000 feet long, 600 feet wide at the base, and from 50 to 100 feet high, almost equal in total volume to the pyramids of Egypt and Mexico. The population at Cahokia may have exceeded 30,000 inhabitants. The Mississippians were the ancestors of the Iroquoians, the Natchez, and other historic tribes.

EXPLORATION AND DISCOVERY

Spain was the dominant European sea-faring power for more than half a century beginning in the 1490s, spurred on by the search for a westward route to the Orient and for gold and other riches along the way. In 1519 the mouths of the Mississippi River and of the Rio Grande were observed by Alonso Alvarez de Pineda during his exploration and mapping of the northern and western coast of the Gulf of Mexico from Florida to Vera Cruz. He named the Mississippi River "Rio del Espiritu Santo" -- River of the Holy Spirit.

The first European to reach the Mississippi by <u>land</u> was Hernando de Soto. He had become wealthy for his part in the conquest of the Incas of Peru, and desired further riches and power. In 1539 his expedition of 600 soldiers landed at Tampa Bay on the eastern Gulf Coast to explore for gold in Florida. Their circuitous route was through parts of six States before reaching the Mississippi River on May 8, 1541, near or just south of present-day Memphis, Tennessee. They called the river "Rio Grande" -- Great River. They crossed the river and explored parts of what are now Arkansas and Louisiana. The following year, de Soto died of a fever and his body was weighted and buried in the river to avoid mistreatment by hostile Indians. The historian of the expedition, Garciliaso de la Vega, described a prolonged and severe flood on the Mississippi beginning about March 10, 1543, reaching its peak 40 days later.

More than a century passed before Europeans again explored the Mississippi, this time from French Canada. Jesuit missionary Father Claude-Jean Allouez, during his travels and preaching among the Indians of the Wisconsin region, reportedly heard in 1665 the Algonkian-speaking Chippewas refer to the "Father of Waters" -- Misi Sipi or Messipi, literally "big water." In 1673, Governor Louis Frontenac ordered Father Jacques Marquette (a colleague of Allouez) and fur trader/explorer Louis Joliet to search for a route to the Pacific Ocean, beginning at Lake Michigan. They paddled their birchbark canoes from Green Bay upstream on the Fox River, carried them across land to the Wisconsin River, and paddled downstream. At the mouth of the Wisconsin, they discovered the Mississippi River on June 17, 1673. On the Mississippi they continued south beyond the mouth of the Arkansas River before returning north. They made the 3,000-mile round trip in four months. Marquette and Joliet were able to conclude correctly that the Mississippi River flowed into the Gulf of Mexico and not into the Pacific Ocean, and this was verified by other explorers by the end of the century.

Another French explorer of the Mississippi River was Robert Cavalier, Sieur de La Salle, who sought to reach and explore the Mississippi as early as 1679, but suffered many setbacks. Finally in 1682 he was successful, ending his southward journey near the mouth of the Mississippi in early April. On April

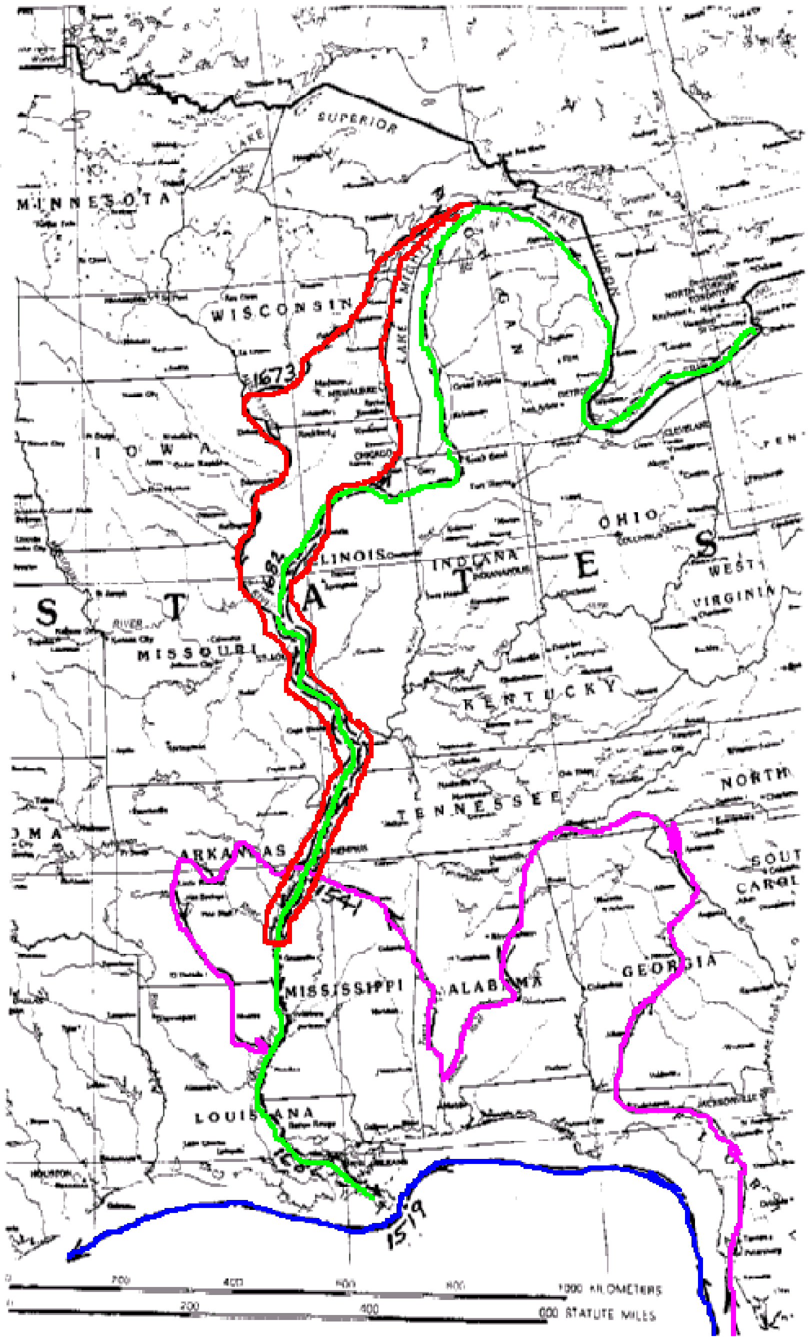
Approximate routes of exploration of the Mississippi River by its earliest European discoverers:

1519 Alonso Alvarez de Pineda

1541 Hernando de Soto

1673 Jacques Marquette and Louis Joliet

1682 Sieur de La Salle



was to colonize the Mississippi Valley, but in 1684 his four ships of 200 colonists from France landed by mistake in Matagordo Bay, Texas, and La Salle was killed by one of his followers on the subsequent foot journey northward toward Canada.

As already described in the SOURCE section of this report, not until 1832 did Henry Schoolcraft explore, name, and declare Lake Itasca as the source of the Mississippi River. Others had sought the source at various times for more than half a century, and Turtle Lake (a tributary of Cass Lake by way of Turtle River) was the source named by British surveyor David Thompson about 1798. Whereas Thompson chose to canoe upstream on a northern tributary of Cass Lake, Schoolcraft chose a western tributary, in their respective searches for the source.

As noted in 1979 by the Minnesota Historical Society, the happenstance of history and geography can play a major role in designation of the source of a river, large or small:

> The story of Itasca [as the source] begins with the story of the Mississippi itself. It descends from the same act of whimsy that brought the first explorers and missionaries from the East rather than the West, and led them to designate the tributary in Minnesota as the main Mississippi stem and the larger, western tributary as the lesser Missouri. On a smaller scale, it was a series of similarly debatable choices among the maze of lakes, streams, and swamps in the headwaters region of north-central Minnesota that finally crowned Itasca as the true source.

[MS-EXPL1]
11/21/95

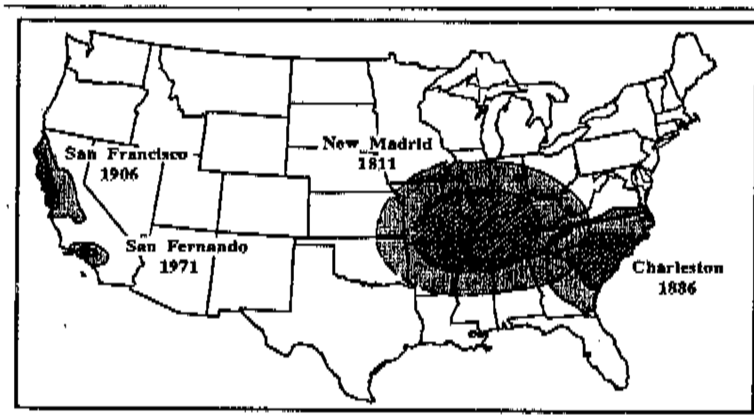
1811-12 NEAR NEW MADRID, MISSOURI

The most widely felt earthquakes in the recorded history of North America occurred in 1811-12 near the Mississippi River town of New Madrid, Mo., about 72 miles downstream from Cairo, Ill. There were three major shocks, one each on December 16, 1811, January 23, 1812, and February 7, 1812 -- each followed by many aftershocks. The magnitude of the quakes has been estimated to be "8" on the Richter scale, extremely devastating had it occurred in a populated, built-up area. Tremors were discernible at least 1,100 miles away (Boston, Mass.). There was extensive movement of land and water surfaces at and near New Madrid, including water waves of considerable size on the Mississippi River itself, as well as caving of banks and movement in the bed of the river.

A 1912 report on the New Madrid earthquake by Myron L. Fuller, states:

> ...there is little room to doubt that the earthquake produced water waves of considerable size on the Mississippi. ...it was the return wave [from the middle to the sides] which did the damage along the shore. That there were upheavals of the bottom is certain, ... and it is not unlikely that the water was thrown back, giving the appearance of a chasm. There is also no reason to doubt that fissures opened and closed beneath the water as they did on the land, giving rise to large waves by the ejection of water. That waves of great size moved upward against the current is certain, and that the movement of the water was retrograde for the moment, at least in shallow water, is probable. The rise in the river about which there is universal agreement was probably due in part to the waves moving upstream, and in part to a temporary ponding due to local uplifts of the channel.

Note the mention of "retrograde." This idea of at least a brief change in direction of flow probably underlies the belief by some people that the New Madrid earthquake temporarily caused the Mississippi River to flow backwards.



Large earthquakes cause more damage east of the Rocky Mountains; this map shows areas that suffered major architectural damage (striped areas) and minor damage (dotted areas) during the magnitude-8 earthquakes in New Madrid and San Francisco and the smaller but still damaging quakes in Charleston and San Fernando.

[MS-MDRD 1]

Coincidentally, the New Orleans, the first steamboat to make the trip from Pittsburgh, Pa., to New Orleans, La.(via the Ohio and Mississippi Rivers), was on her maiden voyage when the first New Madrid earthquake occurred. The boat was passing down the Ohio River along the Indiana shore at the time of the earthquake on December 16, 1811. Normal practice was to bring the steamboat near the shore at night, but not on this occasion when captain and crew could see high banks disappearing, and listen to the sound of the water roaring and gurgling around them. On reaching the Mississippi, they reportedly found the channel unrecognizable, everything having been changed by the shock of the quake. Navigation was further threatened by wreckage and debris on and beneath the water, including, according to pilot Capt. Nicholas Roosevelt, where he had hitherto known deep water, "there lay numberless trees with their roots upward." The journey continued downstream under very difficult conditions, reaching New Orleans on January 12, 1812.

THE TRANSPORTATION ARTERY

The Mississippi River has been a major thoroughfare of transport for more than 500 years. The earliest European-American Indian commerce along the Mississippi was probably in the northern part of the basin, by the French from Canada in the mid- to late 1600s. Travel was by canoe. The French journeyed southwest from the Great Lakes to the Mississippi, usually from Lake Superior via Brule River, portage, and the St. Croix River, or from Lake Michigan via the Fox and Wisconsin Rivers. The French brought bright beads, guns, tomahawks, knives, whiskey, and other goods to the Indians in exchange for animal furs such as from beaver, marten, and mink. The furs were then transported back through the Great Lakes to the St. Lawrence River and to France.

Commerce gradually increased along the Mississippi, especially from the mouth of the Ohio River to the Gulf of Mexico. In 1705, for example, the French floated the first cargo by canoe -- 15,000 bear and deer hides -- from the Indian country around the Wabash River down the Ohio and Mississippi Rivers to the Gulf by way of Bayou Manchac (downstream from Baton Rouge on the Mississippi), the Amite River, and Lake Ponchartrain. (The Bayou Manchac route is no longer available because of levee construction.)

The French, British, and Spanish controlled various parts of the Mississippi during the 1700s. By the terms of the Treaty of Paris in 1763, Britain claimed Canada and all French land east of the Mississippi River; Spain received all French land west of the river as well as New Orleans and the mouth of the river. Many of the French moved to the west side of the Mississippi to escape English rule, and one result was the founding of St. Louis. Not until the Louisiana Purchase of 1803 did the entire river become part of the United States.

In 1804 at St. Louis, Lewis and Clark began their government-sponsored expedition to the Pacific Coast by way of the Missouri River, across the Continental Divide, and down the Columbia River, returning to St. Louis in 1806 by much the same route. This exploration set the stage for future transcontinental east-west travel by way of the Ohio-Mississippi-Missouri-Columbia Rivers.

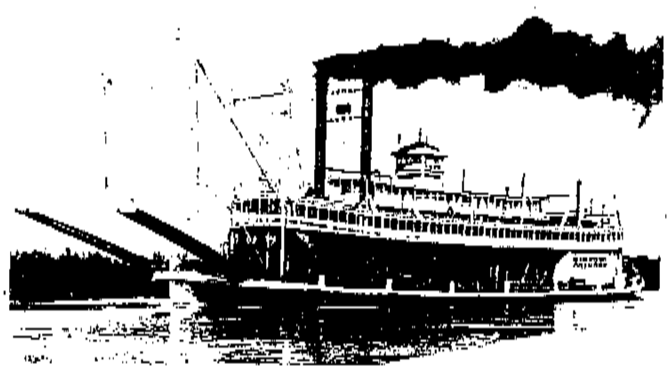
As Mississippi River traffic increased, transportation methods changed so as to increase freight loads. Flatboats and large rafts served for a time, but these were one-way, downstream vessels. When they reached their destination, such as New Orleans, they were dismantled and sold for the value of their lumber. The cargo going south, such as to New Orleans from French settlements near Kaskaskia, included hides, pelts, and buckskins, and also flour, bacon, pork, leather, lumber, wine, and tallow.

The next improvement in transport was the keelboat, the first large "two-way" vessel, built to survive for many trips. It could carry as much as 80 tons of freight. After it had floated to its southern destination and was unloaded, the keelboat was poled or towed up the river. The boat was towed ("cordelled") by a crew of very strong men on a shoreline towpath, pulling a heavy rope towline attached to the upper part of the mast of the keelboat.

The years 1811-12 marked the beginning of the era of steamboats on the Mississippi River. The rapid rise in steamboat traffic is reflected by the number that arrived in New Orleans: 21 in 1814, 191 in 1819, and more than 1,200 in 1833. The major cargoes were cotton and sugar, along with passengers. Capt. Henry M. Shreve improved steamboat design in 1816 with a flat hull (as shallow as that of a barge) and a high-pressure steam engine hoisted high above the water line. A year later his steamboat Washington made the round trip from Louisville to New Orleans and return in 41 days. In 1823, the steamboat Virginia left St. Louis and reached Fort Snelling (at the confluence of the Minnesota and Mississippi Rivers), the first steamboat to make the trip. By 1840 there was heavy river commerce between St. Louis and the head of navigation at St. Anthony's Falls (present-day Minneapolis).

Although the power and speed of steamboats continued to rise during the era, the average life of a steamboat was only 4 or 5 years. This short life was the result of one or more of several factors: Poor construction or maintenance, being sunk by submerged tree-trunks ("snags"), or having overheated boilers explode. Snag removal from the channel of the Mississippi River was authorized by Congress for the first time in 1824.

In and after the mid-1800s, the dominance of steamboat commerce on the Mississippi was increasingly challenged by the growth of railroads from the east, including the large rail hub gradually extending westward from Chicago. This transport rivalry reached a high pitch when the first railroad bridge across the Mississippi River was being built in 1855-56 from Rock Island, Illinois, to Davenport, Iowa. A steamboat crash occurred at a bridge pier site before construction was complete, but after three legal suits (one including the participation of lawyer Abraham Lincoln), the railroads received a final, favorable decision.



[MS-TRANY]

At the beginning of the Civil War in 1861, all normal commerce on the Mississippi River was suspended. Control of the Mississippi was one of the strategic goals of the North so as to divide the South along the line of the river and forbid its use for transport. In May-July 1863, General Grant, aided by the naval squadrons of Admiral Farragut, led a successful, six-week siege that defeated the Southern forces at Vicksburg.

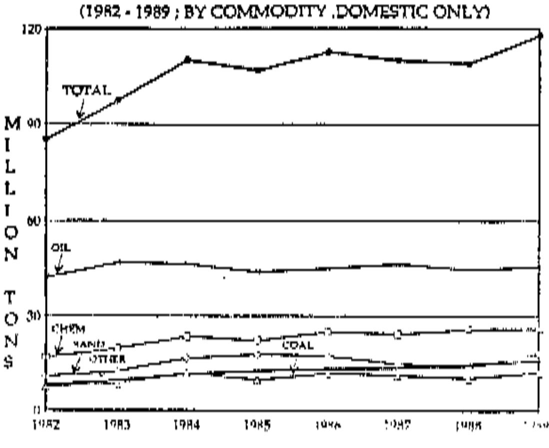
There was at least a temporary resurgence in steamboat traffic after the Civil War, including the occasional renewal of competitive racing that took place from time to time in pre-war decades. One of the fastest times recorded for a long trip upstream was that of the steamboat Robert E. Lee in its race with the Natchez in July 1870: New Orleans to St. Louis (then a distance of 1,278 river miles) in 3 days, 18 hours, 14 minutes (= average velocity of 14.1 miles per hour).

Although the steamboat era had nearly ended by 1900, there were some notable movements of freight using steamboats as towboats pushing multiple barges. In 1907, the paddle-wheeler Sprague set a world's record for towing -- 60 barges of coal, weighing 67,307 tons. The barges covered an area of 6½ acres. In 1931, the St. Louis arrived in New Orleans with 28,200 bales of cotton on eight barges and three other barges of grain and merchandise. This is perhaps the largest cotton tow that ever traveled the Mississippi River.

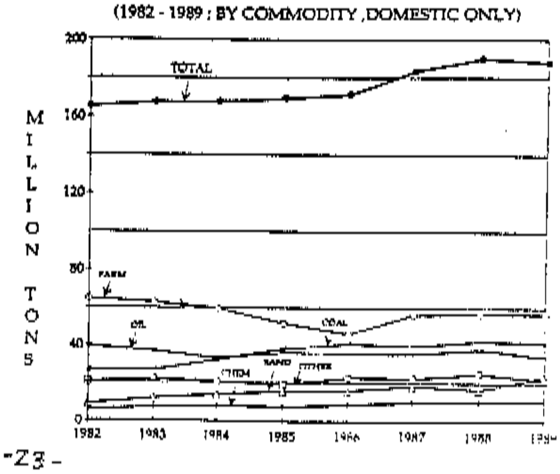
Within the past century a major renewal and expansion of commerce on the Mississippi has occurred as a result of (a) navigation improvements -- locks, dams, dredging -- by the U.S. Army Corps of Engineers, and (b) the extensive use of larger and higher-powered towboats. The average modern steam or diesel towboat may push as many as twenty 1,000-ton steel barges at one time. Waterborne commerce (domestic) on the Mississippi is currently more than 300 million tons per year. Materials transported include grains, coal and coke, ores, steel, petroleum products, sand and gravel, and sulfur and chemicals.

Mississippi River waterborne commerce (domestic), between Minnesota and the Gulf, northbound and southbound, 1982-89.

MISSISSIPPI RIVER - MINN. TO MOUTH, UPBOUND
(1982 - 1989 ; BY COMMODITY ,DOMESTIC ONLY)



MISSISSIPPI RIVER - MINN. TO MOUTH, DOWNBOUND
(1982 - 1989 ; BY COMMODITY ,DOMESTIC ONLY)



11/21/85

MARK TWAIN

World-famous American story-teller and humorist Mark Twain (the pen-name of Samuel L. Clemens) was without peer as he described life and times along the Mississippi River in the mid-1800s. He grew up in the river town of Hannibal, Missouri (referred to as "St. Petersburg" in writing about his childhood). Even the pen-name he adopted in 1863 was a river term: Leadsman used sounding weights to measure the distance to the river bottom; mark twain was two fathoms (= twelve feet). That depth was generally a safe one for steamboats on the Mississippi, provided they encountered no hidden debris protruding upward from the bottom of the river.

Mark Twain served as an apprentice river pilot for two and one-half years, 1857-1859 (age 20-23), and continued as a river pilot until the Civil War brought a temporary end to steamboat travel on the Mississippi. Early in his life he became interested in printing and journalism, especially humorous tales for publication in magazines and newspapers, and resumed those interests after his years on the river. Some of the articles were subsequently compiled into book form. His most famous books relating to the Mississippi River included Tom Sawyer, published in 1876, Life on the Mississippi, published in 1883, and the Adventures of Huckleberry Finn, begun in 1876 but not finished and published until 1884.

Regarding the name Tom Sawyer, the word sawyer is a river-hazard term for a mostly submerged but not firmly fixed (to the river bottom) tree-trunk the top of which "saws" up and down slightly above the water surface. The book Life on the Mississippi was written after Mark Twain's trip on the river in 1882 with his publisher. It is a mixture of autobiography and travel narrative, noting the dramatic differences between steamboat life on the river before and after the Civil War. The following quotation is part of a very brief chapter that separates the pre- and post-Civil War parts of the book:

> But by and by the war came, commerce was suspended, my occupation was gone.
>
> I had to seek another livelihood. So I became a silver miner in Nevada; next, a newspaper reporter; next, a gold miner, in California; next, a reporter in San Francisco; next, a special correspondent in the Sandwich Islands; next, a roving correspondent in Europe and the East; next, an instructural torch-bearer on the lecture platform; and, finally, I became a scribbler of books, and an immovable fixture among the other rocks of New England.
>
> In so few words have I disposed of the twenty-one slow-drifting years that have come and gone since I last looked from the windows of a pilot-house.

[MS-MKTWN]
11/21/95

THE CORPS, THE COMMISSION, NAVIGATION, AND FLOOD CONTROL

For nearly 200 years the U.S. Army Corps of Engineers has been a major force in the nation's military and civilian engineering field, including responsibilities for surveys and management of navigation on inland waterways. For the Mississippi River, the U.S. Congress in 1879 established a closely allied organization, the Mississippi River Commission, with coordinated planning, executive, and operational functions for the entire river from the headwaters to the Head of Passes, Louisiana; the Commission, headquartered at Vicksburg, Mississippi, reported directly to the Secretary of War. Of the seven commissioners, three (including the Commission President) are officers of the Corps of Engineers. With passage of the Flood Control Act of 1928, the responsibility for prosecution of work on the Mississippi River, including both navigation and flood control, reverted to the Corps of Engineers, with the Commission serving in an advisory and consulting capacity. The Act authorized the building of a hydraulic laboratory -- the resulting facility is the Waterways Experiment Station at Vicksburg.

In the early years of settlement along the Mississippi, such as at the founding of New Orleans by the French in 1717, levee construction began in order to protect flooding of adjacent lands at times of high water. The first levees were fairly low embankments because floodwaters were seldom more than a few feet deep on the high ground along the river -- the only ground then under cultivation -- and the waters could spread out across the low ground away from the river. Within ten years, landowners at New Orleans had built a dike or levee on the river front more than a mile long and a top width of 18 feet; and an additional 40 miles of levee line was in place on both sides of the river by 1735. With increased settlement and commerce, levee construction along the lower Mississippi became commonplace despite periodic breaching of some levees during major floods.

Following the introduction of steamboats on the Mississippi in 1811, there was a growing demand for river improvement for **navigation.** Federal operations on the Mississippi began in 1820-21 when Congress authorized the Corps to prepare a survey, maps, and charts of the Ohio and Mississippi Rivers aimed at improving navigation along these rivers. Legislation in 1824 provided for removal of snags and other obstructions in the river channel.

River-shortening "cutoffs" have been considered and debated as improvements for navigation on the Mississippi perhaps as long ago as the early 1800s. (A natural or excavated cutoff is a channel that severs a narrow neck of land between upstream and downstream parts of a meander loop, thus bypassing the river-channel loop that may have been 8 to 15 miles long.) Cutoffs change physical conditions of the river at and near the site of the cutoff, including velocities and depths and the scouring of river banks. The first excavated cutoffs along the Mississippi were at and near the mouth of the Red River. The Shreves cutoff across Turnbull Bend Neck was made in 1831 (sponsored by Captain Henry M. Shreve, father of the Mississippi River steamboat); and the Raccouri Bend cutoff, 4 miles downstream from Shreves cutoff, was made by the State of Louisiana in 1848. Although the cutoffs shortened distances by 15 and 19 miles respectively, neither cutoff achieved the intended purpose of eliminating shoaling near the mouth of the Red River and formation of a bar on the Mississippi River below the mouth of the Red River.

One of the major studies of the Mississippi River in the 1800s, with emphasis on the lower Mississippi, was the comprehensive "Delta Survey" report of 1861 (reprinted with additions in 1876) by Captain A. A. Humphreys and Lieutenant H. L. Abbot of the Corps of Engineers: Report upon the physics and hydraulics of the Mississippi River; upon the protection of the alluvial region against overflow; and upon the deepening of the mouths. The report recommended that: "An organized levee system must be depended upon for protection against floods in the Mississippi valley" [page 445]. The height of the levees, using the flood of 1858 as a basis, was to be 3 to 13 feet above the river banks, the higher levels (6-13 feet) extending from about the northern State line of Arkansas to Vicksburg, Mississippi. The report noted that "... plans of cutoffs, and of new or enlarged outlets to the Gulf, are too costly and too dangerous to be attempted" [page 445]. (The policy of the Mississippi River Commission between 1884 and 1928 was to prevent cutoffs and none occurred during that period. From 1929 to 1942 the Corps of Engineers excavated 16 cutoffs between Memphis, Tennessee and Angola, Louisiana [about 50 miles northwest of Baton Rouge], for improvement of navigation).

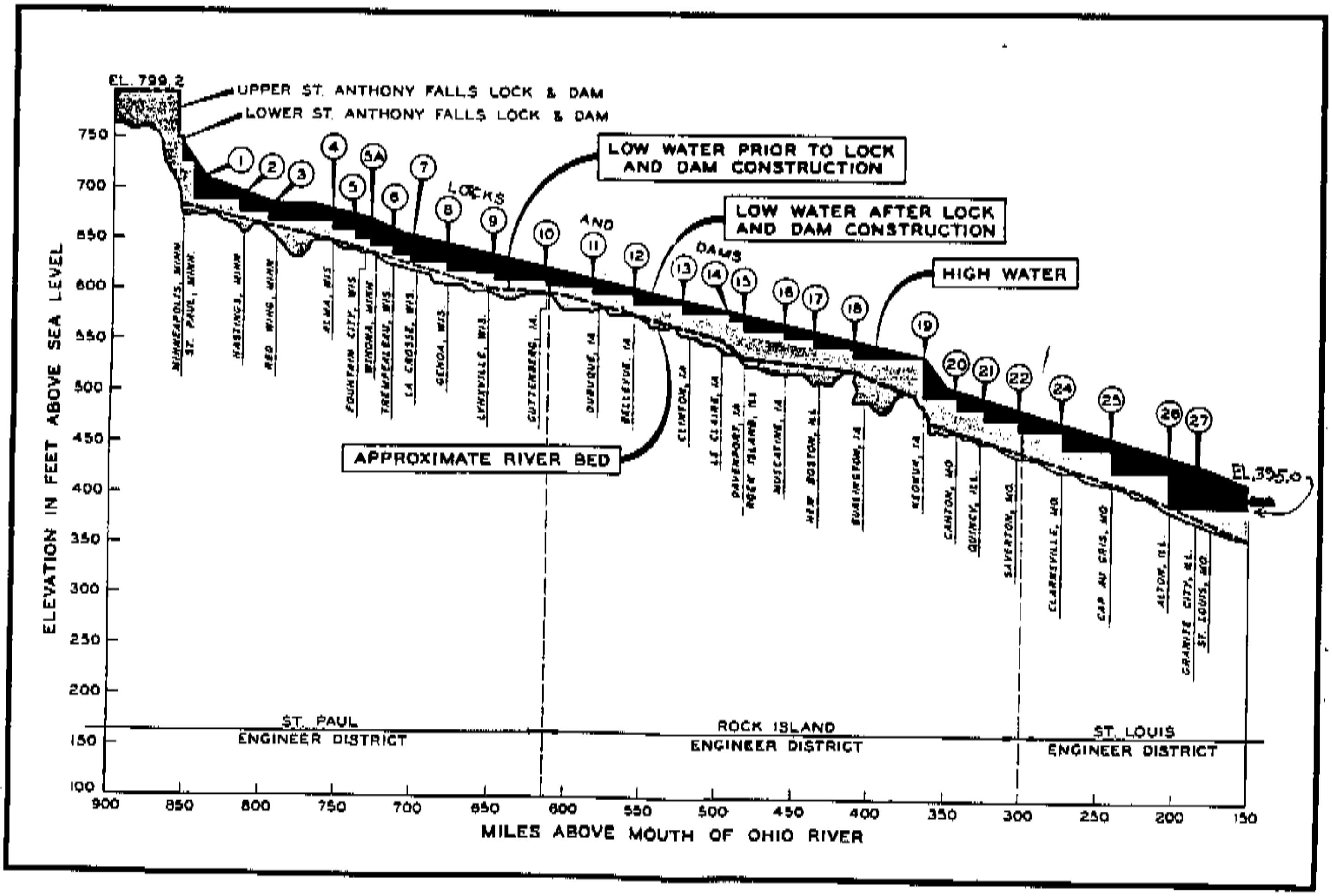
Major navigation development activities of the Corps of Engineers and the Mississippi River Commission on the Mississippi span a period from the 1870s to the present time, much of the effort directed toward dredging, widening, and maintaining the navigable river channel throughout its length, and in the upper Mississippi, the construction of locks and dams from Minneapolis to St. Louis. Major improvements at the mouth of the river for oceangoing ships, were authorized by Congress in 1852, to be done by contract. The difficult engineering problems were finally solved by Captain James B. Eads, using a system of parallel jetties to achieve a 30-foot deep channel at the mouth(s) in 1879.

Timetable of navigation channel development activities on the Mississippi River, 1878-1953

Year	Activity (Auth. = Congress authorizes)
	UPPER MISSISSIPPI
1878	Auth. 4½-foot channel from mouth of Missouri to St. Paul
1907	Auth. 6-foot channel
1914	Construction of Lock and Dam 19
1917	Construction of Lock and Dam 1
1927	Auth. 9-foot deep, 300-foot wide channel from St. Louis to Cairo
1930	Auth. extension of 9-foot channel to St. Paul through construction of locks and dams
1937	Auth. 4.6-mile extension upstream at Minneapolis to ascend St. Anthony Falls by locks and dams
1930-53	Construction of 29 locks and dams
	LOWER MISSISSIPPI
1896	Auth. 9-foot deep, 250-foot wide channel from Cairo to Head of Passes, Louisiana
1928	Auth. widening to 300 feet from Cairo to Head of Passes
1944	Auth. 12-foot channel from Cairo to Head of Passes
1945	Auth. deepening and widening channel for ocean ships, from Baton Rouge, La., to Gulf of Mexico

The locks and dams constructed on the upper Mississippi River provide a depth of at least nine feet above the bed of the river, including times of low water. The majority of the locks are 110 feet wide and 600 feet long, readily accommodating "tows" of ten or more barges at a time pushed upstream or downstream by a towboat. The locks fill and empty by gravity; the only power required is that for operation of the valves and gates. During flood periods the gates are lifted entirely above the water level, allowing the river to flow freely downstream. The average navigation season between Minneapolis, Minn., and Rock Island, Ill. (Davenport, Iowa), is April 1 to December 1.

The river distance from above St. Anthony Falls at Minneapolis-St. Paul, Minnesota, to below lock no. 27 near the lower end of the 10-mile canal at Granite City, Illinois (east of the river channel at St. Louis), is 669 miles. The river falls a total of 420 feet between those two points, equal to an average slope of 0.63 foot per mile. Most of the time, however, and especially when water levels are low, the series of locks and dams resemble giant stair steps consisting of lakes known as "pools." For the 29-lock-and-dam system, the pools range in river length from 0.3 mile to 46.2 miles, and the differences in level from pool to pool range from 5.5 to 49.2 feet.



Flood control -- measures taken to prevent or reduce flood damages to people and property -- has been a periodic and increasingly serious concern in the Mississippi valley since the beginning of towns and farms along the river, especially when they have been located at least partly on the floodplain itself. Levee-building began in the 1700s and by the mid-1800s there were extensive levees along the Mississippi, mainly built by landowners and local levee districts. However, many of the levees were deficient in height and cross-section and were breached and damaged by such floods as those of 1849, 1850, 1858, and 1859.

Federal involvement by the Corps of Engineers began in the 1800s, with emphasis on expansion and improvement of levee-building, as noted earlier regarding the recommendations of the Delta Survey of 1861. Levee construction by the Mississippi River Commission began in 1882. By the early 1900s, methods of riverbank protection and stabilization by means of heavy willow mattress revetments were successfully developed and in general use. (Revetments of later years included asphalt mattresses and articulated concrete mats.)

The flood of 1927, one of the most disastrous floods of record in the lower Mississippi River basin, caused the failure of levees built to the levels and standards of the time, and attracted national attention and sympathy. A significant result was preparation and adoption of a major plan (project) by the Corps of Engineers for both flood control and navigation on the Mississippi. This project was adopted as part of the Flood Control Act of 1928, and included re: flood control, not only construction, extension, and repair of levees, but also works designed to increase the flood-carrying capacity of the river, reduction of flooding by tributaries on adjacent floodplains, and the provision of floodways -- Bonnet Carre, Birds Point-New Madrid, Eudora, Boeuf, and Atchafalaya -- all adjacent to parts of the lower Mississippi, to carry water in excess of the safe capacity of the leveed channel. Eight years later, the Flood Control Act of 1936 established the Corps of Engineers as the nationwide planning and construction agency for flood control. The work of the Corps to the present time on the upper and lower Mississippi continues the same general pattern established in the projects begun as a result of the Acts of 1928 and 1936.

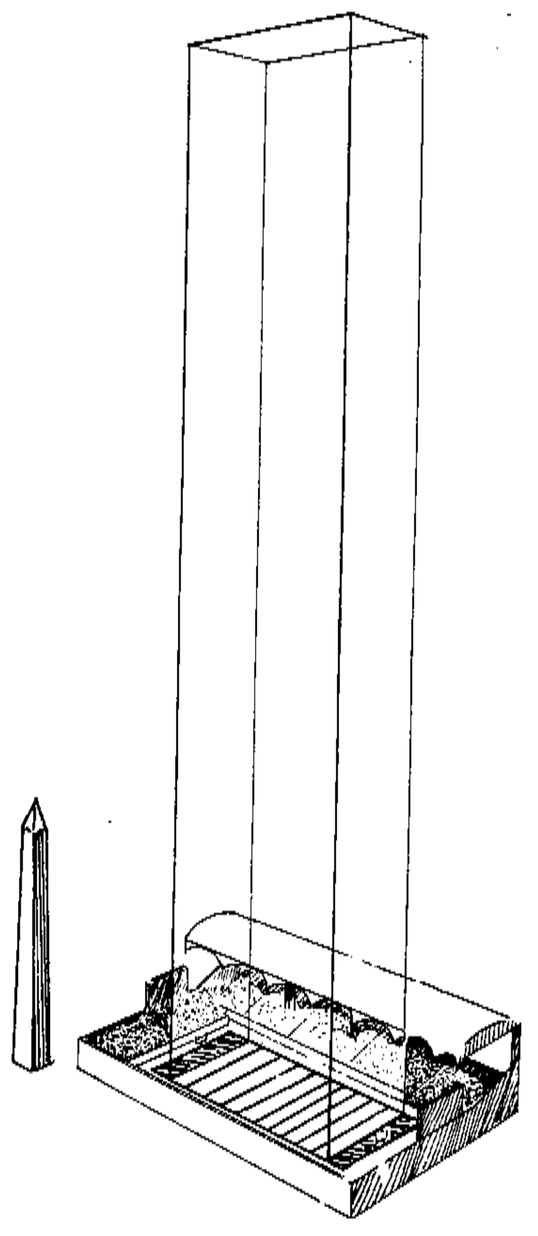
[MS-CORPS]
3/10/96

AVERAGE AND EXTREME FLOWS (DISCHARGES), SELECTED DATA

In common with streams generally, the Mississippi River is a dynamic resource -- its flow changing in time and place. The changes result from the complex interaction of many factors, including precipitation, temperature, evapotranspiration, and other characteristics of the river basin. The following paragraphs and accompanying table describe briefly the increase in average and extreme flows, proceeding downstream from the source of the river to Vicksburg, Mississippi, where the flow is the total from more than ninety percent of the entire basin.

In Minnesota where the Mississippi begins at the outlet of Lake Itasca -- a 38.5-square-mile drainage basin -- the average flow is probably about 14 cubic feet per second or 9 million gallons a day. Extreme flows may be as low as one-one hundredth of the average, such as in a rain-deficient late summer or autumn, or as high as several times the average, such as under flood conditions brought on by a sudden melting of winter ice and snow and augmented by rainfall.

By the time the Mississippi has traveled some 500 miles downstream and reached St. Paul, Minnesota, the drainage basin has increased to 36,800 square miles and the average flow of the river has increased to more than 13,000 cubic feet per second or nearly 9 **billion** gallons a day. If the magnitude of "billion gallons" is difficult to comprehend, consider this -- a billion gallons is equal to a column of water whose base is the size of a football field and whose height is more than 2,300 feet (160 x 360 x 2,321).



One billion gallons is equal to a column of water whose base is equal to that of a football field and whose height is more than 4 times that of the Washington Monument.

[MS-FLOW] [MS-FLOW4]
3/10/96

Average and extreme discharges at selected stream-gaging stations in the Mississippi River basin, in downstream order

Station (drainage area in square miles, percent of basin, period of record)	Maximum day	Minimum day	Average discharge, 1961-90: cubic feet per second	billion gallons per day	inches of runoff, annual
	cubic feet per second				
Mississippi River at St. Paul, Minn. (36,800 sq. mi., 3%, 1892-1995)	171,000 April 16, 1965	632 Aug. 26, 1934	13,497	8.7	4.98
Mississippi River at Keokuk, Iowa (119,000 sq. mi., 9.5%, 1878-1995)	435,000 July 10, 1993	5,000 Dec. 27, 1933	71,962	46.5	8.21
Missouri River at Hermann, Mo. (524,200 sq. mi., 99%, 1897-1995)	750,000 July 31, 1993	4,200 Jan. 10, 1940	84,845	54.8	2.20
Mississippi River at Thebes, Ill.; at Cape Girardeau, Mo. (713,200 sq. mi., 57%, 1932-1995)	975,000 Aug. 7, 1993	24,700 Jan. 21, 1940	213,100	137.7	4.06
Ohio River at Metropolis, Ill. (203,000 sq. mi., 100%, 1928-1995)	1,850,000 Feb. 1, 1937	15,000 July 20, 1930	286,990	185.5	19.2
Mississippi River at Memphis, Tenn. (932,800 sq. mi., 75%, 1933-1995)	1,970,000 Feb. 8, 1937	80,000 Aug. 24, 1936	509,813	329.5	7.42
Mississippi River at Vicksburg, Miss. (1,140,500 sq. mi., 91%, 1928-1995)	*2,080,000 Feb. 17, 1937	99,400 Nov. 1, 1939	614,683	397.3	7.32

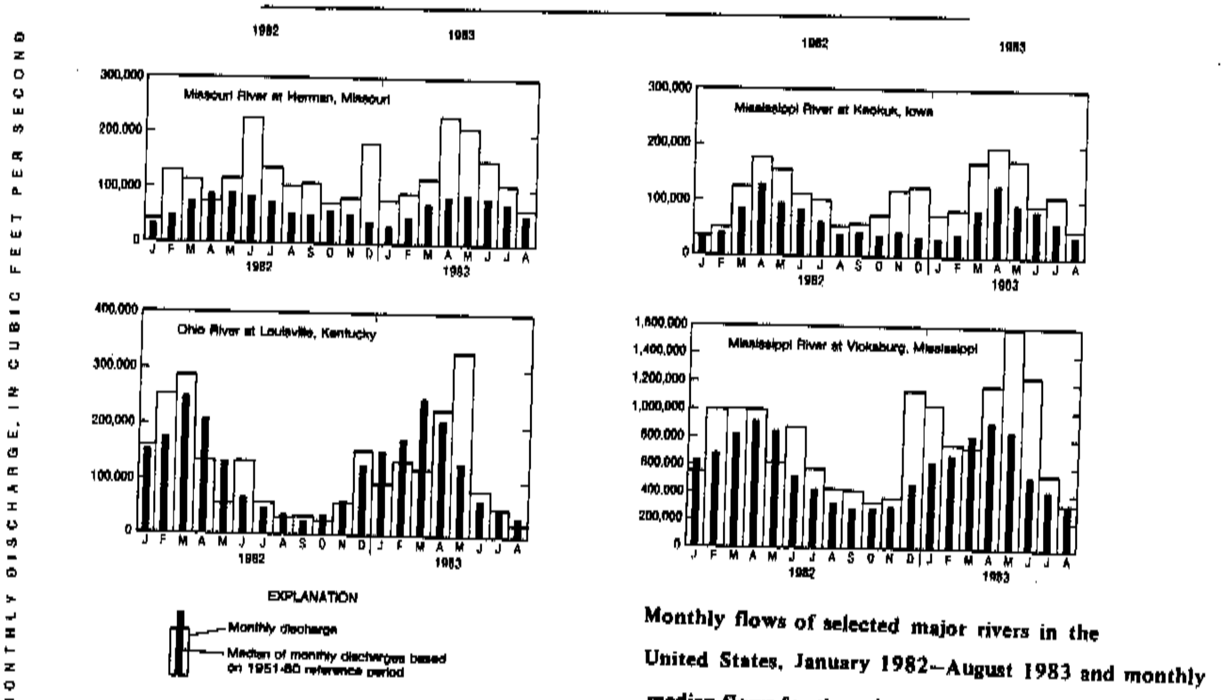
* Estimated maximum discharge in June 1927, if all flow had been confined between levees: 2,278,000 cubic feet per second.

[MS-FLOOF]

The accompanying table lists the average and extremes of flow at four additional stream-measurement sites downstream on the Mississippi, as well as sites near the mouths of its two largest tributaries, the Ohio and the Missouri Rivers. By the time the Mississippi River reaches the Gulf of Mexico, the Mississippi discharges an average of about 650,000 cubic feet per second (more than 400 billion gallons per day).

The table also shows the inches of average annual runoff (equal to the average annual discharges shown on the same line), so that such data may be compared to average annual precipitation expressed in inches, especially in the upper Mississippi River basin and in the Missouri and Ohio River basins. For example, in the Mississippi headwaters region, average annual precipitation is about 25 inches, and the table shows the average annual runoff is about 5 inches as measured at St. Paul, Minnesota. The difference of 20 inches is water that is evaporated from water surfaces and transpired from vegetation. Just comparing the runoff data for the Ohio and Missouri River basins in a very general way, emphasizes that the much higher runoff in the Ohio River basin (about 19 inches) reflects the humid conditions to the east of the Mississippi River in contrast to the relatively dry conditions characteristic of large parts of the Missouri River basin (2.2 inches of runoff) to the west of the Mississippi River.

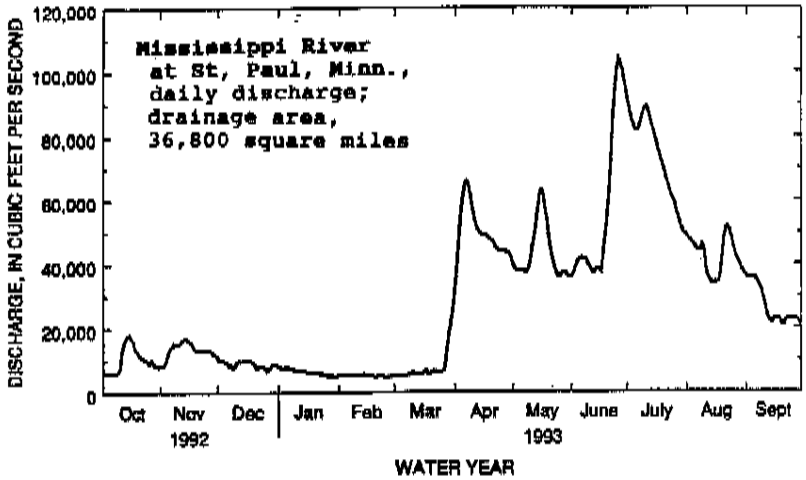
Annual averages of streamflow mask the variability that occurs throughout the year. The small graphs show month-to-month changes at four sites during the 18 months from January 1982 to August 1983, a time of generally above-normal streamflow in the Mississippi River basin; also shown are the average monthly flows at the same sites. As is typical of streamflow in much of the United States, the higher monthly flows generally occur in the late winter and early spring, and the lower flows in late summer and autumn.



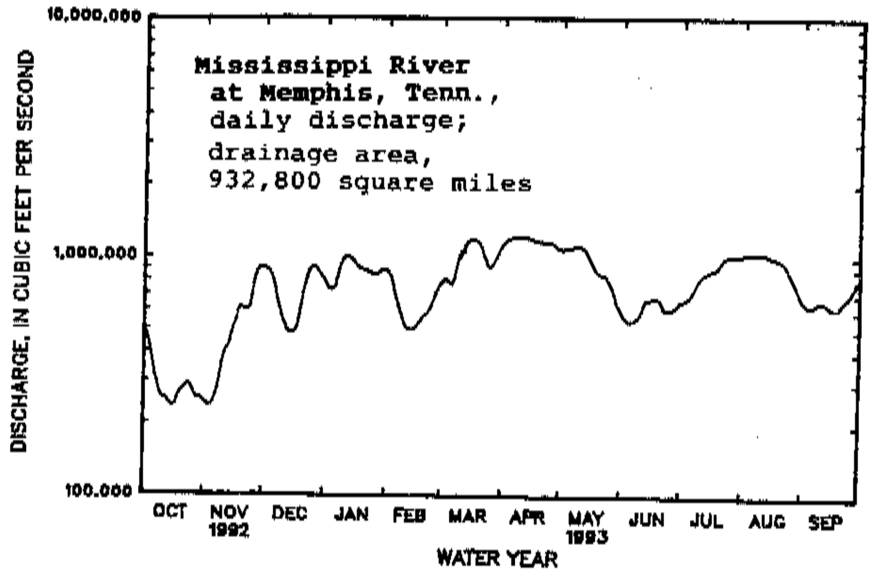
Monthly flows of selected major rivers in the United States, January 1982—August 1983 and monthly median flows for the reference period 1951—80.

[MS-FLOWG]
3/10/8.

Examples of day-to-day variations in streamflow: Mississippi River at three measurement sites, October 1, 1992 to September 30, 1993.



Mississippi River
at Keokuk, Iowa,
daily discharge;
drainage area,
119,000 square miles



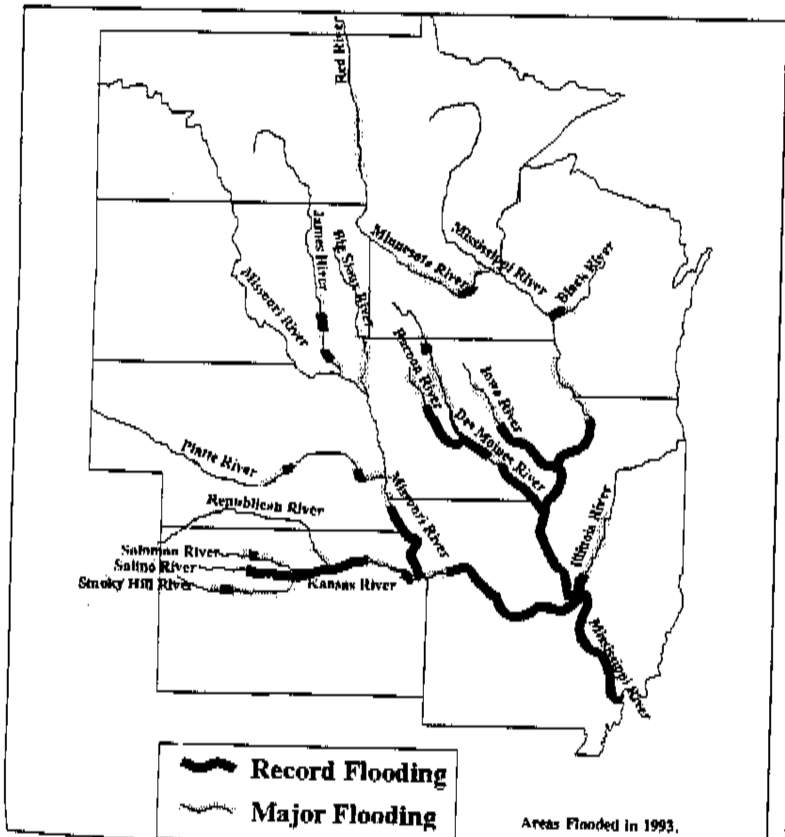
FLOODS

Floods have occurred every few years along the Mississippi River "since time began," so to speak, whenever a combination of temperature, precipitation, and soil saturation in the river's tributary basins produced more water than could be contained within the river banks. Years of major floods along substantial parts of the Mississippi River in the 1800s include 1809, 1844, 1851, 1858, 1880, 1881, and 1882. The floods of 1927 and 1937 along the lower Mississippi, as indicated by the maximum discharges measured at Memphis, Tennessee, and Vicksburg, Mississippi, are the largest since 1900.

Most floods along the river occur in the spring or summer, the seasons when precipitation is usually greater than in autumn and winter. The major flood of January-February 1937 along the Ohio and lower Mississippi Rivers was a seasonal exception and was caused largely by the extraordinary precipitation (on saturated soil) and runoff from a series of storms that were most severe in the Ohio River basin.

Within the past thirty years, the floods of 1965, 1973, and 1993 are among the most severe in modern times in terms of flood damages along the Mississippi. The floods of 1965 and 1993 were concentrated in the upper Mississippi, whereas the flood of 1973 had major impact nearly the entire north-south length of the river.

	1965	1973	1993
Lives lost	15	28	
Total damages dollars that year:	160 million	More than 400 million	More than 12-16 billion
"1987" dollars: (to compare data)	560 million	More than 960 million	More than 10-13 billion
Homes flooded	11,000	More than 30,000	
Farmland inundated (acres) .	Many thousands	12 million	

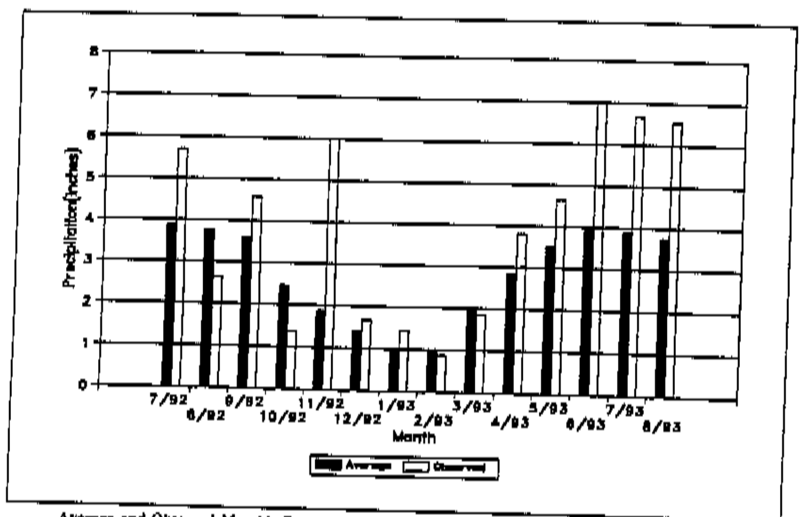


Areas Flooded in 1993.

Source: U.S. Department of Commerce, NOAA, National Weather Service.

The March-October flood of 1993 in the upper Mississippi River basin States of Illinois, Iowa, Kansas, Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin, was the most devastating U.S. flood in modern times. Property damage alone exceeded $10 billion. "Damaged highways and submerged roads disrupted overland transportation throughout the flooded region. The Mississippi and Missouri Rivers were closed to navigation before, during, and after the flooding. Millions of acres of productive farmland remained under water for weeks during the growing season. . . . Industrial and agricultural areas were inundated, which caused concern about the transport and fate of industrial chemicals, sewage effluent, and agricultural chemicals in the floodwaters. The extent and duration of the flooding caused numerous levees to fail." [Part of Foreword of USGS Circular 1120-H, 1995.]

Precipitation was persistently above normal for most of the fourteen months July 1992 through August 1993. The result was major and often record-breaking floods, not only along the upper Mississippi and lower Missouri Rivers, but also along many of their tributaries such as the Minnesota, Iowa, Des Moines, and Kansas Rivers.



Average and Observed Monthly Precipitation Totals for the Upper Mississippi River Basin.

Source: U.S. Department of Commerce, NOAA, National Weather Service.

[MS-FLOOX]
3/21/96

Maximum discharges during the 1993 flood at five sites along the Mississippi River, were as follows, expressed in cubic feet per second; the years of measurement are listed for each site:

At St. Paul, Minn., 1892-1995	104,000 on June 26
At Clinton, Iowa, 1874-1995	245,000 on July 5
At Keokuk, Iowa, 1878-1995	435,000 on July 10
At St. Louis, Mo., 1862-1995	1,080,000 on Aug. 1
At Thebes, Ill., 1933-95 (downstream from Cape Girardeau, Mo.)	975,000 on Aug. 7

The maximum discharge at the mouth of the Missouri River upstream from St. Louis (at Hermann, Mo., 1897-1995) was 750,000 cubic feet per second, on July 31. With the exception of the Mississippi River at St. Paul, all the discharges listed above are the highest for the entire period of years of continuous record at those sites. (The highest discharge of record at St. Paul, Minn., occurred on April 16, 1965 -- 171,000 cubic feet per second -- at a stage of 26.01 feet.)

Easier to visualize and measure than river discharges with respect to potential, impending, or actual damages incurred by major floods, are the stages (water levels) of a river as it rises to or above the level -- "flood stage" or "bankfull stage" -- at which flooding begins (unless prevented by such efforts or construction as sand-bagging or floodwalls). At most measurement sites the "zero" level or "datum" of a stage is at or near the bottom of the river when the reference site was established many years ago.

The highest stages reached along most of the **upper** Mississippi in 1993 were record-breaking and occurred on or about the same day as the maximum discharges. Regarding the **lower** Mississippi in 1993, it should be noted that the discharge of the Ohio River, normally by far the largest water-volume tributary to the Mississippi, was discharging less than one-third of its average rate of flow for August. Both the Ohio at its mouth and the Mississippi River at Memphis, Tenn., and Vicksburg, Miss., remained below flood stage throughout the summer of 1993.

A major reason for the extreme devastation caused by the 1993 flood in the upper Mississippi and lower Missouri River basins was the extremely high, record-breaking number of consecutive days that the rivers in many areas remained above flood stage, generally exceeding what had also been unusally long periods of above-flood-stage conditions during the major flood of 1973. For example, in 1993 on the Mississippi at Clinton, Iowa, a consecutive-day period of 43 days above flood stage in April-May was followed by one of 33 days in June-July. Two somewhat corresponding periods of time of 44 days and 97 days above flood stage occurred on the Mississippi at St. Louis; at the mouth of the Missouri River, four consecutive-day periods totaled a combined 69 days.

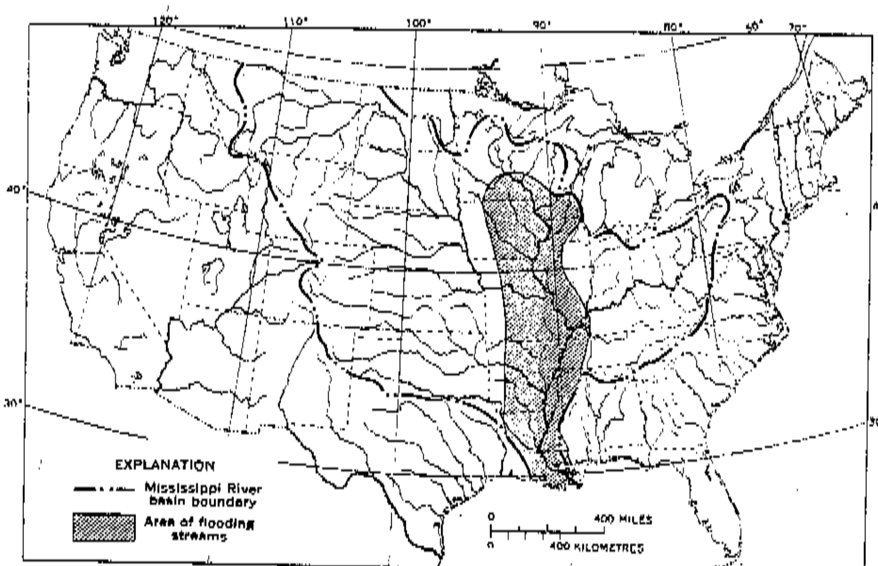
The flood of 1973 was severe in the lower as well as the upper Mississippi because of the very high discharges of the Ohio River. Both the Ohio River at its mouth and the Mississippi at Memphis were above flood stage for more than 60 days.

[MS-FLOOD]
3/6/96

Consecutive days above flood stage at several gaging stations on and near the Mississippi River during floods of 1973 and 1993

Gaging Station	Consecutive days above flood stage (Durations of 9 or more consecutive days) 1973 Days (dates)	1993 Days (dates)
Mississippi River at St. Paul, Minneapolis	0	27 (June 23 - July 19)
at Clinton, Iowa	18 (March 17 - April 3) 9 (April 22-30) 12 (May 9-20)	43 (April 6 - May 18) 33 (June 19 - July 21)
Missouri River at Hermann, Missouri	73 (March 6 - May 17)	10 (April 14-23) 17 (May 5-21) 25 (July 1 - Aug 25) 17 (Sep 14-30)
Mississippi River at St. Louis, Missouri	77 (March 10 - May 25)	44 (April 11 - May 24) 97 (June 26 - Sep 30)
at Thebes, Illinois	95 (March 11 - June 13)	57 (April 1 - May 27) 121 (June 2 - Sep 30)
Ohio River at Metropolis, Illinois	69 (March 13 - May 20)	0
Mississippi River at Memphis, Tennessee	63 (March 24 - May 25)	0

3/4/96



The Mississippi River basin, showing general area of flooding streams, spring 1973.

(11/21/95)

Highest Stage During 1993 Flood at Several Sites on and Near the Mississippi River (Source of data: USGS Circular 1120-A and Professional Paper 937)

River & Site	Flood Stage (approx bankfull stage in feet)	Highest Stage during 1993 flood	
		Stage (feet)	Date
Miss. River at St. Paul, MN	14.0	19.13	June 26
at Clinton, Iowa	16	22.98	July 8
Iowa R. at Wapello, Iowa	20	29.53	July 7
Miss. River at Keokuk, Iowa	16	27.15	July 10
Des Moines R. below Racoon R, at Des Moines, Iowa	23 ?	34.29	July 11
Missouri R. at Kansas City, MO	32 ?	48.87	July 27
at Hermann, MO	21	36.97	July 31
Miss. River at St. Louis, MO	30.0	49.58	Aug. 1
at Chester, IL	27.0	49.59	Aug. 6
Ohio R. at Metropolis, IL	43	(below flood stage)	
Miss. River at Memphis, TN	34.0	(below flood stage)	
at Vicksburg, MS	43.0	(below flood stage)	

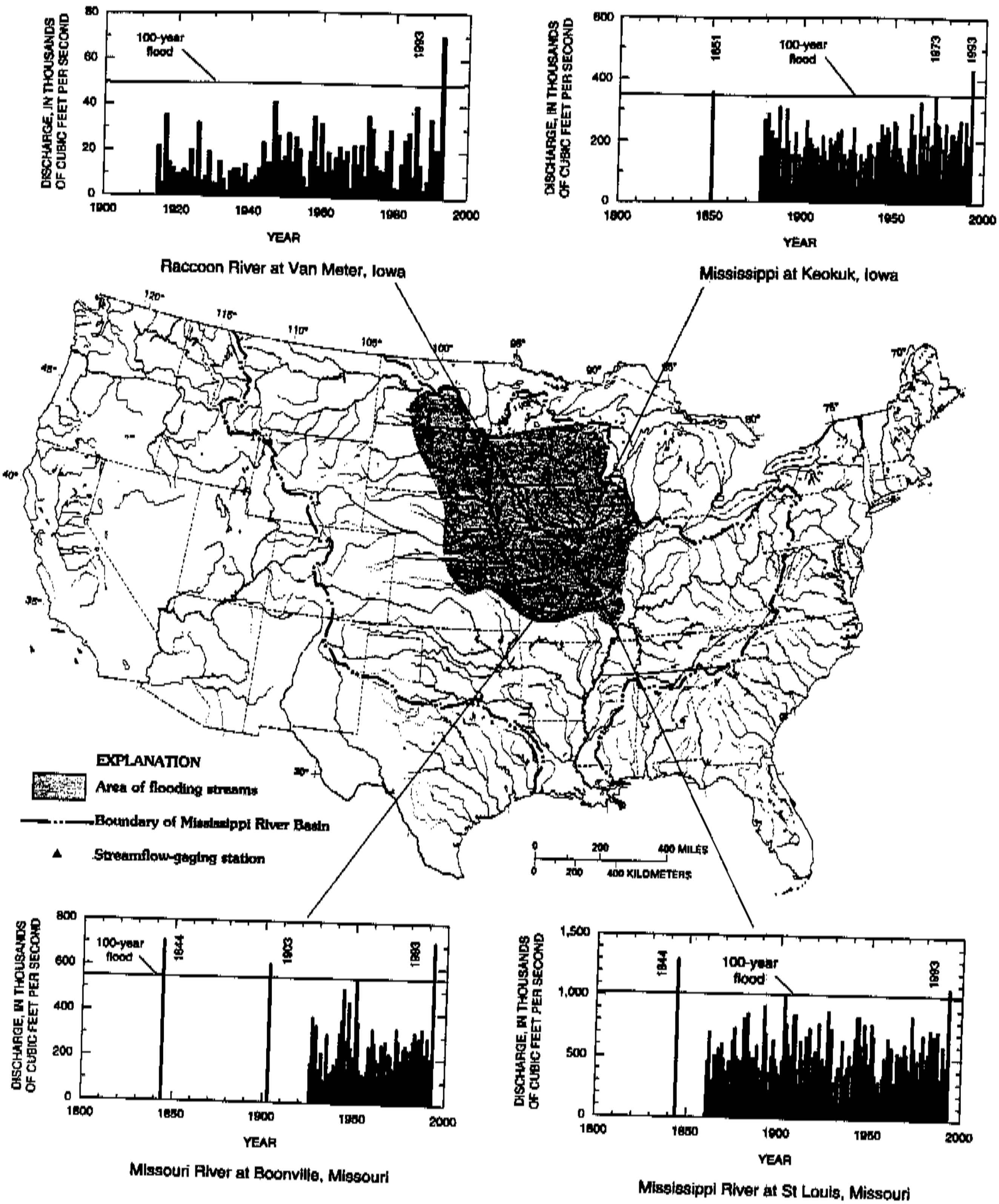


Figure Historic peak discharges and peak discharges for the 1993 flood at selected streamflow-gaging stations in the upper Mississippi River Basin.

11/21/95

Questions that always arise after a flood of great magnitude and severity are -- Will a flood of that size (such as in 1993) happen again? How often? When? The answer to the first question is probably "Yes," and to the third question is "No one knows." As to "how often," engineers and hydrologists and climatologists study long periods of past records of such weather and flood events as well as natural and man-made changes in the environment, and express their conclusions in terms of mathematical probabilities -- "recurrence intervals" -- such as once in 50 years (a "50-year flood") or once in more than 100 years, etc. That conclusion gives some idea of "how often," but little or no idea of "when." (In a specific year, of course, analysis of weather and other climatic-hydrologic factors occurring at that time are used to forecast warnings and other information of what may occur in coming days or weeks.) In many places along the Mississippi River, the floods of 1973 and/or 1993 were in the category of once in 100 years -- a 100-year flood -- irrespective of the fact that the floods occurred only 20 years apart.

There are no easy answers to these questions, but measures have been and can be taken to reduce the loss of lives and property (in addition to forecasts) that occur when these extreme events of nature take place. Flood-control reservoirs have been effective in reducing flood stages in the lower Missouri River, but are not feasible along the Mississippi River because of the low slope along most of the river's length and the corresponding lack of sites for major reservoir water storage. Floodways to divert excess water away from the main channel of a river also reduce flood flows under suitable conditions. Levees are another form of control if strong and high enough to cope with extreme flood events. However, all of these measures have their limits when "Mother Nature" vents her wrath with excessive, widespread, and persistent precipitation, especially when the timing is such that the high waters of tributaries combine in succession as massive volumes of floodwaters move downstream. Then, high ground is probably the only place of safety, and homes and farms and industries built on floodplains will suffer greatly and many will be destroyed.

The text at right is a unique explanation of the possibility of a "100-year flood" -- as noted in the 1994 report of the (U.S.) Interagency Floodplain Management Review Committee: "Sharing the Challenge -- Floodplain Management into the 21st Century."

MARBLES AND FLOODS

At one of the public meetings attended by the Review Committee, a young Missouri farmer provided a correct explanation of the possibility of experiencing a 100-year flood. He described a bag full of 100 marbles with 99 clear marbles and one black marble. Every time you pull one of those marbles out, and it's black, you've got a 100-year flood. After each draw, you put all 100 marbles back in the bag and shake it up. It's possible that you could pull the black one out two or even three times in a row. To represent the uncertainty of estimating a 100-year flood, it's also possible that the bag could hold two or three black marbles.

[MS-FL-92]
2/22/96

DROUGHTS

The following paragraphs refer mainly to "hydrological droughts" -- those droughts that are characterized by unusually low-flow conditions in streams or very low ground-water levels resulting from long periods, such as some months or a year or more, of minimal precipitation. "Agricultural droughts" are caused by shorter periods of deficient precipitation that are nonetheless long enough to damage the growing of non-irrigated crops.

The primary impact of severe hydrological droughts on the Mississippi River is upon navigation because of the intensive use of the river for that purpose. Also subject to the damaging effects of lowered water levels are the many headwater lakes and reservoirs, thereby reducing their use for recreation, irrigation, and for storage of supplemental water as may be needed to maintain river navigation levels downstream. Lowered river levels may also reduce the efficiency of river intake systems for municipal water systems or power plants.

The most severe droughts during the past 70 years that have affected navigation on the Mississippi River are those of the early 1930s, especially in the upper Mississippi, 1936, and 1988. The lowest flows of the river during those years generally occurred in the 1930s.

Regarding the droughts of 1930-31, the Chief of the Corps of Engineers reported serious impairment of navigation between Minneapolis-St. Paul and the mouth of the Illinois River in 1931 because the use of upstream storage in 1930 was not replenished by adequate precipitation during the winter and spring of 1931. Navigation depth was reduced to as little as 4 feet. In the lower Mississippi, the navigation depth of 9 feet was able to be maintained.

During the drought of 1936, navigation in the upper Mississippi was suspended during July and August because of low water, but as in the earlier 1930s, navigation was maintained on the lower Mississippi. Some 200 to 800 miles west of the Mississippi River was the 1936 "dust bowl" region -- so named because of the extreme soil destruction of farmlands by wind erosion, primarily affecting the States of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, and Texas.

[MS-DROUY]
3/16/92

The drought of 1988 adversely affected much of the nation, including the Mississippi River as well as its largest tributaries, the Ohio and Missouri Rivers. During the summer, a wedge of salt water from the Gulf, began moving upstream from the mouth of the Mississippi -- a potential threat to the New Orleans municipal water intake system. Potential problems caused by low water levels at water intakes for public water systems were not limited to the Gulf region of the lower Mississippi. For example, on July 14, 1988, Senator Danforth of Missouri stated at a Senate hearing that the water level at Cape Girardeau, Missouri, was less than 5 feet (in contrast to the average of 20 feet), only 1½ feet above the water intake.

Regarding navigation, parts of the river were repeatedly shut down to barge traffic because of relatively shallow water levels in the channel and sometimes reduced width of the channel. Emergency channel dredging by the Corps of Engineers was sometimes necessary to re-open the channels to barge transportation.

In the vicinity of West Memphis, Arkansas, in July and August, water levels were so low -- at least 10 feet **below** "zero" stage -- that steamboat wreckage of 60 or more years ago was found resting on or near what at one time had been one of the navigation channels of the river. By the end of 1988, the drought had subsided, water levels had again covered the wreckage, and water depths were adequate for uninterrupted navigation.

[MS-DROUZ]
3/6/96

WATER QUALITY AND SEDIMENT

The Mississippi River is a polluted waterway along much of its length. However, in many areas the contaminants may be removed or reduced to such an extent that the water is usable for many purposes, including drinking water. There are many municipal water systems that depend upon the Mississippi River as the source of supply -- the largest of these systems are at Minneapolis and St. Paul, Minn., St. Louis, Mo. (using water from both the Mississippi and Missouri Rivers), and New Orleans, La.; the largest cities along the Mississippi that depend on ground water -- from wells 500 to more than 2,000 feet deep -- are Memphis, Tenn., and Baton Rouge, La.

A major water-quality improvement in the Mississippi in recent decades has been the construction of sewage treatment plants at cities along the river, thereby eliminating the major load of raw sewage that once drained continuously into the river. On the other hand, a major cause of increased pollution has been the residual pesticides and herbicides in runoff entering the river and its tributaries from millions of acres of crops treated with these chemicals, including agricultural areas in the upper Mississippi River basin. The wastes from chemical and other industries have long been major sources of pollution, probably most severe in the lower Mississippi between Baton Rouge and New Orleans, Louisiana.

Some of the contaminants are dissolved in the river water itself and some of them become affixed to particles of clay and silt that comprise the prodigious quantities of sediment moving gulfward, partly suspended in the moving water and partly settling to the river bottom, at least temporarily. Fish and other organisms sometimes retain the polluted components of sediments that they ingest or absorb. Thus, there are potential hazards to human health not only from the water itself but also from foods associated with the water environment, such as fish and waterfowl.

From 1987 to 1992, the U.S. Geological Survey carried out a research project to examine the water quality of the Mississippi River and its tributaries, including an emphasis on the transport and storage of pollutants in large rivers and on obtaining a foundation of facts on the present condition of the river. The accompanying two illustrations and captions are from reports by Robert S. Meade, the project leader, and Jerry A. Leenheer of the Geological Survey, summarizing some of the results of the research project.

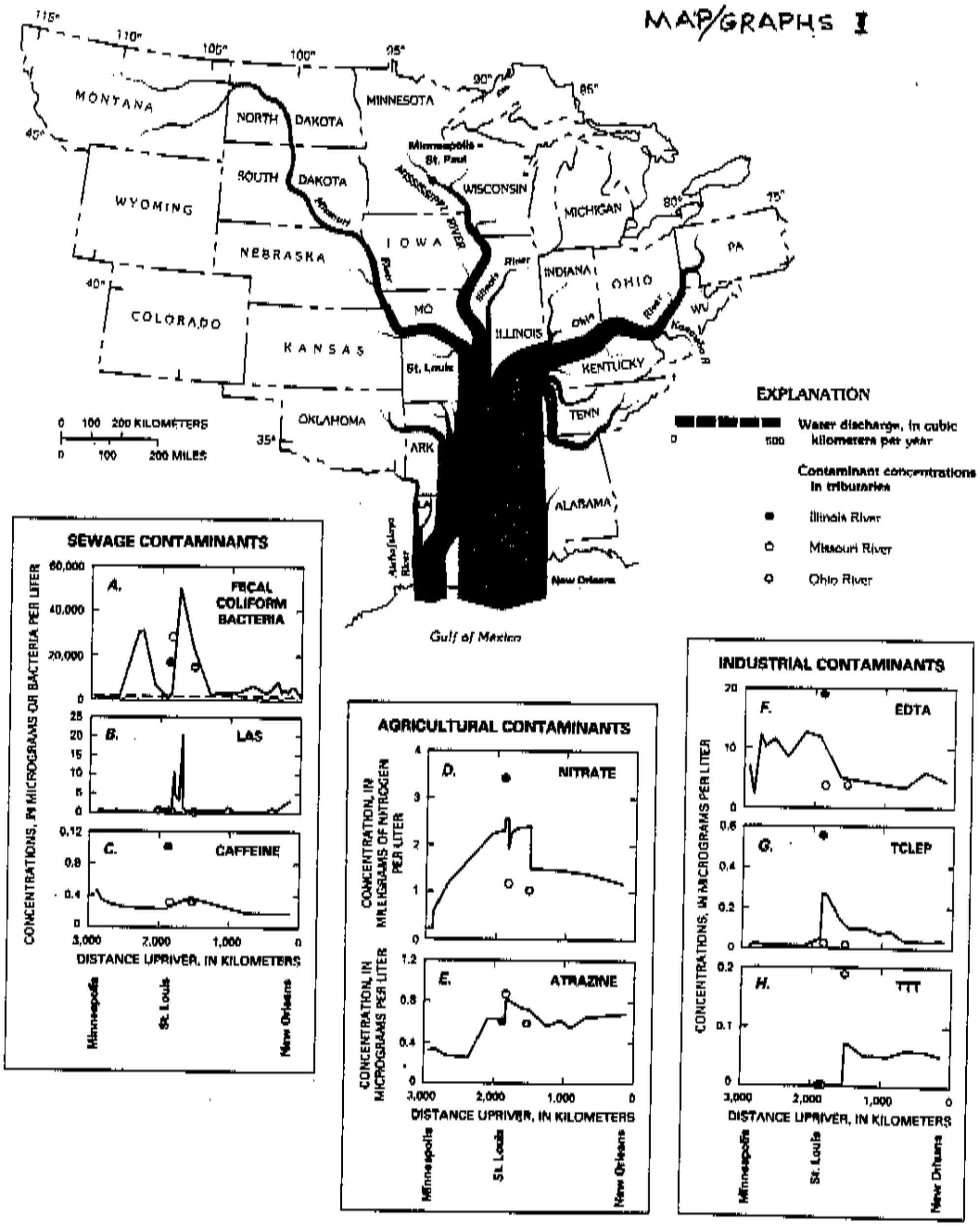
[MS-QUAL2]

3/6/96

Contaminants in the Mississippi River

(Two map-graph illustrations prepared by Robert H. Meade and Jerry A. Leenheer.)

Explanations are on page following each map-graph illustration.



Note:

Water discharge of 100 cubic kilometers per year = 112,000 cubic feet per second

River length of 1,000 kilometers = 621 miles

3/6/96

The waters of the Mississippi River carry dissolved contaminants and bacteria that originate from a variety of municipal, agricultural, and industrial sources. This map shows the amounts of water discharged by the Mississippi River and its tributaries during an average year. About 2 percent of the average discharge of the Mississippi River comes from municipal and industrial point sources. The distribution of contaminants along the Mississippi River depends on the nature and locations of their sources, the degree of wastewater treatment, and the stability of the contaminants and their dilution by receiving waters. The graphs show the concentrations of contaminants dissolved in the Mississippi River between Minneapolis–St. Paul, Minn., and the Gulf of Mexico. The data in the graphs are generalized from chemical analyses of representative samples of water collected at between 10 and 15 sites along the Mississippi River on as many as 10 separate occasions from 1987 to 1992 in the lower river and on 3 separate occasions during 1991 and 1992 in the upper river.

As the Mississippi River flows southward from its headwaters in the northern States of the Midwest, its discharge is more than doubled by the waters it receives from the Illinois and Missouri Rivers. This combined discharge is more than doubled again as it is joined by the waters of the Ohio River. About 500 kilometers upriver of its principal mouth, the Mississippi River bifurcates, and a quarter of its discharge is diverted by way of the Atchafalaya River to the Gulf of Mexico.

A. Fecal coliform bacteria derived from human and animal wastes survive only briefly in river water, but their averaged concentrations exceed the maximum contaminant level of 2,000 per liter for recreational use in much of the Mississippi River because of incomplete wastewater treatment.

B. Linear alkylbenzene sulfonate (LAS) is a biodegradable detergent primarily derived from domestic sewage. Its presence in high concentrations in the Mississippi River in the St. Louis metropolitan area corresponds with elevated counts of coliform bacteria and probably reflects the incomplete treatment of wastewater discharged into the river.

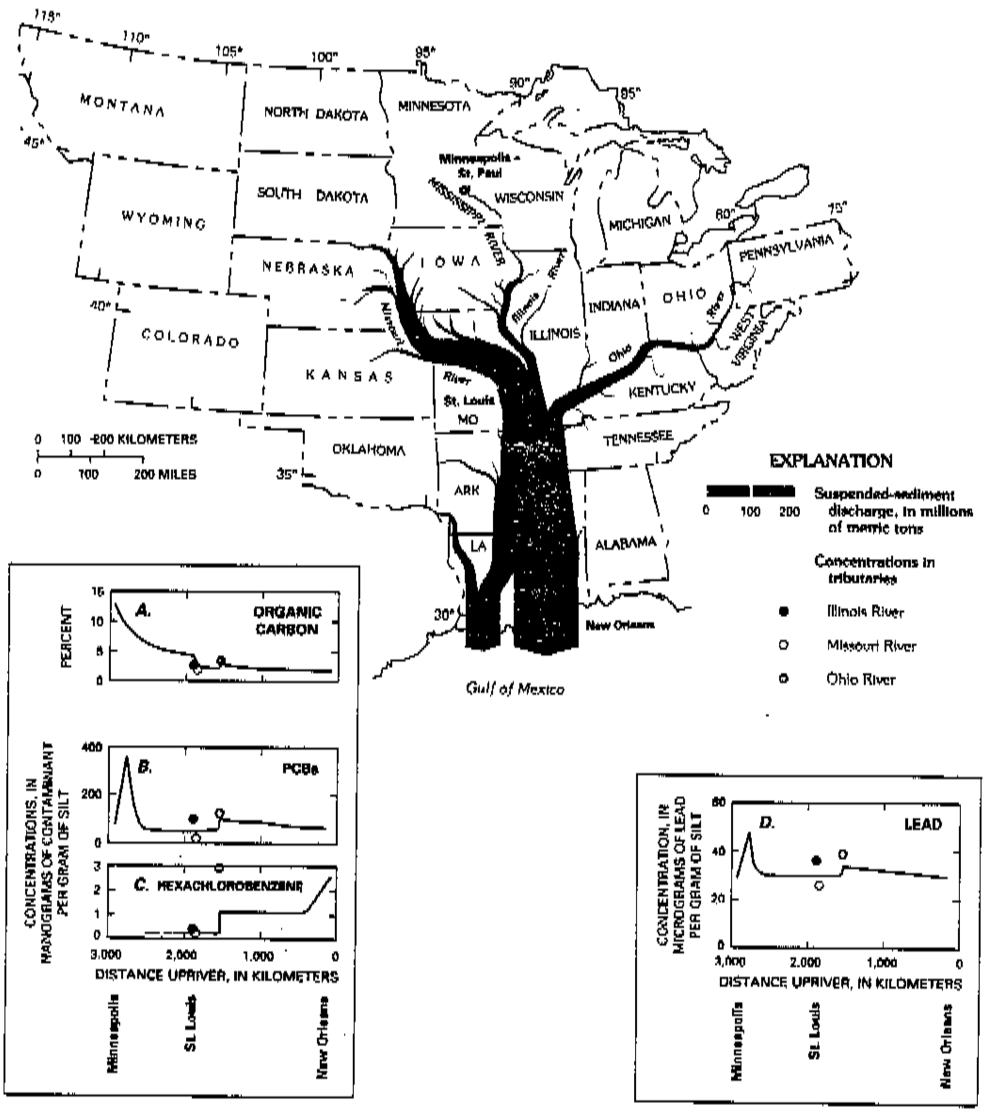
C. Caffeine is a stimulant chemical in coffee and soft drinks. Because it is consumed only by humans, it serves as an indicator of domestic sewage and illustrates the extent to which sewage is diluted by the river. Concentrations of caffeine in municipal wastewaters usually range between 20 and 300 micrograms per liter. The much lower concentrations of less than 1microgram per liter of caffeine shown in the graph indicate that municipal wastewaters may be diluted as much as a thousand fold after they are well mixed into the Mississippi River.

D, E. Agricultural chemicals enter the rivers from mostly nonpoint sources, usually as runoff from croplands during spring and summer. Nitrate in the Mississippi River (*D*) comes mostly from fertilizers. Its concentration in the river fluctuates seasonally, depending on when it is applied to farmlands and the timing of rainfall and runoff. Nitrate concentrations generally are smaller in the Mississippi River below the confluence of the Ohio River; the major portion of nitrate in the Mississippi River is derived from tributaries that drain intensively farmed regions in Illinois, Iowa, and Minnesota. Atrazine (*E*) is a preemergent herbicide that is used mostly on corn fields and is nearly ubiquitous in the Mississippi River. Atrazine concentrations usually are greatest near St. Louis because of inputs from the Missouri and Illinois Rivers and other rivers that drain the farming regions of the Corn Belt. Concentrations usually are smaller in the lower Mississippi because of dilution by water from the Ohio River. Atrazine concentrations vary seasonally and occasionally exceed the maximum contaminant level of 3 micrograms per liter during spring runoff in the Mississippi River between St. Louis and the Ohio River confluence.

F. Ethlenediaminetetraacetic acid (EDTA) is the dissolved organic chemical contaminant present at the greatest concentration in the Mississippi River. Generally considered nontoxic, this chemical is a general indicator of industrial contamination and is found in the Mississippi River at about one-fourth of the concentration found in some European rivers.

G, H. Two examples of contaminants from industrial point sources are tris-2-chloroethyl-phosphate (TCLEP) and 1,3,5-trimethyl-2,4,6-triazinetrione (TTT). TCLEP (*G*) is a flame retardant that is added to polyurethane foams and textiles; in the Mississippi River system, it is derived almost exclusively from the Illinois River Basin. Its exclusive source and its persistence in solution make TCLEP a useful tracer and indicator of waters from the Illinois River as they mix down the Mississippi River with waters from other tributaries. TTT (*H*) is a byproduct of the manufacture of methylisocyanate. Its overwhelmingly singular source in the Mississippi River system is the basin of the Kanawha River of West Virginia, which is a tributary of the Ohio River. Proportions of TTT dissolved in the water can be used to follow the mixing of the Kanawha River with the Ohio River and the Ohio with the Mississippi River.

MAP/GRAPHS II



3/6/96

Re: MAP/GRAPHS II

The suspended sediments that are transported by the Mississippi River and its tributaries adsorb and carry pollutants. Organic pollutants, such as polychlorinated biphenyls (PCB's), and inorganic pollutants, such as lead, are many times more likely to adhere to sediment particles than they are to remain in the dissolved state. The map shows the amounts of suspended sediment discharged by the Mississippi River and its tributaries during an average year near 1990. The graphs show the concentrations of the constituents adsorbed on the sediments in suspension in the Mississippi River between Minneapolis–St. Paul, Minn., and the Gulf of Mexico. The data in the graphs are generalized from chemical analyses of representative samples of suspended sediment collected at between 10 and 15 sites along the Mississippi River on as many as 10 separate occasions from 1987 to 1992 in the lower river and on 3 separate occasions during 1991 and 1992 in the upper river.

Suspended-sediment discharges in the upper Mississippi River are fairly small when compared with those of the major tributaries. The sediment discharge of the upper Mississippi is increased 5 to 10 times by the sediment discharge of the Missouri River. The average sediment load is increased by another significant increment by the contribution from the Ohio River.

A. Organic carbon (expressed here as a weight percentage of dried suspended silt and clay) is proportionately greater in the uppermost Mississippi River, and its proportion decreases downriver. Particulate organic carbon in the Mississippi River is mostly natural, but it affects the ways in which pollutants, especially organic pollutants, are adsorbed by suspended sediment. The Missouri and Illinois Rivers transport suspended sediment in which organic carbon is somewhat less concentrated; where these two tributaries enter the Mississippi (near kilometer 1850), the organic carbon percentages are decreased by dilution. Organic carbon percentages in the suspended sediment of the Ohio River, however, are typically greater than those in the Missouri and Illinois Rivers, and the organic carbon in suspended sediment is increased slightly where the Ohio River joins the Mississippi (kilometer 1535).

B. PCB's, which are pollutants that were once widely used in industrial applications, are typically most concentrated on the suspended sediments in the upper Mississippi River near Minneapolis–St. Paul. The difference between PCB concentrations on the suspended sediments near Minneapolis and those near St. Louis is the result of the greater amounts of suspended sediment in the river at St. Louis rather than an indication that Minneapolis–St. Paul contributed 5 to 10 times more PCB's to the river than St. Louis did. The high concentrations in the upper river decrease rapidly downriver, and they are increased significantly only as the suspended sediment from the Ohio River, which usually contains more PCB's than the middle reaches of the Mississippi River do, enters and mixes.

C. Hexachlorobenzene, another organic pollutant of industrial origin, is predominantly derived from two main sources in the Mississippi River basin—the Ohio River, which enters the Mississippi at kilometer 1535, and the industrial corridor that lines the lowermost 400 kilometers of the Mississippi River.

D. Lead and other heavy metals are associated with the suspended sediments along the length of the Mississippi River. Spatial variations in their concentrations are less pronounced than in those of PCB's and hexachlorobenzene. However, they do tend to be most concentrated on the suspended sediments in the river just downstream from Minneapolis–St. Paul (as in the case of PCB's, because of the relative scarcity there of suspended sediment), and they show slight increases related to more concentrated inputs from the Ohio River.

3/6/96

FURTHER READING -- SOME OTHER PUBLICATIONS ABOUT THE MISSISSIPPI

Marquis W. Childs, 1982, Mighty Mississippi -- biography of a river: Ticknor & Fields, New Haven, Conn., 204 pages.

Edwin H. Chin, John Skelton, and Harold P. Guy, 1975, The 1973 Mississippi River basin flood -- compilation and analyses of meteorologic, streamflow, and sediment data: U.S. Geological Survey Professional Paper 937, Washington, D.C., 137 pages.

William S. Ellis, 1993, The Mississippi under siege (Pollution case study), pages 90-105 in National Geographic Society (NGS), 1993, Water--the power, promise, and turmoil of North America's fresh water: NGS, Washington, D.C., National Geographic Special Edition (special Nov. issue), 120 pages.

Holling C. Holling, 1951, Minn of the Mississippi: Houghton Mifflin Co., Boston, Mass., 87 pages. (The story of a turtle's travel adventure from the source to the mouth of the Mississippi. The book contains extensive supplemental information -- drawings, maps, text -- in the outer margin of nearly every page.)

Robert H. Meade (editor) and others, 1995, Contaminants in the Mississippi River, 1987-92: U.S. Geological Survey Circular 1133, Washington, D.C., 230 pages.

Charles Parrett, Nick B. Melcher, and Robert W. James, Jr., 1993, Flood discharges in the upper Mississippi River basin, 1993: U.S. Geological Survey Circular 1120-A, Washington, D.C., 14 pages. (Report available only from Denver, Colo.)

Mark Twain, 1990 (text of 1883), Life on the Mississippi (with introduction and notes by John Seelye): Oxford University Press, New York, 475 pages (429-page text).

U.S. Army Corps of Engineers (USACE), 1985, Mississippi River navigation: USACE, Lower Mississippi Valley Division, Mississippi River Commission, Vicksburg, Miss., folder with 16-page text.

U.S. National Oceanic and Atmospheric Administration (NOAA), 1994, The Great Flood of 1993 -- National Disaster Survey Report: NOAA and National Weather Service, Washington, D.C., 281 pages.

James G. Wiener, Richard V. Anderson, and David R. McConville, 1984, Contaminants in the upper Mississippi River -- Proceedings of the 15th Annual Meeting of the Mississippi River Research Consortium: Butterworth Publishers, Boston (Stoneham), Mass., 368 pages.

[MS-BIBL3]

3/6/96

Word processor used to prepare MISSISSIPPI report

The first draft of the report on the Mississippi River was keyboarded on a Brother Word Processor model WP-5500DS (Serial no. D46573073) purchased in 1995. The machine uses 3.5" double sided/double density (2DD) floppy disks. Among the features on the list printed on the cover of the machine is: "WP⇆PC conversion software supports major word processing programs." However, this feature may possibly be limited to spreadsheet programs, such as Lotus 1-2-3.

The text of the report was prepared in single-spaced format in order to be able to see how text, tables, and illustrations might be formatted or sequenced to be of maximum interest or assistance to the reader, realizing that some readers would look mainly at illustrations, only slightly at the text, and scarcely at all at the tables. Most of the text is written primarily for the lay reader having some interest or curiosity concerning the river, whereas many of the tabular data provide facts for the more technically inclined. In many instances the text does not make specific reference to illustrations or tables. Additional illustrations that would improve the report, in my opinion, include one each of a large barge tow, a lock and dam on the upper Mississippi, a cross-section of a levee, and a photograph from the 1988 drought

These sample paragraphs were typed on the Brother word processor.

John C. Kammerer
March 12, 1996

[MS-EXMPL.WPT]