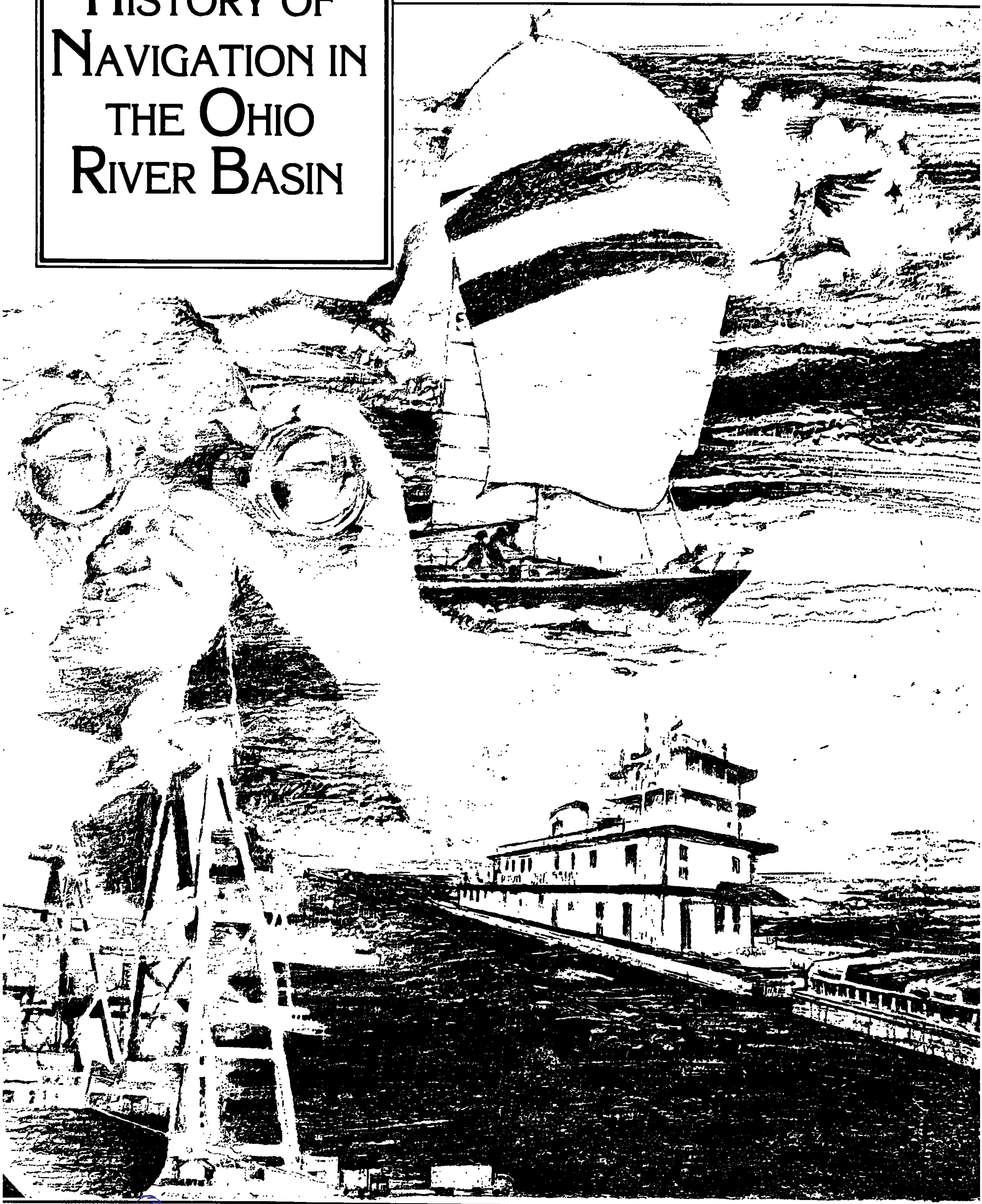
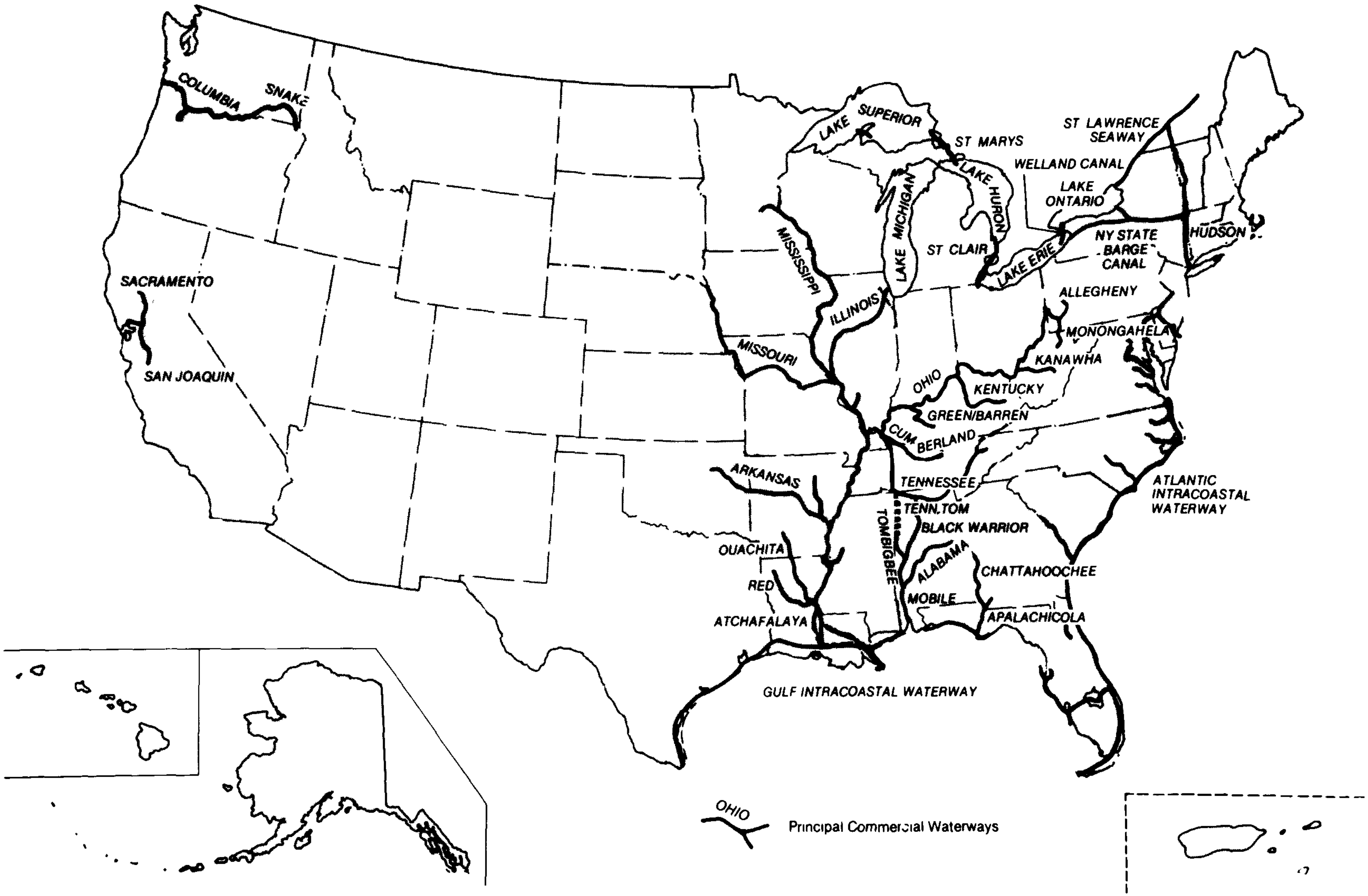
History of Navigation in the Ohio River Basin



National Waterways Study □ U.S. Army Engineer Water Resources Support Center □ Institute for Water Resources

THE NATIONAL WATERWAYS
OHIO RIVER SYSTEM



History of Navigation in the Ohio River Basin

Michael C. Robinson

January 1983
Navigation History NWS-83-5

National Waterways Study □ U.S. Army Engineer Water Resources Support Center □ Institute for Water Resources

AUTHORITY FOR THE NATIONAL WATERWAYS STUDY

The Congress authorized the National Waterways Study (NWS) and provided the instructions for its conduct in Section 158 of the Water Resources Development Act of 1976 (Public Law 94-587):

> The Secretary of the Army, acting through the Chief of Engineers, is authorized and directed to make a comprehensive study and report on the system of waterway improvements under his jurisdiction. The study shall include a review of the existing system and its capability for meeting the national needs including emergency and defense requirements and an appraisal of additional improvements necessary to optimize the system and its intermodal characteristics. The Secretary of the Army, acting through the Chief of Engineers, shall submit a report to Congress on this study within three years after funds are first appropriated and made available for the study, together with his recommendations. The Secretary of the Army, acting through the Chief of Engineers, shall upon request, from time to time, make available to the National Transportation Policy Study Commission established by Section 154 of Public Law 94-280, the information and data developed as a result of the study.

PREFACE

This pamphlet is one of a series on the history of navigation done as part of the National Waterways Study, authorized by Congress in Public Law 94-587. The National Waterways Study is an intensive review by the Corps of Engineers' Institute for Water Resources of past, present, and future needs and capabilities of the United States water transportation network. The Historical Division of the Office of the Chief of Engineers supervised the development of this pamphlet, which is designed to present a succinct overview of the subject area.

John T. Greenwood

JOHN T. GREENWOOD
Chief, Historical Division

TABLE OF CONTENTS

Chapter I

RIVERS TO THE WEST

PROLOGUE

The Ohio River Basin is a vast area of some 204,000 square miles. It reaches northeast to Chautauqua Lake in northern New York, west to the flat land of Illinois, and south to the Tennessee River drainage--which extends into Georgia, Alabama, and Mississippi. Through the region's heart, the 981-mile-long Ohio River carries the largest volume of water of the six major Mississippi tributaries. The Ohio River is formed by the joining of the Allegheny and Monongahela rivers at Pittsburgh, Pennsylvania. Between the "Golden Triangle" and Louisville the river gathers the cool mountain water of the Little Kanawha, Great Kanawha, Big Sandy, Licking, and Kentucky rivers. Below Louisville from the south come the warmer waters of the Green, Cumberland, and Tennessee rivers. From the north the Beaver, Muskingum, Scioto, Miami, and Wabash rivers add their discharge to the Ohio.[1]

In the past two centuries, the pristine wooded river valleys have been transformed into sprawling centers of urban population and industry. The river and many of its tributaries have been equally transformed by navigation and multiple-purpose water projects that ease the flow of waterborne commerce and provide other public benefits. The following chronicle will attempt to trace the evolution of the basin from canoe to towboat, from unruly streams to slackwater lock and dam projects, from virgin forests to factories and cities.

RIVERS OF EXPLORATION

Rivers provided European explorers and settlers their first access to the North American interior. The abundant streams had been used for centuries by Indians who glided along in canoes, dugouts, and bull boats respectively built from bark, tree trunks, and skins stretched over crude wooden frames. The French advanced into the interior via the St. Lawrence River, the Great Lakes, and the Mississippi River as well as smaller streams. The British followed with westward expeditions across the Appalachians that took full advantage of natural waterways. Despite hazards to navigation, the rivers offered a much easier route through the often mountainous woodlands than did the horses and wagons that struggled along crude trails and roads. Colonial settlers and frontiersmen followed eastern rivers to their headwaters, established routes through the Appalachian barrier, and again headed west on the waterways. Since the streams of the Ohio Basin flow generally westward, they were frequently plied by explorers, traders, and settlers. The crude vessels used by the Indians and first pioneers were leaky, small, and carried little cargo. However, they were adequate for the needs of the region's first travellers.[2]

THE FRENCH PRESENCE

The first significant waterborne travel and commerce on the inland streams largely stemmed from military activities. The Royal Engineers of France were involved in the Ohio and Mississippi valleys for over a century prior to the American Revolution. They engaged in extensive mapping, constructed a chain of fortifications that stretched from Lake Erie to the Monongahela River, and made some river improvements. For example, in 1729 a French Engineer named Chaussegros de Lery made a compass survey of the Ohio River while on a military expedition. The results of his observations were printed in 1744. The French constructed Fort Duquesne in 1754 at the forks of the Ohio River to control the Ohio Valley. The construction was partly responsible for launching the French and Indian War.[3]

In the same year George Washington was dispatched by the governor of Virginia to make a reconnaissance of the Allegheny, Monongahela, and Upper Ohio valleys. A subsequent defeat of a large British force sent to dislodge the French resulted in a decisive struggle that gave the British control of the St. Lawrence and Ohio valleys in 1763.

BRITISH AND AMERICAN ENGINEERS

Although the 1763 Treaty of Paris gave the British possession of the Ohio region, some French and Indian resistance continued. Several expeditions were sent down the Ohio and overland to take possession of French forts in the basin. The British soon realized that supplying troops and maintaining communications within its new possession required the preparation of maps of the Ohio River to guide future voyages. In 1766 an expedition was sent downriver from Fort Pitt (present-day Pittsburgh) and Captain Harry Gordon, chief engineer, and Ensign Thomas Hutchins were assigned to map the river.

The Hutchins-Gordon report was the first detailed hydrographic-topographic survey of the Ohio River. The authors provided reliable information about river navigation, accurate descriptions of transportation routes, and potential sites for camps and fortifications. The engineers continued their work on the Mississippi River. Following their return the map Hutchins prepared of the Ohio River was copied and distributed to the British forces. Hutchins later joined the Americans in their struggle for freedom and was appointed by the Continental Congress as "Geographer to the United States" at the close of the revolution. His maps of the Ohio Basin were published in London in 1778 and remained for many years the only reliable source of information about the Ohio Valley frontier. Thus, he had a major influence on the opening of the valley to settlement.[4]

Despite the demobilization that took place following the revolution, former military engineers continued to remain active in the Ohio Valley. Colonel Rufus Putnam, former chief engineer of the Continental Army, helped organize the Ohio Company in 1786. The company sought to settle veterans on public lands in the Ohio Valley. In 1788 Putnam led a group of pioneers down the Ohio River to settle the town of Marietta. In 1794 Congress authorized the raising of a composite Corps of Artillerists and Engineers, which resulted in a few engineer officers navigating and studying the Ohio River at the close of the eighteenth century.[5] But by this time a flood of immigrants were settling the region and pushing back the frontier.

THE ARK OF EMPIRE

The Indian dugouts, canoes, and other simple craft were eventually replaced by the sturdy, utilitarian flatboat. This "ark of empire" was usually a large watertight wooden box of simple construction that varied in size and design according to the needs and abilities of the builders. With its flat bottom and sides half covered with a roof to shelter the occupants, the vessels resembled a floating house shed. One Ohio River traveller described them as "flat bottomed, with upright sides and stern, and the front turns up like a skate. They seldom use any sail, and are steered by means of a long oar from the stern, and two or three oars are occasionally used to conduct them, for the stream, which runs at the rate of about 5 miles an hour, carries the boat with great rapidity."[6]

The flatboat appeared on the Ohio River before the end of the American Revolution, and it was the principal means of transportation for the mass of immigrants that sought homesteads in the Ohio Basin in the late eighteenth and early nineteenth centuries. Pioneers crossed the mountains to the Upper Ohio and its tributaries to buy or build boats to carry family, possessions, and livestock. Constructing these vessels became a major enterprise in the Upper Ohio Valley. The boats, in addition to offering economical transportation, were a long-term asset to river travellers. At the end of the voyage, they were disassembled and the lumber was used to construct new homes.

During this period, the flatboat contributed to the rapid settlement of the Ohio River Basin. In 1775 the area's population consisted of settlements near Fort Pitt and a few scattered frontier posts. By 1790 the great migration was in full tide and the population had risen to 125,000. In 1788 no less than 308 flatboats--carrying some 6,000 settlers, 3,000 head of livestock, and 150 wagons--swept past Fort Harmar (present-day Marietta) during the spring rise of the Ohio River.[7]

TRADE WITH NEW ORLEANS

Ohio Basin pioneers were soon seeking outlets for their agricultural produce, but eastern markets could only be reached by packhorses and wagons that had to cross mountainous terrain. They naturally looked downriver for more accessible Spanish buyers at New Orleans. Barthelemi Tardiveau, a French immigrant from Nantes, is generally credited with attempting the first flatboat trip down the Ohio and Mississippi rivers to sell goods at New Orleans in 1782. In 1787 he published an influential document that outlined the advantages of establishing a regular trade with New Orleans. This commerce developed slowly at first due to the unreliability of the New Orleans market. Spanish authorities closed the port to Americans in the mid-1780s. However, it was reopened by General James Wilkinson, who sent a cargo from Kentucky in 1787. He negotiated a deal that enabled him to dispatch a fleet of twenty-five flour-and-tobacco-laden boats a year later.[8]

As diplomatic relations improved between the United States and Spain, trade was opened to others and it reached major proportions by the mid-1790s. The 1803 Louisiana Purchase gave the United States possession of the port and advanced the trade even further. In 1807, for example, some 2,000 boats arrived at New Orleans carrying commodities valued in excess of $5 million. In 1810-1811 about 1,200 flatboats departed from the Upper Ohio for the "Crescent City," carrying 130,000 barrels of flour; over 600,000 pounds of bacon; 10,000 barrels of whiskey; huge quantities of butter, hemp, cheese, livestock; and other agricultural produce. Flatboat commerce continued on this vast river system despite the later introduction of the steamboat and did not peak until 1847, when railroads began to offer alternative transportation routes.[9]

OHIO SHIPBUILDING INDUSTRY

By the late 1700s, some businessmen were avoiding the payment of duties at New Orleans by building seagoing ships in the Ohio Basin, loading them with commodities, and entering the foreign trade directly from river ports. The ships usually were floated down the Ohio and Mississippi rivers by experienced sea captains who commanded them as they sailed to the West Indies or Atlantic ports. Because the inland rivers were too narrow for navigating under sail, the brigs, schooners, and ships--as the flatboats--never travelled upriver. Sailing ships were constructed at Pittsburgh, Marietta, Cincinnati, Louisville, and other ports in extremely large numbers. Merchants found it economical to contract for ships built near cheap and plentiful sources of lumber. Even the United States Navy negotiated for the construction of gunboats used for harbor and coastal patrol. The shipbuilding industry continued on the Ohio River and its tributaries until 1865.[10]

KEELBOAT COMMERCE

Despite the utility of the ships and flatboats, they were limited to downstream travel. Thus, merchants and navigators sought some means of establishing a dependable two-way commerce. Bringing goods across the Appalachians to the Ohio Basin by land cost as much as $200 a ton, and the small canoes, dugouts, and bateaux used initially for upstream navigation had limited cargo capacities. By the early 1790s, the keelboat was providing an economical means of upriver navigation. The long, sleek craft were ribbed and planked like a ship, and their heavy timber keel and pointed prow allowed for easier navigation against river currents as well as through shallows and rapids.[11]

Keelboats varied in dimensions from 30 to 75 feet long and from 5 to 10 feet wide. They could carry cargoes of 15 to 40 tons. One navigator described the craft's superstructure as "a covered way, a kind of cabin occupying the entire hold of the boat, excepting spaces for small decks at each end, and a ship on each side the whole length of the boat, about 15 inches wide, called the 'run,' on which the men walked when 'poling' the boat upstream."[12]

Although some keelboats had masts and sails, they were commonly driven upstream by crewmen with iron-tipped poles. They stabbed the pole into the stream bottom, braced it against their shoulders, and "walked" the boat upriver until they reached the stern. The agonizing process was repeated over and over as the boat fought against the river.

Keelboats usually remained near banks to avoid rapid currents, which often enabled the crew to bushwack (to pull the branches of trees to drag the boat along). When the opposing current became too swift, they resorted to "cordelling" and "warping." The former consisted of putting the crew ashore to drag the boat along with an attached rope. The latter involved tying the rope to an upstream tree and reeling it in from the bow.

Navigating the inland rivers was a dangerous business undertaken by rugged and profane men who faced Indian attacks, pirates, navigational hazards, and unrelenting daily toil. But the commercial ventures were often quite profitable. A keelboat owner reported in 1817 that the cost of operating a 36-ton boat from New Orleans to Louisville was $1,750 and provided a profit of $1,490 for each trip on a total capital investment of less than $2,000.[13] Thus, despite the herculean efforts required to move the keelboats upstream, they significantly lowered transportation costs. The vessels eventually lost passenger traffic and long-distance freighting to steamboats, but for short routes--particularly on the headwaters of tributaries--they were extensively used unitl railroads and improved roads reduced their numbers at the close of the nineteenth century.

THE STEAMBOAT REVOLUTION

The hard labor involved in upstream keelboat navigation and the need for more economical transportation boasted development of the steamboat. This important technological innovation touched off a transportation revolution that transformed the Ohio Valley. Development of the powered craft was an evolutionary process involving the contributions of many individuals, but Robert Fulton is most often credited with building the first successful steamboat in the United States (1807). The inventor put a steamboat into operation on the Hudson River and organized a firm to expand operations to other rivers.

In 1809, Nicholas J. Roosevelt, one of Fulton's agents, travelled by flatboat from Pittsburgh to New Orleans to observe the rivers, determine the prospects for steamboat trade, and identify coal deposits for fuel. He returned to the upper Ohio and built the steamer New Orleans, which completed a successful downriver voyage to New Orleans in 1811. Fulton and his associates planned to build a comprehensive steamboat transportation system from Pittsburgh to New Orleans, and sought a monopoly by obtaining exclusive charters from state governments. But independent rivermen opposed the scheme by building their own steamboats, engaged in lobbying, and fought Fulton in the courts.[14]

Captain Henry M. Shreve made the greatest contribution to smashing the Fulton monopoly. He challenged the company by piloting the steamboat Enterprize and its cargo of munitions to New Orleans in time to help beat off a British attack in 1815. The Enterprize returned to Louisville in 1815, making the first upstream trip from New Orleans. Despite suits by the Fulton interests, Shreve built the larger, more powerful Washington, which made many highly profitable trips after its launching in 1816. Shreve and other independents claimed that the navigable rivers and interstate commerce were under federal jurisdiction. In 1824 the United States Supreme Court issued a landmark decision against the Fulton company--thus freeing waterways from special privilege.[15]

Steamboat technology was further advanced by Major Stephen H. Long, who designed and built the Western Engineer in 1819. Constructed for a military reconnaissance and scientific expedition, the craft was launched from Pittsburgh and successfully navigated down the Ohio and far up the Missouri River. The Western Engineer drew but 19 inches of water, as compared with 4 to 6 feet for earlier boats. Long made other improvements such as the cam cutoff, a device which enabled the steam to be used more efficiently. In the expedition's report, Long commented on the various navigation problems he encountered. The report marked the beginning of Long's distinguished career as a waterways engineer.[16]

GROWTH OF COMMERCE AND CITIES

The steamboat made a major contribution to the growth of cities such as Pittsburgh, Cincinnati, and Louisville. Expanding commerce and manufacturing were causes of urbanization. But steam navigation, by quickening transportation and cutting distances, telescoped a half-century's development into a single generation. It was an enchanter's wand transforming an almost raw countryside of scattered farms and towns into a settled region of cultivated landscapes and burgeoning cities. This technological device during the 1820s became a key element in a transportation system that eventually included new canals and improved road systems that eased travel to inland cities. By 1830 the steamboat had a virtual monopoly on passenger traffic and, except at low water, handled most upstream freight. Its operations encompassed all the principal rivers, while smaller craft plied many of the larger tributaries.

The first successful runs between Louisville and New Orleans were followed by regular trips between Pittsburgh and Louisville after 1820. The increase in steamboat numbers and the tonnage they carried was remarkable. In 1817 seventeen steamboats with an aggregate tonnage of 3,290 were navigating western rivers. Within five years their number had grown by sixty, and 187 steamboats capable of carrying 29,841 tons of cargo were in service in 1830. This total represented half of all American steam tonnage and equaled the volume of steam shipping in the whole British Empire.[17]

Steamboat arrivals, once a cause of civic celebrations, became routine. By the mid-1820s, a substantial number of steamboats docked at Pittsburgh and Cincinnati. But Louisville, because of its strategic location on the Falls of the Ohio, became the focus of Ohio River steamboating. In 1829 over 1,000 steamboats landed at Louisville--300 more than at New Orleans and ten times more than at Pittsburgh. The next year 278 vessels arrived at St. Louis, many of which were based in the Ohio Valley.[18]

Western cities expanded due to the increased commerce and they added to their growth by becoming major shipbuilding centers. Some three-fifths of the steamboats and four-fifths of the tonnage constructed in the West were built at Pittsburgh, Cincinnati, and Louisville.[19] Thus, the steamboat accelerated trade and became one of the West's major industries. Nevertheless, keelboats and flatboats remained important, bringing raw materials, bulky farm products, and semifinished goods to Pittsburgh and other cities. Not until 1830 did the steamboat equal their volume of freight.

WHARFING FACILITIES

Steamboats and keelboats initially could make landings at most points along the shore without the aid of docks and wharves. A few gangplanks were placed between the boat and shore--and the bare ground served as a natural dock. As river towns grew and steamboat traffic increased, local authorities began to improve landings by grading the waterfront to facilitate the loading and unloading of goods at all river stages. Boats using the facilities paid fees that defrayed maintenance costs and provided for new improvements such as paving and clearing additional areas of shoreline. Regulating traffic became an important municipal function as waterfronts grew crowded with craft and cargo, particularly during the periods of high water. Louisville faced especially difficult circumstances since nearly every boat on the Ohio used its installations. The community limited the stay of any boat to forty-eight hours, and instructed the harbor master to auction off vessels that exceeded the limit.[20]

The river cities were constantly hard-pressed to keep pace with traffic demands. Early nineteenth-century waterway commerce grew so rapidly that these port communities sought ways to expand their limited facilities. Some communities purchased private docks and extended the public landings, while others entered into joint ventures with private firms to build new docks. All mercantile interests recognized the necessity of accommodating the flow of goods. As the St. Louis mayor observed in 1824, "Commerce is the vital principle of the town." No large municipality, however, was able to deal efficiently with the mounting flow of goods. Landings remained crowded and officials struggled to keep craft moving and docks open. Ordinances were strengthened to prohibit vessels from loitering in port, areas were set aside for special cargoes, and shipbuilding and repair activities were prohibited near heavily used landings. Nevertheless, in busy seasons the waterfronts presented a solid rank of steamboats lying side-by-side, sometimes two or three tiers deep. The equally crowded shorelines were piled high with bales, crates, barrels, hogsheads, and other goods.[21]

HAZARDS TO NAVIGATION

Although early navigators with light-draft vessels opened the Ohio to transportation, later users with deeper draft craft often fell victim to rocks, snags, shifting sandbars, and shallow channels, as well as other hazards. As the river and its tributaries became extensively used for the movement of people, agricultural commodities, and manufactured goods, commerce was often disrupted by long delays and even by losses of boats and cargoes. Flatboats and keelboats commonly found themselves ripped by rocks, stuck fast on sandbars, and driven furiously down rapids and chutes. Furthermore, the river's channel constantly shifted. Annual periods of high water moved the location of sand and gravel bars, cut new channels, and undermined trees, which fell into the stream and became hazards to navigation.[22]

The maze of hazards along the river's 981-mile course arose chiefly because of its snag and boulder-strewn conditions. Furthermore, the Ohio's 429-foot slope from its head to mouth was not uniform. Steep gradients at some points caused swift currents, which were in sharp contrast to long pools where the fall was negligible. Fluctuations between low- and high-water stages ranged from as little as a foot during severe droughts to as much as 80 feet during floods.

Commercial craft required a mere 3 feet to navigate the Ohio, but this minimum depth was available for only a few months each year. Low water severely retarded navigation in the Ohio Basin from July through

October. Rivermen relied on rises in the late fall and spring to move most goods to market. Until alternative transportation systems were developed, the unpredictable Ohio continually disrupted business affairs. In 1819, for example, the fall rise did not occur. The result was serious economic consequences.[23]

SUMMARY

Throughout the evolution of commerce from canoe to flatboat and from keelboat to steamboat, the Ohio River and its tributaries provided the principal means of moving goods and people in the trans-Appalachian West. In spite of natural hazards--such as snags, shoals, and rapids--as well as dangers posed by Indian attack and robbers, the Ohio Valley region became the route followed by the great western migration of the late eighteenth and early nineteenth centuries. The rivers and the craft placed on them transformed the economy from frontier subsistence to a burgeoning, complex commercial structure. As its population and settlements grew, the region began to seek navigation improvements that would further enhance waterborne commerce.

Chapter II

IMPROVING NAVIGATION IN THE OHIO BASIN, 1824-1861

ORIGINS OF FEDERAL NAVIGATION IMPROVEMENTS

Prior to the Civil War, the United States Congress spent a great deal of time debating the constitutionality of federally funded internal improvement projects. Sectionalism and factionalism caused some to view federal public works as unwarranted extensions of federal powers. Before 1824 federal navigation improvements were largely limited to the construction of lighthouses, harbor improvements, and other aids to navigation. State governments were granted public lands to finance a few public works projects, but the initial federal effort was largely piecemeal and uncoordinated. In 1808 Secretary of the Treasury Albert Gallatin made a farsighted and ambitious report to Congress that called for the investment of $20 million in an extensive road and canal system. He recommended construction of a north-south canal and a road network across the Atlantic states from Maine to Georgia as well as four routes across the Appalachians to link the Ohio Basin with the seaboard states.[1]

The subsequent War of 1812 disrupted action on the Secretary's plan. The conflict also convinced many political and military leaders that reliable navigation routes and other transportation facilities were essential to national defense. In 1816 a special Board of Fortifications, consisting of two Army Engineers and one Navy officer, analyzed the nation's defense requirements. They concluded that improved transportation routes to the interior were fundamental to the nation's military and economic well-being. As a member of Congress, John C. Calhoun strongly advocated an ambitious federal internal improvement program. But a bill he authored in 1817 to initiate many of the projects Gallatin advocated was vetoed by President James Madison on constitutional grounds.[2]

While congressmen exchanged opinions on the constitutionality of federal public works, the steamboat boom in the Ohio Valley prompted state governments to address the question of navigation improvements. In 1817 the state of Ohio invited other basin states to appoint members to a joint commission to recommend surveys and plans for navigation improvements on the Ohio from its headwaters to Louisville. Several states participated in a survey completed in 1819 that mapped the 102 worst obstacles. The commission recommended that the states undertake the removal of snags, the blasting of chutes through rocky shoals, and the dredging of channels through bars. However, the only official action taken was to ask the federal government to fund the project.[3]

In response to state appeals, Congress appropriated $5,000 in 1820 to expand the survey begun by the states. A board of engineers departed from Louisville in 1821 and successfully surveyed the Lower Ohio and the Mississippi River to New Orleans. They suggested that the safety and ease of waterborne commerce could be improved by constructing a canal around the Falls of the Ohio, removing snags and boulders, and controlling the river channels by building wing dams and longitudinal spur dikes. Their report considerably influenced subsequent congressional authorizations for improving the Ohio.[4] It gave much polemical ammunition to congressmen such as Henry Clay and Robert P. Henry of Kentucky, who wished to enhance the flow of commerce on western rivers. Arguing that the West's great rivers were the common commercial highways of all the people, Clay and Henry warned Congress against state control of the streams. Opposition came principally from eastern congressmen, who maintained that federal projects for inland navigation were unconstitutional.

Clay and like-minded proponents prevailed, and the Eighteenth Congress enacted legislation marking the beginning of Corps of Engineers involvement in improving the nation's rivers. In April 1824 President James Monroe signed the General Survey Act, authorizing the Army Engineers to conduct surveys and planning studies for transportation projects that might enhance national defense and commerce. The following month he signed the 1824 Rivers and Harbors Act, which appropriated $75,000 for improvement of the Ohio and Mississippi rivers. The act authorized the President to assign Army Engineers to undertake experiments at certain Ohio River bars to determine the best methods of making improvements at those localities. It also stipulated that "prompt and effectual" steps be taken to remove "planters, sawyers, or snags" that might endanger traffic on the rivers.[5]

FIRST IMPROVEMENTS ON THE OHIO

One of the first actions taken by the chief of engineers was to dispatch Major Stephen H. Long to the Ohio River to launch experiments on deepening channels across sand and gravel bars. Long chose a compacted gravel bar near Henderson, Kentucky, below the mouth of the Green River, that was covered by merely 15 inches of water at low-river stages. After studying riverflow and channel conditions, he outfitted several flatboats with hand-powered pile drivers and began to build a wing dam. The structure, which extended at a 45-degree angle from the bank, decreased the width of the channel, increased the velocity of the current, and caused the river to scour a deeper channel.

During periods of low water in 1824 and 1825, Long experimented with various designs of contrasting widths, lengths, and heights. The 402-yard-long completed dam consisted of twin rows of 1,400 piles joined with stringers and filled with brush. Gravel and sand settled against the dam and anchored it to the riverbed. The total cost of the project was exactly $3,778.93. Until the late nineteenth century, Long's wing dam, often called a spur dike, was the main method used for deepening channels on the Ohio River and many of its tributaries.[6]

SNAG CLEARING ON THE WATERWAYS

The 1824 act also called for development of watercraft and machinery necessary to clear thousands of snags from the Ohio and Mississippi rivers. These deadly obstacles were perhaps the most feared hazards of early river navigators. They were of several types: a "planter" was a log fixed in the river bottom which would impale passing boats; a "sawyer" was a planter with a free end that moved up and down in harmony with the current. One riverman estimated in 1824 that there were at least 50,000 snags in the Ohio and Mississippi rivers and speculated that "if these were removed and kept so, the river would assume a new aspect, highly creditable to those engaged actively or passively, in the contemplated improvements."[7]

Since no snag-removal equipment had been developed, General Alexander Macomb, Chief Engineer of the Army, offered a $1,000 prize for the best "plan, machine, or instrument" that would clear the rivers. Numerous plans were submitted for devices that were novel, of varying utility, and sometimes absurd. The award was given to John W. Bruce, a Kentucky flatboat and steamboat captain. Bruce devised what became known as a "machine boat," one joined by 8-to-12-foot timbers. The cross-structure supported a long lever tipped by an iron claw that was attached to the snag. Use of the lever and a rope and windlass enabled the crew to dislodge the snags from the river bottom.[8]

Bruce entered into a contract with the federal government for $60,000 that stipulated he would remove all snags on the Ohio and Mississippi rivers by January 1, 1827, and submit his activities to inspection by an Army Engineer officer. He assembled a force of thirty-two men, four machine boats, and eight skiffs--and began operating on the Upper Ohio in June 1825. Rivermen soon assailed Bruce and the engineer inspector, for Bruce confined snag removal to the river's low-water channel. Critics pointed out that during high water steamboats and other craft would continue to be endangered. Because of the resulting imbroglio over the specific intent of the agreement, the Chief Engineer in 1827 cancelled Bruce's contract. At the recommendation of Stephen H. Long and others, Henry M. Shreve was appointed Superintendent of Western River Improvements. He was given responsibility for the snag clearing operation.[9]

Bruce's operation suggested that "prompt and effectual" snag removal was unrealistic and that waterways improvement must be an ongoing process undertaken by individuals intimately acquainted with the river and engineering. These lessons were reflected in the 1827 Rivers and Harbors Act, the first in a series of annual appropriations to 1838 that directed removal of obstructions and required that a "practical agent" with long experience on inland rivers be placed in charge of the project.[10]

Shreve significantly advanced the technology of snag removal by planning and building the first steam-powered snagboat. After obtaining authorization for construction of a prototype, in April 1829 Shreve launched the Heliopolis at a shipyard near New Albany, Indiana. The vessel was actually two 100-foot-long steamboats spaced 10 feet apart and joined with timbers. An iron-sheeted wooden bulkhead was mounted near the bows. Thus, the Heliopolis could ram snags and force them loose by bringing to bear the combined force of the boat and its engines. The water-soaked trees were then raised between the hulls by windlasses and sawed into appropriate lengths for fuel or stacked and burnt on nearby banks. Other snagboats were soon authorized--such as the Archimedes, Eradicator, and Henry M. Shreve, all built during the 1830s.[11]

The benefits of the snag-removal projects were soon evident. In 1832 Shreve reported that no watercraft were lost on the Ohio River due to snags. Furthermore, insurance rates on steamboat cargoes declined by 50 percent from 1827 to 1835 as the natural risks to navigation decreased. Fires, collisions, and boiler explosions replaced snags as the chief hazards of river travels.[12]

Snag clearance was but one dimension of Shreve's river improvement responsibilities. As Superintendent of Western River Improvements, he was directed to reduce the hazards at the Grand Chain of Rocks near the Ohio River's mouth. During 1829 and 1830, a deeper channel was blasted through the boulders of the Grand Chain. Some 3,375 tons of rock were removed and placed in a wing dam extending from the Illinois shore to divert more water into the navigation channel. Completed in 1830, the project increased the channel depth from 22 inches to 48 inches at low-river stages. The buoys installed at the head of the Grand Chain to mark the channel were the first used on the Mississippi and Ohio rivers.[13]

The success of Long's wing dam near Henderson, Kentucky, and the Grand Chain project induced Congress to appropriate $150,000 in 1831 for additional dikes on the Ohio. Their construction posed different engineering problems at each project site and required detailed hydraulic studies and planning before construction could begin. From 1831 to 1835 Shreve oversaw the building of loose stone and longitudinal spur dikes at five shoals on the Lower Ohio. Stone was obtained near the river, transported by scows to the site, and dropped into place. When the projects were completed, minimum navigational depth was extended from 2 to 4 feet.

A more ambitious project was undertaken at Cumberland Island, which divided the Ohio River into two chutes near the mouth of the Cumberland River. The dam was built across the Ohio's principal channel to achieve two purposes: to divert the main channel to the left bank of the river to facilitate steamboat traffic at Smithland, Kentucky (the main point of trade between the Ohio and Cumberland rivers) and to remove the bar that impeded navigation at the mouth of the Cumberland. Despite objections and various delays, the dam was completed in 1834. Concurrently, Congress authorized similar improvements on the Cumberland River, and wing dams were completed at several points below Nashville by 1835. That same year, Congress appropriated $50,000 for the Upper Ohio, enabling Lieutenant George Dutton to remove snags and begin construction of a dike. The location was Brown's Island, between Wheeling and Pittsburgh, the first permanent structure built by the Army Engineers to ease navigation on the upper section of the river.[14]

Because of constricting navigation requirements on the Upper and Lower Ohio, in 1835 responsibility for improving the two reaches of the river was divided, and Captain John Sanders was given supervision of projects above the Falls in 1836.

Sanders was a brilliant, inventive engineer who developed a steam powered pile driver, mechanical cement mixer, and other technological innovations. His skills and dedication were reflected in an ambitious survey of the Upper Ohio that he described as "a survey of the river, comprising a complete hydrographical and topograhical survey, giving the bars, channel, and shores; ascertaining the soundings and velocity of the current, and exhibiting everything necessary for the most judicious location of the dams, the formation of the best adopted project of improvements." He personally interviewed long-time rivermen to learn about the stream's navigational history, and spent many weeks with his survey parties. The subsequent report was a major contribution to the science of fluvial hydraulics, and Sanders' maps were not surpassed until the twentieth century.

Sanders directed snag clearance operations and the removal of dangerous rocks at the Falls of the Ohio. Furthermore, he planned to increase the minimum navigable depth to 30 inches. Dams at Brown's Island were followed by structures at twelve of the worst obstructions. These projects increased low-water depth by building stone riprap dams to close secondary channels and wing dams to erode bars and constrict the flow to channels. Construction of the riprap dams was supplemented by blasting rocks and rock ledges out of the channel.[15]

DELAYS AND FRUSTRATIONS

Contrasting views on the constitutionality of federal waterway improvements remained a source of national sectionalism and factionalism in the two decades prior to the Civil War. The East clashed with the West in seeking appropriations for public works. In addition, political groups such as Republicans, Free Soilers, and northern Whigs advocated federal navigation improvements while Democrats and southern Whigs remained opposed. The tumultuous political climate of this era precluded systematic project planning and often thwarted attempts by Army Engineers to make the rivers reliable commercial arteries. From 1841 to 1861, continuity was impossible as different administrations adopted policies that made improvement of inland waterways a sporadic affair.

The major depression following the Panic of 1837 caused the Van Buren administration to cease federal investments in navigational improvements. Congress made no appropriations for this purpose from July 1838 to August 1842 and projects under development were suspended. The snagboat fleet was either sold at auction or withdrawn from service. The consequences were disastrous. From 1839 to 1842, 138 steamboats sank on western rivers with an estimated annual financial loss of $1 million.

President John Tyler approved a few waterway projects. In August 1842, Congress provided funds for building and repairing snagboats and renewing navigation projects--the first of three successive annual rivers and harbors investments. Studies demonstrated the need for more ambitious improvements along the Ohio, but due to limited funding projects were confined to traditional dike construction and river clearance. Work again stopped in 1845 when President James K. Polk, believing that federal waterway projects were unconstitutional, vetoed navigation bills. Following his veto of a $1.5 million appropriation in 1846, one western newspaper charged that every lost life, cargo, and vessel would be a memorial to the President. Rivermen began referring to snags as "Polk stalks."

By 1850 the West was haranguing Congress to restore the river improvement program, but no major appropriations were voted until the close of Millard Fillmore's administration. The 1852 Rivers and Harbors Act provided $150,000 for dike repair and construction on the Ohio River, the construction of a new snagboat fleet, and other undertakings. But the expectations of westerners were dashed by President Franklin Pierce, who vetoed all bills that would have continued the waterways projects. Congress overrode five of the vetos in 1856, but none of these provided funds for the Ohio River.[16]

By 1857 navigation improvement had come to a virtual halt in the Ohio Valley despite the continued need for safe waterway travel. In 1854, the last year of snagboat operations, some 56,000 obstructions were removed from western rivers. And after each river rise new hazards studded the streams. In 1855 twenty steamboats sank in the Ohio River. Steamboat trade grew during the 1850s despite the rise of railroad competition, long periods of low water that disrupted navigation, and snag-filled rivers. In 1855, for example, 76 steamboats were based in Louisville and 2,427 made landings at the Falls city. As commerce increased on the inland rivers, the number of accidents also rose. In the decade prior to the Civil War, about 3,000 people were killed or injured in accidents on the Ohio and other western streams.[17]

TRIBUTARY STREAM PROJECTS

The federal government made appropriations intermittently from 1824 to 1852 for the improvement of Ohio River navigation. However, politics stood in the way of the regular funding needed to sustain maintenance activities and implement comprehensive improvement programs. The same factors impeded federal work on Ohio River tributaries. Only projects on the Cumberland and Tennessee rivers received federal funding before 1861, and the endeavors were primarily minor clearance and dike projects.

Throughout the pre-Civil War era, internal improvement advocates turned to the states and private interests for support. Commerce flourished on many tributaries of the Ohio River, but the tributaries' usefulness was reduced by the same hazards as existed on the principal river. In many streams, water depths were too limited to permit the operation of steamboats during most of the year. Thus, minor improvements such as snag and rock removal as well as open channel work were inadequate. Ironically, the more severe conditions on the tributaries sometimes prompted development of pioneer slackwater projects, a method that was eventually used to achieve year-round navigation on the Ohio. Prior to 1850, various attempts were made to achieve slackwater navigation by building systems of locks and dams. These undertakings met with a wide range of success.

During the enthusiasm for internal improvements in the 1830s and 1840s, the first slackwater systems were begun on lower portions of the rivers such as the Kentucky, Green, Licking, Muskingum, and Monongahela. By building dams across the rivers at proper intervals, an adequate depth for small steamboats was made available. A lock was provided at each dam to permit the vessels to pass up and down the stream. Touted by promoters, the systems rarely provided optimum service. Insufficient capital, poor engineering and construction, natural disasters such as floods and ice, and inadequate maintenance and repair delayed their completion and stifled their usefulness. In addition, revenues were frequently inadequate to justify operations. A project on the Kentucky River begun in 1836 was suspended in 1842 after the completion of five dams that provided for navigation to Frankfort, which is 65 miles above the river's mouth. The slackwater system on the Muskingum completed in 1842 from Marietta to Dresden, Ohio, showed profit for about a decade, but it later became a financial liability for the state. Projects on the Green and Barren system during the 1840s likewise experienced limited success. State-supported open channel projects fared little better. Navigation improvements on the Kanawha River benefited flatboat, keelboat, and light steamboat traffic, but the improvements were inadequate for large coal barge tows.[18]

The most successful of the early slackwater projects was on the lower Monongahela. Engineers and navigation companies proposed locks and dams as early as 1814. But river interests such as coal boatmen and farmers argued that dams would obstruct the river, require needless tolls, cause excessive lockage delays, and ruin the river for flatboat and steamboat trade. Chartered in 1837, the private Monongahela Navigation Company completed two dams and locks by 1841. Financial disaster was narrowly averted by General James Moorhead, who invested money in the venture when the company was near bankruptcy. By 1844 the system was completed to Brownsville, 55 miles above Pittsburgh, and in the next decade the project was extended by adding two additional dams. Certain economic conditions, especially the great expansion of coal shipments to Pittsburgh from the Lower Monongahela, underpinned the project's success. However, the lack of heavy traffic and toll revenues for the similar West Fork and Youghiogheny slackwater projects resulted in financial disaster for the dams' backers.[19]

LOUISVILLE AND PORTLAND CANAL

The main barrier to navigation on the Ohio River was the Falls of the Ohio, a series of rock ledges extending across the river at Louisville. The first great achievement in western river improvement was construction of a canal to permit the passage of watercraft around the rapids. With a total fall of some 22 feet in 2 miles, the Falls impeded the flow of commerce for about ten months of the year. For many years the Falls were the head of navigation on the Ohio River, and the growth of Louisville was in part due to its location near the natural barrier. As early as 1804 attempts were made to build a canal, but the companies incorporated by the state of Kentucky failed.

In 1825, however, the Louisville and Kentucky Canal Company was chartered by the state of Kentucky with an authorized capital of $600,000. Citizens of several states purchased stock in the new company, but capital came principally from Philadelphia entrepreneurs, who hoped to develop a trade route to the West by building a canal over the Appalachians to Pittsburgh. When it was apparent that subscriptions would be inadequate, Congress was induced to subscribe for 1,000 shares. In 1828 when the contractor failed, Congress again bailed out the project by purchasing the rest of the forfeited stock. The project ultimately cost $750,000 and opened to commerce in December 1830. In 1831 over 400 steamboats and a like number of other vessels passed through the canal. Some 1,000 vessels used the facility in 1835 and an average of 1,300 used the facility every year thereafter until the Civil War. The tolls collected from this traffic made the canal a profitable venture for its investors.

The Louisville and Portland Canal provided the shipment of goods from the Upper Ohio without transferring cargoes, but it had several drawbacks. It was difficult to operate and maintain, and its dimensions were inadequate. The canal was 2 miles long and 64 feet wide and contained three locks that could accommodate vessels 183 feet long and 49 1/2 feet wide. After a decade, the lock chambers were too small for the steamboats best suited for trade between the Upper Ohio and Mississippi rivers.

The facility also became a political football. The canal's owners, the Kentucky legislature, and navigation interests supported federal ownership of the project to facilitate improvements and remove tolls. The people of Indiana, however, hoped for construction of a federal canal on their side of the river and strict constitutionalists opposed any federal ownership on constitutional grounds. By 1855 the United States had acquired nearly all of the canal stock, but five shares remained in the hands of individuals on the board of directors.[20]

THE TENNESSEE RIVER

The principal rapids on the Tennessee River, called Muscle Shoals, were much more formidable than the Falls of the Ohio. Located in northern Alabama some 150 miles above Paducah at the mouth of the Tennessee and about 400 miles below the river's head at Knoxville, the 35-mile-long series of rapids had an aggregate fall of some 134 feet. At low stages, the flow over the rapids fell to as little as 6 inches, and the narrow channel was strewn with rock ledges and boulders. Upriver navigation was impossible, though flatboats and similar craft could run the course during brief periods of high water.

As long as this natural barrier seriously restricted commerce between the upper and lower valleys, commercial development in the region was retarded. Army Engineers reported in an 1828 survey of the shoals that goods had to be brought into the upper Tennessee overland from Nashville at a cost of fifty dollars a ton. As previously mentioned, downstream travel was available only at brief flood stages and supplies brought upriver from New Orleans were expensive due to the need for trans-shipment.

Some simple state and private improvements were made on the Tennessee River prior to the Civil War, but only one major effort focused on the rapids. In 1824 Congress authorized Alabama to improve navigation on the Tennessee and Coosa rivers. Subsequently, the state received 400,000 acres of federal land to sell in order to obtain the capital necessary to make improvements at Muscle Shoals. A survey by Army Engineers in 1828 recommended bypassing the hazard with a canal. By the mid-1830s the project was under construction. Some $700,000 was spent on the canal, but the funds were wasted. Less than half of the canal was built and even this portion was rendered useless by an 1841 flood that cut several breaches in the banks. Even if completed, the canal's value would have been limited because the locks, which departed from Army Engineer recommendations, would accommodate only the smallest steamboats. The project lay virtually dormant until the federal government assumed control of the undertaking in the 1870s.[21]

NEW WATERWAY IMPROVEMENT STRATEGIES

By 1860 western commerce had grown in volume and complexity to the point where seasonal interruptions to navigation were a major concern. The onset of a series of low-water years in the 1850s caused severe losses to merchants and steamboat owners and, consequently, gave rise to serious consideration of more ambitious river improvements. The failure of the fall rises to occur in 1854 and 1856 set in motion various schemes to obtain year-round navigation. But the Democratic hold on Congress ruled out programs of extensive river improvements and such efforts exceeded the capabilities of states. The Civil War further diverted attention, but in the more favorable climate of the postwar years "radical" improvements of the Ohio River once again became a major topic of discussion and controversy in the commercial centers of the Ohio Valley.

Despite the political imbroglios that undermined systematic river improvements, many engineers were advancing theories and proposals for ambitious riverine programs. These inquiries and speculations set the stage for engineering controversies that continued into the twentieth century. Three plans received the most attention.

The first was put forth by Charles Ellet, Jr., a brilliant young engineer who based his calculations on stream measurements taken at Wheeling in 1848 while he was engaged in construction of a suspension bridge. Ellet concluded that there was an ample water supply to maintain year-round navigation on the Ohio River. The solution was to build six large dams on Ohio River tributaries to store floodwaters that could be released to balance fluctuations. The cost of building reservoirs adequate to maintain a minimum channel depth of 6 feet was estimated at $12 million, with $15,000 for annual operating expenses. Ellet published his reservoir idea in engineering journals during 1849, and he launched a campaign to obtain funding from Congress for studies and an experimental reservoir project.

William Milnor Roberts, principal engineer of the slackwater Monongahela River project, was the chief critic of the reservoir plan. He stressed the engineering problems of building large storage dams, challenged Ellet's calculations, and pointed out that the reservoirs would inundate towns, highways, and canals. Roberts stated that canalizing the Ohio with locks and dams would be more effective and easier to accomplish than the Ellet reservoir plan, noting that slackwater systems were already in operation on several Ohio River tributaries. But Roberts' critics argued that his system would injure flatboat commerce, create ice formations, increase the severity of floods, and delay trips by requiring time-consuming lockages. Interests on the Lower Ohio contended that destruction of natural navigation during ten months of the year was not worth providing uninterrupted travel during the remaining two months.

Increasing discontent with federal inaction led in 1855 to a third proposal for improvement of Ohio River navigation. Herman Haupt's plan called for some one hundred low dams and other works to create a 200-foot-wide canal down one side of the Ohio River. This elaborate and expensive undertaking found little support among engineers and rivermen and was rejected by a Senate committee.[22]

SUMMARY

Prior to the Civil War, navigation improvement efforts were directed toward the elimination of obstructions such as rapids, rocks, snags, and bars. The ultimate goal was creating an open channel by removing or cutting through these obstructions or bypassing them with canals. With the increasing scale and complexity of western commerce, dissatisfaction with limited relief measures mounted and river improvement came to take on a broader meaning. Engineers and rivermen began to think in terms of not merely a channel cleared of obstructions but one filled with a year-round navigable depth of water. The seasonal limits on river transportation increasingly irked commercial interests. Piecemeal improvement strategies gave way to ambitious schemes for maintaining navigation by building elaborate slackwater systems of locks and dams and even storing floods in huge reservoirs on the headwaters.

Chapter III

THE QUEST FOR SLACKWATER, 1861-1929

POST-CIVIL WAR RIVER COMMERCE

When river improvements resumed after the Civil War, it was evident that the conditions and needs of Ohio River transportation had changed radically. As railroads began to extend their networks beyond the Appalachians, the dependence on rivers steadily declined. Furthermore, the character of the river traffic was beginning to change, creating new navigational requirements. This new era in Ohio Valley commerce was largely spawned by the coal trade. By the 1870s, coal was no longer being shipped in coal boats, but by large aggregates of barges, sometimes 150 feet wide and hundreds of feet long pushed by steam towboats.

Prior to the Civil War, steamboat operators experimented with attaching auxiliary craft ahead of and at the sides of the vessels. Reportedly, 2.5 million bushels of coal was moved down river in coalboats in 1844--and by 1866 ninety steamboats were carrying 40 million bushels of coal down the Ohio annually. During one week in 1866, seven steamboats arrived at New Orleans from the Ohio Valley with fifty-eight barges that contained 45,000 tons of coal. Since the tows drew from 6 to 8 feet of water, the periods available for using this method were of short duration. The prospect of frequent long-term disruptions of industrial and urban fuel supplies increased the conviction of riverine business interests that the "seasonal curse must be removed from river transportation."[1]

RESUMPTION OF IMPROVEMENTS

In 1866 William Milnor Roberts was appointed to oversee improvements and surveys on the Ohio River authorized by the 1866 Rivers and Harbors Act. The farsighted engineer was sensitive to the requirements of the burgeoning coal trade and continued to advocate his "radical" plan for a slackwater, lock and dam canalization project for the Ohio River. In 1867 two survey parties began a comprehensive survey of the river starting at a point 271 miles below Pittsburgh (where the Sanders survey of 1844 ended). Completed despite great hardship in 1869, the surveys offered indispensable engineering and hydrological data later used to plan navigation improvements.[2]

While the survey progressed, Roberts began removing snags and other obstructions from the channel and constructing dikes at various points to enhance low-stage navigation. In 1870 he resigned to become chief construction engineer for the famous Eads Bridge at St. Louis. Prior to departing he conducted an analysis of the river's commerce and hydrology and proposed a canalization project that would provide for year-round navigation.

The commercial and military waterborne traffic generated by the Civil War helped to kindle increased concern and interest in waterway improvements. In addition, navigation proponents found a more receptive hearing in Congress. The conflict had put to rest states' rights interests, and the dominant Republican Party was strongly committed to federal public works programs. Thus, the constitutionality of waterway projects was neither opposed by the Congress nor the presidency. The 1866 Rivers and Harbors Act charged the Chief of Engineers to examine all riverine projects and to plan for additional undertakings. The act also appropriated $550,000 to build a new fleet of snagboats, to renew channel clearance operations on the Ohio and other major rivers, as well as to reestablish the moribund Office of Western River Improvements. Richard Delafield, Chief of Engineers, after a quick review of prewar projects reported that the abandonment of these projects in the 1850s eroded their benefits.[3]

After Roberts' resignation, Colonel William E. Merrill assumed responsibility for most Ohio River projects. Merrill, who directed improvements on the Ohio River for over twenty years, moved the Army Engineer's office from Pittsburgh to Cincinnati to locate the improvement activities more centrally. He stepped up operations on the lower river and contracted for dam repairs and the removal of boulders and other obstructions. The engineer was able to convince Congress that contract snag and dredging operations were unsatisfactory, and he gained approval for a new government fleet. Under Merrill's leadership, contracts were let for iron-hulled river watercraft, which were much more durable than their wooden predecessors. The snagboat E.A. Woodruff was in service by 1875 and operated on the Ohio until 1925. Merrill put two steam dredges into operation in the early 1870s that significantly reduced the cost of dredging work.[4]

Merrill also launched a campaign for the installation of beacons and buoys to mark river channels. Until 1874 river navigators relied on the positions of trees, bluffs, and other landmarks to guide them in channel. Due to recommendations by Merrill and the efforts of rivermen, Congress in 1874 extended the jurisdiction of the Lighthouse Board to inland rivers. Some 150 beacons and buoys were placed in the Ohio in 1875, and 503 signal lights and daymarkers were in service by 1920.

The U.S. Coast Guard assumed control of these aids to navigation in World War II.[5]

ORIGINS OF SLACKWATER MOVEMENT

After the Civil War, Army Engineers continued the open channel improvements of the prewar era. This work no doubt benefited river traffic, but its effects were seldom permanent and in few instances significantly aided deeper draft barge tows. New snags filled the rivers after each high stage, and increased depths created by dikes at specific shoals were often offset by reduced water levels at downstream bars where the scoured sand and gravel settled.

In 1870 Roberts concluded that the existing navigation facilities on the Ohio River, while "productive of public benefit more than commensurate with the outlay required," were no better than an "amelioration of the present difficulty." He proposed instead to canalize the river by means of sixty-six locks and dams that would offer 6-foot slackwater navigation from Pittsburgh to Cairo, Illinois. Estimated at a cost of $23.8 million, the project would include 370-by-80-foot locks and a 300-foot-wide chute through the dams. Appeals from Ohio Valley states and commercial interests led to the appointment of Merrill and General Godfrey Weitzel to a special Board of Inquiry to report on canalization of the Ohio.

Merrill decided that locks and dams were the best solution. Slackwater strategies had worked on the Monongahela and many other streams, and in 1872 the engineer recommended building a slackwater system that would extend downstream from Pittsburgh.[6]

Ironically, the plan received a hostile response from the very groups it was designed to benefit. Coal shippers and towboatmen feared that dams would obstruct channels and require time-consuming tow breakages at locks. Critics also charged that the scheme would increase flood heights, create stagnant slackwater pools, and ultimately cause the siltation of river channels. In Pittsburgh rivermen organized a torchlight parade to protest Merrill's plan.[7]

DAVIS ISLAND DAM

To placate opponents, Merrill began investigating movable dams that could be raised to increase depths during shallow periods and lowered at high water to pass tows through without locking. He sent his deputy, Lieutenant Frederick A. Mahan, to Europe to study such structures on French rivers and began experiments and model studies of movable dams and chutes proposed by Americans.

Eventually, Merrill and other officers recommended the adoption of the Chanoine wicket, invented by the Frenchman Jacques Chanoine in 1852. The ingenious device consisted of a large number of wickets (resembling large folding boards) hinged to a concrete foundation on the bottom of the river. Each wicket was about 3 1/2 feet wide and 13 feet long. In its raised position, the wicket was supported by a heavy iron pole extending downstream. When the river rose high enough to provide for natural navigation, the prop was removed and the wickets would lie flat on the river bottom. When the river fell again a crew of men on a special maneuver boat attached a grapple to the wickets to raise them.[8]

In 1874 Merrill recommended that a series of movable dams, using the Chanoine wickets, be adopted for canalization of the Ohio. He viewed this option as meeting the needs of the coal interests for open-channel navigation while at the same time providing a series of navigation pools during low stages. To accommodate the large tows, he developed plans for 110-by-600-foot locks that included an innovative rolling lock gate.

Merrill proposed to build the first experimental movable dam and lock at Davis Island to provide a better harbor for 5 miles below Pittsburgh, located 5 miles farther upstream. Critics continued to howl, but the project obtained support from the Ohio River Commission as well as the Grange, an organization of farmers that sought cheaper transportation by enhancing the position of waterways in competing with railroads.[9]

In 1873 and 1874, the Senate Committee on Transportation Routes (the Windom Committee) held hearings on Ohio canalization. It concluded that waterways remained "the cheapest line of transport" and recommended the "improvement of the Ohio River in such a manner as to secure from Pittsburgh to Cairo a depth of 6 feet of water at all seasons...."

In 1875 Congress appropriated $100,000 for land acquisition and initial construction of the project at Davis Island. However, construction was delayed because the Pennsylvania legislature had to grant the federal government jurisdiction over riparian land. Coal interests lobbied against the transfer, but the appropriate special legislation was finally enacted in 1877. The work began in 1878 but was not completed until 1885 because of intermittent funding and the project's experimental character. Careful records were kept to create a fund of information for later projects.

When completed, the 1,223-foot dam--containing 305 wickets--was the longest in the world. The project's 110-by-600-foot lock was also unexceeded. Merrill fortunately suggested deferring the building of additional locks and dams until experience was gained in operating the prototype. Problems were, in fact, identified and corrected in future projects. However, the general success of the Davis Island project put the critics to rest. The increased depth of the Pittsburgh harbor proved a great asset. The large pool facilitated the assembling of large tows and in 1888 protected the fleet in the harbor from a serious flood.[10]

THE 6-FOOT PROJECT

Largely due to the success of the Davis Island project, in 1888 Congress authorized a study of an extension of the 6-foot minimum depth down the Upper Ohio. The board recommended building a series of dams and locks to create a 6-foot depth from Davis Island to just below the mouth of the Beaver River. Lock and Dam No. 6, named Merrill Dam in honor of the great engineer, was built next. The first appropriations were made in 1890, but meager annual funding delayed the dam's completion until 1906. The first appropriations for Nos. 2 through 5 were not made until 1896.

The high cost of these facilities--about $1 million for each combined locks and dam--delayed extension of the slackwater system down the Ohio. To prompt Congress to more favorable action, rivermen and shippers created the Ohio Valley Improvement Association (OVIA) in 1895. The organization sponsored river trips by members of Congress, giving them a firsthand look at navigation conditions as well as commerce and industry in the Ohio Valley. Army Engineers completed a survey of the river from the mouth of the Beaver River to Marietta in 1898 and recommended construction of twelve more locks and dams (Nos. 7 to 18) that were authorized in 1899. The strategy was altered and the decision made initially to build the structures below major river ports and at the mouths of large streams, rather than to continue seriatim. The survey was extended to Cincinnati in 1900, and in 1901 the building of twenty additional locks and dams (Nos. 19 to 38) below the mouth of the Muskingum was recommended. Thus, by the turn of the century, the Davis Island project was completed, Nos. 2 to 6 were in progress, and thirty-two more were authorized to create 6-foot navigational depth downriver to

Cincinnati. In 1902 Congress approved canalization to the Indiana state line.[11]

THE LOCKWOOD BOARD

By the early 1900s, members of the OVIA and other groups were pointing out that large barge tows often drew more than 6 feet of water. They asked Congress to consider creating 9-foot minimum depths. In 1905 Congress authorized an analysis of the feasibility of extending the slackwater system to the mouth of the Ohio. A special board of engineers called the Lockwood Board after its senior member--Colonel Daniel W. Lockwood--conducted the study. The board confirmed that the steamboat packet trade was dying out, but some 9 million tons of bulk commodities, mainly coal from the Monongahela and Kanawha valleys, were annually sent downriver. After an economic evaluation, the board estimated completion of a 6-foot project from Pittsburgh to Cairo would cost about $51 million, while the more ambitious 9-foot alternative would require construction of fifty-four dams at a cost of $63 million. The board argued, however, that the latter alternative would greatly extend economic benefits by encouraging the development of large bulk traffic volumes.

In reviewing the proposal, the Board of Engineers for Rivers and Harbors (created in 1902 to independently review projects and eliminate "pork") observed that, although the scale of the undertaking was unprecedented, the project was worthwhile. In the progressive climate created by the studies of the Inland Waterways Commission, created in 1907, support for the huge effort grew. Skeptics suggested it was foolhardy to canalize a river on which commerce was declining and to spend money based on projected future economic activity. But with the support of individuals such as President William H. Taft and Ohio Congressman Theodore E. Burton, in 1910 Congress approved construction of all fifty-four locks and dams required to provide 9-foot navigation the length of the Ohio. The bill called for completion of the $66 million project by 1922, but a mere $1 million was appropriated for the first year.[12]

OHIO RIVER COMMERCE

As the Ohio River Canalization Project was being built, the waterborne commerce it intended to serve continued to decline. In 1917 cargoes carried on the river reached an all time low of some 4.6 million tons. This nadir of commercial activity was caused largely by the abrupt halt of coal shipments from Pittsburgh to New Orleans. The Monongahela River Consolidated Coal and Coke Company, a combine of vitually every coal shipper in the Pittsburgh area, ceased downstream operations due to the steel industry's demand for coal in the Upper Ohio Valley. In addition, losses of towboats and barges on the unimproved Lower Ohio and Mississippi rivers, as well as competition from Alabama coal and Oklahoma oil in the New Orleans market, reinforced this decision. This major decline in coal traffic reduced the total waterborne commerce on the Ohio by some 50 percent.[13]

Critics began to question the economic justifications for the canalization project, but World War I added impetus for its completion. Wartime shipping demands overburdened the transportation system and the federal government assumed control of both the railroads and waterway traffic. This experience increased support for waterway improvements and after 1922 Congress made substantial appropriations for the Ohio River Canalization Project. River transportation grew in volume as the pace of construction increased. By 1930 the annual volume had increased to 22.3 million tons--more than double the 1920 total. Much of this rise in volume was largely due to the growing trade in steel and petroleum products.[14]

From 1920 to 1930 the navigation industry began to make changes in equipment in anticipation of the project's completion. Tows were becoming larger--and increasing numbers of boats and barges with loaded drafts of from 7 to 9 feet were put in operation. More powerful vessels with screw propellers were beginning to replace the stern paddle steamboats that had for so long characterized the inland river packet and freight trade. For example, in 1925 no trips were made by towboats with drafts of from 7 to 9 feet, but 884 were made by these larger craft in 1929.[15]

CHARACTERISTICS OF THE CANALIZATION PROJECT

By 1926 the 9-foot slackwater system had been completed as far as Cincinnati. Construction was pushed forward rapidly downstream to meet the goal of finishing the project by 1929. Completed at a cost of $125 million, the Ohio River Canalization Project was designed much as Colonel Merrill had proposed in 1875. The number of structures was reduced from fifty-four to fifty as the undertaking proceeded. Lock and Dam No. 53 was opened on August 27, 1929, and the OVIA staged a dedication cruise from Pittsburgh to Cairo in October to celebrate the birth of a new era in Ohio River commerce. President Herbert Hoover joined the cruise at Cincinnati and in a subsequent speech at Louisville prophetically stated: "While I am proud to be the President who witnesses the apparent completion of its improvement, I have the belief that some day new inventions and new pressures of population will require its further development."[16]

The location of each dam was based primarily on the suitability of the site from a navigation standpoint as well as considerations such as the character of the foundations and banks and the width and depth of the river. After 1910 an attempt was made to build the structures in the following order: first, in the upper reach where the slope was greatest and where they would serve as an extension of the canalized Monongahela River, and second, below large cities to create harbors so as to encourage terminal construction by private interests. The third priority was construction of alternate dams to aid low-water traffic as much as possible while the remaining dams were being built.[17]

All locks and dams built above Louisville had rock or compacted gravel foundations, but downriver from No. 31 the locks and dams usually rested on 30- to 40-foot-long wooden piles with interlocking wooden and steel piles on the upstream face. Only one dam failed due to foundation problems. The navigable pass at No. 26 had to be rebuilt when the foundation shale slipped downstream.

Each structure of the Ohio River Canalization Project was unique in some respects, but the typical facility had a 110-by-600-foot lock chamber with concrete land- and riverwalls. Adjacent to the lock was a navigable pass section from 600 to 1,200 feet long that featured the movable Chanoine wickets. Originally the lift of the dams did not exceed 8 feet, requiring Chanoine wickets about 16 feet long. Later, wickets as much as 20 feet long were used to provide lift of 12 feet. Next to the wickets were three piers that supported two 91-foot beartrap weirs, and next to the beartraps was a long Chanoine weir section to close the river from the beartraps to the dam abutment on the bank opposite the lock.

The first two locks were constructed of expensive cutstone masonry but later structures were built of portland cement concrete. The locks' inner walls were initially faced with timber to reduce damage from the movement of barges through the facility. But with the gradual adoption of steel barges after 1910, lock wall faces were protected against abrasion by horizontal lines of steel fenders embedded in the concrete. Locks constructed prior to 1916 had rolling gates. Although they worked well on the Upper Ohio, downstream deposits of mud and sand caused serious operation and maintenance problems. Mitering gates were first adopted in 1914. The gates opened and closed with a single stroke by pistons in hydraulic oil cylinders. The locks, with few exceptions, were filled and emptied through openings in the riverwall.

At first, power for operating the gates and valves was obtained from coal-burning steam plants or natural gas engines. Lock and dam structures built after 1914 included water turbines that provided the primary source of power for operations. At Louisville the original navigation dam was replaced by a power-navigation dam that rendered the construction of one of the original dams unnecessary. This was the only point on the river where the commercial development of power was deemed feasible. Construction of the new dam and powerhouse on the Falls began in 1925 and was completed in 1927.

The movable dams on the upper part of the river were only partially successful. The steep slope and variable flow of the river required frequent manipulation of the dams, making it extremely difficult to maintain a constant depth of 9-feet. In 1917 Congress approved construction of Emsworth Locks and Dam, which replaced Nos. 1 and 2. It was the first fixed dam with double locks built on the Ohio. The structure included two locks, one with the standard 110-by-600-foot Ohio River dimensions and the other, 56 by 360 feet. Double locks allowed repairs without stopping navigation, permitted two simultaneous lockages, and, when necessary, conserved water during low stages through use of the smaller lock. Completed at a cost of $3 million, the Emworth Locks and Dam were placed in service in September 1921, thirty-six years after completion of the Davis Island Dam, which it replaced.[18]

IMPROVEMENTS ON THE TENNESSEE AND CUMBERLAND

In 1868 the federal government turned its attention to the Tennessee River after a sixteen-year lapse. For the first time, plans were developed to improve the entire length of the river. The Army Engineers divided the stream into three sections that had contrasting navigation characteristics: Knoxville to Chattanooga, Chattanooga to Riverton, Alabama, and Riverton to the mouth.

Little attention was given to the upper portion of the river. Open-channel improvements were made sporadically but depths even during the high-water season averaged no more than 3 feet. In 1912 a low dam was authorized upstream from Chattanooga, but Congress failed to provide funds for this and other low-lift lock and dam schemes. Until the 1930s, the Upper Tennessee was an undeveloped waterway that offered no inducements for modern barge traffic.[19]

The middle section of the Tennessee, a distance of 237 miles, received the greatest federal investment prior to the creation of the Tennessee Valley Authority. This reach of the river contained the treacherous Muscle Shoals and similar hazards at Colbert and Bee Tree that effectively blocked navigation. In 1875, some forty-five years after the state-built Muscle Shoals Canal was abandoned, the Army Engineers began construction of a new bypass canal. Work proceeded slowly and the canal took fifteen years to build. Vexing delays were caused by insufficient congressional appropriations, flooding, disease, and problems with contractors. In 1890 a lateral canal was also authorized around the Colbert and Bee Tree shoals, but this project experienced similar delays and was not completed until 1911. The canals contributed to the revival of trade and industry, but were clearly not the answer to reliable navigation on the Tennessee. They were abandoned as modern engineering made possible the construction of multiple-purpose high dams that raised the water level well above natural obstructions.

In the early 1900s, private interests seeking to develop hydroelectric power in the Chattanooga area joined with the Army Engineers to build the first multiple-purpose dam on the river. From 1905 to 1913, a power dam and navigation lock were constructed at Hales Bar, 33 miles downstream from Chattanooga. The construction created 6-foot slackwater navigation from the dam to the Tennessee city. In exchange for building the dam (the federal government paid for the lock apparatus) the company received the right to produce and market power at the site for ninety-nine years. The dam eliminated the "Suck," a treacherous series of rapids that had seriously impeded navigation near Chattanooga.

The 1916 Rivers and Harbors Act authorized two additional dams and locks to improve navigation in the middle reach of the Tennessee River. The first, Widow's Bar, some 23 miles downstream from Hales Bar Dam, was built from 1920 to 1925. A second, planned for 17 miles below Widow's Bar, was not built because Congress refused to appropriate funds. Between 1916 and 1927 the Muscle Shoals and nearby obstructions were eliminated by the massive Wilson Dam and a lower dam constructed a few miles downstream. The main dam was the world's largest concrete structure and annually produced power equivalent to burning a half million tons of coal.

Federal improvements on the lower portion of the river were less costly and complex. The 225-mile reach of the Tennessee from Riverton, Alabama, to Paducah, Kentucky, was the scene of open-channel work and annual maintenance. Five Rivers and Harbors Acts from 1868 to 1912 contained provisions for dredging and removing obstructions in the lower river. By 1930 a dependable 4 1/2 foot depth had been achieved from Riverton to the Tennessee's confluence with the Ohio.

In the final analysis, federal efforts to develop the Tennessee for navigation prior to 1930 were only partially successful. Progress was slow and sometimes wasteful and year-round navigation was impossible except at peak stages. Even under ideal conditions, navigable depths varied from 3 feet between Knoxville and Chattanooga to 6 feet for the remainder of the river. In 1930 the Corps of Engineers admitted that "the money which is being expended does not accomplish any material good toward furthering water transportation."[20]

Engineers on the Cumberland River were eager to facilitate year-round navigation by construction of locks and dams. Various surveys and plans were made during the 1880s, but the projects were delayed when the state of Kentucky chartered a stillborn company to build locks and dams on the Upper Cumberland. Canalization of the Upper Cumberland above Nashville began in 1888. Work was extended to the lower river by Congress in 1892. With one exception the six dams built below Nashville and the eight above were timber-crib, stone filled structures. The initial locks were built of masonry stone but concrete was used for the later structures. The last of the series of locks and dams was completed in 1924. With the opening of Lock and Dam No. 52 on the Ohio River project a 6-foot depth was assured.

TRIBUTARY AND PORK BARREL PROJECTS

The late nineteenth century was the era of "pork barrel" projects as Congress spent federal funds on many tributary projects of doubtful value. In 1882, for example, Congress funded eighteen projects on which the Corps of Engineers made unfavorable reports and sixteen projects on waterways never surveyed by the Corps. States petitioned Congress to assume their deteriorating projects and construction occurred on streams where waterborne commerce had seriously declined. Moderate successes were obtained on the Green, Kentucky, Kanawha, Tradewater, and a few other rivers, but these were the exception rather than the rule. The following are but two examples of these dubious ventures.[21]

In the late 1870s, Congress was asked to assume responsibility for the rapidly decaying locks and dams on the Muskingum River completed by the state of Ohio before 1842 and managed by a private corporation after 1861. In 1880 the Corps of Engineers began building a new lock in Marietta, but inadequate appropriations delayed its completion until 1891. Even then the facility was little used. In 1887 the federal government took control of the entire decadent Muskingum system, and the Army Engineers subsequently took measures to repair the crumbling dams and locks. In 1892 the Muskingum for the first time was kept open to navigation, but the limited traffic probably did not justify the effort. By the turn of the century, Congress was being asked to rebuild Lock and Dam No. 11 between the Ohio ports of Zanesville and Dresden to assist the shipment of coal from the Upper Muskingum to Cleveland via the Ohio and the Erie Canal. The project was approved in 1905 with the condition that Ohio would repair the canal. Construction finished in 1910 but little traffic developed. In addition the funds spent by Ohio were wasted when a record flood ruined the canal in 1913.[22]

In 1890 Congress authorized a project to reestablish waterborne commerce on the Rough River. Trees were removed from banks, snags cleared from the channel, and a new lock and dam were built. The structure, completed in 1896 at a cost of $85,000, included a number of engineering innovations--it was the first built of concrete. But except for its precedent-setting construction, it was a signal failure as no extensive traffic developed on the Rough River.[23] After the Board of Engineers for Rivers and Harbors was created in 1902, it disapproved 70 percent of the proposed waterway projects it studied. Thereafter funds spent on streams like the Guyandotte and Gauley rivers, and other smaller streams, were funneled into the accelerated program on rivers such as the Ohio. But political and commercial pressures combined to win support for projects on the Little Kanawha, Big Sandy, and other tributaries long after their roles as commercial arteries had ended.

SUMMARY

After the Civil War, Army Engineers made advances in open-channel river improvements. However, these methods did not offer the optimum goal--year-round navigation. Under the leadership of Colonel Merrill, the Corps initiated slackwater, lock and movable dam projects that were eventually adopted as the best means of canalizing the Ohio River from Pittsburgh to Cairo. As the steamboat packet business died out and was replaced by deep-draft barge tows, Congress sought to encourage the expansion of waterborne commerce by authorizing the 9-foot Ohio River Canalization Project. Its completion in 1929 signaled the beginning of a new era of riverine transportation on the Ohio as well as on its major tributaries.

Chapter IV

THE WATERWAY RENAISSANCE, 1930-1981

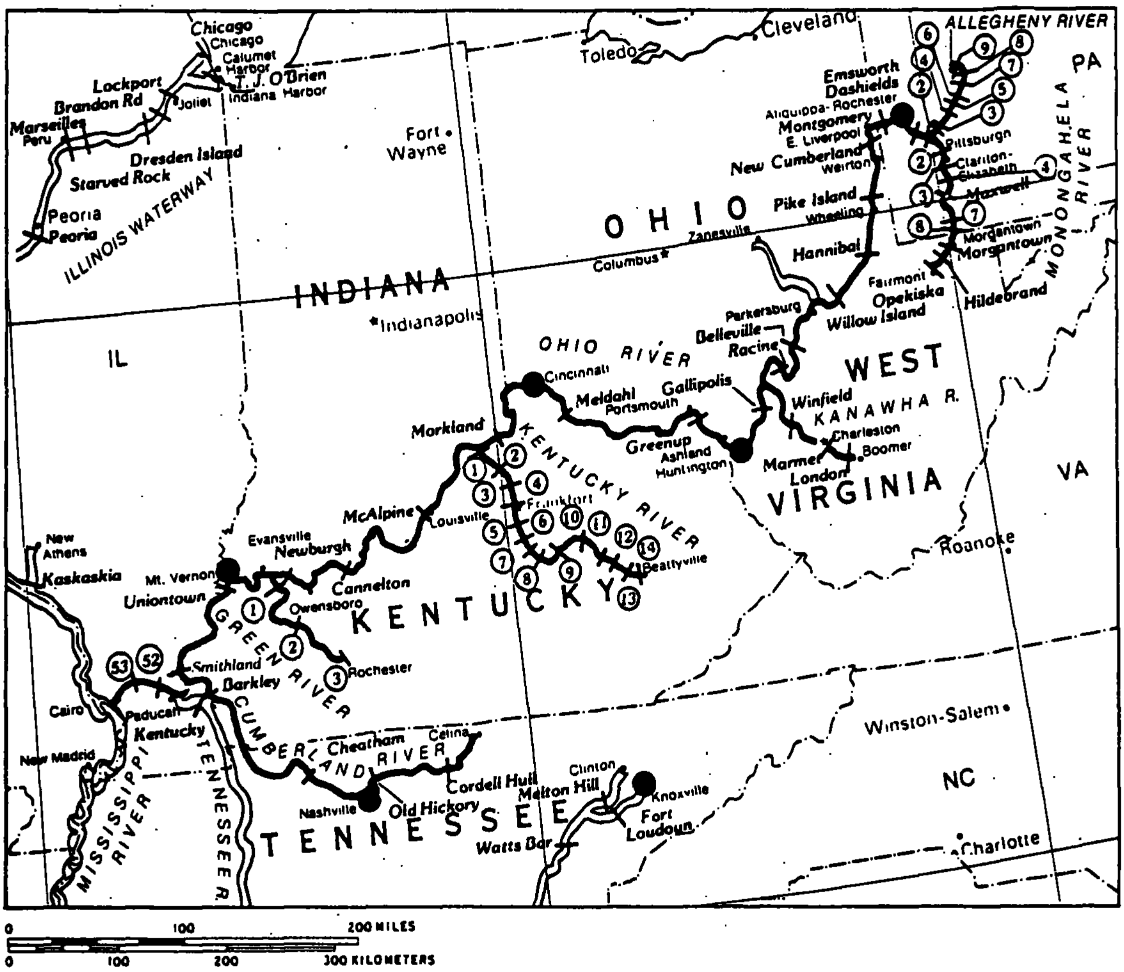
EXPANSION OF COMMERCE ON THE OHIO RIVER

The completion of the Ohio River Canalization project helped to stimulate a renaissance in waterborne commerce even though the system's influence was set back somewhat by the depression. The 22.5 million tons shipped in 1930 fell slightly in 1931 and 1932 but grew every year thereafter and reached 36.5 million tons in 1941. The average distance of tows on the Ohio increased from 55.6 miles in 1926 to 142 miles in 1941, indicating that the local character of Ohio River trade was changing. Coal traffic remained the principal source of commerce. However, by 1941 petroleum as well as iron and steel were becoming a significant part of the river's volume. By the outbreak of World War II the Ohio River 9-foot project was clearly a success, stimulating new traffic and greater total tonnage, contributing to the economic and industrial growth of the region, and far exceeding the expectations of the Lockwood Board.[1]

The waterway was of great value to the nation during World War II. The Ohio and other inland rivers reduced the load on the railway system; transported bulky commodities such as steel, petroleum, and chemicals; and provided for the safe flow of strategic materials as coastal shipping became vulnerable to submarine attacks. Inland streams also allowed wider distribution of wartime industries. Because coastal shipyards were working at capacity, 4,031 small vessels and landing craft were built on inland rivers and floated to the Gulf of Mexico. Some 1,000 of these vessels were constructed in the Ohio Valley. Approximately 38 million tons of commodities, mostly destined for the war effort, travelled the Ohio in 1942, the peak year of wartime commerce. Volume fell to 33 million tons in 1945 but increased to 62 million in 1953--twice the amount handled by the Panama Canal.

From 1946 to 1953, approximately 2,500 new industries located in the Ohio Valley, and $5.5 billion was spent to create or expand industries set on or near the navigable streams of the Ohio River system. The market for coal grew as steam electric plants were rapidly built. By the mid-1950s, 30 million tons of the fuel were helping to produce some 12 million kilowatts of electric power annually. The advent of 9-foot slackwater on the Tennessee and Ohio rivers promoted coal production in Illinois, Indiana, and western Kentucky. Furthermore,

OHIO RIVER SYSTEM



the dependable water supplies and savings derived from transporting petroleum, coal, sulfur, and crude ores on the rivers caused an expansion of the chemical industry. The Kanawha Valley exhibited a steady growth of industrial development due to unprecedented demands for industrial chemicals. The region profited from the improved waterways and its proximity to oil and natural gas supplies as well as from raw materials such as brines, clay, and limestone.[3]

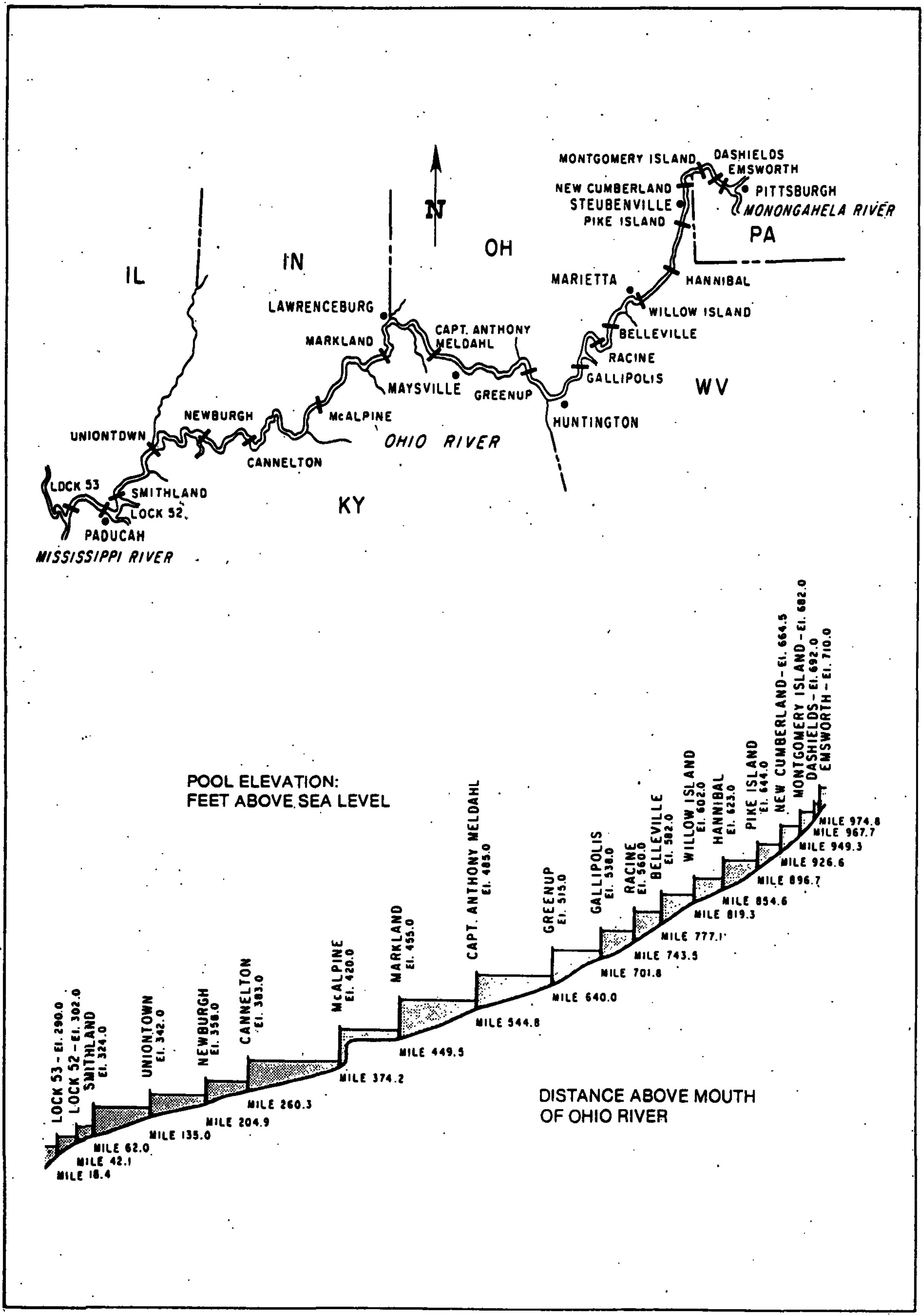
By the early 1950s, Ohio Basin traffic was being handled by the construction of combined river-rail-truck terminals that afforded trans-shipment of coal and coke, oil and gasoline, iron and steel, sand and gravel, chemicals and automobiles. In 1953 a multimillion dollar terminal went into operation at Louisville. One of the nation's largest terminals was completed near Pittsburgh with a river frontage of 1/2 mile. Hundreds of facilities have been built throughout the Ohio Basin. Most are privately owned, but the growth of barge transportation spurred interest in public terminals. States, counties, municipalities, and port districts have recognized the economic benefits that result from publicly owned facilities. Newer facilities are highly mechanized installations that permit fast unloading and reduce turnaround time. They include various sizes of cranes, fork trucks, conveyors, power mules, and clam shells; and hoppers for bulk commodities. Most ports along inland waterways also have access to railroads and highways. This access permits direct freight interchanges between barges, trucks and railcars.[4]

THE MODERNIZATION PROGRAM

After 1929 the tonnage on the Ohio actually doubled at about eleven-year intervals. By the 1950s the low-lift navigable dams and 600-foot-long lock chambers had become obsolete. In some respects, they were an impediment to the navigation they were designed to facilitate because tows had to be broken, locked through, and reassembled. Serious deterioration had taken place and costs for maintenance and rehabilitation were rising rapidly. In summary, a system designed to handle 13 million tons of commerce annually was straining under a volume five times greater.[5]

After 1929 and prior to modernization, three additional navigation structures were built on the Ohio River. They were the auxiliary 56-by-360-foot lock at No. 41 at Louisville, plus Montgomery Locks and Dam and Gallipolis Locks and Dam. By World War II the Ohio slackwater navigation system included forty-six projects--forty-one with movable wickets and locks and five nonnavigable dams with locks. Two of the latter--

PROFILE OF OHIO RIVER NAVIGATION POOLS



Note: Sites of locks and dams are shown by a name or number.

Emsworth (1921) and Dashields (1929) were part of the original 9-foot waterway, having replaced the original lock and dam structures Nos. 1, 2, and 3.

The Corps of Engineers began planning the modernization of the Ohio River slackwater system in the early 1950s. Nineteen new dual locks and high-lift dams, with an average lift of 23 feet, were proposed to replace the former Ohio River Canalization Project locks and dams that had an average lift of only 9 1/2 feet. Higher lifts would reduce the number of structures on the river by about half, cut the travel time of river tows by 50 percent, and create much longer slackwater pools. The latter factor became increasingly important as upriver traffic began to equal the downstream trade for which the earlier wicket dams had been built. Moreover, riverside terminals and industries became increasingly dependent on uniform water supplies and pleasure boats required stable pools. Thus, the Corps decided to abandon the movable wicket dams in favor of high-lift, nonnavigable gated dams. The high-lift dams created longer, deeper pools, and the gates could be opened at high-river stages to pass river discharge without affecting flood levels.

Most river navigators concluded that a 110-by-1,200-foot lock could handle the largest tows operated on the Ohio. The Corps agreed and designed the new locks accordingly. An auxiliary 110-by-600-foot lock was also incorporated into each structure to add flexibility and additional capacity. The smaller lock could handle tows when the larger lock was under repair, and could also lift small recreational craft and boats without tows.

The designs also called for the use of tainter gates. These massive radial steel structures (named for Jeremiah B. Tainter) are used to regulate the flow of water over a spillway or dam. The upstream face of the gate is in the form of an arc centered on the gate hinge. The gates can be raised high enough to clear the highest floods and do not impede waterflow during high water. The locks were equipped with an improved conduit and valve system that permitted filling and emptying of the locks in eight minutes; ten minutes less than the time required at the old dams.[6]

When construction of the Ohio River Modernization Program began in 1954, traffic on the stream had reached 71 million tons and trips averaged 208 miles. In undertaking the program, priority was assigned to projects on river reaches where the traffic was heaviest. Thus, structures were first built at New Cumberland, Greenup, Meldahl, and Markland; all were in operation by 1963. The Greenup project was sited so that its pool could serve the port of Huntington, West Virginia, which exceeded Pittsburgh as the busiest port on the waterway in 1953.

Millions of tons of coal arrived annually by rail from the fields of West Virginia and Kentucky to be loaded on barges at Huntington for delivery to Ohio Valley industries and steam powerplants.

Construction of a new dam at the Falls of the Ohio became imperative as traffic volumes increased. Because Lock No. 41 had an annual capacity of only 19 million tons, tows stacked up waiting to get through. Widening the old Louisville canal from 200 to 500 feet got underway in 1959 and was completed in 1962. The William H. McAlpine Lock and Dam was completed in 1964. The lock, the third there, was 1,200 feet long. The dam included two tainter gate sections and 4,500 feet of fixed concrete weir.[7]

CHANGES IN WATERWAY EQUIPMENT

The rapid advance of towing technology may have been the leading cause of the modernization program. The twin-screw diesel-powered towboat Herbert Hoover, built in 1931 for the Inland Waterways Corporation, was the forerunner of the modern powerful inland river towboats. Multiple-screw towboats with 5,000 horsepower powerplants were available by the mid-1950s. Vessels with ratings of as much as 7,000 horsepower were built thereafter. Economies gained by the larger powerplants were augmented by other innovations. The use of auxiliary equipment such as powered winches, radios, and radar expedited tow assemblages and enabled tows to operate in periods of low visibility.[8]

Revolutionary changes have also been made in the design of barges. The old "Pittsburgh standard" barges had capacities of about 1,000 tons. But the newer "super jumbo" 3,000-ton barges now ply the principal rivers of the Ohio Basin. Improved hull designs offer less resistance in towing without sacrificing cargo capacity, and the trend toward integrated tows increased standardization of barge size and design. A wide variety of barges have been developed. The versatile open-hopper barge carries coal and other bulk commodities. Dry cover barges are equipped with watertight covers and carry grain, cement, and other perishable goods. Tank barges were developed for petroleum products and other liquid cargoes. They have been modified to safely transport acids, liquified sulfur, liquid hydrogen, and other dangerous substances.[9]

In short, complex changes in marine design and technology, coupled with longer slackwater pools and modern terminals, have made barge towing the most cost-effective means of moving bulk freight.

NEW DIRECTIONS IN WATER RESOURCE PLANNING

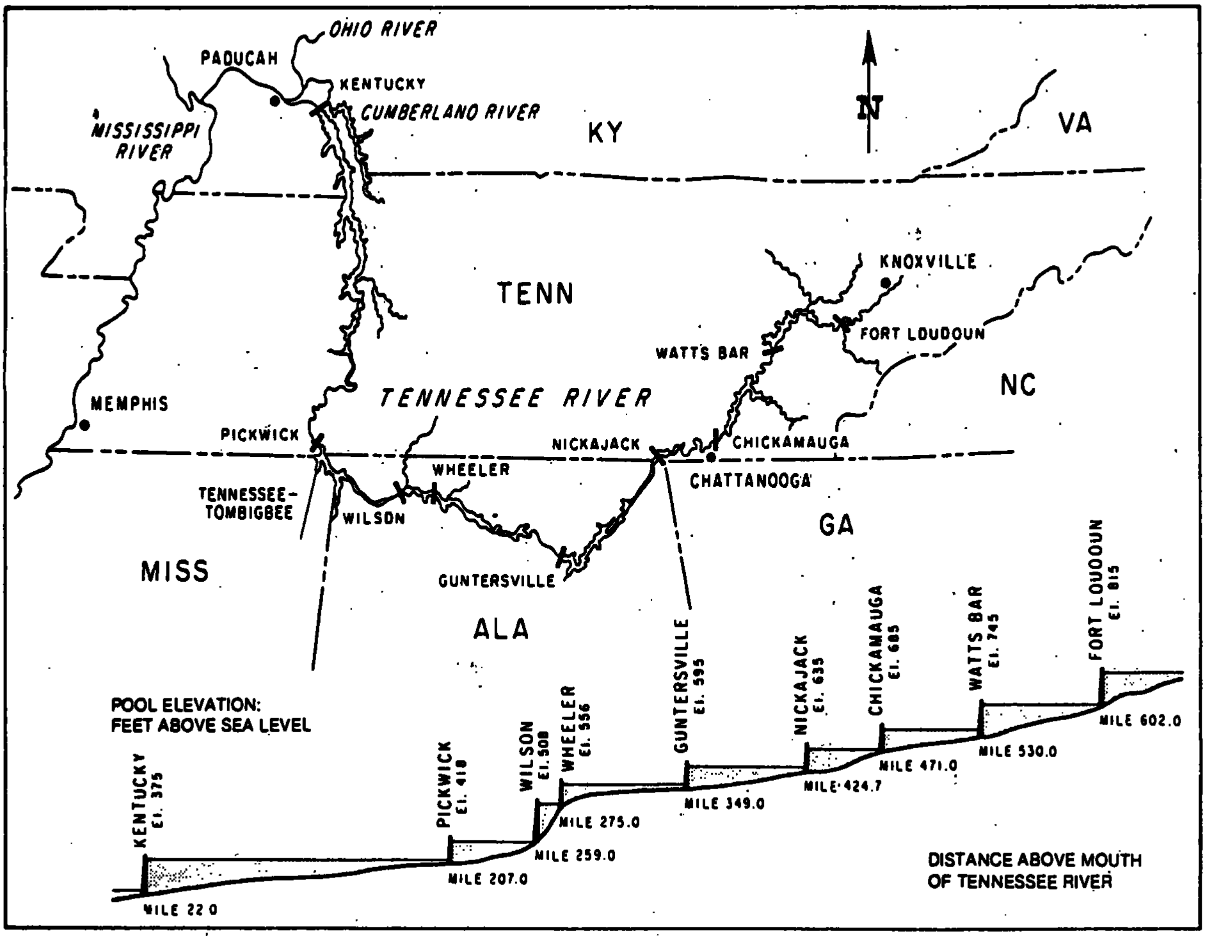
By the 1920s, engineers were beginning to develop comprehensive plans for river navigation in conjunction with consideration of benefits derived from flood control, hydroelectric power generation, and irrigation. In 1925 Congress asked the Corps of Engineers and the Federal Power Commission to submit cost estimates for making basinwide, multiple-purpose surveys of every major river in the nation. Published as House Document No. 308 in 1926, the massive agenda of surveys (known as "308 Reports") was authorized in 1927. The Corps was asked to conduct detailed surveys of each basin to help analyze the ultimate potential of major drainage areas for navigation, power flood control, and allied uses. The 308 Report for the Ohio was completed in 1933 and called for the construction of flood control reservoirs on the main river's tributaries. Many of these projects were part of the historic 1936 Flood Control Act that initially authorized some 270 flood control projects. By the 1930s, therefore, the Corps of Engineers was fully committed to multiple-purpose planning. Due to hydraulic conditions, navigation remained the principal focus on the main stem of the Ohio, but on two major tributaries the broad multiple-purpose approach was implemented.[10]

TRANSFORMATION OF THE TENNESSEE RIVER

The transformation of the Tennessee River was unique in two respects: (1) the river was the first major stream to be developed on the basis of multiple-purpose principles, and (2) it was the only river with development directed by a regional agency charged with reviving the economy of an entire drainage basin. The Tennessee Valley Authority (TVA) was created by Congress in May 1933 as an independent government corporation to provide for unified development of all the region's resources. The act identified navigation improvement as one of the agency's missions.

The Tennessee and its tributaries are one of the nation's most important river systems. Formed by the confluence of the Holston and French Broad rivers near Knoxville, the river flows 652 miles through three states into the Ohio River at Paducah. Its tributaries extend into four additional states, and its total drainage area is almost 41,000 square miles. Annual rainfall in the region is about 52 inches. By 1930 there were two locks and dams on the river: Wilson Dam near Florence, Alabama, which provided a 15-mile channel; and Hales Bar Dam near Chattanooga, which furnished a 6-foot depth for 33 miles.

TENNESSEE RIVER



Note: Sites of locks and dams are shown by a name or number.

But navigation continued to be retarded by variable and uncertain depths. Furthermore, the river's unregulated flow subjected the region to increased flooding problems on the Lower Ohio and Mississippi rivers.[11]

TVA's early operations were greatly aided by previous studies of the Corps of Engineers that culminated in 1930 with an exhaustive analysis that recommended the enhancement of flood control, navigation, and power production by "securing regulation of stream flow in order to reduce flood flows and increase low-flows." The report outlined a system of high dams on the mainstream as well as additional tributary projects. It also briefly presented an alternative plan for 32 low Ohio River type dams and locks for navigation.

The high-dam plan was authorized in the 1930 Rivers and Harbors Act, with the provision that the federal government would contribute an amount equal to the cost of the low dams if power companies or state governments would build the large water storage structures. The Corps attempted to enlist the cooperation of public and private interests, but the onset of the 1930s depression precluded this river development alternative.

When TVA was created in 1933, no dams had been built under the 1930 authorization. Army Engineers had begun construction, however, on a 60- by 360-foot lock and dam at the present site of Wheeler Dam. The structure was eventually completed by the Corps.

Canalization of the Tennessee from Paducah to Knoxville by a slackwater channel was completed by TVA in a twelve-year construction program. The high-dam system generally resembled the plan proposed by the Corps in its 1930 report. As in that plan, seven locks and dams were built on the Tennessee River and the pre-TVA Wilson and Hales Bar projects were incorporated into the system. By 1945 TVA had also built nine storage dams on the tributaries that were operated in conjunction with the mainstream structures to achieve regular navigation depths and other benefits. The 9-foot channel was virtually assured by the end of World War II. A larger main lock, 110 by 600 feet, was added at Wilson Dam in 1959. In subsequent years locks at other dams have been enlarged. A new dam and lock were completed in 1963 on the Clinch River, a Tennessee tributary, that increased the 9-foot channel on the waterway system to 750 miles.

The nine mainstream dams and locks raise vessels a total of 600 feet on upstream trips, an average of nearly a foot per mile. The Corps of Engineers operates the locks and performs regular dredging, and the

Coast Guard maintains the navigation aids as they do on other inland waterways.[12]

Completion of the 9-foot system caused an immediate upsurge in commerce. Cities such as Decatur and Huntsville in Alabama and Knoxville and Chattanooga, Tennessee, became important inland port and industrial centers. Oil companies were the first industry to recognize the utility and economy of the new waterway. They built terminals on the river in the 1940s and began sending cargoes from Houston and Port Arthur, Texas, up the Mississippi River to customers in the Tennessee Valley. Grain companies, recognizing the expanding livestock industry along the Tennessee system, built mills and shipped large quantities of corn, soybeans, alfalfa pellets, and other agricultural commodities. A brisk commerce in coal, forest products, chemicals, and steel also developed. Industries were early attracted to the area because the multipurpose river development project provided low-cost hydroelectric power and abundant supplies of water.

Moreover, TVA's resource development activities are "total" in concept and extend beyond the river. Its forestry activities provide an expanding source of raw materials for the paper, timber, housing, and furniture industries. Fertilizer production has made adjacent farmlands much more prosperous. The growth of industry and river commerce has been paralleled by the expansion of other forms of transportation. By fostering industrial growth, TVA's activities have led to the growth of an interdependent truck, rail, and barge transportation system in the region.

Shortly after its creation, TVA identified the need to build a system of public river terminals to increase use of the waterway and bring the advantages of water transportation to the region. Citizens of the valley, including representatives from the nine principal port cities on the Tennessee, formed the Tennessee Valley Waterways Conference to obtain optimum use of the waterway by developing adequate river terminals and water transportation services. The net long-term result of these cooperative efforts is that public terminals are available along the entire waterway.

The TVA assists state and local agencies by evaluating proposed terminal sites and by examining economic and engineering features of planned facilities. The federal agency also furnishes information on functions and operations of terminal facilities, identifies potential terminal users, and estimates shipping costs. In addition to its many other functions, TVA also participates in proceedings before the Interstate Commerce Commission in an effort to coordinate transportation rates and services between land and water carriers and to remove barriers to optimum use of the Tennessee River system.[13]

THE TENNESSEE-TOMBIGBEE WATERWAY

The Tennessee-Tombigbee Waterway is designed to fulfill the long-held dream of a "Southern Route" for inland river commerce. A partially navigable inland water route exists from Mobile Bay up the Alabama and Tombigbee rivers to Columbus, Mississippi, but halts a few miles from the Tennessee River. The trip from Muscle Shoals to New Orleans via the Tennessee and Mississippi rivers is more than 1,121 miles. The new waterway would cut the distance by almost 500 miles.

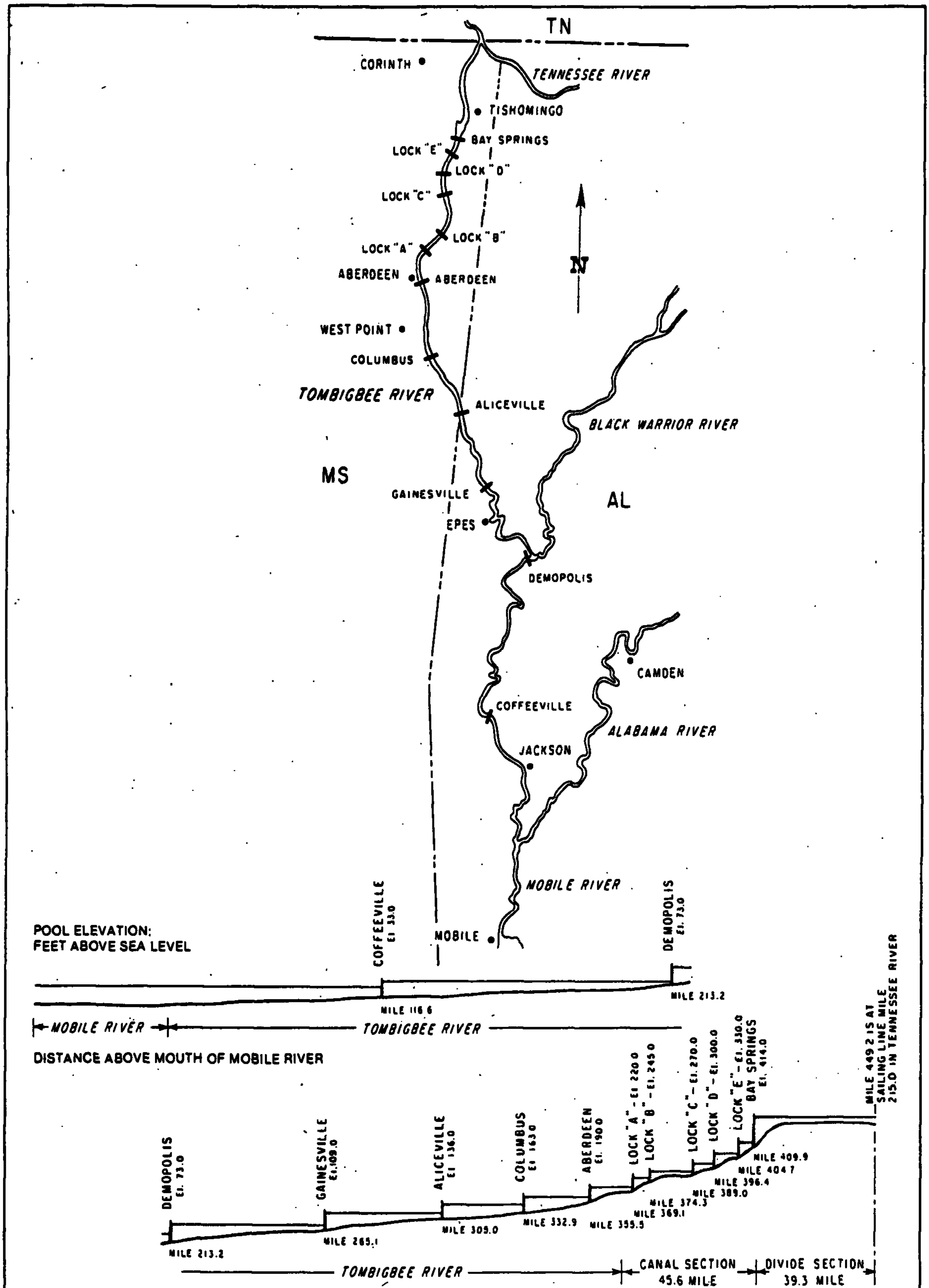
A canal connecting the Tennessee and Tombigbee rivers was conceived by the French as early as the eighteenth century and in 1819 the state of Alabama enacted legislation that called for a feasibility study of the canal. The Corps of Engineers studied the route during the nineteenth century and drew up plans for the project in 1878. Despite continued interest the undertaking was not authorized until the 1946 Rivers and Harbors Act. The project was deferred for study in 1951. It was revived in 1967 and work on the 232-mile waterway began in December 1972.

When complete, the waterway will join the Tennessee River with the Black Warrior-Tombigbee Waterway at Demopolis, Alabama. The project extends upstream from Demopolis via the Tombigbee River and Mackeys Creek, through a deep cut across the divide into Yellow Creek and from there to Pickwick Pool on the Tennessee River. The entire waterway is to include four locks and dams on the Tombigbee, five locks on the canal, and an additional lock and dam at the head of the canal to impound water through the cut. The anticipated cost of the project is $1.9 billion and through fiscal year 1979 some $622 million had been allocated. As the first large waterway project constructed under the 1969 National Environmental Policy Act, the public work has encountered strong environmental opposition and has been the subject of litigation.[14]

NAVIGATION IMPROVEMENTS ON THE CUMBERLAND

The Cumberland River, just as its twin waterway, the Tennessee, has been transformed by multiple-purpose projects since the 1930s. Increased traffic in petroleum products in the 1930s prompted the installation of innovative A-frame wickets on the crests of several navigation dams below Nashville. However, a series of flood storage and multiple-purpose dams initially authorized in the 1938 Flood Control Act soon surpassed these simple devices in scale and purpose. The Wolf Creek Dam, when completed in 1952 on the river's main stem, created a 101-mile-long reservoir in south central Kentucky for flood control and hydroelectric power

PROFILE OF TOMBIGBEE RIVER AND WATERWAY NAVIGATION POOLS



Note: Sites of locks and dams are shown by a name or number.

generation. The 242-foot-high, 5,730-foot-long structure is one of the largest dams in the eastern United States.[15]

Wolf Creek and several other projects ended commercial traffic on the upper reaches of the river, but the post-World War II expansion of waterborne commerce gave an impetus to projects that included navigation features. In 1946 Congress authorized a 9-foot channel on the Lower Cumberland, which was to be obtained by three dams of moderate heights. In addition, the same Rivers and Harbors Act authorized three dams on the Upper Cumberland between Nashville and the Wolf Creek project.

By 1954 moderate-height navigation power dams were in operation at Old Hickory and Cheatam, respectively above and below Nashville, with two additional structures planned for each section of the river. Attention, however, focused on a proposal for a high dam on the Lower Cumberland that had drawn fire from private power interests and citizens who opposed the inundation of farms and villages by the reservoir. Congress nevertheless approved the huge Barkley project in 1954, which is the keystone of navigation on the river.

Located about 25 miles east of Paducah, Kentucky, the multiple-purpose earthfill structure (completed in 1966) is the most important unit in a comprehensive basin system that provides a 9-foot channel from the river's mouth to Celina, Tennessee, 385 miles upriver. The dam includes a 110-by-800-foot lock chamber that has a normal lift of 57 feet. Lake Barkley, the 118-mile-long reservoir formed by the dam, is linked by a 1.7-mile-long canal to Kentucky Lake on the Tennessee River. The canal was cut through the "Land Between the Rivers" to provide alternative and shorter routes between the Cumberland, Tennessee, and Ohio rivers. The canal also offers integrated operation of the two reservoirs thus affording better use of the Barkley powerplant.

THE MONONGAHELA AND OTHER TRIBUTARIES

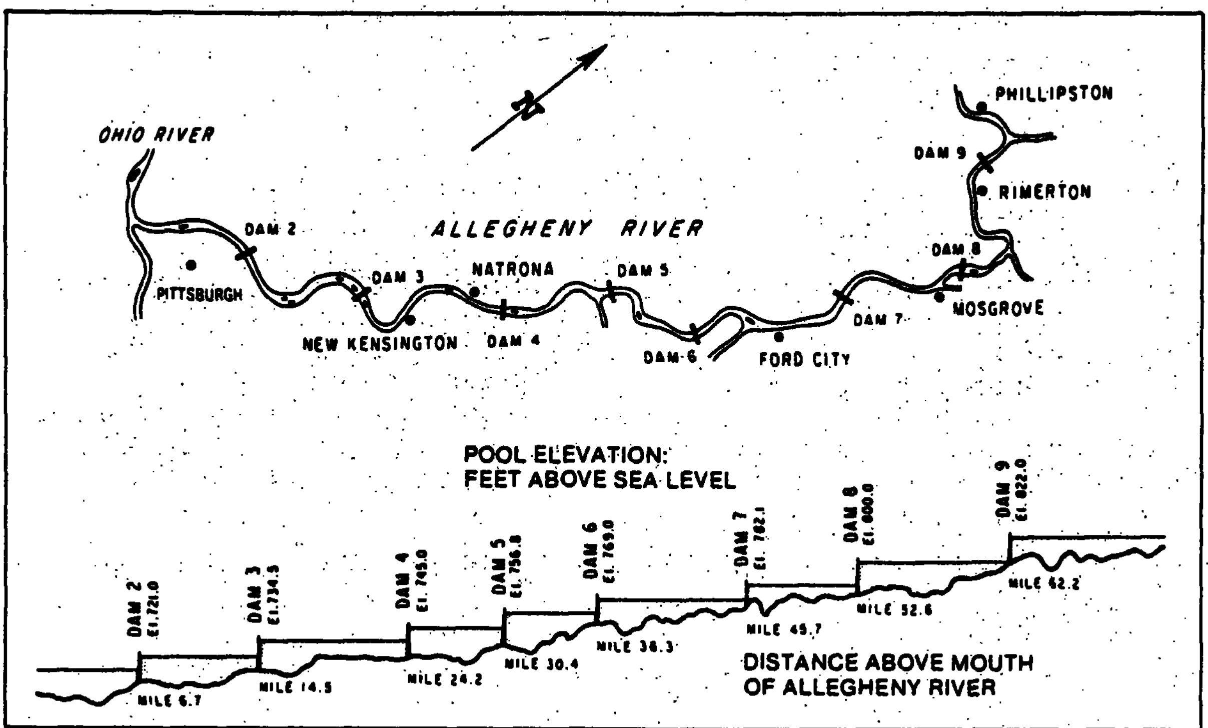
Throughout the late nineteenth and early twentieth centuries, the Monongahela carried more tonnage than any other inland waterway. The relatively short 129-mile-long stream was called the "Little Giant" because of the large quantities of coal transported downstream to Pittsburgh and beyond. In 1916 when coal tows ceased to most ports below Pittsburgh, commerce on the Monongahela in fact increased as coal was moved to fuel new steel mills on the Upper Ohio. At this point, iron ore was brought via rail from Lake Erie ports, limestone via rail and river from western Pennsylvania and eastern Ohio, and coal via river from the Monongahela and Allegheny valleys to produce millions of tons of iron and steel.[16]

After protracted litigation from 1883 to 1897, the federal government acquired the system built by the Monongahela Navigation Company, eliminating tolls and opening the river to free commerce. The Corps of Engineers built six small steamboat locks and dams on the upper reach of the river from 1895 to 1904, bringing the total on the river to fifteen. However, these projects provided only a 7-foot navigable depth, inadequate for the 9-foot draft of fully loaded barge tows. Improvements primarily consisted of rebuilding or strengthening dams and enlarging locks. The costs of these repair and maintenance activities were very high. In addition to structural renovations, changes in the system prior to World War II included relocating locks and dams Nos. 7 and 8 to eliminate No. 9 in 1926, rebuilding No. 4 in 1932, and the elimination of No. 1 near Pittsburgh (caused by increasing the height of Emsworth Dam on the Ohio). Thus, for the first half of the twentieth century the Monongahela slackwater system was largely a patched-up relic trying to meet modern navigation needs.

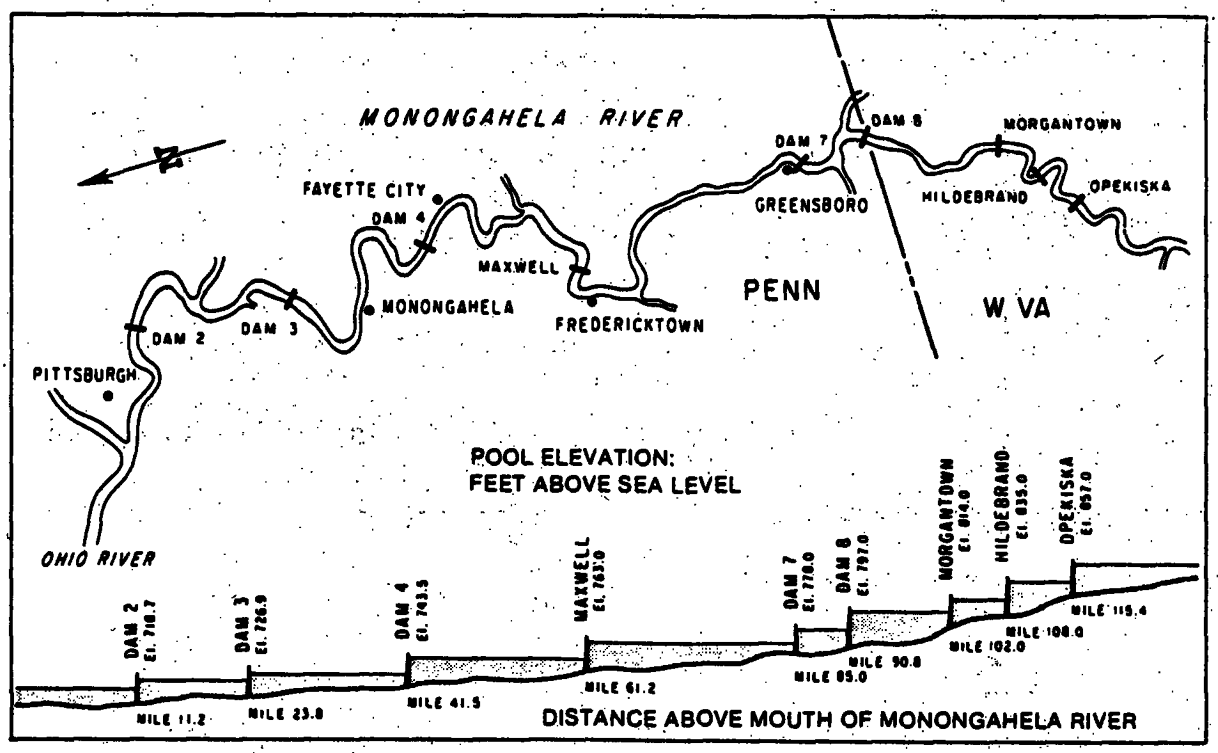
Due to the growth of traffic and the limited capabilities of the old locks and dams, the Corps launched a modernization program in 1948 that initially called for three new high-lift dams at the Morgantown, Hildebrand, and Opekiska sites, and raising Dam No. 8 to obtain a 9-foot depth to Morgantown. All of these facilities, completed from 1950 to 1967, included 84-by-600-foot locks that could pass a standard six-barge tow. Their design generally followed the principles developed for the modern structures on the Ohio River. Progress on the Monongahela modernization project ceased in 1967 with half of the proposed project as yet unbuilt.

Commercial use of the Allegheny has not developed as expected. Its 5.1 million tons of traffic in 1979 was almost seven times less than that on the Monongahela. Its present system of nine locks and dams, built from 1920 to 1938, is largely used by pleasure craft. The original ten low-lift structures on the Kanawha River were replaced from 1931 to 1937 with four high-lift locks and dams: Winfield, Marmet, and London Locks and Dam on the Kanawha itself and Gallipolis Locks and Dam on the Ohio River below the Kanawha's mouth. The modern system provided a 9-foot navigable depth and was equipped with 56-by-360-foot lock chambers. Freight haulage on the improved Kentucky River has never been significant, but the creation of a 9-foot depth for 103 miles of the Green River has facilitated large shipments of coal from the valley. Thus, while commerce has grown markedly on the Tennessee and Cumberland rivers, many other tributaries have not participated significantly in the post-World War II waterway renaissance.[17]

PROFILE OF ALLEGHENY RIVER NAVIGATION POOLS

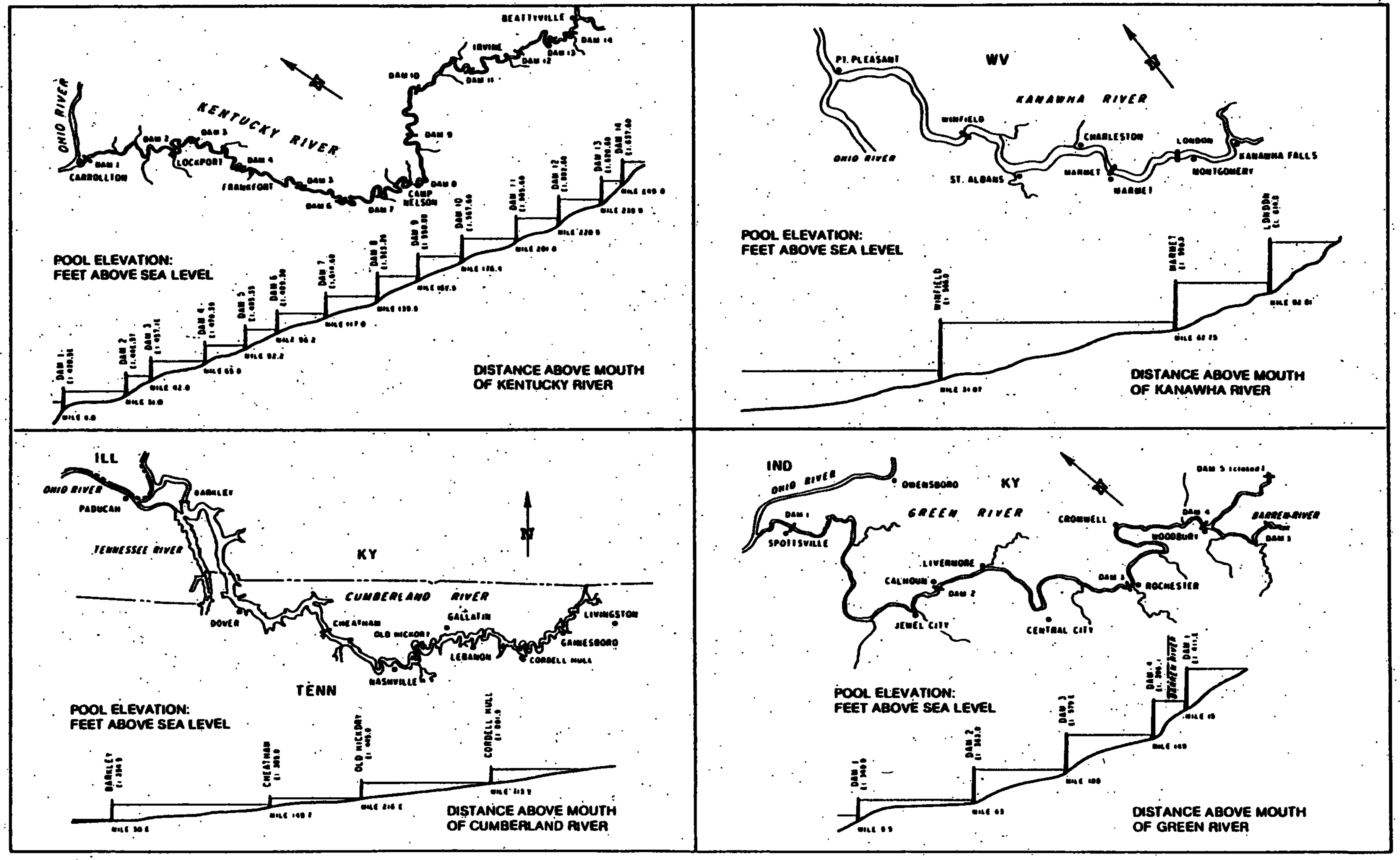


PROFILE OF MONONGAHELA RIVER NAVIGATION POOLS



Note: Sites of locks and dams are shown by a name or number.

PROFILES OF KENTUCKY, KANAWHA, CUMBERLAND AND GREEN RIVERS NAVIGATION POOLS



Note: Sites of locks and dams are shown by a name or number.

SUMMARY

In 1981 the Corps of Engineers maintained a 9-foot navigation channel depth on the Ohio River from Pittsburgh to the mouth (981 miles) and on some 1,300 miles of tributary streams. The major tributaries and their navigable distances are: Allegheny River, 72 miles; Monongahela River, 129 miles; Kanawha River, 91 miles; Green River, 103 miles; Tennessee River, 652 miles; and Cumberland River, 385 miles. The Kentucky River is navigable for 259 miles, but the depth is limited to 6 feet and the lock chambers are too small for the use of standard Ohio River barges. The lock and dam system on the Ohio River comprises twenty-one lock and dam structures as well as the Louisville and Portland Canal. (The canal has been markedly altered since it was first opened in 1830 to bypass the Falls of the Ohio.) Four of these facilities were built from 1921 to 1937--the Emsworth, Dashields, and Montgomery immediately downstream from Pittsburgh, as well as the Gallipolis Locks and Dam at River Mile 279. Two of the present dams, Nos. 52 and 53, were part of the original Ohio River Canalization Project. Fifteen of the navigation structures comprise the modernized portion of the Ohio River Waterway. The structures were put in operation from 1961 to 1981. They all contain 1,200- and 600-foot-long locks and were built to replace two or more of the original low-lift structures.[18]

The waterway revolution in the Ohio River Basin since World War II was largely grounded on the channel improvements made by the Corps of Engineers in response to growing traffic volumes and advances in marine technology. The reciprocity of riverine commerce and economic and industrial resurgence is unquestioned. Long tows of coal and other primary materials move efficiently and safely on the once capricious and hazardous streams. These resources are drawn upon to manufacture steel, chemicals, and other basic products, as well as consumer goods. Once the natural pathways of exploration and frontier trade, the major rivers of the Ohio Basin have been transformed to meet the requirements and expectations of twentieth-century commerce and industry.

CHRONOLOGY

1729 - French engineer Chaussegros de Lery makes a compass survey of the Ohio River.

1742 - John Peter Salley and three other Virginians navigate the Kanawha, Ohio, and Mississippi rivers to New Orleans.

1744 - The French construct Fort Duquesne at the forks of the Ohio River.

1754 - George Washington conducts topographical and military reconnaissance into the Allegheny, Monongahela, and Upper Ohio Valleys.

1763 - Treaty of Paris gives England legal possession of the Ohio Valley.

1766 - Thomas Hutchins prepares map of the Ohio River, the first detailed hydrographic study of the stream.

1775 - Continental Congress authorizes the appointment of a chief engineer and two assistants for the Continental Army.

1782 - Barthelemi Tardiveau begins trade between the Ohio Valley and New Orleans.

- Jacob Yoder makes the first flatboat trip down the Ohio and Mississippi to sell produce at New Orleans.

1788 - Colonel Rufus Putnam and a group of settlers found the town of Marietta, Ohio.

1802 - Thomas Jefferson signs the bill creating the modern Army Corps of Engineers.

1803 - The Louisiana Purchase gives the United States control of the port of New Orleans.

1807 - Robert Fulton builds the first successful steamboat in the United States.

1808 - Secretary of the Treasury Albert Gallatin makes his report to Congress recommending a system of transportation improvements.

1811 - The steamboat New Orleans becomes the first such vessel to navigate the Ohio River.

1815 - Captain Henry Miller Shreve pilots the steamboat Enterprize on the first upstream trip by a steamboat on the Ohio River.

1816 - Board of Fortifications concludes that waterway improvements are essential for national defense.

1819 - Major Stephen H. Long conducts military reconnaissance and scientific expedition in the steamboat Western Engineer.

- Joint state commission makes a study of the Ohio River and recommends the making of improvements.

1820 - Regular steamboat commerce begins between Pittsburgh and Louisville.

- Congress appropriates $5,000 for survey of navigation problems on the Ohio and Mississippi rivers.

1824 - On May 24 President James Monroe signs the Rivers and Harbors Act, which includes $75,000 for improvements on the Ohio and Mississippi rivers.

- On April 30 the General Survey Act authorizes the Army Engineers to undertake surveys for internal improvement projects.

- John Bruce awards the first contract for snag removal on the Ohio and Mississippi rivers.

1825 - Wing dam is completed near Henderson, Kentucky, the first navigation improvement built by the Corps of Engineers on the Ohio River.

1827 - Captain Henry M. Shreve begins snag clearing on the Ohio River after termination of John Bruce's contract.

- Rivers and Harbors Act recognizes that experienced engineers should direct inland river development.

- Improvement of the Grand Chain of Rocks at the mouth of the Ohio River is approved by Congress.

1828 - Army Engineers conduct survey of the Tennessee River.

1829 - *Heliopolis*, the first steam-powered snagboat, is launched at New Albany, Indiana.

1830 - First steamboat passes through the Louisville and Portland Canal, bypassing the dangerous Falls of the Ohio.

- Grand Chain of Rocks improvement project is completed near the mouth of the Ohio River.

1835 - Congress appropriates $50,000 for the improvement of the Upper Ohio.

1836 - Slackwater project undertaken by the state of Kentucky commences on the Kentucky River.

1837 - The private Monongahela Navigation Company is chartered to build locks and dams on the Monongahela River.

- Captain John Sanders begins surveys and improvements on the Upper Ohio.

- Panic of 1837 touches off severe national depression.

1838 - Improvement projects on the Ohio and Mississippi rivers are suspended.

1842 - The state of Ohio builds a lock and dam system on the Muskingum River.

1843 - Captain John Sanders puts the McCarthy scraper into service, the first crude dredge used on the Ohio River.

1847 - Flatboat traffic has a peak year on the Ohio and Mississippi rivers as 2,792 people arrive at New Orleans.

1849 - Charles Ellet, Jr., publishes his farsighted report advocating construction of reservoirs on tributaries to retain water that could be released during periods of low water.

1852 - Rivers and Harbors Act provides $150,000 for dike repair and construction on the Ohio River.

1857 - William Milnor Roberts advances slackwater and dam plan for the Ohio River.

- All navigation improvements on inland rivers are suspended.

1866 - Rivers and Harbors Act directs Chief of Engineers to review prewar projects and renew channel clearance on the Ohio and other rivers.

1870 - After lengthy hydrographic and topographic investigations, William Milnor Roberts recommends construction of a comprehensive lock and dam, slackwater project for the Ohio River.

1874 - Jurisdiction of the Lighthouse Board is extended to inland rivers and beacons, and buoys are put into service on the Ohio and other rivers.

- Windom Committee recommends authorization of the Ohio River Canalization Project.

1875 - Iron-hulled snagboat E.A. Woodruff is placed into service on the Ohio River.

1885 - Davis Island project is completed near Pittsburgh, the first lock and movable dam on the Ohio River.

1888 - Congress authorizes study of a 6-foot slackwater project for the Upper Ohio.

1890 - Muscle Shoals Canal is completed on the Tennessee River, the first permanent structure on the river.

1895 - Commercial interests in the Ohio Valley form the Ohio Valley Improvement Association.

1897 - After fifteen years of litigation, the federal government assumes ownership of the lock and dam system on the Monongahela River.

1902 - Board of Engineers for Rivers and Harbors is created to determine the feasibility of riverine projects.

1906 - The Lockwood Board recommends adoption of a 9-foot navigation project for the entire length of the Ohio River.

1907 - President Theodore Roosevelt creates the Inland Waterways Commission to study the nation's water resources.

1910 - Rivers and Harbors Act authorizes construction of a 9-foot slackwater project on the Ohio River to its mouth.

1913 - Hales Bar Dam is completed on the Tennessee River at Chattanooga.

1921 - Emsworth Locks and Dam is completed, the first fixed dam with double locks built on the Ohio River.

1927 - Corps of Engineers is authorized to undertake a broad evaluation of the nation's water resources--the "308 Reports."

- Wilson Dam, at that time the largest concrete dam in the world, is completed on the Tennessee River.

- Combined power dam and lock structure is completed on the Falls of the Ohio at Louisville.

1929 - The Ohio River Canalization Project is completed at a cost of $125 million.

1930 - Corps of Engineers completes "308" study for the Tennessee River that serves as the basis for the valley's development.

1931 - The diesel-powered Herbert Hoover, the prototype for modern towboats, is built.

1933 - Tennessee Valley Authority (TVA) is created by Congress.

1936 - Flood Control Act authorizes 270 flood control projects.

- Gallipolis Locks and Dam are completed on the Ohio River.

1938 - Flood Control Act authorizes dams for the Cumberland River.

1945 - Channel depth of 9 feet is obtained on the Tennessee River.

1946 - Congress authorizes a 9-foot navigation project for the Lower Cumberland River.

- Tennessee-Tombigbee project is authorized by Congress.

1948 - Modernization program that initially called for three high-lift dams is launched for the Monongahela River.

1952 - Wolf Creek Dam, the first storage dam built on the river's mainstream, is completed on the Cumberland River.

1954 - The Corps of Engineers begins Ohio River Modernization Project, consisting of nineteen high-lift locks and dams.

1959 - New navigation lock is added to Wilson Dam on the Tennessee River.

1964 - William H. McAlpine Locks and Dam are completed on the Ohio River at Louisville.

1966 - The Barkley project, key water storage structure on the Lower Cumberland River, is completed.

1972 - Construction begins on the Tennessee-Tombigbee waterway.

1980 - Smithland Locks and Damsare completed on the Ohio River to replace Nos. 50 and 51.

FOOTNOTES

The navigation history of the four Army Corps of Engineers Districts that cover the Ohio River Basin has been studied by Dr. Leland R. Johnson. His four definitive and comprehensive volumes were heavily relied on to prepare this shorter survey of waterways development in the region: Men, Mountains and Rivers: An Illustrated History of the Huntington District, U.S. Army Corps of Engineers, 1754-1974 (Washington, D.C., 1977); The Falls City Engineers: A History of the Louisville District, Corps of Engineers, United States Army (Louisville, 1975); Engineers on the Twin Rivers: A History of the Nashville District, Corps of Engineers, United States Army (Nashville, 1978); and The Headwaters District: A History of the Pittsburgh District, U.S. Army Corps of Engineers (Pittsburgh, 1979). Abbreviated forms of Dr. Johnson's books are hereafter cited.

CHAPTER 1

1. Ellis L. Armstrong, Michael C. Robinson, Suellen M. Hoy, eds., History of Public Works in the United States, 1776-1976 (Chicago: American Public Works Association, 1976), 37; Johnson, Falls City Engineers, 1.

2. Charles H. Ambler, A History of Transportation in the Ohio Valley (Glendale, Calif.: Arthur H. Clark Company, 1932), 1-29.

3. Johnson, Falls City Engineers, 8-9.

4. Ibid., 11-15; Anna Margaret Quattrocchi, "Thomas Hutchins, 1730-1789" (unpublished doctoral dissertation, University of Pittsburgh, 1944), passim.

5. Johnson, Falls City Engineers, 15-16.

6. Quoted in Johnson, Headwaters District, 21.

7. Dale Van Every, Ark of Empire: The American Frontier, 1784-1803 (New York: William Morrow, 1963), 35-36.

8. Johnson, Falls City Engineers, 24-25; W. Wallace Carson, "Transportation and Traffic on the Ohio and Mississippi before the Steamboat," Mississippi Valley Historical Review, 7 (June 1920), 33-35.

9. Johnson, Falls City Engineers, 25-26; Thomas D. Clark, The Kentucky (New York: Harpers, 1942), 55-64; Ambler, Transportation in the Ohio Valley, 71-73.

10. Leland D. Baldwin, "Shipbuilding on the Western Waters, 1793-1817," Mississippi Valley Historical Review, 20 (June 1933), 29-34; Johnson, Falls City Engineers, 26-27; Johnson, Headwaters District, 31-35.

11. Leland D. Baldwin, The Keelboat Age on Western Waters (Pittsburgh: University of Pittsburgh Press, 1941), 1-45.

12. Quoted in ibid., 44-45.

13. Johnson, Falls City Engineers, 29.

14. Louis C. Hunter, Steamboats on the Western Rivers: An Economic and Technological History (Cambridge: Harvard University Press, 1949), 1-62.

15. Johnson, Falls City Engineers, 31-32.

16. Richard G. Wood, Stephen Harriman Long, 1784-1864: Army Engineer, Explorer, Inventor (Glendale, Calif., 1966), 59-84.

17. Richard C. Wade, The Urban Frontier: The Rise of Western Cities, 1790-1930 (Cambridge, Mass.: Harvard University Press, 1959), 190-91.

18. Ibid., 191.

19. Ibid.

20. Ibid., 86-87, 286-87; Hunter, Steamboats on the Western Rivers, 352-53, 619-20.

21. Ibid.

22. Johnson, Falls City Engineers, 21; William L. Sibert, "The Improvement of the Ohio River," Transactions of the American Society of Civil Engineers, 63 (June 1909), 391-92.

23. Johnson, Falls City Engineers, 22.

CHAPTER 2

1. Johnson, Falls City Engineers, 39.

2. Ibid., 40.

3. Ibid., 41-42.

4. Ibid.

5. Johnson, Men, Mountains and Rivers, 25.

6. Wood, Stephen H. Long, 145-46.

7. Quoted in Johnson, Falls City Engineers, 48.

8. Hunter, Steamboats on the Western Rivers, 198-203.

9. Johnson, Falls City Engineers, 50-55.

10. Ibid., 74-75.

11. Hunter, Steamboats on the Western Rivers, 198-203.

12. Ibid., 196-99.

13. Johnson, Falls City Engineers, 75-76.

14. Hunter, Steamboats on the Western Rivers, 201-03.

15. Johnson, Headwaters District, 83-86.

16. Johnson, Falls City Engineers, 88-98.

17. Ibid., 101.

18. Hunter, Steamboats on the Western Rivers, 206-07; Johnson, Falls City Engineers, 137-54; Johnson, Headwaters District, 38-54; Johnson, Men, Mountains and Rivers, 51-63.

19. Johnson, Headwaters District, 91-101.

20. Johnson, Falls City Engineers, 57-73.

21. Johnson, Twin Rivers, 46-60.

22. Hunter, Steamboats on the Western Rivers, 208-09.

CHAPTER 3

1. Ambler, Transportation in the Ohio Valley, 295-303; Hunter, Steamboats on the Western Rivers, 569-70; Johnson, Falls City Engineers, 118-20. "Bushels" were commonly used to measure coal.

2. Johnson, Men, Mountains and Rivers, 72-75.

3. Ibid.

4. Hunter, Steamboats on the Western Rivers, 115-16.

5. Johnson, Men, Mountains and Rivers, 77.

6. Johnson, Falls City Engineers, 160-62.

7. Johnson, Headwaters District, 135.

8. Ibid., 136-40; Johnson, Falls City Engineers, 165-68.

9. Johnson, Falls City Engineers, 165.

10. William L. Sibert, "The Improvement of the Ohio River," Transactions of the American Society of Civil Engineers, 63 (1909), 405-10.

11. Johnson, Falls City Engineers, 168-70; Edmund L. Daley, "The Mastery of the Ohio River," Military Engineer, 29 (May, June 1927), 189-95.

12. Johnson, Falls City Engineers, 170-72.

13. Hunter, Steamboats on the Western Rivers, 585-605; Ambler, Transportation in the Ohio Valley, 316; Johnson, Falls City Engineers 178-80.

14. Charles W. Kutz, "Ohio River Canalization--Its History and Possibilities," Engineering News-Record, 104 (March 13, 1930), 436.

15. *Ibid.*, 437.

16. Quoted in Johnson, *Falls City Engineers*, 187.

17. Kutz, "Ohio River Canalization," *passim*.

18. Johnson, *Headwaters District*, 166-67.

19. Wilmon Henry Droze, *High Dams and Slack Waters: TVA Rebuilds a River* (Baton Rouge: Louisiana State University Press, 1965), 3-18; Johnson, *Twin Rivers*, 101-42, 163-80.

20. Quoted in Droze, *High Dams and Slack Waters*, 17. For a discussion of Cumberland River canalization see Johnson, *Twin Rivers*, 143-61.

21. Johnson, *Falls City Engineers*, 137-54; Johnson, *Headwaters District*, 118-31; Johnson, *Men, Mountains and Rivers*, 99-120; Johnson, *Twin Rivers*, 101-22.

22. Johnson, *Men, Mountains and Rivers*, 97-102.

23. Johnson, *Falls City Engineers*, 144-47.

CHAPTER 4

1. Paul Mason, "The Ohio River--Path of Empire," *Waterways Journal*, 11 (June 1950), 54-56.

2. *Ibid.*, 55-56.

3. "Rededication 2--Silver Anniversary Marks Quarter Century of Economic Growth," *Waterways Magazine*, 19 (October 1954), 17-19.

4. *Ibid.*, 19-20; Armstrong et al., *History of Public Works*, 48-49.

5. Johnson, *Falls City Engineers*, 232-33.

6. James A. Neill, "Modern Facilities for Ohio River Navigation," *Journal of the Waterways and Harbors Division*, American Society of Civil Engineers, 83 (May 1957), paper No. 1239.

7. U.S. Army, Corps of Engineers, Ohio River Navigation (Cincinnati: Ohio River Division, 1979), 36-39; Johnson, Falls City Engineers, 233-35.

8. Charles F. Michiels, William F. Lail, and Robert E. Mytinger, "Current Trends in Ohio River Traffic and Equipment," Journal of the Waterways and Harbors Division, American Society of Civil Engineers, (December 1956), paper No. 1123.

9. Ibid.

10. Johnson, Falls City Engineers, 199-203.

11. Maurice Henle, "Navigation on the Tennessee River," Waterways Magazine, 11 (June 1950), 79.

12. Droze, High Dams and Slack Waters, 42-66; Johnson, Twin Rivers, 181-83; C. T. Barker, "Developments in Tennessee River Navigation," Waterways Journal, 17 (August 1953), 31-34.

13. Armstrong, et al., History of Public Works, 42-43; Droze, High Dams and Slack Waters, 67-132; Tennessee Valley Authority, River Traffic and Industrial Growth (Knoxville: Tennessee Valley Authority, 1962), 1-21.

14. Johnson, Twin Rivers, 241-44, 253-54.

15. Johnson, Twin Rivers, 184-98, 215-31; Arthur W. Pence. "Development of the Cumberland River," Waterways Journal, 11 (June 1950), 71-78; Jesse L. Fishback, "Cumberland River Modernization," Military Engineer, 34 (July 1942), 331-36.

16. Johnson, Headwaters District, 234-42; H. E. Anderson and J. H. Dodds, "The Monongahela River: Indispensable Artery of National Defense," Military Engineer, 34 (July 1942), 331-36.

17. Johnson, Falls City Engineers, 237-46; Johnson, Men, Mountains and Rivers, 135-40, 201, 203.

18. U.S. Army, Corps of Engineers, Ohio River Navigation (Cincinnati: Ohio River Division, 1979), 51-53.

BIBLIOGRAPHY

BOOKS

Ambler, Charles H. A History of Transportation in the Ohio Valley. Glendale, Calif.: Arthur H. Clark Company, 1932.

American Waterways Operators, Inc. A Study in Economic Growth: Waterside Plant Locations and Expansions since 1952. 2d. ed. Washington, D.C.: American Waterways Operators, Inc., 1962.

Armco Steel Corporation. River Shipping and Industry: A Compilation of Historical and River Shipping Data on the Ohio River and Its Tributaries. Middletown, Ohio: American Rolling Mill Company, 1923.

Arnow, Harriette Louisa. Flowering of the Cumberland. New York: Macmillan, 1963.

Baldwin, Leland Dewitt. The Keelboat Age on Western Waters. Pittsburgh: University of Pittsburgh Press, 1941.

Banta, Richard Elwell. The Ohio. New York: Rinehart, 1949.

Blood, Dwight M. Inland Waterway Transport Policy in the U.S. Laramie, Wyo.: Wyoming University, 1972.

Bramlett, Gene A. Economic Development in the Ohio River Region. Lexington, Ky.: Spindletop Research, 1964.

Chorpening, C.H. Development of Waterways in the United States. n. p., 1952.

Clowes, Ernest Seabury. Shipways to the Sea: Our Inland and Coastal Waterways. Baltimore: Williams and Wilkins, 1929.

Collins, Francis Arnold. Our Harbors and Inland Waterways. New York: The Century Company, 1924.

Daggett, Stuart. Principles of Inland Transportation. 4th ed. New York: Harper, 1955.

Davidson, Donald. The Tennessee. Knoxville: University of Tennessee Press, 1978. (Reprint of the 1946 ed.)

Douglas, Byrd. Steamboatin' on the Cumberland. Nashville: Tennessee Book Company, 1961.

Droze, Wilmon Henry. High Dams and Slack Waters: TVA Rebuilds a River. Baton Rouge, La.: Louisiana State University Press, 1965.

Fernow, Berthold. The Ohio Valley in Colonial Days. New York: B. Franklin, 1971.

Folmsbee, Stanley J. Sectionalism and Internal Improvements in Tennessee, 1796-1845. Philadelphia: University of Pennsylvania, 1939.

Fowke, Gerard. The Evolution of the Ohio River. Indianapolis: Hollenbeck Press, 1933.

Haites, Erik F. Western River Transportation. Baltimore: The Johns Hopkins University Press, 1975.

Havinghurst, Walter. River to the West. New York: Putnam, 1970.

Havinghurst, Walter. Voices on the River: The Story of the Mississippi Waterways. New York: Macmillan, 1964.

Hulbert, Archer Butler. The Ohio River: A Course of Empire. New York and London: G.P. Putnams Sons, 1906.

Hull, William J. The Origin and Development of the Waterways Policy of the United States. Washington, D.C.: National Waterways Conference, 1967.

Hunter, Louis C. Steamboats on the Western Rivers: An Economic and Technological History. Cambridge, Mass.: Harvard University Press, 1949.

Hunter, Louis C. Studies in the Economic History of the Ohio Valley. New York: Da Capo Press, 1973.

Johnson, Leland R. Engineers on the Twin Rivers: A History of the Nashville District, Corps of Engineers, United States Army. Nashville: Corps of Engineers, 1978.

Johnson, Leland R. The Falls City Engineers: A History of the Louisville District, Corps of Engineers, United States Army. Louisville, Corps of Engineers, 1975.

Johnson, Leland R. The Headwaters District: A History of the Pittsburgh District, U.S. Army Corps of Engineers. Pittsburgh: Corps of Engineers, 1979.

Johnson, Leland R. Men, Mountains and Rivers: An Illustrated History of the Huntington District, U.S. Army Corps of Engineers, 1754-1974. Washington, D.C.: Corps of Engineers, 1977.

Klein, Benjamin Franklin, ed. Ohio River Handbook. Cincinnati: Young and Klein, 1949.

Mayer, Albert J. Follow the River. Garden City, N.Y.: Doubleday, 1969.

McCague, James. The Cumberland. New York: Holt, Rinehart and Winston, 1973.

McCague, James. Flatboat Days on Frontier Rivers. Champaign, Ill.: Garrard Publishing Company, 1968.

National Research Council. Transportation Research Board. Inland Waterway Transportation. Washington, D.C.: Transportation Research Council, National Research Council, 1975.

Nolan, Jeanette Covert. Getting to Know the Ohio River. New York: Coward, McCann & Geoghegan, 1973.

Ogg, Frederic Austin. The Old Northwest. New Haven: Yale University Press, 1919.

Rosskam, Edwin. Towboat River. New York: Duell, Sloan and Pearce, 1948.

Teuton, Frank L. Steamboating on the Upper Tennessee. Washington, D.C.: Teuton, 1975.

U.S. Army. Corps of Engineers. Ohio River Division. Ohio River Navigation. Cincinnati, Ohio: U.S. Army Corps of Engineers, Ohio River Division, 1979.

U.S. Bureau of Foreign and Domestic Commerce. Inland Water Transportation in the United States. Washington, D.C.: GPO, 1923. (Miscellaneous Series No. 119.)

U.S. National Resources Planning Board. Transporation and National Policy. Washington, D.C.: GPO, 1942.

U.S. Office of Federal Coordinator of Transportation. Section of Research. Public Aids to Transportation. 3 vols. Washington, D.C.: GPO, 1939.

U.S. Tennessee Valley Authority. A History of Navigation on the Tennessee River System: An Interpretation of the Economic Influence of this River System on the Tennessee Valley. Washington, D.C.: GPO, 1937.

U.S. Tennessee Valley Authority. Major Freight Terminals on the Tennessee River Waterway. Knoxville, Tenn.: Tennessee Valley Authority, Division of Navigation Development, Navigation Engineering Branch, 1963.

Van Every, Dale. Ark of Empire: The American Frontier, 1784-1803. New York: William Morrow and Company, 1963.

Wade, Richard C. The Urban Frontier. Cambridge: Harvard University Press, 1959.

Wattenberg, Ben. Busy Waterways: The Story of America's Inland Water Transportation. New York: John Day, 1964.

ARTICLES

Albig, W. Espy. "Early Development of Transportation on the Monongahela River." Western Pennsylvania Magazine, 2 (April 1919), 115-24.

Altstaetter, H. E., and J. H. Dodds. "The Monongahela River: Indispensable Artery of National Defense." Military Engineer, 34 (July 1942), 331-36.

Baldwin, Leland D. "The Rivers in the Early Development of Western Pennsylvania." Western Pennsylvania Historical Magazine, 16 (May 1933), 79-98.

Baldwin, Leland D. "Shipbuilding on the Western Waters, 1793-1817." Mississippi Valley Historical Review, 20 (June 1933), 29-34.

Bell, J. Franklin. "The Emsworth and Davis Island Dams." Military Engineer, 60 (Sept. 1923), 405-08.

Bond, P. S. "The Permanent Improvement of the Ohio River." Engineering Record, 59 (Jan. 23, 1909), 97-99.

Bowden, Nicholls W. "Improving Tennessee River above Chattanooga, Tennessee, by Regulation or Open-Channel Methods." Professional Memoirs, 6 (Nov.-Dec. 1914), 663-91.

Bruce, James W., Dwight W. Keller, and James A. Neill. "Modern Facilities for Ohio River Navigation." Journal of the Waterways and Harbors Division, American Society of Civil Engineers, 83 (May 1957), paper No. 1239.

Brunot, Felix R. "Improvement of the Ohio River." Journal of the Franklin Institute, 97 (May 1874), 315-17, 327.

Carlson, W. Wallace. "Transportation and Traffic on the Ohio and Mississippi before the Steamboat." Mississippi Valley Historical Review, 7 (June 1920), 26-38.

Casey, Hugh J. "Deadman Island Lock and Dam, Ohio River." Military Engineer, 21 (Sept.-Oct. 1929), 444-51.

Daley, Edmund L. "The Mastery of the Ohio River." Military Engineer, 19 (May-June 1927), 188-93.

Dorland, Gilbert M., and George R. Bethurum. "Growth of Commerce: Tennessee and Cumberland Rivers." Journal of the Waterways and Harbors Division: Proceedings of the American Society of Civil Engineers, 82 (Sept. 1956), 1-17.

Downes, Randolph C. "Problems of Trade in Early Western Pennsylvania." Western Pennsylvania Historical Magazine, 12 (Oct. 1930), 261-71.

Fishback, Jesse L. "Cumberland River Modernization." Military Engineer, 59 (May-June 1967), 183-85.

Fishback, Jesse L. "Keystone on the Cumberland." Military Engineer, 59 (Sept.-Oct. 1967), 338-41.

Fowler, Ila Earle. "The Tradewater River Country in Western Kentucky." Register of Kentucky Historical Society, 82 (Oct. 1934), 277-300.

Galpin, W.F. "The Grain Trade of New Orleans, 1804-1814." Mississippi Valley Historical Review, 14 (March 1928), 496-507.

Gaum, Carl H. "History and Future of Ohio River Navigation." Journal of the Waterways and Harbors Division: Proceedings of the American Society of Civil Engineers, 96 (May 1970), 483-97.

Gronert, Theodore G. "Trade in the Blue-Grass Region, 1810-1820." Mississippi Valley Historical Review, 5 (Dec. 1918), 317-23.

Hall, C. L. "Economics of the Ohio River Improvement." Transactions of American Society of Civil Engineers, 103 (1938), 1527-78.

Harts, William W. "Cumberland River Canalization." Engineering Record, 61 (April 16, 1910), 512-14.

Hopkins, Arthur E. "Steamboats at Louisville and on the Ohio and Mississippi Rivers." Filson Club History Quarterly, 17 (July 1943), 143-62.

Hulbert, Archer Butler. "The Ohio River." Ohio Archeological and Historical Quarterly, 20 (1911), 220-35.

Jansen, Carl B. "Century of Progress Marks Many Improvements in Construction of Locks and Dams." Civil Engineering, 18 (October 1948), 628-33, 672.

Johnson, Leland R. "Army Engineers on the Cumberland and Tennessee, 1824-1854." Tennessee Historical Quarterly, 31 (Summer 1972), 149-69.

Johnson, Leland R. "19th Century Engineering: The Muscle Shoals Canal." Military Engineer, 63 (July-Aug. 1971), 260-65.

Kutz, Charles W. "Ohio River Canalization--Its History and Possibilities." Engineering News-Record, 104 (March 13, 1930), 433-37.

Lane, John W. "Lifeline to Mid-America." Water Spectrum (Summer 1969), 15-18.

Loveland, P.W. and T.P. Bailey. "Navigation on the Ohio River." Military Engineer, 41 (May-June 1949), 171-75.

Nichols, Roger L. "Army Contributions to River Transportation, 1818-1824." Military Affairs, 33 (April 1969), 242-49.

Sprague, Stuart Seely. "The Canal and the Falls of the Ohio and Three Cornered Rivalry." Register of the Kentucky Historical Society, 72 (Jan. 1974), 38-54.

Stickle, Horton W. "Monongahela River Navigation." Professional Memoirs, Corps of Engineers, 10 (Nov. 1919), 695-713.

Trescott, Paul B. "The Louisville and Portland Canal Company, 1825-1874." Mississippi Valley Historical Review, 44 (March 1958), 686-708.

Vance, John E. "The Improvement of the Ohio River." Annals of the American Academy of Political and Social Science, 31 (Jan. 1908), 139-45.

Wiley, Richard T. "Ship and Brig Building on the Ohio and Its Tributaries." Ohio Archeological and Historical Publications, 22 (1913), 54-64.

Willoughby, William R. "Early American Interest in Water Connections Between the East and the West." Indiana Magazine of History, 52 (Dec. 1956), 319-42.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1983-399-071

January 1983

Navigation History NWS-83-5