Management of Mississippi and Ohio River Landscapes

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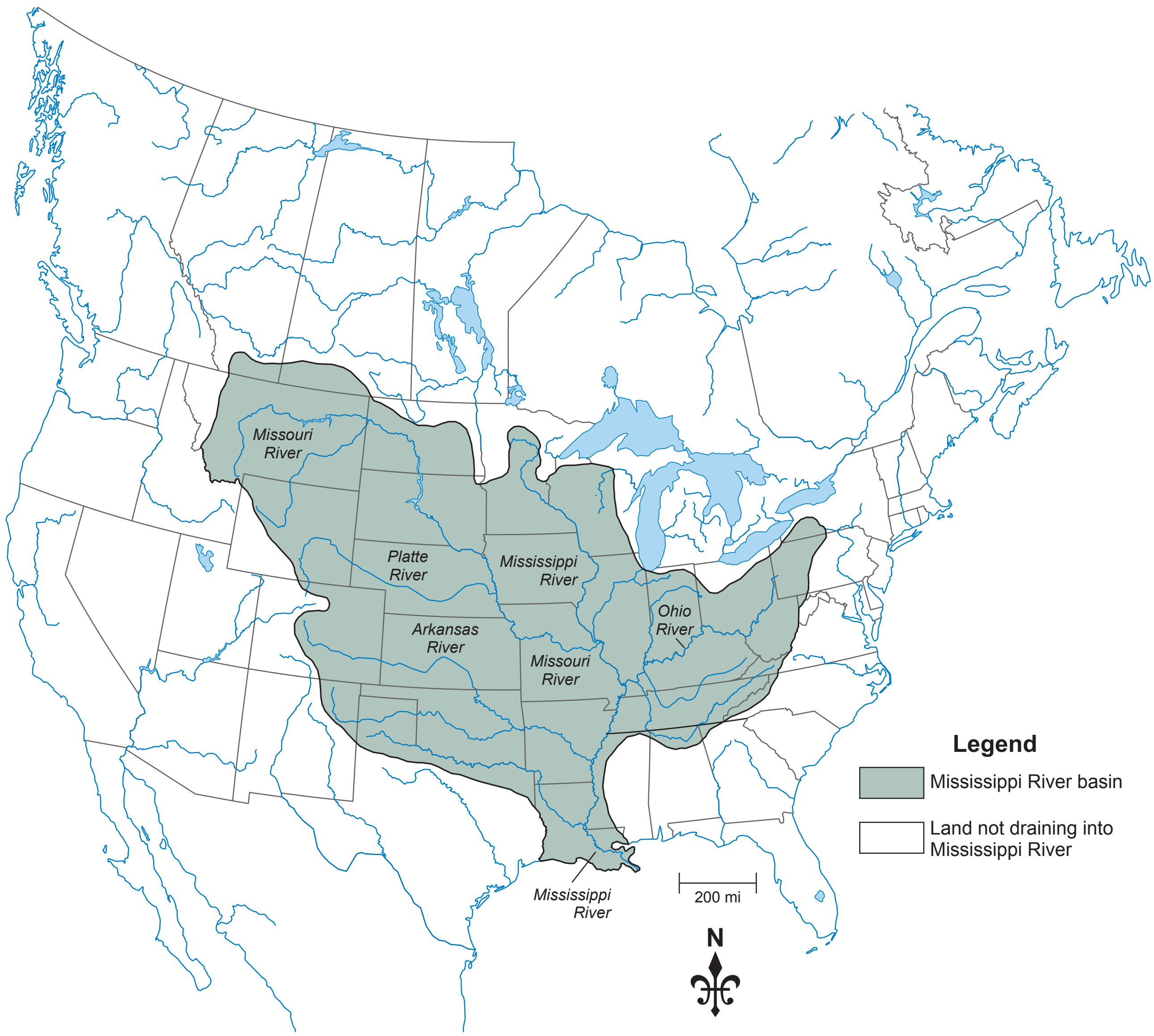
Two powerful rivers, the Ohio and Mississippi, and their tributaries drain more than 41% of the interior continental United States of America (map 1.1). Their shifting paths have shaped and reshaped the landscapes through which they flow and the confluence (map 1.2) where their sediment-laden waters comingle on the voyage to the Gulf of Mexico. Changing climates and extreme weather events over the millennia have carved new channels through river bottomlands, leaving rock-exposed uplands and fertile valleys behind while altering the location where the Ohio and Mississippi rivers meet. These great rivers often became state boundaries, and their historic realignments have added and subtracted land from many states that border them. For much of their history, the lands adjacent to these rivers were low-lying bottomlands that, unconstrained by human structures, flooded with the seasons.

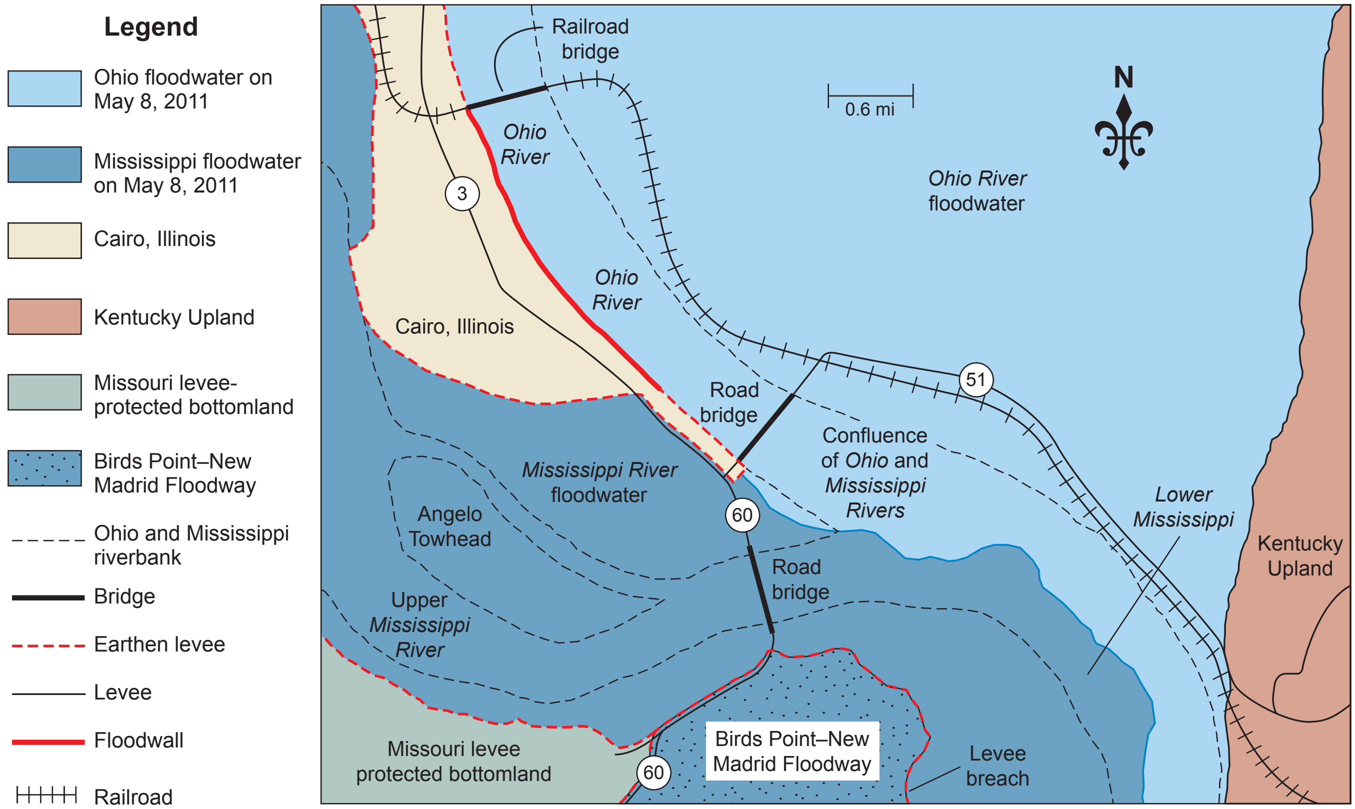
However, in the last century these rivers—highways of trade, settlement, and adventure—have become agricultural economic engines as humans reengineered the rivers and their bottomlands. Locks and dams, levees and floodwalls, aqueducts, and an extensive system of reservoirs have been constructed to manage these rivers for navigation and to protect communities, agriculture, and other high-value land uses. Alongside attempts to control the height and courses of these rivers and their tributaries, diversion ditches and systematic draining of interior swamps and wetlands have transformed hydric but fertile soils into highly productive, intensely managed agricultural lands. Paradoxically, these infrastructure investments, intended to facilitate navigation and reduce direct risks of flooding, have led to unexpected consequences to the larger ecosystem. Recent levee breaching has created unanticipated shocks to the river ecosystem while generating new knowledge about hydrology, soils, and the vegetation of rivers and their bottomlands. The occasional failure of well-engineered structures reminds us that the river landscape is a complex human-natural system. This complex system is dynamic, ever changing, and often managed based on assumptions of steady state—expectations that the past predicts the future. These assumptions do not well prepare communities to deal with diverse and often competing societal goals under an increasingly variable climate, increasing populations, and intensified land uses [1, 2].



MAP 1.1 The location of the Mississippi and Ohio river basins, which occupy 41% of the continental United States.

The Great Flood of 2011 and drought of 2012 [3] well illustrate some of the vulnerabilities and unintended consequences that arise from designing and managing river systems without taking into account their changing nature and the need for more flexible-adaptive capacities [1, 4, 5]. Following the Great Flood of 1927, it became apparent that the extensive use of levees, channelization, and confinement of the rivers was inadequate to effectively contain these great rivers [6]. The subsequent addition of reservoirs upstream of the confluence of the Ohio and Mississippi rivers at Cairo, Illinois, and four downstream floodways below Cairo was a substantive shift by the US Army Corps of Engineers (USACE) to strategically incorporate a dispersion risk management strategy with confinement engineering [6, 7]. The underlying premise of dispersion is to replicate the natural floodplain functions of bottomlands, which historically served as outlets to rivers under flood conditions.

The 2011 induced levee breaching of the Birds Point–New Madrid Floodway reaffirmed the effectiveness of dispersion management and its capacity to protect the integrity of communities and land uses along the larger river system. However, many homeowners and landowners were unprepared for the consequences of opening the floodway. With the reemergence of social tensions and competing social values for the uses of river bottomlands, public policy makers, community leaders, environmental advocates, and government agencies are challenged to reassess the impacts of leveed structures that in recent history have protected urban and rural agricultural land uses. Although most river flooding has repetitive patterns that reoccur seasonally and over periods of years presenting known risks, floods are complicated in their range of intensity



MAP 1.2 The confluence of the Mississippi and Ohio rivers during the flood of 2011. The sediment in the Mississippi has a much darker color reflecting the soil organic–rich sediment.

and duration and can result in unexpected consequences [8]. Levee breaching and other structural failures are often the result of unusually large runoff in a system cut off from its historical floodplain. Science is just beginning to understand the relationship between the river and its floodplain, the beneficial aspects of flooding, and the roles of wetlands and riparian corridors as well as the extensive social and economic damage floods wreak on the livelihoods of those along the river.

There is evidence that a new type of river management is needed, one that goes beyond the current confinement-dispersion strategy. Park et al. call for resilience management [1], an adaptive management approach to changing conditions that preserves the natural functions of the river ecosystem in ways that minimize catastrophic failure of engineered structures. This concept is just emerging, and there remain many practical details to work out. Some of these details involve better inventories and assessments of the soil resource immediately after levee breaches and subsequent flood events. Updated soil surveys and land scouring and deposition surveys can be used to create a better understanding of the ecosystem services the floodplain provides and guide restoration decisions when engaging and informing the public so as to come to politically acceptable agreement on management and land use decisions.

Early Attempts to Manage the Mississippi and Ohio River Landscapes

The first recorded attempt to manage the Mississippi and Ohio river landscapes occurred in 1717. New Orleans, a deep water port, was established by the French on the Mississippi River about 50 miles from the current Gulf of Mexico. The original settlement was 14 city blocks with drainage ditches around each block; these ditches were the first recorded attempt to manage the landscape. The first levee along the banks of the Mississippi River was allegedly erected in 1718, but this date has not been confirmed. Documented levees were built in 1722 by the French. The levees constructed in 1722 were four-foot-high earthen levees, which began a 300-year struggle to combat high water with embankments. The levees were privately maintained by area landowners, who used slaves, state prisoners, and poverty-stricken Irish immigrants to perform the deadly work. Situated on land with poorly drained soils and unfavorable topography, the New Orleans settlement was prone to periodic flooding by the Mississippi River. The city was a few feet above the sea on the deltaic floodplain of the Mississippi River, which was settling at a rate of between 2 and 10 feet per century.

Early US attempts to manage Mississippi and Ohio rivers can be tracked back to June 16, 1775, or shortly before the United States was established. The Continental Congress organized General George Washington's army with a chief engineer, Colonel Richard Gridley. The USACE, as it is known today, was established by President Thomas Jefferson in 1779. In 1803, the United States acquired New Orleans and 828,000 square miles mostly located in the Mississippi River valley from the French. The land transfer became known as the Louisiana Purchase (map 1.3) at the cost of $15 million. By 1811, steamboats started to arrive in New Orleans. When Lewis and Clark headed down the Ohio River in 1803, the water depth was very low. It was a dry year, and navigation was a challenge since locks and dams had not yet been built. The major navigation problem that delayed steamboat travel on the Ohio River was the Falls of the Ohio River near Louisville, Kentucky. Steamboats could only travel over the falls during times of flooding or high water. Consequently the steamboats dropped passengers and freight off at one end of the falls for overland transport to the opposite end of the falls, where they were picked up by another steamboat.

MAP 1.3 United States and Canadian lands were part of the 1803 Louisiana Purchase from the French.

The General Survey Act of 1824 authorized the use of army engineers to survey roads and canal routes. In 1824 Congress also passed a river improvement act to promote navigation on the Ohio and Mississippi rivers and to remove sandbars on the Ohio and sawyers (fallen trees stuck on the bottom of a river) and snags on the Mississippi River. The act, often called the first rivers and harbors legislation, combined authorizations for both surveys and projects. In 1825, construction began on a canal to bypass the Falls of the Ohio, and by 1830 the privately financed Louisville and Portland Canal was completed. The canal was constructed by hand tools and animal-drawn scrappers and carts. When completed, the two-mile-long canal had three locking chambers with a total lift of 26 feet. Increasing steamboat trade on the Cumberland River by 1825 led Congress to survey the river and finance river improvements to transport eastern Kentucky coal, Tennessee produce, and lumber throughout the region.

In 1859, a levee breach near New Orleans flooded a hundred city blocks and displaced thousands of residents. In response, Congress passed the Swamp Act and sponsored the survey of the lower Mississippi River. The funds sparked a debate on how to best control the Mississippi River—more levees versus outlets and human-made outlets and spillways. In addition, the American Civil War between 1861 and 1865 damaged the levee system in New Orleans. After the war, the State Board of Levee Commissioners authorized the replacement of damaged sections of the levee system, but little work was completed by 1870.

In 1879, Congress created the Mississippi River Commission (MRC) to replace the State Board of Levee Commissioners. Still serving today, the MRC has a seven-member governing body. Three of the officers are from the USACE, including the chairman who is the final decision maker when it comes to opening the floodways. Another member is an admiral from the National Oceanic and Atmospheric Administration. The other three members are civilians, and at least two of the civilian members are civil engineers. Each member is appointed by the president of the United States. Senate confirmation of the selection is no longer necessary. The MRC is the lead federal agency responsible for addressing the improvement, maintenance, and control of the Mississippi River. The MRC and USACE sought to deepen the Mississippi River and make it more navigable and less likely to flood. In 1885, the USACE adopted a "levees-only" policy. For the next 40 years, the USACE extended the levee system, sealing many of the river's natural outlets, including the ones near New Madrid and Cape Girardeau, Missouri, along the way. By 1926, levees ran from Cairo, Illinois, to New Orleans.

Lock and dam construction on the Ohio, Cumberland, and Tennessee began in the late nineteenth century and continued into the twentieth century. In 1885, the first complete lock and dam project built by the USACE on the Ohio River was at Davis Island, a few miles south of Pittsburgh, Pennsylvania. The project proved its worth, and in 1910 Congress passed the Rivers and Harbors Act. The act authorized construction of a lock and dam system to provide a 9-foot channel for the entire length of the Ohio River. The "canalization" project was completed in 1929 and consisted of 51 movable dams with wooden wickets. The 600-by-110-foot lock chamber was used during low water to move boats up or down stream. During high water, the wickets were laid flat on the riverbed to allow vessels to use the main river channel and bypass the locks.

The Tennessee Valley Authority (TVA) was created in the 1930s as part of President Franklin D. Roosevelt's vision to address unemployment, rural poverty, and bring the country out of the Great Depression. The TVA, as authorized by Congress, is a unique public-private corporation with multiple missions, including hydroelectricity production, river navigation, flood control, malaria prevention, and land management (e.g., reforestation and erosion control). Built and managed by the TVA, the reservoirs and systems of locks and dams on the Tennessee and Cumberland rivers and their tributaries have continued to be social, cultural, and economic sources of prosperity for the region.

The Flood Control Act of 1936 made flood control management a federal policy and the USACE the major federal flood control agency. On December 1, 1941, the USACE mission was expanded to include civil works such as hydroelectric energy provision, recreation opportunity creation, natural disaster response, and environmental preservation and restoration. The USACE initiated the Ohio River Navigation Modernization Program in the 1950s. The new dams made of concrete and steel replaced the moveable wicket dams with permanent nonmovable structures. Each dam has two adjoining locks designed to accommodate 15 barges and a tow that can lock through in one maneuver. This has reduced locking-through time and the wait time for other vessels. In the 1940s, the TVA built the Kentucky Dam on the Tennessee River to better control the fast rise of the Ohio River during spring rains. The river has been dammed numerous times over the years, primarily by the TVA. The Barkley Dam, a 58,000-acre reservoir in Kentucky, was constructed by the USACE across the Cumberland River and completed in 1966. The lake is maintained at different levels throughout the year for flood control and navigation purposes.

The Mississippi and Ohio rivers have been managed since the 1800s by the USACE in partnerships with the MRC, TVA, and states with levee and drainage districts. Much of their efforts have been to reduce the effects of flooding on agricultural bottomlands and river cities and to create shipping channels that can function in droughts. Since the 1970s and into present time, the USACE river managers have invested substantively in infrastructure maintenance and replacement. The entire lock and dam system on the Ohio River will have been upgraded and replaced once the Olmsted Lock and Dam is completed in 2020 (see chapter 18). River siltation is an annual problem, and ongoing dredging is required to keep port city harbors open and assure navigation depths. A variable and changing climate continues to create natural and human catastrophes as evidenced by the 2011 record flood at the confluence of the Mississippi and Ohio rivers. This record flood, reaching 61.7 feet on the Cairo, Illinois, river gage (figure 1.2), was followed by a near-record drought in 2012 that reduced the Ohio River depth to 7.5 feet above the 9-foot-deep shipping channel, resulting in only 16.5 feet of water for deep drafting barges. Dredging to maintain the shipping channel on the upper Mississippi River near Thebes, Illinois, during the 2012 drought was extremely difficult because of the narrow, bedrock-lined navigation channel, a remnant of an ancient upland bridge [3]. In recent years the USACE has conducted extensive research on wetlands and river ecosystems to better understand the river-land relationship. They have restored, created, and enhanced tens of thousands of acres of wetlands yearly to increase floodplain storage capacities during high water and protect the biodiversity of the natural river ecosystem.

Managing Great River Landscapes for the Future

As we enter the twenty-first century, three major societal concerns have emerged: a changing climate; food insecurity; and homeland security associated with infrastructure, navigation, and water quality and supply. All three themes run throughout this book. Each chapter is a case study from which much can be learned to better plan for the future. These short documentaries focus on the Mississippi and Ohio rivers, how their confluence creates something far greater than the sum of their

FIGURE 1.1 The Birds Point levee breach created a crater lake that extended many feet through the levee.

FIGURE 1.2 The Cairo, Illinois, river gage on the Ohio River is used to determine river height and when it is necessary to open the Birds Point–New Madrid Floodway to relieve downstream river pressure.

flows, and the bottomlands that are sources of wealth and risk to those whose lives are intertwined with the rivers. They illustrate levee-protected agriculture and breach management when the river exceeds flood stage (figure 1.1); dredging in drought to assure a navigable channel; and locks, dams, aqueducts, and reservoirs engineered to tame the two great rivers and their tributaries for human uses. Collectively these chapters portray the multifunctional value of the rivers and human attempts to manage rivers and their bottomlands under intensified agricultural uses, changing settlement patterns, and shifting social values.

Each chapter presents historical geology and underlying soil and landscape features that frame the convergence of recent flood and drought events, the structures built to contain and manage the river system, and the resulting planned and unexpected consequences. The language of the river and its management represents a distinct culture with meanings that can inspire fear, confidence, and uncertainty: sand boils and sinkholes, river readings on the Cairo gage (figure 1.2), earthen levees, floodwalls, channel dredging, aqueducts (figure 1.3), swamp busting, diversions, levee districts, slurry trenches, relief wells, reservoirs, locks and dams, and floodways.

Maps, photographs, and diagrams are extensively used throughout the book and are central to understanding geography, time scales, and soil and water relationships. These visuals offer valuable illustrations and spatial orientations to the rivers and their surrounding landscapes and provide snapshots in time of historical and current geologic and geopolitical boundaries; levee boundaries; riparian corridors, swamps, and wetlands; and disappearing and emerging lands as the rivers change course.

The Human-Natural Systems of River Landscapes

Why recount the levee breaches of the recent past, the flooding impacts on agriculture and other land uses, and drought effects on navigation on the Mississippi and Ohio rivers? Despite attempts to control and manage the impacts of seasonal flooding and less predictable drought and extreme weather events, there is much unknown about coupled human-natural river systems [1]. Human history is the coevolution of learning how to govern ourselves, shape ecosystems, and learn from each other [9] to avert disaster and reduce hazards and vulnerability. Management of river landscapes under changing climates, population growth, global food insecurity, and threats to water scarcity and water quality will determine much of the future of civilization.

Although these case studies are intended to be accessible, engaging reading, there are a number of key themes for readers with an interest in learning a little river science and exploring the human-natural systems of river landscapes:

1. ***Change is the only constant over the millennia.*** Rivers and their landscapes are complex, dynamic, and ever changing.

FIGURE 1.3 One of two Sny River aqueducts transports floodwaters and sediment to settling basins.

2. ***There are many external drivers of change.*** Climate, population growth, settlement patterns, agriculture, industries, changing markets and economies, new technologies, and new scientific knowledge about water and soil and their interactions within river ecosystems exert pressure and present challenges and new opportunities.
3. ***Soil and water resources are essential assets but are highly vulnerable in modern-day river systems.*** Soil and water are the geologic legacies of the river landscape and represent the assets upon which past and current social, economic, and ecological well-being are built. How these resources are managed affects future opportunities and vulnerabilities.
4. ***Contested views make managing river landscapes difficult.*** People differ in their social values and what they consider the best functional uses of rivers and their floodplains. Managing river landscapes based on engineering and biogeophysical sciences alone will fail to reduce vulnerability and unforeseen risks. The diversity of social values, land use preferences, and human relationships with rivers and their floodplains must be better understood and made part of the management processes.
5. ***Resilience management can improve capacities to adapt and adjust to system disruptions and change.*** Effective management for future unknown risks and catastrophes will need new approaches beyond the confinement-dispersion strategies that current levee, floodway, and reservoir structures represent. While many river floodplains are likely to never be fully restored, the purposeful placement of wetlands and engineered structures can improve floodplain functionalities and rebalance competing human values and preferences for land uses with the natural behavior of the river ecosystem.

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