

Reconstruction and ecological management of the floodplain in the Lower Yellow River

J L Zhang^{1,2}

¹Yellow River Engineering Consulting Co. Ltd., Zhengzhou 450003, China

E-mail: jlzhangyrec@126.com

Abstract. Constrained by the special physiographic conditions and the progress of safety construction, the economic development in the floodplain area is slow and people still live in poverty. This study aimed to propose a reconstruction and ecological management concept, “flood control with graded, standard sediment deposition in the partitioned zone, regionalized reconstruction, and the development of the floodplain” with the guidance of the national development strategy and the current water management policy. This was after considering the natural characteristics and physics of the flow and transport of sediments in the Lower Yellow River floodplain. The reconstruction and ecological management of the Lower Yellow River floodplain is an effective combination of river management and economy development, which is in accordance with the national requirement for ecological civilization construction. Moreover, this was vital in taking targeted measures to help people out of poverty and promoting the development of the Central Plains Economic Zone. It is advised to conduct studies on schemes for the reconstruction and ecological management of the Lower Yellow River floodplain. Pilot projects should be launched in selected reaches to conduct reconstruction experiments, and then the experience can be popularized along the entire lower river.

1. Introduction

1.1. Overview of the floodplain

There is a vast floodplain with a total area of 3154 km² in the Lower Yellow River watercourse, accounting for more than 65% of the total area of the lower floodplain. The floodplain of the upstream reach of Taochengpu Village covers 2624.9 km², accounting for 83.2% of the total area. Apart from Pingyin County and Changqing County, the remaining floodplain downstream of Taochengpu Village covers a small area.

Among the 120⁺ natural floodplains in the Lower Yellow River watercourse, 7 floodplains cover more than 100 km², 9 floodplains cover 50~100 km², 12 floodplains cover 30~50 km², and more than 90 floodplains cover less than 30–50 km². Five natural floodplains in Yuanyang County, Changyuan County, Puyang County, Dongming County, and Changqing County cover a total area of about 150 km². The Changqing floodplain is located downstream of Taochengpu Village and the other four floodplains are located in the upstream reach of Taochengpu Village, as seen in figure 1.

The Lower Yellow River floodplain is not only the flood-flowing zone and the flood detention and deposition zone, but it is also an important place for production and habitation. The floodplain has 227,000 hm² of existing cultivated land, 1928 villages, and a population of 1.895 million (1.246



million in Henan Province and 0.649 million in Shandong Province) [1]. The floodplain economy is a typical agricultural economy, and the crops are mainly wheat, soybean, and corn. The local economy is poorly developed, and the economic gap between the floodplain and the surrounding area is gradually expanding, influenced by floods and the restriction of the production environment and conditions [2,3].

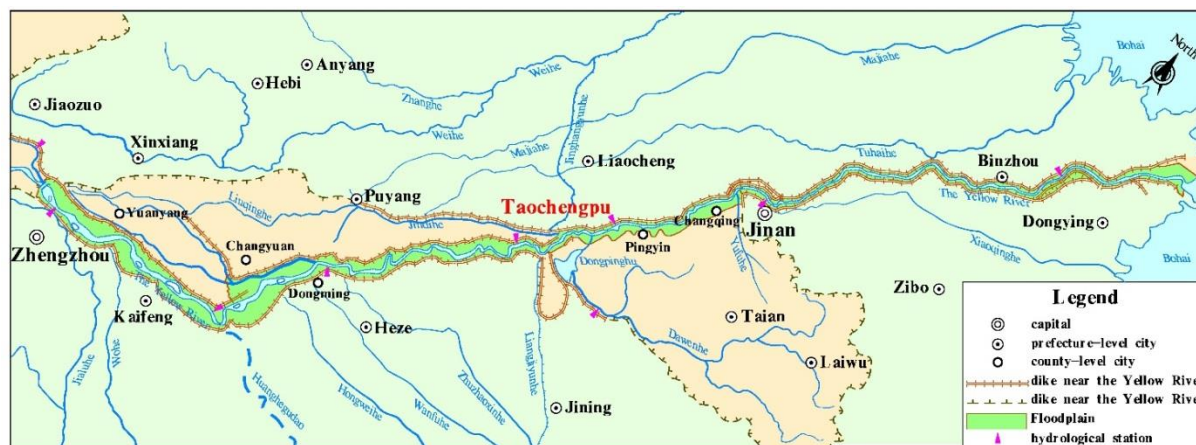


Figure 1. General view of the floodplain in the Lower Yellow River.

1.2. Problems inherent to floodplain management

Since the founding of new China, the management of the Lower Yellow River watercourse and floodplain has made great achievements, including increasing the height and thickness of the embankment by a multiple of four. Watercourse regulation and engineering have been put in place and Dongping Lake, Beijing Embankment, and other-flood retarding basins have been opened up. In addition, floodplain safety construction has been implemented, and the "Secondary Suspended River" governance experiment and the governance model and compensation policy of the downstream watercourse and floodplain have been conducted [4]. However, many problems exist in floodplain management due to changes in the water-sediment situation of the Yellow River and rapid socioeconomic development [5], which are listed as follows:

- The "Secondary Suspended River" threatens flood control, affecting floodplain development. The Lower Yellow River is not only "the aboveground river," but also the "Secondary Suspended River" with a high channel, low floodplain, and low-lying embankment foundation. At present, the beach edge of the Dongbatou–Taichengpu reach is at a minimum of about 3 m higher than the embankment's riverside ground on average, while the maximum is 5 m. The traverse gradient of the beach face is around 0.1%, which is 10 times the longitudinal gradient of the watercourse. First, the adverse form of the "Secondary Suspended River" increases the probability of forming cross, oblique, and rolling flows in the floodplain, which easily leads to a flood flowing along the embankment and increases the danger of breaching it. Second, the adverse form of the "Secondary Suspended River" is likely to cause rainfall ponding in the embankment root area, which is difficult to drain out. In addition, water logging leads to a reduction in crop production or crop failure and land salinization makes it increasingly difficult for people to improve land. After Xiaolangdi Reservoir was put into use, although the minimum full discharge of the bank in the downstream watercourse recovered more than 4000 m³/s [6], the adverse form of the traverse gradient of the floodplain was much larger than the longitudinal gradient of the river channel. This issue has still not been solved effectively.
- The safety construction of the floodplain lags behind, and people in the floodplain area have no safety guarantee. For a long time, the progress of construction has been slow because of insufficient investment of funds into floodplain safety construction [7]. Among 1.895 million

people in the downstream floodplain, only 282,000 people enjoy up-to-standard safety construction that can prevent the once-in-20-years flood from breaching the embankment; 894,600 people have safety production facilities that do not reach the accepted standard and have no water facilities; and 718,400 people have no water avoidance facilities. At the same time, a few substandard retreat roads, a shortage of lifeboats, and early warning facilities cannot meet the needs of local flood avoidance, evacuation, and transfer. The security of the life and property of the vast majority of people in the floodplain is not guaranteed. In recent years, as a pilot project, Henan Province and Shandong Province have been promoting the relocation of residents in the floodplain.. The density of the relocated population is still low due to investment restrictions.

- The economic development of the floodplain is slow. The Lower Yellow River floodplain is part of the watercourse. According to the relevant provisions of watercourse management, the development of industries within the floodplain is limited and the economy is dominated by agriculture. Farmers have low income levels and live in poverty. According to the statistics of the government work report, the per capita disposable income of rural residents in Henan Province in 2015 was \$ 1706.9, while the income of those in Fengqiu County, Taiqian County, and Fanxian County was \$ 1290.6, \$ 1169.2, and \$ 1227.5, respectively.
- Obvious contradictions exist between economic development and river regulation in the floodplain. Residents in the floodplain have continued to build production dykes so as to develop the economy and prevent small overbank flooding. Although the productive embankment can reduce the loss of some parts of the floodplain due to small floods, it hinders the free exchange of water and sediments in swales during flooding periods. This further accelerates the development of the "Secondary Suspended River," increases flood-related disasters in the floodplain, and is more unfavorable for downstream flood control. On the contrary, to reduce the breaching of the productive embankment, the local government requires the Xiaolangdi Reservoir to retain medium flood and protect the beach, which affects the full interplay of flood control and siltation reduction at the reservoir. The contradiction between the downstream flood and sediment treatment and the economic and social development of the floodplain has become increasingly prominent and has become the bottleneck of Yellow River downstream treatment.
- Floodplain treatment problems are complex. The progress of floodplain management was affected due to different opinions. Yellow River downstream floodplain treatment is extremely complicated because of the involvement of flood control, sediment, ecology, society, policy, and other issues. The decision-making involved in floodplain management is affected because the water and sediments flowing into the downstream of the Yellow River have undergone great changes in recent years. In addition, disagreements on floodplain management exist among all sections of society.

1.3. Floodplain management in the Lower Yellow Stream

For problems related to the management of the downstream floodplain of the Yellow River, experts recognized several relevant achievements in the 1980s and 1990s [8,9]. In 2004, the Yellow River Conservancy Commission held seminars on the Yellow River downstream governance strategy in Beijing and Kaifeng and carried out a wide range of in-depth discussions on the changes in water and sediments in the Yellow River, water and sediment regulation and reservoir scheduling, downstream watercourse and floodplain management, and the floodplain policy [10]. Subsequently, a large number of studies were carried out in a targeted way and a series of achievements were obtained, including the Analysis and Study on the Advantages and Disadvantages of the Production Dyke in the Downstream of the Yellow River [11], the Study on the Floodplain Governance Model of the Downstream of the Yellow River [12], the Study on the Application of the Compensation Policy in the Downstream Floodplain of the Yellow River [13], and the Study on Governance Model and Safety Construction in the Downstream Floodplain of the Yellow River [14]. A lot of work on the wide and narrow river

governance strategy and the abandonment or reservation of the productive embankment has been done in "Study on Watercourse Management Strategy for Lower Yellow River" and other related topics [15] included in Comprehensive Planning of Yellow River Basin, which was launched in 2007. In addition, the governance model of embankment strengthening by widening the river and abolishing the productive embankment used in the entire floodplain area was put forward. This forms the Lower Yellow River watercourse management strategy of "stabilizing the main channel, water and sediment regulation, stabilizing embankments by widening the river, and policy compensation." The watercourse management strategy is included in "Flood Control Planning for Yellow River Basin" and "Comprehensive Planning of Yellow River Basin (2012–2030)," which was approved by the State Council, and has become the basis to guide the management of the Lower Yellow River watercourse and floodplain in the future.

In 2012, the 12th Five-Year National Science and Technology Support Plan Project, "Research and Application of Yellow River Water and Sediment Regulation Technology" separately listed the topic "Research on the Flood Detention and Sediment Deposition Function of the Wide Beach Area in the Lower Yellow River and Floodplain Disaster Reduction Technology" for research [16]. Furthermore, it raised the recommended operational program for the future wide beach area as follows: The productive embankment shall be reserved, and the floodplain shall be protected from the loss caused by the floods below $6000 \text{ m}^3/\text{s}$ at Huayuankou Station by the productive embankment. For the floods that were above $6000 \text{ m}^3/\text{s}$ at Huayuankou Station, all the productive embankments shall be abolished for flood detention and sediment deposition in the wide beach area.

In 2013, the Yellow River Conservancy Commission carried out the research work, "Lower Yellow River Watercourse Renovation and Floodplain Governance" together with China Institute of Water Resources and Hydropower Research, Tsinghua University, and other units. Since the complexity of the "Secondary Suspended River" problem, the research results have not been implied completely and the floodplain problems still exist.

2. The reconstruction and ecological management scheme of the floodplain in the Lower Yellow River

2.1. Reconstruction and ecological management scheme

The present study considered the current concept of water control and the new requirements of the economic development of the; fully absorbed the management achievements in the Lower Yellow River floodplain; described the changes in the Yellow River water and sediment and flood control conditions, and the problems confronted by the management of the floodplain; and dealt with the reconstruction and ecological management program of the Lower Yellow River floodplain through research and analysis.

- The primary basis of the program. (a) Various types of protection objects in China are set up according to flood standards. (b) The function of the Lower Yellow River floodplain is flood flowing, flood retarding, and sediment desilting. To adapt to the sediment-laden river characteristics of the Yellow River, the lower watercourse has a wide top and a narrow bottom (at its widest, it is 24 km long, and at its narrowest, it is 275 m long). The watercourse gradient is steep in the upper part and gentle in the lower part (the reach in Henan Province is about 2 ‰ , and the reach in Shandong Province is about 1 ‰). The flood discharge capacity of the upper part is larger than the lower part (Huayuankou $22,000 \text{ m}^3/\text{s}$, Sunkou $17,500 \text{ m}^3/\text{s}$, and Aishan $11,000 \text{ m}^3/\text{s}$). It is advised to use a wide reach to detain and handle floods (use the flood diversion area if the flood exceeds the flood detention capacity) and the vast floodplain for desilting (after a flood with a high sediment concentration flows on the floodplain and silts, a flow with a low sediment concentration returns to the channel to adapt to the watercourse feature of gentle gradient and the low transportability of sediments in the Shandong Reach). According to this, the vast floodplain is not only an important place for dealing with flood sediments but also the homeland on which the masses depend; and. (3) The acceleration of the

construction of an ecological civilization is an important national strategy currently.

- Guiding ideology of the program. The ideology adheres to the people-oriented, people-water harmony, and green development concept, while maintaining the pattern of "stabilizing the river using wide embankments" in the lower reach; aims to change the Yellow River water and sediment situation and the development pattern of the governance project; by the means of transforming the Lower Yellow River floodplain and combining ecological management measures; forms different functional areas, including the resettlement area for Lower Yellow River residents, an efficient ecological agriculture area, and a flood-flowing and desilting area; achieves "flood-graded fortification, sediment desilting in different areas, and free exchange of swale water and sediment" in the floodplain; protects the long-term flood control safety for the Lower Yellow River; constructs an ecological corridor for the Lower Yellow River; and promotes rapid poverty alleviation for the masses in the floodplain.
- Program ideas. It is suggested to combine the topographic conditions and water and sediment characteristics in the Lower Yellow River reach; take the local regional economic development plan into full consideration; divide the floodplain into an immigrants arrangement area, an efficient agricultural area, and a resource development and utilization area according to their functions; use sediment desilting, dredging, and other means to successively transform the floodplains into a "Class III floodplain," a "Class II floodplain," and a "Class I floodplain" from the Yellow River levee to the main channel; and set different fortification standards for overbank floods for various types of floodplains. The inadequate part shall reach the standard through transformation and governance (this should be combined with a comprehensive analysis of overbank flow in different reaches to determine specific fortification flow standards). A "Class III floodplain" area can also be called a high tableland and, combined with the terrain of the floodplain, delimits the accretion within 1–2 km near the embankment as a immigrants arrangement area to solve the life and work problems of the people. It is allowed to build an ecological landscape in some areas, and the flood control standard shall be a once-in-20-year flood. A "Class II floodplain" is the area between a Class III floodplain and constraint works, which is higher than a Class I floodplain. This should be combined with "Secondary Suspended River" governance, the adverse form of the "Secondary Suspended River" should be changed, and efficient ecological agriculture, agricultural tourism, and so on should be developed. This area has a high probability of overbank and bears the function of flood detention and sediment deposition. A "Class I floodplain" is the floodplain inside the "Class II floodplain." A wetland park is built to bear the function of flood flowing and sediment transport together with the channel.

The reconstruction and ecological management of the Lower Yellow River floodplain not only retains the functions of water and sediment exchange, flood detention, and sediment deposition of the Lower Yellow River floodplain, but also solves the safety and development problems of the people in the floodplain. This scheme is significant to the protection of the Yellow River's long-term peace, the rapid promotion of the social and economic development of the floodplain, and the poverty alleviation of the masses. Figures 2 and 3 show the typical cross-section and concept diagrams after the reconstruction and ecological management of the Lower Yellow River floodplain, respectively.

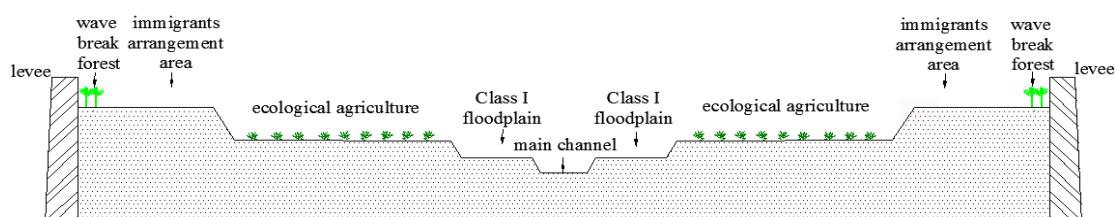


Figure 2. A schematic drawing of the typical cross-section of reconstruction and ecological management of the Lower Yellow River floodplain.

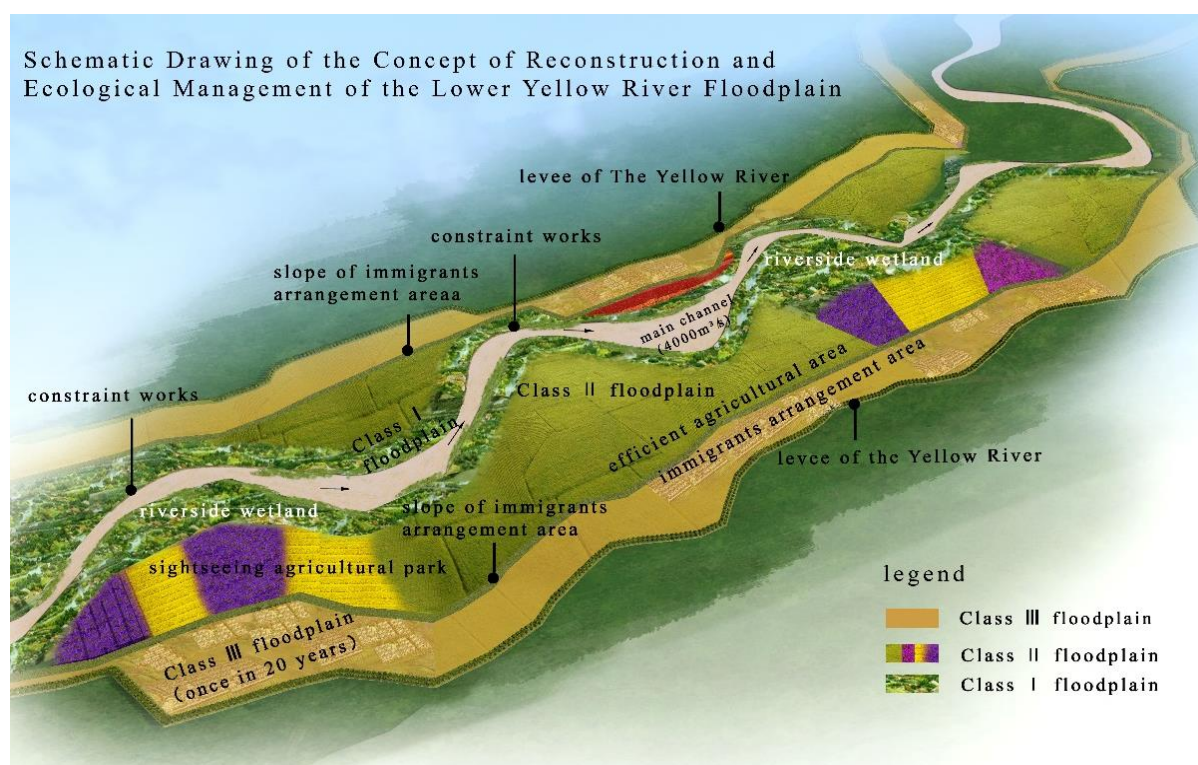


Figure 3. A schematic drawing of the concept of reconstruction and ecological management of the Lower Yellow River floodplain.

2.2. Significance of the implementation of the scheme

- This scheme is an important aspect of the current management of the Lower Yellow River floodplain. The governance of the Yellow River is closely related to the political, social, economic, and technical background of the country. In May 2015, the CPC Central Committee and State Council released *Views on Speeding up the Development of Ecological Civilization*. Adhering to the spirit of the CPC Central Committee and State Council and complying with the needs of economic and social development, the Leading Party's Group of Yellow River Conservancy Commission put forward the management idea of "safeguarding the healthy life of the Yellow River and promoting the human-water harmony in the watershed." The reconstruction and ecological management of the Lower Yellow River floodplain places the management of the floodland into the overall situation of regional economic and social development and the building of an ecological civilization, makes the river shoal serve the region's economic, social, and ecological development needs in a better way, build green water and clean beaches, improve the regional ecological environment, create more benefits for the masses in the benchland and along the Yellow River, and realize the human-water harmonious coexistence in the area, as well as the economic and social development of the floodplain and along the Yellow River in a green, coordinated, and sustainable manner. The reconstruction and ecological management in the Lower Yellow River floodplain complies with the national development strategy and is an important direction for the governance of the Lower Yellow River in the future.
- The scheme is an objective demand for boosting the development of the Central Plains Economic Zone. The Lower Yellow River floodplain is rich in land, light, and heat resources but is quite poor in economic development. The location advantage of the floodplain has no significance, and the quality of economic development lags far behind that of the surrounding region, encumbering the pace of the construction of the Central Plains Economic Zone. While

implementing the reconstruction and ecological management of the floodplain, we should, according to the advantages of different floodplains, highlight the safeguard function of flood control safety, actively develop leisure tourism, vigorously develop high-efficiency agriculture, exploit the land and water resources of the Yellow River, adjust the structure of traditional small-scale peasant economy, promote the rapid development of the floodplain, and construct an ecological barrier of regional development; these are objectives to drive the development of the Central Plains Economic Zone and enhance the overall competitiveness of urban agglomeration in the Central Plains.

- It is an important measure for targeted poverty alleviation and the promotion of the sustainable development of the region. While implementing the reconstruction and ecological management of the floodplain, we should carry out poverty alleviation and relocation in the floodplain; conduct governance for dykes and low-lying land; adjust the production structure, develop characteristic industries and efficient agriculture; provide a basic solution to the problem of poverty alleviation for floodplain masses, which are the major measures taken to plan the development of urban and rural areas along the Yellow River; guarantee and improve the people's livelihood in the floodplain; decrease the gap in development between the floodplain and surrounding areas; enhance reform and development achievements for the people around the floodplain as a whole, as well as essential means to promote the close combination of poverty alleviation development and regional development in the floodplain; and improve regional industrialization and urbanization levels. Since 2014, Henan Province has focused poverty alleviation development on "Three Mountains and One Floodplain" (Dabie Mountains, Funiu Mountains, Taihang Mountains, and Yellow River Floodplain). The reconstruction and ecological management of the floodplain are of significance for Henan Province in the implementation of targeted poverty relief and poverty alleviation.
- It is the basic way to maintain the healthy life in the Lower Yellow River floodplain and realize the harmony between human and water. Reconstruction and ecological management in the Lower Yellow River floodplain has maintained the governance pattern of "stabilizing the river using wide embankments" in the lower watercourse of the Yellow River; preserved the functions of water and sediment interaction, detention, and settling in the Lower Yellow River floodplain; and controlled the flood and sediment problem. At the same time, one should take the historical opportunity of building an ecological civilization and develop the Central Plains Urban agglomeration; exploit and utilize the water and land resources of the floodplain; build artificial lakes or ecological wetlands; cultivate crops; develop the leisure tourism and sightseeing industry and an efficient ecological agriculture through the function zoning of the floodplain; promote the rapid development of the economy and society in the floodplain; and achieve win-win results in river management and benefits to people.

2.3. Suggestions for the implementation of the scheme

The reconstruction in the Lower Yellow River floodplain and the ecological control plan is in accord with the national strategy of economic and social development, which plays an important role in rapid poverty alleviation and the promotion of ecological civilization construction in the area. The present study suggested to carry out research work on reconstruction and ecological management in the Lower Yellow River floodplain as soon as possible; comprehensively investigate the bottom value of the economy, population, and ecological index in the downstream floodplain; and study key problems, including lower floodplain function zoning, floodplain ecological governance model, floodplain reconstruction scheme, control measures and governance effect evaluation, security and guarantee measures, and so on. At the same time, it is necessary to select typical floodplain area pilots in different lower reaches, further study and compile a pilot reach implementation scheme (feasibility study scheme), carry out a pilot management test, explore the experience, and popularize the downstream watercourse gradually.

3. Conclusions

In the Yellow River floodplain there is a great potential of economic and social development, which can be exploited through the implementation of government integral plans and programs that include population.

- The Lower Yellow River floodplain has a total area of 3154 km², an existing arable land of 227,000 hm², 1928 villages, and a population of 1.8952 million. The “Secondary Suspended River” of the Yellow River downstream keeps increasing, threatening flood control safety. In addition, because of the lag in safety construction in the floodplain, masses lack security assurance and have a low quality of life. As the gap between economic and social development inside and outside the floodplain widens, the conflict between floodplain development and river governance becomes increasingly prominent.
- The proposed reconstruction and ecological management scheme of the Lower Yellow River floodplain, based on the basic water-sediment theory and the national development strategy, has not only preserved the functions of water and sediment exchange, flood detention, and sediment deposition in the lower floodplain of the Yellow River, but also solved the problem of the safety and development of the people in the floodplain and realized an effective combination of river harnessing and economic development. This is significant to precision poverty alleviation and the rapid development of the Central Plains Economic Zone.
- It is suggested to conduct the research work on the reconstruction and ecological management of the Lower Yellow River floodplain as soon as possible. At the same time, typical floodplain area pilots in the downstream must be selected, the implementation plan for the control of the pilot river reach should be compiled, a pilot management test must be carried out, and the downstream watercourse should be popularized.

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