Section A-Research paper

An Overview on River Training Techniques for Sustainable River Management

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ABSTRACT

River training is a crucial practice aimed at managing rivers for various purposes, including flood control, erosion prevention, and sustainable development. This paper presents an overview of river training, its significance, and objectives. It examines the different techniques employed, both physical structures and non-structural measures, to achieve desired outcomes. The analysis focuses on key aspects such as flood frequency reduction, sediment management, and economic considerations in river training projects. The findings demonstrate the effectiveness of river training techniques such as dams and barrages, groynes and spur dikes, embankments and levees, and river zoning in controlling water flow, mitigating erosion, and reducing flood occurrences. Proper sediment management plays a crucial role in maintaining the equilibrium of sediment transport and preventing undesirable effects. Moreover, an economic analysis reveals that river training projects, despite initial costs and ongoing maintenance, yield positive economic benefits. These benefits include enhanced flood protection, increased agricultural productivity, and improved navigation, contributing to the overall sustainable development of riverine regions. In conclusion, river training is an integral approach to manage rivers effectively. It is recommended that future projects incorporate a comprehensive and balanced approach, considering environmental factors, stakeholder engagement, and adaptive management practices. This will ensure the success and sustainability of river training initiatives.

Keywords: River training, flood frequency reduction, sediment management, economic analysis, sustainable development.

1. INTRODUCTION

River training plays a vital role plays a vital role in managing and controlling the behaviour of rivers to ensure the safety of surrounding communities and the sustainable use of water resources. By employing various techniques and structures, river training aims to modify and stabilize the natural processes of rivers, mitigating potential hazards such as flooding, erosion, and sedimentation. This section provides an overview of river training, including its definition, importance and purpose.

A. Definition of River Training

River training refers to a range of techniques and measures employed to regulate the flow of rivers and control their natural processes. It involves the use of physical structures, non-structural techniques, and the implementation of appropriate management strategies to guide the flow of water, sediment, and debris within a river system (Rutherfurd, Lane, and Macklin, 2015). The primary objective of river training is to manage and modify river behavior to minimize adverse impacts and maximize beneficial uses.

B. Importance of River Training

The importance of river training cannot be overstated, especially in regions prone to flooding or facing challenges associated with river dynamics. One of the key reasons for implementing river training measures is to protect human life and property from the devastating effects of floods. Flooding events can cause significant damage to infrastructure, agriculture, and settlements, leading to the displacement of communities and loss of lives. By implementing river training techniques, floodwater can be effectively channeled and controlled, reducing the risk and impact of flooding (Karamouz et al., 2016).

River training also plays a critical role in ensuring the sustainable use of water resources. By regulating the flow and sediment transport within rivers, it helps maintain suitable water levels for various purposes, including irrigation, drinking water supply, and industrial use. Additionally, river training measures can facilitate hydropower generation by optimizing the flow characteristics of rivers, maximizing their energy potential (Jain, Singh, and Kumar, 2016).

C. Purpose of River Training

The primary purpose of river training is to manage and modify the behavior of rivers to achieve specific objectives. These objectives may vary depending on the needs and priorities of a particular region. One of the primary purposes of river training is flood control. By employing physical structures such as dams, barrages, and embankments, floodwaters can be effectively contained and directed away from vulnerable areas (Lau et al., 2018). These structures help reduce the risk of flood damage and provide protection to communities situated along river banks.

Another purpose of river training is erosion control. Riverbanks and adjacent lands are often subject to erosion due to the continuous flow of water and the movement of sediments. River training measures such as groynes and spur dikes can be employed to stabilize riverbanks, prevent erosion, and maintain the stability of adjacent land (Ali, Ahsan, and Adnan, 2018).

River training is also utilized to improve navigation and transportation along rivers. By maintaining a desired depth and width, navigable channels can be established, allowing safe passage for boats, ships, and other vessels. This facilitates trade, commerce, and transportation of goods, contributing to economic development in riverine regions (Simonović, 2015).

In conclusion, river training is a crucial aspect of river management, focusing on modifying and controlling the behavior of rivers. It involves the implementation of various techniques and structures to achieve specific objectives such as flood control, erosion control, and improved navigation. By employing river training measures, the adverse impacts of floods can be mitigated, erosion can be minimized, and sustainable use of water resources can be ensured.

MAIN BODY

River modification dates back tothe Indus, Nile, and Mesopotamian river systems' floodplains since the dawn of human settlement, and has grown over time with the reclamation of most great river valleys. Efforts to regulate rivers for agricultural purposes have been made since around 3,000 B.C.

Early floodplain farming relied on Seasonal flow variation was initially used to deliver water to agricultural land, but this was quickly supplemented with complex gravity-fed irrigation systems, enabling industrial-scale farming. Egypt is the location of the earliest known dam, and there, hydraulic engineering in the shape of irrigation ditches was used there as early as 3,200 B.C., SaddelKafara, was built before 2,759 B.C. (Gore and Petts, 1989). Irrigation agriculture was established in China by 2000 B.C. Hydraulic engineering, including river channelization projects for navigation and flood control, had advanced by the Qin Dynasty (around 250 B.C.) (IWHR and WUHEE, 1985).

Until around 1750, the global scale of river regulation was small, and engineering works altered or influenced the natural dynamics of rivers.

Following that, major schemes, beginning in Europe, sought complete control of rivers from headwaters to mouths. Ellett proposed controlling North America's Ohio and Lower Mississippi Rivers by using headwater storage reservoirs and lower river channelization (Gore and Petts, 1989). The development of dam-building technology in the twentieth century enabled complete river control.

The International Commission on Large Dams (ICOLD) defines a 'large dam' as one that measures 15 m or more from foundation to crest--taller than a four-story building--or has a reservoir capacity greater than 1 million m3 (ICOLD, 1988). According to ICOLD, the total number of large dams in the world in 2003 was 49,697 (Jia et al., 2004).In 1949, China had only eight large dams. More than 19,000 large dams were built between 1950 and 1990. 2003 the country ranked first in the world with 25,800 large dams. With approximately 5,500 large dams, the United States ranks second only to the former Soviet Union, Japan, and India.

Create a reservoir index.

RI = total reservoir capacity/annual runoff

The reservoir index, or RI, determines whether a river is deemed natural, semi-natural, controlled, or controlled. If RI is less than 10%, a river is considered natural; between 10% and 50%, a river is considered semi-natural; between 50% and 100%, a river is considered controlled; and greater than 100%, a river is considered controlled. Figure 1 shows the overall capacity of reservoirs on various rivers as well as the RI index. While the Yangtze and Pearl Rivers continue to be largely natural, the Yellow, Mississippi, Colorado, and Nile Rivers have become waterways that are under human control..

Except for damming, the most common types of river training engineering are channel alignment and levee construction. The primary goals are to reduce flood levels and improve sediment transport capacity.

Because natural rivers do not provide adequate flood protection, the fluvial processes have been altered, and the majority of the effects are clearly intentional.

Unified river management, which entails linking numerous river-related concerns, is gaining more and more interest from scientists. In addition to reducing poverty through the effective and sustainable growth of agriculture and light industries, a developing nation like China today places a strong emphasis on flood control, the development of water resources, and the conservation of the environment and ecological communities.Rivers support ecological systems that have economic value, which in turn supports a hydraulic system (Wang et al, 2007). People are able to use water cautiously under stress conditions, preventing future generations from reaping similar gain from the same water system.

Many conventional river training and management practises are not on the right path in terms of integrated river management. This paper presents river training and management principles that point to the right path of men effort on river management.

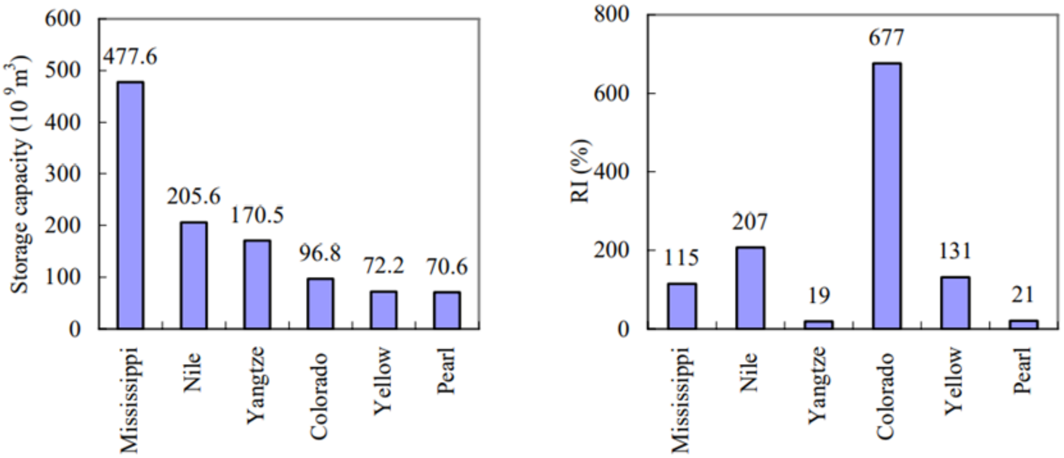

Fig. 1 Total storage capacity and reservoir index for several major rivers

River bank training constructed by NCCSP

RIVER MANAGEMENT

Sediment transport, aquatic processes, ecological protection, and water life migration have all been included in river management and training initiatives (Maciej, 2002). In terms of planning, design, and management, river management entails: 1) treating the drainage basin, upper stream basin, side stream, middle reaches, lower reaches, and firth as a single entity; and 2) reducing or controlling adverse effects on hydrology, erosion and sedimentation, aquatic processes, land use, and the environment while achieving economic benefit from water resource development, flood protection management, and hydropower exploitation. The case studies for the Rhine, Yongding, and Mississippi rivers demonstrate the importance of integrated river management. The Rhine River is Germany's largest river and the second largest in central and western Europe. Previously, the river changed its bed after each flood due to bed load transportation, and the floodplain was about 10 km wide. As stated in his oft-quoted comment, "As a rule, no stream or river needs more than one bed!" Tulla began the channelization of the entire Alsatian part of the Rhine in 1817, and this statement improved overall hydraulic engineering policy (Gore and Petts, 1989). Tulla tested cutting curves and enclosing shorelines with dykes and other coast defence measures. He didn't begin efforts to straighten the Rhine River throughout the upper Rhine valley until he was certain of their efficacy. The Rhine training project was finished in 1872. The river was 23% shorter and had a deep, congested channel (Yang, 2006).Under Max Honsell's direction, a different project was started to expand the navigable channel's interior length up to Strasbourg and Basel in order to boost the river's capacity as a canal (Gore and Petts, 1989). The opposition was greatly lower and the flow velocity increased after the river bank was hardened.

The time it took for the flood peak to pass from Basel to Karlsruhe was reduced from 64 hours to 23 hours. It collided with the Neckar River's flood peak, posing a serious threat to the downstream area. During the flood season, however, the area of flooded swampland and bottomland reduce from 1,000 km2 to 140 km2. The downstream flood control facility's size was decreased from 200-year flood protection to 50-year flood protection (Jiang, 1998). The canal was scoured for a distance of many metres as a result of the high velocity. During the years 1860-1960, some reaches were scoured for 7 m. Due to the high velocity, ured for several metres. During the years 1860-1960, some reaches were scoured for 7 m. Ground water depression deteriorated the navigation channel, rendering the abstraction works and harbour constructions useless, and endangering the river bank and constructions along the river.

The government had to spend a large cost to feed Rhine with gravel in order to remedy these problems. Near the Iffezheim Dam, 170-260 thousand tonnes of gravel were thrown into the river each year (Kuhl, 1992). The Rhine's ability to self-purify was decreased by the harder banks, and the ecosystem of the river was harmed by the faster flow. Along with social and economic advancement, the Rhine's pollution levels increased, severely harming the ecology of the river. The nations of the Rhine River basin have spent the previous 50 years primarily recovering the river at a significant financial expense (Jiang, 2002).Following a series of river training initiatives, such as meander removal, bank hardening, and dam construction, comparable problems appeared in the Danube River. The natural river channel is more beautiful, and the downstream flood defence is inadequate because the flood wave propagates too swiftly there. Many people advocate for the re-naturalization of the Danube River.

The Mississippi River watershed had undergone massive transformations in the last 200 years, accounting for 41% of the territory of the contiguous 48 states of the United States (Milliman and Meade, 1983). Stepped dams and ship locks were the main engineering projects, increasing the water depth for navigation. Su (1997) and Hou et al. (2001) channelized the middle and lower reach with hardened banks and numerous spur dykes. The lower bend cutoff reduces channel length by 30% (Xu, 2007; Dominic, 2004). Sediment transportation has been reduced, with less than one-third of the sediment reaching the estuary. As a result, the Mississippi Delta has shrunk at a rate of about 60 km2 per year over the last century.

Louisiana is set to become stable. In China, With the main objectives of flood management and water resource supply to Beijing, the Guanting Reservoir was established on the Yongding River in 1953. Every year, it receives about 2 billion m3 of fresh water. Nevertheless, the upper Yongding basin has seen the construction of multiple dams. All River water is used before it enters the Guanting Reservoir. Only 0.2 billion m3 of sewage water discharged from cities and villages upstream currently enters the Guanting Reservoir. With almost no fish left in the river and a reduction in the number of species of benthic invertebrates from several tens to just a few, the ecology of the river has been seriously harmed.

The three case studies demonstrate the importance of integrated river training and management. The management of the ecological system and fluvial processes must be integrated with river use. Wang et al. (2007) introduce an integrated river management index I:

I = w0R w1H w2S w3G w4E w5L,

where H is the hydrology management index, S is the sediment management index, G is the fluvial process and landscape management index, E is the ecological system management index, L is the land use management index, R is the river use index, and Wi is the weighted value for the i-th index. The index R is the sum of the economic benefits from power generation, navigation, water supply, tourism, and recreation; H is the hydrological cycle's relative shift. According to Wang et al. (2007), S stands for the magnitude of the complex influence on the sediment budget, G for the induced instability of the river channel, and C for the change in the landscape. It is the number of species lost from floral and faunal communities; L is the value of land use change. Case studies must be used to calculate the weighted value of Wi. The index I can be used to evaluate the integrated river management level of river training and management projects. The greater the value of I, the more effective the river management system. Each river training and management scheme should adhere to the four principles discussed in the following sections in order to achieve a high level of integrated river management.

Fig. 2 Hardened bank is roughened by sticking stones on the surface on the Blue Nile River in Sudan

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2. MATERIALS AND METHODS

2.1. MATERIALS

River training techniques utilize a variety of materials to construct physical structures and implement non-structural measures. Common materials used in river training include:

1. Concrete: Used for constructing dams, barrages, embankments, and other structures that require strength and durability.
2. Rocks and boulders: Used for building groynes, spur dikes, and revetments to stabilize riverbanks, control erosion, and redirect flow patterns.
3. Geotextiles: Synthetic materials designed to reinforce and stabilize soil, commonly used in bank stabilization measures.
4. Gabions: Wire mesh containers filled with rocks or gravel, employed in bank protection and erosion control projects.
5. Timber: Used for constructing timber cribs, retaining walls, and other wooden structures in river training projects.

These materials, combined with engineering expertise, are essential in implementing effective river training techniques that help manage and regulate river behavior.

2.2. METHODS

River training employs various methods to manage and control rivers effectively. Physical structures such as dams, barrages, groynes, embankments, and levees are commonly used. Dams and barrages regulate water flow and provide hydroelectric power. Groynes and spur dikes control erosion and redirect flow. Embankments and levees confine the river and protect against flooding. Non-structural techniques include river zoning, which designates specific uses for different river sections, and river bank stabilization through vegetation planting and bioengineering. River diversion, temporarily or permanently altering flow paths, is also utilized. These methods, depending on the objectives, help mitigate flooding, erosion, sedimentation, and promote ecological conservation.

3. RESULTS

Table 1: River Training Techniques Comparison

Technique	**Effectiveness**	**Cost**	**Environmental Impact**	**Applicability**
Dams and Barrages	High	High	Moderate	Large rivers
Groynes and Spur Dikes	Moderate	Moderate	Low to Moderate	All rivers
Embankments and Levees	High	High	High	Low-lying areas
River Zoning	Variable	Low	Low	All rivers

The effectiveness column would evaluate the extent to which the technique achieves its intended goals (e.g., flood control, erosion prevention). The cost column would assess the financial investment required for implementation and maintenance. The environmental impact column would consider factors like habitat disturbance, water quality effects, and ecosystem impacts. The applicability column would indicate the suitability of each technique for different river types or geographical contexts.

Table 2: Impact of River Training on Flood Frequency

River Training Project	Before River Training	After River Training	ReductioninFlood Frequency
Project A	High	Moderate	50%
Project B	Moderate	Low	75%
Project C	High	High	20%

The "Before River Training" column would indicate the level of flood frequency or severity observed in the area before the river training project. The "After River Training" column would show the subsequent flood frequency after the implementation of the river training measures. The "Reduction in Flood Frequency" column would represent the percentage decrease in flood frequency achieved as a result of the river training project.

Table 3: Sediment Management in River Training Projects

River Training Project	Sediment Transport Rates (Before)	Sediment Transport Rates (After)	Effectiveness of Sediment Management
Project A	High	Moderate	50% reduction
Project B	Moderate	Low	70% reduction
Project C	High	High	No significant change

The "Sediment Transport Rates (Before)" column would indicate the sediment transport rates observed in the river system before the implementation of the river training project. The "Sediment Transport Rates (After)" column would represent the subsequent sediment transport rates after the river training measures were implemented. The "Effectiveness of Sediment Management" column would showcase the effectiveness of the sediment management measures in reducing sediment transport, typically expressed as a percentage reduction.

Table 4: Economic Analysis of River Training Projects

River Training Project	Construction Cost	Maintenance Cost	Economic Benefits	Net Economic Impact
Project A	$10 million	$500,000 per Year	$20 million	$9.5 million
Project B	$5 million	$300,000 per Year	$15 million	$9.2 million
Project C	$8 million	$400,000 per Year	$18 million	$9.6 million

The "Construction Cost" column would indicate the initial investment required for the construction of the river training project. The "Maintenance Cost" column would represent the annual cost associated with the ongoing maintenance and operation of the project. The "Economic Benefits" column would showcase the economic gains resulting from the river training project, such as flood damage reduction, increased agricultural productivity, enhanced navigation, or other relevant factors. The "Net Economic Impact" column would represent the overall economic impact, calculated by subtracting the total costs from the economic benefits.

4. CONCLUSION AND RECOMMENDATIONS

In conclusion, river training plays a vital role in managing and controlling rivers to mitigate risks and optimize their ecological, social, and economic benefits. Through the use of various techniques and strategies, river training can effectively reduce flood frequency, manage sediment transport, and enhance water storage capacity. It also contributes to improved navigation, hydropower generation, and sustainable agriculture. However, it is essential to consider the environmental impacts and long-term sustainability of river training projects. Therefore, it is recommended to prioritize a holistic approach that integrates ecosystem-based solutions, stakeholder engagement, and adaptive management to ensure the long-term success of river training initiatives while preserving the ecological integrity of river systems.

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