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Human Impact on Mississippi by Reservoirs, Dams and Levees

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Abstract. Over 84 million people live within the Mississippi Basin. As one of the world's five largest river basins, the Mississippi River Basin's agricultural landscape supports 92% of the U.S.'s agricultural exports and 78% of the world's grain and soybean exports. Therefore, it is important to pay attention to the impact of human activities on the hydrological conditions of the Mississippi River Basin. As a regulating and storage project, reservoirs are responsible for controlling floods, providing water resources, controlling river water levels, and providing ecological protection; at the same time, dams can protect farmland, roads, factories and other facilities on both sides from being submerged when floods occur. As artificial facilities, dams have a greater impact on hydrological conditions than small-scale precipitation and reservoirs impact the hydrological status of river basins to a great extent. So, through the reservoir, we can directly see the impact of human beings on the natural water system. In some traditional views, the impact of dams and reservoirs on watersheds is completely within human control, but research has found that artificial water conservancy facilities under normal operation will invisibly change the hydrology, ecology and environment of the basin.

Keywords: Hydrology, Mississippi basin, Dams, Levees, Reservoir

1. Introduction

The Mississippi River is located in the south-central part of North America, with a drainage area of about 298 km2. It originates from Redstone Creek, a tributary of the Missouri River in the Rocky Mountains in the western United States [1]. It is 6,021km long, and its main tributaries include the Ohio River, the Missouri River, the Arkansas River, the White River, and the Red River. The flow of the Mississippi River ranks as the world's third largest behind those of the Amazon and Congo. The outflow of the river into the Gulf of Mexico averages 173,600 cubic meters per second (m^3/s) and represents five percent of all the freshwater discharged into the oceans of the world [2].

The upper tributaries of the Mississippi River, such as the Missouri River and the Arkansas River, pass through mountainous areas [3]. The upper rivers flow through the temperate continental climate zone. The precipitation in this area is seasonal. The rivers are mainly replenished by precipitation in summer. Some tributaries receive spring snowmelt water. The middle and lower reaches of the Mississippi River flow through the subtropical monsoon climate zone (Figure 1). The region has abundant rainfall. The mainstream of the middle and lower reaches flows through the central plains,

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which has a flat terrain and a riverbed gradient of 0.08 ‰ [4]; the water flows slowly. Due to sediment deposition at the delta at the mouth of the sea, the river channel is claw-shaped.

Because there are many tributaries in the study basin, human activities are frequent, and the river channel and hydrology are constantly evolving, it is of great significance to study the impact of human activities on the hydrological conditions of the basin, which is related to flood control, production, ecology and other aspects. Various hydraulic structures such as reservoirs, dams, and levees are particularly valuable as facilities that concentrate on human activities. This paper draws a conclusion by comparing the measured hydrological records and simulated hydrological values from ancient times to now [5].

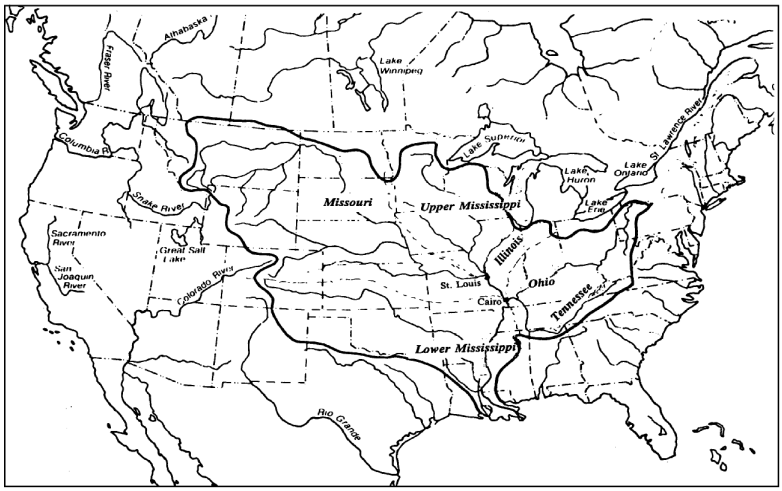

Figure 1: The Mississippi River system and its main rivers [6]

2. Changing trend of basin hydrological conditions before and after the construction of water conservancy projects

The upper Mississippi River is easily flooded by melting ice and snow in spring due to the climate; in the lower reaches of the river, due to the integration of tributaries and the regulation of reservoirs, the seasonal characteristics of hydrological parameters are not as significant as in the upper reaches. There are 42,000 reservoirs in the Mississippi River Basin, 79 of which have flood control functions. The purpose of building reservoirs and dams is to provide a stable way to obtain water resources and prevent river disasters. Humans also use river water for irrigation, and municipal and industrial purposes. The construction of dams and reservoirs has the following effects on the hydrological characteristics of the river [6].

The Mississippi River has a high shipping value, and the levees along the main and tributary rivers also change the river hydrology. In the Illinois River, by comparing the annual flood process lines before and after the large-scale construction of modern dams and ship locks on the same river section, it can be found that regardless of the water level, the flood peaks of the flood process lines after the construction of the dams are sharper than before; and since the 1880s, the frequency of floods has increased, and the wicket dam has raised the water level, expanding the range of fish migration.

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3. The impact of dams and levees on flood processes

The direct impact is the increase in the average water level of the river and the increase in the width of the river in front of the dam, which is less affected by the change in river flow. The long-term impact is the increase in sediment deposition, resulting in a continuous decrease in water volume. The following article will explore the impact of reservoirs and levees on flood process lines by comparing historical measured data with simulation results of hydrological models. The article refers to the annual average runoff published by the Mississippi River Commission and the daily runoff published by the United States Geological Survey (USGS).

3.1. Dams and levees' effect on flood process line

1930-1980 was a period of rapid reservoir expansion, with a rapid increase in reservoir capacity across the basin. Only 24 of these reservoirs are directly able to reduce peak discharges along segments of the river. These reservoirs have a normal storage capacity of 25 km^3. During this period, the reservoir capacity of the entire basin increased rapidly, and the ratio of reservoir capacity to annual flow increased year by year, as shown in Figure 2.

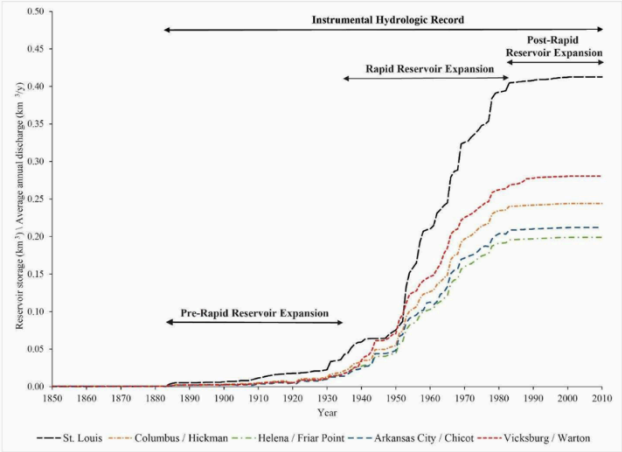

Figure 2: Changing trend of the ratio of storage capacity to flow rate [1]

By comparing the measured data in the time series, it can be found that the annual minimum flow in the main channel of the Mississippi River has generally shown an upward trend from 1870 to 2019. The annual minimum flow in Vicksburg, Mississippi after 1970 was 32% higher than before 1970. The change is due to the addition of reservoirs to intercept summer flooding in the upper Mississippi River and to vacate the reservoirs during the dry season to maintain water levels.

By St. Louis, the Mississippi River is divided into the Upper and Lower Mississippi Rivers. A comparison shows that the increase in the proportion of stations close to the downstream is not as obvious as that of stations on the upstream side. This is because the coordinated dispatch of the reservoir group has stored a large amount of floodwater, making the water situation in the downstream river close to the natural state [7].

3.2. Changes in seasonal flood flows

Based on the measured results, in the 19th century, when a large number of water conservancy projects were built, the flood peaks in the flood process diagrams at the same location and time scale

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were more acute. In order to protect agricultural land, a large number of dams were built, the flood storage capacity along the river has dropped significantly, and the floods in the river channel were discharged downstream more quickly than before, resulting in an increase in the peak flow during the summer flood season.

Moreover, through simulations of different hydrological models, it can be found that the closer to the downstream of the river section, the greater the proportion of the total water volume from November to February. Taking into account the increase in the number of reservoirs close to the downstream, the regulating effect of the reservoirs will cause the flow rate in the dry season to increase.

In addition, the construction of dams and artificial drainage in floodplains can raise the water level in the river. Under the support of the main river water, the drainage of some tributaries is blocked, and the summer flood time is prolonged, posing a certain threat to flood control safety in the basin.

3.3. Special flood

According to records, the Mississippi River has experienced many extreme floods. Some people once believed that humans could eliminate flood disasters in the Mississippi River basin by relying on water conservancy facilities, but in 1927, a large flood occurred in the Mississippi River, killing about 250 people [8]. In addition, every year, floods submerge public facilities such as roads and communication equipment, which also causes economic losses. At present, researchers are gradually turning disaster reduction measures to local flood storage and using flood detention areas to achieve economic benefits, such as introducing waterfowl in river floodplains and developing tourism.

4. Suspended mass changes caused by reservoir construction

The greatest impact of reservoir regulation on the hydrology, geomorphology and ecology of the river section occurs near the reservoir and decreases with the increase in the downstream distance of the dam. For example, at the mouth of the Mississippi River, a comparison shows that the flood scale before and after the dam construction is basically similar.

Some researchers claim that the construction of water conservancy facilities will not affect the transport of suspended sediment in the lower Mississippi River [9], but by comparing the state of the delta at the mouth of the river, it can be seen that the interception of sediment by the reservoir has greatly affected the topography of the downstream river section.

Reservoirs in the Mississippi River basin, mainly the main stem reservoirs in Missouri, are believed to reduce the sediment load along the river section studied in this paper. The suspended sediment transport of the Missouri River has been reduced by more than 80%. The reduction in sediment transport associated with the reservoir, combined with other activities such as channelization of floodwaters by river regulation and levees, has resulted in substantial adjustments to the riverbed along the study segment [10].

The average lifespan of a reservoir is 100 years. From the 1930s to the 1980s, a large number of reservoirs were built, which brought with them the problem of siltation. Reservoirs are often larger than natural lakes in terms of water storage area and water depth. Reservoirs are also responsible for flood control. The fluctuation of water levels reduces the suspended sediment in the river. At the lower reaches of the Mississippi River where it flows into the sea, the amount of sediment transported by the river has dropped significantly.

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5. Conclusion

After the large-scale construction of the reservoir group, it directly caused a huge change in the river flow. The water volume is directly related to human life, industrial and agricultural production, and is closely related to the physical parameters of the river and ecological stability. Therefore, quantifying the impact of reservoirs and dams and exploring the impact mechanism of reservoirs on rivers through comparison and simulation is not only closely related to social stability, but also can expand and improve the knowledge framework of hydrology.

The reservoirs and dams located on the main stream of the Mississippi River have a significant impact on the flow in the nearby river channel, but due to the comprehensive regulation of the reservoirs, the flow at the downstream entrance to the sea is less affected by hydraulic structures; however, according to the actual measurement results of different measuring stations on the main road, the construction of the reservoir has caused the annual minimum flow in the main road to increase year by year, the increase in the minimum flow in the river will eliminate seasonal differences to a certain extent, appropriately extend the shipping period, and change the habitat of aquatic organisms; over the past 50 years, the average annual flow has been on an upward trend [11]. Considering that there has been no drastic change in climate during the same period, it can be concluded that the construction of the dam has caused upstream floods that would have otherwise remained in the flood storage area to be discharged into the river channel.

In addition, because the levees prevented the flood from flowing into the flood detention areas on both sides of the river, it could only flow downstream along the river. The peak shape of the Mississippi River's annual flood process line tended to be sharper after the 19th century; on the other hand, in order to maintain the reservoir capacity, the reservoir should be desilted regularly and artificial floods should be created under appropriate conditions to transport silt.

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