Study on Mechanical Dredging Schemes Based on Different Dredging Positions in Gongzui Reservoir

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Abstract. This paper conducts a study on mechanical dredging schemes aiming at the siltation problem near the water intake of the right bank shoal in the right bank expansion area of Gongzui Reservoir. Four different dredging positions are set: 300m upstream of the dam on the right bank shoal (A1), near the funnel area in front of the dam (A2), a channel led out from the upstream of the dam (A3), and the area more than 300m upstream of the dam (A4). Combined with three typical water and sediment processes in high-flow year, normal-flow year, and low-flow year, the sedimentation volume and the change of flow field in front of the dam under different schemes are analyzed through a two-dimensional flow-sediment mathematical model. The results show that dredging within 300m in front of the dam results in a small overall sedimentation volume, which plays a positive role in reducing siltation. To further optimize the effect, it is suggested to construct a diversion dike in the area in front of the dam.

Keywords: Mechanical dredging, Sedimentation volume, Circulation flow, Dredging positions.

1 Introduction

Sedimentation poses significant hazards to reservoirs, which are reflected in multiple aspects. Firstly, sedimentation directly reduces the effective storage capacity of reservoirs, affecting their regulating capacity, thereby weakening their comprehensive benefits in flood control, water supply, power generation, etc. [1-3]. Secondly, with the continuous deposition of sediment, the sediment layer at the bottom of the reservoir gradually thickens, which may lead to a decrease in the water storage capacity of the reservoir [4], further affecting the demand for irrigation water downstream, especially during the peak irrigation period [5]. In addition, sedimentation may also cause a series of environmental problems, such as water quality deterioration and ecosystem destruction, which will have a negative impact on the surrounding ecological environment [6-7].

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Gongzui Reservoir is located in Gongzui Town, Shawan District, Leshan City, in the middle and lower reaches of the Dadu River in Sichuan Province. It is located in the middle and lower reaches of the Dadu River, the largest tributary of the Minjiang River system in the Yangtze River Basin, 90km away from Leshan City, controlling a drainage area of 76,130km². The right bank expansion is an important engineering goal of Gongzui Hydropower Plant, CHN ENERGY Investment Group Co.. Currently, Gongzui Power Plant is promoting the project approval and other related work. Once approved, the management of siltation in the right bank reservoir area will become an inevitable requirement. The continuous siltation caused by circulation affects the water diversion for the expansion, and understanding the impact of circulation on siltation can provide a basis for formulating targeted measures. At present, there is obvious siltation near the water intake of the right bank shoal, and the elevation of this area exceeds 520m, which affects water diversion after the expansion. Meanwhile, silt (especially coarse sand) and floating objects are prone to accumulate in front of the trash rack at the water intake, increasing water flow resistance, reducing water diversion flow, and even affecting the safe operation of the units. Therefore, based on the siltation situation of the right bank shoal in front of the dam and the location of the water intake, this paper formulates mechanical dredging schemes with different dredging positions and scales, uses a two-dimensional flow-sediment mathematical model to simulate and calculate the working conditions of different engineering schemes combined with different incoming water and sediment conditions, and studies the sedimentation and flow field changes at different dredging positions, so as to provide a scientific reference for engineering practice.

2 Study on Dredging Schemes of Gongzui Reservoir

Four dredging schemes are set according to the siltation of the right bank shoal and the hydrodynamic conditions in front of the dam to study the sedimentation of different dredging schemes.

2.1 Dredging Area A1

According to the requirements of water diversion for expansion, it is necessary to dredge the 300m upstream right bank shoal in front of the dam, as shown in Fig 1 (a) (the dredging area is referred to as A1). The elevation in the white closed line after dredging needs to be reduced to 510m, and the dredging volume is 123,900 m³.

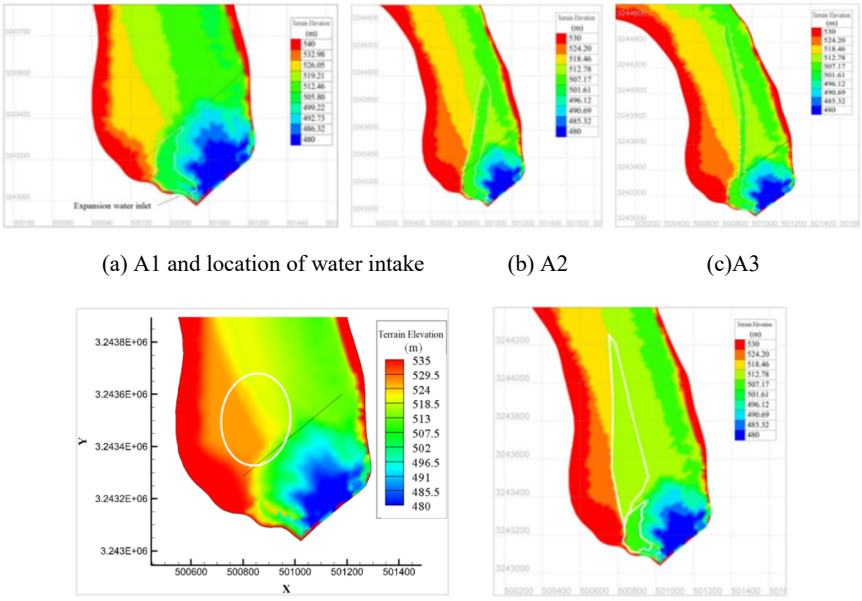
2.2 Dredging Areas A2 and A3

Considering that the flow field in front of the dam is mainly in the left area, and there is a circulation on the right bank in front of the dam, which is not conducive to water diversion and easily causes sedimentation, it is considered to dredge a flow path from the nearby main channel to divert the main flow to the right bank. Two schemes are mainly set here: one is to directly dredge near the funnel area in front of the dam, as

shown in Fig 1 (b) (the dredging area is referred to as A2); the other is to directly lead out a channel from the upstream of the dam, as shown in Fig 1 (c) (the dredging area is referred to as A3). The dredging volumes are 316,500 m³ and 302,000 m³ respectively.

2.3 Dredging Areas A4

Considering that the circulation of the right bank shoal in front of the dam may be affected by the siltation in the area more than 300m upstream of the dam (Fig 1 (d)), the area more than 300m upstream is dredged, as shown in Fig 1 (e) (the dredging area is referred to as A4). The dredging volume of this scheme is 706,900 m³.



(a) A1 and location of water intake (b) A2 (c)A3

(d) Siltation area more than 300m upstream of the dam (e) A4

Fig. 1. Dredging areas in front of the dam

3 Analysis of Mechanical Dredging Effects at Different Dredging Positions

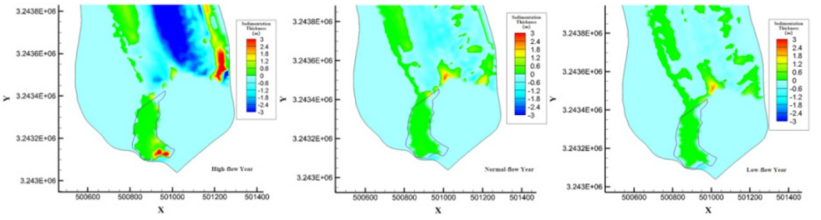
Based on three typical water and sediment processes (high-flow, normal-flow, and low-flow year), combined with the measured water level in front of the dam and the water diversion conditions of the left and right plant units and the expanded units, the sedimentation and flow field characteristics of each dredging position are analyzed. The rated water diversion flow per unit of the left and right plant units of Gongzui Hydropower Station is 289 m³/s. Here, two expanded units are installed, with a rated water diversion flow of 310.57 m³/s per unit. The specific schemes are shown in Table 1.

Table 1. Calculation Conditions of Dredging Schemes (Conventional Operation Mode)

Working Condition	Typical Year	Dredging Area	Working Condition	Typical Year	Dredging Area
Scheme Q1	High-flow year	A1 (123,900 m³)	Scheme Q4	High-flow year	A2 (316,500 m³)
Scheme Q2	Normal-flow year		Scheme Q5	Normal-flow year	
Scheme Q3	Low-flow year		Scheme Q6	Low-flow year	
Scheme Q7	High-flow year	A3 (302,000 m³)	Scheme Q10	High-flow year	A4 (706,900 m³)
Scheme Q8	Normal-flow year		Scheme Q11	Normal-flow year	
Scheme Q9	Low-flow year		Scheme Q12	Low-flow year	

3.1 Effect of Dredging Area A1

The sedimentation of the dredging position (A1) is counted, as shown in Table 2. From the calculation results, after adopting this dredging scheme, a certain amount of sedimentation occurs under different water and sediment conditions: 7,900 m³ in high-flow year, 640 m³in normal-flow year, and 200 m³ in low-flow years. Fig 2 shows the sedimentation distribution. There is obvious sedimentation within the dredging position, but the overall sedimentation thickness is not large, mainly due to the construction of upstream cascade reservoirs, resulting in a small sediment concentration in incoming water. Fig 3 shows the distribution of the flow field in front of the dam under different flow levels. It can be seen that there is a circulation at the dredging position of the right bank shoal. With the increase of flow, the range involved in the circulation becomes larger and closer to the water intake. The existence of the circulation will reduce the velocity at the location; the greater the sediment concentration, the more serious the sediment deposition. If the sediment retention efficiency of the upstream Pubugou Reservoir decreases and the sediment concentration in incoming water increases, the sedimentation in the dredging area will be accelerated.



(a) High-flow year (b) Normal-flow year (c)Low-flow year

Fig. 2. Cumulative scouring and silting distribution in front of the dam (dredging position A1)

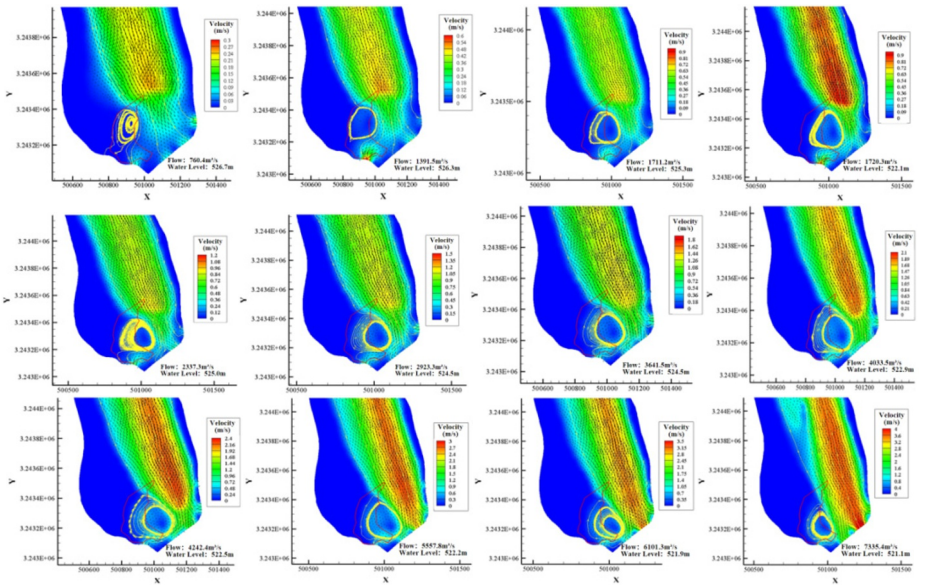


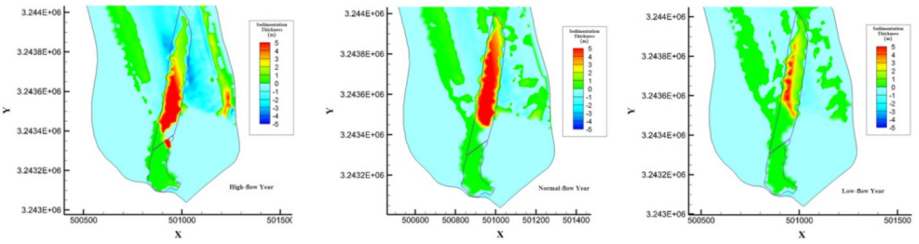
Fig. 3. Distribution of flow field in front of the dam (dredging position A1)

Table 2. Sedimentation Volume in Dredging Area A1

Working Condition	Typical Year	Dredging Volume	Sedimentation Volume in A1 Area (10,000 m³)
Scheme Q1	High-flow year	123,900 m³	0.79
Scheme Q2	Normal-flow year		0.064
Scheme Q3	Low-flow year		0.020

3.2 Effect of Dredging Area A2

The sedimentation of the dredging position (A2) is counted, as shown in Table 3. Different degrees of sedimentation occur under different water and sediment conditions. The sedimentation in the 300m area in front of the dam (A1 range) is equivalent to that of Schemes Q1-Q3, while the sedimentation in the dredging area beyond 300m in front of the dam is obvious. It can be seen from Fig 4 that sedimentation is serious in high-flow years and normal-flow year, and the sediment almost fills the flow path formed by dredging. Fig 5 shows the distribution of the flow field in front of the dam under different flow levels. It can be seen that the circulation can be eliminated to a certain extent when the flow is small, but there is still a circulation at the dredging position of the right bank shoal when the flow is large, but the circulation range is smaller than that of Schemes Q1-Q3. Although it can eliminate the circulation under small flow, the sedimentation in front of the dam mainly occurs during the high-flow period in the flood season. This scheme cannot well reduce the sedimentation in front of the dam, and the dredging volume is much larger than that of Schemes Q1-Q3.



(a) High-flow year (b) Normal-flow year (c)Low-flow year

Fig. 4. Cumulative scouring and silting distribution in front of the dam (dredging position A2)

Table 3. Sedimentation Volume in Dredging Area A1

Working Condition	Typical Year	Dredging Volume	Sedimentation Volume (10,000 m³)	
			A2 Area	A1 Area
Scheme Q4	High-flow year	316,500 m³	17.13	0.97
Scheme Q5	Normal-flow year		18.39	0.059
Scheme Q6	Low-flow year		7.36	0.012

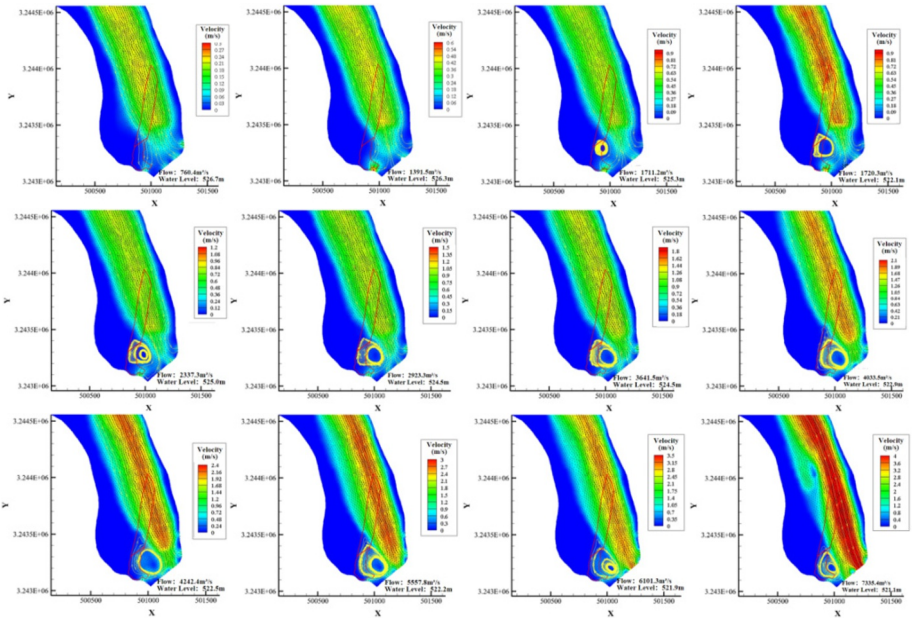
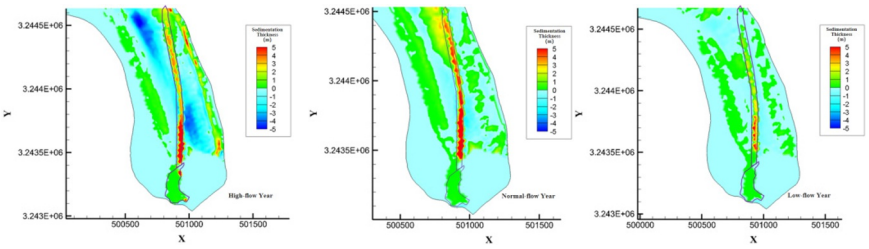


Fig. 5. Distribution of flow field in front of the dam (dredging position A2)

3.3 Effect of Dredging Area A3

The sedimentation of the dredging position (A3) is counted, as shown in Table 4. Different degrees of sedimentation occur under different water and sediment conditions.

The sedimentation in the 300m area in front of the dam (A1 range) is equivalent to that of Schemes Q1-Q6, while the sedimentation in the dredging area beyond 300m in front of the dam is serious. It can be seen from Fig 6 that the entire dredged channel has increasingly serious sedimentation from top to bottom in high-flow year and normal-flow year. Fig 7 shows the distribution of the flow field in front of the dam under different flow levels. It can be seen that the existence of the dredged channel can only reduce the circulation range but cannot eliminate the circulation, especially with little impact on the high-flow process. It can be seen that this scheme cannot well reduce the sedimentation in front of the dam, and the dredging volume is much larger than that of Schemes Q1-Q3.



(a) 2018 high-flow year (b) 2017 normal-flow year (c) 2022 low-flow year

Fig. 6. Cumulative scouring and silting distribution in front of the dam (dredging position A3)

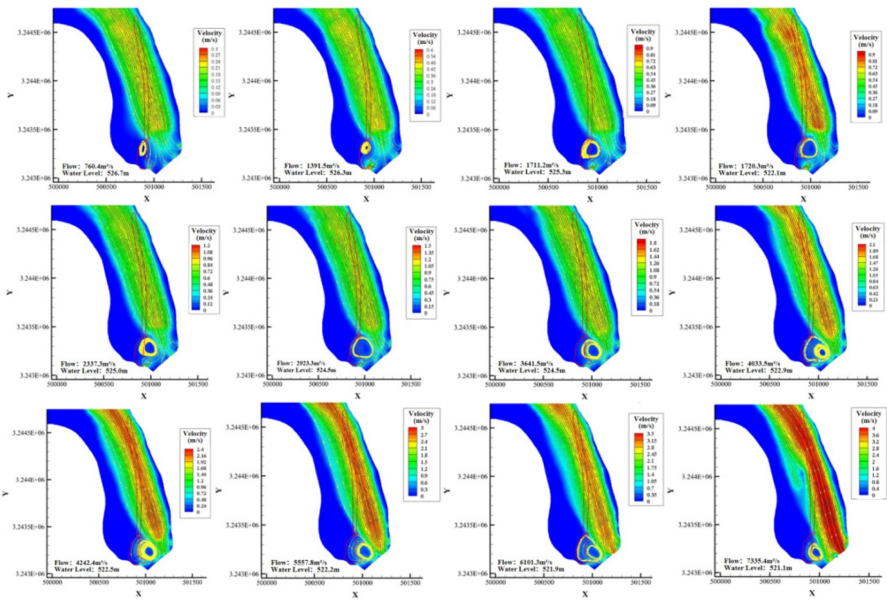


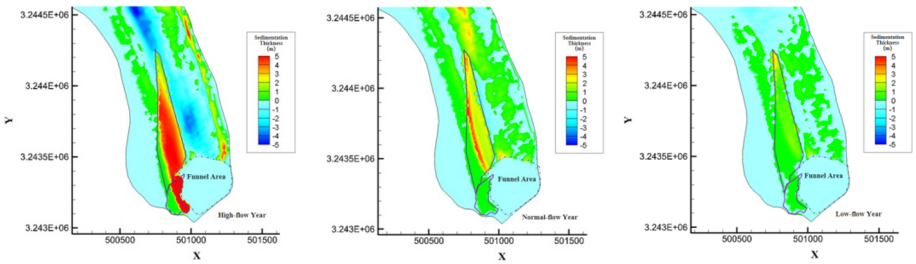
Fig. 7. Distribution of flow field in front of the dam (dredging position A3)

Table 4. Sedimentation Volume in Dredging Area A1

Working Condition	Typical Year	Dredging Volume	Sedimentation Volume (10,000 m³)	
			A3 Area	A1 Area
Scheme Q7	High-flow year	302,000 m³	14.47	0.86
Scheme Q8	Normal-flow year		15.60	0.060
Scheme Q9	Low-flow year		6.10	0.014

3.4 Effect of Dredging Area A4

The sedimentation of the dredging position (A4) is counted, as shown in Table 5. Different degrees of sedimentation occur under different water and sediment conditions. The sedimentation in the 300m area in front of the dam (A1 range) is small, and different degrees of sedimentation occur in the dredging area beyond 300m in front of the dam (as shown in Fig 8). Fig 9 shows the distribution of the flow field in front of the dam under different flow levels. It can be seen that although this scheme cannot completely eliminate the swirling flow, it can reduce the circulation range to a certain extent and keep the circulation away from the unit water intake, which is beneficial to the safety of water diversion of the power station. The serious sedimentation in the area beyond 300m in front of the dam is mainly because the main channel of the river is close to the right bank, where the flow velocity is small. In addition, the upstream river channel has a certain amount of scouring, resulting in a high sediment concentration in the water body, leading to obvious sedimentation here. It can be seen that this scheme can weaken the circulation to a certain extent, but the sedimentation in front of the dam is still obvious, and the dredging volume is much larger than that of Schemes Q1-Q3.



(a) High-flow year (b) Normal-flow year (c) Low-flow year

Fig. 8. Cumulative scouring and silting distribution in front of the dam (dredging position A4)

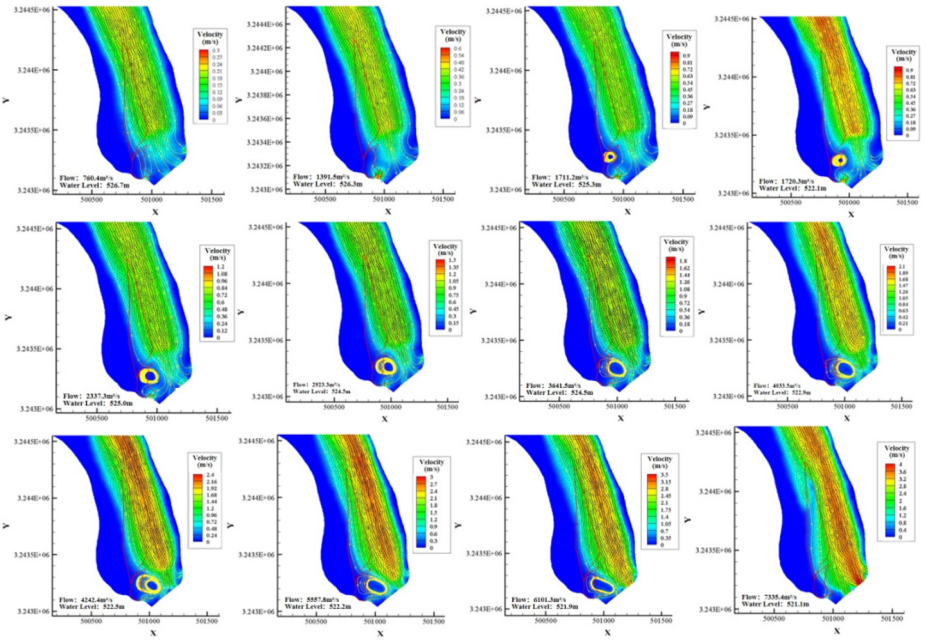


Fig. 9. Distribution of flow field in front of the dam (dredging position A4)

Table 5. Sedimentation Volume in Dredging Area A1

Working Condition	Typical Year	Dredging Volume	Sedimentation Volume (10,000 m³)	
			A4 Area	A1 Area
Scheme Q10	High-flow year	706,900 m³	44.19	10.82
Scheme Q11	Normal-flow year		17.61	0.20
Scheme Q12	Low-flow year		5.18	0.0043

4 Conclusions

This study addresses the practical engineering needs of Gongzui Reservoir, where the siltation elevation near the water intake of the right bank shoal exceeds 520m, affecting water diversion for the expansion project, and the accumulation of silt and floating objects threatens the safe operation of the units. Based on the siltation situation of the right bank shoal in front of the dam and the location of the water intake, four mechanical dredging schemes with different dredging positions and scales were formulated. The impacts of different dredging positions on sedimentation volume and flow field under various water and sediment conditions were analyzed, aiming to provide a scientific basis for reservoir dredging engineering practice. Comprehensively, the dredging scheme for the 300m right bank shoal in front of the dam (A1) is a relatively better choice at present, which can divert water to the right bank to a certain extent. However, the sedimentation in the dredged areas of all four schemes is relatively obvious,

requiring engineering measures to eliminate the impact of backflow. Therefore, it is suggested to construct a diversion dike in the area in front of the dam to guide the main river channel to the middle of the river, so as to reduce the siltation of the right bank shoal.

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