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A Study on Optimization of Limited Water Level and Water Impounding Time of Three Gorges Project

A STUDY ON OPTIMIZATION OF LIMITED WATER LEVEL AND WATER IMPOUNDING TIME OF THREE GORGES PROJECT

Deng Jinyun[1], Gan Fuwan[2] ,Yue Hongyan[3]

[1] Associate Professor, State Key Laboratory of Water Resources and Hydropower Engineering Science, Wuhan University, Wuhan, Hubei, 430072, China, e-mail: djywh@263.net

[2] Researcher, State Key Laboratory of Water Resources and Hydropower Engineering Science, Wuhan University, Wuhan, Hubei, 430072, China, e-mail: gfwenjoylife@163.com

[3] Researcher, Yangtze River Scientific Research Institute, Wuhan, Hubei, 430072, China, e-mail: djywh@263.net

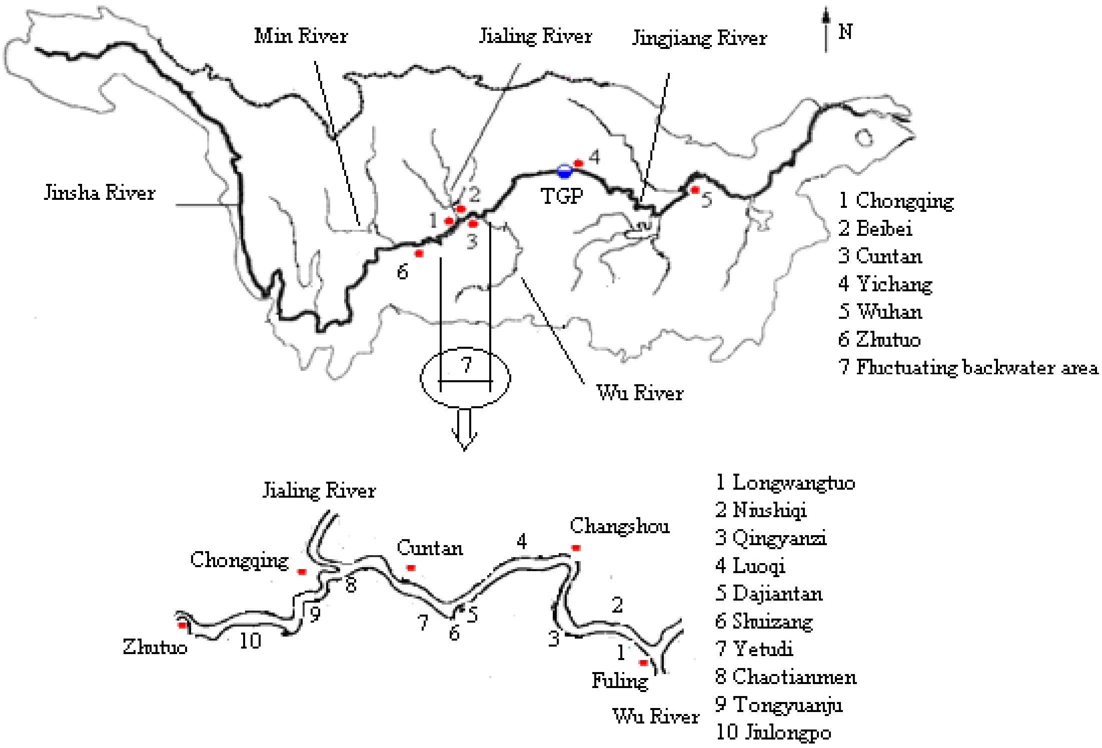
ABSTRACT

The Three Gorges Project(TGP) is the key project in developing and harnessing the Yangtze River, with huge comprehensive benefits of flood control, navigation improvement and power generation. The rule of regulation will generate great impact on its comprehensive benefit. Following the hydroelectric development and the change of incoming water and sediment conditions in the upper Yangtze basin, in order to impound more water in flood recession period and realize the maximum comprehensive benefit, it is necessary to study the readjustment of the flood limited water level and impound time of TGP. In this paper, we present an optimal rule that is impounding water ahead of normal schedule. Comparing with the design rule, the impacts of the optimal on flood control, navigation and power generation are discussed. The results show that under the precondition of satisfied with the need of flood control, the optimal rule of TGP can greatly increase the total benefit of the reservoir, which can be referred to the actual operation of TGP.

Key Words: regulation, sediment deposition, optimization

1. INTRODUCTION

It is more and more important of the efficient utilize of water resource in recent years than ever for the world economy development. The reservoir is a main project and efficient method of human-being to exploit the water resource, and more attention is paid on exerting its comprehensive benefit. The Three Gorges Project(TGP) is the key project in developing and harnessing the Yangtze River, with huge comprehensive benefits of flood control, navigation improvement and power generation(Figture 1). It is the largest water conservancy project ever built in China, and also in the world. With the normal pool level at 175m, the total storage capacity is about 39.3 billion m^3(Dai, et.al,2006). The designed regulation rule of TGP which framed twenty years ago is as follows: The water level at dam is limited below 145m during the flood season from June to September, elevated to 175m from 1October to the end of this month by impounding enough water, and slowly dropped down during the period from January to April for the purpose of meeting the need of navigation and power generation. In additional, the release discharge of flow in flood season is controlled no larger than $55000m^3/s$, in order to keep the safety of the downstream area, especially the safety of the Jingjiang Reach.



Figture 1 Sketch Map of the Yangtze River

The water and sediment conditions at the upper basin of Yangtze River has been changed largely since 1990s, the incoming water and sediment of TGP decreased obviously, especially in the flood recession period which mainly including September and October(Gan et.ai,2006). Following the hydroelectric development in the upper Yangtze basin, dams of Xiangjiaba and Xiluodu being constructed in the upstream reach will operate soon in 2014, large amount of sediment will be trapped and the distribution of water runoff will be altered by water impoundment(Deng et al,2007), the decrease trend of the incoming water and sediment of TGP in the flood recession period might be more serious than ever, which will cause the reservoir can not impound enough water at the end of October, and will affect the accommodation in the next dry season, which will reduce the total benefit of the TGP. Under such conditions, in order to impound more water in flood recession period and realize the maximum comprehensive benefit, it is necessary to survey the rationality of the design regulation rule over again, and readjust the flood limited water level and impound time of TGP. Meanwhile, it had already been pointed out in the design argumentation of TGP that the design regulation rule was conservative and had possibility to be optimized.

Considering the flood situation in the upper Yangtze basin, the source of flood of TGP is coming from Jinsha River, Jialing River, Min River, Wu River and the region among them(Figure 1).The main flood season is July and August, flood begins to decrease in September, and the flood in the following months is also small(Xu, et al, 2004). In order to impound more water in flood recession period, especially after the construction of the dams in upper basin, an optimal regulation rule is presented as follows: considering the receding trend of flood in September, the impounding time of TGP is changed to 1 September, and the continuance length of limited water level is also shortened down(Deng,2006).The possibility and rationality of the new regulation rule is connect closely with the flood control, navigation and power generation of TGP, and in this paper, the impact of the optimal rule on flood control, navigation and power generation of TGP is analyzed, and the comparison with design rule is also discussed.

2. IMPACT ON FLOOD CONTROL

Flood control is the key factor of TGP, and also is the most important one. The possibility of change the impounding time of TGP to 1 September is mainly decided by its impact on flood control. Herein, the field data series from 1890 to 2002 at Yichang station is chosen to analyze the flood in September, because the Yichang station is the closest gauging station near the dam of TGP and the runoff series at Yichang can represent the runoff condition at dam site. Analyses are paid on the flood at Yichang station in September from following portions.

(1)The super flood was only occurred in the first ten days of September, but scarcely occurred in the rest days of this month. There were 8 floods in the Yangtze River in historical documents (Yuan, 2001). Among them, there were 5 times occurred in June, 2 times in July, and only 1 times maybe occur in September of 1796. In the field discharge series from 1890 to 2002, there were 12 super floods gauged. But most of them were occurred in July and August, only the floods in 1896, 1945 and 1966 were occurred in the first ten days of September.

(2)Based on the mean daily discharge series from 1890 to 2002, it is found that the trends of incoming discharge at Yichang station fluctuated largely. Years in which peak discharge in September exceeds 55000m^3/s are 1896, 1905, 1938 and 1966, occupies 3.7 percent of total years. Meanwhile, it is only 14 days in which perk discharge is larger than 55000m^3/s, the ratio is 0.4 percent of the total days. Based on the design regulation rule of TGP, it can be seen that the possibility of which runoff discharge larger than 55000 m^3/s is also small.

(3) It is shown by the flood routing simulation that the floods in the series from 1890 to 2002 can be safely regulated by TGP when impounding water in 1, September (Gan, et al.,2006).

In short, it is shown that the probability of the super flood occurrence at Yichang is very small. Due to the important role of TGP in Yangtze River, it should be considered for TGP to deal with the super flood that may occur in the future, though its probability is so small(Li et al, 2006). Herein, we presented a new method to deal with the super flood in September through controlling water level in impounding period. To the different kinds of flood, firstly, it needs to decide the control level in each ten days in September. Secondly, in the process of impounding water, if the water level reaches the corresponding control level in each ten days, the reservoir needs to increase the release discharge to keep the control level. If the incoming discharge is less than maximum release discharge of the reservoir, the reservoir release discharge will equal to the incoming discharge, or else, the reservoir release discharge equal to the maximum release discharge. According to this method, when super flood occurs in September, the maximum water level at the dam will not exceed the normal pool level 175 m. Table 1 lists the control water levels under the different designed floods.

Table 1 Control levels in each ten days of September under different kinds of flood

Return period(Year)			Control level(m)		
First ten days	Second ten days	Last ten days	First ten days	Second ten days	Last ten days
1000	1000	1000	154	168	172
1000	1000	100	158	171	175
1000	100	1000	159	172	172
1000	100	100	162	174	175
100	1000	1000	166	168	172
100	1000	100	169	171	175
100	100	1000	169	172	172

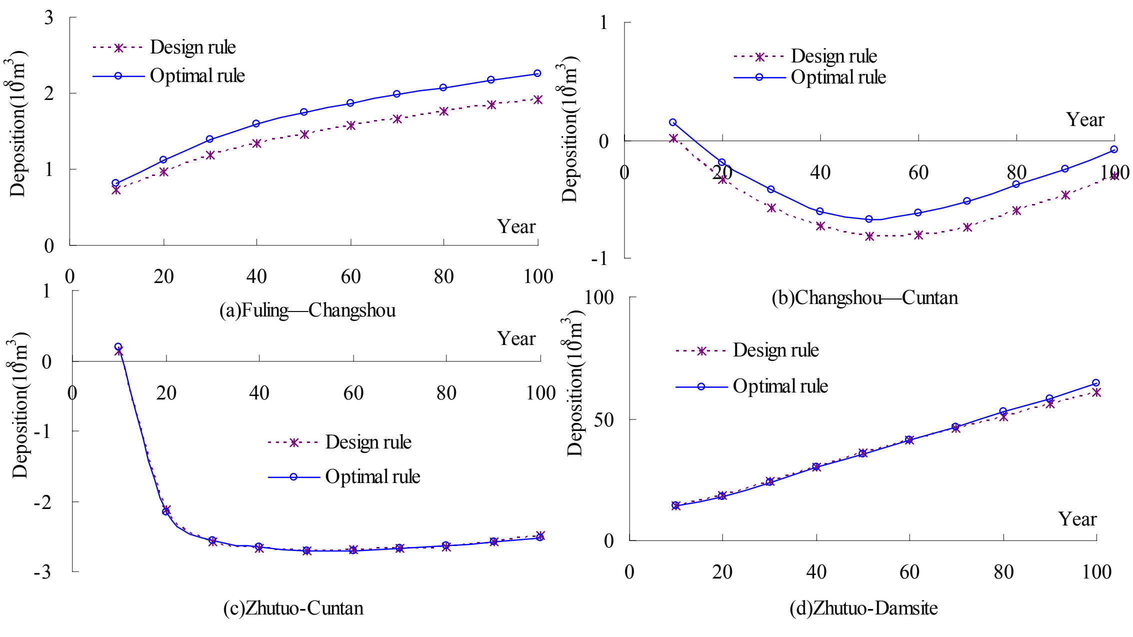
3. IMPACT ON NAVIGATION

3.1 Fluctuating backwater area

Navigation is also an important aspect of reservoir comprehensive benefit.

After the built of reservoir, especially after the change of limit water level and impounding time of TGP, the navigation conditions upper to dam improves for the water level at dam increased, but in the fluctuating backwater area, the reach has he attributes of natural river and reservoir, sediment deposition may cause obvious navigation problem.

The sediment deposition of TGP is calculated by 1-D model, which detail equations and methods are shown in the literatures of Peng (Peng et al. 2004). The study area ranges from Zhutuo to the Dam with the length of 756km, including the branches named Jialing River and Wu River. In the model, the runoff and sediment series from 1991 to 2000 is used, and the effect of construction of Xiajiaba and Xiluodu reservoirs are also considered. Meanwhile, considering the safety of super flood, the control level of September adopts the lowest one, namely, the control water level respectively is 154, 168, 172m.Based on the result of the 1-D model, sediment deposition and its affect on navigation in fluctuating backwater area are analyzed. Figture 2 shows the sediment deposition in the fluctuating backwater area and whole reservoir. It is shown that sediment deposition under the condition of optimal rule is larger than that under the design rule, but the difference is small comparing with the huge amount of deposition in the whole reservoir. In the reach upper to Changshou, the erosion occurs for the reason of dam built of Xiangjiaba and Xiluodu, which will be advantage to increase the water depth for the purpose of navigation.



Figture.2 Sediment deposition in the fluctuating backwater area

In the fluctuating backwater area, there are many deposited shoals in which the navigation conditions are worse in the natural condition, such as Jiulongpo, Tongyuanju, Chaotianmen, Yetudi, Shuizang, Dajiantan, Luoqi, Qingyanzi, Niusiqi and Longwangtuo(Figture 1). It is shown in Figture 3 that the relative water depth increment comparing with the natural condition of the shoals in fluctuating backwater area under the conditions of design rule and optimal rule. After the TGP built, the water level increase largely at dam site, and the water depth in the fluctuating backwater area increases, which will improve the navigation condition in the reach upper to dam(Li et al,2007). After the change of the impounding time, the sediment deposition will increase in the fluctuating backwater area, and the water depth decrease for the increment of deposition, but comparing with the increased water depth caused by damming, the integrated water depth is also increased than that before the building of dam, and the minimum increment is about 1.1m even at the end of 100 th year after the construction of TGP. In a word, both the water depth under the condition of design rule and optimal rule are all improved that that of natural condition, which satisfied with the need of navigation in the reach upper to dam.

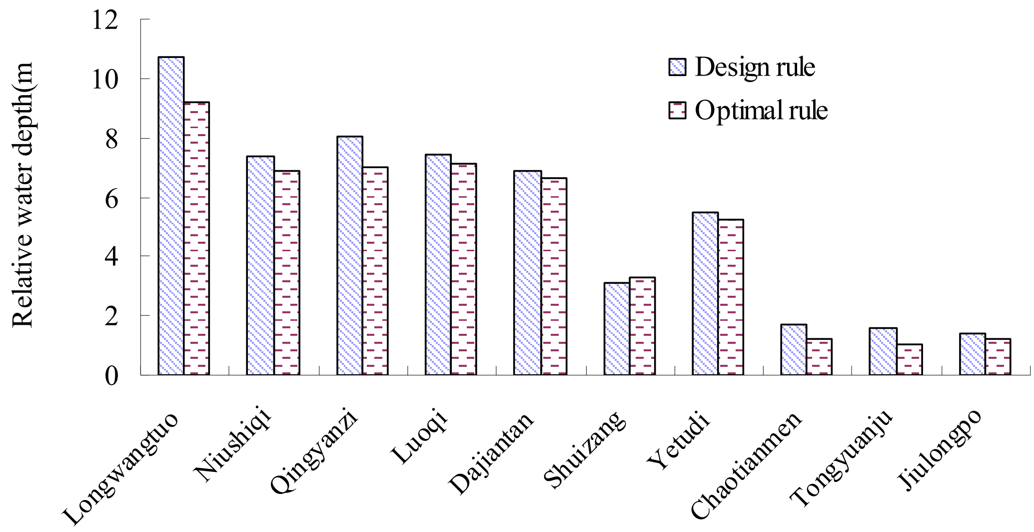


Figure 3 Change of relative water depth of shoals in the fluctuating backwater area at the end of 100^{th} year after the TGP construction

3.2 Downstream reaches

The release discharge is a factor affecting the navigation conditions of the whole downstream reaches. In order to compare the change of navigation conditions between the design rule and optimal rule, the flood routing model is built, which detail equations and methods are shown in the literatures of Deng (Deng, 2006). In this model, the runoff series from 1950 to 2002 is used. Table 2 shows the amount of years in which the reservoir is full impoundment under the conditions of design rule and optimal rule. It is shown that there are only 13 years in which the reservoir can impound enough water at the end of October during the total 53 years. On the contrary, there are 49 years under the condition of optimal regulation. It is shown that the optimal rule is advantage to impounding enough water of the reservoir.

Table 2 Amount of years in which TGP full impounded under the series from 1950 to2002

Month	Design rule	Optimal rule
October	13a	49a
November	48a	52a
December	50a	52a

The runoff in the year of 2002 is the lowest in the series from 1991 to 2002(Deng, 2006). Figure 4 shows the comparison of release discharge under the conditions of design rule and optimal rule. From the figure, it can be seen that the release discharge under both design rule and optimal rule increases in the dry season, the release discharge is larger under the condition of optimal rule, which is more benefit to the navigation in the downstream reaches.

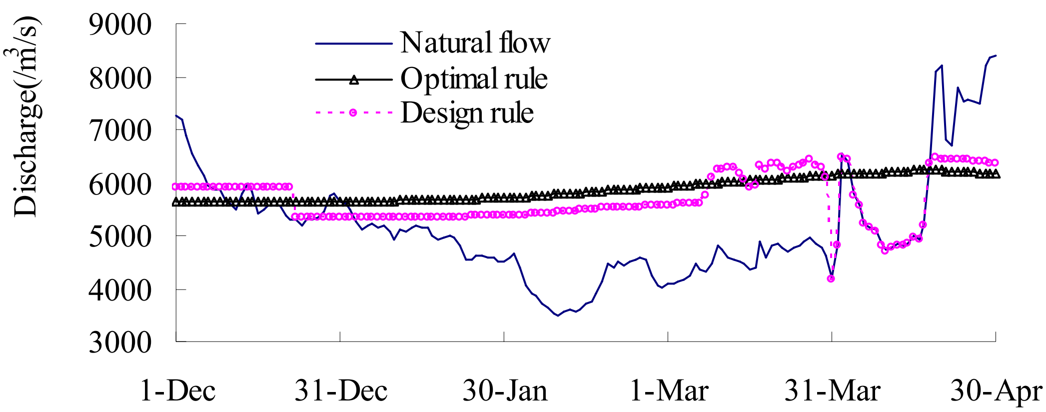


Figure 4 Comparison between the different release discharge under the conditions of design rule and optimal rule

4 IMPACT ON HYDROPOWER GENERATION

Compared with the design rule, the amount of power generation under the condition of optimal rule is larger for the longer time of the high water level at dam. Table 4 lists the increased hydropower and the benefit under the condition of design rule and optimal rule. The price of each degree of hydropower is calculated as 0.245 RMB. It can be seen that the amount of hydropower increases largely if theTGP adopts the optimal rule, and the economic profit would increase 11.6 billion RMB per year.

Tab.3 Increment of hydropower and profit under the condition of optimal rule comparing with the design rule

Item	Optimal rule- Design rule
Increment of hydropower(10^8kwh)	47.52
Economic profit(10^8RMB)	11.6

5 CONCLUSION

TGP is the key project in developing and harnessing the Yangtze River, with huge comprehensive benefits of flood control, navigation improvement and power generation. In order to impound more water in flood recession period and realize the maximum comprehensive benefit, it is necessary to study the readjustment of the flood limited water level and impound time of TGP. Comparing with the design rule, it is more advantage to navigation and power generation of optimal rule of TGP, under the precondition of satisfied with the need of flood control. The optimal rule of TGP can greatly increase the total benefit of the reservoir, which can be referred to the actual operation of TGP in the future.

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