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Comprehensive operation of reservoirs and sluice-pump groups in the pearl river basin

Hydrolink

COMPREHENSIVE OPERATION OF RESERVOIRS AND SLUICE-PUMP GROUPS IN THE PEARL RIVER BASIN

BY ZHIPENG MA, SEN WANG, DONGHUI WAN, KANG ZHANG & HUAZHI ZOU

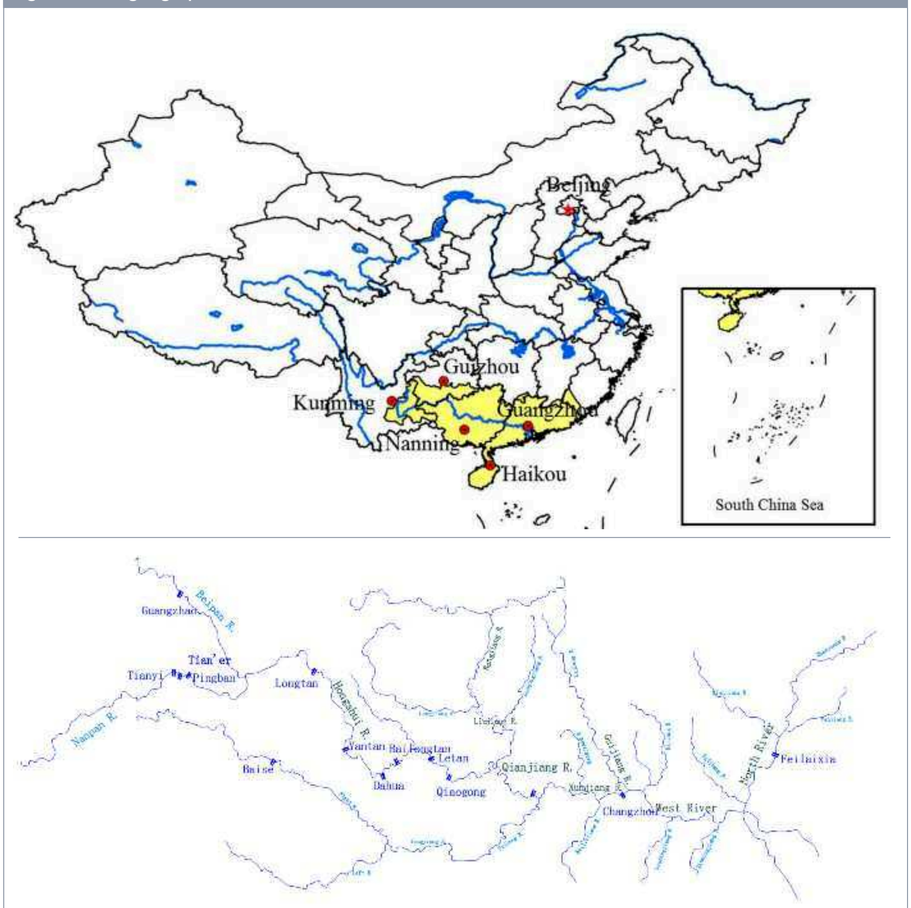
In order to prevent flood and drought disasters, cascade reservoirs and embankments have been constructed in the main river, and numerous sluices and pumps have also been installed in the delta of the Pearl River. These manmade projects have caused substantial changes in the hydraulic regime in the Pearl River basin. We propose a 1D/2D coupled flood model to precisely characterize flood flows accounting for how the water flows out of and then returns to the main channel.

In order to better satisfy the various water demands in the Pearl River basin, such as flood control, power generation, water supply, suppression of saltwater intrusion, navigation security, and eco-environment protection, we have developed a multi-objective comprehensive management model, which takes into account the flood control operation of key cascade reservoirs, the storage of water at the end of the flood period, water releases in the dry period, and the combined operation of sluice-pump groups. Significant social, economic, and environmental benefits can be achieved from the comprehensive operation of the sluices in the Pearl River basin.

Introduction

The Pearl River is the second largest river in China next to the Yangtze River in terms of discharge. In order to generate power, control flooding, and supply fresh water, numerous reservoirs have been constructed in the upper and middle reaches of the Pearl River, and the embankments in the middle and lower reaches of the river have been strengthened, resulting in substantial changes in the hydraulic regime in the Pearl River basin. A major problem is that the control and use of water resources for multiple purposes, such as flood control, power generation, water supply, salinity suppression, satisfying ecological and environmental constraints and navigation, should be well coordinated, which can be complicated by the large drainage area with no reservoirs providing river flow regulation and long water transfer distance (about 1000 km from the upstream Tianyi Reservoir to the estuary).

Figure 1. The geographic location of the Pearl River basin

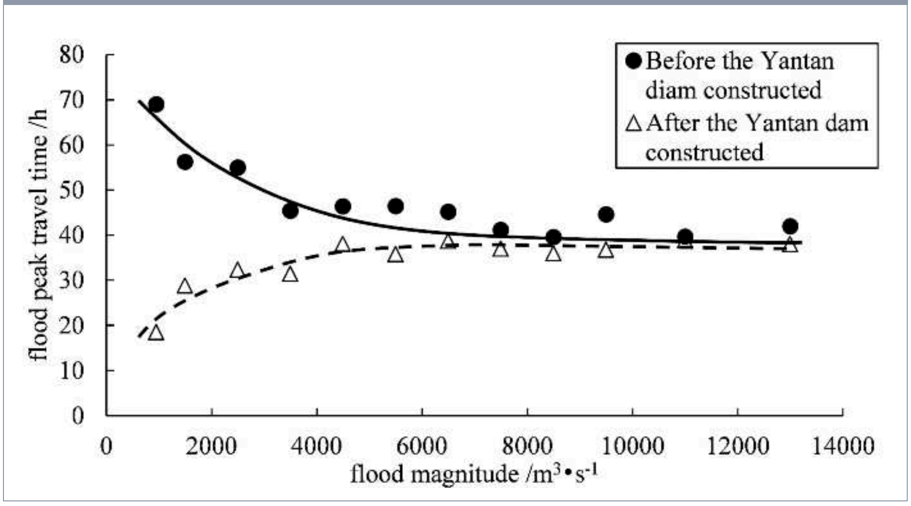


Obviously, the existing operation rules may not be adaptable to such dramatic changes in the Pearl River basin. The Pearl River Delta is a low-lying area surrounding the Pearl River estuary with a dense network of cities and a large population, and it is now one of the three largest economic zones in China. The river system of the Pearl River Delta consists of thousands of river branches with numerous sluices and pumps The hydrodynamics and mass transfer in the Pearl River Delta can be affected simultaneously by multiple factors such as runoff, tides and hydraulic structures. Thus, the Pearl River Delta is considered to be one of the most complex delta water systems in China, making it extremely difficult for the multi-objective operation of sluices and their pumps.

Changes in hydrologic regime

A total of 257 flood events of different magnitudes in the river section with cascade reservoirs were measured, and changes in their travel time before and after the construction of cascade reservoirs in the upper reach were comprehensively compared by statistical analysis, hydrological methods and hydrodynamic models. The results of this comparison showed that the speed of propagation of moderate and small floods increased after the construction of the cascade reservoirs, resulting in a decrease in the average travel time over the reach from Longtan Reservoir to Qiaogong Reservoir (about 422 km) by about 13 hours. This comprehensive comparison approach uses the hydrological method and the hydrodynamic model mutual verification method to calculate the flood propagation time, which can make full use of available data and information and improve the computational efficiency without compromising accuracy compared with traditional hydrological method. For the middle and downstream part of the system with numerous embankments, in order to deal with the problem of needing to estimate empirically main channel outflows in the hydrological method, we propose a 1D/2D coupled flood model to precisely describe how part of the flood waters flows out of and then returns to the main channel, which can be solved by the Riemann problem-based method. The peak flood flow that returns to the main channel is increased by about 10.4% on average compared with the natural flood flow, and the higher the flood magnitude, the more pronounced the phenomenon of water returning to the main channel. This contributes to better understanding of the variation and evolution parameters of flood events of different magnitudes, and thus provides valuable insights into the water control for the complete or partial returning of water to the main channel, flood control in the Pearl River basin, and the construction of key water conservancy projects.

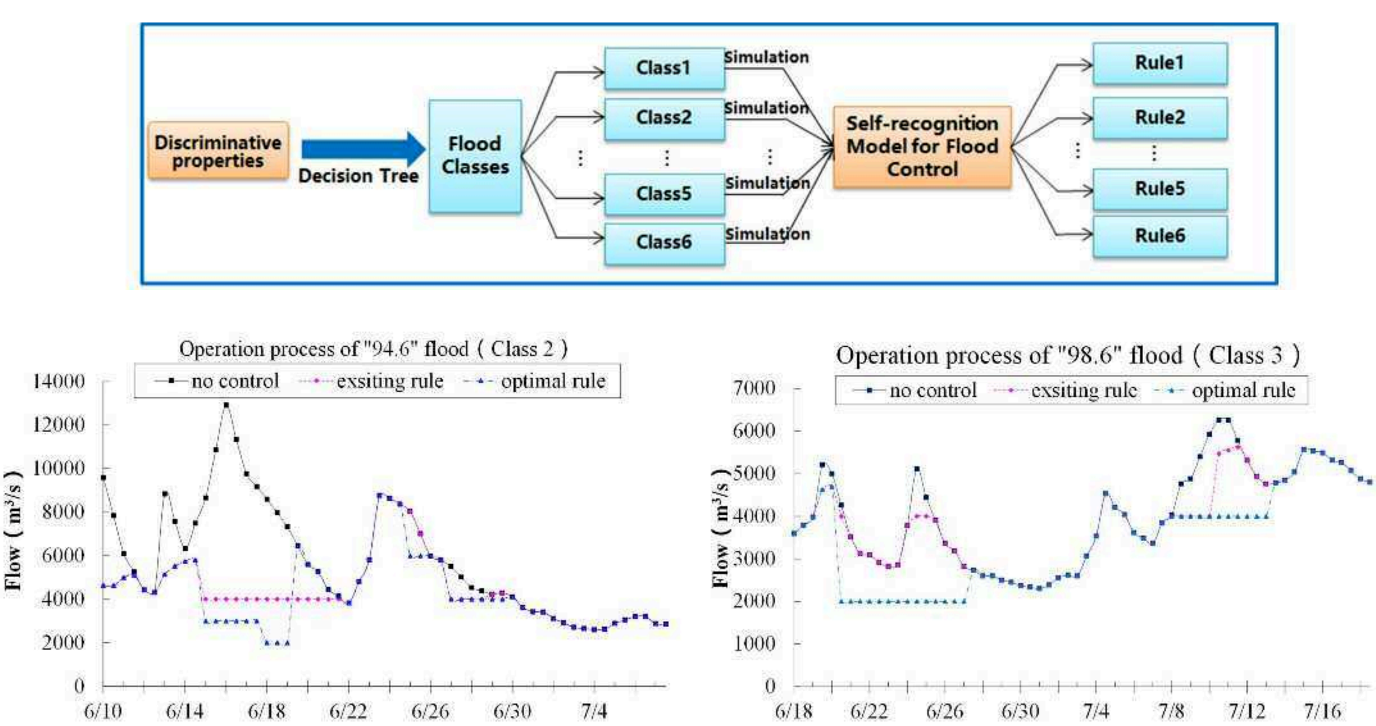
Figure 2. Changes of flood travel time and flood hydrograph in the Pearl River basin



Flood control operation

Considering the complex flood scenarios and limited flood control capacity, we propose a method for classifying flood events based on their discriminative properties, such as the stage of flood, the difference in the occurrence time of flood peak, and the ratio of flood volume between upstream and downstream. We developed a flood control operation model based on the self-recognition of flood classes, and the discrimination of different flood events and corresponding discharge of reservoirs. This enables the dynamic self-recognition of flood classes and real-time control of discharge, making it possible to make full use of limited

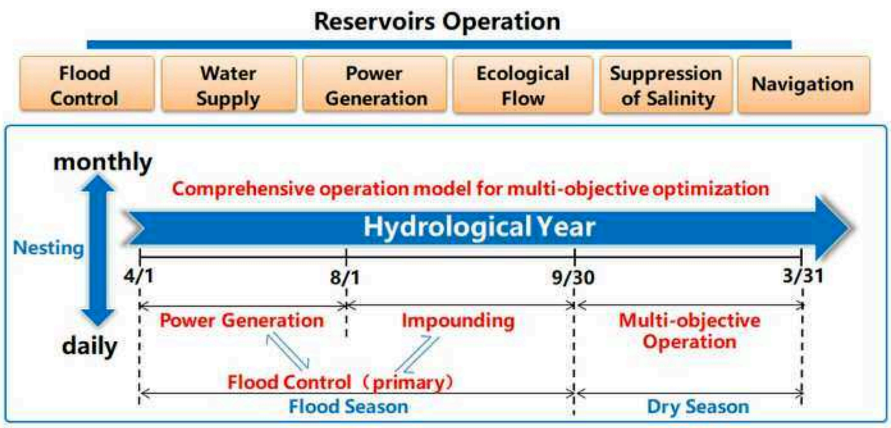
Figure 3. Self-recognition of flood classes and operation process of typical floods

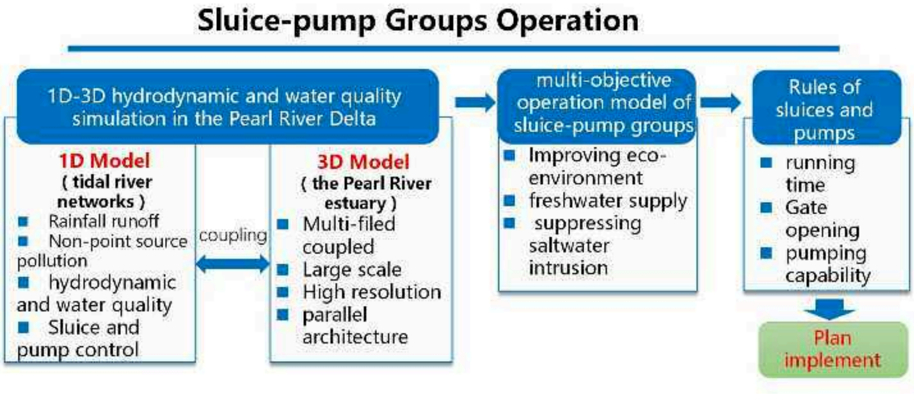


flood control storage. As a result, the flood control capacity can be significantly improved in cases of floods occurring in the basin, or in the middle and lower reaches of the river. Compared with the existing method, the peak flood flow occurring in the basin in June 1994 is reduced by 1600 m³/s, and its probability of occurrence is reduced from once in 200 years to once in 60 years; whereas the peak flood flow occurring in the middle and lower reaches of the river in June 1998 is reduced by 2300 m³/s, and its probability is reduced from once in 200 years to once in 100 years.

Comprehensive management

In order to better satisfy the diverse water demands in the Pearl River basin, we developed a multi-objective comprehensive management model consisting of both mid-and-long term scheduling and short-term scheduling. This model can serve multiple purposes such as flood control, power generation, water supply, satisfying ecological and environmental constraints, navigation, and suppression of salinity by integrating monthly multi-objective operations in the flood and dry seasons and daily flood control and power generation operations, the impounding of water at the end of the flood period, and the water storage in the dry period. Attempts have also been made to ensure reliable interconnection and switching between different tasks under different hydraulic conditions. As a result, the total power generation of the cascaded hydropower stations increased by 0.9 billion kWh over the period from 2014 to 2016, and the daily reliability of ecological flow and discharge for the suppression of saltwater intrusion in the control section have respectively reached 95% and 85% respectively over the period from 2015 to 2016. In addition, the water storage increased by 0.85 billion m3 with an increase rate of 8.6% in 2015. A simulation platform was used for mass (e.g., pollutants and salts) transfer and for the operation of sluices and their pumps, taking into account various dynamic factors such as runoff, tide and wind. This makes it possible to produce high-precision simulations of hydrodynamics and mass transfer in the Pearl River Delta. The coordinated operation of sluices and their pumps contributes to improved management of the cascade reservoirs in terms of the opening and closing timing of sluices and their pumps, salinity suppression and freshwater supplement. The results show that some hydrological indexes, such as the pollutant concentration in river branches and water storage and supply can be effectively improved. ■



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