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Editorial

Reservoir Control Operations and Water Resources Management

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1. Introduction

Water resources are among the most essential materials required for human survival and development. Water resources management is the activity of planning, developing, distributing, and managing the optimum use of water resources. Effective water resources management is crucial for sustaining ecosystems, supporting economic development, and ensuring social well-being [1]. It optimizes the use of water for food production and energy generation, ensuring that water, food, and energy systems have access to necessary resources while preserving environmental sustainability. Additionally, it strengthens resilience against natural disasters such as floods and droughts, promotes equitable access to resources, and upholds cultural and recreational values. Overall, it is essential for balancing human and environmental needs while ensuring long-term water availability [2]. However, water resources management is currently under increasing strain due to factors such as population growth, climate change impacts, and growing demand for water, food, and energy [3,4].

Reservoirs are a central component of water resources management, offering essential storage and regulation capabilities that support a range of water needs and environmental objectives. Optimal reservoir operation is one of the most effective non-structural measures for improving water utilization efficiency without requiring additional investment [5]. The successful operation of reservoirs and water resources requires a comprehensive understanding of modeling-related uncertainties and the integrative application of artificial intelligence technology to generate sustainable solutions for water, food, and energy systems in a changing environment [6,7]. Through the publication of this Special Issue, we seek to stimulate further research and dialogue on this critical topic, thereby contributing to global efforts aimed at achieving water security and sustainability.

2. Summary of the Contributions in This Special Issue

2.1. Reservoir Flood Control Operation

Flood control operation is a significant way to prevent the threats from flood risks to ecology, environment, infrastructure, agriculture, and even human life. Three papers addressed new models in reservoir flood control operation (contributions 1–3). Contribution 1 developed a dual-objective five-reservoir operation model by considering the flooding risks both downstream of the basin and in the Miyun reservoir area. A parameterization–simulation–optimization approach was employed to obtain the Pareto-optimal front, providing a list of optimal rule parameters for customized risk preferences. They found that the current schemes result in a 10.5% higher upstream inundation loss and an unsatisfactory CNY 17 million of equivalent water transfer loss compared to the operating rule optimized in the study.

Contribution 2 presented a flood risk control method oriented towards floodwater utilization that considers multiple main flood risk factors. The proposed method not only achieved the specifications of the flood limited water level (FLWL) under various acceptable risks but also dynamically controlled the water level to enhance floodwater utilization.

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They indicated that the proposed method raised the FLWL by 1.00 m above the present FLWL in the absence of flood risk. The available flood resources in both the wet and dry seasons increased, on average, by 0.83 and 0.81 billion m^3, and the flood risk remained within an acceptable range after raising the FLWL by 1.00 m.

In Contribution 3, a joint-optimized operation model of sluices in the group that combined "offline calculation" and "online search" was proposed to investigate the optimal sluice operation under high-intensity peak shaving and frequency regulation. The authors found that the total number of adjustments of the sluices of the cascade hydropower stations was reduced from 1195 to 675, a reduction of 43.5%, and the leading hydropower station, Pubugou, met water level control requirements, whereas the fluctuations in the water levels of the two downstream daily regulating hydropower stations, Shenxigou and Zhentouba, were reduced by 1.38 m and 0.55 m, respectively.

2.2. AI-Based New Monitoring Technology in Water Research

Climate change has exacerbated severe rainfall events, leading to rapid and unpredictable fluctuations in river water levels, necessitating the development of new monitoring technology (contributions 4 and 5). In Contribution 4, an innovative methodology was proposed that leveraged ResNet-50, a Convolutional Neural Network (CNN) model, to identify distinct water level features in Closed-Circuit Television (CCTV) river imagery under various weather conditions. They indicated that the method provided an accuracy range of 83.6% to 96%, with clear days providing the highest accuracy and heavy rainfall providing the lowest accuracy. The study introduced a promising real-time river water level monitoring solution, significantly contributing to flood control and disaster management strategies. Contribution 5 introduced a dam deformation prediction model based on a long short-term memory (LSTM) model with interferometric synthetic aperture radar (InSAR). With a case study in the Xiaolangdi reservoir, they revealed that the cumulative deformation accuracy was 95% compared with the on-site measurement data at the typical point P. The correlation between the reservoir level and dam deformation was found to be 0.81. The overall deformation error of the dam was predicted to be within 10 percent. The results showed that the combination of InSAR and LSTM could predict dam failure and prevent potential failure risks by adjusting the reservoir levels.

2.3. Changing Environmental Evaluation

Current global climate change and human activities have increased uncertainty in the hydrological cycle. In this changing environment, the risks and characteristics of flood, drought, and other disasters are varied, posing challenges to water safety (contributions 6–8). Contribution 6 investigated sedimentation characteristics under the influence of multiple factors in the main urban area of the Chongqing River section as a case study for the operation of cascade reservoirs in the Jinsha River. They found that the rate of sedimentation increased with sediment inflow, peak flow rate, and duration, while the location of sedimentation shifted as the concentration ratio changed. Contribution 7 analyzed the temporal and spatial evolution patterns of the baseflow through statistical analysis and the Mann–Kendall test. They found a higher baseflow contribution in upstream areas compared to downstream areas at both stations. The baseflow and BFI had significant upward trends in the dry season, while their trends were not uniform during the wet period. In Contribution 8, a new composite drought index was proposed that could comprehensively characterize meteorological and hydrological drought by combining the standardized precipitation index (SPI) and the standardized baseflow index (SBI). The results showed that the established composite drought index combined the advantages of SPI and SBI in drought forecasting, with an accuracy greater than 80% based on the trained random forest model. The study provided reliable and valid multivariate indicators for drought monitoring and could be applied to drought prediction in other regions.

2.4. Integrated Water Resources Management

Water resources management is a challenging task caused by huge uncertainties and complexities in hydrological processes and human activities (contributions 9 and 10). In Contribution 9, a multifaceted analytical framework comprising the CRITIC method, the standard deviation ellipse, the harmonious development coefficient, and the coupling coordination coefficient was developed to investigate spatiotemporal evolutionary trends and overarching harmonious development states between the high-quality economic development and water resource systems. They indicated that the epicenter of high-quality economic development indices was situated in the periphery of Lake Tai, whereas the fulcrum of the water resource system indices was in Huzhou City, both displaying a northwest–southeast orientation. Contribution 10 conducted a scientometric review and metasynthesis of the existing uncertainty analysis research for supporting hydrological modeling and water resources management through a co-citation, collaboration, and co-occurrence network study. They found that the USA contributed greatly to the publications and cooperated with most countries/territories. The Chinese Academy of Sciences was the leading institution and had a relatively intimate relationship with other institutions. The study also indicated that synthetical uncertainty management for hydrological models and water resource systems under climatic and land use change will continue to be studied.

3. Conclusions

This brief report provides a valuable overview of the ten selected papers featured in this Special Issue, with each making original contributions to advancing the state of the art in water resources management. The ten contributions encompass four major research subjects: (I) reservoir control operation, (II) artificial intelligence methods, (III) changing environmental evaluation, and (IV) integrated water resources management. They offer a high level of research and practical insights into the implementation of new methods and strategies for water resources management and reservoir operation, supported by case studies from various regions around the world. The future of research on water resources management hinges on a comprehensive understanding of environmental, socioeconomic, and technological factors. We hope that this Special Issue will encourage further research in this area, leading to improved methods and techniques and providing a deeper understanding of water resources management and reservoir operation.

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Conflicts of Interest: The author declares no conflicts of interest.

List of Contributions

1. Wan, W.; Liu, Y.; Zheng, H.; Zhao, J.; Zhao, F.; Lu, Y. Optimization of Multi-Reservoir Flood Control Operating Rules: A Case Study for the Chaobai River Basin in China. *Water* **2023**, *15*, 2817.
2. Zhou, L.; Kang, L.; Hou, S.; Guo, J. Research on Flood Risk Control Methods and Reservoir Flood Control Operation Oriented Towards Floodwater Utilization. *Water* **2024**, *16*, 43.
3. Mou, S.; Qu, T.; Li, J.; Wen, X.; Liu, Y. Joint Optimal Use of Sluices of a Group of Cascade Hydropower Stations Under High-Intensity Peak Shaving and Frequency Regulation. *Water* **2024**, *16*, 275.
4. Chen, J.-F.; Liao, Y.-T.; Wang, P.-C. Development and Deployment of a Virtual Water Gauge System Utilizing the ResNet-50 Convolutional Neural Network for Real-Time River Water Level Monitoring: A Case Study of the Keelung River in Taiwan. *Water* **2024**, *16*, 158.

5. Fang, Z.; He, R.; Yu, H.; He, Z.; Pan, Y. Optimization of Reservoir Level Scheduling Based on InSAR-LSTM Deformation Prediction Model for Rockfill Dams. *Water* **2023**, *15*, 3384.
6. Li, J.; Ge, H.; Ping, Y.; Dong, X.; Zhu, L.; Ma, Y. Sedimentation Characteristics of the Fluctuating Backwater Area at the Tail of Cascade Reservoirs: A Case Study of the Three Gorges Reservoir. *Water* **2023**, *15*, 4011.
7. Xie, H.; Hu, H.; Xie, D.; Xu, B.; Chen, Y.; Zhou, Z.; Zhang, F.; Nie, H. Spatial and Temporal Assessment of Baseflow Based on Monthly Water Balance Modeling and Baseflow Separation. *Water* **2024**, *16*, 1437.
8. Huang, S.; Zhang, H.; Liu, Y.; Liu, W.; Wei, F.; Yang, C.; Ding, F.; Ye, J.; Nie, H.; Du, Y.; Chen, Y. Assessment of Hydrological and Meteorological Composite Drought Characteristics Based on Baseflow and Precipitation. *Water* **2024**, *16*, 1466.
9. Liu, D.; Dai, Q.; Yuan, G. Evolutionary Trends and Coordinated Development Analysis of Water Resources Systems and High-Quality Economic Growth in the Yangtze River Delta. *Water* **2023**, *15*, 4030.
10. Li, C.; He, L.; Liu, D.; Feng, Z. A Scientometric Review for Uncertainties in Integrated Simulation–Optimization Modeling System. *Water* **2024**, *16*, 285.

References

1. Nagata, K.; Shoji, I.; Arima, T.; Otsuka, T.; Kato, K.; Matsubayashi, M.; Omura, M. Practicality of integrated water resources management (IWRM) in different contexts. *Int. J. Water Resour. Dev.* **2022**, *38*, 897–919. [CrossRef]
2. Chen, D.; Cai, Y.; Wang, X.; Li, C.; Yin, X.; Liu, Q. An inexact modeling approach for supporting water resources allocation under natural and social complexities in a border city of China and Myanmar. *Resour. Conserv. Recycl.* **2021**, *168*, 105245. [CrossRef]
3. Cai, X.; Wallington, K.; Shafiee-Jood, M.; Marston, L. Understanding and managing the food-energy-water nexus–opportunities for water resources research. *Adv. Water Resour.* **2018**, *111*, 259–273. [CrossRef]
4. Wang, X.; Chen, Y.; Li, Z.; Fang, G.; Wang, F.; Hao, H. Water resources management and dynamic changes in water politics in the transboundary river basins of Central Asia. *Hydrol. Earth Syst. Sci.* **2021**, *25*, 3281–3299. [CrossRef]
5. Jain, S.K.; Shilpa, L.S.; Rani, D.; Sudheer, K.P. State-of-the-art review: Operation of multi-purpose reservoirs during flood season. *J. Hydrol.* **2023**, *618*, 129165. [CrossRef]
6. Yu, X.; Xu, Y.-P.; Gu, H.; Guo, Y. Multi-objective robust optimization of reservoir operation for real-time flood control under forecasting uncertainty. *J. Hydrol.* **2023**, *620*, 129421. [CrossRef]
7. Zeng, Y.; Liu, D.; Guo, S.; Xiong, L.; Liu, P.; Chen, J.; Yin, J.; Wu, Z.; Zhou, W. Assessing the effects of water resources allocation on the uncertainty propagation in the water–energy–food–society (WEFS) nexus. *Agric. Water Manag.* **2023**, *282*, 108279. [CrossRef]