Research on the Availability of Surface Water Resources Based on GWAS Water Cycle Model

Jianmin Xu[1], Panqin Yang[1], Huawei Liu[1], Kanghui Xu[2] and Ying Liu[2*]

[1] Yueqing Water Conservancy Bureau, Wenzhou,325600,China
[2] Zhejiang Keteng Engineering Consulting Co., Ltd., Hangzhou,310020,China

*cumtliuying@163.com

Abstract. As an important part of water resources, the available amount of water resources is one of the main factors restricting the rapid development of regional social economy. Based on the General Water Allocation and Simulation for Management System (GWAS), this paper constructs a regional water cycle model. Taking Yueqing City as an example, different hydrological units are modeled to study the amount of water resources. Comparing the actual measured traffic data to verify the accuracy of the model, Nash coefficient is 0.9234, water resource error rate is 1.7%, model fitting results are good. The deduction method is used to deduct the ecological water demand and the amount of abandoned water in flood season to determine the available amount of surface water resources under different hydrological years. It can be used as an important basis for the revision of river basin or regional planning, water allocation and scheduling, and total amount control index revision in the future.

Keywords: Water resources, Available quantity, Water cycle.

1 Introduction

As a city located in the southeast coastal area of China, Yueqing is characterized by river-mouth alluvial plains and mountainous and hilly regions. The terrain slopes from northwest to southeast. The climate is mild and humid with abundant rainfall. Due to the influence of topography and landforms, there are few suitable sites for the construction of mature water storage projects. As a result, it is difficult to effectively regulate water resources during periods of abundant and scarce water. Yueqing is a typical area that suffers from both engineering water shortage and water quality water shortage in Zhejiang Province. With the rapid economic development, the contradiction between water supply and demand has become increasingly prominent, and the carrying capacity of water resources is facing major challenges. To promote the coordinated development of high-quality economic growth and water resource utilization, it is necessary to analyze the available water resources in different hydrological years. The available water resources are included in the total water resources of the basin and are an important component. They have the attribute of water consumption [1].

S. Sing et al. (eds.), *Proceedings of the 2025 7th International Conference on Civil Architecture and Urban Engineering (ICCAUE 2025)*, Atlantis Highlights in Engineering 43,
https://doi.org/10.2991/978-94-6239-682-1_4

Based on the "Nature-Society" dual water cycle theory [2] established by Academician Wang Hao, some researchers [3] have developed the "General Water Allocation and Simulation for Management System", which can achieve functions such as regional water quantity and quality simulation, evaluation, water resources allocation, and dynamic change simulation analysis of water resources under the allocation process. This paper used the GWAS to construct a water cycle model of Yueqing City, comprehensively evaluate the water resources status of the study area, and provide decision support for the efficient management and optimal allocation of regional water resources.

2 Research Methods and Data Sources

This paper constructed the water cycle model based on the " Nature-Society " dual water cycle theory to analyze the quantity of water resources, used hydrology method to calculate ecological water demand and water discarded coefficient [4] to calculate water discarded during flood season, and calculated the available amount of water resources by deduction method [5].

Land use information comes from the World Cover Dataset [6], rainfall and evaporation come from the observation data of Yueqing Hydrological Station from 1991 to 2021, the economic data comes from the statistical yearbook, the index of water use comes from the water resources bulletin, and the urban construction land data comes from the urban construction statistical yearbook.

3 Results Analysis

3.1 Model Construction

The construction of water cycle model is mainly divided into hydrological unit division, unit parameter input, reservoir parameter import, determination of topological relationship of water supply, model calculation, cross-section flow calibration, parameter calibration and result output.

24 hydrological units (including 1 verification unit) are divided according to the distribution of the basin and topography. Importing the characteristic parameters of 23 reservoirs. The water supply topological relationship is determined according to water system connection and inter-regional water supply. The rainfall and evaporation amount of each hydrological unit are determined through the Tyson polygon method. Land use situations determine the land use type data of each unit based on the World Cover Dataset. The data is shown in Figure 1.

Operation of GWAS model based on the principle of confluence of precipitation products, and the model default value is used to optimize the simulation parameters (population size is 50, cross probability is 0.3, variation probability is 0.05, maximum number of runs 1000). Selecting the observation traffic data of the Feitou Station for model verification. Using 1995.1-2003.12 as the parameter adjustment period and 2006.1~2021.12 as the verification period, the cross-section runoff simulation value is fitted with the actual measured value. The fitting effect R^2=0.9675, the Nash coefficient is 0.9234, the error rate is 1.7%, and the fitting effect is good [3]. The verification comparison results are shown in Figure 2.

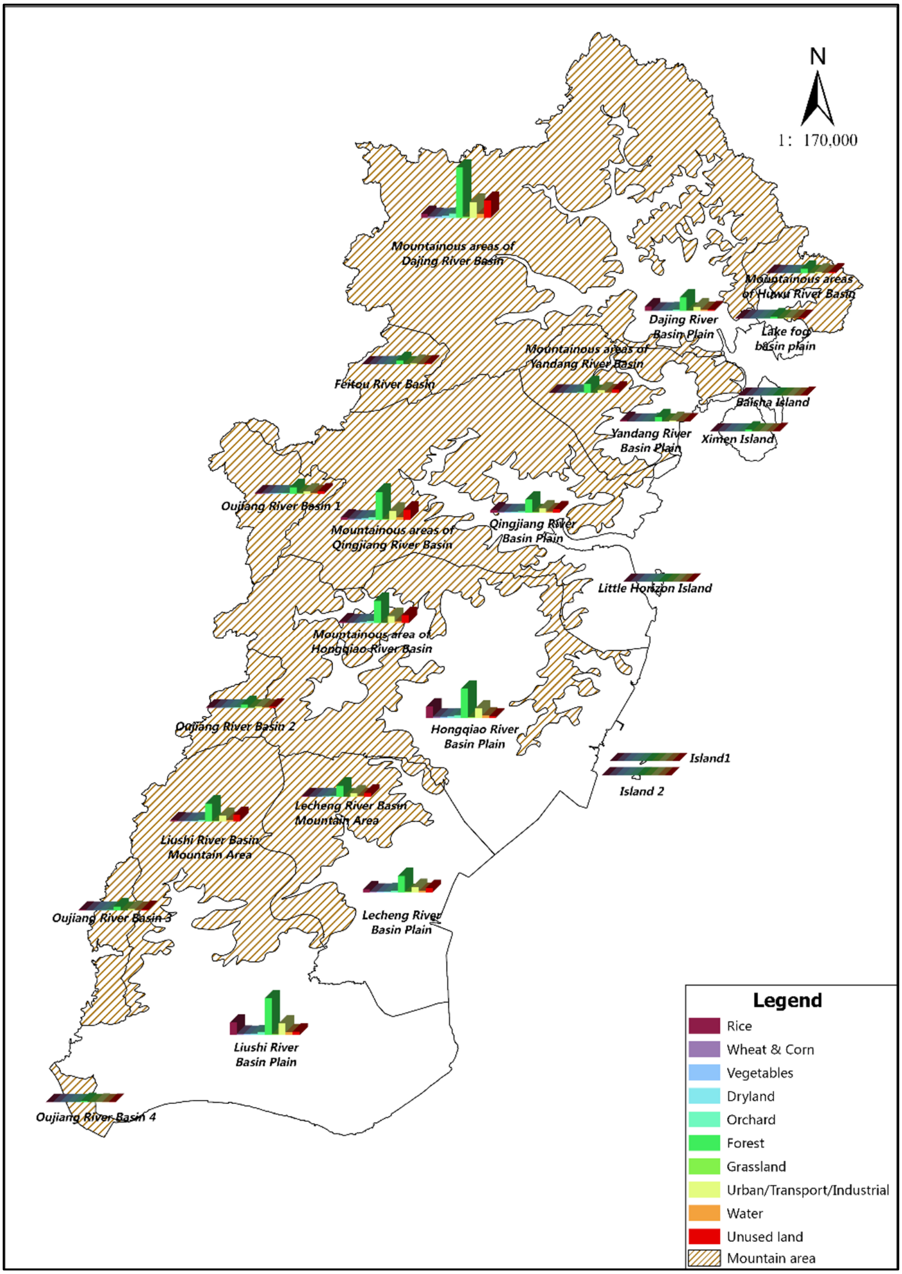

Fig. 1. Distribution of land use types of hydrological units.

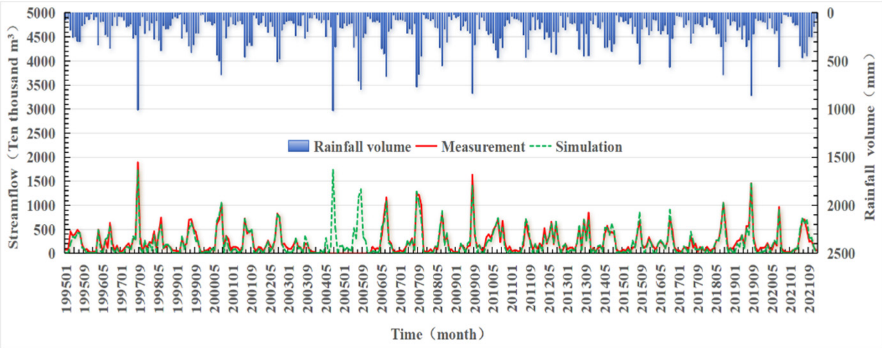

Fig. 2. Comparison of cross-section runoff simulation and actual measurement of Feitou Station.

3.2 Surface Water Resources

After the model is determined in parameter rates, the water resources simulation results of each basin are output. Yueqing City is mainly divided into six major river basins, and 24 small hydrological units are merged to finally obtain the total water resources of the six major river basins of Yueqing City.

Comparing the simulation data with the results of Yueqing's surface water resources in the " The Third Investigation and Evaluation of Water Resources in Wenzhou City", it can be seen that the GWAS model simulates water resources and the third investigation and evaluation of water resources data in the multi-year average, 50%, 75%, and 90% are 0.40%, 0.72%, 1.92%, and 2.92%, respectively. The error rate is within 3%. Therefore, it is believed that the simulation data of model is relatively accurate and the data is trustworthy. The surface water resources at different frequencies in various river basins in Yueqing City are shown in Table 1.

Table 1. Surface water resources in different incoming frequencies of six major river basins in Yueqing City.

River basin	Multi-year Average (10,000 m^3)	50% (10,000 m^3)	75% (10,000 m^3)	90% (10,000 m^3)	95% (10,000 m^3)
Dajing	50364	47761	38040	29961	28710
Yandang	8294	7899	6345	5030	4835
Qingjiang	19062	17992	14199	11106	10611
Hongqiao	26494	25107	19971	15714	15051
Lecheng	10554	9915	7759	6031	5747
Liushi	25134	23723	18721	14643	13990
Yueqing City	139902	132397	105036	82486	78945

3.3 Ecological Water Demand

Ecological water demand is the amount of water resources that must be guaranteed to maintain the virtuous cycle of the basin ecosystem. This paper used three methods: Tennant method, Qp method and frequency curve method to conduct a comparison analysis. It was found that the calculation results of the Qp method ecological flow are relatively small, and the results of the frequency curve method are relatively large. The Tennant method is selected to calculate the ecological water demand, and 10% to 20% of the annual runoff is taken as the ecological reserved water volume of the river. The analysis results are shown in Table 2.

Table 2. Ecological water demand under different conditions.

Advanta-geousness	Stand-ard	Da-jing	Yan-dang	Qingjia ng	Hongq iao	Leche ng	Lius hi	Yueqing City
Normal or poor	10%	4743	933	1908	2581	1138	245 8	13761
Better	20%	9486	1866	3816	5162	2275	491 6	27521

3.4 Water Abandonment During Flood Season

The amount of water abandoned during the flood season is difficult to control and utilize. This paper calculated the water abandonment amount by the water abandonment coefficient during flood season in every river basin. Through the 31-year observation rainfall data, the ratio of the maximum rainfall in previous years and the average rainfall in many years is selected as the benchmark to determine the water discarded coefficient. The interval cumulative ratio is shown in Table 3.

By analyzing the data on rainfall and runoff over the years, Yueqing City is the flood season from May to September. The water discarded coefficient determined through actual measured data is shown in Table 4. According to the upstream incoming water volume that is based on the water cycle model and flood season time, the amount of incoming water in flood season over the years was determined, then multiplied by the water discarded coefficient. Finally, the amount of water abandoned during flood season under different inlet frequency conditions was calculated, the results are shown in Table 5. Affected by the monsoon climate, the amount of water abandoned during the flood season is proportional to the annual rainfall. The amount of water abandoned during the flood season in mountainous areas is more than that in plain areas.

Table 3. Monthly maximum/year average monthly ratio and cumulative ratio.

Ratio	<1	<2	<3	<4	<5	<6	<7	>7
Cumulative ratio(%)	0	19	52	74	90	97	100	0

Table 4. The discarded water coefficient determined based on monthly maximum/year average rainfall.

Ratio	1~2	2~3	3~4	4~5	5~6	6~7	>7
Discarded water coefficient (%)	20	45	60	70	80	85	90

Table 5. The amount of water abandoned in different incoming frequencies in the six major basins of Yueqing City.

River basin	Multi-year Average (10,000 m^3)	50% (10,000 m^3)	75% (10,000 m^3)	90% (10,000 m^3)	95% (10,000 m^3)
Dajing	19594	15264	8229	4627	3889
Yandang	3332	2942	1862	1161	974
Qingjiang	7797	6971	4364	2598	2040
Hongqiao	10109	8656	5152	2986	2374
Lecheng	3922	3179	1763	973	773
Liushi	8786	7217	3974	2095	1553
Yueqing City	53540	44230	25345	14441	11603

3.5 The Available Amount of Surface Water Resources

The available amount of surface water resources is based on the river basin, in order to maintain the ecology, protect the environment and sustainable use of water resources, taking reasonable and technically measures in the foreseeable future, the maximum amount of water available for development and utilization outside the river in the local water resources can be used [7]. Calculation method is shown in equation 1.

$$W_a = W_t - W_e - W_f \tag{1}$$

W_a is the available amount of surface water resources; W_t is the total amount of surface water resources; W_e is the ecological water demand; W_f is the amount of water that cannot be utilized during the flood season.

Because there are changes in the interannual rainfall, the ecological water demand standards are considered at the better level of abundance and normal water year (20%), and at the general level (10%).

According to equation 1, W_a can be obtained in different hydrological years. Compared with the multi-year average amount of surface water resources available of Yueqing City in the " The Third Investigation and Evaluation of Water Resources in Wenzhou City", the error rate of water resources available is 1.79%, comparison of model simulation results with the third water resource survey is shown in Figure 3. Therefore, the results of using GWAS to carry out the water circulation simulation of small river basin are relatively high, the available amount of surface water resources available in different hydrological years is shown in Table 6.

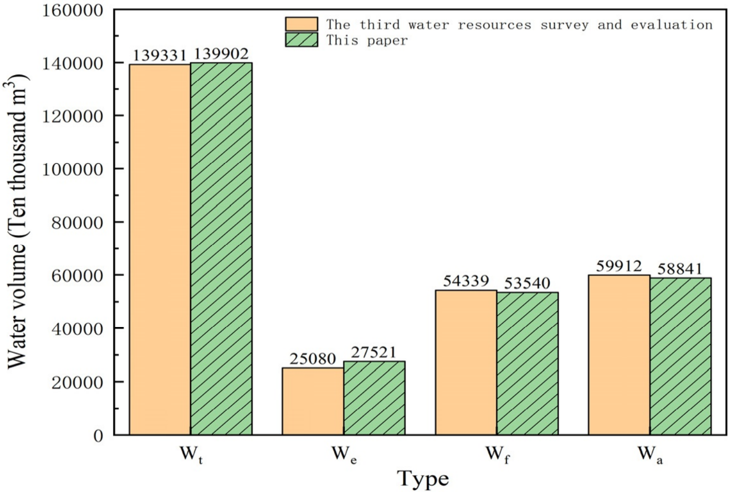

Fig. 3. Comparative chart of rationality verification of multi-year average water resources.

Table 6. The available amount of surface water resources available in six major river basins of Yueqing City.

River basin	Multi-year Average (10,000 m^3)	50% (10,000 m^3)	75% (10,000 m^3)	90% (10,000 m^3)	95% (10,000 m^3)
Dajing	21284	23011	25068	20591	20078
Yandang	3096	3091	3550	2936	2928
Qingjiang	7449	7205	7927	6600	6663
Hongqiao	11223	11289	12238	10147	10096
Lecheng	4357	4461	4858	3920	3837
Liushi	11432	11590	12289	10090	9979
Yueqing City	58841	60646	65930	54284	53581

Yueqing City's available amount of surface water resources accounted for about 42% of the total water resource in many years, which is close to the conclusion that some scholars believe that the reasonable upper limit of water resource development is 40%. With the decrease of rainfall, the proportion of water resources development and utilization is on the rise at the expense of a certain ecological flow guarantee. The proportion of water resource development in different hydrological years is shown in Table 7.

The total amount of water used is 256.84 million m^3 in Yueqing City, and the utilization rate of surface water resources is 20.4 %, which is still a certain margin from the red line of water resources development and utilization. As a water-scarce city in the coastal areas, Yueqing City has abundant water resources, but the distribution of rainfall during the year is extremely uneven. In order to improve this situation, it is recommended to promote the construction of water network backbone projects, build a differentiated water supply network, promote the reform of water rights in water-rich areas, and strengthen the policy guarantee of rigid constraints on water resources.

Table 7. The upper limit of reasonable development of surface water resources in Yueqing City.

Type	Multi-year Average (10,000 m³)	50% (10,000 m³)	75% (10,000 m³)	90% (10,000 m³)	95% (10,000 m³)
W_t	139902	132397	105036	82486	78945
W_e	27521	27522	13761	13761	13761
W_f	53540	44230	25345	14441	11603
W_a	58841	60645	65930	54284	53581
The upper limit of reasonable development (W_a/W_t)	42.06%	45.81%	62.77%	65.81%	67.87%

4 Conclusions and Suggestions

In view of the characteristics of the natural-social water circulation system, the established cross-sectional flow process model verification can be used to characterize the parameter adjustment target of the GWAS model and reflect the accuracy of the model's water resource evaluation and water resource management.

Through the verification and analysis of the water cycle model, the annual average, 50%, 75%, 90% and 95% surface water resources were 139902, 132397, 105036, 82486, and 78945 ten thousand m^3 respectively. The observation data of vegetation, land use, rainfall and evaporation in each river basin were synchronously simulated to obtain the water resources of each small river basin, providing a theoretical basis for subsequent river basin water resources development.

In terms of the proportion of water resources development and utilization, the annual average surface water resource utilization is 588.41 million m^3 in Yueqing City, the error rate is 1.79% compared with the results of the third water resource survey, accounting for about 42% of the total water resources, which has exceeded the 40% proportion of internationally recognized reasonable development. The actual water consumption is 256.84 million m^3 in 2023, with potential development potential of about 230 million m^3. However, Yueqing City is still a typical water-scarce area. It is necessary to further strengthen the protection of water quality and ecological flow in each river basin, establish cross-basin water resource allocation channels, tap local engineering development potential, and optimize the dispatch and utilization of water resources in the entire region.

References

1. Tong Chang, Yunling Li. Analysis of Chinese water and soil resources matching status based on the available amount of water resources [J]. Journal of Irrigation and Drainage, 2023, 42 (6): 74-80.

2. Hao Wang, Cunwen Niu, Yong Zhao. Research on the binary water cycle and water resources in the "Nature-Society" watershed in the basin[J]. Acta Geography, 2023, 78(07):1599-1607.
3. Xuefeng Sang, Yong Zhao, Zhengli Zhai, et al. Comprehensive simulation and allocation model of water resources WAS(II): Application[J]. Journal of Water Conservancy, 2019, 50(02):201-208.
4. Shuiping Yao, Zonglou Guo, Ji Ren, et al. Discussion on the calculation of surface water resource utilization [J]. Journal of Zhejiang University (Agriculture and Life Sciences Edition), 2005, (04): 479-482.
5. Honggang Zhang, Xiang Zhang, Sunyun Lu, et al. Discussion on the calculation method of surface water resource utilization [J]. China Rural Water Conservancy and Hydropower, 2007, (10): 1-4.
6. Zanaga, D., Van De Kerchove, R., Daems, D., De Keersmaecker, W., Brockmann, C., Kirches, G., Wevers, J., Cartus, O., Santoro, M., Fritz, S., Lesiv, M., Herold, M., Tsendbazar, N.E., Xu, P., Ramoino, F., Arino, O., 2022. ESA WorldCover 10 m 2021 v200.
7. Xiaolin Zhang, Yimin Zhang, Chang Chen, et al. Calculation of surface water resources available in the Xijiang River Basin based on the reverse reversal of the water demand in the ecological environment [J]. People's Pearl River, 2024, 45 (11): 72-78.