Analysis of water resources in the Li River Economic Zone

Yanguang Zhu

College of Environmental Science and Engineering, Guilin University of Technology, Guilin, Guangxi, 541004, China
Author’s e-mail: 415024471@qq.com

Abstract: A series of water resources data (from 1991 to 2014) were obtained from Guilin Hydrological Station, on which the statistics of the annual average total water resources and the amount of available water resources in the Li River Economic Zone were calculated. Results showed that the annual average total water resources of the Li River Economic Zone were 93.13 hundred million m$^3$. Under the precipitation guarantee rates of 50%, 75% and 95%, there were 92.55, 68.40 and 65.21 hundred million m$^3$, respectively. At the same time, the annual average available water resource the Li River Economic Zone was 47.57 hundred million m$^3$, which were 47.01, 34.98 and 22.94 hundred million m$^3$ under the 50%, 75% and 95% precipitation guarantee rates, respectively. The analysis results provide a theoretical basis for the effective use of water resources in Guilin.

1. Introduction
Water resource is renewable, but its quantity is limited within a specific time and space[1]. Since the 1980s, the Li River has carried out water resources distribution mainly based on hydration[2]. The total amount of water resources in the Li River Basin is large, but the per capita is small and the distribution is uneven during the year. The utilization and development of water resources will directly affect the economic development of this basin[3]. Problems such as less water in the dry season, irrational use of water resources and pollution of the fords have increased the demand for water resources in the Li River Basin [4]. In order to achieve the goal of improving the carrying capacity and the comprehensive utilization level of water resources, the Li River Economic Zone was established by the government of Guilin in June 2013[5]. It includes five districts of Xufeng, Qixing, Yanshan, Diecai and Xiangshan and five counties of Xing’an, Lingchuan, Lingui, Yangshuo and Pingle, which is a zonal economic cooperation region. Based on multi-year of Hydrological data of Guilin, the amount of the total water resources and of available volume in the Li River Economy Zome was measured under the precipitation guarantee rate 50%, 75% and 95%, in order to provide a reference for the optimal allocation of water resources in Guilin.

2. The total amount of water resources in the Li River economic zone
The total amount of water resources in the Li River Economic Zone includes the water resources of the Li River Basin, the Xiangjiang River Basin and the Luoqing River Basin. It needs to be calculated by subtracting duplicate parts after summation. The multi-year average surface water resources can be indicated by the value of the annual average natural runoff, which includes the measured runoff and impact of human activities on runoff.
2.1. The total water resources in the Li River Basin
Yangshuo Hydrological Station was selected as the control station of the Li River Basin within the economic zone, with a catchment area of 5,585 km². Based on the data of water resources from 1991-2014, it can be learned that the measured average runoff volume in the Li River Basin was 68.67 hundred million m³. At the same time, it is necessary to reduce the water resources used by human activities when the amount of surface water resources was calculated, of which includes agriculture, industry, and domestic water resources. According to the Guilin Water Resources Bulletin, this part water resources volume of reduction was 1.48 hundred million m³. Therefore, the final natural runoff volume of the Li River Basin above the Yangshuo Hydrological Station was 70.15 hundred million m³.

Groundwater resources can be calculated based on the average of the lowest flows over these years[6]. Based on existing data, the minimum monthly average flows value of each year of the Li River Basin were selected. The results showed that the average lowest monthly runoff volume was 34.98m³/s, which the groundwater runoff volume in the Li River Economy Zone was about 11.04 hundred million m³. However, the total amount of groundwater discharge in the karst area of Guilin will finally replenished to surface water. The amount of groundwater can be used as the calculated repeat. Therefore, the total water resources in the Li River Basin under different precipitation guarantee rates are shown in table 1.

| Name | Surface water volume | Underground water volume | Repeated water volume | Total water resources volume under different precipitation guarantee rates |
|------|----------------------|--------------------------|-----------------------|-------------------------------------------------------------------------|
|      |                      |                          | 70.15                 | 69.60                                                                   |
|      |                      |                          | 11.04                 | 48.99                                                                   |

2.2. The total water resources in the Xiangjiang River Basin
Within the economy zone, the total water resources of Xiangjiang River Basin was equal the summation of Xing’an Hydrological Station and Mochuan River annual average measured runoff volume, then reduce the resources which introduced into the Ling Canal[7]. According to the data, the catchment area of this station is 570 km², the annual average measured runoff volume in the Li River Basin was 5.20 hundred million m³, of which about one-third were introduced into the Ling Canal. In this basin, human activities had less impact on water resources, so the water restored volume can be neglected. According to the "County of Xing’an" records, the water resources in the Mochuan River within the economy zone was 13.91m³/s, equivalent to an annual average natural runoff volume of 4.39 hundred million m³. And the groundwater resource volume of this basin was 1.31 hundred million m³, which was also counted as repeated calculation. Therefore, the total amount of water resources in the Xiangjiang River Basin under different precipitation guarantee rates are shown in table 2.

| Name            | Surface water volume | Underground water volume | Repeated water volume | Total water resources volume under different precipitation guarantee rates |
|-----------------|----------------------|--------------------------|-----------------------|-------------------------------------------------------------------------|
| Xing’an         | 5.20                 | 1.31                     | 1.31                  | 5.52                                                                     |
| Ling canal      | 1.73                 | —                        | —                     | 1.84                                                                     |
| Mochuan River   | 4.39                 | —                        | —                     | 4.66                                                                     |
| Xiangjiang River| 7.86                 | 1.31                     | 1.31                  | 8.34                                                                     |
2.3. The total water resources in the Luoqing River Basin
The Luoqing River Basin in the economic zone is distributed in Lingui County, named as the Yijiang River, and the Daping River is its main tributary. According to the hydrological data of the Liangjiang Hydrological Station, the annual average measured runoff volume of Yijiang River was 40.96 m³/s, which translates into surface runoff volume of 12.92 hundred million m³. And the "Lingui County" showed that the one of Daping River in was 6.98m³/s, which translates into surface runoff of 2.20 hundred million m³. Since the human activities had little impact on Yijiang, the amount of water restored was ignored also.

Using the minimum monthly average runoff value of each year to calculate the groundwater volume, it can be seen that the average water flow of Yijiang for multi-year was 3.46m³/s, which translates into 1.09 hundred million m³. Meanwhile, the Daping River like that were 1.28m³/s and 0.40 hundred million m³. Therefore, the groundwater resources in the Luoqing River Basin are 1.49 hundred million m³, which also as the double-calculation. The total water resources in the Luoqing River Basin under different precipitation frequencies are shown in table 3.

| Name        | Surface water volume | Underground water volume | Repeated water volume | Total water resources volume under different precipitation guarantee rates |
|-------------|----------------------|--------------------------|-----------------------|-------------------------------------------------------------------------|
|             |                      |                          |                       | 50% | 75% | 95% |
| Yijiang River | 12.92               | 1.09                     | 1.09                  | 12.49 | 10.44 | 9.81 |
| Daping River  | 2.20                 | 0.40                     | 0.40                  | 2.12  | 1.78  | 1.67 |
| Luoqing River | 15.12               | 1.49                     | 1.49                  | 14.61 | 12.22 | 11.48 |

2.4. Total water resources volume
The amount of the annual average total water resources volume of the Li River Economic Zone was 93.13 hundred million m³, and under the precipitation guarantee rates of 50%, 75% and 95% were 92.55, 68.40 and 65.21 hundred million m³, respectively.

3. Water resources available in the Li River economic zone
It must ensure the river circulation, biological and shipping water requirements of river basin to its normal operation when we use the surface water resources, and the Tennant method can be used to calculate the amount of available surface water resources[8].

3.1. The available water resources in the Li River Basin
According to the research, the surface water volume above the Yangshuo Hydrological Station was 70.15 hundred million m³. Under the “very good” level of Montana method, the ecological water demand of the Li River Basin was equivalent to 31.77 hundred million m³, so the available value of that was 38.38 hundred million m³. When the requirement of water resources of ecological hydration and the navigation in dry season of the Li River Basin were performed, the amount of available water resources which can be applied for outside the river above the section of Yangshuo Hydrological Station are shown in table 4.

| Surface water volume | Ecological water requirement | Available water volume | Available surface water under different precipitation guarantee rates |
|----------------------|-----------------------------|-----------------------|-------------------------------------------------------------------|
|                      |                             |                       | 50% | 75% | 95% |
| 70.15                | 31.77                       | 38.38                 | 37.83 | 27.22 | 15.96 |
3.2. The available water resources in the Xiangjiang River Basin

According to the Montana method, 60% of the flow (the optimal level) is guaranteed as the base flow of ecological water, and another 40% is the amount available water resources applied for outside the channels of the Xiangjiang River Basin within the economic zone. As shown by data, the annual average water resources of the Xiangjiang River Basin was 7.86 hundred million m$^3$, the ecological water demand in the river channel was 4.72 hundred million m$^3$, and the one of available was 3.14 hundred million m$^3$. Under the different precipitation guarantee rates, the available water resources in the Xiangjiang River Basin are shown in table 5.

| Surface water volume | Ecological water requirement | Available water volume | Availability of surface water under different precipitation guarantee rates |
|----------------------|------------------------------|------------------------|--------------------------------------------------------------------------|
|                      |                              |                        | 50% | 75% | 95% |
| 7.86                 | 4.72                         | 3.14                   | 3.34 | 2.88 | 2.40 |

3.3. The available water resources in the Luoqing River Basin

The total annual water resources in the Luojiang River Basin within the Li River Economic Zone was 15.12 hundred million m$^3$. Meanwhile, the ecological water requirement under the “optimal level” was 9.07 hundred million m$^3$, and the available volume was 6.05 hundred million m$^3$, and the annual years under different precipitation guarantee rates of Luoqing River Basin are shown in table 6.

| Surface water volume | Ecological water requirement | Available water volume | Available surface water under different precipitation guarantee rates |
|----------------------|------------------------------|------------------------|--------------------------------------------------------------------------|
|                      |                              |                        | 50% | 50% | 50% |
| 15.12                | 9.07                         | 6.05                   | 5.84 | 4.89 | 4.59 |

3.4. The available water resources in the Li River Economy Zone

Based on the data of the Li River Basin, the Xiangjiang River Basin and the Luoqing River Basin, the annual average available water resource of the Li River Economic Zone was 47.6 hundred million m$^3$. Under the different rainfall guarantee rates of 50%, 75% and 95% were 47.0, 34.81 and 22.94 hundred million m$^3$, respectively.

4. Conclusion

The annual average water resources volume of the Li River Economic Zone was 93.13 hundred million m$^3$. Under the precipitation guarantee rates of 50%, 75% and 95% were 92.55, 68.40 and 65.21 hundred million m$^3$, respectively. Meanwhile, the annual average available water resource of the Li River Economic Zone was 47.57 hundred million m$^3$, which were 47.01, 34.98 and 22.94 hundred million m$^3$ under the 50%, 75% and 95% precipitation guarantee rates, respectively.

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