

Analysis and Prediction of the Lowest Ecological Water Level of the Inland Lake in Arid Region of China

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Abstract

As a key component of the water cycle in arid regions, inland lakes have relatively fragile biological and ecological systems. Once the environment deteriorates, inland lakes in arid regions will be the first to respond accordingly. In view of the lack of ecological water quantity, the continuous decline of lake water level and the insufficient carrying capacity of water resources caused by the changes in precipitation and evaporation, the construction of water replenishment projects and domestic water use for industrial and agricultural production in the inland lake basin in the arid region of China in recent years, the analysis and prediction of the minimum ecological lake water level were carried out. Taking Chenghai Lake as the case study, a comprehensive analysis of the historical water level evolution was conducted using the lowest annual average water level method, the natural water level data method, and the lake morphology data method, and got the current lowest ecological water level of Chenghai Lake was found to be 1495.43 m. And then, taking the year when the legal minimum water level is restored as the boundary for the future, the minimum ecological water level of Chenghai Lake was calculated to be 1499.20m. On this basis, combined with the water replenishment of the existing and under-construction diversion projects in Chenghai Lake, it is predicted that the year when Chenghai Lake will restore its legal minimum ecological water level will be 2025. The research will provide data support and a basis for decision-making for ecosystem restoration, lake area governance and protection, rational development, and utilization of watershed water resources in inland lakes.

Keywords

Chenghai Lake, Minimum Ecological Water Level, Ecological Water Volume, Water Diversion Projects

1. Introduction

Lakes are important components of the terrestrial hydrosphere and the water cycle. Inland lakes in arid regions possess unique hydrological, hydrochemical, and hydroecological characteristics [1]. As the key to the water cycle in arid regions, the biology and ecosystems of inland lakes are relatively fragile, and they will be the first to respond to environmental degradation. Due to the impact of production, living, industrial, and agricultural activities, as well as local environmental factors, water levels change and seriously endanger the health of lake ecosystems. It is necessary to monitor and protect the ecological water levels of inland lakes in arid regions in real time to ensure the sustainable development of the economy and society in arid areas.

The study of ecological water demand began in the late 20th century, with Raskin *et al.* [1] proposing that to meet the sustainable use of lake water resources, a certain demand for ecological water volume of lakes should be ensured. Ngana *et al.* [2] suggested that the ecological water demand of lakes is the basic water volume required to maintain the stability of lake ecosystems and the coordinated development of the ecological environment. Chinese scholars have focused on determining the ecological water level of lakes within the ecological water volume to intuitively reflect the water conditions of the lakes [3]. Xu Zhixia *et al.* [4] believe that the minimum water level that can ensure the lake ecosystem does not continue to degrade is the minimum ecological water level of the lake area; Cui Baoshan *et al.* [5] pointed out that the minimum ecological water level of a lake is the lowest ecological water level that ensures the integrity of the lake ecosystem structure and function and the biodiversity within the system is not damaged, and proposed three calculation methods for the minimum ecological water demand from the principles of ecological hydrology; Wang Hongxiang *et al.* [6] combined the ecological water level annual distribution method with the IHA-RVA method to calculate the minimum and suitable ecological water levels of lakes. Jin Xin *et al.* [7], in combination with the practical needs of reservoir group ecological scheduling, proposed an integrated model for basin ecological water demand under the support of distributed hydrological model technology. Kang Ling *et al.* [8] calculated the minimum ecological flow of the Han River and conducted river ecological water demand and artificial flood scheduling for Danjiangkou, in response to the main ecological issues in the middle and lower reaches of the Han River and in combination with observational data from different periods. Li Jian *et al.* [9], based on the response relationship between water blooms and hydrological processes, proposed key indicators and control thresholds for suppressing wa-

ter blooms, and constructed a joint ecological scheduling plan for water conservancy projects in the middle and lower reaches of the Han River, clarifying the ecological scheduling methods and duration for suppressing water blooms. Gao Xun *et al.* [10] comprehensively considered the requirements of flow velocity, water level, and water quality, and determined the river channel water volume scheduling method that can achieve ecological flow velocity, ecological water level, and water quality targets using a hydrodynamic model.

The inland lake in arid areas—Chenghai Lake is located in the least rainy area of Yunnan Province and is in the subtropical plateau monsoon climate zone, with a long annual sunshine time, evaporation far greater than precipitation, coupled with rapid economic development and increased water resource utilization, leading to a gradual decrease in water level, affecting the ecological environment safety of Chenghai Lake. This paper takes Chenghai Lake as the research object, adopts different ecological water level calculation methods to analyze and obtain its minimum ecological water level, and combines the water supply project of Chenghai Lake, the evaporation and precipitation situation of the basin, and the water used for industrial and agricultural production and daily life to conduct a water resource supply and demand balance analysis, to obtain the future ecological water level of Chenghai Lake, and finally predicts the year when Chenghai Lake will recover to the legal minimum ecological water level based on the existing and under-construction water diversion and allocation projects of Chenghai Lake. The research results can provide a good basis for optimizing the allocation of water resources, restoring the good connectivity of rivers and lakes, maintaining the lake water surface area, and repairing the damaged river and lake ecosystems [11].

2. Study Area and Water Resource Balance Analysis

Chenghai Lake is one of the nine plateau lakes in Yunnan Province, an inland closed lake located at the junction of the northwestern Yunnan Plateau and the Yunnan-Guizhou Plateau, in the middle section of the Jinsha River [5]. The lake's surface water area is about 19 km long from north to south, and about 3.0 to 5.5 km wide from east to west, with a lake area of 75.97 km² and a basin area of 318.3 km². The eastern, western, and northern parts are characterized by continuous high mountains, with a central depression that holds water, and the southern part has lower terrain. The annual average precipitation in the basin is 733.6 mm; the annual average evaporation is 2169 mm, placing it in the area with the least rainfall in Yunnan Province [4]. The water level is decreasing year by year, and there are a total of 47 main inflow rivers and gullies, but they are short and seasonal.

The Hekou Street Hydrological Station is the only station with complete water level monitoring data for Chenghai Lake. According to the principles for selecting control sections and in conjunction with the distribution of Chenghai Lake's hydrological stations, Hekou Street Hydrological Station is chosen as the ecological water level control section for Chenghai Lake. As shown in **Figure 1**, Hekou Street Hydrological Station is located in Chenghai Lake Town, Yongsheng County, Lijiang City, with a catchment area of 318.3 km² and an elevation of 1540 m.

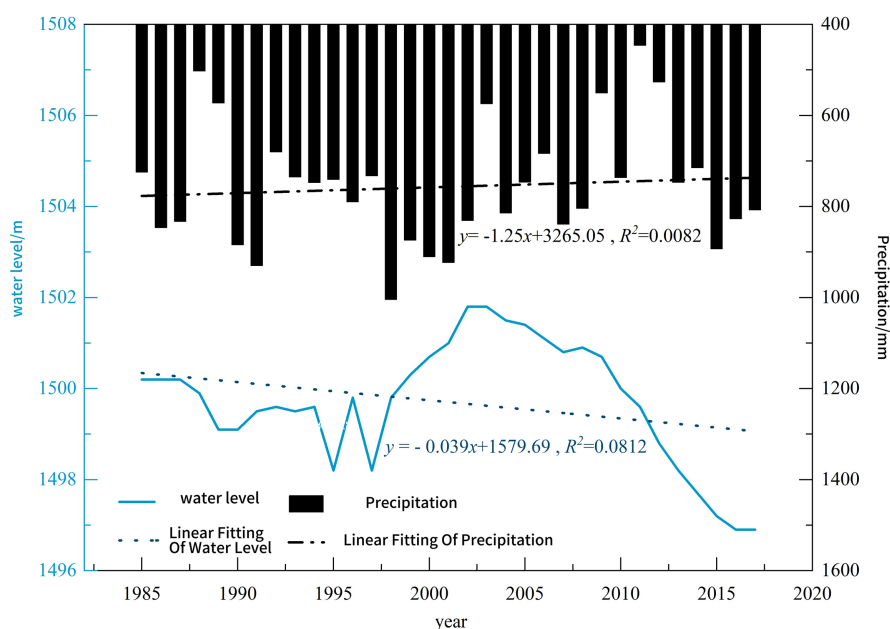


Figure 1. Three stages of Chenghai water level variation trend line.

Based on the relevant data from the “Chenghai Protection and Management Plan,” a hydrological frequency analysis of Chenghai Lake was conducted using the precipitation data from Hekou Street Hydrological Station from 1985 to 2021 as a benchmark. Annual characteristic values were used, and empirical frequencies were calculated based on the P-III type distribution to obtain surface runoff and lake precipitation under different hydrological frequencies. The water surface area was calculated using the water level-water area relationship function of Chenghai Lake, and the annual average water surface area was used to estimate the lake’s surface runoff for various typical years. Based on the relevant basic data of the Chenghai Lake area, various water balance relationships were calculated (**Table 1**). The main sources of water income for Chenghai Lake are surface runoff and lake precipitation, with lake evaporation accounting for more than 80% of the total water resource consumption.

Based on the water balance conditions of the watershed, without any additional water input, the Chenghai Lake basin is in a chronic state of water deficit, with a surplus of water only occurring when precipitation exceeds 785 - 803 mm ($P = 45\%$). According to the historical water level and precipitation data from the Hekou Street Hydrological Station, in non-water replenishment years, consecutive years of annual precipitation are required to be greater than 785 mm for the water level to slow down or slightly rise. According to the principle of water balance, the negative water volume difference in Chenghai Lake, with the water level decreasing year by year, is mainly due to low precipitation, high evaporation and transpiration, and insufficient surface runoff recharge. As shown in **Figure 1**, the precipitation and water levels in the basin are trending downward year by year. Furthermore, the continuous growth of the population, the ongoing development of agriculture and industry, and the large-scale withdrawal of water from Chenghai

Lake have altered the natural conditions of the water cycle, increasing terrestrial evaporation and transpiration, and reducing inflow into the lake.

Table 1. Basic situation of Hekou Street control section.

Hydrological Frequency P/%	Water Revenue/Hectare-cubic meters		Water Expenditure/Hectare-cubic meters					
	Surface runoff	Lake precipitation	Lake evaporation	Agricultural irrigation water consumption	Livestock and poultry water consumption	Domestic water consumption	Industrial water consumption	Other water consumption
20	1.1258	0.6593						
50	0.958	0.568						
75	0.8185	0.5014	1.3635	0.1825 - 0.2175	0.0102 - 0.0131	0.0058 - 0.0082	0.0055	0.0452
95	0.5933	0.416						

3. Calculation of the Current Minimum Ecological Water Level

3.1. Analysis of the Trend in Water Level Changes at Control Sections

Based on the actual hydrological data from the Hekou Street Hydrological Station of Chenghai Lake, the trend of water level changes in Chenghai Lake from 1985 to 2021 was analyzed. The annual average minimum water level of Chenghai Lake was 1495.62 m (in 2021), and the overall linear trend of the annual average water level from 1985 to 2021 was a continuous and significant decrease. The multi-year average water level was 1499.25 m, and the annual average maximum water level was 1501.80 m (Figure 2).

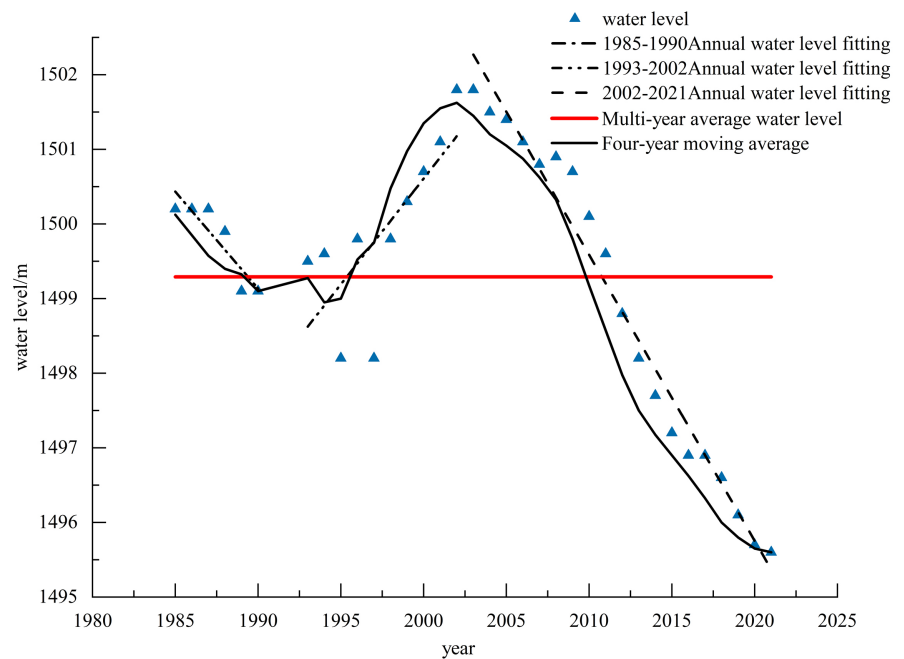


Figure 2. Trend line of water level changes of Chenghai Lake.

The study refers to Article 5 of the “Chenghai Lake Protection Regulations of Yunnan Province” (2007), which states that the maximum operating water level of Chenghai Lake is 1501 meters, and the minimum controlled water level is 1499.2 meters. The annual average water level in 2017 had already fallen 2.34 meters below the minimum controlled water level. **Figure 3** shows that the water level changes of Chenghai Lake over 32 years can be divided into three stages, and **Table 2** shows the water level changes in these three stages: 1) The first stage. From 1985 to 1990, the water level fluctuated and decreased, with an overall drop of 1.1 meters and an average annual decrease of 0.22 meters; 2) The second stage. From 1993 to 2002, the water level fluctuated and increased, with an overall rise of 2.36 meters and an average annual increase of 0.26 meters; 3) The third stage: From 2002 to 2021, the water level continued to decrease significantly, well below the legal water level red line (1501 meters), with a total drop of about 6.18 meters, an average annual decrease of about 0.33 meters, an accelerated rate of water level decline, a continuous reduction in the water storage capacity of Chenghai Lake, and an average of 26.28 million cubic meters over the past 15 years.

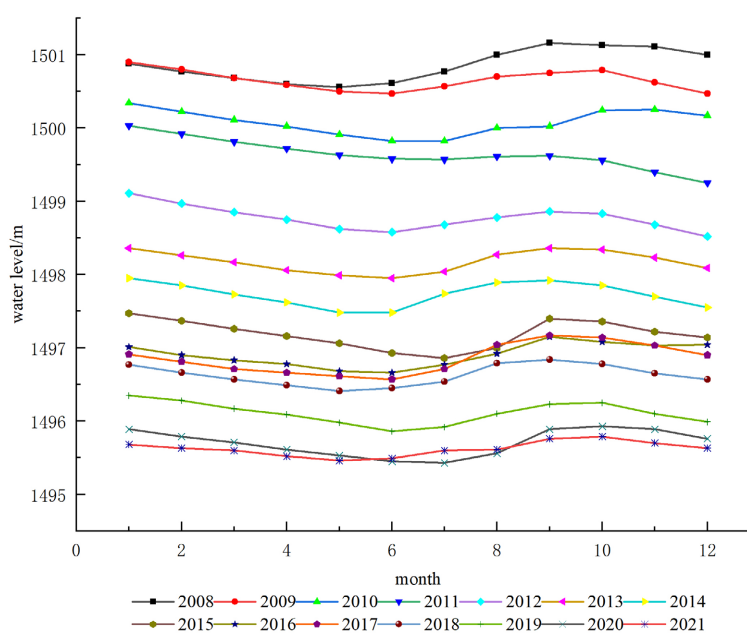


Figure 3. Water level hydrograph from 2008 to 2021.

Table 2. Chenghai water level characteristic table.

Hydrologic series	Multi-year mean water level	Annual minimum water level	Annual maximum water level
1985-1990	1499.78 m	1499.10 m	1500.20 m
1993-2002	1499.92 m	1498.20 m	1501.80 m
2002-2021	1498.97 m	1495.62 m	1501.80 m
1985-2021	1499.34 m	1495.62 m	1501.80 m

According to the data in the “Lijiang City Water Resources Comprehensive Plan,” a phased analysis of the impact of existing and under-construction water conservancy projects, water diversion projects, and climate change on Chenghai Lake was conducted: 1) The first stage (1985-1990), there was no water replenishment from water diversion projects, and rainfall was relatively scarce. However, human activities had a minimal impact during this stage, and the water usage for agriculture and industry was not significant, so the water level of Chenghai Lake showed a declining trend but with small fluctuations. 2) The second stage (1993-2002), the Xianxian River inter-basin water diversion project was initiated, which diverted water from the Xianxian River to Chenghai Lake through a tunnel (1993-2000), with an average annual replenishment of 17 million m³. Although the production and living activities developed rapidly in the vicinity of the basin during this stage, and the water usage for agriculture and industry increased compared to the previous stage, the water level of Chenghai Lake still showed a fluctuating upward trend; after 2000, due to the deterioration of the water quality in the Xianxian River, no more water was diverted from the Xianxian River to Chenghai Lake, and the water level stopped rising. 3) In the third stage (2002-2021), no water diversion projects were implemented, and the development of agriculture and industry in the vicinity of the basin accelerated, leading to increased water usage. Additionally, from 2009 to 2012, Chenghai Lake experienced drought years with a sharp decrease in precipitation, causing a continuous and significant decline in the water level of Chenghai Lake during this stage. After 2017, the ecological emergency water replenishment project from the Baqing River and Pinghe River to the Xianxian River tunnel was put into operation, which moderated the rate of water level decline in Chenghai Lake. In September 2020, the Yongsheng County Chenghai Lake Basin Ecological Comprehensive Management Water Conservancy Emergency Water Supply Project was completed and tested for water flow, making the water level decline of Chenghai Lake slower and more stable.

3.2. Ecological Water Level Targets at Control Sections

In recent years, the water level of Chenghai Lake has continued to decline significantly, with an average water level of 1496.97 meters over the past 10 years and 4 years, and the highest water level was only 1499.11 meters (in 2012), failing to meet the requirements of the legal minimum ecological water level. The statutory ecological water level targets proposed by previous studies are not in harmony with the current water level situation of Chenghai Lake and cannot ensure ecological environment safety; hence, there is a need to re-determine the minimum ecological water level of Chenghai Lake.

According to **Figure 3**, the water level of Chenghai Lake has shown a high consistency in the trend of change in recent years, and the monthly average water level has been declining year by year [12]. Except for the driest month of the year, which is distributed from May to July, the multi-year driest monthly average water level was 1495.46 meters in May 2021.

According to the SL/Z 479-2010 “Guidelines for the Assessment of Ecological Water Demand in Rivers and Lakes (Trial)” and SLT712-2021 “Specifications for the Calculation of Ecological Water Demand in River and Lake Ecological Environments”, the minimum ecological water level refers to the lowest water level in the lake area that maintains the basic form and basic ecological functions of the lake wetland, and is the minimum limit value to ensure the structure and function of the lake wetland ecosystem. The calculation method for the minimum ecological water level is as follows:

1) Minimum Annual Average Water Level Method. Based on the method of calculating the average flow of the driest month in hydrology and the Texas method, combined with lake biological indicators and multi-year water level conditions, a method for calculating the minimum ecological water level of lakes is proposed. The calculation formula is as follows [6]:

$$H_{\min} = \lambda \frac{\sum_{i=1}^n H_i}{n} \quad (1)$$

In the formula: H_{\min} represents the minimum ecological water level of the lake, in meters; λ is the weight, with a typical range of 0.65 to 1.55; H_i is the minimum water level of the i -th year, in meters; n is the number of years of statistics. By selecting the average water level of the driest month in the last 14 years for calculation, the result is = 1497.706 m.

2) Natural Water Level Data Method. Starting from the natural fluctuation of water levels, the multi-year minimum water level of the lake is taken as the minimum ecological water level of the lake, where the minimum water level can be selected as the monthly average minimum water level, daily average minimum water level, or instantaneous minimum water level, etc. [4]. This paper adopts the monthly average minimum water level as the minimum ecological water level, and the calculation formula is as follows:

$$Z_{e \min} = \min(Z_{\min 1}, Z_{\min 2}, \dots, Z_{\min n}) \quad (2)$$

In the formula: $Z_{e \min}$ represents the minimum ecological water level, and $Z_{\min 1}, Z_{\min 2}, \dots, Z_{\min n}$ represents the minimum monthly average water level of the i year.

3) Lake Morphological Data Method. Corresponding to the maximum value of the lake water level, as the lake level decreases by one unit, the reduction in the lake surface area will significantly increase. If this maximum value corresponds to a water level near the natural minimum water level of the lake, then the hydrological and topographical subsystems of the lake will undergo severe degradation [4]. Therefore, this maximum value is considered the minimum ecological water level.

$$\begin{aligned} F &= f(H) \\ \frac{\partial^2 F}{\partial H^2} &= 0 \\ (H_{\min} - a) &\leq H \leq (H_{\min} + b) \end{aligned} \quad (3)$$

In the formula: F represents the lake surface area (m^2); H represents the lake

water level (m); H_{\min} represents the multi-year minimum water level under natural conditions of the lake (m); a and b are small positive numbers representing the range of lake water level fluctuations (m). The calculation yields = 1499.09 m.

According to the minimum annual average water level method [6], natural water level data [4], and lake morphological data method [4], the calculated minimum ecological water levels for Chenghai Lake are 1497.706 m, 1495.43 m, and 1499.09 m, respectively.

According to the “Chenghai Lake Protection Regulations of Yunnan Province” (2007), the maximum operating water level of Chenghai Lake is 1501.00 meters, and the minimum controlled water level is 1499.20 meters. The “Lijiang City Water Resource Protection Planning Report” (2016) also proposes that the minimum ecological water level of Chenghai Lake is 1499.20 meters, which is also the legal minimum ecological water level of Chenghai Lake.

Based on the hydrological data series from the Hekou Street Hydrological Station and by comprehensively determining the ecological water level targets for Chenghai Lake, the minimum ecological water level should be lower than the multi-year average water level. By comparing the results of the three ecological water level calculations, it is determined that the minimum ecological water level should be 1495.43 meters. Therefore, until the year when the water level of Chenghai Lake recovers to the legal minimum water level in the future, 1495.43 meters will be used as the minimum ecological water level of Chenghai Lake, and after the recovery of the legal minimum water level, 1499.20 meters will be used as the minimum ecological water level of Chenghai Lake (Table 3).

Table 3. Control section ecological water level target results table.

Name of Section	Type of section	Multi-year mean water level	“Regulations of Yunnan Province on Cheng Hai Protection”/“Water Resources Protection Planning Report of Lijiang City” Results in progress	Method of mean water level of the last 10 years	The minimum ecological water level determined at this stage
Hekou Street	River system node	1499.34 m	1499.20 m	1495.43 m	1495.43 m

4. Prediction of Future Minimum Ecological Water Levels

4.1. Status of Water Conservancy Construction in the Basin

In the Chenghai Lake basin, there are 5 constructed reservoirs, all of which are small (Type II) reservoirs, including Mayiping Reservoir, Maojiaqing Reservoir, Majia Cemetery Reservoir, Honghaizi Reservoir, and Hongfen Reservoir. The total designed storage capacity of these reservoirs is 843,000 m³, and the beneficial storage capacity is 570,000 m³. There are a total of 27 pump stations with water intakes in the basin, of which 22 are for agricultural water use, 4 are for industrial water use, and 1 is for ecological water use, with an annual designed total water extraction volume of 4.78 million m³.

Due to the continuous decline of water levels in Chenghai Lake, the amount of

water diverted by the reservoirs and pump stations is relatively small and far from meeting the ecological water demand of Chenghai Lake. To increase the clean water inflow into the lake, restore the operational water level of Chenghai Lake, and curb the continuous decline in water levels, an inter-basin water diversion model has been adopted to construct inter-basin water diversion projects. The control sections of Chenghai Lake and water projects are shown in **Figure 4**. Currently, the Baqing River Emergency Ecological Water Supply Project for Chenghai Lake (Project A), the Yangping River to Xianxian River Tunnel Emergency Ecological Water Supply Project for Chenghai Lake (Project B), and the Yongsheng County Chenghai Lake Basin Ecological Comprehensive Management Water Conservancy Emergency Irrigation Water Supply Project (Project C) have been completed. In 2022, the Yongsheng County Xiaomi Tian Reservoir to Xianxian River Water System Connectivity Project (Project D) and the Mingzi Bridge River to Bai Cao Ping Reservoir Connectivity Water Supply Project (Project E) were constructed. At present, the water level restoration and water quality improvement of Chenghai Lake mainly relies on the water supply from the water diversion projects, and this trend is expected to continue in the future.

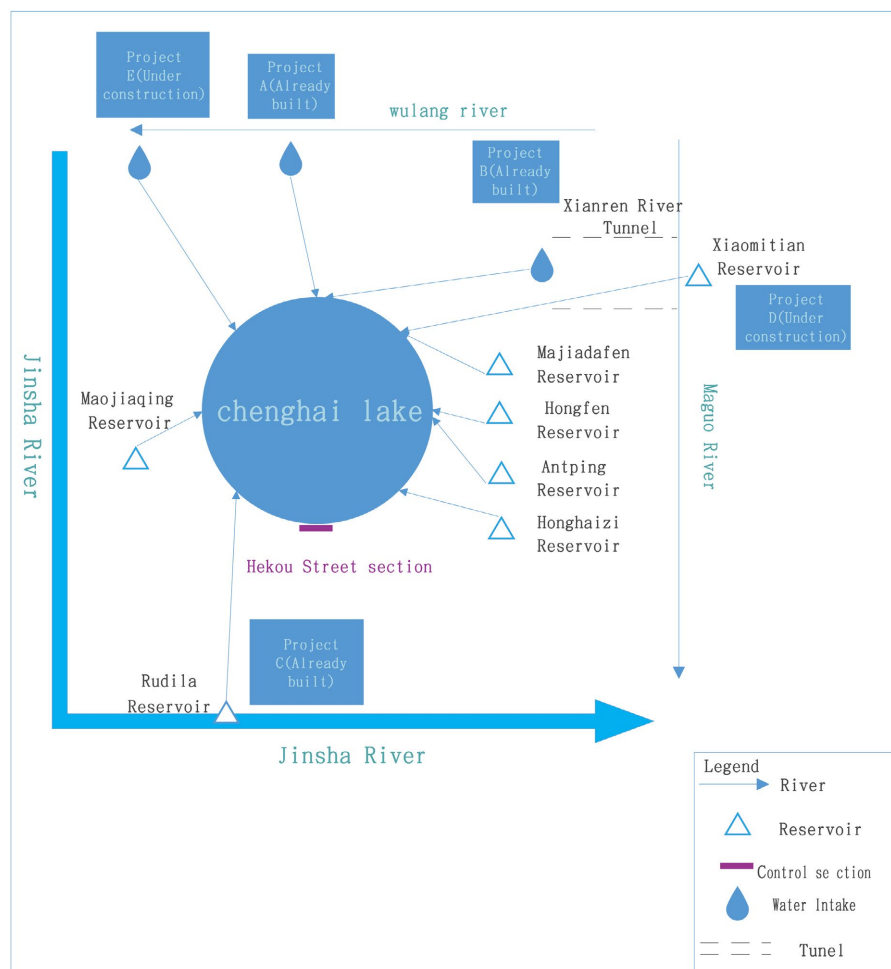


Figure 4. Schematic diagram of Chenghai control section and water engineering.

4.2. Analysis of Ecological Water Volume Scheduling for Water Diversion Projects

According to the “Yunnan Province Water Quota” standard, based on the population statistics of the Chenghai River basin in 2019, with an annual natural growth rate of 1.06%, and the rural population is estimated to be 20% of the total population. The water demand for processing in rural enterprises is calculated at an average annual increase of 10,000 m³, and the water consumption coefficient is estimated at 0.2. The rest of the water volume expenditure is estimated according to **Table 1** in the text. The annual water volume expenditure and income details are shown in **Table 4**.

Table 4. Water balance of Chenghai Lake Basin.

Years	Water Revenue			Water Expenditure					Difference
	Surface Runoff	Lake Precipitation	Lake Evaporation	Agricultural Livestock	Domestic Use	Industrial Use	Tourism Water Use	Other Water Consumption	
2019	7800	5127	12367	3201	106	155	211	452	-3565
2020	8035	5830	11642	2998	106	155	211	452	-1699
2021	5357	4485	12340	2835	0.0106	155	211	452	-6258

As shown in **Table 5**, during the period from 2018 to 2021, Project A, Project B, and Project C respectively replenished Chenghai Lake with 6.8268 million m³, 22.025 million m³, and 84.68 million m³ of water. The amount of water replenishment far exceeds the deficit in the water balance of the basin, as shown in **Table 4**. Through the water diversion projects, the water used for production and daily life within the Chenghai Lake basin has been essentially replaced by water sources from outside the basin, with all the water in the Chenghai Lake basin being used for ecological purposes. The projects have effectively curbed the continuous decline in the water level of Chenghai Lake and show an improving trend. However, as of December 2021, the water level of Chenghai Lake was 1495.63 m, which is still 3.57 m lower than the legal minimum operating water level; the corresponding lake capacity is 1.502 billion m³, which is 190 million m³ less than the lake capacity corresponding to the legal minimum water level. The ecological water demand for the recovery period of Chenghai Lake is about 3.73 billion m³, and the actual total replenishment from the three existing water replenishment projects from 2018 to 2021 is about 1.14 billion m³, with a water shortage of 2.59 billion m³. Projects D and E are expected to be completed and operational by 2025, working in conjunction with the three existing water diversion projects to change the current declining trend of the water level in Chenghai Lake. The estimated future water replenishment of the under-construction projects is shown in **Table 6**.

Table 5. Water replenishment of the existing water diversion projects in Chenghai Lake.

	Design water supply	Replenishment water quality	Water refill time	Water replenishment in 2018	Water replenishment in 2019	Water replenishment in 2020	Water replenishment in 2021
Project A	256	II class	From June to November	73.78	/	334.1	274.8
Project B	1121	II class	From June to November	/	619.5	927.5	655.5
Project C	Near-term 6816.6/ =long-term 2210.6	II class	Year-round water refill	/	/		4234

Note: Unit of water supply: ten thousand cubic meters.

Table 6. Water replenishment of Chenghai Lake under construction water diversion project.

Name of Project	Class of Engineering	Water replenishment	Traffic (m ³ /s)	Replenishment water quality	Water refill time
Project D	Work in progress	6756	9.50	Class II Water quality	Year-round water refill
Project E	Work in progress	257.5	1.0	Class III Water quality	Year-round water refill

Note: Unit of water supply: ten thousand cubic meters.

Based on the information related to the existing and under-construction projects, as well as the aforementioned water extraction and use situation of Chenghai Lake, a feasibility analysis is conducted on whether Chenghai Lake can recover to the legal minimum water level of 1499.20 m in the future. Projects D and E both commenced construction in 2022, and it is expected that they will be operational by 2025. According to the predicted water replenishment volume of the existing projects, the year when the legal minimum water level is expected to be reached is 2025. Assuming the actual measured water replenishment volumes of 2021 and 2020, as per **Table 7**, it is forecasted that Project D will have an average annual ecological water replenishment volume of 67.56 million m³, and Project E will have an average annual ecological water replenishment volume of 2.875 million m³.

5. Conclusions

1) To change the recent decline in the ecological water level of Chenghai Lake, hydrological data from the Hekou Street Hydrological Station was utilized, referring to existing results of the minimum ecological water level. Based on the minimum annual average water level method, natural water level data method, and lake morphological data method, the current minimum ecological water level of Chenghai Lake is calculated to be 1495.43 m, which will be used as the minimum ecological water level until the legal, ecological water level is restored.

Table 7. Prediction of water replenishment for Chenghai Lake water diversion project.

Project		End of 2021 (Actual measurement)	In 2022 (prediction)	In 2023 (prediction)	In 2024 (prediction)	In 2025 (prediction)
Water level value (m)		1495.63	/	/	/	>1499.20
Capacity of lake (hundred million cubic metres)		15.02	/	/	/	>16.92
Water supply for existing projects (ten thousand cubic meters)	In 2021	5164	5164	5164	5164	5164
	In 2020	5164	5496	5496	5496	5496
Water supply for projects under construction (ten thousand cubic meters)		/	/	/	/	7043.5
Water to be replenished (hundred million cubic metres)	In 2021	2.59	2.07	1.56	1.04	-0.18
	In 2020	2.59	2.04	1.49	0.94	-0.31

2) By analyzing the ecological water volume scheduling of the existing and under-construction water diversion projects in Chenghai Lake, and analyzing the feasibility of restoring Chenghai Lake to the legal water level, it is projected that Chenghai Lake will be restored to the legal minimum ecological water level of 1499.20 m by 2025. With the joint operation of the five water diversion projects, the issue of the declining water level and water resource shortage in Chenghai Lake is expected to be improved by 2025.

3) This paper only analyzes the feasibility of restoring the future ecological water level of Chenghai Lake based on water diversion projects. To ensure the ecological environment safety of Chenghai Lake, it is necessary to further optimize the calculation of the minimum ecological water level of Chenghai Lake from multiple aspects, such as the water demand of various organisms in the basin and the management objectives of water body quality. Moreover, modern scientific and technological means should be combined for real-time monitoring of the ecological environment of the basin, and the water diversion and allocation projects should be adjusted in a timely manner to alleviate the water shortage in the basin.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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