Research on Water Replenishment Mechanism and Regulation of Water Resources for Wetlands

——A case study of Xianghai Wetland

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1. Introduction

Xianghai Nature Reserve locates in Tongyu County in the west of Jilin province. Jilin Provincial People's Government approved its establishment in 1981. It is characterized with inland wetland and water ecosystem aiming at protecting rare water birds (red-crowned crane) and rare plant communities (Mongolia Huang Yu). [1]

In recent 20 years, ecological environment of Xianghai Wetland has been seriously damaged as a result of human activities, the lack of water resources and unified wetland management, leading to frequent change of land type, degradation of water environment structure, severe pollution in parts of areas, change of community structure and decline of habitat quality, rapid development of desertification and hindering the sustainable development of the local economy.

To protect the environment and gradually restore wetlands' ecological functions, research on water replenishment for wetlands are necessary for providing effective basis to management of wetlands and regulation of water resources.

2. Definitions related to water replenishment for wetlands

2.1 Ecological water demand of wetlands

Ecological water demand of wetlands refers to the quantity of water that wetland requires to maintain its own continuation and conserve its major biological diversity. And it is divided into appropriate ecological water demand and minimum ecological water demand. Appropriate ecological water demand refers to the quantity of water that prevents the present status of wetland from further deteriorating and gradually improves the ecological environment. Minimum ecological water demand refers to the lowest quantity of water that wetland requires to maintain its own development or it will deteriorate, degrade and even disappear. [2]

2.2 Ecological water replenishment for wetlands

Ecological water replenishment for wetlands refers to transferring water from adjacent areas with engineering measures to replenish water for wetlands artificially so that wetlands can maintain constant water surface and ecological functions.

The calculation of ecological water replenishment for wetlands is the premise of rational allocation of water resources. Based on natural conditions of wetland ecosystem, practical demand of ecology and environment and practical abundant-lack change of water resources should be considered so that the rational fluctuation of wetlands' water storage on spatial and temporal scale can be ensured. [3]

3. Supply and demand analysis of water resources for Xianghai Wetland

3.1 Analysis of ecological water demand of Xianghai Wetland

According to the calculation results of ecological water demand of Xianghai Wetland, appropriate ecological water demand is $1.94\times10^8m^3$; minimum ecological water demand at P=75% is $0.94\times10^8m^3$; minimum ecological water demand at P=95% is $1.12\times10^8m^3$, as is shown in Table 1 (P stands for the accumulated frequency of rainfall).

Table 1 Results of appropriate and minimum ecological water demand Unit: 10^8m^3

Appropriate ecological water demand	Minimum ecological water demand	
	P=75%	P=95%
1.94	0.94	1.12

3.2 Analysis of water resources of Xianghai Wetland

(1) Rainfall and evaporation

According to rainfall data (Water Resources Bulletin of Baicheng City) of the latest 20 years (1986-2008), the annual average rainfall is 360.6mm; the annual average evaporation is 1686.5mm.

(2) Surface runoffs

The main outer water resources of Xianghai Wetland are Huolin River, E'mute River and Tao'er River. Besides the little quantity of water generated by the nature reserve itself, main water resources of Xianghai Nature Reserve are the divided floods of Tao'er River, E'mute River floods and Huolin River floods.

The water quantity of Xianghai Reservoir is the sum of floods of Tao'er River divided at Longhuatu and floods of E'mute River. The annual average water quantity is $8.338\times10^8m^3$. The annual average water quantity of Huolin River flows into Xianghai Nature Reserve is $2.212\times10^8m^3$. Besides, there are $1054.67km^2$ of areas around Xianghai Nature Reserve that can generate runoffs whose annual average water quantity is $0.0871\times10^8m^3$. So the total annual average natural water supply of Xianghai Wetland is $3.13\times10^8m^3$.[4] The results are shown in Table 2.

Table 2 Natural water supply of Xianghai Wetland Unit: 10^8m^3

Rivers	Annual average water quantity	Frequency				
		10%	25%	50%	75%	95%
Xianghai Reservoir	0.83	1.74	1.06	0.76	0.50	0.32
Huolin River	2.21	5.47	3.51	1.25	0.54	0.52
Other runoffs	0.09	0.22	0.07	0.04	0.00	0.00
In total	3.13	7.43	4.64	2.05	1.04	0.84

(3) Development and utilization situation of water resources

Xianghai Reservoir was built on the purpose of providing water environment for Xianghai Nature Reserve and meanwhile functioning on flood prevention, flood detention, fishery, irrigation and tourism. However, continuous drought has led to desperate water storage. Tao'er River water transferring project and Huolin River water transferring project can both defend the rivers against floods and supply water to Xianghai Reservoir.

4. Components of water replenishment program for Xianghai Wetland

4.1 Sources of water replenishment

E'mute River is a seasonal river and is short of water annually. Only when in wet years, its floods can flow into Xianghai Reservoir. Most of the water of Huolin River flows into Xianghai Nature Reserve can finally be transferred to Xianghai Reservoir. In non-flood season, most of water of Tao'er River is provided to the downstream irrigation area. Only in flood season the water can be divided at Longhuatu and flow into Xianghai Reservoir through the trunk channel. Cha'ersen Reservoir is the only controlling project on the main stream of Tao'er River. The annual average water quantity is $8.3\times10^8 m^3$, and the total capacity is $12.53\times10^8 m^3$.

As is mentioned above, sources of water replenishment can be determined as Tao'er River and Cha'ersen Reservoir on its upstream.

4.2 Quantity of water replenishment

According to the results of ecological water demand and total annual average natural water supply of Xianghai Wetland, guarantee extent of water demand and the results of ecological water replenishment can be obtained as is shown in Table 3 and Table 4.

Table 3 Guarantee extent of water demand of Xianghai Wetland Unit: $10^8 m^3$

Water demand / Water supply	Appropriate water demand	Minimum water demand (P=75%)	Minimum water demand (P=95%)
	1.94	0.94	1.12
Quantity of water supply (P=50%)	2.05	2.05	2.05
Guarantee extent (P=50%)	100%	100%	100%
Quantity of water supply (P=75%)	1.04	1.04	1.04
Guarantee extent (P=75%)	54%	100%	93%
Quantity of water supply (P=95%)	0.84	0.84	0.84
Guarantee extent (P=95%)	43%	89%	75%

Table 4 Results of ecological water replenishment of Xianghai Wetland Unit: $10^8 m^3$

Quantity of water replenishment	Types of water demand		
	Appropriate water demand	Minimum water demand at P=75%	Minimum water demand at P=95%
P=75%	0.90	0	0.08
P=95%	1.10	0.10	0.28

4.3 Situation of water replenishment

When in wet years (P=10% P=25%), the predicted water supply is much more than the water demand, there is no need to replenish water for Xianghai Wetland. In general years (P=50%), the predicted water supply approximately equals to the water demand. Besides, Xianghai Wetland has abundant underground water resources. There is no need to replenish water for Xianghai Wetland. When in dry years (P=75% P=95%), the predicted water supply is less than the water demand. It must be considered to transfer water out from the river basin to meet the ecological water demand of wetlands.

4.4 Time of water replenishment

Reeds are main plant of swamps in wetlands. In August, growth of reeds needs more water and August is also flood season of rivers. So it coincides with rules of nature. Spring and autumn are respectively the germination and mature period of reeds, and they don't require a high quantity of water.[5] The characteristic of wetlands' water demand within one year is that more water demand in summer and less water demand in spring and autumn, which coincides with the characteristic of natural water supply. So it is reasonable to determine the time of water replenishment as flood season.

5. Water replenishment program for Xianghai Wetland

With the analysis of sources, quantity, situation and time of water replenishment synthesizing the existing water resources, water supply and water division projects, water replenishment program of

Xianghai Wetland can be constructed.

5.1 Transferring water from Tao'er River to Xianghai Wetland

Here is a recommendation of constructing a water division dam that can transfer water into Xianghai Reservoir from Tao'er River instead of making the water replenish irrigation areas in flood season (June, July and August) of dry years.

(1) Forecast of practical quantity of water replenishment

Fig. 1 shows the monitoring stations along Tao'er River and the trunk channel of water replenishment.

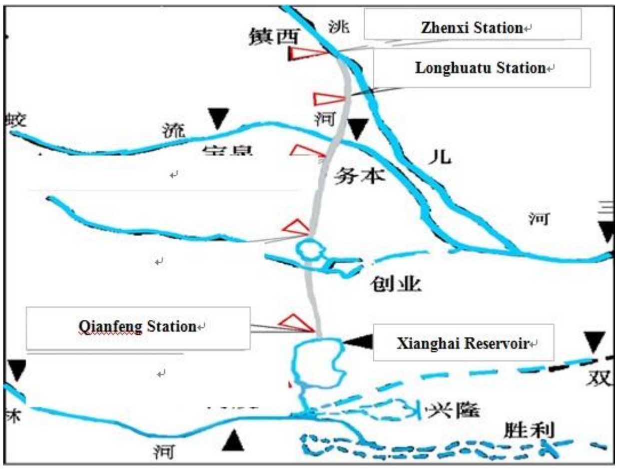

Fig. 1 Course of transferring water from Tao'er River to Xianghai Reservoir

Here is an example of water replenishment forecast in dry years at P=75%. And the typical year of P=75% is 2006. The water quantity of Longhuatu can be calculated by the water quantity data of Zhenxi. Time of water replenishment is chosen as in June, July and August. The original water quantity of Longhuatu is duplicated and should be deducted. In addition, the river water demand of Tao'er River before Longhuatu should also be deducted. Here it is roughly determined as $0.02\times10^8m^3$ according to related materials of Tao'er River. Because of evaporation, leakage and the bad conditions of the trunk channel, there is water loss between Longhuatu and Xianghai Reservoir. Here the loss percentage is roughly determined as 60%.

Summarizing all the results calculated above, total quantity of water replenishment can be obtained as is shown in Table 5.

Table 5 Practical quantity of water replenishment transferred from Tao'er River Unit: 10^8m^3

Month / Water quantity	June	July	August	In total
WQ of Longhuatu	0.71	1.29	1.13	3.13
Original WQ of Longhuatu	0.00	-0.22	-0.37	-0.59
River water demand	-0.02	-0.02	-0.02	-0.06
Loss	-60%	-60%	-60%	-60%
Total water quantity	0.28	0.42	0.30	1.00

So total practical quantity of water replenishment at P=75% can be determined as $1.00\times10^8m^3$. With similar method, total practical quantity of water replenishment at P=95% can be determined as $0.87\times10^8m^3$.

(2) Feasibility analysis of practical water replenishment

As Table 4 shows, theoretical water replenishment to meet the appropriate water demand at P=75% and P=95% is $0.9\times10^8m^3$ and $1.1\times10^8m^3$. The contrast of theoretical water replenishment and practical water replenishment from Tao’er River is shown in Table 6.

Table 6　Contrast of theoretical and practical water replenishment　Unit: 10^8m^3

Water replenishment / Frequency	Theoretical quantity of water replenishment	Practical quantity of water replenishment	Guarantee extent
P=75%	0.90	1.00	100%
P=95%	1.1	0.87	79%

So in the years when P=75%, practical quantity of water replenishment is larger than theoretical quantity of water replenishment. The water replenishment program is feasible. In years when P=95%, practical quantity of water replenishment is smaller than theoretical quantity of water replenishment. The water transferred from Tao’er River is not enough to meet the appropriate water demand of Xianghai Wetland. More water needs to be transferred to Xianghai Wetland.

5.2 Transferring water from Cha’ersen Reservoir to Xianghai Wetland

When in extreme dry years, the water transferred from Tao’er River is not enough to meet the appropriate water demand of Xianghai Wetland. Urgent water supply from Cha’ersen Reservoir can relief the desperate drought crisis.

The water replenishment course starts from Cha’ersen Reservoir, passes through Tao’er River watercourse and the trunk channel, and ends in Xianghai Reservoir as is shown in Fig. 2.

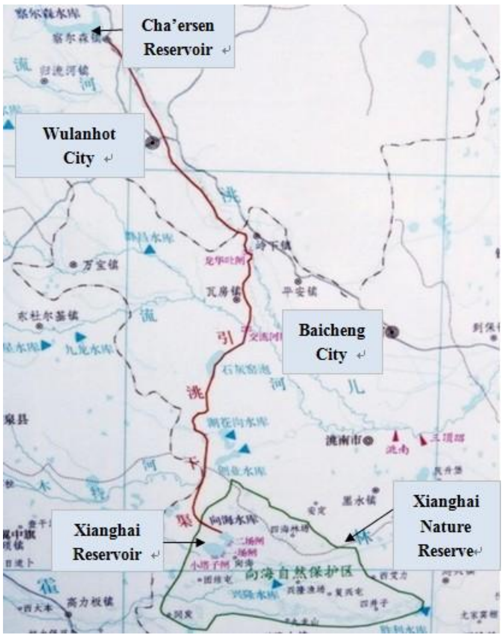

Fig. 2　Course of transferring water from Cha’ersen Reservoir to Xianghai Reservoir

Here is a discussion about the calculation of practical quantity of water replenishment taking the past cases in 2004 as example.[6]

The adjustable water quantity of Cha’ersen Reservoir relates to current and fixed capacity of reservoir, water supply in flood season, loss of evaporation and leakage, water agreements of reservoir and other areas and so on. With the data of the conditions mentioned above in 2004, the adjustable water quantity of Cha’ersen Reservoir can be determined as $0.63\times10^8m^3$.

The adjustable water quantity between Cha’ersen Reservoir and Zhenxi station relates to water supply from other rivers (Guiliu River), water discharged by upstream irrigation areas and evaporation loss. With the data of the conditions mentioned above in 2004, the adjustable water quantity between Cha’ersen Reservoir and Zhenxi station can be determined as $0.23\times10^8 m^3$. And the water quantity before Longhuatu can be determined as $0.85\times10^8 m^3$.

Referencing 5.1, because of evaporation, leakage and the bad conditions of the trunk channel, there is 60% of water loss between Longhuatu and Xianghai Reservoir.

So total practical quantity of water replenishment can be roughly determined as $0.34\times10^8 m^3$. This is the water quantity that can serve as an urgent water supply to Xianghai Wetland without bringing damage to functions of Cha’ersen Reservoir itself.

6. Conclusions and recommendations

6.1 Conclusions

(1) This thesis analyzes the surface water resources quantity and the utilization situation of Xianghai Wetland. Based on the results of appropriate and minimum water demand, the sources, quantity, time and situation of water replenishment are determined.

(2) Summing up the status of water demand and supply and the sources, quantity, time and situation, this thesis systematically proposes the detailed water replenishment program of Xianghai Wetland, providing a reference for the establishment of long-term water replenishment mechanism.

6.2 Recommendations

(1) Quantitative research of water replenishment for wetlands

Further research on distribution rules and control mechanism of wetlands on spatial and temporal scale; and the establishment of simulation model of water replenishment and regulation model of water environment system from an integrity point is necessary. So that a more effective and operational water replenishment program can be constructed.

(2) The establishment of ecological compensation mechanism of water replenishment for wetlands

Wetlands obtains water supply from other river basins through water division projects. However, the downstream areas of the water-transferring source will suffer from huge opportunity cost due to the lack of water. In order to coordinate the inequitable distribution of ecological and economic benefit between beneficiaries and victims, it is imperative to compensate for the downstream areas of the water-transferring source.

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