

Study of Ecological Water Demand of Rivers in Shenyang City, Northeastern China

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Abstract: The ultimate goal of the protection and restoration of water ecosystem is intended to facilitate the healthiness of ecosystems in rivers and lakes, and the basic premise of river healthiness is to ensure the ecological water demand of rivers. Shenyang City is the economic and cultural center of Northeastern China, and most rivers in the territory of Shenyang City are plagued with the ecology and environment problems such as dry-up of river way, wetland shrinkage and groundwater overdraft. In protection and restoration of water ecosystem, Shenyang City should first study the ecological water demand of rivers. In this paper, we first defined the connotation, composition and calculation method of ecological water demand of rivers and selected eight major rivers in Shenyang City for ecological water demand study and calculation according to the characteristics of the rivers and water resources conditions in Shenyang City. We calculated the basic eco-environmental water demand and consumptive water demand for evaporation and seepage of river ways respectively and thus obtained the total eco-environmental water demand for eight rivers. In total eco-environmental water demand of rivers, consumptive water demand for evaporation and seepage of river ways accounts for 51% and the eco-environmental water demand of rivers accounts for 49%.

Keywords: Water demand, Ecosystem, Shenyang City

Introduction

Shenyang City is located in Northern China with acute shortage of water, and the availability of water resources per capita is 341 m³, lower than 1/2 of the provincial average level and 1/6 of the national average level. The shortage of water resources in Shenyang has caused dry-up of river ways, degradation of water environment, groundwater overdraft, wetland shrinkage and other serious problems (Hao YU et al., 2007).

Under the current macro background of protection and restoration of ecological system at home and abroad (Hao WANG et al., 2010; Wei GUO et al., 2010), Shenyang City takes “Harmony Between Human and Water” and “Sustainable Development” as its final goal of development and <http://gwse.iheg.org.cn>

utilization of water resources and management and expects to fundamentally restore and maintain the healthiness of water ecosystems (Norris R H et al., 1999; Karr J R, 1999). To maintain the healthiness of river ecosystems, we should first identify the basic ecological water demand of rivers.

Shenyang City is the largest economic center in Northeast China and one of the important industrial bases in China. Shenyang City ranges in latitude from 41° 11' to 43° 02' N and in longitude from 122° 25' to 123° 48' E. It covers a total area of 12,980 km², including the urban built-up area of 185 km².

Shenyang mainly consists of plain; the land is flat and tilts gradually from east to west slowly, with an average elevation of about 50 m. The area of mountains and hills is less than 10%. Shenyang is

under a semi-humid continental climate in the temperate zone. The annual average temperature is 8.3°C. The average annual precipitation is 625 mm in the southern part and 525 mm in the northwest part.

There is a total of 23 surface water systems in Shenyang City. Among them, the large rivers include the Liaohe River, the Hunhe River, the Raoyang River and the Liuhe River; the medium-sized rivers include the Puhe River, the Yangximu River, the Beisha River, the Xiushui River and the Lama River. Except the Beisha River that runs into the Taizhi River, the other rivers flow into the Liaohe River and the Hunhe River (Hao YU et al., 2007).

Calculation Method of Ecological Water Demand

Based on the eco-environment water demand of Shenyang City, we provide here the methods for determining ecological base flow of the river, evaporation and seepage water consumption and environmental flow.

The calculation formula for the ecological water demand of river is as follows:

$$Q_L = \max(Q_V, Q_h) + Q_Z + Q_S \quad (1)$$

Where: Q_L is the ecological water demand of river; Q_V is the ecological base flow of river; Q_Z is the evaporation loss of river way; Q_S is the seepage loss of river way; Q_h is the water demand for river self-purification.

In this paper, we use the Tennant method to calculate the ecological base flow of river (Q_V). This method believes that instream flow should be no lower than 10% of the average annual natural runoff; otherwise the basic functions of river ecosystems will lose (Tennant D L, 1975).

The difference between average annual evaporation from water surface and precipitation is evaporation loss of a river way (Q_Z).

The recharge for seepage from a river way refers to the amount of water seepage for recharging groundwater when the water level of a river way is higher than the groundwater level in a riverbank (Q_S).

The water demand for self-purification of a river was determined based on the driest month flow method. In this paper, the average flow in the driest month was adopted (Q_h).

Integration of ecological water demand of river (Q_L): Both the ecological base flow of a river way and the water demand for self-purification of a river belong to flux water, while evaporation and seepage losses of a river way belong to consumptive water, so they should be treated differently when integrating the water demand of ecological needs of a river. The ecological base flow of a river way or the water demand for self-purification of a river, whichever is greater, among the amount of water for the flux part of a river should be utilized in the basic eco-environmental water demand of a river. The water demand at the control cross section can be calculated by adding it to the amount of consumptive water of a river way.

Calculation Results of Ecological Water Demand of the Rivers in Shenyang City

Selection of Rivers and Hydrometric Stations

There are eight large and medium-sized rivers in the territory of Shenyang. Xiushui River, Yangximu River, Liuhe River and Raoyang River are tributaries of Liaohe River. Puhe River is a tributary of the Hunhe River. Beisha River is a tributary of Taizi River and a secondary tributary of Hunhe River.

While analyzing the ecological flow of all river sections, we determined the hydrologic control cross sections of all rivers in Shenyang City: Juliuhe Station and Zhujiatang Station on Liaohe River; Shenyang Station and Xingjiawopeng Station on Hunhe River; Dongbaichengzi Station

on Raoyang River; Xinmin Station on Liuhe River; Gongzhutun Station on Xiushui River; and Xiaohuangdi Station on the Yangximu River. The basic information on the major hydrometric

stations in Shenyang is shown in Table 1, and the rivers and the major hydrometric stations are shown in Fig.1.

Table 1 Basic Information on Selected Hydrometric Stations in Shenyang City

Name of Station	Name of River	Flowing-to	Catchment Area (km ²)	Average Annual Natural Runoff (10,000 m ³)
Gongzhutun	The Xiushui River	The Liaohe River	6,443	1,775
Xiaohuangdi	The Yangximu River raising interest rates	The Liaohe River	8,562	1,783
Xinmin	The Liuhe River	The Liaohe River	33,497	5,647
Dongbeichengzi Baicheng	The Raoyang River	The Liaohe River	8,807	2,138
Shenyang	The Hunhe River	The Bohai Sea	204,214	7,919
Xingjiawopeng	The Hunhe River	The Bohai Sea	256,060	11,090
Juliuhe	The Liaohe River	The Bohai Sea	409,498	129,361
Liaozhong	The Liaohe River	The Bohai Sea	427,076	136,277

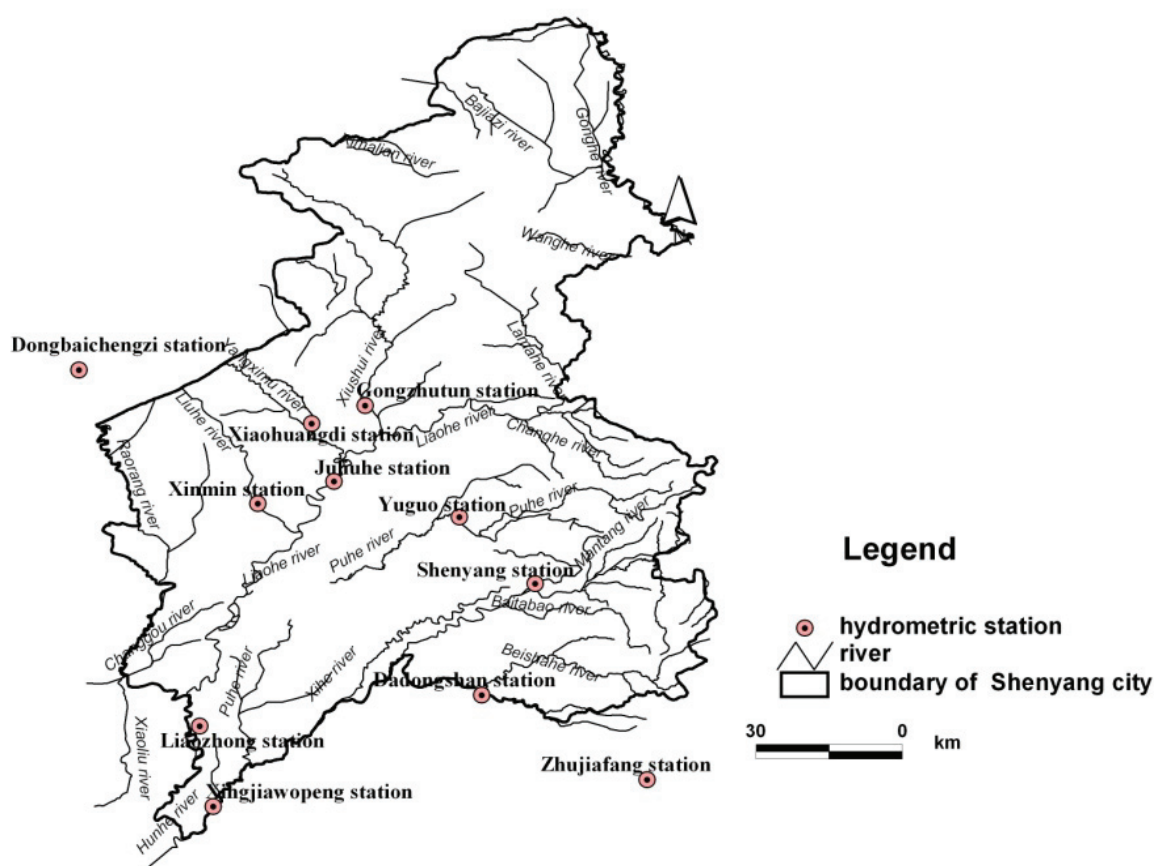


Fig.1 Distribution of the Rivers and Hydrometric Stations in Shenyang City

Table 2 Summary of the Calculation Results of the Ecological Water Demand of the Rivers in Shenyang City

Name of River	Name of Hydrometric Station	Average Annual Natural Runoff (10,000 m ³)	Basic Eco-environmental Water Demand of the Rivers (10,000 m ³)	Proportion of Basic Eco-environmental Water Demand of the Rivers (%)	Water Demand for River way Evaporation and Seepage (10,000 m ³)	Ecological Water Demand of the Rivers (10,000 m ³)
Xiushui River	Gongzhutun	6,443	644	10	7,378	8,022
Yangximu River	Xiaohuangdi	8,562	856	10	2,013	2,869
Liuhe River	Xinmin	33,497	3,350	10	2,746	6,096
Raoyang River	Dongbaichengzi	8,807	881	10	3,278	4,158
Liaohe River	Liaozhong	427,076	42,708	10	33,393	76,101
Puhe River	Yuguo	25,500	2,550	10	10,937	13,487
Beisha River	Dadongshanbao	27,612	7,033	25	2,709	9,742
Hunhe River	Xingjiawopeng	256,060	43,677	17	45,127	88,804

Note: The proportion of basic eco-environmental water demand of a river is the ratio of the basic eco-environmental water demand of the river to the average annual natural runoff of the hydrometric station.

Results and Discussion

The calculation results of the ecological water demand for the eight major rivers in Shenyang City are shown in Table 2.

Basic Eco-environmental Water Demand of Rivers

The basic eco-environmental water demand of the six rivers in Shenyang at the hydrometric stations, including Xiushui River, Yangximu River, Raoyang River, Liaohe River, Liuhe River and Puhe River, accounts for 10% of their annual average natural runoff. The basic eco-environmental water demand of the Beisha River accounts for 25% of annual average natural runoff, and Hunhe River accounts for 17%.

Evaporation and Seepage Consumption

The annual average water surface evaporation in Shenyang during 1980~2000 is about 800 mm. The average annual evaporation of the 8 rivers is 77.7 million m³, among which the annual average

evaporation in the Liaohe River catchment is 43.23 million m³ and that in the Hunhe River catchment is 34.47 m³.

The annual average seepage of the eight rivers is 998 million m³, among which the annual average seepage in Liaohe River catchment is 445 million m³ and that in Hunhe River catchment is 553 million m³.

Total Ecological Water Demand of Rivers

The total ecological water demand of a river is the sum of three subitems of basic eco-environmental water demand of the river, river way evaporation and river way seepage consumption. The total ecological water demand of 8 selected rivers in Shenyang City is 2.093 billion m³, of which: the water demand for river way evaporation and seepage consumption is 1.076 billion m³, accounting for 51%, and the basic eco-environmental water demand of the rivers is 1.017 billion m³, accounting for 49%.

Conclusions

Because of the impact of water shortages, Shenyang is facing many eco-environmental problems, such as river way dry-up and lake and wetland shrinkage. To protect and restore the ecosystems of rivers and lakes, we should first study and calculate the elementary ecological water demand of rivers.

In this paper, we first defined connotation and composition of the ecological water demand of rivers. Ecological water demand should include four subitems: the lowest runoff to survive most aquatic species, the amount of water to ensure evaporation on a certain water surface area of river ways, the amount of water to ensure the seepage of river ways and the amount of water for river self-purification.

We selected the eight major rivers in the territory of Shenyang City: Xiushui River, Yangximu River, Liuhe River, Raoyang River, Liaohe River, Puhe River, Beisha River and Hunhe River as the objects of study and calculated the basic eco-environmental water demand, the water demand for evaporation and seepage and the total ecological water demand of the rivers. The total ecological water demand of eight selected rivers in Shenyang City is 2.093 billion m^3 , of which: the water demand for river way evaporation and seepage consumption is 1.076 billion m^3 , accounting for 51%, and the basic eco-environmental water demand of the rivers is 1.017 billion m^3 , accounting for 49%.

The major reason affecting the healthiness of the aquatic ecosystems in Shenyang City is water amount guarantee. To protect and restore the green corridors of the rivers, it is necessary to set out from water resources allocation, provide the necessary ecological flow for ecosystems and regard instream water demand as one of service objects of water resources allocation and management.

The amount of local water resources in Shenyang is only about 2.3 billion m^3 , and the actual water consumption is 2.8 billion m^3 . In the future planning period, Shenyang will continue economic and social development, but the local water resources are a far from enough to meet the water demand for social and economic development, and the level of guarantee of ecological water demand is lower. Therefore, in the ecological water demand, Shenyang should be a priority for the use of upstream runoff, especially ecological water demand of river ways. The water demand for lakes and wetlands should mainly depend on reuse of reclaimed water and utilization of rainwater and flood resources.

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