J. Resour. Ecol. 2010 1(3) 211-215
DOI:10.3969/j.issn.1674-764x.2010.03.003
www.jorae.cn

Water topic

The Instream Ecological Water Flow Research at the Lower Reach of Guanting Reservoir on Yongdinghe River, Beijing

MEN Baohui[1]*, ZHANG Shifeng[2] and XIA Jun[2]

1 National Engineering Laboratory for Biomass Power Generation Equipment, Renewable Energy Institute, North China Electric Power University, Beijing 102206, China;
2 Key Laboratory of Water Cycle & Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China

Abstract: Yongding River, as the mother river of Beijing city, has been dried up from Sanjia Dian since 1980s. The naked riverbed and the desertification of its both sides play a main role of sandy weather in spring of Beijing. The Quaternary period underground water of the west Beijing has been drained off, because of the overload of the underground water plus with no supply pouring into. The ecological system of Yongding River has severely been devastated. If we want Yongding River to be recovered, we should clarify the quantity of the most active and the most important water. This paper calculated the instream ecological flow in three monitored sections of Yongding River Guanting Reservoir with wetted perimeter method. The three sections are Guanting Reservoir (under dam), Yanchi and Lugou Bridge. Respectively, the flows in the instream of each section are 3.7 m^3 s^{-1} (the normal flow year, P=50%, 1978) accounting for 20.7% of the average annual flow, 4.1 m^3 s^{-1} (the normal flow year, P=50%, 1981) accounting for 20.1% of the average annual flow and 1.3 m^3 s^{-1} (the normal flow year, P=50%,1978) accounting for 22.1% of the average annual flow. If the supplies are according to the calculated flows, Yongding River will return back from it. Still according to the Tennant method, the Yongding River will maintain a health situation.

Key words: wetted perimeter method; Yongding River; ecological water flow; Tennant method

1 Introduction

Ecological water flow is a hot research issue in and abroad. Ecology and environment is the fundamental thing related to human development, among which water play an absolute decisive role. "The ignorance of the connection between the water resource and ecology along with environmental system" is a big mistake made by water resource management in 20th century. For a long time, people only focus on solve the production and domestic water supply in the exploit of water resource. However, the ignorance of the connection between them caused a series of ecological and environmental problems, such as the shrink of lakes, the drought-up of rivers, the destroy of the wild's habitat, the loss of the biological diversity, the sedimentation of the streams, the weakening of water self-cleaning capacity, the deterioration of water environment and so on. Until 1970s, the importance of ecological water has gradually been seriously valued. To assure the benign circulation of water resource, realize the sustainable utilization of water resource and rebuild the ecological environment, the first goal is to coordinate the configuration of the ecological water and domestic water. The ecological water theory is generated by a new thinking model. The emphasis of it is to develop our water resource reasonable on the condition of protecting our nature first, stopping the deterioration and eventually realizing the sustainable utilization of water resource (Wang *et al.* 2002; Qiu 2006).

As the biggest and the important flood discharge river across Beijing, Yongding River is located in the west of the city and seen as the key flood control spot. And it was

Received: 2010-08-26 **Accepted:** 2010-09-02
Foundation: this study was supported by the Item of Yongding River ecological architecture and the restoration of technology research and demonstration, Open Research Fund Program of State Key Laboratory of Water Resources and Hydropower Engineering Science (No.2009B050), and the National Natural Science Foundation of China (No.50809027).
* **Corresponding author:** MEN Baohui. Email: menbh@126.com.

listed on the Top Four Flood Control Rivers in 1985 by the State Council. Since 1980s, Beijing has always been in the lack of water. To meet the water demand, the water flow of Yongding River from Sanjia Dian section above all has been introduced into the city, which made the 70 miles bellow dry up for years, and both sides desertification. In the recent years, people rampantly exploited the sands illegally which left the river way a mess and the river bed naked. Every winter, Beijing city is shrouded by the sands carried by northwest wind along the river way. The Quaternary period underground water of the west Beijing has been drained off, because of the overload of the underground water plus with no supply pouring into. The ecological system of Yongding River has severely been devastated. As an ecological link to southwest region and an important ecological corridor in Beijing, Yongding River can greatly get the environment and regional economy promoted in Beijing southwest, if it is well managed, not to mention the positive effect in the city plan, the ecological environment improvement and international livable city development (Yan *et al.* 2004; Sun *et al.* 2004; Yan *et al.* 2006).

Therefore, how to allocate the water resource of Yongding River and leave the appropriate ecological water flow in the meanwhile of guaranteeing the production and domestic water is the most urgent problem to be solved.

Currently, there are four methods to estimate the ecological water flow: Hydrologic Methodology, Hydraulics Methodology, IFIM (Instream Flow Incremental Methodology) and BBM (Building Block Methodology). Tennant method or Montana method (Tennant 1976), 7*Q*10 method (Caissie *et al.* 1998) and Texas method (Mathews and Bao 1991) are belong to hydrologic method. The advantage of it is simple to calculate and easy to operate and not so limited to data. However, the method is too simple to keep the real data of the river. Without considering biological variables and their mutual influence and the fluent flows (Karim *et al.* 1995), hydrologic time sequence of the river cannot keep consistency. Therefore this method should be processed by hydrologic sequence. IFIM (Gore *et al.* 1991; Stalnaker *et al.* 1994) and BBM (King *et al.* 1994; Rowntree and Wadeson 1998; King *et al.* 1998) not only consider hydrologic information (such as the flow), but also biological information. So the results are more reliable. But they require large quantity data and complex model. Considering the hydrologic and biological information of our country, the two methods are hard to be realized. Nevertheless, as a typical method in hydrologic methodology, wet perimeter methodology has a large room to perform. Because it only requires little data, such as the wet perimeter, the flow, water level and so on. These data can be acquired from hydrologic station and the method isn't limited by the influence which is made to the flow by human beings' activities.

In recent years, scholars in and abroad made a deep research on wet perimeter methodology. Gippel (Gippel *et al.* 1998) established the wet-flow fitting function by measured wet perimeter and flow data. And he compared the difference of wet-flow curve derived from curvature method and slope method. Ji *et al.* (2006) theoretically established the relationship of wet perimeter and flow of various geometric cross sections with her people. It reveals that rectangle cross section and trapezoid cross section match logarithm fitting function better. Triangle, U and parabola cross section match exponential fitting function better. They applied two methods, slope equal to 1 and the maximum curvature, to find the change points in the wet perimeter- flow curve. The results show that the ecological water calculated by slope equal to 1 is more than by maximum curvature. Liu *et al.* (2006) deduced that different method applied to *P-Q* curve would lead the two results deviate too much. It means wet perimeter method is not so stable. This paper plans to revise principle of the WPL curve by analyzing the *P-Q* relationship and hopes to unify the results get by the above two methods, reduce the instability caused by wet perimeter method, calculate the basic ecological water demand in the at lower reach of Yongding Guanting reservoir and provide a scientific support to environment management.

2 Methods

Wet perimeter method applies wet perimeter as the indicator to judge a habitat so as to estimate the minimum ecological water flow. Based on the above assumption, wet perimeter will have a direct connection with the aquatic lives' habitat. Therefore, to assure the wet perimeter of the habitat is to survive the aquatic lives (Gippel *et al.* 1998). The minimum ecological water demand can be derived from building the *P-Q* curve and finding the change points. The relation of *P-Q* can be derived from the measured data of one geometric dimension of multiple cross sections or multiple geometric dimension of one single cross section (Cui 2001; Miao *et al.* 2003). It can also be acquired from Manning formula (McCarthy 2003). Generally, wet perimeter increases along with the flow's growing. However, when the wet perimeter achieves a threshold, the increase will only change a little bit. Generally, shoals are chosen to be the cross section in wet perimeter method (McCarthy 2003), because shoals are the watershed of the aquatic lives' habitat. It is very sensitive to the change of the flow, river width, and water depth and flow velocity. When the flow subsides, it is the shoal that breaks the surface of the water. And the shoal is the habitat of fishes and invertebrates. Thus protecting the shoal can meet the requirement of the whole riverine ecosystem.

It is easy to run the wet perimeter method. Short term data can satisfy the method. Besides, it costs little and easy to realize. Compared with hydrologic methodology, wet perimeter considers more about the habitat on the condition of different flows. And it is backed up by hydrologic theory. Compared with IFIM and BBM, wet perimeter costs less and is faster to be used and not so strict with the long-term data. Only a few days' data can meet the needs. It has been wildly used in many countries. Wet perimeter method applies in those regions where their food is not so sufficient or where a simple method needed to be applied to the initial standard of the river basin planning (Thomas *et al.* 1998). However, wet perimeter method ignores the water depth and the change of flow velocity. The diverse aquatic livings' need in different periods and water demand in different seasons are ignored (Xu *et al.* 2004). Wet perimeter method is affected by shape of the channel and need the shape to be stable. Otherwise, the *P-Q* curve will not stable which will lead no constant growth change points (Yang *et al.* 2003). Yet, there are some assumptions involved in this method still need further discuss and some limitations. The main assumption is that the flow reflecting by the change point can meet the fishes' living demand. But this assumption has not been validated. And the corresponding flow is the lower limit of ecological water demand.

The key point of wet perimeter is to determine the change points or the catastrophe points on the curves. In analytic geometry, catastrophe point is defined as: the slope of the curve increases in one side of the point, while descends in the other side of the point. But it is hard to find it in *P-Q* curve. So when the flow change arouses little change of wet perimeter, the corresponding point is seen as the catastrophe point. And the corresponding flow of the first catastrophe point is the minimum ecological water flow. It is a subjective action to judge the catastrophe point. Grippe thought the judge will easily lead to mistakes. And he gave that the point should be located in the maximum slope or the slope equal to 1 point. Although it sounds reasonable in the science circumstance, still need further study in practice.

3 The case study

3.1 Data information

In wet perimeter method, *P-Q* relation should be clarified first. And there are many data information needed to establish *P-Q* function, such as monthly water level (maximum, minimum and average monthly water level), flow information (maximum, minimum and average monthly flow), and measured large cross section and so on. Therefore, the three hydrologic stations with measured large cross section are chosen to be analyzed the ecological water by wet perimeter method. The three stations are Guanting reservoir, Yanchi and Lugou Bridge, respectively. The information is shown in table 1.

3.2 Results

3.2.1 Guanting Reservoir Station (under dam)

According to information of the measured large cross section from 1970 to 1991, Yongding River generally keeps stability except for some light change in some part of the section (Fig. 1).

Set normal year（P=50%）from 1970 to 1991 as the representative year and calculate the minimum ecological water. After frequency calculation, 1987 is chosen to be the representative year. And its PQ curve is shown in Fig. 2. With the maximum curve, it can be derived that the ecological water is 3.7m^3 s^{-1} accounting for 20.7% of the annual mean flow.

3.2.2 Yanchi Station

The typical cross section of Yanchi sation from 1965 to 1966 and from 1970 to 1991 goes like parabola (Fig. 3).

Table 1 Information of the three stations.

Station	Guanting Reservoir (under dam)	Yanchi	Lugou Bridge
Location	115°36′ E, 40°14′ N	115°53′ E, 40°02′ N	116°13′ E, 39°52′ N
Catchment area (m^2)	42 500	43 674	44 400
Years of the measured information (Flow, flow velocity, water depth, area of cross section)	1955–1966, 1970, 1955–1966, 1970, 1979–1982, 1984–1991	1963–1966, 1970, 1973–1991	1955–1966, 1970, 1972–1978, 1980–1985
Years of the measured large cross section	1970–1991	1965–1966,1970–1991	1965–1966, 1970–1978, 1980–1985

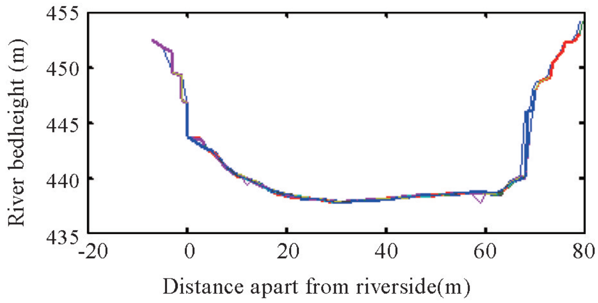

Fig. 1 The large cross section of Guanting Reservoir (under dam)

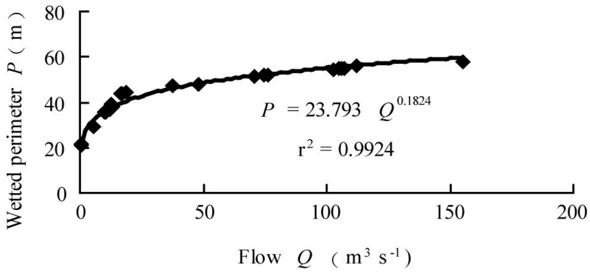

Fig. 2 *P*-*Q* curve of Guanting Reservoir (normal year *P*=50%, 1978).

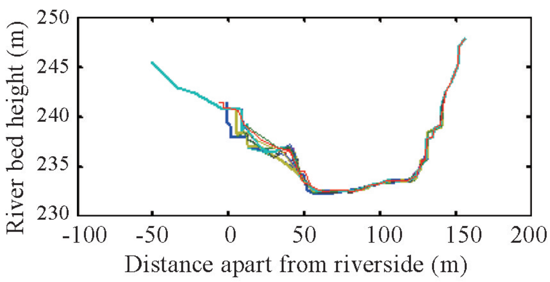

Fig. 3 The large cross section of Yanchi Station.

Set normal year(*P*=50%)from 1970 to 1991 as the representative year and calculate the minimum ecological water. After frequency calculation, 1981 is chosen to be the representative year. And its PQ curve is shown in Fig. 4. With the maximum curve, it can be derived that the ecological water is 4.1m^3 s^{-1} accounting for 20.1% of the annual mean flow.

3.2.3 Lugou Bridge Station

The large cross section of Lugou Bridge changes violently, but still keeps a wide and tender parabola or trapezoid shape (Fig. 5).

Set normal year(*P*=50%)from 1970 to 1985 as the representative year and calculate the minimum ecological water. After frequency calculation, 1978 is chosen to be the representative year. And its PQ curve is shown in FIg. 6. With the maximum curve, it can be derived that the ecological water is 1.3m^3 s^{-1} accounting for 22.1% of the annual mean flow.

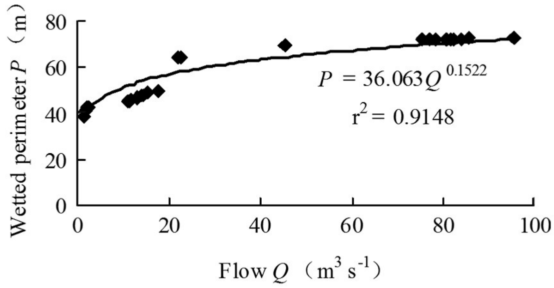

Fig. 4 *P-Q* curve of Yanchi Station (normal year *P*=50%, 1981).

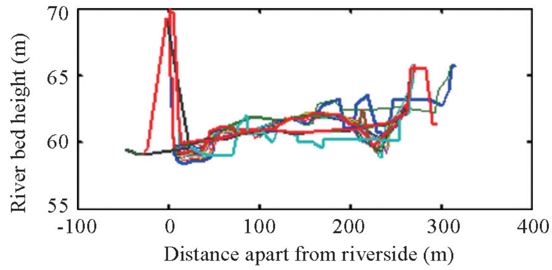

Fig. 5 The large cross section of Lugou Bridge Station.

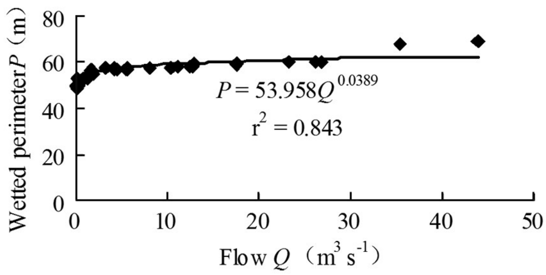

Fig. 6 *P-Q* curve of Lugou Bridge Station (normal year *P*=50%, 1978).

From the above results, it is clear that the ecological water flow of each cross section accounts for 20.1% to 22.1% of the annual mean flow. According to the Tennant standard, the results can keep the riverine ecosystem in healthy condition.

4 Conclusions

How to manage our mother river, make its ecological barrier into use and improve the drought-up situation is of great significance on "Culture-enriched Beijing, Technology-empowered Beijing and environment- friendly Beijing" establishment. However, if the lower reach of Yongdong River wants to recover to ecological barrier and green corridor, the minimum ecological water flow should be guaranteed. Then the ecological management can be realized.

This paper estimated the ecological water flow of the typical cross sections (Guanting Reservoir [under dam], Yanchi and Lugou Bridge), selected the representative normal year, established *P-Q* curves and calculated the minimum ecological water demand. The results shows, the ecological water accounts for about 20% of the annual mean flow. According to the Tennant standard, the results can keep the riverine ecosystem in healthy condition.

This paper only stepped forward a little bit on ecological water demand of the internal river. As to the external river problems, such as ecological water demand of lakes and wet land, still need a further study.

References

Caissie D, N El-Jabi, G Bourgeois. 1998. Instream flow evaluation by ydrologically-based and habitat preference (hydrobiological) techniques. *Rev. Sci. Eau*, 11 (3): 347–363.

Cui S B. 2001. A Research on issues of water demand for eco-logical environment. *China Water Resources*, 8: 71–75. (in Chinese)

Denslinger T L, D R Jackson, W A Gast, *et al.* 1998. Instream flow studies. Pennsylvania and Maryland.

Gippel C J, M J Stewardson. 1998. Use of wetted perimeter in defining minimum environmental flows. *Regulated Rivers: Research and Management*, 14(1): 53–67.

Gore J A, J M King, K C D Hamman. 1991. Application of the instream flow incremental methodology to southern African rivers: Protecting endemic fish of the Olifants River. *Water Sa Wasadv*, 17(3): 225–236.

Ji L N, Liu S X, Lv H X, *et al.* 2006. Theorrtical study of minimum instream flow requirement using the wetted perimeter method. *Journal of Northwest Sci-tech University of Agriculture and Forestry* (*Natural Science Edition*), 34 (2): 124–130. (in Chinese)

Karim K., Gubbels M. E., Goulter I. C. 1995. Review of determination of in-stream flow requirements with special application to Australia. *Water Resources Bulletin,* 31(6): 1063–1075.

King J M, R E Tharme. 1994. Assessment of the instream flow incremental flow methodology and initial development of alternative instream flow methodologies for South Africa. *Water Research Commission Report*, 295 (1): 590.

King J, Louw D. 1998. Instream flow assessments for regulated rivers in South Africa using the Building Block Methodology. *Aquatic Ecosystem Health & Management*, 1(2):109–124.

Liu S X, Mo X G, Xia J. *et al.* 2006. Uncertainty analysis in estimating the minimum ecological instream flow requirements via wetted perimeter method: curvature technique or slope technique. *Acta Geographica Sinica,* 61(3): 273–281. (in Chinese)

Mathews R C, Bao Y X. 1991. The Texas method of preliminary instream flow assessment. *Rivers*, 2(4): 295–310.

McCarthy J H. 2003. Wetted perimeter assessment. *Shoal Harbour River, January* 8.

Miao H, Wei Y C, Jiang L J, *et al.* 2003. Ecological water use and the estimate method. *Acta Ecologica Sinica,* 23 (6): 1156–1164. (in Chinese)

Qiu H. 2006. Eco-environmental water demand about the main current of the Huifa River in river course. Master's Thesis of Northeast Normal University. (in Chinese)

Rowntree K, R A Wadeson. 1998. geomorphological framework for the assessment of instream flow requirements. *Aquatic Ecosystem Health & Management,* 1(2): 125–141.

Stalnaker C B, B L Lamb, J Henriksen, *et al.* 1994. The instream flow incremental methodology: a primer for IFIM. National Ecology Research Center, International Publication, Fort Collins, Colorado, USA, 99.

Sun X Y, Yang Y, Xue S P, *et al.* 2004. Design and consideration on water quality improvement project at the upper reaches at Sanjiadian sector of Yongdinghe River. *Beijing Water Resources*, (4): 30–32. (in Chinese)

Tennant D L. 1976. Instream flow regimens for fish, wildlife, recreation, and related environmental resources. *In:* Orsborn J F and C H Allman (eds.). Proceedings of Symposium and Specility Conference on Instream Flow Needs Ⅱ, American Fisheries Society, Bethesda, Maryland, 359–373.

Wang X Q, Liu C M, Yang Z F. 2002. Research advance in ecological water demand and environmental water demand. *Advances in Water Science,* 13 (4): 507–514. (in Chinese)

Xu Z X, Chen M J, Dong Z C. 2004. Comments on calculation methods for river ecological water demand. *Journal of Hohai University* (*Natural Sciences*), 32 (1): 5–9. (in Chinese)

Yan J, Miao H, Cai H M, *et al.* 2006. Ecological inflow of lower reach on Yongding River. *Yellow River*, 28 (2): 51–53. (in Chinese)

Yan L, Zhao W J. 2004. A study on the marsh environment of the Yongding River, Beijing City. *Jilin Geology*, (2): 33–39. (in Chinese)

Yang Z F, Zhang Y. 2003. Comparison of methods for ecological and environmental flow in river channels. Journal of Hydrodynamics, 18 (3): 294–301. (in Chinese)

永定河官厅水库下游河道内生态需水量研究

门宝辉[1]，张士锋[2]，夏 军[2]

1 华北电力大学 可再生能源学院 生物质发电成套设备国家工程中心，北京 102206；

2 中国科学院地理科学与资源研究所 陆地水循环及地表过程重点实验室，北京 100101

摘要：作为北京市母亲河的永定河自上个世纪80年代以来三家店以下一直处于断流，河床裸露、河道两岸土地沙化严重，是北京春季沙尘天气的主要沙源之一，由于地下水超采严重，加之无水补给地下水，使得北京西部地区第四纪地下水已经基本枯竭，永定河的生态系统已经受到严重破坏。要想恢复或治理受损的河道生态环境，作为生态系统中最活跃最重要的水分多少要先算清楚。本文采用湿周法计算了永定河官厅水库下游三个控制断面（官厅水库（坝下）、雁翅、卢沟桥）的河道内生态需水流量，计算结果为：官厅水库（坝下）站的河道内流量为3.7 $m^3 s^{-1}$（平水年P=50%，1978年），占年平均流量的20.7%，雁翅站的河道内流量为4.1 $m^3 s^{-1}$（平水年P=50%，1981年），占年平均流量的20.1%，卢沟桥站的河道内流量为1.3 $m^3 s^{-1}$（平水年P=50%，1978年），占年平均流量的22.1%。若能按照计算的流量来补充河道水量，即可使永定河恢复其基本的生态功能，按照Tennant法的标准，基本能使当地的河道生态系统处于较为良好的状态。

关键词：湿周法；永定河；生态需水；Tennant法