

Theoretical framework of the urban river restoration planning

Y. W. ZHAO, Z. F. YANG^{*}, F. XU

State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, Beijing
100875, China

Abstract: Urban river restoration has seized the attention of many researchers and decision-makers due to the seriously degraded urban river health worldwide. In this paper, the concept of urban river restoration planning is verified as a reasonable allocation for the river ecosystem and disturbance sources in certain spatial and temporal scales, directed by the ecological theory and oriented to the harmony of human and urban water system. The natural boundary of urban river restoration planning is defined, and a 3-step planning procedure, including degradation factor identification, setting up restoration targets and restoration scenario formation, is proposed. Finally, the key point of the urban river restoration, including diagnosis of the river ecosystem health, construction of the restoration target and indicator system, prediction of the river ecological trend, development and optimization of the river restoration scenario is illustrated in detail.

Keywords: Urban river restoration, Diagnosis, Optimization

1 Introduction

River provides many ecological service functions for cities such as water supply, biological protection and landscape amusement, and contributes to promote urban development with its social, economical and environmental values. But with the urban size expansion, increasing disturbances to rivers, such as dam building, water resources exploitation, water allocation, meander cutoff, river branches building up, riverbank (course) solidification and riverside vegetation destruction, disturb river flow regime and water cycle process, have resulted in degradation of river ecosystem, especially the accumulative effects of water pollution, over fishing, etc. (Poff, 1997; Aguiar, 2001; Chovanec, 2002). River restoration has increasingly drawn attention, and corresponding activities have been carried out extensively (Holmes, 1998). The earliest river restoration projects are launched in Europe. The US started the activities in 1976, and later in China (Ren, 2001). In Europe, the US, Japan and many other countries, there have been many restoration practices for small river ecosystems with mature restoration technology. In great river ecosystems, such as Mississippi, Rhine, etc., there also has been much restoration work. Theoretically, existing research mainly focus on the river restoration strategy, river restoration in catchment's scale, and restoration of river elements as flow and riverbank etc. (Ebersole, 1997; Petersen, 1999; Pedroli, 2002; Bohn, 2002; Clarke, 2003; Arthington, 2003; Lusk, 2003). However, current studies basically aim at the natural rivers, and few at the urban river restoration, especially about concept, boundary, procedure and basic contents for the urban river restoration planning, which to some extent blocks the implementation of river restoration activities.

The paper discusses the basic technical procedure of urban river restoration planning, brings forward planning boundary, and also illustrates the planning focus in detail on the basis of connotation identification of urban river restoration planning.

2 Connotation of urban river restoration planning

River ecosystem impairment often results from the joint disturbance from nature and human being, and the dominant disturbance are always from human activities, together with natural disturbance, oppresses or changes

* Corresponding author: zfyang@bnu.edu.cn

succession process of river ecosystem, leading to the interruption or destruction of ecological process, and finally result in river ecosystem degradation. Therefore, the main purpose of river restoration is to eliminate constraints to river's natural patterns or biodiversity, which from human activities (Ebersole, 1997), but not necessarily to rehabilitate certain natural structures and conditions of river ecosystem, such activity should concentrate on rebuilding a kind of state which can make river's natural process regenerated (Naiman, 1998), and drive river ecosystem go back to the track of natural succession, keeping a state of ecological balance.

Comparing to the rivers in other areas, urban river has suffered the serious disturbance from human activities. It's impossible to complete entire restoration. So urban river restoration planning should be the trade-off of consideration in river ecology, applied restoration technology measures, socio-economical supporting conditions, etc. Firstly, it should be a kind of construction or alteration to urban river via some man-made or natural restoration measures. Meanwhile, due to the key support of the urban river to the urban system, more emphasis should be given on enhancing human anticipated characters and reducing human undesirable ones in setting up restoration planning, so as to form a healthy ecosystem different from primary or aboriginal ecosystem and provide more urban socio-economy system.

Enhancement of irrational socio-economic activities is the fundamental driving force for urban river degradation. Urban river restoration should be carried out from both direct and indirect aspects. Direct activity is to restore the river itself immediately by reconstruction and rehabilitation. However, in order to achieve perpetual restoration of urban river, economic development patterns must be optimized; exploitation and utilization intensity and mode of water resources and other river elements should be reasonable regulated. Meanwhile, the disturbance from cities should be controlled to realize strategic river restoration.

In brief, urban river restoration planning is a reasonable allocation for the river ecosystem and disturbance sources in certain spatial and temporal scales, directed by the ecological theory and oriented to the harmony of human and urban water system.

3 Technical procedure of urban river restoration planning

Scientific and normative technical procedure of urban river restoration planning can help to complete planning exactly, quickly, can also take advantage of fund and time effectively, and provide credible and reasonable support for urban river restoration. In terms of existing degradation characteristic, scientific and systematic requirement, combining with the consideration of the characters of planning activities, the planning procedure fall into 3 steps: identification of degradation factor, setting up restoration targets and restoration scenario formation, which is shown in Figure 1.

Emergence and settlement of urban river degradation are the starting point and end point of urban river restoration planning. Whether the problems have been identified exactly or not determines feasibility, veracity and implementation validity of planning objects and scenario. Degradation factor identification should not only be on the basis of the field survey and evaluation of in urban river catchments area, including social economy development, ecological status, pollution discharge, character of water area, exploitation and utilization of water resources, river health state, etc., but also on prediction of the river ecological trend, thus confirming the current and potential problems. Objects should be set up in terms of identified degradation factors, and divided into four phases: near future, middle-term, long-term, and future vision to satisfy management requirements in different time scales. Prior to objects confirmation, multi-scenarios comparison and repeated argumentation should be made. Moreover, indicator system and target values in various periods should be developed to characterize the targets. Establishment of urban river restoration scenario is the ultimate result and expression of the whole planning, and also the most important part of the planning. Scenario establishment should follow the combination of "top to down" and "bottom to up" methods, and embody the requirement for social development

and river itself. As to concrete planning scenario screening based on current and potential ecological issues, the constraints and bottleneck factors should be firstly identified and the planning scenarios dispatched into different planning periods so as to improve feasibility, save human resource, material resource and cost. Finally, the formative scenarios should be oriented to the concrete situation, emphasizing the idea to “get off on the ground”.

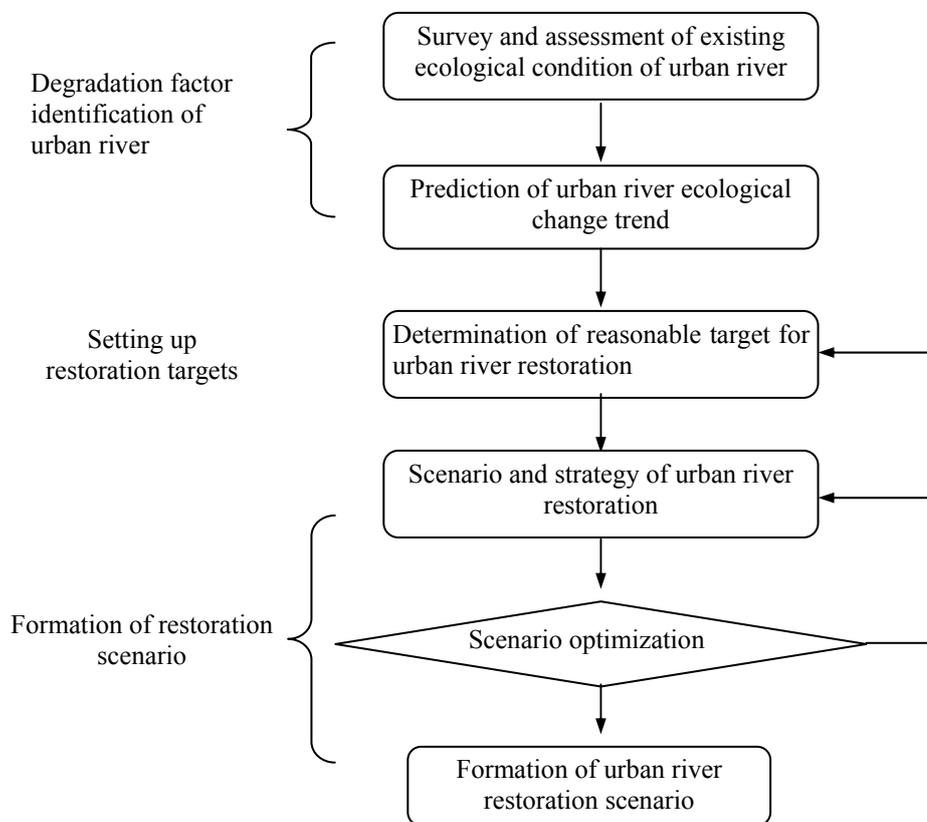


Fig. 1 Technical procedure of urban river restoration planning

4 Boundary of urban river restoration planning

The selection of planning boundary is mainly to confirm the extension of field investigation, reasonably ascertain scope of planning scenario implementation and follow-up ecological monitoring. In present practice, in order to acquire, coordinate, and summarize information expediently, planning boundary is usually confirmed subjectively. Generally, the administrative area is identified as planning boundary, which leads to conflict with the integrality of the planning object—river ecosystem, and to loss of background information and confusion of planning process, reducing the planning implementation effects.

Urban river system is a kind of open system continuously exchanging energy and materials with surrounding environment. Due to the effect of food chain and limited tolerance capability of river ecosystem, the external disturbance on urban river ecosystem can be accumulated, and cumulative effects sometimes can transmit along with flows to the larger spatial areas. Therefore, the ideal boundary for river restoration planning should be “naturalization”, that is, concentrated on catchments scale.

In practice, boundary confirmation is a dynamic feedback process, and should be adjusted in accordance with field investigation and concerned ecological monitoring result preliminarily. In some necessary conditions, expert consultation is needed for confirm the cost-effective and technically feasible boundary.

5 Key point of urban river restoration planning

5.1 Diagnosis of river health

Diagnosis of river health plays an important role in understanding present ecological situations of river degradation and defining dominant factor of river degradation. Referring to related domestic and abroad research, river health assessment methods can be divided into biological monitoring method and aggregative indicator method (Zhao Yanwei & Yang Zhifeng, 2005), thereinto. the aggregative indicator method has been widely applied in practice, covering physical, chemical, biological and even socio-economical indicators and reflecting multiple information with different dimensions. The classical aggregative indicator method are RCE grading method (Petersen,1992) and Index of Stream Condition (ISC) (Ladson al et.,1999). In the study of ISC, Ladson emphasized that river ecosystem can be described by five elements including water quality, water quantity, riverine zone, physical structure and aquatic life, which are interdependent and interactive, and can cover different river ecological processes, perform different functions and form the whole river ecosystem. As to the diagnosis of urban river health, indicator system should be set up in accordance with the above five main factors, and the chosen indicator should not only reflect the ecological integrality, but also embody the river's service capacity for urban ecosystem. The proposed urban river diagnosis indicator system is shown in Table 1 (Zhao Yanwei & Yang Zhifeng, 2005).

Table 1 River health diagnosis indicator system

Elements	Items	Indicators
Hydrology	Hydrology	Changes of flow velocity and water level caused by water exploitation
	Water quantity	Exploitation and utilization rate
Water quality	Fluid	Water quality index
	Sediment quality	Sediment pollution index
Aquatic life	Biotic integrity,	IBI of fish
	Rare and endangered species	Surviving conditions of rare and endangered species
Riparian zone	Soil and water erosion	Width of riverine area
	control	Vegetation coverage of riparian area
	Landscape construction	Area, effect and reachability of hydrophile landscape
	Flood control	Flood control guarantee rate
Physical structure	Exchange ability	Solidified condition of river bank and river course
	Physical fixness	River-bed stability
		Riverbank stability
	Connectivity	Connectivity with natural ecologic patches
		Connectivity of river corridor
	Inhabitant and migration	Habitat status
		Fishway setting

Another key point of river health diagnosis is to choose a reasonable diagnosis method. The presently applied methods includes score method, weighing method, TOPSIS method and fuzzy assessment method, etc, of which, the fuzzy assessment method has obvious advantage for the dynamic and relative nature of river health. Moreover, in order to overcome the subjectivity of indicator weights determination and promote the diagnostic accuracy, the reasonable method to determine the weights is required in assessment, and the Analytic Hierarchical Process (AHP) method, combing with qualitative analysis and quantitative assessment, has been widely used.

5.2 Prediction of the river ecological trend

Prediction of the river ecological trend contributes to identify the potential ecological problem. The foundation of prediction of the river ecological trend is the single-element prediction in urban river's catchment area, including social economical development, population distribution, construction area and size, water pollutants discharge, water resources demands from urban development, and the trend of water quantity and water quality from upper stream should also be found out. The "input- response" model can reflect the relation between of river ecosystem condition and all kinds of disturbance, and is an effective way of trend prediction. But it is hard to establish effective model in practice due to long-time series data demand, high precision, complexity of model, severely degradation of urban river and seriously damaged natural succession process. Under such circumstances, the ecosystem analysis method, based on single element prediction (such as water quality and water quantity) is suggested, combining with expert judgment and public participation.

5.3 River restoration target and indicator system

The ecological service provided by urban river has multi-functions. Healthy development of urban social and economic system depends on each service function of the river ecosystem. Therefore, urban river restoration should be multi-object, facing up the maintenance and improvement of all ecological service functions, including flood control, landscape service, biodiversity protection, water and soil conservation, unobstructed shipping and water quality improvement, etc..

Meanwhile, the concept of health has been admitted by the public, governments and academic institutes. For urban river, health indicates more emphasis on the maintaining and optimizing of the river's ecological service function, and provides a better ecological service for the urban social and economic system. Therefore, the river ecosystem health becomes a fundamental requirement of urban system, which also gradually becomes an important instruction standard of river restoration planning. Restoring damaged river ecosystem to healthy conditions and maintaining this state also become an important object of the river management. In short, urban river restoration should be carried out in a multi-object restoration way (Figure 2), of which river health is the core demand and final object of the restoration activity.

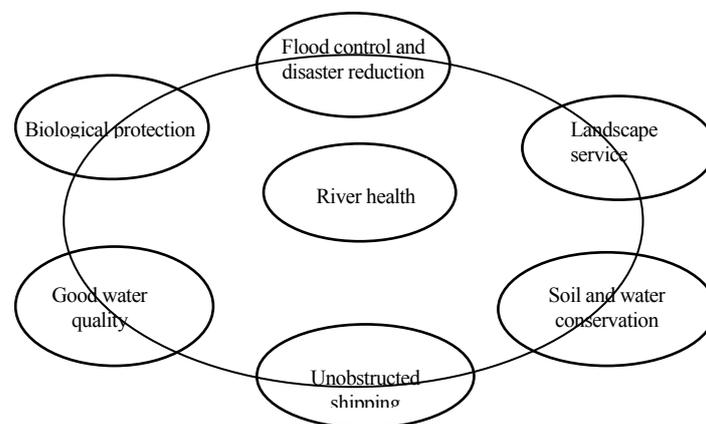


Fig. 2 Sketch of integrated multi-object river restoration

Indicator is an expression of object's concrete contents, character and value, and scientific and reasonable indicator system is the technological key for the urban river restoration planning. Generally speaking, the indicator system should reflect the "pressure-state-response" relationship between socio-economic activities and river system. Therefore, the indicator system of urban river restoration planning should at least include two categories: the catchment indicator and the river indicator. The catchment indicator includes population, social economy, pollution treatment and vegetation system construction etc., while the river indicator can be chosen from the health diagnosis indicator system.

5.4 Optimization of the river restoration scenario

River ecosystem is a system including living and non-living things, with the integrity constructed by the components being its notable characteristics. According to the systems theory, system is not the simple addition of each component, but the interrelation and interaction of all coupled elements forming a whole. The property of urban river can not be explained and expressed by single factor. Some elements realize restoration and achieve the requirement of one object, which just ensures necessary conditions of the whole restoration. Therefore, urban river restoration scenario should have the integrity to realize the whole restoration of river structure, function and dynamic process.

In detail, developed river restoration scenario should embody the requirements in macro, middle and micro-scales. In macro-scale, the first step is to establish and improve security system of river restoration. The target of the system is the minimization of disturbance intensity and its measures are recycling economy, ecological industry and cleaner production. In mid-scale, the focus is to establish scenarios concerning non-point source pollution control in catchment area, water quality improvement, river corridor and aquatic life habitat construction, etc.. In micro-scale, emphasizes should be concentrated on ecological design and carry out concrete project of sewage treatment, urban non-point source retention and hydrophile landscape etc.. The scenario established should include some feasibly alternatives in order to provide basis for the scenario optimization.

To achieve better ecological effects and improve feasibility in cost and technology, the alternative selection can adopt the relevant methods and means, such as linear programming, dynamic programming, discrete programming, multi-object programming, systematic dynamics, and fuzzy decision, etc.

6 Conclusions

Increasingly serious disturbance has impacted on the urban river. To develop river restoration planning becomes a significant way of keeping the trend of river degradation and maintaining the urban river health.

The disturbance stressed on urban river comes from many sources, and its restoration should be carried out on river itself and optimization of socio-economic development pattern. Urban river restoration planning should be a reasonable allocation for the river ecosystem and disturbance sources in certain spatial and temporal scales.

Scientific and normative technical procedure of urban river restoration planning can help to complete planning exactly and quickly, and also, take advantage of fund and time effectively. The planning procedure of urban river restoration falls into 3 steps: identification of degradation factor, setting up restoration targets and restoration scenario formation, all of which are integrated into a whole feedback loop.

Due to the openness of urban river, the boundary of urban river restoration planning can not be determined as administrative area, for natural boundary, that is, watershed, is the proper boundary.

As the response to the technical procedure of the planning, the key point of urban river restoration planning should involve diagnosis of river health, prediction of river ecological trend, river restoration target and indicator system, optimization of river restoration scenario.

Acknowledgement

This work is supported by the National Basic Research Program of China (973 Program, Grant No. 2005CB724204) and National Natural Science Foundation of China (NO. 50509002). The authors are grateful to Dr Chen Bin for his revising the draft of the manuscript.

References

Aguiar F. C., Ferreira M. T., Moreira I.(2001). Exotic and native vegetation establishment following channelization of a western Iberian river [J]. *Regulated rivers: research & management*,17,509–526.

- Arthington A. H., Pusey B. J.(2003). Flow restoration and protection in Australian rivers [J]. *River Research and Applications*, 19,377-395
- Bohn B. A., Kershner J. L.(2002). Establishing aquatic restoration priorities using a watershed approach [J]. *Journal of Environmental Management*, (6)4,355-363.
- Chovanec A., Schiemer F., Waidbacher H., et al (2002). Rehabilitation of a Heavily Modified River Section of the Danube in Vienna (Austria): Biological Assessment of Landscape Linkages on Different Scales [J]. *Internet. Rev. Hydrobiol*,87,183–195
- Holmes N. T. H.(1998). The river restoration project and its demonstration sites [A]. DeWaal L C, Large A R G, Wade P M(eds). *Rehabilitation of Rivers: Principles and Implementation [C]*, John Wiley: Chichester, 133-148
- Clarke, S. J., Bruce-Burgess, C. L. Wharton, G.(2003). Linking form and function: towards an eco-hydromorphic approach to sustainable river restoration [J]. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 13, 439-450.
- Ebersole J. L., Liss W. J., Frissell C. A.(1997). Restoration of stream habitats in the western United States: Restoration as re-expression of habitat capacity [J]. *Environmental Management*, 21,1-14
- Ebersole J. L., Liss W. J., Frissell C. A.(1997). Restoration of stream habitats in the western United States: Restoration as re-expression of habitat capacity [J]. *Environmental Management*, 21,1-14
- Ladson A. R., White L. J., Doolan J. A., et al (1999). Development and testing of an index of stream condition for waterway management in Australia [J]. *Freshwater Biology*,41,453–468
- Lusk S., Halacka K., Luskova V.(2003). Rehabilitation the floodplain in the lower river Dyje for fish [J]. *River Research and Application*, 19,281-288
- Naiman R. J., Biley R. E.(1998). *River ecology and management: lessons from the pacific coastal ecoregion [M]*, New York: Springer –Verlag New York, 599-603
- Pedroli B., Blust G. D., Looy K. V. et al.(2002). Setting targets in strategies for river restoration [J]. *Landscape Ecology*, 17(Suppl. 1),5-18
- Petersen M. M.. A natural approach to watershed planning, restoration and management [J]. *Water Sciences and Technology*, 1999,39(12):347-352.
- Petersen R. C.(1992). The RCE: a riparian, channel, and environmental inventory for small streams in the agriculture landscape [J]. *Freshwater Biology*, 27, 295–306
- Poff L. N., Allan D., Bain M. B., et al.(1997). The natural flow regime, a paradigm for river conservation and restoration [J]. *Bioscience*, 47,769–784.
- Zhao Y. W., Yang Z. F.(2005), *River Health: Concept, Assessment Method and Direction[J]*. *Scientia Geographica Sinica*, 25(1),119~124
- Ren H., Peng S. L.(2001). *Introduction to restoration ecology [M]*.Beijing: Science Press, 59
- Zhao Y. W., Yang Z. F.(2005). Preliminary study on assessment of urban river ecosystem health [J].*Advances in Water Science*, 16(3),349-355