Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 13	No. 3	pp. 505-510	2014

Original Research Paper

Sensitivity Analyses of Environmental Impact Factors for Songyuan Backwater Dam, Jilin Province, China

Bingchuan Cheng, Hua Yin*, Fanli Kong* and Yu Li
MOE Key Laboratory of Regional Energy Systems Optimization, North China Electric Power University, Beijing, 102206, China
* Hydrology and Water Resource Bureau of Jilin Province, Changchun, 130022, China
Corresponding Author: Yu Li

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 22-4-2014
Accepted: 26-6-2014

Key Words:
Backwater Dam
Environmental impact factors
Sediment deposition
Songhua river

ABSTRACT

The main environment impact factors (EIFs) to the normal water level of Songyuan Backwater Dam, in Jilin Province, China, were identified through principal component analysis for managers to develop a more rational, comprehensive decision support. This research is based on a comprehensive ecological index system, including land resources utilization, water occupancy of the city, reservoirs sediment deposition, reservoir temperature structure and water reservoir structure. The results obtained are as follow: Significant sensitive EIFs were contributed from the land resource utilization and the water occupancy of the city (Songyuan); insignificant sensitive EIFs were recognized as the reservoir temperature structure and backwater reservoir length; and those factors uncertain for sensitivity were found to be the reservoir silt accumulation. This information is very helpful for Songyuan Backwater dam, especially for the environmental impact assessment of the project construction.

INTRODUCTION

Water conservancy construction is an important part of national infrastructure. It is not only a measure of economic development (Petts 1984, Poff et al. 1997, Poff & Hart 2002, Ward 1979), but also an important factor for the sustainable development of national economy (Cernea 1999). A water ecological-economic system is crucial for social development, but rapid development due to human activities, such as dam construction which have contributed to human development by providing reliable sources of drinking water and irrigation, hydropower recreation, navigation, income, and other important benefits (World Commission on Dams (WCD) 2000), has negative ecological consequences on ecosystem structures, processes and functions (Western 2001), including deforestation, loss of fauna and flora species and destruction of historical remains (Sang-Yong Han et al. 2007).

But the construction of water conservancy projects, especially the formation of large water conservancy projects, will have significant impact on the surrounding environment. Different water conservancy projects have different characteristics. Water conservancy projects usually do not directly produce pollution, and the main object of their impact is regional ecological environment.

The Backwater Dam construction project in Songyuan was proposed to be built in Songyuan city (the Second Songhua River), China. Dikes between the two sides can only share 20% of the water without dams. Flood and river island were most exposed. Urban ecological environment and urban development are discordant, especially in windy weather. The sky dust and poor air quality bring much inconvenience to local residents. The main task of Songyuan Backwater Dam is to improve the urban section of the main dry season water level, improve urban water environment, and form the water landscape. Due to the special nature of the environmental impact of water projects, different storage levels will bring the influence of different natural environments and social environment for Songyuan, so each factor identification and quantitative research become very important.

Many domestic and international scholars have carried out research mainly on the environmental impacts of the dam project construction on the human body health, ecology, hydrology, agriculture and groundwater. They research on the effects of deposition flux conditions. For some scholars, they analyse the economic impact caused by the dam removal (Lewis et al. 2008, Brovencher et al. 2008, Robbins & Lewis 2008).

The objective of this study is to identify the main environment impact factors (EIFs) to the normal water level of Songyuan Backwater Dam in Jilin Province, China, through principal component analysis for managers to make more

Table 1: Normal storage levels and the water occupancy of the city.

Normal storage level(m)	The water occupancy (%)		
	Hada Mountain-Longhua Bridge	Longhua Bridge-Songyuan Dam	Qianfu Bridge-Qianfu Bridge
131.0	7.4	29.6	47.5
131.5	7.9	42.0	64.1
132.0	11.5	57.9	88.9
132.5	18.3	92.0	97.7

reasonable and comprehensive decision support, so as to realize the role to guide the actual project construction.

STUDY AREA AND RESEARCH CONTENTS

Characteristics of the study area: The Second Songhua River is located in the eastern region of Jilin Province (124° 00'~128°45' E; 41°45'~ 45°30' N), originated from Changbai Mountain. The river flows from southeast to northwest, 958 km long, having the total area of 73834 km^2. Songyuan Backwater Dam was to be built next to the White Mountains, Red Rock, Fengman and Hada Mountain hydropower stations. They changed water regime of the Second Songhua River. Hada Mountain Water Conservancy Project locates in Songyuan about 25 km upstream. Songyuan Backwater Dam which is near about 4.5 km to Fuyu hydrological station controls drainage area 71783 km^2. Watercourse is 790.6 m long, and the average gradient is 0.5 ‰.

Research contents: Through the qualitative analysis of the Backwater Dam project in Songyuan city on the natural and social environment impacts, the main natural environmental influencing factors chosen through principal component analysis are as follows: Land resources utilization, share of the main city water, reservoir sediment deposition and water reservoir structure. Social environment impact factors are reservoir backwater length and urban ecological level in Songyuan.

METHODS AND DISCUSSION

Sensibility of land resource utilization: In general, after the completion of the reservoir project, the normal storage level directly affects the size of flood area. Songyuan Backwater Dam will directly submerge farmland, forest land and any others which is in the reservoir area. In a certain range, the relationship with them is positive. Obviously, the land resource utilization is a directly sensitive factor for Songyuan Backwater Dam.

Sensibility of water occupancy of the city: Considering the overall urban planning of Songyuan, the water occu-

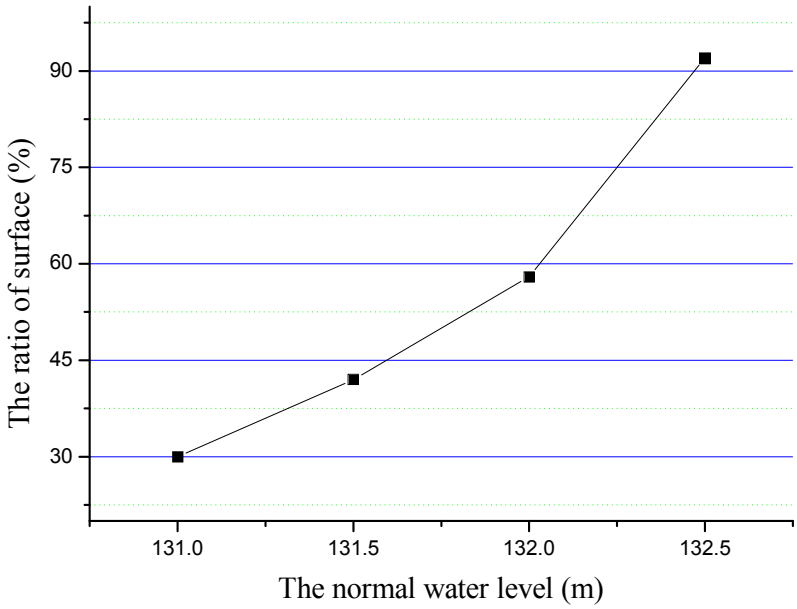

Fig. 1: The water occupancy of the city between Qianfu Bridge and Longhua Bridge.

Table 2: Capacity of Songyuan Backwater Dam with water level.

Water level (m)	Capacity ($\times 10^4 m^3$)	Water level (m)	Capacity ($\times 10^4 m^3$)
120.6	0	128	260
121	0.003	129	688
122	0.09	130	1437
123	0.48	131	2700
124	1.69	132	4899
125	5	133	8381
126	17	134	13156
127	745	135	18962

Table 3: Results of average backwater at 132.1m elevation.

Section	Distance of backwater (m)	Average (m)	
		Natural	Backwater
S1	0	130.19	132.10
S2	1180	130.36	132.13
S3	2330	130.50	132.17
S4	3480	130.65	132.21
S5-1	4470	130.83	132.25
S5-2	4530	130.84	132.25
S6	5490	130.96	132.29
S7	6410	131.09	132.33
S8	7450	131.21	132.38
S9	8840	131.30	132.42
S10	10130	131.37	132.46
S11-1	10910	131.45	132.47
S11-2	11740	131.54	132.50
S12	13650	131.62	132.56
S13	14890	131.70	132.67
S14	16070	131.89	132.81
S15	17410	132.08	132.98
S16	19110	132.19	133.19
S17	20310	132.81	133.46
S18	21860	133.65	133.70
S19	23150	133.75	133.75
S20	24480	133.93	133.93
S21	25440	134.18	134.18
S22	26380	134.42	134.42
S23	27100	134.58	134.58
S24	28320	134.81	134.81
S25	28790	134.90	134.90
S26	29260	135.04	135.04
S27	29690	135.14	135.14
S28	30390	135.22	135.22
S29	31220	135.36	135.36
S30	31790	135.47	135.47
S31	32310	135.68	135.68

pancy between Qianfu Bridge to Longhua Bridge (Fig. 2) must not be less than 40%. While an ecological leisure island which is 131.3~134.1 m higher, should be built according to the Songyuan River island planning. As shown in Fig. 2, the water level raises to the normal level and the water occupancy cannot be higher than 60%.

$$40\% \le R_{wa} \le 60\% \quad ...(1)$$

Where, R_{wa} is the water occupancy between Qianfu Bridge and Longhua Bridge, %.

Under different normal storage level plans, the part of Qianfu Bridge ~ Longhua Bridge has different water occupancies. According to normal storage levels and the water occupancy of the city (Songyuan) (Table 1), a curve about the water occupancy against normal storage levels is shown in Fig. 1.

Fig. 1 shows that when the water occupancy was set as 40%, corresponding normal storage level is 131.4 m; when the water occupancy was up to 60%, corresponding normal storage level is 132.1 m. Therefore, Formula (1) can be represented as:

$$134.1 \le X_{wl} \le 135.2 \quad ...(2)$$

Where, X_{wl} is normal storage level, m.

From this analysis, we can get the overall interval for the normal storage levels (131.4, 132.1 m). Thus, we could analyse the other sensitive environmental impact factors when the normal water level of Songyuan Backwater Dam changes between these intervals based on interval value.

Sensibility of reservoir silt accumulation: Volume between normal storage level and dead water level of the reservoir was called irrigation capacity, namely the regulating capacity. In order to ensure the demand of urban landscape, the reservoir water level requirement is not lower than 129.5 m, and the corresponding capacity is 917×10^4 m^3. Get the following constraints:

$$\frac{S \times (1-\theta)}{\rho} \times n < V_{rs} \quad ...(3)$$

According to Boulogne formula:

$$\theta = 1 - \frac{\frac{V_r}{W_{入}}}{0.012 + 0.0102 \times \frac{V_r}{W_{入}}} \quad ...(4)$$

Where, S - the incoming sediment, t/year; θ - ratio of sand, %; ρ - sediment deposition calculation of dry density, t/m^3; n - the dam calculation period, years; V_{rs} - dead capacity, m^3; V_r - adjusting capacity (water level between the capacity of normal and dead level), m^3.

According to the ecological environmental protection for Songyuan Backwater Dam data provided by the feasibility study report (Table 2), we can get the relation between normal storage levels with the reservoir storage.

Through data analysis, the model of the normal storage level and reservoir capacity is established as follow:

$$V = e^{(-743.878+10.83575X_{wl}-0.03891X_{wl}^2)} \quad ...(5)$$

Table 4: The water temperature structure and α in Songyuan Backwater Dam.

Flow of runoff (10^8m^3)	Water levels (m)	Capacity (10^8m^3)	α	Construction of temperature	Remark
103.57	131.4	0.3365112	307.77	mixed type	delamination (α<10); mixed (α>20)
	132.1	0.5060861	204.65	mixed type	transition (10<a<20)

Fig. 2: Plan of ecological leisure island (A. Longhua Bridge, B. Longhua Bridge, C. Ecological Leisure Island, D. Songyuan Backwater Dam).

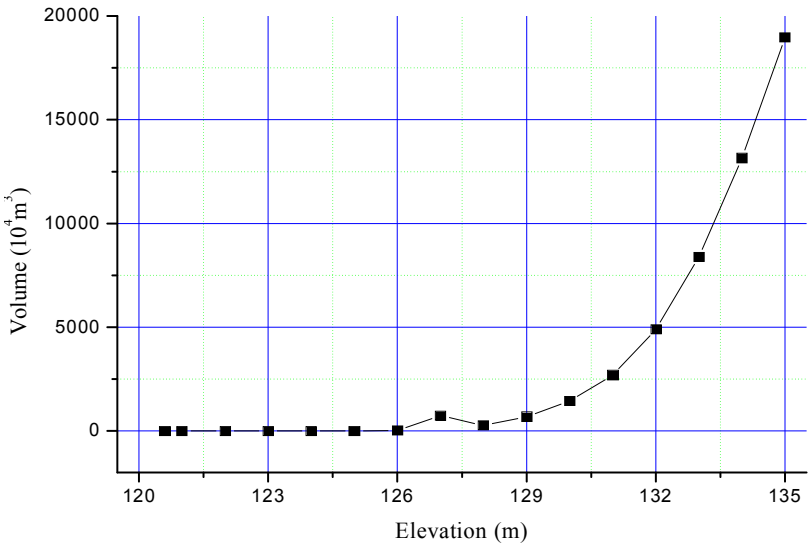

Fig. 3: The relation curve of normal water level against reservoir capacity.

Where, V- reservoir capacity, m^3; X_{wl} - normal storage level, m.

The relation curve of normal water level against reservoir capacity is shown in Fig. 3.

Based on this analysis, the lower limit of normal storage level interval changes faster than silt sedimentation, and the upper limit of normal storage level interval changes slower than it. Therefore, it is unable to determine the sensibility of reservoir silt accumulation.

Sensibility of backwater reservoir length: Songyuan Backwater Dam should block a part of the river water flow to downstream, so making the river water which arrives at the dam to hold back and return. Backwater will raise the water level in dam area. The distance from the dam to the end of backwater is backwater reservoir length. The relation about reservoir backwater length and normal storage level presents direct ratio. Under the normal storage level plan, when the backwater length is less than 30 km, Songyuan Backwater Dam brings no impact to Hada Mountain hydropower station upstream.

$$L_{bw} \leq 30 \quad ...(6)$$

The reservoir backwater calculation formula was described as indicated in Lewis et al. (2008):

$$L_{bw} = \Delta L = \frac{2g * (z_2 - z_1) + (\alpha - \beta) * (v_1^2 - v_2^2)}{g * (\gamma * Q)^2 (\frac{x_1^{\frac{4}{3}}}{A_1^{\frac{10}{3}}} + \frac{x_2^{\frac{4}{3}}}{A_2^{\frac{10}{3}}})} \quad ...(7)$$

Where, L_{bw} - the backwater length, m; V_1, V_2- the flow rate, m/s; A_1, A_2 - area of section, m^3; z_1, z_2 - water levels of section, m; α, β - resistance coefficient.

Thus, at the normal water level (132.1 m), the average backwater calculation results and the backwater end position are as given in Table 3.

According to Table 3, we can find that when the normal storage level is 132.1m, the end of position locates between s19 section and s20 section. When the normal storage level plan is (131.4, 132.1 m), the reservoir backwater lengths are all less than 30 km. The plan will not affect the Hada Mountain hydropower station. Obviously, when the normal storage level changes between these areas, the backwater length impact factor sensitivity is poor.

Sensibility of the reservoir temperature structure: After the reservoir is filled, the water temperature structure of reservoir will have a certain influence. The water tempera-ture structure will influence the ecological environment if it changes too much.

$$\varphi_1 \leq \Delta T \leq \varphi_2 \quad ...(8)$$

Reservoir water temperature structure type is generally divided into layered, transitional and hybrid. According to the value of α (average incoming capacity/total capacity), approximately normal storage level in (131.4, 132.1 m) was as given in Table 4.

From Table 4, when the normal storage level ranged in (131.4-132.1 m), α levels floated between 204.65 and 307.77 m). The reservoir was a mixed type one. Although the water temperature structure will change, it will not produce low temperature water, so will have no influence on aquatic ecological environment.

When the normal storage level plan interval was in the range of 131.4 to 132.1 m, Songyuan Backwater Dam was satisfied with the standard of ecological environmental protection from the perspective of water temperature influence, that is, the water temperature structure sensitivity is poor.

CONCLUSION

Based on the above analyses, we can conclude that environment impact factors, land resources use and the main water share were of high sensitivity to the normal storage level of Songyuan Backwater Dam, next are reservoir backwater length and water temperature structure; and those factors uncertain for sensitivity were attributed to the reservoir silt accumulation. Thus, environmental impact factors with higher sensitivity to the normal storage level will be chosen for further environmental impact assessment for Songyuan Backwater Dam.

ACKNOWLEDGEMENT

This study was sponsored by the Ministry of Water Resources of China; and financial support was supplied by a special fund from the Finance Department of Jilin Province (2013-931).

REFERENCES

Brovencher, B., Sarakinos, H. and Meyer, T. 2008. Does small dam removal affect local property values? An empirical analysis. Contemporary Economic Policy, 26(2): 187-197.

Cernea, M.M. 1999. The Economics of Involuntary Resettlement: Questions and Challenges. World Bank, Washington, DC.

Lewis, L.Y., Bohlen, C. and Wilson, S. 2008. Dams, dam removal and river restoration: A hedonic property value analysis. Contemporary Economic Policy, 26(2): 175-186.

Petts, G.E. 1984. Impounded Rivers: Perspectives for Ecological Management. Wiley, Chichester, New York.

Poff, L.N., Allan, D.J. and Bain, M.B. 1997. The natural flow regime: A paradigm for conservation and restoration of river ecosystems. Bioscience, 47(11): 769-784.

Poff, L.N., and Hart, D.D. 2002. How dams vary and why it matters for the emerging science of dam removal. Bioscience, 52(8): 659-668.

Robbins, J. and Lewis, L. 2008. Demolish it and they will come: Dam removal and the ex-post measurement of fisheries benefits. Journal of the American Water Resources Association, 44(6): 330-341.

Sang-Yong Han, Seung-Jun Kwak and Seung-Hoon Yoo 2007. Valuing environmental impacts of large dam construction in Korea: An application of choice experiments. Environmental Impact Assessment Review, 28: 256-266.

Ward, J.V. 1979. The Ecology of Regulated Streams. Plenum Press, New York.

Western, D. 2001. Human-modified ecosystems and future evolution. Proceedings of the National Academy of Sciences of the United States of America. 98(10): 5458-5465.

World Commission on Dams 2000. Dams and Development: A New Framework for Decision-Making, Earthscan, London.