

# Potential for Wetland Restoration in the Drawdown Zone of Hanfeng Lake\*

Martin J. H. WILLISON<sup>1</sup>, LI Bo<sup>2,3</sup>, WANG Qiang<sup>2,3</sup>, YUAN Xing-zhong<sup>2,3</sup>

- (1. School for Resource and Environmental Studies, Dalhousie University, Halifax, Nova Scotia B3R 2C6, Canada;  
2. College of Resources and Environmental Science; 3. Key Laboratory of Exploitation of Southwest Resources & Environmental  
Hazards Control Engineering (Ministry of Education), Chongqing University, Chongqing 400044, China)

**Abstract:** In 2008 Hanfeng Lake was created in Kai County, Chongqing, by the filling of the reservoir associated with the Three Gorges Dam. The lake is partially separated from the Pengxi River by a water-level regulatory dam, and is surrounded by urban development. The drawdown zone of Hanfeng Lake requires special attention because of its urban location and the status of the lake as a nature reserve. Here we discuss some of the management issues for the drawdown zone, with special consideration to eco-design principles and engineered wetlands. Given the unique nature of the lake, we argue that management of the drawdown zone requires an approach that is experimental and therefore adaptive. Given that the nature reserve objectives include a focus on bird abundance and diversity, we argue that the management approach must be ecosystem-based. Given the urban location, we argue that community-based processes must be used for the management approach to be socially acceptable. We consider that the effective ecosystem is the watershed of the lake and that both large-scale and local zoning are necessary management tools. Within the drawdown zone itself, we consider that eco-design principles can be applied to achieve the provision of valuable ecosystem services including: bank stabilization, improved water quality, wetland productivity and biodiversity, natural science education, food production, and agricultural education. By taking these community-based and ecosystem-based approaches to raising awareness about the values provided by wetlands, natural ecosystem services will be delivered and these will promote the sustainable economic and social development of Kai County.

**Key words:** Three Gorges; Kaixian; eco-design; dike-pond; wetland

**Chinese Library Classification:** X171.4

**Documet Code:** A

**Artide ID:** 1672-6693(2012)03-0087-07

Hanfeng Lake lies within Kai city in Kai County (Kaixian) of Chongqing Municipality at 31° 11' N, 108° 25' E. It is the terminal component of the Three Gorges Reservoir on the Pengxi River, which drains a basin on the northern side of the Yangtze River (known locally as ChangJiang) lying south of the Daba Mountains in the centre of China (Fig. 1). The lake has a maximum surface area of 14.8 km<sup>2</sup> and a circumference of 36.4 km. Most of the Pengxi River basin lies above Hanfeng Lake, and thus most of the flow of water in the river passes through the lake on its way to the Yangtze River.

The lake was created because of the special situation of the old city of Hanfeng. The city had existed for at least 1 700 years and at the time of its relocation had a population of about 60 000 people. Most of the old city was built on natural terraces at the edge of a branch in the Pengxi River (Fig. 1). The terraces were about 165 to 175 m above sea level and so would be flooded by construction of the Three Gorges Dam, which would raise the water level in the reservoir to a maximum planned height of 175 m. In addition, much low-lying land in Kaixian County would also be flooded, and so a larger urban centre was planned near the

\* Received: 02-06-2012

**First author biography:** Martin J. H. WILLISON, male, professor, Ph D., research fields are biodiversity education and wetland protection.

old city in order to relocate those displaced from both the flooded city and some of the nearby countryside.

Kai city is now a modern city that surrounds Hanfeng Lake and accommodates about 180 000 people.

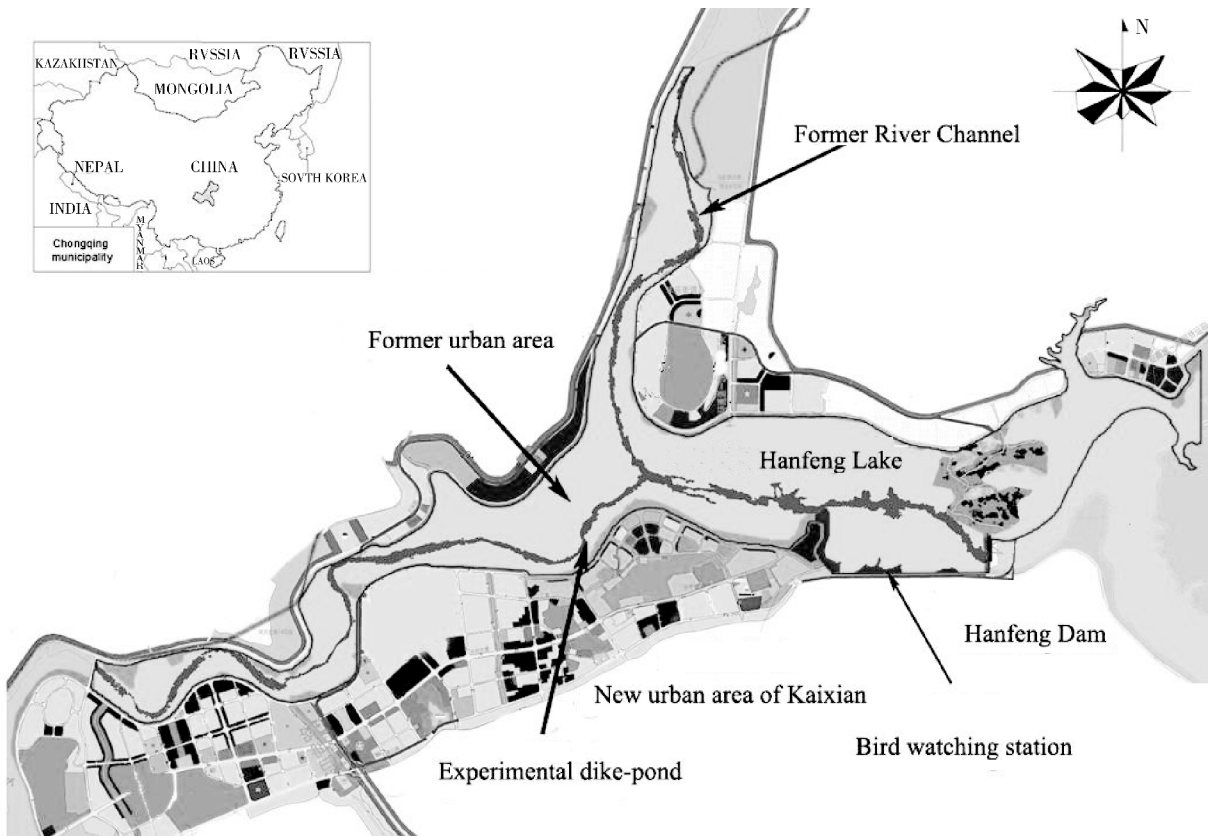


Fig. 1 Map of Hanfeng Lake showing the locations of: former urban area of Hanfeng, new urban area of Kai city, original river channel, lake, dam, constructed dike-ponds, and bird-watching station.

The location of Chongqing within China is shown at top left

Like the Three Gorges Reservoir, the water level in Hanfeng Lake is altered in a controlled annual cycle: higher in the winter and lower in the summer (Fig. 2). The high water-level of the lake is determined by the regulation of the Three Gorges Dam, but its level during the reservoir low-water period is altered by a water regulatory dam, completed in 2010, that separates Hanfeng Lake from the Pengxi River itself (Fig. 1). The Hanfeng Lake dam is 507 m long and 24 m high. It is not a permanent barrier to river flow, being open during the winter and allowing free flow of water. Instead, the dam raises the water level of Hanfeng Lake above that of the reservoir during the low-water period of the main reservoir, from March to October (Fig. 2). As a result, the Hanfeng Lake water level fluctuates only about 3 m during the annual cycle, be-

tween 175 and 172 m, thereby creating a permanent lake with a drawdown zone that is less extensive than would otherwise be the case.

Management of the Three Gorges Reservoir poses many challenges<sup>[1-2]</sup>, but new opportunities have also arisen, such as opportunities to use the substantial resources of the newly created reservoir drawdown zone in a sustainable manner<sup>[3-5]</sup>. This zone now constitutes almost 350 km<sup>2</sup> of land that is available for use for over five months during the peak growing season<sup>[6]</sup>. The drawdown zone of Hanfeng Lake is a special component of the reservoir drawdown zone and is a suitable site for experiments in the sustainable use and management of an extensive water-level-fluctuation zone within an urban setting in China.

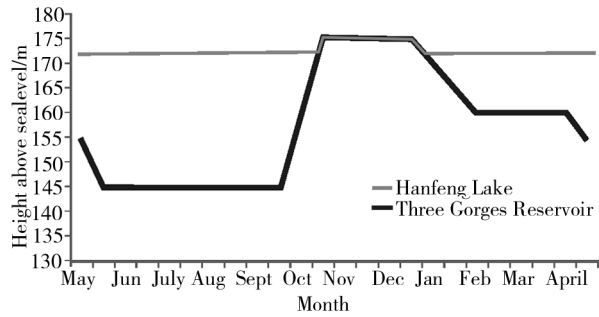


Fig. 2 Planned annual cycle of the water levels of Three Gorges Reservoir and Hanfeng Lake. Actual levels vary somewhat from those shown in the diagram due to natural events and management decisions

## 1 Hydrology

There is strong contrast in the hydrological regime of the Three Gorges Reservoir by comparison with the pre-existing conditions of the same regions of the Yangtze and Pengxi rivers<sup>[5-7]</sup>. The summer climate in this region of China is dominated by the East Asian summer monsoon which produces heavy rains in June-July and to a lesser extent in the later part of the summer<sup>[8]</sup>. Thus, the rivers in the region are typically high in the summer, sometimes with periods of raging floodwater. Precipitation is relatively light at other times of the year, and river water levels are much lower as a result.

Water flows into the Three Gorges Reservoir along about 400 tributary rivers in addition to the flow in the main stem of the Yangtze River. Most of these reservoir-associated tributaries flow through steep valleys among mountainous countryside. As a result, the drawdown zones in these second-order reservoir branches are not very large due to the steepness of the valleys. The Pengxi River is exceptional in this regard, having relatively shallow slopes and the most extensive drawdown area of all of the reservoir tributaries. The Pengxi River drawdown zone is about 55 km<sup>2</sup> in area and accounts for about 18% of the total drawdown area of the Three Gorges Reservoir.

Flood control is a major factor determining the management of the Three Gorges Reservoir, and so the reservoir water level is lowered in May, in preparation

for the beginning of the flood season in June. Once threat of flooding is over, the reservoir water level is raised again in October in order to optimize both electrical power generation at the Three Gorges Dam and river transportation along the reservoir. As a result, the water level in the Pengxi River is very high in the winter, creating a lake at Kai city, when the water level would normally be low; while the water level is relatively low in the summer, when flooding would usually be experienced. Despite this, for the purpose of flood control in the Yangtze River system as a whole, it is sometimes necessary to allow flood water to accumulate in Hanfeng Lake during the summer for short periods before it is released in a controlled manner. Nevertheless, the primary purpose of Hanfeng Lake is its amenity value as a resource for the citizens.

Due to the monsoon climate, the Pengxi River has the ecological characteristics of a small flood-pulse river system (for description, see<sup>[8]</sup>), as indicated by its braided channels. This means that there are wild species associated with the river that are adapted to periodic flooding, albeit for relatively short periods during the summer season rather than for long periods during the winter, as in the hydrological regime created by the dam. Similar altered conditions also apply to several other rivers in the Three Gorges Reservoir region, including the Yangtze River itself. The presence locally of flood-resistant ecotypes of plant species is a key factor in making decisions about how to manage the drawdown zone from an ecological perspective. This has led to considerable interest in local varieties of trees and shrubs such as willow (*Salix matsudana*) and mulberry (*Morus alba*)<sup>[9]</sup> that have shown remarkable flood tolerance.

## 2 Ecodesign

Based on the general concepts of eco-design<sup>[10]</sup> and biomimicry<sup>[11]</sup>, we can consider design principles for the drawdown zone of Hanfeng Lake. Shu-Yang et al. stated that “... any form of design that minimizes

environmentally destructive impacts by emulating and integrating with natural ecosystems can be referred to as eco-design.”<sup>[10]</sup> For Hanfeng Lake the eco-design principles of importance include a range of environmental concepts: design for nature, ecosystem-based management, community-based management, sustainable use, eco-friendly resource utilization, and ecological engineering<sup>[12-13]</sup>. By applying these principles, we can imagine eco-designs that are in contrast with simple covers made of concrete or other manufactured solids that are commonly used for hardening sloping surfaces next to water bodies in order to reduce erosion. While hard covers are effective for reducing erosion, they result in significant loss of ecosystem services in addition to loss of many opportunities for land use. This results in a loss of potential benefits and an increase in long term economic costs due to these lost opportunities. By contrast, eco-design applied to the drawdown zone provides the ecosystem service of erosion control in addition to a range of other valuable services such as biological productivity, water purification, and providing attractive surroundings.

Ecodesign is an adaptive approach to finding environmental solutions based on experimental science. Any solution that is adopted must suit both the local environmental and social conditions, and therefore must integrate community-based and ecosystem-based approaches<sup>[14]</sup>. The goal of ecodesign is to obtain healthy ecosystems that support healthy human communities based on a rigorously scientific approach to assessing ecosystem health<sup>[15]</sup>.

When Hanfeng Lake was filled for the first time in 2008 it was declared to be part of a new national nature reserve, the Pengxi River Wetland Nature Reserve, the first such reserve associated with the Three Gorges Reservoir. While the lake itself is not part of the protected core area of the nature reserve, it is planned to be maintained as an area that supports native biodiversity, including migratory birds. In June 2010 the national government announced a significant budget for the pur-

pose of managing the nature reserve. The budget included funds for the construction of artificial wetlands so as to restore and create the ecological conditions for the provision of wetland ecological services, and for scientific research in support of this work.

## 2.1 Dike-pond and floating bed experiments

A dike-pond wetland experiment was begun in the drawdown zone of Hanfeng Lake in the summer of 2011. This experiment is based on earlier research carried out in the experimental dike-pond system at the Wetland Research Station in Laotudi Bay which lies in a rural region at the edge of the Kaixian nature reserve in the Three Gorges Reservoir (for details, see<sup>[4,5,13]</sup>). Although in Kaixian, Laotudi Bay is not part of Hanfeng Lake itself. Plants grown in the diked ponds at Laotudi Bay included lotus (*Nelumbo nucifera*), arrowhead (*Sagittaria sagittifolia*), water chestnut (*Eleocharis dulcis*), aquatic Canna (*Canna glauca*) and water caltrop (*Trapa bicornis*). These plants were selected for several reasons including their ornamental value, their potential for use in water purification, and as wetland crops.

In the urban experiment at Hanfeng Lake, various species of wetland plants were transplanted into a constructed set of large diked ponds established for experimental purposes in the drawdown zone of Hanfeng Lake next to the Kai city urban centre. Plants such as lotus (*Nelumbo nucifera*) and pickerelweed (*Pontederia cordata*) were rooted in sediment in the normal way. The plantings were established in 2011 and grew vigorously in their first season. Their ongoing status will be assessed in 2012.

Floating bed agriculture is an ancient system that has been used in parts of Asia and central America for millennia<sup>[16-17]</sup>, and its use has recently been revived in China using modern materials and technological approaches for the purpose of pollution control, particularly the sequestration of nitrogen and phosphorus from wastewater<sup>[18-19]</sup>. In the traditional approach to floating bed agriculture, local people used various wetland and

riparian plants, as well as waste crop materials such as paddy straw, to make floating islands on which crop plants were grown. These traditional practices continue in several parts of the world and some of the traditional practices could provide models for application in the drawdown zone of the Three Gorges Reservoir.

Experiments with floating beds will be conducted at Hanfeng Lake in 2012, based on work that has been conducted at Laotudi Bay<sup>[5]</sup>. Species to be tried will include purple loosestrife (*Lythrum salicaria*), Canna (*Canna glauca*), water spinach (*Ipomoea aquatica*), wild rice (*Zizania latifolia*), arrowhead (*Sagittaria sagittifolia*), watermilfoil (*Myriophyllum spicatum*), lotus (*Nelumbo nucifera*), water lily (*Nymphaea tetragona*), and iris (*Iris spp.*). These plants have the potential to provide a range of benefits including food sources, pollutant absorption for water purification, control of eutrophication, and attractive flowers for public enjoyment.

The experimental site in the drawdown zone at Hanfeng Lake is important for both ecological and social research. It is necessary for the purposes of discovering whether the plants will survive flooding at the site, whether they will sequester pollutants and reduce the eutrophic status of the lake, and whether the ponds and floating beds will be accepted and used by local residents.

## 2.2 Bird watching

Bird watching has been identified in the Biodiversity Strategy and Action Plan for Chongqing<sup>[20]</sup> as one of the conservation-related economic development strategies for the Pengxi River Wetland Nature Reserve. In a study of the economic value of wetlands, Woodward and Wui<sup>[21]</sup> found that “... the data indicate that a wetland that provides bird watching opportunities is more valuable than the average wetland, while those that offer bird hunting or amenity services are less valuable.” While this analysis is based on studies in western societies where bird watching is relatively popular, it provides support for the concept that the wetlands as-

sociated with Hanfeng Lake have the potential to provide an economic benefit in Kaixian. While several species of wetland birds, including rafts of Eurasian coot (*Fulica atra*), have been observed on Hanfeng Lake (personal observations of the authors), no detailed surveys have yet been conducted.

In natural living systems there is generally a positive correlation between the abundance and diversity of species and the structural complexity of habitat (for review, see<sup>[22]</sup>). In order for bird watching to become economically significant, habitats that are attractive to migrating and over-wintering birds will have to be created or maintained. Wetland habitats in the Pengxi River Wetland Nature Reserve therefore need to be structurally complex and have characteristics as close to those of natural wetlands as possible. Bird watchers are attracted to places that attract a diversity of birds and so diverse wetland habitats are necessary, including variations in water depth, benthic structure, plant species, shade, edge, and other variables. The provision of foods that are required by a wide diversity of wetland birds should be naturally produced and available at critical periods of the year. Of special interest in this regard are the effects of water level fluctuation. When the water level drops in May, invertebrate animals are stranded in the drawdown zone and are plentifully available as food for birds. When the water level rises again in October, the newly flooded areas contain submerged vegetation that may sustain diving waterfowl. For these reasons, Hanfeng Lake may have the potential to become an important bird area, but this is yet to be realized in practice. The same general principles may also apply to fish species, including the provision of artificially enhanced habitat<sup>[23]</sup>, but no studies on fish have yet been conducted at Hanfeng Lake.

## 3 General Sites in the Drawdown Zone

The Hanfeng Lake drawdown zone is extensive and varied. It includes sites from which the ancient town has been cleared, sites that have been disturbed by

new developments, sites of abandoned farmland, and sites that were previously relatively undisturbed. In addition to these differences in historical land use, slopes within the drawdown zone vary from flat to steep, and there are several substrates having various particle sizes from mud (very small) to rock (very large). Adjacent land uses are as variable now as previously, albeit with altered locations. Given this high level of variability, awareness of ecological opportunities and limitations with respect to selecting future land uses is indicated. The effects of future land uses within the drawdown zone will vary according to the nature of the individual site. Adjacent land uses will also have effects, and these will compound the effects of land uses within the drawdown zone itself. For these reasons, a zoning approach should be taken to land use planning that takes account of the ecological opportunities and limitations of the various categories of land within the drawdown zone.

The same need for eco-friendly planning is true, to some extent, throughout the watershed of the lake and the rivers that feed into it. Geomorphology, susceptibility to erosion, land cover, and historical land uses within the watershed all affect the quantity and quality of water run-off, and therefore the flow rates of influent rivers and the quality of water in the lake. Run-off from agricultural lands is specially important for lake water quality because, along with sewage input, it is the most significant source of the nutrients that lead to damaging eutrophication. While wetland engineering, such as artificial floating islands<sup>[18-19]</sup>, can help to address the problem of eutrophication, reducing inputs of pollutants at source is the most important issue to address and this requires land-use zoning, such as retention of forest cover, and provision of buffer strips along rivers and streams to absorb the nutrient inputs.

Among the land-use options that can be considered, the most significant for use in the urban core of Kai city will probably have to serve multiple uses. A-

mong these uses are provision of ecosystem services such as clean water and attractive environment, enjoyment of the amenities of the lake, business opportunities, food production, biodiversity education, as well as promoting practical awareness of the lake and its watershed. The various communities that live around the lake have distinctive and variable socio-economic conditions, and thus a suitable community-based and ecosystem-based approach must be taken for selecting the set of uses suitable for any specific site, as in the example provided by Pan and co-workers<sup>[24]</sup> at Dongting Lake.

Dike-pond wetland engineering has existed for thousands of years in China and rice-cultivation using this approach is an agricultural staple in the Chongqing region. For this reason, it makes good sense to grow wetland crops at some sites within the drawdown zone if this can be achieved. Doing so would provide not only the value of the agricultural produce, but also the values of education for urban children and healthy enjoyment of the land for citizens.

In addition to zones that are focused on using the land, it is important to maintain a system of parks and protected areas that exist to provide for the native biodiversity of the region and maintain the ecological integrity of the lake and its associated riparian area. Systematic planning of this sort for biodiversity is an integral part of modern land-use planning<sup>[20]</sup>.

**Acknowledgements:** The senior author is grateful to the Municipal Government of Chongqing for funds to visit Kaixian in 2011, and to the EU-China Biodiversity Programme for assistance to visit Kaixian in 2008 and 2009.

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(Editors: Martin WILLISON, FANG Xing)