J. Geogr. Sci. (2009) 19: 681-690
DOI: 10.1007/s11442-009-0681-0

Palaeofloods recorded by slackwater deposits on the Qishuihe River in the Middle Yellow River

ZHA Xiaochun, HUANG Chunchang, PANG Jiangli

College of Tourism and Environment Sciences, Shaanxi Normal University, Xi'an 710062, China

Abstract: Palaeoflood hydrological study is a frontal subject of global change study. Using sedimentology, geomorphology and OSL dating methods, the typical palaeoflood slackwater deposits were studied in the Qishuihe River valley. The results showed that five flooding episodes with 21 palaeoflood events occurred during 4300–4250 a B.P., 4250–4190 a B.P., 4190–4100 a B.P., 4100–4000 a B.P. and 3100–3010 a B.P., respectively, during the Holocene period. The palaeoflood peak discharges were calculated with hydrological models. With a combination of the gauged flood, historical flood and palaeoflood hydrological data, the archives of flood events were extended to over 10,000 years in the Qishuihe River valley, and the flood frequency–peak discharge relationship curve was established accurately. These research results played important roles in mitigating flood hazard, hydraulic engineering and also the development of water resources in the semiarid Weihe River basin.

Keywords: Qishuihe River; Holocene; palaeoflood; Yellow River; Shaanxi Province

1 Introduction

Palaeofloods are ancient floods recorded by geomorphological and sedimentological evidence and can not be observed directly by human. Palaeoflood events are hydrologic process responding instantaneously to Holocene extreme climatic events (Benito *et al.*, 2003). They play very important roles in hydraulic engineering construction, water resources development, and also in mitigating flood hazard. The main task of palaeoflood hydrology is to identify and reconstruct the palaeoflood water stage, discharge and occurrence frequency from the geological sediment records (Li *et al.*, 2002). Based on the palaeoflood slackwater deposits in the palaeo-floodplain or riverside platform, many researchers have reconstructed the palaeoflood process, and extended the temporal sequence of flood hydrological data beyond those of the instrumental period (Baker *et al.*, 1983; Baker, 1987; Yang *et al.*, 2000; Yao *et al.*, 2008; Xie and Jiang, 2001; Zhan *et al.*, 1997). The length of flood records could be extended to the scale of thousand or even ten thousand years due to reconstructing past

---

Received: 2008-06-06 **Accepted:** 2009-02-12
Foundation: National Natural Science Foundation of China, No.40771018; Natural Science Foundation of Shaanxi Province, No.2006D01; Basic Research Fund of Shaanxi Normal University, No.200702001

Author: Zha Xiaochun (1972–), Ph.D and Associate Professor, specialized in resource development and environment changes. E-mail: zhaxch@snnu.edu.cn

flood discharges by geomorphological indicators and documentary evidences, which provided very valuable information for the hydrology calculation in hydraulic engineering construction and mitigating flood hazards.

Weihe River basin belongs to the semiarid monsoon climate region, the frequent rainstorms and flood disasters have seriously influenced the economic and social development in Guanzhong basin (Zhang *et al.*, 2000; Zhang, 2005). Therefore, it is necessary to enhance the accuracy of flood hydrological calculation and extend the temporal sequence of flood hydrological data. However, the palaeoflood hydrological study is still a blank in the Weihe River basin. Qishuihe River, a big tributary of Weihe River in Guanzhong basin, flows into Weihe River in the east of Yangling–a famous agriculture science and technology town in China. Based on field investigation, a very clear and complete palaeoflood slackwater deposits (SWD) were found in the Holocene loess profile on the second terrace where the tributary Weishui River flowing into the Qishuihe River. These SWD units provided best information for palaeoflood hydrological study in Weihe River basin in the middle reaches of the Yellow River. The study results have very important application value to reduce and control flood disaster and develop water resource in the Weihe River basin.

2 Study area and river

The Qishuihe River originates from Ningli gully in Zhaoxian town, Linyou County, flows through Yongshou County, Qianxian County and Wugong County in Shaanxi Province, the length of the mainstream is 160.8 km and the total catchment area is 3835 km^2. The Weishui River, a tributary of Qishuihe River, originates from Laoye Mountain range, flows eastwards through Fengxiang County, Qishan County and Fufeng County, finally entering the Qishuihe River near Huxizhuang village of Wugong County (Figure 1). The annual mean runoff volume is 1.3×10^8 m^3 and annual mean flow is 4.15 m^3/s at the Chaijiazui hydrologic gauge station below the Huxizhuang village. The Weishui River, flowing through the whole Zhouyuan loess tableland, has a catchment area of 2043.4 km^2. With the development of agriculture civilization from the early Neolithic age to the Pre-dynastic Zhou age, the Bronze-age "Qiyi" city was built on the middle Zhouyuan tableland. The upper reaches of Qishuihe River are mountainous and hilly region and middle reaches are loess tableland region. Due to the sparse vegetation cover and the intensive human activities, the soil and water loss is very serious, the annual mean sediment discharge is 1.51×10^9 kg at the Chaijiazui gauge station. The mean annual temperature is 12.9℃, accumulated temperature (≥10℃) is 4184℃, the mean annual precipitation is 552.6–663.9 mm, and more than 50% of which happens from June to August (Compilation Committee for Records of Wugong's Geography, 2001).

The Zhangbaocun, Chaijiazui, Longyansi and Antou hydrologic gauge stations were established successively in Qishuihe River valley. At present, only Antou hydrologic gauge station is working, which is the representative hydrologic station in the intermediate region of northern Weihe River basin. The Chaijiazui hydrologic gauge station was established in 1955, and the total catchment area was 3806 km^2, and abolished in November of 1970 because the Yangmaowan reservoir was built in the upper reaches of Qishuihe River. Chaijiazui hydrologic station had hydrologic gauged data from 1955 to1970, and data of 5 historical

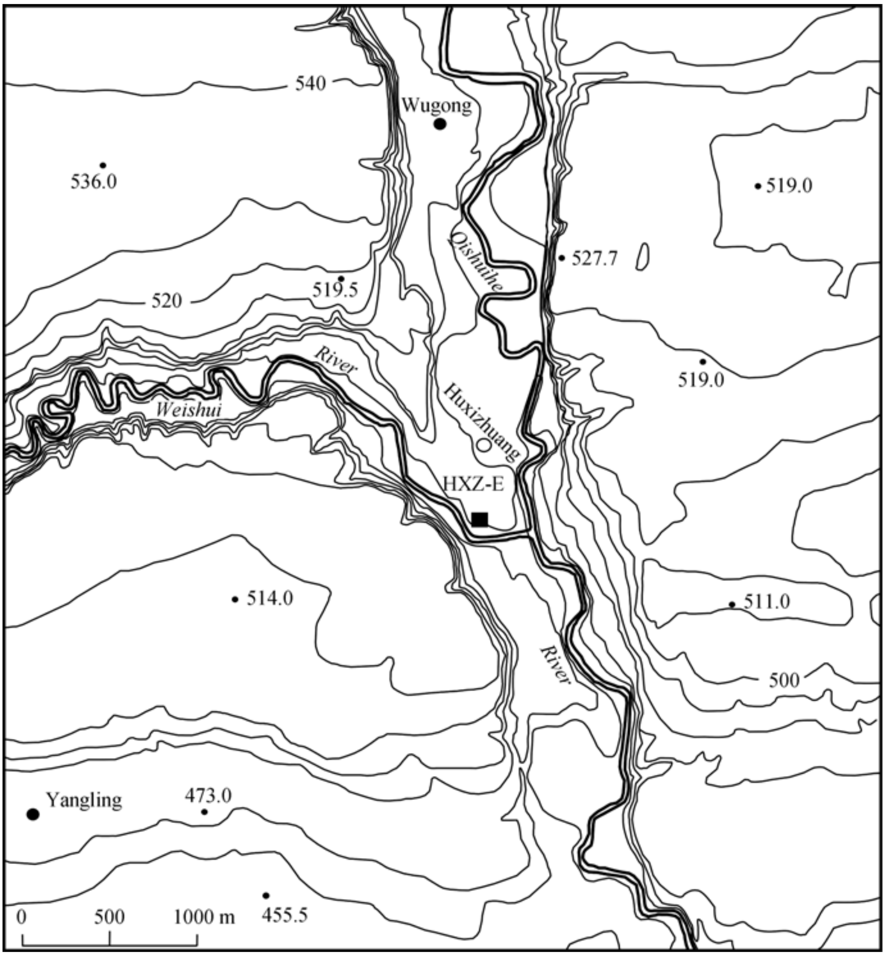

Figure 1 Contour map of the Qishuihe River valley and the location of HXZ-E site on the terrace land between Weishui River and Qishuihe River in Weihe River basin in the middle reaches of the Yellow River

floods took place in 1901, 1920, 1925, 1933 and 1954 respectively. However, only the historical flood discharge in 1954 could be more reliable and adopted. Therefore, palaeoflood hydrological study was needed to extend the gauged data and the historical flood data to provide more complete data series for flood mitigation.

3 Sediment profile and study methods

The Huxizhuang-E (HXZ-E) profile (Figure 2) located on the terrace land where the Weishui River flows into Qishuihe River, which was about 2 km from the Wugong town and 1 km from the Chaijiazui hydrologic station in lower end of the gorge reach of Qishuihe River. The profile was not disturbed by human activities, the pedological and stratigraphic characteristics were completely preserved, and the boundaries of palaeoflood slackwater deposits (SWD) layers were also very clear. Based on the field detailed observation, 140 samples of soil and SWD were taken every 4 cm continuously down the profile. According to the field observation and laboratory analysis, the HXZ-E profile was described as follows: (1) 0–40 cm, topsoil (TS); (2) 40–120 cm, Holocene loess (L_0); (3) 120–200 cm, palaeoflood

Figure 2 The HXZ-E Holocene loess-soil profile containing the bedding of palaeoflood slackwater deposits at the HXZ-E site in the Qishuihe valley

slackwater deposits (SWD_5); (4) 200–260 cm, upper palaeosol (S_{01}); (5) 260–300 cm, palaeoflood slackwater deposits (SWD_4), and 286–296 cm with pedogenesis obviously; (6) 300–336 cm, palaeoflood slackwater deposits (SWD_3); (7) 330–360 cm, palaeoflood slackwater deposits (SWD_2); (8) 360–380 cm, palaeoflood slackwater deposits (SWD_1); (9) 380–450 cm, lower palaeosol (S_{02}); (10) 450–500 cm, transitional loess (L_t); and (11) below from 500cm, the typical Malan loess (L_1), its bottom was not seen, respectively.

Grain-size distribution was determined using the Mastersizer-S laser analyzer with $(NaPO_3)_6$ as dispersing agent after pretreatment with 10% HCl and 10% H_2O_2 to remove $CaCO_3$ concretions and organic matter. Magnetic susceptibility was measured on a mass of 10 g of ground sediment with a Bartington MS_2 Magnetic Susceptibility Meter. Optical simulated luminescence (OSL) dating was carried out on a Risø-TL/OSL-DA15 Dating System in the environment change laboratory of Shaanxi Normal University.

For the chronology of HXZ-E profile, firstly, based on the potteries samples buried in different culture phases with more accurate age and individual sample was OSL dated. The black grey pottery shards of typical Miaodigou Ⅱ Culture (4800–4300 a B.P.) retrieved from 435–430 cm in S_{02} was OSL dated to be 4840±340 a B.P., The grey pottery shards of typical Keshengzhuang Ⅱ Culture (4300–4000 a B.P.) retrieved from 295–290 cm in SWD_4 was OSL dated to be 4370±280 a B.P. Secondly, referenced the Holocene archaeological stratigraphy and chronology data of ^{14}C and Thermo-luminescence (TL) in Holocene loess-soil profile (IACASS, 1991; Zhou *et al.*, 1991; Zhou *et al.*, 1998), and contrasted with the chronology of Jiangyangcun profile on the loess tableland in the catchment (Huang *et al.*, 2003), the chronology boundary in HXZ-E profile could be identified in Figure 3. Then, because no other palaeoflood slackwater deposits layers were found below 380 cm in HXZ-E Holocene profile, so all the extreme palaeoflood records acquired from palaeoflood slackwater deposits layers in HXZ-E represented the largest floods since about 11,500 a B.P. during the Holocene.

4 Results and analysis

4.1 Grain-size distribution and magnetic susceptibility

Magnetic susceptibility was very sensitive to environment change in loess region (Liu *et al*., 1993; Barbara, 1995). From Figure 3, magnetic susceptibility values varied between 93.3×10^{-8} m^3/kg and 134.3×10^{-8} m^3/kg in HXZ-E profile. The higher values were present in the palaeosols (S_0), which indicated the warmer and wetter climate, the more precipitation and flourisher vegetation and stronger pedogenesis. Among which, the magnetic susceptibility values varied between 103.4×10^{-8} and 134.3×10^{-8} m^3/kg in S_{02} and between 93.3×10^{-8} and 119.5×10^{-8} m^3/kg in S_{01} respectively. Magnetic susceptibility values in loess (L_0 and L_1) were blower than those of S_0, which indicated the climate tended to dry. Because the influence of pedogenesis in connection with the long time farming activities, magnetic susceptibility values increased and the highest values was 136.3×10^{-8} m^3/kg in the topsoil (TS).

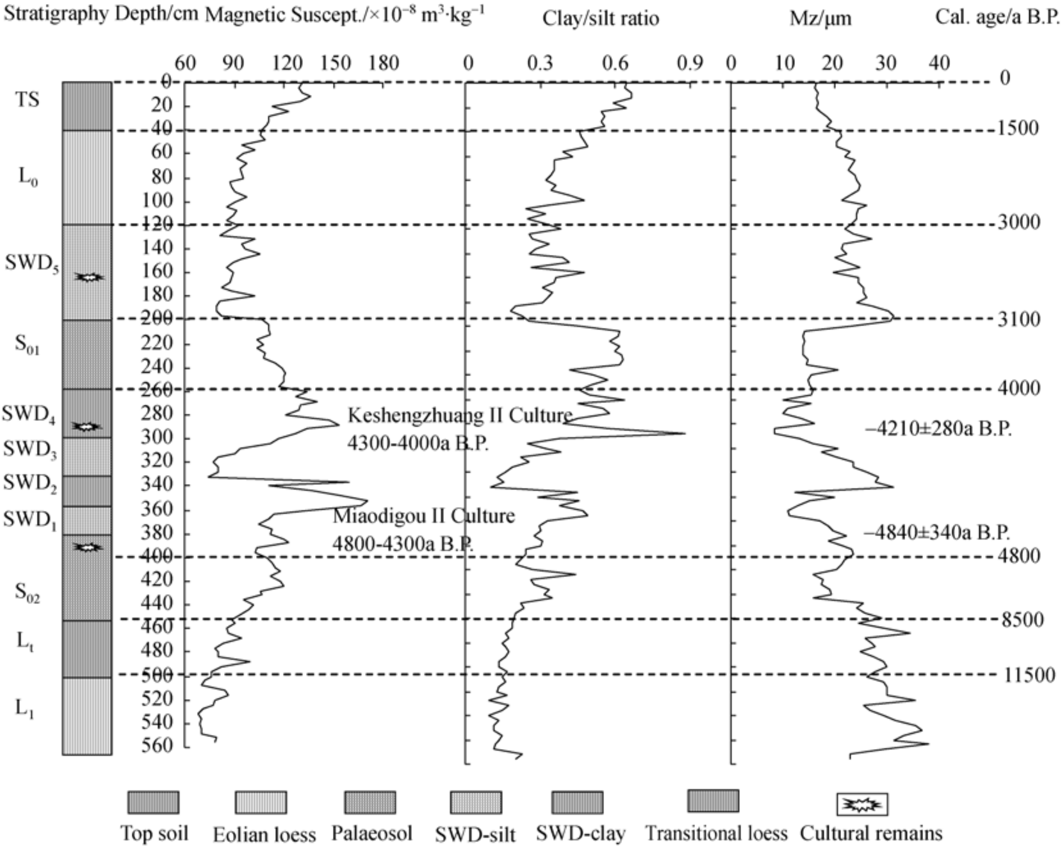

Figure 3 Diagrams showing the magnetic susceptibility, clay/silt ratio and median grain size distribution in the HXZ-E profile in the Qishuihe valley at Wugong County, Shaanxi Province

The clay/silt ratio indicated the pedogenesis under the influence of biological process, climate and environment change (Liu Tungsheng, 1985). In Figure 3, the value of clay/silt ratio changed dramatically in different stratigraphic subdivisions, the highest values were present in S_0, and with average values 1.17 in S_{02} and 0.55 in S_{01}, respectively, the lowest value 0.37 was present in L_0, which indicated that the pedogenesis was stronger in S_0.

A total of 5 palaeoflood slackwater deposits layers, namely SWD_1, SWD_2, SWD_3, SWD_4 and SWD_5, were identified in HXZ-E profile (Figure 3). Firstly, the grain-size characteristics among SWD_1, SWD_2, SWD_3, SWD_4 and SWD_5 were very different. The median grain size (Mz) in SWD_1, SWD_3 and SWD_5 layers varied between 22.01 μm and 24.76 μm, but the Mz in SWD_2 and SWD_4 layers were only 14.60 μm and 13.20 μm respectively, which showed the pedogenesis was at interval of floods, so the clay contents in SWD_2 and SWD_4 were higher than those of SWD_1, SWD_3 and SWD_5. And the 5 palaeoflood slackwater deposits layers had the better sorting during deposition. Therefore, all of the grain-size characteristics of the SWD layers were much similar to those of the palaeoflood slackwater deposits elsewhere (Yang, 1997; Zhan *et al.*, 2001; Benito *et al.*, 2003).

Secondly, HXZ-E profile was located on the second terrace at the entrance of Weishui River flowing into Qishuihe River (Figure 1). The site was subjective to overbank flood of the Qishuihe River, and was the best location for slackwater deposits. When the earlier slackwater deposits were preserved, it tends to be blanketed by the later slackwater flood deposits. Then, the multiple palaeofloods could be recorded in slackwater deposit stratigraphy. Thirdly, the level bedding in palaeoflood slackwater deposits was very clear in Figure 2, which was well correlated with those of the Weishui River at the same level. According to field observation, thickness change of the SWD beds, the 3, 3, 4, 3 and 8 flood events could be identified in SWD_1, SWD_2, SWD_3, SWD_4 and SWD_5 layer, respectively. Therefore, the overall characteristics of the SWD_1, SWD_2, SWD_3, SWD_4 and SWD_5 layers in HZX-E profile showed that there were 5 flooding episodes of palaeofloods representing 21 flood events since 11,500 a B.P. in Qishuihe River.

Based on the chronological framework, the first 4 episodes of palaeofloods represented by SWD_1, SWD_2, SWD_3 and SWD_4 were dated to be 4300–4000 a B.P. at the end of the Miaodigou II Culture (4800–4300 a B.P.), it took place almost simultaneously with the Keshengzhuang II Culture (4300–4000 a B.P.). The last episode of palaeoflood represented by SWD_5 was dated to be 3100–3000 a B.P. because the cultural remains of the Pre-dynastic Zhou Culture (3100–3000 a B.P.) were found over the SWD beds.

4.2 Hydrologic reconstruction of the palaeofloods

4.2.1 Reconstruction of the palaeoflood stages

The main objective of this study was to identify palaeoflood water stage and further to reconstruct the flood discharges. The reconstruction of palaeoflood water stage completely depended on top elevation of palaeoflood slackwater deposits in the past (Xie and Fei, 2001). Numerous studies of laboratory flume experiment, field observations and investigation proved that the elevation of end-units of palaeoflood slackwater deposits could accurately indicate the water stage (Kochel, 1988; Waythomas *et al.*, 1994). This study showed that the palaeoflood slackwater deposits layers were gentle in the HXZ-E profile. Therefore, according to the top elevation of palaeoflood slackwater deposits, the water stages of the 5 flooding episodes with 21 palaeofloods could be reconstructed (Table 1).

Because Qishuihe River is located on the northern side of the Weihe River, a great part of Qishuihe River flows through loess tableland region, due to sparse vegetation cover, loose loess and heavy rainstorms, soil erosion has been very serious, and the sediment usually de-

Table 1 Hydrological results of Holocene palaeofloods in the Qishuihe River valley

Palaeoflood episodes and events	Bottom elevation of palaeoflood SWD (m)	Thickness of palaeoflood SWD (m)	Reconstructed depth of palaeoflood slackwater (m)	Reconstructed palaeoflood stage (m)	Reconstructed total flood water depth (m)	Reconstructed palaeoflood discharge ($m^3.s^{-1}$)
SWD$_{5-8}$	459.22	0.18	0.72	459.94	11.94	3970
SWD$_{5-7}$	459.06	0.16	0.64	459.7	11.70	3770
SWD$_{5-6}$	458.96	0.1	0.4	459.36	11.36	3510
SWD$_{5-5}$	458.84	0.12	0.48	459.32	11.32	3480
SWD$_{5-4}$	458.76	0.08	0.32	459.08	11.08	3300
SWD$_{5-3}$	458.71	0.05	0.2	458.91	10.91	3170
SWD$_{5-2}$	458.65	0.06	0.24	458.89	10.89	3160
SWD$_{5-1}$	458.6	0.05	0.2	458.8	10.80	3090
SWD$_{4-3}$	457.88	0.12	0.48	458.36	10.36	2790
SWD$_{4-2}$	457.72	0.16	0.48	458.2	10.20	2790
SWD$_{4-1}$	457.6	0.12	0.48	458.08	10.08	2610
SWD$_{3-4}$	457.56	0.04	0.16	457.72	9.72	2380
SWD$_{3-3}$	457.47	0.09	0.36	457.83	9.83	2450
SWD$_{3-2}$	457.32	0.15	0.6	457.92	9.92	2500
SWD$_{3-1}$	457.24	0.08	0.32	457.56	9.56	2290
SWD$_{2-3}$	457.16	0.08	0.32	457.48	9.48	2240
SWD$_{2-2}$	457.04	0.12	0.48	457.52	9.52	2260
SWD$_{2-1}$	457	0.04	0.16	457.16	9.16	2060
SWD$_{1-3}$	456.95	0.05	0.2	457.15	9.15	2050
SWD$_{1-2}$	456.84	0.11	0.44	457.28	9.28	2120
SWD$_{1-3}$	456.8	0.04	0.16	456.96	8.96	1950

posited thickly on the flooded area after flood recession. The sediment load of Qishuihe River was very high, the mean gauged sediment discharge was 1.51×10^9 kg annually, and the largest bulk sediment load accounted for 25% during the flood (Compilation Group for "Records of Xianyang's Geography" of Geography Department of Shaanxi Normal University, 1991). Thus, the thickness of palaeoflood slackwater deposits and sediment load were taken into account to reconstruct the water stage (Table 1).

When we did field investigation in the Qishuihe River valley, the elevation of the present riverbed was measured to be 445 m a.s.l. The river channel was down-cut for about 3 m during the last 3000 years. The elevation of the riverbed was 448 m a.s.l. during the 5 flooding episodes in Qishuihe River. Then the flood water depth could be figured out by detracting the elevation of palaeoflood riverbed from the elevation of water stage represented by SWDs (Table 1).

4.2.2 Calculation of the palaeoflood discharge

Many models could be adopted to estimate flood discharge, for example, control section method, return water curve method, the water level-discharge relation model, slope-area method. However, these methods and models were limited under some conditions. For example, using the control section method to estimate flood discharge, the advantage was that ascertaining hydraulic factors could be avoided, such as roughness coefficient, hydraulic radius, however the control section was not easy to be found in the river channel. The advantage of return water curve method was that each flood marks could be utilized, but many sections must be calculated. The slope-area method was widely adopted, but it was also affected by the accuracy of estimating roughness coefficient. If the hydrologic gauge station was established on or near the study river reach, and the hydrologic gauge station also possessed data about flood water stage and discharge relation, so, it was better to adopt water stage–discharge relation model to estimate palaeoflood discharge (Shi *et al.*, 2000; Zhan *et al.*, 2001).

In the Qishuihe River valley, the Chaijiazui hydrologic station is located 1 km downstream from the HXZ-E profile at the study site. It had the data about flood water stage and discharge from 1955 to 1970. The water stage and discharge relation was expressed below:

$$Q=8.46\times(H-z)^{2.48} \quad r=0.987$$

where Q is flood peak discharge (m^3/s); H is flood water stage (m); and z is low water stage (m). Due to the single river channel and regular cross section shape in the mainstream of the Qishuihe River, the water stage–discharge relation model was directly adopted and extended to estimate the 5 flooding episodes of 21 palaeoflood discharges occurred during 4800–3000 a B.P. in the Qishuihe River (Table 1).

4.2.3 Calculation of Holocene palaeoflood frequency in the Qishuihe River

With a combination of the 16-year gauged flood data from 1955 to 1970 and historical flood in 1954 and the five flooding episodes of 21 palaeoflood data during the Holocene, the flood data series was extended to be 11,500 a B.P. in the onset of the Holocene, and all the flood ages were converted to A.D. 1970 for calculating the flood frequency.

In Figure 4, only based on gauged flood data, food discharge was 1040 m^3/s in return period of one thousand years and 580 m^3/s in return period of one hundred years respectively on the flood frequency–discharge curve. When combined with the historical flood and palaeoflood data, the flood data sequence was extended to 11,556 years, and the credibility of flood frequency calculation was greatly enhanced. The peak flood discharge was as big as 3970 m^3/s in return period of ten thousand years, and 2100 m^3/s in return period of one thousand years, and 900 m^3/s in return period of one hundred years. This improvement discharge–infrequency relation by palaeoflood hydrological study was very important in hydraulic engineering and flood hazard mitigation.

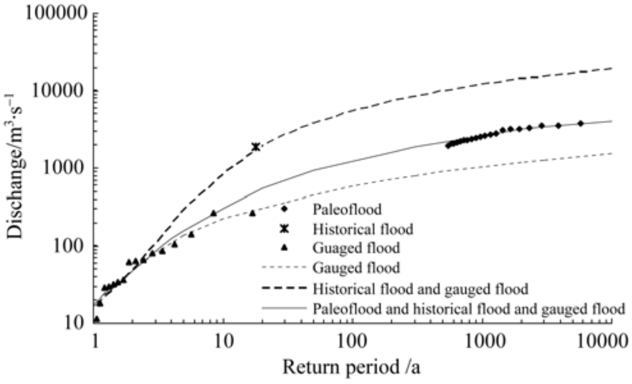

Figure 4 Flood frequency–peak discharge relationship curve in 10000 year time-scale, established with a combination of gauged flood, historical flood and palaeoflood data of the Qishuihe River in the middle reaches of the Yellow River

5 Discussion and conclusions

The occurrences of extreme floods are related with climate change and human activities in the catchments. The global climate gradually ameliorated in the early Holocene (11,500–8500 a B.P.), and in the middle Holocene (8500–3100 a B.P.), the climate was wetter and warmer in the middle latitude area of Northern Hemisphere. An aridity phase took place during 6000–5000 a B.P., the climate was much arid. In the late Holocene (3100–0 a B.P.), the climate tended to be dry and cool (Huang *et al.*, 2000; Huang *et al.*, 2002).

During 5000–3000 a B.P., the second phase of the mid-Holocene Climate Optimum. The archaeological sites of the Longshan Culture at the Huxizhuang village and Zhaojia'ai village were found and located near the HXZ-E profile. This indicated the Neolithic people settled in the Qishuihe valley, and developed dry farming. During the Miaodigou II Culture (4800–4300 a B.P.), there was no extreme flood recorded in the study sites. However, during the Keshengzhuang II Culture (4300–4000 a B.P.), the four episodes of palaeofloods occurred during 4300–4250 a B.P., 4250–4190 a B.P., 4190–4100 a B.P. and 4100–4000 a B.P. in Qishuihe River, respectively. The settlement on the terrace land in the valley was flooded several times. The people of the Keshengzhuang II Culture (4300–4000 a B.P.) were forced to move from western river bank and relocated to the loess tableland near the Zhaojia'ai village on the eastern side of the Qishuihe River.

Because the climate tended to be dry, and the degradation of water and land resources from 3100 a B.P., the nomadic tribes (Rong, Di and Xianyun) migrated to the southern part of the Loess Plateau, the political capital of Pre-dynastic Zhou was relocated from Bin in the middle reaches of Jinghe River southward to the Zhouyuan loess tableland, the capital city "Qiyi" of Pre-dynastic Zhou was built on Zhouyuan loess tableland in the middle reaches of the Qishuihe River (Huang *et al.*, 2001; Huang *et al.*, 2003). Where the elevation was 650–750 m, the flat ground and fertile soil was fit to agricultural cultivation. But because the instable climate system and intensified influence on soil and vegetation over the loess tableland, another phase of palaeoflood occurred in the Qishuihe River between 3100 and 3000 a B.P. during the Pre-dynastic Zhou Culture.

Based on sedimentology, geomorphology and OSL chronology, Holocene palaeoflood slackwater deposits were studied on the terrace land in the Qishuihe River where it was the entrance of the Weishui River flowing into Qishuihe River. There 5 flooding episodes with 21 flood events took place during 4300–4000 a B.P. and 3100–3000 a B.P. By detailed study on the SWD layers and reconstruction of the palaeoflood stages, the palaeoflood discharges were calculated. With extended flood data series, the more accurate frequency–discharge relation of 10,000 years time-scale was established in Qishuihe River. Now, the flood discharge was found to be 3970 m^3/s in return period of ten thousand years, and 2100 m^3/s in return period of one thousand years and 900 m^3/s in return period of one hundred years. These results not only had an important implications in mitigation flood disasters, but also very useful in hydraulic engineering.

References

Baker V R, 1987. Palaeoflood hydrology and extraordinary flood events. *Journal of Hydrology*, 96: 79–99.

Baker V R *et al.*, 1983. Desert palaeofloods in Central Australia. *Nature*, 301: 502–504.

Barbara A Maher, Roy Thompson, 1995. Paleorainfall reconstructions from pedogenic magnetic susceptibility variation in the Chinese loess and paleosols. *Quaternary Research*, 44(3): 383–391.

Benito G, Sopeña A, Sáchez–Moya Y *et al.*, 2003. Palaeoflood record of the Tagus River (central Spain) during the Late Pleistocene and Holocene. *Quaternary Science Reviews*, 22(15–17): 1737–1756.

Compilation Committee for Records of Wugong's Geography, 2001. Records of Wugong's Geography. Xi'an:

Shaanxi People's Press, 79–83. (in Chinese)

Compilation Group for Records of Xianyang's Geography of Geography Department of Shaanxi Normal University, 1991. Records of Xianyang's Geography. Xi'an: Shaanxi People's Press, 3–86.

Huang Chunchang, 2001. The deterioration of land resources and the change in human–earth relationships in the Weihe River basin at 3100 a B.P. *Scientia Geographica Sinica*, 21(1): 30–35. (in Chinese)

Huang Chunchang, Pang Jiangli, 2002. An early Holocene erosion phase on the loess tablelands in the southern Loess Plateau of China. *Geomorphology*, 43(1): 209–218.

Huang Chunchang, Pang Jiangli, Chen Baoqun *et al.*, 2003. Land degradation and its social impaction in the Weihe River drainage basin during the Predynastic Zhou–Western Zhou Dynasty. *Quaternary Sciences,* 23(4): 404–414. (in Chinese)

Huang Chunchang, Zhou Jie, Pang Jiangli *et al.*, 2000. A regional aridity phase and its possible cultural impact during the Holocene Megathermal in the Guanzhong Basin. *The Holocene*, 10(1): 135–143.

Institute of Archaeology, Chinese Academy of Social Sciences (IACASS), 1991. Collection of the ^{14}C Dating in Chinese Archaeology between 1965–1991. Beijing: Antique Press, 125–131. (in Chinese)

Kochel R C, 1988. Extending stream records with slackwater palaeoflood hydrology: Examples from West Texas. In: Baker V R, Kochel R C, Patton P C (eds.). Flood Geomorphology. New York: John Wiley and Sons, 377–392.

Li Chang'an, Huang Junhua, Zhang Yufen *et al.*, 2002. Preliminary study of palaeoflood of Last Glacial Maximum in upper reaches of the Yellow River. *Earth Science-Journal of China University of Geoscience*, 27(4): 456–458. (in Chinese)

Liu Tungsheng, 1985. Loess and Environment. Beijing: Science Press, 62–81. (in Chinese)

Liu Xiuming, Liu Tungsheng, John Shaw, 1993. Magnetic mineral characteristics of Chinese loess and its palaeoclimatic significance. *Quaternary Sciences*, 13(3): 281–287. (in Chinese)

Shi Fucheng, Yi Yuanjun, Mu Ping, 2000. Investigation, Research and Study on the Yellow River Historical Flood. Zhengzhou: Yellow River Water Conservancy Press, 81–123. (in Chinese)

Waythomas Christopher F, Jarrett Robert D, 1994. Flood geomorphology of Arthurs Rock Gulch, Colorado: palaeoflood history. *Geomorphology*, 11: 15–40.

Xie Yuebo, Fei Yuhong, 2001. Slackwater deposits and flow peak level of a palaeoflood. *Acta Geoscientia Sinica*, 22(4): 320–323. (in Chinese)

Xie Yuebo, Jiang Hongtao, 2001. Palaeoflood study: Excavating great flood history on rivers. *Journal of Nanjing University* (Natural Sciences), 37(3): 390–395. (in Chinese)

Yang Dayuan, 2000. Sedimentary records of large Holocene floods from the middle reaches of the Yellow River, China. *Geomorphology*, 33: 73–88.

Yang Dayuan, Xie Yuebo, 1997. Palaeoflood slack water deposits. *Acta Sedimentologica Sinica*, 15(3): 29–32. (in Chinese)

Yao Ping, Huang Chunchang, Pang Jiangli *et al.*, 2008. Palaeoflood hydrological studies in the middle reaches of the Beiluohe River. *Acta Geographica Sinica*, 63(11): 1198–1206. (in Chinese)

Zhan Daojiang, Xie Yuebo, 1997. New advance in flood calculation: Palaeoflood study. *Hydrology*, (1): 1–6. (in Chinese)

Zhan Daojiang, Xie Yuebo, 2001. Palaeoflood Study. Beijing: China Waterpower Press, 1–89. (in Chinese)

Zhang Xingnan, Luo Jian, Chen Lei *et al.*, 2000. Zoning of Chinese flood hazard risk. *Journal of Hydraulic Engineering*, (3): 1–7. (in Chinese)

Zhang Yusheng, 2005. Flood analysis on Weihe River basin. *Gansu Water Resources and Hydropower Engineering*, (4): 345–346. (in Chinese)

Zhou Mingfu, Zhou Weijian, Head J, 1991. Stratigraphy and ^{14}C dating of Beizhuangcun profile during the last 30,000 years. In: Liu Tungsheng (ed.). Loess, Quaternary Geology and Global Change (I). Beijing: Science Press, 12–19. (in Chinese)

Zhou Weijian, An Zhisheng, Jull A *et al.*, 1998. Reappraisal of Chinese Loess Plateau stratigraphical sequence over the last 30000 years: Process of an important Holocene monsoon climatic event. *Radiocarbon*, 40(2): 905–913.