Runoff and Sediment Reduction Effects through Hydraulic and Soil-water Conservation Measures in the Middle Yellow River and Its Influence on the Lower Yellow River

Xu Jianhua, Wang Jian and ***Jiang Xinhui***

Hydrology Bureau, YRCC, Zhengzhou, 450004, China
E-mail:xujian-hua@371.net

Abstract: Based on the actual measured runoff and sediment records, the reasons for changes of runoff and sediment in the middle Yellow River in recent years and its influence on the lower channel are analyzed and studied in the paper. The results demonstrated that runoff and sediment into the Yellow River has been reduced greatly in recent years by the effects of both climate and hydraulic and water and soil conservation measures. Runoff reduction has made finer sediment silt increase, more severe of flow cut-off in the Lower Yellow River channel, though sediment reduction has made decrease of silt in the channel of the Lower Yellow River. It is pointed out furthermore that it is possible to alleviate the problems of flow cut-off and high water level at normal floods in the Lower reach, only if the treatments in the coarse and overburden sediment area are speeded up, and water saving measures are carried out in the Lower Yellow River and the area of clear water and lower sediment content.

Keywords: change of runoff and sediment, hydraulic and soil-water conservation measure,sediment and runoff reduction, flow cut-off, influence

1 Variety of runoff-sediment and derivative phenomena in Middle Yellow River

1.1 Variety of runoff and fine of deposit in Lower Yellow River

In Upper and Middle Yellow River (the sum of Longmen, Huaxian, Hejin, Zhuangtou, Heishiguan and Wuzhi), the annual mean observing runoff is 49.86 billion m^3 and 35.46 billion m^3 in 1950—1969 and in 1970—1999 respectively. The latter is less 28.9% than the former, especially in 1990—1999 the reduced amount up to 45.4%. The annual mean observing runoff in Middle Yellow River in 1950—1969 and in 1970—1999 is 24.03 billion m^3 and 11.56 billion m^3 respectively. The latter is less than the former 51.9%. While in the same period in Upper Hekouzhen, the reduced amount is only 39.3%. The decreasing amount in Middle reach is larger than that in Lower reach. In Middle reach, the annual runoff reduction in 1990—1999 compared to in 1950—1969 is 4.71 billion m^3 in Weihe, 3.51 billion m^3 in Luohe and Qinhe, 2.91 billion m^3 in Hekouzhen-Longmen district, 1.26 billion m^3 in Fenhe, 74 million m^3 in Beiluohe. Suspended-sediment concentration of flood runoff in Weihe, Luohe, Qinhe is relative small. These rivers are the main water-source area of riverbed scoring in Lower reach. The runoff reduction in these rivers is 65.9% of that in the whole Middle reach in same period. The runoff reduction is very disadvantage to sediment scouring of Lower channel. On the one hand, resulted the increasing deposit in Lower reach, especially to main channel. Under the condition of sediment reduction, the deposition in 1987—1997 in Lower reach is 1.88 billion m^3, which is equivalent to the deposition in 1950s. On the other hand, resulted the deposit fine as runoff reduction in Lower reach. According to analysis, since 1980, the ratio of sediment diameter larger than 0.05mm in Lower reach is from 50% in 1950—1960 to 37.6% in 1990—1998. The ratio of sediment diameter larger than 0.025mm increased more. The reason is base flow reduction in flood season which resulting from the reservoir interception in Upper reach and flood reduction in Weihe, Luohe and Qinhe basin etc.

1.2 Variety of sediment discharge

The annual mean observing sediment in 1950—1969 is 1.79 billion ton and in 1970—1999 is 1.02 billion ton in Upper and Middle reach. The latter is less 43% than the former. It is 0.88 billion ton in 1990—1999, less than 50.8%. The annual mean observing sediment in 1990—1999 is 0.84 billion ton in Middle reach, less 48.1% than that in 1950—1969. The reduced amount in 1990—1999 in Middle reach is 0.52 million ton in Hekouzhen-Longmenzhen, 156 million ton in Weihe, 49 million ton in Fenhe, 35.5 million ton in Luohe and Qinhe, 14.5 million ton in Beiluohe.

2 The reason of variety of runoff and sediment in Middle Yellow River

2.1 Climate

Soil erosion in Middle Yellow River resulted from storm flood. The main climatic factor is precipitation, rainfall intensity and the distribution of time and space. The variety of climatic factor has direct relation with runoff and sediment yielding. Taking the district from Hekouzhen to Longmen as example, the annual mean rainfall before 1969 is 467.2mm, in 1970s is 433.3mm, in 1980s is 412.1mm, and in 1990s is 411.2mm. The sum of average rainfall that the day rainfall larger than 10mm is 317.2mm in 1950s and 1960s, 282.1mm in 1970s, 271.5mm in 1980s, 276.4mm in 1990—1995, which indicate the precipitation and rainfall intensity are reducing in recent 30 years. This is the direct reason of runoff and sediment yielding reduction in this district. According to estimation, the runoff reduction in Middle Yellow River resulted from climate change is 2 billion m^3 after 1970, which is 42% of the total runoff reduction. And the sediment reduction is 0.25 billion ton, which is 38% of total. Therefore, the action of climatic factor is obvious.

2.2 The influence of water conservancy and soil-water conservation project

2.2.1 The water conservancy and soil-water conservation project

According to statistics, the harness area is 14.4 million hm^2 in Upper and Middle Yellow River up to 1995, which include terrace 2.84 million hm^2, occupy 19.7% of total, forest and grass 10.21 million hm^2, occupy 74% of total, check-dam 0.38 million hm^2, occupy 2.6% of total, 755 reservoirs that capacity larger than 1 million m^3, the sum of reservoir capacity is 64 billion m^3, and some irrigation land. These projects of water conservancy and soil-water conversation make the very large change of underlying surface in this district, and have the distinct effect to runoff and sediment yielding.

2.2.2 The evaluation of runoff and sediment reduction of water conservancy and soil-water conservation project

At present, the main computation method of runoff and sediment reduction of water conservancy and soil-water conservation project is soil-water conservation method and hydrology method (The two methods are the action on reduction of runoff and sediment yield through soil conservation measure). The annual mean runoff reduction in 1970—1996 in Middle reach through computation of soil-water conservation method and hydrology method is 4.9 billion m^3 and 5.6 billion m^3 respectively. The annual mean sediment reduction is 0.4 billion m^3 and 0.55 billion m^3, respectively. The district of total runoff reduction from large to small in the same period is Weihe, Fenhe, Hekouzhen-Longmen, Beiluohe, which of sediment reduction is Hekouzhen-Longmen, Weihe, Fenhe, Beiluohe. The details are shown in Table 1. The area from Hekou to Longmen is the main source of coarse sand in Yellow River basin. The much sediment reduction in this area is advantage to deposit reduction in Lower reach. According to computation of experts, sediment reduction is 100 million ton in upper Longmen, then silting reduction is 50—70 million ton in Lower reach channel, which include coarse sediment reduction of sand diameter larger than 0.05mm 20—30 million ton [1]. The main sand retention in Hekouzhen-Longmen is check-dam and reservoir, which is 90% of the total. The deposition storage in this area is about 6.9 billion m^3. The silting ratio is up to more than 70%. It is quite difficult to deal with infinite sand that only rely on finite storage. So the harness strength in this area must be increased.

Table 1 Runoff and sediment reduction effect of water conservancy and soil-water conservation project in Middle Yellow River

Unit: runoff, $10^8 m^3$; sediment, $10^8 t$

Item	River	Station	Soil-water conservation method				Hydrology method			
			1970—1979	1980—1989	1990—1996	1970—1996	1970—1979	1980—1989	1990—1996	1970—1996
Runoff	Yellow River	Hekouzhen-Longmen	10.6	15.6	12.8	13.0	8.2	13.9	12.8	11.5
	Jinghe	Zhangjiashan	6.8	6.2	6.6	6.5	6.2	5.6	4.4	5.5
	Beiluohe	Zhuangtou	2.9	2.5	3.1	2.8	2.9	2.5	3.1	2.8
	Weihe	Xianyang	13.2	14.5	16.4	14.5	22.0	16.4	23.4	20.3
	Fenhe	Hejin	13.8	12.2	11.0	12.5	14.0	16.8	16.9	15.8
	Σ		47.2	51.0	49.9	49.3	53.2	55.0	60.7	55.8
Sediment	Yellow River	Hekouzhen-Longmen	1.90	2.72	3.16	2.53	2.26	4.48	4.73	3.72
	Jinghe	Zhangjiashan	0.42	0.45	0.48	0.44	0.57	0.63	0.44	0.56
	Beiluohe	Zhuangtou	0.19	0.11	0.13	0.14	0.19	0.11	0.13	0.14
	Weihe	Xianyang	0.35	0.38	0.39	0.37	0.36	0.78	0.80	0.63
	Fenhe	Hejin	0.58	0.48	0.46	0.51	0.61	0.43	0.37	0.48
	Σ		3.43	4.14	4.61	4.00	3.98	6.43	6.46	5.53

3 The effect to lower reach channel of runoff and sediment reduction of water conservancy and soil-water conservation project in middle reach

On the basement of above analysis, knowing the recent observing runoff and sediment in Middle reach decrease distinctly, and the action of water conservancy and soil-water conservation project is quite obvious. It not only retards and reduces runoff and sediment, but also affects yearly distribution, retention flood and increase base flow. As sediment is carried with flood, sediment reduction achieved only through flood reduction in Middle reach, especially in Hekouzhen-Longmen district. Through analyzed the relation between 298 floods source in Huayuankou and silting in Lower reach, Wangling (1991) and so on pointed out: in 298 floods, deposition larger than 100 million ton only occupy one-tenth, the most sediment in these floods came from coarse sand region in Hekouzhen-Longmen. It is feasible that intensive harness the area, and reduce coarse sediment entering Yellow River and decrease silting in Lower reach [2]. According to the above analysis, knowing sediment reduction in Hekouzhen-Longmen occupy 65% either with hydrology or soil-water conservation method, which is advantage to decrease the Lower reach channel rising. Furthermore, from the analysis of soil-water conservation method, it concludes that sediment reduction of check-dam and reservoir in Hekouzhen-Longmen occupy near 90%. Whereas, check-dam and reservoir is excessive silting at present, and ill-danger reservoir is increasing. So for the purpose of retain sediment reduction efficiency in this region, harness must be strengthened.

The sediment discharge is relative small and sand diameter is thin in other Middle reach branch out of Hekouzhen-Longmen. Especially in small branches of south mountain of Weihe, Luohe and Qinhe, the scouring occurred in Lower reach, which is advantage to ensure flood flowing. But the recent observing runoff decreased obviously in this region, which increased the silting of flood main channel in Lower reach. The highest level in history occurred in Aug.5, 1996 with flood only 7,680 m^3/s in Huayuankou. At the same time, the runoff reduction made the cut-off in lower reach increased. It is obviously that main channel silting increasing in lower reach not only related to base flow reduction resulted from retention in flood season of water conservancy project in Upper reach, but also related to water diversion increasing of irrigation in Lower reach. The water diversion in Huayuankou-Lijin is 2.3 billion m^3 in 1950s and

1960s, 10 billion m^3 in 1980s and 1990s. The water diversion occurred mostly in lower Gaocun, which has the large effect to Lower channel silting.

4 Conclusions

(1) The positive effect to deposit reduction in lower reach channel of sediment reduction of water conservancy and soil-water conservation project in Hekouzhen-Longmen is much less than the negative effect resulted from flood runoff reduction in relative small suspended-sediment concentration region.

(2) Although the action of runoff and sediment reduction of water conservancy and soil-water conservation project in Middle Yellow River is obvious, it is formed with little storm in Middle reach and excessive deposit of check-dam and reservoir that build in 1970s, once encountered large storm, the effect is very difficult to keep.

(3) The Hekouzhen-Longmen district is the main coarse and overburden sediment area in Yellow River, so we should increase invest, enhance harness strength, and consolidate the effect of sediment reduction.

(4) The decreasing of flood runoff in less sand region, especially in upper Xianyang in Weihe, Luohe and Qinhe, is disadvantage to scouring of Lower channel. It should be carried out that save using water in this area and Lower reach, use artificial flood-peak of main-branch reservoir to scour sand, and obtain larger flood section.

On the whole, it is possible to make ecological environment in Lower reach well, only if the treatments in the coarse and overburden sediment area are speeded up, and water saving measures are carried out in the Lower reach and the area of clear water and lower sediment content.

References

[1] Zhangren, Cheng Xiuwen, Xiong Guishu, The effect to scouring variety in Yellow River channel of retention and reduction of coarse sand, Zhengzhou, Yellow River Conservancy Press, July, 1998, p.128.

[2] Wangling, etc. The analysis and statistics of data of each flood in Yellow River to silting of Lower channel, Papers of research of environment evolvement and water-sand run rule in Yellow River (the first volume), Beijing, Geological Press, 1991.