Application of Shuangchao Hydrological Model in Shanxi Semiarid and Semi-humid Area

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Abstract. At present, the watershed hydrology model in semiarid and semi-humid areas do less work whether in foreign or in our country, therefore studying on the hydrology simulation in semiarid and semi-humid area is very important. This paper focuses on the principle and the structure of Shuangchao hydrological model, which was applied to simulate 5 historical floods of Zhangfeng Reservoir in Shanxi, and the results show the model is very suitable for this basin. Finally, the author puts forward some suggestions for future improvement of Shuangchao hydrological model in the future.

Keywords: Flood forecasting, Shuangchao Hydrological Model, semiarid and semi-humid.

1 Introduction

Hydrological phenomenon of the nature is a complex process, which is interacted with multiple factors, and because of its formation mechanism is not entirely clear, hydrological model becomes into a very important tool for studying the complex hydrological phenomenon and hydrological forecasting. The generation of hydrological model is the inevitable result in studying the law of the hydrological cycle. Hydrological model belongs to mathematical model, it uses mathematical methods to describe and simulate the process of the hydrological cycles, explains some experience laws by physics, expresses by a series of rigorous mathematical equations, and at last integrates all hydrological together to form the water balance calculation system of the basin[1-2].

The forecasting is an important part of the hydrological work, in the past few decades, it has great development and has accumulates wealth of experience. Especially recently, with computers, networks, remote sensing, geographic information technology applying in the hydrological forecasting, the progress of hydrological forecasting has new development. However, in the development work of in hydrological model, there are so much works doing in the south humid areas, and calculation methods are more mature, while the work in semi-dry areas has done less. Whether foreign or domestic hydrological models, when they are used in semiarid and semi-humid areas, there exist problems such as unknowing the flood courses, low

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prediction accuracy, which can not be good for the drought, water diversion, mountain hazards control, water environment manage and hydrology projects optimize to provide technical services.

Semi-dry areas of our country are mainly distributed in north, northeast and central and eastern Tibetan Plateau, and the semi-dry areas accounting for about 52% land area in China, therefore, it has very important in studying of the semi-dry areas' hydrological situation and it is very significant to establish the region hydrological model.

In this paper, the author mainly studies the application of Shuangchao hydrological model at Zhangfeng Reservoir in Shanxi. Through the analysis of the model, the author is going to further explore the rainfall runoff characteristics in the semiarid and semi-humid area, and proposed recommendations of the model for future development.

2 Shuangchao Hydrological Model

In the semiarid and semi-humid area, because of less precipitation, the soil often in the status of lacking water, and its runoff producing and confluence process characteristics are different with the humid areas. The high intensity short time rainfall will excess to generate surface runoff after long time drought, and the volume of the water infiltration is not so much at this time. The infiltration front is often difficult to reach the less permeable layer, upper water will not exceed and has no lateral flow of water, and thus it can not produce interflow. When it happened to the rainfall or the behind of the long period precipitation after long time rain, the interflow will appear since the above aquitard interface layer exceed holding water. According to the semiarid and semi-humid area runoff mechanism, Senior Engineer Wang Yinjie,whom works in Hydrology and Water Resources Survey Bureau of Shanxi Province, bring forward the Shuangchao hydrological model. In this model, excess infiltration will produce surface runoff; excess holding will produce interflow and underground runoff. The Shuangchao model is drawn on the design ideas by the Shanbei hydrological model, Xin'anjiang hydrological model, Janpan Tank model, the United States Sacramento model and other models [3-4].

Shuangchao runoff model thinks that: as soon as the rainfall intensity exceeds infiltration capacity, then it becomes the surface runoff, which is an integral part of the runoff, but not all. The precipitation, which penetrates into the unsaturated zone or the influence layer, will move along with the interface of the layered media when it reaches to water holding capacity and forms the gravity water. And when encountering with gully or foot of the river slope or slopes of the saturated zone, it will escape and form interflow, which its proportion in total runoff is determined by the characteristics of the precipitation and land surface in the basin. The structure of the model is designed according to the physical mechanism of three kinds of water and includes five components: fictitious infinitesimal infiltration, watershed distribution of the infiltration capacity, surface runoff, interflow and groundwater runoff, soil evaporation and soil moisture.

The basin confluence runoff model is taken advantage of hysteresis Nash model, and is used water storage balance and discharge equation to solve the differential equation of Nash model, s(t)curves, and period confluence curve. River confluence model is adopted by diffusion simulations method, which is the hydraulic linear analytical solution of diffusion wave for the Saint-Venant equations. It can be used for the channel which the bottom width is B, the average water depth is D, the wide-shallow water surface down is SW and the channel is wide-shallow prism and without water seepage fill.

Shuangchao hydrological model structure is shown in Figure 1 [5-11].

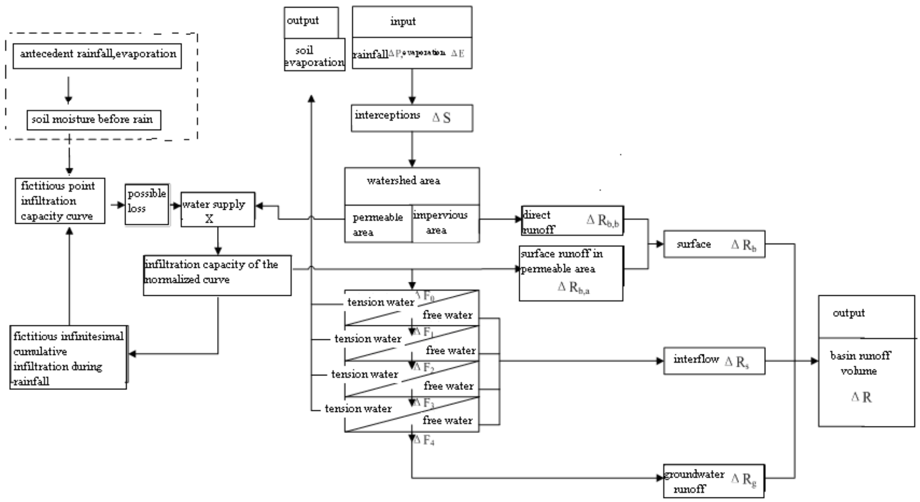

Fig. 1. Shuangchao hydrological model flow chart

3 Engineering Background and Application

3.1 Engineering Background

Zhangfeng Reservoir is located in Village Qinhe River in Zhengzhuang town Qinshui County of Jincheng City, Shanxi Province, and the distance to the Jincheng City is 90km. The reservoir control drainage area is 4990km^2, the total capacity of the reservoir is 394 million m^3, it is a large scale hydro project which undertaking the main object of water supply to urban living and industrial, and the secondary object is flood control, power generation and other utilization task. The hydro project is built up by the dam, diversion tunnel, spillway, water supply power tunnel and headwork pumping station and other components. The average annual precipitation in the basin is between 550 ~ 583.9mm, and the precipitation proportion in flood season (June to September) is 67 to 74%of the total annual. The average annual evaporation is 1517 to 1827.8mm, and the designed years average runoff is 479 million m^3, annual average flow is 15.2m^3/s.

Zhangfeng reservoir engineering started to build on November 17, and the main project, that is the weir dam, began to build in June 2005.The dam is clay slope core rock fill dam, the maximum height is 72.2m, normal water level is 759m. Cofferdam High 23.24m, crest elevation of 725.24m, the design flood standard of once in 10 years, and the corresponding high flood water level is 724.04m.

Hydrological flood forecasting station network of Zhangfeng reservoir includes: 4 hydrological station such as Kongjiapo,Feiling,Youfang,Zhangfeng and 19 telemetry rainfall station between Feiling and Zhangfeng. Among the 23 telemetry station, Dajiang, Weizhai and Longqu observe both the water level and flow.

3.2 Application of Shuangchao Model in Zhangfeng Reservoir

The flood forecast program of Zhangfeng reservoir is as follows: according to the river inflow course of the Feiling hydrological station and the interval precipitation between Feiling and Zhangfeng, and river confluence runoff model, basin rainfall runoff and confluence model to calculate the flood process of the Zhangfeng reservoir. The method utilizes sub-unit,sub-perion and sub-water to calculate runoff and confluence process of every unit of the basin. The runoff model uses Shuangchao model, the basin confluence model uses Nash model and the river confluence uses diffusion simulation to compute. In order to better control the every tributary's rainfall runoff, the every tributary is thought as a unit. Thus the basin of Zhangfeng is divided into 9 units and every unit calculates lonely. Basin unit is shown in Figure 2 and Table 1.

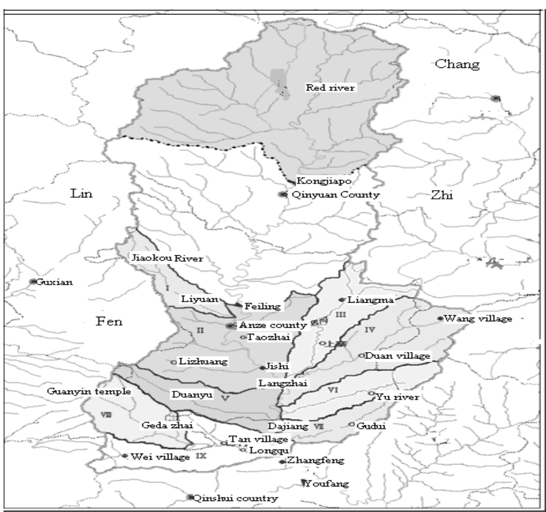

Fig. 2. Forecasting unit of Zhangfeng reservoir

Table 1. Unit area and rainfall station tables of Zhangfeng reservoir

Unit	Area (km^2)	Section of river confluence	Length from the section before (km)	Rainfall station
Ⅰ	162	Weizhai	41.6	Jiaokouhe,Liyuan
Ⅱ	491	Weizhai	0	Lizhuang,Feiling,Jishi,Taozhai
Ⅲ	262	Weizhai	0	Shangzhai,Liangma
Ⅳ	358	Weizhai	0	Wang village,Du willage
Ⅴ	219	Dajiang	0	Duanyu,Dajiang
Ⅵ	195	Dajiang	0	Weizhai,Wang river
Ⅶ	130	Zhangfeng	0	Dajiang,Gudui
Ⅷ	177	Longqu	28.6	Zhaigeda,Guanyin temple
Ⅸ	313	Longqu	0	Wei and Tan village,Longqu

We choose 10 typical historical floods in 7 years of Zhangfeng reservoir, 1988, 1992, 1993, 1996, 2001, 2003, and 2005. And the former 5 historical flood are used to calibrate the parameters of the model, the last 5 flood data are used to test model accuracy. Runoff depth forecast error is 20% of the measured, and when it is less than 3mm, the take 3mm as the error. The parameters of Shuangchao hydrologic model are list below from table 2 to table 4.And the last five runoff flood forecasting pass rate is 80% [12]. The assessment of the flood results is in table 5.

Table 2. Parameters of runoff for each unit

Unit	Hydraulic conductivity ks	Diffusivity kr	Infiltration curve index b	Lateral discharge share coefficient δ	Critical rainfall intensity α0
Ⅰ	10	65	5	0.04	0.05
Ⅱ	10	65	5	0.04	0.05
Ⅲ	6	50	5	0.04	0.05
Ⅳ	6	50	5	0.04	0.05
Ⅴ	10	80	5	0.04	0.05
Ⅵ	6	50	5	0.04	0.05
Ⅶ	6	50	5	0.04	0.05
Ⅷ	20	100	5	0.12	0.1
Ⅸ	15	100	5	0.12	0.1

Table 3. Parameters of basin confluence

Unit		Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ	Ⅵ	Ⅶ	Ⅷ	Ⅸ
Surface	Displacement delay time τ	3	3	3	3	3	3	3	3	3
	Planarization delay time kr	3	5	3	4	3	3	3	3	4
	n	1	1	1	1	1	1	1	1	1
interflow	Displacement delay time τ	4	4	4	4	4	4	4	4	4
	Planarization delay time kr	7	7	7	7	7	7	7	7	7
	n	2	2	2	2	2	2	2	2	2

Table 4. Parameters of river course confluence

River course	Outlet of unit Ⅰ to Weizhai	Weizhai to Dajiang	Outlet of unit Ⅷ to Longqu	Dajiang to Zhangfeng
Diffusion coefficientμ	200	200	200	200
Flood velocity u	1.5	1.5	1.2	1.5
River length L（m）	41.6	20.2	28.6	17.6

Table 5. Assessment results of Zhangfeng reservoir historical flood

No.	Flood	Runoff depth		Error	Allowable Error	Fitness Or not
		Measured	Calculation			
1	19930805	8.4	10.7	2.3	3	√
2	19960731	45.9	43.6	-2.3	9.2	√
3	20010728	5.7	4.0	-1.8	3	√
4	20030827	21.6	24.5	2.9	4.3	√
5	20050921	11.4	22.2	10.8	3	×

Fig 3 and Fig 4 show two large flood event course simulations of historical flood.

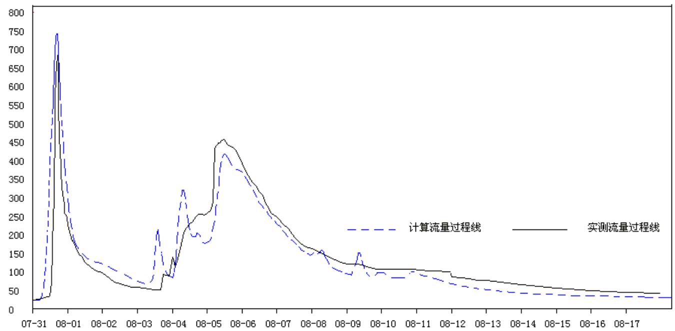

Fig. 3. 19960731

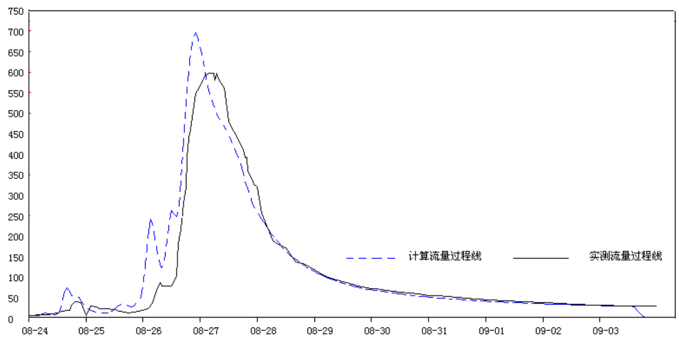

Fig. 4. 20030827

4 Conclusion

The core of Shuangchao hydrological model structure is to use runoff theory combined by infiltration curve and basin infiltration distribution curve, and simulate the exceed surface water. In this paper, five historical floods were predicted using Shuangchao hydrological model and the accuracy of forecasting results were very ideal, so we can see that the model has great applicability in Zhangfeng reservoir. However, as a relatively new hydrological model using in semiarid and semi-humid area, Shuangchao model is not perfect in some respects and it needs adjust in some place.

The model assumes that infiltration capacity distribution curve has the same distribution at any point in time; this generalization can not reflect changes in the basin excavated wetland distribution of infiltration capacity. Therefore this assumption is too simple and can not reflect the variation of the infiltration capacity; we can try to consider soil moisture changes in the model so that to improve the simulation accuracy. At the same time, considering to analysis with other hydrological models and use different models to simulate different reservoirs' flood in order to get the reasonable hydrological model in Shanxi semiarid and semi-humid area future.

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