Researching of Forecast Project of Double Mutual Inflow Reservoir Flood

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Abstract: Zhanghe reservoir is composed by Guan Yinsi reservoir and Ji Gongjian reservoir through semi-natural open channel. The characteristics of two reservoirs are great disparity, and inflow each other. Because of the complicated influence of transmitting water by open channel, observation error of reservoir level and calculation error of backwater storage, many flood forecast projects established in the past did not come to applied level. This text develops the yield and conflux forecast project of anti-error zoning based on analyzing characteristics of error generation of Zhanghe reservoir flood, and adopts real-time adjustment technique. It basically avoids the calculating error problem of Ji Gongjian reservoir flood. It makes the average deterministic coefficient, the qualified rate of flood peak, the qualified rate of time to peak of Zhanghe reservoir flood forecast project come to 91.09%,100%,90.91%.While Guan Yinsi reservoir flood forecast project comes to 90.63%,100%,100%,which establishes Zhanghe reservoir flood forecast project that attains first-rate finally.
Key words: Zhanghe reservoir reservoir flood flood forecast real-time adjustment

The concept of reservoir flood was put forward in 1950's when reservoirs built were checking. Before 60's, the standard of reservoir flood control all adopted design flood of reservoir site. In 1970's reservoir flood was arranged design flood and kinetic energy design criterion, at the same time, in order to manage many reservoirs built, fully exert their flood control and promote benefit, universally developed research and applied work of reservoir flood forecast and attemper, moreover forecast and attempering roboticized system was established[2]. But because the influence factors of reservoir flood are complex, especially Zhanghe reservoir of this text. We first establish Zhanghe reservoir flood forecast project that attains first-rate finally on the basis of deep analyzing its error characteristics and summarizing departed research.

1 Drainage basin and project general situation

Zhanghe reservoir locates in the east branch of Ju Zhanghe which is Yangtse north bank branch, the area of reservoir dominating is 2212km^2, as Fig.1. Zhanghe reservoir is composed by Guan Yinsi reservoir and Ji Gongjian reservoir through semi-natural open channel which was rebuilt by manpower. Guan Yinsi reservoir dominates 1957km^2, reservoir capacity 0.806 billion m^3, the area of water surface 31.45km^2; Ji Gongjian reservoir only dominates 255km^2, but reservoir capacity 1.329 billion m^3, the area of water surface 73.75km^2.Lower reaches of Zhanghe reservoir has these important flood control objects, such as JingJiang levee, JiaoLiu railroad, JingZhou city, so its demand of flood control and attemper is rigorous. In order to sufficiently utilize water resource and guarantee reservoir flood control safety, it necessarily further researches and develops flood forecast project as applied aiming at the complexity of Zhanghe reservoir.

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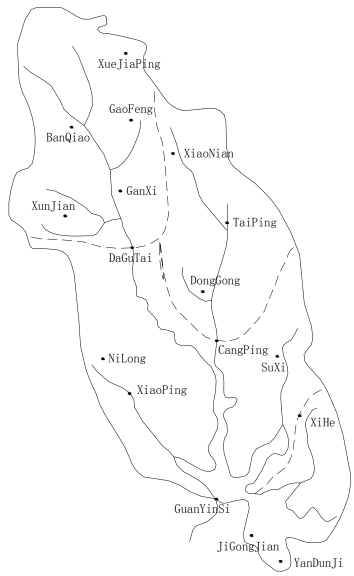

Fig.1 The sketch map of Zhanghe reservoir basin measure station distributing and subarea

2 Total frame design of reservoir flood forecast project

2.1 To the best of our abilities to conquer the problem of calculating error of Ji Gongjian reservoir flood

Zhanghe reservoir is a huge reservoir (Fig.1) which is composed by Guan Yinsi reservoir (west) and Ji Gongjian reservoir (east) through semi-natural open channel. When the flood swells, because nearly 90％ flood comes from former catchment basin, flood from former flows into the latter, surface incline from west to east. While sluice, because nearly all sluice establishment near Guan Yinsi dam site, flood from two east and west reservoirs flows toward spillway nearby Guan Yinsi reservoir, sluices Zhanghe reservoir lower reaches, current from east to west by Ji Gongjian reservoir flows into Guan Yinsi reservoir, surface east high and west low, surface incline from east to west. Surface slope fall magnitude of two reservoirs is not only along with flood fluctuating, but especially Ji Gongjian reservoir follow water store and flood discharge generates change of direction. Moreover, the capacity of Ji Gongjian reservoir is small, surface vast, while the catchment area and flood are small. Elementary estimate, according to State Flood Control and Drought Relief Headquarters ordaining calculated period of time $\Delta t = 1$ h, if calculated error of water level ± 0.05 m，brings the error of calculated Ji Gongjian reservoir flux 1030～2050m^3/s.This more than bigger flood peak of real inflow, still the calculated transporting water error between open channel of two reservoirs is big. So it makes calculated Ji Gongjian reservoir flood turn up prodigious difference. The real calculated reservoir flood also proves it, for example, even in swelling sect, still generates unreasonable phenomenon that series period of time turn up minus flux. Therefore, how to resolve this problem is the key of developing reservoir flood forecast project. Many flood forecast projects established in the past did not come to applied level, without dealing with this problem is a very important cause.

Aiming at the above problems, analyzing and comparing various projects, in total construction design, considering calculated total reservoir flood and Guan Yinsi reservoir flood basically accurate, adopt such method confirming double reservoir flood forecast model:（1）First establish the forecast project of Guan Yinsi reservoir flood, namely confirm yield and conflux forecast project getting through making imitated and calculated reservoir flood error minimum.（2）Based on above project, confirm yield and conflux forecast project of Ji Gongjian reservoir getting through making imitated and calculated reservoir flood error minimum, such as the dotted line ① of Fig.2,consequently avoids the calculating error problem of Ji Gongjian reservoir flood. For proceeding real-time adjustment, according to Guan Yinsi and Ji Gongjian reservoir yield and conflux model separately forecasts Guan Yinsi and Zhanghe reservoir flood. After real-time adjustment, gets forecast Guan Yinsi and total reservoir flood, two minus, gets forecast Ji Gongjian reservoir flood, such as the dotted line ② of Fig.2.

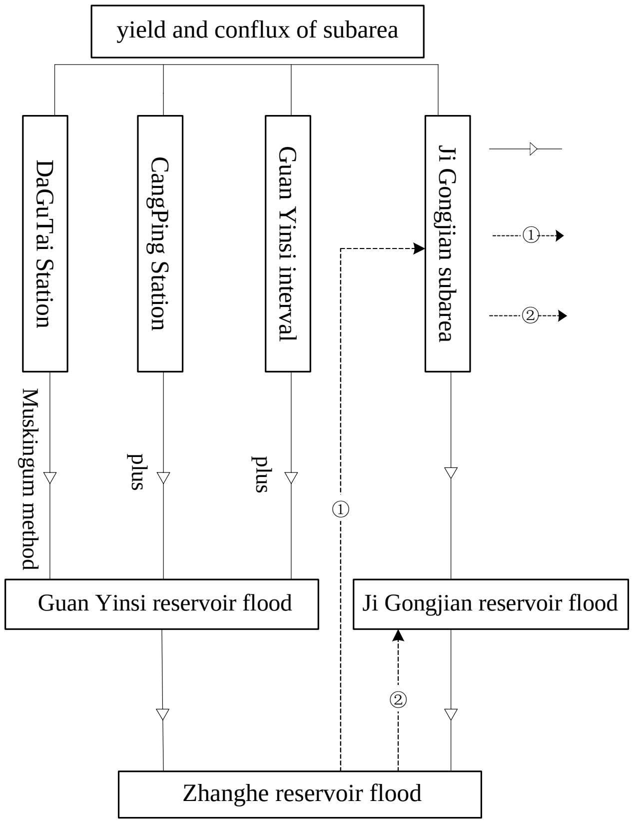

Fig.2 Total frame design of Zhanghe reservoir flood forecast project

2.2 The research on catchment subarea partition

We carve the whole catchment up Da Gutai station catchment, CangPing station catchment, Guan Yinsi interval catchment and Ji Gongjian subarea, besides consider subarea characteristics resemblance, also consider the principle that subarea yield and conflux forecast project can be checked up by real data. Two former have real flux data of hydrological stations，two latter have calculated Guan Yinsi and total reservoir data, such as Fig.1 and Fig.2. Because there are credible data put the examination, preferably guarantees their accuracy.

2.3 Real-time adjustment research on forecast

Considering forecast process, many circumstances have the discrepancy with established yield and conflux forecast project, thereby yield and conflux forecast value deviation appears. So it is necessary to adopt real-time adjustment research on yield and conflux forecast value aiming at appeared error circumstance in forecast process. As above statement, considering the particularity of Zhanghe reservoir, the process of real-time adjustment is:（1）According to real calculated Guan Yinsi reservoir flood proceeds real-time adjustment to yield and conflux forecast value, gets forecast Guan Yinsi reservoir flood；（2）According to real calculated Zhanghe reservoir flood proceeds real-time adjustment to yield and conflux forecast value, gets forecast Zhanghe reservoir flood；（3）Putting forecast Zhanghe reservoir flood of process（2）subtracts Guan

Yinsi reservoir flood of process（1）, gets forecast Ji Gongjian reservoir flood of real-time adjustment.

3 Yield and conflux forecast model of each subarea

3.1 Yield flux calculation

Considering this catchment raining plentiful, plant thick and past experience, yield flux forecast of each subarea adopts Xinanjiang Model (3 water resource) [5].Each subarea is divided into some units area by Tyson polygon of rainfall stations, considering the influence of rain distributing asymmetry, separately proceed yield and conflux calculation of each unit area, further add the average calculation rain process of subarea, for conflux calculation of subarea.

3.2 Conflux Model

Conflux of catchment divides into river network total inflow and river network conflux, the former calculates according to ground net rain, soil net rain and underground net rain, the latter calculates adopting Nash instantaneous unit line of considering net rain intensity influence. For Da Gutai catchment flux, because it is distant away entering reservoir site, further considers adopting Muskingum subsection continuous calculus method calculates to reservoir site.

Nash instantaneous unit line equation of considering net rain intensity influence:

$$u(t) = \frac{1}{K\Gamma(n)} (\frac{t}{K})^{n-1} e^{-t/K} \qquad \text{(3-1a)}$$

$$K = K_{10}\left(\frac{1}{TR}\right)^{a} \qquad \text{(3-1b)}$$

catchment exit flux $Q(t)$:

$$Q(t) = \sum_{i=1}^{m} u(i) * TR(t-i+1) \qquad \text{(3-2)}$$

where n、K relatively is number and store discharge coefficient of linearity reservoir; $\Gamma(n)$ is gamma function; TR is river network total inflow of subarea t time-interval; a is empirical index of total inflow intensity influence; K_{10} corresponds $TR=1$ k value.

3.3 The discussion of model parameter confirming way

The yield flux parameters of catchment are 17 entries: 4～9 month catchment evapotranspiration amendment coefficient K_4～K_9,deep level evapotranspiration coefficient *c*, the capacity of impound in superstratum, substrate and bottom: *WUM*、*WLM*、*WDM*, water-proof area ratio whole catchment area: *IMP*, free water impound capacity curve index *EX*, soil flux day efflux coefficient *KSS*, underground flux day efflux coefficient *KG*; the parameters of catchment conflux are 5 entries, soil flux day subsidise coefficient *KKSS*, underground flux day subsidise coefficient *KKG*, standardization linearity reservoir store discharge coefficient of instantaneous unit line K_{10}, linearity reservoir entries *n* and total inflow intensity influence index *a*; riverway conflux calculated parameters are 2 entries: whole river reach conflux time parameter *KM*, whole river flux proportion factor *XM*, they only exist in Guan Yinsi interval catchment.

Adopt promissory qualification Rosenbrock method confirms model parameters, its promissory qualification is specified according to real physical meaning and experience. Because receding water curve of the catchment is distributing wider curve cluster, if receding water flux bigger, differ each other, it will make calculated runoff depth occur quite error if only calculated runoff depth adopted one standard receding water curve as every field flood receding water process. Especially in Ji Gongjian reservoir, even difficult to paint standard receding water curve, not mention basically accurate calculating every field flood runoff depth. So adopt every field runoff depth confirm yield and conflux parameters, besides Da Gutai and CangPing subarea can proceed, but Guan Yinsi and Zhanghe reservoir for calculated error problem, especially in receding water curve tail, can not adopt field flood runoff depth specify yield flux parameters. Aiming at this situation, we simultaneity adopt two ways specify yield and conflux parameters in Da Gutai and CangPing subarea which have actual measurement rain and flux date: one is traditional method, first adopt field runoff depth confirm yield flux parameters, then specify conflux parameters by yield flux calculation and flux process; the other is yield and conflux parameters together, they are specified by actual measurement rain and flux of calculated reservoir flood. Namely making sum of squares of deviations between imitated reservoir flood and actual measurement or calculated error minimum (namely certainty coefficient maximum), simultaneous considering imitated flood peak flux percent of pass maximum, flood peak present time percent of pass maximum. According to this way, specify four subarea yield and conflux parameters, utilize these projects imitate Da Gutai, CangPing, Guan Yinsi reservoir and Ji Gongjian reservoir actual flood, their certainty coefficient of flood process, flood peak percent of pass, flood peak present time percent of pass show as table 1.

Table 1 Yield and conflux forecast project assessment table

subarea \ index		certainty coefficient of flood process（%）	flood peak percent of pass（%）	flood peak present time percent of pass（%）
Da Gutai		85.3	84.21	84.21
Cang Ping	Big flood	81.1	100	100
	Ordinary flood	75.22	62.5	100
	small flood	83	62.5	62.5
	All field average	80	75	87.5
Guan Yinsi reservoir		81.13	33.3	83.3
Zhanghe reservoir		80.12	83.33	83.33

Table 1 shows, for Da Gutai and Cang Ping station which have actual measurement flood data, the result is well; for Zhanghe reservoir, mainly because of calculated reservoir flood error problem, the result is a little difference; for Guan Yinsi reservoir not only calculated reservoir flood error, but also the influence of transmitting water by open channel calculated inaccuracy, so the result of forecast is difference. But saying totally, the project is basically feasible, it is necessary to discuss and establish forecast error real-time adjustment model which adapts Zhanghe reservoir and Guan Yinsi reservoir flood forecast project, to further advance two reservoir flood forecast accuracy.

4 The compare and choice of Zhanghe reservoir flood forecast real-time adjustment way

4.1 Correlation adjustment way

Aiming at the problem of calculated Zhanghe reservoir flood error, adopt correlation analysis way, establish correlation connection direct utilizing model forecast flux and calculated reservoir flood, use least square technique confirming model parameters,establish correction model of flood forecast, consequently curtailment system forecast error of model, enhances flood forecast precision.

4.2 Residual error autoregression real-time adjustment

Utilizing residual list {*dQ(j),j=1,...,t*} which is catchment yield and conflux forecasting model forecast flux list $\{Q_m(j),j=1,...,t\}$ minus real-time observation flux list $\{Q_r(j),j=1,...,t\}$, establish residual forecast model, then plus forecast residual error {*dQ(j),j=t+1,...*} to forecast flux $\{Q_m(j),j=t+1,...\}$,accomplishes catchment flood forecast adjustment. Thereby increases flood forecast accuracy. This text mainly considers first-order and second-order circumstances.

4.3 Self adapting real-time adjustment

Self adapting real-time adjustment introduces variable oblivion factor least square arithmetic into real-time forecast, and adopts discount factor, the way adding inter-scorers reliability to differ time date,improves variable oblivion factor least square arithmetic. It can stronger real-time follow hydrology system,could adaptive adjust its oblivion factor according to the real flood of each field, achieving the effect of optimally tracing parameters, effective advances flood forecast accuracy. This text mainly considers first-order and second-order adaptive real-time adjustment models.

First-order adaptive real-time adjustment model structure form:

$$Q_f(t+1) = Q_m(t+1) + a_0(t) + a_1(t)dQ(t) \quad (4\text{-}1)$$

Recursive algorithm：

forecast： $$Q_f(t+1) = Q_m(t+1) + X(t+1)\theta(t) \quad (4\text{-}2a)$$

parameter estimate： $$\hat{\theta}(t)= \hat{\theta}(t-1)+G(t)((Q_r(t)-Q_m(t))-X(t)\hat{\theta}(t-1)) \quad (4\text{-}2b)$$

gain factor： $$G(t) = \frac{P(t-1)X^T(t)}{\lambda(t) + X(t)P(t-1)X^T(t)} \quad (4\text{-}2c)$$

covariance array： $$P(t) = (I - G(t)X(t))P(t-1)/\lambda(t) \quad (4\text{-}2d)$$

variable oblivion factor： $$\lambda(t)=1-\frac{((Q_r(t)-Q_m(t)) - X(t)\hat{\theta}(t-1))^2}{(1+X(t)P(t)X^T(t))R} \quad (4\text{-}2e)$$

In above expression:

$$X(t+1) = (1, dQ(t)) \quad (4\text{-}2f)$$

$$\theta(t) = (a_0(t), a_1(t))^T \quad (4\text{-}2g)$$

where $Q_f(t)$ is forecast flux list, $Q_m(t)$ is yield and conflux forecasting model forecast flux list, $Q_r(t)$ is real-time observation flux list, $a_0(t), a_1(t)$ are variable parameters , $dQ(t)$ is residual error,

$dQ(t) = Q_r(t) - Q_m(t)$.

Second-order adaptive real-time adjustment model structure form::

$$Q_f(t+1) = Q_m(t+1) + a_0(t) + a_1(t)dQ(t) + a_2(t)dQ(t-1) \quad (4\text{-}3)$$

Its forecast, parameter estimate, gain factor, covariance array, variable oblivion factor are similar with first-order adaptive real-time adjustment model, except:

$$X(t+1) = (1, dQ(t), dQ(t-1)) \quad (4\text{-}3a)$$

$$\theta(t) = (a_0(t), a_1(t), a_2(t))^T \quad (4\text{-}3b)$$

4.4 Kalman filtering real-time adjustment

Kalman filtering real-time adjustment adopts linearity recurrence arithmetic proceed real-time forecast according to the state equation and observation equation established by hydrology system.Namely filter calculated utilizes forecast date of this time and acquired observed value,then forecasts system state of next time-interval, when calculated date of next time-interval exists, once more filters and forecasts,continuously cycle proceeding.

4.5 The compare and choice of real-time adjustment method

This text adopts above methods proceed real-time adjustment to Zhanghe reservoir and Guan Yinsi reservoir [1~3, 6], the results show as table 2 and table 3.

Table 2 Zhanghe reservoir flood forecast adjust model and arithmetic results synthesis

Model method	Deterministic coefficient (%)	The qualified rate of flood peak (%)	The qualified rate of time to peak (%)
Yield and conflux forecast model	80.12	83.33	83.33
Correlation adjustment way	84.17	45.15	81.82
First-order residual error autoregression real-time adjustment	91.27	100.00	81.82
Second-order residual error autoregression real-time adjustment	90.20	90.91	81.82
First-order self adapting real-time adjustment	91.09	100.0	90.91
Second-order self adapting real-time adjustment	90.18	81.82	81.82
Kalman filtering real-time adjustment	88.14	100	90.91

Table 3 Guan Yinsi reservoir flood forecast adjust model and arithmetic results synthesis

Model method	Deterministic coefficient (%)	The qualified rate of flood peak (%)	The qualified rate of time to peak (%)
Yield and conflux forecast model	81.13	33.3	83.3
Correlation adjustment way	79.79	27.27	81.82
First-order residual error autoregression real-time adjustment	91.66	90.91	100
Second-order residual error autoregression real-time adjustment	89.20	81.82	90.9
First-order self adapting real-time adjustment	90.63	100.0	100
Second-order self adapting real-time adjustment	90.37	100	100
Kalman filtering real-time adjustment	88.58	100	100

We can see from the tables, the effect of first-order self adapting real-time adjustment model is best, for Zhanghe reservoir, deterministic coefficient 91.09%, the qualified rate of flood 100%, the qualified rate of time to peak 90.91% after real-time adjustment of yield and conflux project forecast value; for Guan Yinsi reservoir, deterministic coefficient 90.63%, the qualified rate of flood 100%, the qualified rate of time to peak 100%, all reach first-rate level. So in this flood forecast adopts first-order self adapting real-time adjustment.

5. Epilogue

Zhanghe reservoir is connectivity by Guan Yinsi reservoir and Ji Gongjian reservoir, the characteristics of two reservoirs are great disparity, and inflow each other, these make many flood forecast projects established in the past did not come to applied level. We creativity design double mutual inflow reservoir flood forecast project based on analyzing error characteristics of double reservoir flood, it effectively avoids the calculating error problem of Ji Gongjian reservoir flood. And aiming at the problem of calculated reservoir flood in receding water curve has prodigious error, especially in tail of receding water curve, difficult painting standard receding water curve, put forward yield and conflux parameters together, they are specified direct by adopting actual measurement rainfall and actual measurement flood(or calculated reservoir flood)process. On the basis of yield and conflux model, optimize real-time adjustment model, it makes reservoir flood forecast project attain first-rate. But for the reason of date restriction etc, some problems, such as open channel flux calculation of connection two reservoirs, calculated reservoir flood error influenced by plus-minus flux backwater storage, are necessarily further verified and researched.

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