Establishment of Low Water Runoff Forecast Model in Yichun River Basin by Multiple Linear Regression Method

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Abstract: In this paper, the dry season runoff forecast equation model of the Yichun River Basin is established. Based on the analysis and study of the basin climate, meteorological characteristics, and dry season runoff inflow rules, the multiple linear regression method is used to screen the runoff forecast factors of the Yichun River basin during dry season. Measured hydrological sequence data. The model was tested using the measured data, and its prediction was very accurate. It can provide a reference for related dry river runoff forecast schemes of similar rivers.

1. Introduction
The transformation of three water resources has a profound impact on the surface runoff flow and the balance of water supply and demand in the basin. Due to the impact of human development and global climate change on the transformation of three water resources, the balance of water resources in Yichun River Basin has been broken in recent years, with the equivalent value of surface runoff to the record in dry year. As Yichun River is the main source of water for people's daily life and production in Yichun, there is the incalculable negative impact of the sharp decrease in its surface runoff on local social development and economic activities. In order to deal with this problem, it is necessary to clarify the balance of water resources in the region and the current annual distribution of runoff. So Runoff forecast in dry season is one of the prerequisites for mastering the current situation of Yichun River water resources balance, and is also the data basis for water resources allocation, unified management and water-saving policy formulation in the basin[1,2].

2. Basin Overview
Yichun River is the first tributary on the right bank of Tangwang River. The basin covers an area of 2,472 km² and has a fan-shaped shape. It is a typical mountain stream river. The total length is 89 km, with an average gradient of 2.90‰ and a drop of 371 m. The basin is located in the middle reaches of
Tangwang River and flows through Cuiluan District, Uma River District and Yichun District of Yichun. The landform of the basin belongs to the Xiao Xing’an Mountains and is rich in groundwater[3,4]. Due to its location in seasonal frozen soil area, its surface runoff is affected by supply of precipitation, but also by snowmelt in spring.

The basin, at the southern foot of the Xiao Xingan Mountains, is located in the continental monsoon climate region of the cold temperate zone. It is major climate type is Slope climate, with the typical characteristics of monsoon climate such as the large differences between wintertime and summertime temperatures and distinct seasons. The annual average temperature in the basin is 1.0℃, the lowest temperature of -43.1℃ in January and the highest temperature of 36.3℃ in July [5]. The basin belongs to a semi-humid area, with an average precipitation of 610.2 mm. The annual distribution of precipitation conforms to the law of monsoon climate. During the flood season from June to September, precipitation accounted for 77.2% of the annual precipitation. The average annual runoff is about 754 million m3. The average duration of freezing is 158 days, frozen usually in mid-November, and thawed in early April, the maximum ice thickness 0.8 ~ 1.50 m, and the maximum snow depth on the ice 0.1 ~ 0.20 m.

The main tributaries on the left bank of Yichun River Basin are Cuiluan River and Dangshi River, while the main tributaries on the right bank are Fuyu River, Yao River and Uma River. Although these tributaries are distributed around, their geographical location and their geological and geomorphological features, including meteorology and runoff recharge conditions, are quite similar.

3. Basic Characteristics of Runoff in Dry Season in Yichun River Basin

Among the meteorological factors, the main factors that affect the precipitation in inland basins are topography and monsoon belt. The Yichun River Basin is basically of a sloping land climate with similar topography and even distribution. Therefore, the precipitation in the basin is mainly affected by seasons, that is to say the amount of river runoff in the basin mainly varies with seasons. Each year, precipitation recharge in flood season is the main source of runoff, and the dry season is the season with less rainfall when the main sources of runoff supply in the basin are the storage water from the basin and the snowmelt runoff in spring, both of which depend on the total amount of precipitation in that year. The multi-year distribution of water from the basin is not uniform, and during the year the distribution is also uneven, due to monsoon climate and snowmelt runoff. The annual runoff in the basin is mainly concentrated in the end of spring and the beginning of summer and the following flood season, i.e. from May to October, accounting for 65.7% ~ 93.0% of the whole year. The dry season is other months, i.e. from November to April of the following year. The low water runoff in this basin reached the lowest value in 2002-28 million m3. The maximum value was in 1957-nearly 210 million m3, with a difference of 7.5 times. That is an evidence to show the great difference in annual runoff[6].

The probability statistics of water inflow in different seasons in the basin are shown in Table 1.

| Table1  | The probability statistics of water inflow in different seasons in the basin (1957 ~ 2006) |
|---------|------------------------------------------------------------------------------------------|
| November ~ April of the following year | May ~ October                                      |
| volume of runoff /10⁶m³ | frequency | probability (%) | Time | volume of runoff /10⁶m³ | frequency | probability (%) | Time |
| >2.5 | 0 | | | >15 | 0 | | |
| 2.5~2.0 | 1 | 2 | 1950s | 15~10 | 3 | 6 | 1960s |
| 2.0~1.0 | 8 | 16 | 1970s~1980s | 10~5.0 | 26 | 52 | 1960s~1980s |
| 1.0~0.5 | 29 | 58 | Since the 1990s | 5.0~2.5 | 19 | 38 | Since the 1990s |
| <0.5 | 12 | 24 | Since the 1990s | <2.5 | 2 | 4 | Since the 1990s |
4. Introduction to Forecast Methods

Single correlation series analysis is mainly used to screen various forecasting factors. According to the climate characteristics of the basin and the water inflow law in dry season, we select the period from November to April of the following year and the factors of the flow rate, runoff depth, precipitation, ice thickness, ice snow depth, shore temperature, etc. in each month during the dry season of the basin. According to the results of series analysis, the correlation coefficient with runoff in dry season is highest in "multi-monthly average runoff depth" and "total rainfall amount". Forecast equation is established by multiple linear regression method:

\[ Rt+j = a \times R_j + b \times P_j + C \]  

Where: \( Rt+j \) is the predicted runoff depth in the future T period; \( R_j \) is the measured average runoff depth in known J period; \( P_j \) is the measured amount of rain (snow) in J period; \( a, b \) and \( c \) are coefficients, which can be obtained through planning.

5. Examples Fitting, Test Report Results and Method Test Evaluation

According to the measured data of Yichun Station of Yichun River during the dry season from 1964 to 2000, a linear correlation is established between the average runoff depth and the total rainfall value from November to March of the following year and the runoff depth in April of the following year. After that, the equation coefficients can be solved by using Excel's programming function. So, the historical fitting prediction equation is \( R = 0.24 \times R_j + 0.14 \times P_j + 8.83 \).

The equation was used to make a trial report of each year from 2001 to 2006. The results of historical fitting and trial report are shown in Table 2.

Table 2 Statistical Table of historical fitting and Trial Reporting Accuracy of Yichun River Low Water Runoff Forecast Model

| Year | November ~March of the following year Average Runoff Depth | November ~March of the following year Total precipitation | The Measured April Runoff Depth | Fitting and Forecast April Runoff Depth | Absolute error (Result) | Absolute error |
|------|----------------------------------------------------------|----------------------------------------------------------|-------------------------------|----------------------------------------|------------------------|---------------|
| 1964 | 2.90                                                     | 32.4                                                     | 11.56                         | 14.06                                  | 2.50(√)                | 3.47          |
| 1965 | 1.23                                                     | 31.4                                                     | 10.90                         | 13.52                                  | 2.62(√)                | 3.27          |
| 1966 | 1.41                                                     | 46.8                                                     | 5.54                          | 15.72                                  | 10.18(×)               | 1.66          |
| 1967 | 2.85                                                     | 32                                                       | 11.67                         | 13.99                                  | 2.33(√)                | 3.50          |
| 1968 | 1.47                                                     | 65                                                       | 15.66                         | 18.28                                  | 2.62(√)                | 4.70          |
| 1969 | 1.82                                                     | 33.3                                                     | 19.20                         | 13.93                                  | 5.27(√)                | 5.76          |
| 1970 | 2.58                                                     | 42.8                                                     | 13.35                         | 15.44                                  | 2.09(√)                | 4.00          |
| 1971 | 1.84                                                     | 57.1                                                     | 15.56                         | 17.27                                  | 1.71(√)                | 4.67          |
| 1972 | 2.87                                                     | 34.9                                                     | 19.34                         | 14.41                                  | 4.93(√)                | 5.80          |
| 1973 | 4.64                                                     | 63.7                                                     | 8.15                          | 18.86                                  | 10.71(×)               | 2.44          |
| 1974 | 1.56                                                     | 39.9                                                     | 34.16                         | 14.79                                  | 19.37(×)               | 10.25         |
| 1975 | 2.06                                                     | 42.4                                                     | 11.93                         | 15.26                                  | 3.33(√)                | 3.58          |
| 1976 | 1.12                                                     | 39                                                       | 19.50                         | 14.56                                  | 4.94(√)                | 5.85          |
| 1977 | 0.32                                                     | 50                                                       | 17.76                         | 15.91                                  | 1.86(√)                | 5.33          |
| 1978 | 0.86                                                     | 40.4                                                     | 12.10                         | 14.69                                  | 2.59(√)                | 3.63          |
| 1979 | 1.11                                                     | 71.3                                                     | 10.13                         | 19.08                                  | 8.95(×)                | 3.04          |
| 1980 | 1.09                                                     | 44                                                       | 16.29                         | 15.25                                  | 1.04(√)                | 4.89          |
| 1981 | 2.21                                                     | 30.8                                                     | 11.30                         | 13.67                                  | 2.37(√)                | 3.39          |
| 1982 | 3.35                                                     | 39.6                                                     | 18.60                         | 15.18                                  | 3.43(√)                | 5.58          |
| 1983 | 2.10                                                     | 39.9                                                     | 20.08                         | 14.92                                  | 5.16(√)                | 6.02          |
According to the climatic and meteorological characteristics of Yichun River Basin and the runoff inflow law in dry season, the forecast method of monthly runoff in dry season has been preliminarily

| Year | Se   | Sd   | Sr   | St   | dY   |
|------|------|------|------|------|------|
| 1984 | 1.82 | 51.6 | 33.00| 16.49| 16.51| 9.90 |
| 1985 | 2.63 | 56   | 24.01| 17.30| 6.71| 7.20 |
| 1986 | 5.26 | 47.5 | 16.82| 16.74| 0.07| 5.05 |
| 1987 | 1.38 | 55.8 | 9.10 | 16.97| 7.87| 2.73 |
| 1988 | 5.83 | 78.2 | 17.20| 21.18| 3.98| 5.16 |
| 1989 | 3.56 | 50   | 43.31| 16.68| 26.62| 12.99|
| 1990 | 1.22 | 50.5 | 9.05 | 16.19| 7.14| 2.71 |
| 1991 | 3.21 | 19.3 | 6.67 | 12.30| 5.63| 2.00 |
| 1992 | 3.85 | 29.5 | 8.39 | 13.88| 5.50| 2.52 |
| 1993 | 2.32 | 39.5 | 7.06 | 14.92| 7.85| 2.12 |
| 1994 | 4.16 | 43.5 | 6.12 | 15.92| 9.80| 1.84 |
| 1995 | 3.74 | 55.1 | 24.70| 17.44| 7.26| 7.41 |
| 1996 | 2.58 | 31.4 | 17.03| 13.85| 3.18| 5.11 |
| 1997 | 1.53 | 62.8 | 7.89 | 17.99| 10.10| 2.37 |
| 1998 | 3.20 | 31.9 | 12.61| 14.06| 1.45| 3.78 |
| 1999 | 3.14 | 42.9 | 18.08| 15.59| 2.49| 5.42 |
| 2000 | 0.95 | 42.5 | 11.79| 15.01| 3.22| 3.54 |
| 2001 | 2.00 | 47.3 | 16.71| 15.93| 0.78| 5.01 |
| 2002 | 0.84 | 28.7 | 17.55| 13.05| 4.50| 5.27 |
| 2003 | 1.12 | 37.3 | 6.15 | 14.32| 8.17| 1.84 |
| 2004 | 3.88 | 70.6 | 16.82| 19.64| 2.83| 5.05 |
| 2005 | 2.62 | 67.7 | 14.80| 18.94| 4.14| 4.44 |
| 2006 | 2.60 | 83.5 | 37.73| 21.14| 16.59| 11.32|

As there is no unified evaluation standard for medium and long-term forecast accuracy, we generally make evaluation according to the qualification standard less than 30% of the measured value. As can be seen from Table 2, of the 43 data points, 28 are qualified, with a qualified rate of 65.1%. Evaluation of the effectiveness of hydrological forecasting schemes based on watershed models can also be carried out by using the certainty coefficient dY.

\[
d_r = 1 - \frac{S_e^2}{\sigma_Y^2}
\]

\[
S_e = \sqrt{\frac{\sum (Y_i - \bar{Y})^2}{n}}
\]

\[
\sigma_Y = \sqrt{\frac{\sum (Y_i - \bar{Y})^2}{n}}
\]

Where: Se is the mean square deviation of prediction error; \(\sigma_Y\) is the mean square deviation of forecast element values; Yi is the instance value; \(\bar{Y}\) is the predicted value; \(\bar{Y}\) is the average of the measured values; N is the point data. According to the above formula, the certainty coefficient dY=0.83 is calculated, reaching the standard of second-class forecast scheme.

6. Conclusion

According to the climatic and meteorological characteristics of Yichun River Basin and the runoff inflow law in dry season, the forecast method of monthly runoff in dry season has been preliminarily
analyzed. And the forecast model has been established by screening the forecasting factors of Yichun River Basin runoff in dry season with the multiple linear regression method. In the process of the trial reporting, we have got rather good effect of historical fitting and trial reporting. At the same time, due to the limited conditions, we simplified the topographic and geological factors. If those elements are added to the model, the accuracy should be further improved.

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