Quantifying Analysis of Hydrological Conditions Dynamic Alteration and its Multiple Influencing Factors

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Abstract. Hydrological condition is of great significance to river ecosystems. Alteration in hydrological conditions can directly or indirectly affect ecosystems, causing changes in river ecological health, species habitats, and water-sand relationships. In this paper, the Index of Hydrologic Alteration-Range of Variability Approach method (IHA-RVA) method was used to evaluate the alteration of hydrological condition in Yuanshui river from 1959 to 2010 under the combined action of climate change and human activities. We have reached the conclusion that the current hydrological condition alteration in the Yuanshui River Basin is moderately changing; Regardless of the water diversion, the contribution rates of natural runoff changes and cascade reservoir operations to hydrological change is 58% and 42% respectively, which were quantified by the multi-series contribution rate segmentation method. It can be seen that the natural runoff change was the leading cause of the change of the overall hydrological situation, and the operation of the cascade reservoir was an important cause of the hydrological situation change.

Keywords: Yuanshui River; IHA-RVA method; hydrological conditions; hydrological change.

1. Introduction
Hydrological condition is one of the key factors affecting the structure and function of river ecosystems, which is mainly reflected in the determination of species composition, community structure and ecological function of river ecosystems [1,2]. Alteration in hydrological conditions can directly affect or indirectly affect river ecosystems by changing habitats. The direct effect refers to the dramatic changes in the quantity and composition of vegetation and animals caused by changes in hydrological factors (water level, flow rate, water temperature and sediment concentration) in a short period of time, while the indirect effect is the alteration of habitat conditions caused by the continuous action of hydrological elements over a period of time, thus affecting the distribution and abundance of species, and then affecting the composition and diversity of biomes[3].

Summarizing the research results of many scholars, the impact of hydrological conditions alteration on river ecosystems is mainly reflected in several aspects:(i) River Ecological Health. For example, Maingi et al. [4] pointed out that dam construction increases the minimum flow of the Tanner River while reducing the peak flow and threatening the growth process of riparian forest vegetation according to the results of the analysis of Indicators of hydrologic alteration (IHA); In the investigation of the relationship between flow change and ecological response, Poff et al. [5,6] pointed out that large-scale water abstraction and reservoir runoff regulation make the river ecological flow not guaranteed, which seriously affects river health; Wallin et al. [7] and Townsend et al. [8] believe that although the organisms in rivers generally have life history characteristics to adapt to a range of environmental variability, the dependence on hydrological alteration must be maintained within the range of variation.
Beyond this natural variation, the survival potential of natural species will be affected, and even species extinction will occur; In addition, Some [9-12] also did a lot of researches from the interaction of hydrological dynamics-salt change-vegetation response on the influence of hydrological condition on wetland plant growth mechanism and vegetation spatial pattern distribution. (i) Species Habitats. Such as Shieh [13] assessed the impact of dam construction on runoff and habitat conditions by IHA and indicator of habitat alteration (IHabA), and found that the degree of environmental change was higher near the dam body; Increasing the frequency or duration of high flow rates may destroy the habitats of speed-sensitive organisms such as phytoplankton, large invertebrates, juveniles and deposited eggs. Long periods of low flow can dehydrate the vegetation and cause riparian plants to be replaced by more drought tolerant species, but for species with a broader and specialized foraging strategy, more frequent flow alteration are more conducive to establishing species advantages [14,15]; Some scholars [16,17] respectively evaluated the effects of hydrological condition alteration caused by Danjiangkou Reservoir and the Three Gorges Reservoir on the downstream fish habitats; Guo et al. [18] analyzed the distribution of phytoplankton in the upper reaches of the Wujiang River Basin, and found that the hydrological condition caused by the operation of the cascade reservoirs had a significant impact on the changes in the number of phytoplankton. (ii) The Change of Water-Sand Relationship. In view of the large sediment concentration of Chinese rivers, Chinese scholar like Kong et al. [19] in the study of the distribution characteristics of water and sediment in the sandy rivers during the year, pointed out that the reservoir construction reduces the proportion of runoff and sediment transport in the flood season to the total amount of the whole year, but rises during the dry season; Xu [20] analyzed the influence of natural and human factors on the sediment transport law in the upper reaches of the Yellow River. It is believed that the operation of the reservoir in the upper reaches of the Yellow River and the drainage of water from the irrigation water largely changed the water-sand combination relationship; Yao et al. [21] analyzed the regulation effect of reservoir operation on runoff and sedimentation process and its impact, and revealed the regulation mechanism of reservoir water and sediment relationship in downstream rivers; Peng et al. [22] analyzed the internal correlation of water and sediment changes and revealed that the reduction of high-flow events is an important cause of sedimentation in the upper reaches of the Yellow River.

Correspondingly, the factors that cause alteration in hydrological conditions can be divided into two categories: climate change and human activities [23-27]. The climatic factors affecting the hydrological process are precipitation and temperature, and the precipitation can directly lead to changes in the flow and production of the basin, while the change in temperature can affect the runoff through evaporation. Human activities mainly include reservoir operation, zone water diversion and land use. Their influence on hydrological process is reflected in the disturbance of natural flow regime of the river the underlying surface conditions of the river basin.

Through the analysis of the ecological flow guarantee situation and economic and social impacts of the four major river systems of Dongting Lake, Xiang, Zi, Yuan and Li [28-30]. Selecting the Yuanshui river basin as the research object, this paper uses the IHA-RVA method to assess the change of hydrological condition under the combined action of climate change and human activities. In view of the current situation of hydrologic condition change in the basin, the influencing factors are systematically analyzed, and the contribution rate of climate change and human activities is quantified by the multi-series contribution rate segmentation method [22]. Among them, climate alteration changes the hydrological condition of the Yuanshui river by natural runoff changes, while human activities mainly consider the Watershed diversion and cascade reservoir operations. In order to provide a scientific basis for understanding the extent of the impact of water conservancy construction on the ecological environment of the Yuanshui River Basin, determining the ecological goals of the basin and the sustainable development of the social economy. It also provides a theoretical basis for river health diagnosis and ecological restoration in the Yuanshui River Basin, and provides an empirical reference for nature-based river management.
2. Materials and Methods

2.1. Study Area
Yuanshui River originates from the southeastern part of Guizhou Province and belongs to the second largest water system in the four waters of Dongting Lake, which refers to Xiang, Zi, Yuan and Li. It is also the river with the most abundant water resources and the largest water flow in the four waters. The area of the Yuanshui River Basin is 9×10^4 km^2, and the total length of the main stream is 1050 km, and total drop is 1035 m. The annual runoff of the Yuanshui River is 65.9 billion m^3, but the distribution is extremely uneven during the year. The main flood season accounts for 50% from May to July, but the special dry season is only 8.86% in January, February and December [31].

![Figure 1. The diagram of Yuanshui River basin.](image)

The Yuanshui River is rich in water energy and it is one of the twelve hydropower bases in China with a development capacity of 7.35 million kw. In December 2016, the last backbone hydropower station, the Tuokou Hydropower Station, was filled to the normal water level, marking the official completion of the cascade development of the Yuanshui River Basin since 1994. At present, in addition to the construction of Sanbanxi, Baishi, Tuokou, Hongjiang, Bowlipo, Wuqiangxi and other cascade backbone hydropower stations, in order to meet the water demand of irrigation areas in the basin, a large number of water diversion projects have been built. The cascade reservoirs built on the water can realize the joint optimization operation of cascade hydropower and give full play to the economic and social benefits of the cascade reservoirs with its excellent adjustment ability. At the same time, the operation of cascade reservoirs, coupled with changes in natural runoff, has changed the hydrological condition of the river to a certain extent, which has a great impact on the structure and function of the river ecosystem.

2.2. Methods

2.2.1. Assessment of alteration in hydrological conditions. The hydrologic condition change slack of water is quantified by the mean value of the IHA indicator. The IHA index system is used to describe the characteristics of the five basic components of the hydrological condition (flow, frequency, timing, duration and rate of change). The connotation and ecological effects of the 32 evaluation indicators of the 5 groups of elements are shown in Table 1 [32].

The hydrological change degree was evaluated by the RVA method proposed by Richter et al. [33]. Its definition formula is as follows:

\[
D_i = \frac{N_i - N_e}{N_e} \times 100\% \tag{1}
\]

Where \( N_i = rN_T \), \( D_i \) is the hydrological change degree of the IHA(\( i=1-32 \)); \( N_i \) is the number of observation years of the IHA falling within the RVA target range after being affected; \( N_e \) is the number of years after the affected IHA is expected to fall within the RVA target range; \( r \) is the proportion of the
IHA falling within the threshold range after being affected; $N_f$ is the total number of years after the impact.

Where $0\% < D_i < 33\%$ is a low degree change; $33\% \leq D_i < 67\%$ is a moderate change; $67\% \leq D_i \leq 100\%$ is a height change. If the river runoff characteristics have not changed, $D_i$ is 0, which is the best state. The formula for calculating the overall hydrological change of a river is:

$$D_i = \left( \frac{1}{32} \sum_{i=1}^{32} D_i^2 \right)^{\frac{1}{2}} \times 100\%$$  \hspace{1cm} (2)

**Table 1.** Composition of IHA indicator system and its ecological role.

| Indicator category | Indicator name                      | Indicator symbol | Main ecological role                                                                 |
|--------------------|------------------------------------|------------------|--------------------------------------------------------------------------------------|
| Monthly average flow | Mean value for each calendar month | F1~F12           | Provide habitat for aquatic life; Affect physical and chemical characteristics of water bodies. |
| Flow rate of extreme water conditions | Annual maxima 1-day, 3-day, 7-day, 30-day, and 90-day means | F13~F17          | Meet the nutrient exchanges between rivers and floodplains; Shape the shape of the riverbed; Meet the needs of plant community distribution. |
|                     | Annual minima 1-day, 3-day, 7-day, 30-day, and 90-day means | F18~F22          |                                                                                      |
|                     | Minimum 7-day annual average flow (base flow) | F23              |                                                                                      |
| The timing of extreme water conditions | Date of each annual 1-day maximum | F24              | Meet the needs of biological reproduction, life activities and species evolution         |
|                     | Date of each annual 1-day minimum | F25              |                                                                                      |
| Frequency and duration of high/low flow pulses | No. of high pulses each year | F26              | Trigger biological life activities Shape the natural form of the rivers; Influence the size of the riverbed material; Maintain habitat connectivity and material exchange |
|                     | No. of low pulses each year | F27              |                                                                                      |
|                     | Mean duration of high pulses within each year | F28              |                                                                                      |
|                     | Mean duration of low pulses within each year | F29              |                                                                                      |
| Flow rate change rate and frequency | Average increase rate of flow | F30              | Removal of alien species; Affect the physical and chemical characteristics of water. |
|                     | Average decrease rate of flow | F31              |                                                                                      |
|                     | No. of flow change flip | F32              |                                                                                      |

**2.2.2. Analysis of factors affecting the change of hydrological condition.** The contribution rate of the influencing factors is quantified by multi-series contribution rate segmentation method. The multi-series contribution rate segmentation method was proposed by Peng [22]. The principle of this method is to design different combinations of influence factors (independent variables), and use the differences of hydrological condition (dependent variable) reflected by the data series (runoff series) for distinguishing the impact of each influence factor on the hydrological situation.

Unlike Cumulative slope change rate comparison method and the method of segmentation contribution of regression relationship between variables, which rely on regression analysis, multi-series contribution rate segmentation does not use regression analysis. Therefore, the purpose of characterizing the hydrological condition over a long period of time with all 32 IHA indicators can be achieved, which makes up for the shortcomings of the former two methods using a single index to characterize the dependent variable in order to establish a regression equation.

In order to distinguish the contribution rate of natural runoff variation, inter-basin water transfer and cascade reservoir operation, the flow series was divided into four series: measured series, restored series, restored water diversion series and reference series. Among them, the measured series refers to the
measured daily runoff series during the evaluation period; and the restored series refers to the natural daily runoff series, which was restored calculations during the evaluation period; The restored water diversion series refers to subtracting the interval water intake from the restored series; The reference series refers to the series of daily runoffs that approximate the natural state before the reservoir is operated. The method of segmentation is as follows:

\[
V_{i,1} = \frac{F_{i,1} - F_{iA}}{F_{iA}}
\]

\[
V_{i,2} = \frac{F_{i,2} - F_{iA}}{F_{iA}}
\]

\[
V_{i,3} = \frac{F_{i,3} - F_{iA}}{F_{iA}}
\]

\[
C_n = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{V_{i,2}}{V_{i,1}} \right) \times 100\%
\]

\[
C_w = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{V_{i,3} - V_{i,2}}{V_{i,1}} \right) \times 100\%
\]

\[
C_r = 1 - C_n - C_w
\]

Where, \( F_{i,1}, F_{i,2}, F_{i,3}, \) and \( F_{iA} \) is the \( i \)th IHA index values corresponding to measured series, restored series, restored water diversion series and reference series, respectively; \( V_{i,1}, V_{i,2}, \) and \( V_{i,3} \) is the variation range of the \( i \)th IHA index value of measured series, restored series, and restored water diversion series with respect to the value of reference series; \( n \) is the number of IHA indicators; \( C_n, C_w, \) and \( C_r \) is the contribution rates of natural runoff changes, water diversion in the basin and cascade reservoir operations to IHA index values, respectively.

In order to avoid the contribution rate of the impact factor on some indicators is too large, the index is considered to be basically the same as the reference series when the absolute value of \( V_{i,1} \) does not exceed 10%, and the contribution rate of the impact factor to the indicator is not counted.

3. Results and Discussion

3.1. Results of Hydrological Change Assessment

Combined with the utilization and development of water resources in the Yuanshui River Basin, the long series (1959-2010) daily runoff data of Taoyuan Station of Yuanshui Control Station was selected, the years of the gradual intensification of human activities were regarded as time nodes, and the years (1959-1976) that were less affected by human activities were considered to be natural. According to the formula (1) and (2), the alteration in the hydrological condition of Yuanshui River under the combination of climate change and human activities in the current development conditions (1977-2010) are calculated. The calculation results are shown in Table 2.

As can be seen from Table 2, in addition to the low flow pulse duration and the daily flow change flip count reached a high degree of change, the change of other indexes is in a low or medium change. Among them, the average flow rate of the first group of elements only reached a moderate change in May, which was 39% lower than the natural state, and the monthly average flow rate in the flood season increased compared with the natural state; The flow rate of the extreme flow events in the second group of elements decreased compared with the natural state, The maximum average flow rate reached a moderate change except for the maximum 1d, and the minimum average flow rate was low change, but the decrease was more than 20%, The base flow ratio decreased by 65% from the natural state to a moderate change. The occurrence time of the extreme flow events in the third group of elements is delayed from the natural state, and the increase rate is more than 26%. In the fourth group of elements, the number of occurrences of high/low flow pulses and their durations are abnormally different from those of the natural state, the number of high-flow pulses is reduced by 47% with its pulse duration is also reduced by 67%, The number of low-flow pulses is reduced by 27% while the pulse duration is also reduced by 58%. In the fifth group of elements, the average rate of decline of the daily flow of the natural state is much larger than the average rate of increase of the daily flow, the former has a moderate change of 47%, while the latter has a low of 9%. The former fell by 47%, which was a moderate change,
while the latter fell by 9%, which was a low change, and the number of flips of daily flow changes decreased by 96%.

**Table 2.** Alteration in the hydrological condition of Yuanshui River in the current development conditions.

| Indicator category | Indicator symbol | Natural state (1959-1976) | Current development conditions (1977-2010) |
|--------------------|----------------|----------------------------|------------------------------------------|
|                    |                | Mean value | Lower threshold of RVA | Upper threshold of RVA | Mean value | D(%) | Change degree |
| Monthly average flow(m^3/s) |                   |            |                         |                      |            |      |               |
| F1                 |                | 514        | 303                     | 724                  | 718        | -7   | Low            |
| F2                 |                | 799        | 434                     | 1164                 | 911        | -14  | Low            |
| F3                 |                | 1153       | 571                     | 1735                 | 1318       | -9   | Low            |
| F4                 |                | 2464       | 1336                    | 3591                 | 2117       | 6    | Low            |
| F5                 |                | 4182       | 2706                    | 5657                 | 2929       | -39  | Moderate       |
| F6                 |                | 3321       | 2083                    | 4559                 | 3799       | 10   | Low            |
| F7                 |                | 2508       | 398                     | 4619                 | 2881       | 9    | Low            |
| F8                 |                | 1381       | 585                     | 2177                 | 1738       | 10   | Low            |
| F9                 |                | 976        | 359                     | 1592                 | 1291       | 15   | Low            |
| F10                |                | 859        | 391                     | 1327                 | 1027       | -2   | Low            |
| F11                |                | 1209       | 468                     | 1949                 | 979        | 10   | Low            |
| F12                |                | 647        | 359                     | 935                  | 679        | 25   | Low            |
| Flow of extreme traffic events(m^3/s) |                   |            |                         |                      |            |      |               |
| F13                |                | 16192      | 11863                   | 20520                | 15932      | -18  | Low            |
| F14                |                | 13281      | 10246                   | 16317                | 13895      | -43  | Moderate       |
| F15                |                | 10246      | 8151                    | 12341                | 10740      | -47  | Moderate       |
| F16                |                | 6415       | 5135                    | 7696                 | 6335       | -43  | Moderate       |
| F17                |                | 4622       | 3817                    | 5427                 | 4287       | -42  | Moderate       |
| F18                |                | 288        | 209                     | 366                  | 311        | -25  | Low            |
| F19                |                | 295        | 226                     | 363                  | 345        | -21  | Low            |
| F20                |                | 319        | 245                     | 393                  | 369        | -21  | Low            |
| F21                |                | 368        | 284                     | 453                  | 458        | -31  | Low            |
| F22                |                | 699        | 521                     | 876                  | 725        | -23  | Low            |
| F23                |                | 0.16       | 0.13                     | 0.18                 | 0.19       | -65  | Moderate       |
| The Timing of extreme flow events |                   |            |                         |                      |            |      |               |
| F24                |                | 161        | 131                     | 190                  | 182        | 26   | Low            |
| F25                |                | 198        | 53                      | 344                  | 205        | 29   | Low            |
| High/low flow pulse frequency(%) , duration(d) |                   |            |                         |                      |            |      |               |
| F26                |                | 11         | 8                      | 13                   | 10         | -47  | Moderate       |
| F27                |                | 5          | 3                      | 8                    | 9          | -27  | Low            |
| F28                |                | 5          | 4                      | 7                    | 6          | -67  | High           |
| F29                |                | 12         | 5                      | 19                   | 8          | -58  | Moderate       |
| Flow rate change rate and frequency(%) |                   |            |                         |                      |            |      |               |
| F30                |                | 208        | 123                     | 294                  | 122        | -9   | Low            |
| F31                |                | -91        | -118                    | -65                  | -114       | -47  | Moderate       |
| F32                |                | 83         | 77                      | 90                   | 144        | -96  | High           |
| Whole watershed |                |            |                         |                      | 36         | Moderate |
At present, the overall hydrological condition in the Yuanshui River Basin is moderately changing. The reason for the analysis is that the Yuanshui River Basin covers a large area with rich water resources and lots of tributaries, even though Climate change and human activities have caused certain alteration in the hydrological conditions such as the flow rate, water level and flow regime of Yuanshui River. Considering that the current cascade development in the Yuanshui River Basin is still in the initial stage, these changes have not exceeded the load capacity of the basin. And the basin power generation, water supply, irrigation and shipping planning mainly concentrated in the main stream, many tributaries of the water can provide a large number of water sources. Therefore, the result of the moderate change in the hydrological condition of Yuanshui River is considered to be in line with the actual situation. Although the overall hydrological condition in the Yuanshui River Basin is moderately changing, the individual indicators have changed greatly to a high degree. Therefore, it is necessary to explore the causes of these changes and to strengthen the controllability of the influencing factors. This can also raise issues that need to be paid attention to and considered for the further development of water resources management in the Yuanshui River Basin.

3.2. Analysis of Factors Affecting the Alteration of Hydrological Condition

The Yuanshui River Basin covers a wide area, and owns abundant water volume and large number of tributaries. The interval water diversion does not have a significant impact on the river hydrological situation, and the water reduction in the basin accounts for a relatively small amount, the accuracy of the reduced water has little effect on the natural runoff of the river [34]. Coupled with the lack of the watershed water diversion data, so the analysis of the influencing factors of the hydrological condition change does not make special consideration for the interval water diversion. It Means that the daily runoff series, which is almost unaffected by human activities and approximates the natural state year (1959-1976), serves as the reference series; The daily runoff series, which was affected by human activities before the river basin cascade development (1977-1995), were used as a restored series. Evaluating the contribution rate of natural runoff changes and cascade reservoir operations in the hydrological condition change after the river basin cascade development (1996-2010). Under the current conditions of development and utilization, the average value of the IHA index values of the restored series and the measured series relative to the reference series is shown in Fig. 2.

![Figure 2. The magnitude of the change in the IHA indicator value of the restored series and the measured series relative to the reference series.](image-url)

According to the calculation result of the monthly average flow rate indicator (Fig. 2(a)), compared to the reference series, The average monthly flow of the measured and restored series of the Yuanshui
Taoyuan hydrological station increased from June to October and January, February, but the monthly average flow decreased in April, May and November; Except for the flood season, the variation range of the measured series is significantly larger than that of the restored series, and the maximum variation range reached 64% in January; The average monthly flow of the restored series in March and December barely changed, while the measured series increased by 35% and 13% respectively.

According to the calculation results of the extreme flow events, duration and occurrence timing indicator (Fig. 2(b)), except for the maximum flow of the maximum 1, 30 and 90d, which has a small decrease (less than 8%), Other indicators have increased, with an increase of between 1 and 24%; Among them, the base flow of the restored series and the measured series increased, the increase rate exceeded 20%, and the average flow occurrence time of the maximum 1d and the minimum 1d was delayed, but the former changed greatly.

According to the calculation results of high/low flow pulse and flow change index (Fig. 2(c)), the number of high flow pulse occurrences decreases by 9% and 14%, but the average duration of single pulse increases by 34% and 3%; The number of low-flow pulses increased by 6% and 123%, respectively, and the increase under the measured series was significantly greater than that of the restored series. The average duration of the single pulse decreased by more than 22%. The average daily rate of increase of the daily flow of the hydrological station decreased by more than 37%, and the average rate of decline of the daily flow of the restored series remained basically unchanged, while the measured series increased by 55%; Both the restored series and the measured series have a significant increase in the number of daily flow changes, and the increase in the measured series has reached 112%. The restored series that were less affected by human activities before the development of the river basin cascades and the actual series after the development of the river basin cascades have different effects on the hydrological condition alteration in the Yuanshui River Basin. In both cases, the mean value of the IHA indicator is basically the same as the average of the IHA indicator in the natural state, but the variation range between the indicators is different. The monthly average flow rate changes have obvious seasonal differences, and the magnitude of the change is also large; The flow rate, duration and timing of extreme traffic events are not more than 33%; The variation range of high/low flow pulse and flow change index is very different, and the effect of the measured series on the low flow and daily flow changes is more obvious. Analysis of the reasons, with the cascade development of the Yuanshui River Basin, a large number of reservoirs were built, which can block part of the flood during the flood season and supply water to the downstream river during the dry period, which enhances the river's storage capacity. In addition, the average annual precipitation in the basin has shown a downward trend, which is also an important reason for the above changes in the hydrological situation.

Therefore, the daily runoff series that does not consider the diversion of water is used to segment the contribution of natural runoff changes and cascade reservoir operations to the overall hydrological condition and the eight key hydrological characteristics of the Taoyuan Station. The results are shown in Table 3.

Table 3. Contribution rate of natural runoff change and reservoir operation to hydrological condition change at Taoyuan hydrological station.

| Split object | 1996-2010 |
|--------------|----------|
|               | Natural runoff variation (%) | Cascade reservoir operation (%) |
| Overall hydrological condition (All IHA indicators) | 58 | 42 |
| Monthly average flow value in non-flood season | 50 | 50 |
| Monthly average flow value in flood season | 52 | 48 |
| Average flow value for extreme high flow events | 3 | 97 |
| Average flow value for extreme low flow events | 55 | 45 |
| No. of high pulses each year | 63 | 37 |
| No. of low pulses each year | 5 | 95 |
| Mean duration of high pulses within each year | * | * |
| Mean duration of low pulses within each year | 58 | 42 |
The contribution rates of natural runoff changes and cascade reservoir operations to the change of hydrological condition in the Yuanshui River are 58% and 42%, respectively. Natural runoff changes are the leading cause of the overall hydrological change. The contribution rate of the two influencing factors to the alteration of key hydrological characteristics shows that natural runoff changes and cascade reservoir operations have positive contributions to alteration in hydrological characteristics. Among them, the average flow rate of low-flow events and the number of low-flow pulse occurrences are mainly affected by the operation of cascade reservoirs; Alteration in other key hydrological characteristics are mainly affected by changes in natural runoff, except for changes in monthly mean flow during the non-flood period, which are affected by both. The absolute value of mean duration of high pulses within each year does not exceed 10%, so it was not reflected in the table.

4. Conclusion
In this paper, the hydrological condition of the Yuanshui River basin which is greatly affected by climate change, was selected to evaluate the hydrological condition after the reservoir cascade development in the basin by the IHA-RVA method. The contribution rate of natural runoff variation and cascade reservoir operation to hydrological condition change is quantified through the multi-series contribution segmentation method, and the following conclusions are obtained:

At present, the overall hydrological condition in the Yuanshui River Basin is moderately changing. The contribution rate segmentation results reveal that the natural runoff change is the main cause of the hydrological condition change, and its contribution rate to the hydrological condition change is 58%. The operation of the cascade reservoir is an important cause of the hydrological condition change, its contribution rate is 42%. It is of great significance to quantify the contribution rate of the main factors to the hydrological condition change in the future. In addition, using the daily runoff series that does not consider the water diversion to assess the hydrological condition change, It can provide feasible ideas for the assessment of the river hydrological condition affected by human activities in the southern water-rich area, which is difficult to obtain interval water transfer and water diversion data, and the restored water quality of the basin is relatively small, and the accuracy of the restored water quantity has little effect on the natural runoff of the river.

However, it is worth noting that under the current conditions of development, the hydrological condition change of the Yuanshui river is still controllable due to a large area with rich water resources and lots of tributaries, and the incomplete development of the basin. With the intensification of water conservancy project construction and water resources development, and the difficulty in changing the process of climate change in a short period of time, the degree of change will show an increasing trend, which puts higher requirements on strengthening river protection in water resources development. In the future development and utilization of water resources, it is necessary to scientifically plan the construction of water conservancy projects, strengthen the ecological dispatch of reservoirs, and ensure the ecological health of rivers. In addition, because the basic data is difficult to obtain, the basic data of research in this paper is as of 2010. The development of the Yuanshui River Basin has continued in the past 10 years, which would inevitably increase the contribution rate of the cascade reservoir operation to the river hydrological situation change.

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