Preliminary study on runoff analysis of karst landforms in Yunnan Province

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Abstract: Runoff calculation in non-closed watersheds with no data area is a common problem encountered in the construction of water conservancy projects in our province. Judging from non-closed watersheds to runoff and flood analysis in non-closed watersheds has been a problem for operators. In this paper, based on the common problems in the hydrological calculation of the data-free karst area, the method of judging the non-closed watershed and the treatment of some problems in the actual runoff calculation are proposed. The estimated runoff results are also basically in line with local conditions.

1. Introduction
According to the runoff characteristics of karst areas in Yunnan Province, the relationship between precipitation and runoff in the area is analyzed, and the method of estimating annual runoff in karst areas is proposed.

2. Runoff characteristics of karst landforms in Yunnan
The karst landforms in Yunnan Province are widely distributed, and the eastern and southeastern part of Yunnan are more typical. The karst basin, funnel and blind valley, volcanic flow, underground river, karst spring and other surface and underground karst distribution are common, and the drainage standards on both sides of the watershed are different. The surface watershed and the underground watershed are often inconsistent; as the dissolution continues, the lower side of the drainage standard eventually hits the higher-depositing side of the karst water system, forming a non-closed basin. Because of the problem that the basin is not closed, the mean and CV of the annual runoff in the karst landform area generally do not follow the gradient pattern of the regional hydrological parameters. For the gaining River Basin, the runoff process generally has a relatively stable performance. The runoff modulus is large during the dry period and the annual variation of the runoff is small. For the losing watershed, the situation is reversed, the runoff modulus is small. During the dry period, the runoff even dries out. Therefore, in addition to the meteorological factors such as precipitation and evaporation and the underlying surface conditions, the hydrological characteristics of karst areas also have an important factor, that is, the groundwater systems in the unclosed watershed are mutually captured, resulting in special runoff characteristics. The runoff characteristics do not follow the local parameter evolution pattern.

3. Determination of closed watershed
Closed watershed means that the underground watershed of the basin overlaps with the ground watershed. Under normal circumstances, there are few closed watersheds in a strict sense. Due to the movement of the earth's crust, the surface watershed and the underground watershed will not be
completely on the same vertical line. However, in actual work, in addition to special geological conditions such as very small watersheds or limestone caves, for general watersheds, when there is little impact on the problem, the amount of water exchange between the two basins is extremely small, that is to say, the amount of water exchange between the two basins is extremely small, and when there is no influence on the hydrological parameters of the basin, it can actually be considered as the closed basin. Whether a watershed is a closed watershed, in addition to field surveys and search relevant geological data, it can also be found from the relationship between the precipitation and runoff in the region, the modulus comparison with the rivers in the adjacent areas, and the runoff correlation between the two stations.

For example, in the Luodianhe hydrological station in the Zhaotong area of our province, the runoff modulus is analyzed to be 482,000 m³/km², which is much smaller than the surrounding hydrological station of 80-1.7 million m³/km². Although its precipitation is relatively small, it is still characterized as a non-closed basin, because there are micro-topography phenomena such as underground valleys and closed depressions in the southwest part of the basin, resulting in some of the river basins not flowing through the hydrological station section.

The average annual precipitation of the Binchuan dam in Dali is very small (about 600mm) and the runoff depth is very small (25–30mm), which has been the highest in the province. In the region, the Jindian hydrological station in the Daying River Basin in the region has a measured average runoff depth of 117 mm for 8 consecutive years, which is much larger than the results of the surrounding watershed. Moreover, the eight-year series is still a dry group in the local area, and the results are abrupt in the distribution of runoff. After investigation, there are two spring water points in the upper reaches of the basin. Then look at the 1/200,000 regional geological map. In the upper reaches of the basin, there is a long strip of exposed limestone that is oblique to the main river, and the elevation of the entire limestone belt is basically higher than the spring point. In this way, the Daying River has a runoff recharge in the outer basin, which is the gaining area, and the conclusion is that the basin is not closed.

The Huangcaoling Reservoir dedicated station in Jinghong City, Xishuangbanna has more than three years of measured flow data, and the reliability of the review data is relatively high. After using this three-year data extension series, its average annual runoff depth is 343mm, which is more prominent than the 500–600mm runoff depth in the surrounding area. Moreover, in the “Geological Map of Huangcaoling Reservoir”, there is a long strip of limestone outcrops extending from the north to the south into the Huangcaolin River Basin. The limestone belt is located upstream of the reservoir dam site, and there is also a large range of limestone outcrops in the southwest and northwest of the basin. For this reason, whether the watershed is a water-deficient area of the unclosed watershed is particularly carefully considered in the feasibility study and initial stage of the reservoir. The flow ratio comparison was carried out several times in the upstream, downstream and dedicated stations of the limestone exposed strip, and no water imbalance was found. The results of the survey carried out by geological personnel also concluded that the reservoir area would not leak. Therefore, it is determined that the reservoir basin is a closed watershed. As for the depth of the runoff, it is much smaller than the surrounding area. After in-depth analysis, the main reason is that the precipitation in the basin is relatively small, and the second is that the evaporation is relatively large.

In addition, from the ratio of precipitation to runoff depth and the runoff correlation between the two stations, some watersheds may not be closed. If the Y station is related to the X station, the water collection area of the X station is larger than the Y station. If the two runoffs have a \( Y = aX + b \) relationship, if \( b > 0 \), then the Y station can be questioned as an unclosed watershed, and it is a gaining watershed of unclosed watershed. Because in most rivers in Yunnan Province, the CV value of annual runoff generally increases with the increase of watershed area. When the parameter \( b > 0 \), it means that the CV value of the Y station with a small watershed area is smaller than the X station with a large watershed area.

The conversion of the runoff parameters in the case of a non-closed basin to the corresponding parameters of the closed basin has the following formulas:

\[
W_0 = W_{0_{\text{obs}}} \pm \Delta W
\]
where

\[ W_0 \] — Multi-year average runoff in closed watershed
\[ W_{\text{Shi}} \] — Multi-year average runoff in a non-closed watershed
\[ \Delta W \] — The amount of water exchanged in the basin is estimated by the survey. Take “-” when it is gaining water and “+” when it is losing water.

\[ C_v \] — Variation coefficient in case of closed watershed
\[ C_{v\text{Shi}} \] — Variation coefficient in case of non-closed watershed

The above formula shows that for non-closed watersheds, the runoff CV value of the gaining water basin is smaller than the CV value under the closed condition; the CV value of the losing watershed is greater than the CV value under the closed condition. The correlation map can reflect the relationship between the annual runoff CV values of the two stations.

In general, the average elevation of the losing watershed is relatively high, the surface water system is sparse, and there is no obvious surface river even in a large range. In the gaining River Basin, the average elevation of the basin is relatively low, and there are springs or springs exposed, and the runoff modulus is large during the dry period.

4. Annual runoff estimation of non-closed watershed

When a non-closed watershed has a certain number of measured data, the runoff analysis can also be interpolated according to the conventional method. When the results of runoff are derived, as long as the rationality of the parameters and the characteristics of runoff distribution can be analyzed, the actual results can be analyzed. When it is known that it is a non-closed watershed but cannot know the amount of exchanged water \( \Delta W \), it can only be estimated according to the current horizontal annual runoff.

Generally, runoff analysis in areas without data can use hydrological comparison, contour maps, and regional integration. However, for karst areas where the basin is not closed, the results of these methods are generally not directly usable, and some necessary corrections are needed. It is difficult to estimate the amount of water \( \Delta W \) exchanged in some areas.

For non-closed watersheds with no data area, the runoff analysis can be considered in the closed watershed first, combined with the local field survey, to grasp the abundance and dryness of the runoff and the interruption time and then subtract (or add) the unbalanced amount. For example, we have analyzed the Dagan River Basin in Luoping County. The average annual precipitation of the Dagan River Basin is 1600mm. The Dagan River passes through the entire limestone area and is seriously dissolved. The river section with a length of about 40km is continuously flooded into the ground. The surface runoff area is 641km\(^2\), and the dry season is a veritable “Dagan River”; however, in the flood season, disasters frequently occur. Because it was in a state of interruption for half a year, the local hydrological department did not have a hydrological observatory in the basin.

The water intake of the Lashi Power Station, which was once planned, is located in the lower reaches of the Dagan River. The area above the water intake of the Lashi Power Station is regarded as a closed watershed. According to the hydrological comparison method, the comprehensive formula method and the runoff depth contour method, the average annual flow of the water intake section is 12.6~14.0m\(^3\)/s. The depth of the reduced runoff is 736~818mm, and the runoff result of 13.7m\(^3\)/s is finally taken. The above results are the flow rate in the case of a closed basin. The actual situation is that the main stream of the Dagan River has a flow interruption of 7-8 months per year, and the river channel is seriously leaked. Considering that the actual runoff of the Lishi Power Station is the difference between the natural runoff formed by the basin precipitation and the leakage of the cave, the actual annual runoff should be as follows

\[
\int_0^t Qdt - \int_0^t qdt = w(t)
\]

where
\[ \int_0^t q \, dt \quad \text{the amount of water loss within a certain period of time} \]

\[ \int_0^t Q \, dt \quad \text{The amount of incoming water in a certain period of time in the closed case} \]

The amount of losing water is generally difficult to estimate. For the water intake of the Lashi Power Station, a certain flow value has been deducted by trial-and-error method until it has been cut off for 7 or 8 months in most years. After continuous trial-and-error analysis, when the deductible flow rate reaches 12.0 m³/s (when the monthly runoff is less than 12.0 m³/s, it is deducted according to the actual flow). In most years, there are 7-8 months of interruption, which is basically consistent with the field survey visits. After deducting the infiltration flow rate, the average flow of the main stream of the Dagan River for many years is 4.90 m³/s, accounting for 40% of the case without water leakage. The amount of deducted water ΔW over the years is 5.33–8.63 m³/s, with an average of 7.20 m³/s.

The annual runoff CV of the Hegu hydrological station is 0.26. If the annual runoff CV of the Lashi Power Station is also based on the value of the Hegu Station, according to the formula (2) of this paper, the actual annual runoff CV value of the power station intake is about 0.54.

The author also used the above method when analyzing the runoff in other karst areas in Yunnan Province. At the time of the relevant review, the results of the method were basically recognized without other solutions to the problem.

Strictly speaking, the assumed exchange volume is discreet and is obtained by a method of presuming trial and error. However, in the absence of data, it is undoubtedly necessary to assume a water leakage, so that the proposed flow process can be more realistic. At least there is currently no other way to solve this problem than building the hydrological station.

For the non-closed watershed, if the flow area (usually the unseen valley area) of the exchanged water volume ΔW can be clearly separated on the topographic map, the problem is better solved. The exchanged water amount ΔW can be calculated by using the conventional method according to the water collecting area.

The watershed area of the hydrological station in the karst area of Yunnan Province has changed greatly compared with the early ones. For example, the early runoff area of Wenshan Geophysical Station was 765 km², and later changed to 956 km²; The early stage of Xiyang Street (2) station is 2740 km², and the later stage is 2473 km²; the early stage of Hegu hydrological station in Qujing area is 1676 km², the late stage is 1910 km², the early stage of Youjiazhai in Honghezou is 2516 km², and the later stage is 1856 km². Most of these hydrological stations with large changes in area are located in the karst area of eastern Yunnan. Calculating the runoff depth according to the later area is generally closer to the results of the check contour and is more closely matched with the precipitation. This shows that the watershed in a karst area is difficult to trace, and the second part of the hydrological station has taken into account the problem of watershed ownership in the closed area when determining the watershed area. Therefore, in actual work, when hydrology is compared with these hydrological stations, as long as the runoff parameters are not very inconsistent compared with the surrounding, and there is not much contradiction with the precipitation, these watersheds can be seen as a basin that is basically closed or has a basic balance of gaining and losing.

For the engineering section, if it is the gaining River Basin, if the recharge area outside the basin is known, the runoff area can be added to the replenishment area when considering the closed watershed; For the same reason, for the losing watershed, if you know the losing area (usually the unseen valley area or the closed basin), you can also consider it as the closed watershed after deducting the losing area.

For example, if the hydrological station and the engineering section are located on the same river, the spring water supply in the outer basin will be replenished. When the hydrology is compared, the amount of upstream spring water should be deducted first, and then the spring water is added to the project section. The Wenshan Dehou Reservoir Project completed by us has operated this way. When there is spring water in the hydrological station and the section of the project, the spring water should be deducted and then hydrologically compared to the engineering section (the hydrological station is located downstream) or compared to the engineering section and then add the spring water (the hydrological station is located upstream) (Used in the research of Nanpanjiang Bridge Power Station
completed by us).

5. Problems that should be noted

5.1 Data collection
First, we must pay attention to sporadic flow data. Due to the large amount of spring water in the southeastern part of the country, the local water conservancy department will have relatively more flow measurement data. These materials are generally not systematic and incomplete, but they generally have more important reference values for local river runoff analysis; Second, we should visit more local people, study the pattern of river runoff changes, understand the situation of river channel cutoff and the recharge of the outer river basin. Many local elderly people know the source of spring water. Third, runoff estimation should be carried out as much as possible for flow patrols, field surveys, and the extent of changes in runoff and the average annual flow.

5.2 Runoff estimation
Some large watersheds often have some closed basins. The runoff of these basins does not appear in the engineering section, but appears in the downstream or elsewhere, like the "feidi" in administrative divisions. When the "feidi" is large enough, it will affect the results of runoff, and the runoff should pay attention to the problem of "feidi".

5.3 Rationality issues
For the unclosed watershed, the hydrological parameters should conform to the characteristics of the non-closed watershed. The gaining water area has a large runoff modulus and a small CV value. The losing area has a small runoff modulus and a large CV value. The greater the proportion of exchanged water, the greater the deviation from the closed condition.

6. Conclusion
The above content is some of the thoughts after the author's study on runoff analysis in karst landforms. It is also a summary of experience. For karst areas without data, runoff analysis is often impossible. This article hopes to inspire or help people involved in runoff analysis in karst geomorphic areas. The above viewpoints are only my one-sided understanding, and mistakes are inevitable, and I hope to receive criticism and correction.

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