How to divide the water level and danger zone of mountain floods along the river in the hilly area

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Abstract. With the precision of mountain flood disaster prevention work in the hilly area, the local key areas (villages and towns) in the hilly areas have become the focus of disaster prevention. This paper introduces analytical process of the flood control capacity of village along river, gives the calculating method of water level-river discharge relationship in control section, puts forward a feasible method of calculating the disaster water level and counting number of people in danger zone by point projection and judging point-line relationship. And this method is calculated by taking typical village along river for instance. The results show that this method can ascertain the household that is the weakest in the aspect of flood control capacity by combining field investigation and determine the relationship between households and different frequencies of flood water line, thus the flood control capacity of village along the river can be calculated accurately.

1.INTRODUCTION
The mountain torrents in the small watersheds of the hilly area are formed by heavy rainfall, and the ditch (river) roads have a large ratio of decline, with short duration, strong rainfall, large ratio drop, steep rise and steepness, etc., which are quite different from river floods in large basins \cite{1,2}. At present, with the precision and refinement of mountain flood disaster prevention, some key areas along the river channel in small watersheds (villages and market towns) have become the focus of mountain flood disasters \cite{3}. On the one hand, many riverside villages are distributed around the mountain rivers, which are affected by rainstorms and floods to varying degrees. On the other hand, the riverside villages are different in threatened by mountain floods due to differences in river sections, distribution of households and topography. For a specific riverside village, its flooding water level and dangerous area are important indicators for determining the flood control capacity and danger degree of the village, and also the basis for the formulation of early warning indicators \cite{4,6}. Therefore, it is necessary to use a simple and reliable method to calculate the flood level and the division of dangerous areas along the river village.

The existing research on flood control capacity of mountain flood disasters usually takes the whole river basin and river channel as the research object, and calculates the overall flood control capacity of the river channel, which is less accurate to a single riverside village. On the other hand, some studies have
refined the objects to the villages along the river, but the lowest resident heights along the river villages are used as disaster-causing (warning) water levels, and the danger zones are divided by their horizontal planes. In addition, some scholars have established a hydrological model coupled with a two-dimensional hydraulic model, using high-precision DEM data combined with GIS spatial analysis functions for risk zone division [7-8]. However, this method is not suitable for a wide range of application practices.

This paper takes the village along the river in the hilly area as the research object, and proposes a method for dividing the flood level and dangerous area of the mountain flood disaster: based on the calculation and analysis of the storm flood design, locate the most vulnerable households along the river village. Calculate the disaster water level and corresponding flood peak flow, count the households under different flood water levels, and classify the flood disaster area, which can provide support for mountain flood disaster prevention plan preparation, personnel transfer, temporary resettlement, etc.

2. DISASTER WATER LEVEL CALCULATION AND DANGER ZONE DIVISION PRINCIPLE

2.1 Disaster water level definition and calculation principle

The flood level of the mountain floods along the river in the hilly area can be defined as: selecting a control section within the river channel of the river along the river. When the flood waters in the upstream basin reach a certain water level, the flood control capacity of the village is the weakest. The households have just started to suffer from the disaster, and the characteristic water level is the disaster water level. Therefore, the water level of the control section represents the overall flood control capacity of the village along the river, and can be used as an early warning indicator for mountain flood disasters along the river.

(1) For the river channel in the plain area or the downstream section of the mountain river channel, the water surface ratio is small, and it can be considered that the water surface of the river along the river village is a horizontal plane. Therefore, the two elements of the location of the households and the distance along the river can be simplified, and the households along the river with the lowest elevation can be directly used as the most vulnerable households, and the elevation can be directly used as the control section to become the disaster level.

(2) For the villages along the river in the hilly area, the water surface ratio is large. It is impossible to judge whether the households on other sections are flooded by the water level of one section. The inclined flood surface must be used to judge whether the residents along the river are affected. Basic calculation principle: draw the surface line with the flood surface ratio, and unify the residents along the river and the surface line in the same coordinate system to determine the relationship between the different frequency water surface lines and the elevation of the residents along the river, and comprehensively determine the most dangerous residents. The household and its elevation values, and based on the flood surface ratio, the elevation value is converted into the disaster level on the control section. The basic principle is shown in Figure 1.

2.2 Hazardous area definition and calculation principle

The definition of the mountain flood disaster area along the river in the hilly area is defined as: the different dangerous area levels are set according to the frequency of the disaster, combined with the disaster frequency of different villages along the river, the range of different levels of dangerous areas is drawn on the map, which is the warning of mountain flood. Support for work such as personnel transfer.

The basic calculation principle is as follows: Firstly, it is assumed that the short-duration storm and flood are the same frequency. Different frequencies can be selected. The design stormwater flood calculation method is used to estimate the flood peak flow value at different control sections along the river village. The Manning formula or measured data is used to calculate the control section water level-flow relationship. The ~flow relationship converts the peak flow into a flood surface line, accurately counts the inundated households under the flood water surface at different frequencies, and uses the ArcGIS tool to plot the danger zone on the map.
3. CALCULATION OF FLOOD CONTROL CAPACITY OF VILLAGES ALONG THE RIVER

According to the definition and calculation principle of flood water level and dangerous area of mountain flood disaster, a method for dividing the flood level and dangerous area of mountain river floods along the river in the hilly area was proposed. Using relatively simple data, the river survey was integrated and the storm flood was designed. Calculations, water level flow relationship calculations and other multidisciplinary methods can accurately calculate the flood water level along the river, count the flooding of residents under different flood water lines, and map the danger zone. The main link is shown in Figure 2.

FIGURE 1. Calculation of Waterlogging and Hazardous Area Division of Mountain-level Flood Disaster in Mountainous Area

FIGURE 2. Flowchart of Water Disaster and Danger Zone in Mountainous Villages along Mountainous Villages
3.1 Calculation of the elevation-start distance relationship of residents along the river

(1) Conduct on-the-spot investigations on the riverside villages along the river in the hilly area, and conduct longitudinal and cross-sectional measurements and measurements by households along the river. Generally, 3-5 cross sections can be selected along the upper, middle and lower reaches of the river course according to the set spacing, and the spacing of each cross section is generally about 300-500 meters[9]. The longitudinal section measurement is generally arranged along the deep channel of the ditch (river) road (the valley line), and extends 100m to 200m outside the upper and lower sections, as shown in Figure 3.

![Figure 3: A survey of the horizontal, vertical section and inhabitants of the river along the river section and inhabitants of the river along the river in the hilly area](image1)

(2) Projecting the residents along the river to the river line

Establish a plane coordinate system (X-Y), and use the method of point line projection to project the coordinates of the residents along the river to the middle line of the river: make a vertical line from the coordinate point of the resident to the middle line of the river, and determine the coordinate value of the intersection. See Figure 4.

(3) Calculate the starting distance of the river channel, the control section and the projection point of the resident

1) Define the first measuring point upstream or downstream of the longitudinal section of the river as the starting point, and use the two-point distance formula of the plane to calculate the distance between the other measuring points on the longitudinal section and the starting point, that is, the starting distance;

2) According to the coordinates of the projection points of each resident on the middle line, using the plane two-point distance formula, the starting distance of the projection point of each resident can be calculated;

3) According to the intersection of the control section and the center line, the starting distance of the control section can be calculated.

3.2 Calculation of different frequency flood surface lines

Firstly, using the design stormwater flood calculation method[10-11], the flood peak flow at the control section along the river village is derived; then the water level-flow relationship of the control section along the river village is calculated; and the flood water surface lines of different frequencies are drawn.

(1) Flood peak flow calculation

For the basin above the control section of the riverside village, assuming the same frequency of heavy rain and flood, considering the characteristics of watershed production and convergence, the design and analysis of storm floods at different frequencies are carried out.
(2) Using Manning’s formula to calculate the water level-flow relationship of the control section of the river along the river

(3) Calculation of different frequency flood surface lines

According to the peak flow values of different frequencies at the control section of the river along the river, the flood peak flow is converted into the flood water level by using the control section water level to flow relationship, the schematic is shown in Figure 5.

3.3 Judging the relationship between residents in riverside villages and different frequency floods

The vertical and horizontal cross-sections along the river and the residents along the river, the different frequency flood water surface lines are unified in the established starting distance-elevation coordinate system (X-Z), and the formula for determining the riverside households-flooding water surface line is established to determine the village along the river. The relationship between households and different frequency flood water lines determines the inundated households under the flood water surface lines of different frequencies.

![FIGURE 5. Along the river village residents ~ different frequency water line to determine the diagram](image)

![FIGURE 6. A schematic diagram of the calculation of the flood control surface of the river channel in the river](image)

(1) Assuming that the households are at the coordinate points in the starting distance-elevation coordinate system, the flood water surface equations of different frequencies are obtained. According to the point-line relationship judgment method, to calculated \( \Delta Z \) the difference between the elevation of the resident and the elevation of the flood surface.

(2) If \( \Delta Z > 0 \), the household is above the flood level of a certain frequency; otherwise, it is below the flood level. Judging the positional relationship between the residents in the village and the flood water surface lines of different frequencies, the number of submerged households located under the flood water surface line of different frequencies is counted.

3.4 Disaster water level calculation

According to the relationship between the households along the river and the different frequency floods, the most vulnerable households along the river route are screened and converted into the disaster level of the control section.

(1) According to the flood water surface ratio, the elevation of all households is converted into the elevation of the control section, and the elevation of all the residents along the river relative to the control section is obtained.

(2) Select the minimum value of the elevation of all households into the elevation of the control section as the flood level at the control section, and use it as the flood level of the entire village. The corresponding households are the easiest in the village along the river. Residents affected by the disaster, see Figure 6.
3.5 Dangerous area of mountain flood disaster along the river

According to the calculated different frequencies, the flooded households under the flood water surface line classify the hazard level according to the frequency, and classify the households. The classification criteria are shown in Table 1. According to the latitude and longitude coordinates and elevation of each household, ArcGIS is used on the map. Paint the danger zone and indicate it in different colors.

### TABLE 1. Standard of danger zone dividing

| Danger zone level | Danger zone name      | P   | Number of households | Description                      |
|-------------------|-----------------------|-----|----------------------|----------------------------------|
| 1                 | Very high risk zone   | 20% | X                    | High frequency                   |
| 2                 | High risk zone        | 20% | Y                    | Medium frequency                 |
| 3                 | Danger zone           | 5%  | Z                    | Frequency of occurrence of rarity|

4. CALCULATION OF FLOOD CONTROL CAPACITY OF TYPICAL RIVERSIDE VILLAGES

Take Xiaolizhuang Village in Jinyangchuan River Basin of Jinan City as an example. Measurements, a total of 56 households along the river, within 20 m from the river. In recent years, there have been many torrential rains and floods in Xiaolizhuang. According to the above theories and methods, the Matlab program is used to calculate the population level of the disaster-causing water level and the danger zone.

(1) Calculation of flood peak flow and water surface line at different frequencies along the river village

1) Using the rainwater data of the basin rainfall station for a short duration (10 min, 30 min, 1 h, 3 h, 6 h, 12 h, 24 h), Calculate the 20%, 10%, 5%, 2%, 1% frequency design storm rainfall time and time allocation; calculate the net rain with reference to the rainfall runoff relationship curve; using inference formula for convergence calculation, calculate the peak flow value of each frequency.

2) Using the Manning formula to obtain the water level-flow relationship of the control section, calculate the water level of the control section corresponding to the flood peaks of different frequencies, and draw the flood water surface line.

(2) Elevation of households in Xiaolizhuang Village - Determination of the relationship between different frequency water lines

The longitudinal and cross-section survey points of Xiaolizhuang Village River are measured along the river, and the flood water surface lines of different frequencies are unified in the starting distance-elevation coordinate system (X-Z) to calculate the elevation difference between the resident and the surface line. According to calculations, the number of households under the five frequency flood water lines is 10, 30, 45, 50, 56 households, as shown in Figure 7.

(3) Calculation of disaster water level in Xiaolizhuang Village

According to the results of the elevation difference between the riverside households and the flood surface line in Table 3, the most vulnerable households along the river route are selected as Guo Yingjing. The starting point of the projection point is 462.52 m and the elevation is 51.33 m. The elevation ratio of the flood to the control section is 51.45 m, that is, the flood control level along the river village control section. When the water level in the control section exceeded 51.45 m, Guo Yingjing residents began to suffer disasters, as shown in Figure 7.
(4) Classification of mountain flood disaster areas in Xiaolizhuang Village

According to the results of households under different flood waters in Table 3, the hazard classification is carried out according to the frequency. Combined with the coordinate information of the households, the ArcGIS software is used to circle the danger zone on the map and express it in different colors: very high risk zone. It is indicated in red, the high-risk area is indicated by orange, the dangerous area is indicated by yellow, and the Xiaolizhuang Village mountain flood disaster area is divided as shown in Figure 8.

5. CONCLUSION

(1) In view of the existing problems of the current disaster level and danger zone, this paper proposes a method based on site survey and measurement data, comprehensive design of stormwater flood calculation, water level-flow relationship calculation, point projection, and point-line relationship judgment. Feasible water level calculation, disaster population determination and danger zone mapping methods. Practice shows that this method can accurately locate the households with the weakest flood control capacity, calculate the flood water level in the village along the river, determine the relationship between the households and the flood water surface lines of different frequencies, and accurately map the flood disaster areas along the river.

(2) Although the calculation method of disaster-producing water level proposed in this paper considers the river channel and flood ratio, and the distribution of households along the river, it can theoretically locate the most vulnerable households in the village and push for the disaster level. However, due to the complexity of mountain flooding, it is still necessary to check with the on-site investigation; in addition, the design stormwater and production flow calculation methods used in this paper should be combined with the measured data to determine the demographic and dangerous area of the dangerous area. Constantly revised, from the establishment of a reliable basis for the identification of early warning indicators for mountain floods.

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Chengshan Yan is mainly engaged in mountain flood disaster prevention, hydrology and water resources, hydrological model, mountain flood disaster warning and other work research.

REFERENCES

[1] LI Hongxia, QIN Guanghua, WANG Xin, , et al. Advances in Study on Flash Flood Forecast and Warning [J]. Journal of China Hydrology, 2014, 34(5):12-16.
[2] CHENG Weishuai. A review of rainfall thresholds for triggering flash floods[J]. Advances in Water Science, 2013,24(6):901-908. DOI: 10.13243/j.cnki.slxb.2010.04.003.

[3] QI Lan, LI Nan, LI Shaoming. Study on flash flood disasters for the villages along river in small watershed of Zhejiang Province[J]. Journal of Water Resources & Water Engineering, 2016,27(6):113-117.DOI: 10.11705/j.issn.1672 — 643X.2016.06.20.

[4] LIU Zhiyu, YANG Dawen, HU Jiangwei. Method of mountain flood warning based on content level and its application [A]. Zheng Zhou city, 2010.

[5] YUAN Ximin, ZHANG Jianwei, TIAN Fuchang. Calculation of Rainfall Warning Value of Mountain Torrent Disaster in Ningxia[J]. South - to - North Water Transfers and Water Science & Technology, 2017,15(1):33-48.DOI:10.13476/j.cnki.nsbdqk.2017.01.006.

[6] JIANG Jinhong, SHAO Liping. Standard of mountain flood warning based on the precipitation observation data[J]. Journal of Hydraulic Engineering, 2010,41(4):458-463.DOI: 10.13243/j.cnki.slxb.2010.04.003.

[7] HUANG Guoru, XIAN Zhuoyan ,CHENG Guodong, et al. Risk Assessment of Mountain Torrent Disaster at Yaoan Small Watershed in Qingyuan City Based on GIS Technique[J]. Water Resources and Power, 2015,33(6):43-47.

[8] GAO Yufang, CHEN Yaodeng, JIANG Yifang, et al. Effects of DEM source and resolution on the HEC-HMS hydrological simulation[J]. Advances in Water Science, 2015,26(5):624-630. DOI: 10.14042/j.cnki.32.1309.2015.05.003.

[9] Group of mountain flood prevention project. Technical requirements for mountain flood disaster investigation[R]. 2014: 86-93..

[10] LI Kexian.Calculation Method of Flash Flood Warning Rainfall Based on Reasoning Formula[J].Journal of China Hydrology, 2015, 35(3):20-25.

[11] Liu Yuanyuan, Hu Changwei, Zhang Hongping, et al. Analysis on method for determination of critical rainfall of mountain torrent disaster in data deficient region[J].Water Resources and Hydropower Engineering, 2014, 45(8):15-17.