Monitoring and Early Warning Platform of Mountain Torrent Disasters Based on “3S” Technology

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Abstract: In view of several core problems in the research area, such as large mountainous area, scattered population distribution and limited informatization and intelligence level of mountain flood monitoring and forecasting, a multi-factor integrated monitoring database is built based on the perception data of GIS, GPS, RS and the Internet of Things, and the early warning and forecast mechanism of mountain torrent disasters, risk assessment, emergency command and support system are analyzed in detail. Then, a precise monitoring and early warning platform of mountain torrent disasters is built, which realizes accurate prediction, accurate forecast, accurate early warning and timely emergency dispatch and command of mountain torrent disasters.

Keywords: “3S” technology; mountain torrent disaster; monitoring and early warning

1. Research Background

Mountain torrent disaster has the characteristics of strong burstiness, large impact range and great destructive power, which often leads to casualties, damages of houses, earth, roads, bridges, and even the burst of reservoir, pond dam, embankment, causing serious harm to the national economy and people’s lives and property [1]. With the rapid development of information technology, geographic information system (GIS) technology has been widely used in water conservancy industry. The mountain torrent disaster monitoring system can obtain all kinds of geospatial information, attribute information, image and video information via the Internet [2]. At the same time, geospatial analysis can be carried out to obtain more comprehensive, intuitive and effective comprehensive information, so that the geographic location and related attributes can be organically combined, and all kinds of data can be delivered to users according to actual needs.

In view of the large mountainous area and scattered population distribution in the study area as well as limited information and intelligence level of monitoring, forecasting and early warning, a monitoring, forecasting and early warning platform of mountain torrent disaster is established as part of the digital promotion project. With the help of the Internet of Things and “3S” technology, based on the multi-source hydrological information from hydrological station, flow station, rain gauge station and water level station and through fusing and analyzing the multi-source mountain torrent disaster early-warning data, the multi-element integrated monitoring database is established. On the basis of multi-source fusion data, multi-index mountain torrent early warning model, local rainstorm forecast model and mountain torrent dynamic simulation model are established. On this basis, a multilevel-linkage and multi-objective dynamic early warning and emergency dispatching platform of mountain torrent disaster is realized, which provides support for mountain torrent disaster data collection, monitoring and early warning, auxiliary analysis and decision-making, and enhance the research area’s prevention and emergency handling capacity against mountain torrent disaster.

2. Overall Design Idea

2.1. Establishing “One Map” Information-Resource Integration Mode

The basic geospatial information framework provides the data basis for the integration and sharing of information resources [3]. Based on geographic information technology, the emergency information in geographic space can be displayed in the form of visual layer. Based on the “one map” mountain torrent disaster information-resource integration and sharing mode, information on disaster monitoring, emergency supplies, rescue forces, disaster impact assessment and other information can be effectively implemented in space and finally displayed as the visual layers that can be queried, retrieved and analyzed through electronic map.

2.2. Establishing Multi-Index Early Warning Forecast and Simulation Analysis Model

Based on the analysis of the formation mechanism of medium and small scale weather system, the short-time approaching rainstorm prediction technology in mountainous areas is developed so as to improve the prediction accuracy of disaster-causing floods in mountainous areas and extend the early warning period of mountain torrent disasters. The formation process and disaster-causing dynamic mechanism of rainstorm and mountain torrent are explored, and a dynamic simulation model of mountain torrent process is established based on rainfall prediction and dynamic monitoring of soil moisture content. The effective relationship among early-warning indicators, associated stations, associated villages and early-warning personnel is established. The multi-index warning model of mountain torrent disaster is established, and the threshold ranges of multiple indexes are given.

2.3. Establishing the System Application Process with "Combination of Peacetime and Wartime"

Based on the "one map" mountain torrent disaster monitoring data sharing, combined with the existing responsibilities of all functional departments in the study area in response to natural disasters, an efficient system application process with "combination of peacetime and wartime" is established. In terms of system application, information management and monitoring and prevention should be emphasized in "peacetime" and emergency treatment should be emphasized in "wartime". Leaders should make decisions and deploy in a unified way, and all departments should make corresponding coordination.

2.4 Analysis method of one-dimensional and two-dimensional coupled hydrodynamic model

The one-dimensional unsteady flow mathematical model is used to calculate the water level, flow rate and other information of the river system in the flood protection area. The dike break model is used to calculate the width, depth, water level and flow of the breach. The two-dimensional hydrodynamic model is used to calculate the submergence depth, submergence duration and flood volume in the flood protection area In order to accurately simulate and calculate the flood risk of the flood protection area under different disaster factors, the one-dimensional and two-dimensional hydrodynamic models and the breakwater model are coupled. The main calculation method is shown in Figure 1.

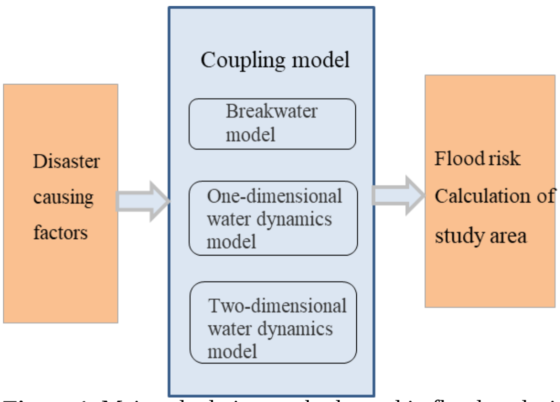

Figure 1. Main calculation methods used in flood analysis

One dimensional unsteady flow mathematical model and two-dimensional flood unsteady flow model are coupled to solve the problems of dike break and dike break flow evolution. According to different research areas, one-dimensional and two-dimensional flood evolution models are used to give full play to the advantages of their respective models.

The one-dimensional and two-dimensional mathematical models of flood routing are coupled by the connection conditions on the "interface" (flow transition surface). The "interface" refers to the position of the breach after the dike break. The key of model coupling is to accurately describe the flow information interaction inside and outside the breach.

At the breach, the two-dimensional calculation unit is connected with the one-dimensional calculation unit through grid points. Because the hydraulic parameters in the calculation results of one-dimensional model are the section average values of physical quantities, and the two-dimensional model calculates the average values of each grid, it is necessary to transform and connect the interactive data of one-dimensional and two-dimensional models at the breach connection.

The one-dimensional model provides the flow value Q for the two-dimensional model as the boundary condition of the two-dimensional model, and distributes the Q value to the flow boundary of the two-dimensional calculation unit. Since the water level values of the two-dimensional calculation grids at the junction are not equal, the average water level values of each calculation grid are returned to the one-dimensional model for the next period of calculation, so as to realize the coupling calculation of one-dimensional and two-dimensional models.

One dimensional hydraulic method

The hydrodynamic simulation of unsteady flow is based on Saint Venant equation.

Continuity equation:

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=q \tag{1}$$

Momentum equation

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\alpha\frac{Q^2}{A}\right)+gA\left(\frac{\partial y}{\partial x}\right)+gAS_f-u\cdot q=0 \tag{2}$$

Where, A-river flow area;

Q-discharge; u-velocity of lateral flow in river direction;

T-Time; horizontal coordinate along flow direction;

q-lateral flow of river; α - momentum correction coefficient;

g-acceleration of gravity; y-water level; Sf- friction gradient.

The calculation method is as follows:

$$S_f=\frac{Q|Q|}{K^2}=\frac{n^2u|u|}{R^{4/3}} \tag{3}$$

At the confluence of the river, the river reaches are connected by water balance

$$Q_m^{n+1}+\sum_{j=1}^{L(m)}Q_{m,j}^{n+1}=\Delta V \quad , \ m = 1,2,\ldots,M \tag{4}$$

Where, L (m) - the number of river sections connected to node M;

M - total number of nodes;

Q_m^{n+1} —External flow into node m in n+ 1 period;

$Q_{m,j}^{n+1}$ —The inflow node of the reach of m,j in n+l period;

V-water storage capacity of river confluence;

Manning's formula can be used to simulate the steady flow

$$Q = A\frac{1}{n}R^{2/3}\sqrt{i} \tag{5}$$

where, A - cross section area; Q - discharge; n - roughness; R - hydraulic radius; i - bottom slope.

3. Multi-Factor Integrated Monitoring Database

Data is the foundation for system construction, and the database construction is particularly important. Main databases are shown as follow:

1. Basic database including basic geographic information, population data, legal person data and social and macroeconomic data.
2. Dynamic monitoring database including rainfall information, underlying surface information, runoff information, soil water content information, etc.
3. Monitoring and early warning model database including short-term rainstorm forecast model data, dynamic simulation data of mountain torrent process, early warning indicators and thresholds, as well as the effective correlation data among survey stations, villages and early warning personnel [4].
4. Risk assessment database including risk zone classification data, index evaluation data, etc.
5. Emergency command database including hazard sources, emergency plans, emergency materials, emergency teams, relevant emergency plans and other information [5].

4. Dynamic Early Warning Forecast and Emergency Dispatch Platform of Mountain Torrent Disaster

4.1. "One-map" Basic Monitoring and Forecasting of Water and Rain Conditions

The data on rainfall, river, water level, geological hidden danger and atmospheric environment at each monitoring point in the whole research area are monitored, and then displayed on the map in real time.

Monitoring cameras will be installed at all monitoring stations and geological hazard points within the research area, and the image will be collected at the monitoring points. In this way, staff at peacetime can complete the video monitoring of the area, and when an emergency occurs, the video of the disaster points can be automatically popped up, so that leaders can know the situation of the disaster area in the first time and direct the on-site work, which is shown in Figure 2.

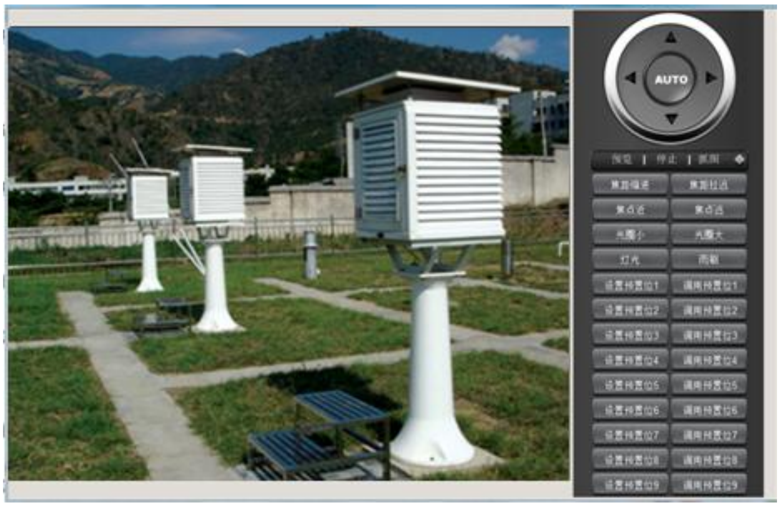

Figure 2. Video surveillance

4.2. Early Warning and Risk Assessment Analysis

According to meteorological, hydrological and other forecast data, the rainfall, river, water level, geological hidden dangers of each monitoring point in the study area are effectively monitored, which avoid the harm caused by a variety of natural disasters and reduce economic losses to the greatest extent.

By setting thresholds of various monitoring indexes such as rainfall and water level, various alarm levels can be adjusted dynamically. Moreover, by setting the sound of the alarm and the pattern of rolling letters, the staff can be reminded when the monitoring alarm occurs. The retrieval period of monitoring data can also be set according to the actual situation.

When a natural disaster occurs, it is necessary to understand the impact of the disaster, such as: the number of damaged houses and affected population so as to realize a faster and more reasonable deployment of relief materials. At the same time, by selecting the disaster point and setting the buffer radius, one can complete the statistical work of the data through the emergency evaluation and analysis function.

4.3. Emergency Command System

When a disaster occurs, the emergency start is prompted by highlighting or warning; the command and dispatch system obtains information related to emergency events from the monitoring system and incident reporting system; a variety of solutions are obtained from the decision aid system. After comprehensive processing by the command and dispatch system, a task statement is formed and released, which includes information about events, early warning information, resource allocation, responsibilities and responsibilities of departments, emergency procedures, matters needing attention, leadership instructions, implementation measures, etc. According to the content of the announcement, the decision will be made through the emergency platform in various ways, such as the Internet, phone calls and text messages.

4.4. Emergency Support System

It is necessary to realize the management of existing emergency manpower, materials, medical and health care, transportation, communication support and other resources, including resource monitoring (tracking and feedback of emergency resources, distribution and status of emergency resources, etc.), as well as resource reserve and allocation management. Resources information should be provided for emergency management. For example, in the process of event handling, it is necessary to figure out where the required resources are, how to dispatch them, and how many can be dispatched. In daily work, direct information can be provided for the planning, distribution and other work of emergency resources.

5. Conclusion

Mountain torrent early warning and monitoring platform mainly includes four major functions: “one-map” basic monitoring and forecasting of water and rain conditions, early warning and risk analysis, emergency command and emergency support. Based on this, daily visual monitoring and forecasting, early warning analysis, the establishment of dynamic early warning mechanism, assist in emergency decision-making and dispatch can be realized.

Through sharing of data and information, the meteorological warning of mountain torrent disasters and the display of hydrological information on multi-terminal platforms can be realized, so as to realize the purpose of “accurate measuring, quick transmitting, precision forecasting, and timely reporting”. Through the construction of the early warning platform, the disaster prevention and mitigation mechanism is established to improve the emergency response and treatment time.

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