Research on hydrological emergency monitoring scheme and technology of Barrier Lake

S Deng¹, J Y Mei¹, B Zhou¹, J Zuo² and T Zhang¹
¹Bureau of Hydrology, Changjiang Water Resource Commission, Wuhan 430010, China
²Hanjiang Bureau of Hydrology and Water Resources Survey, Changjiang Water Resources Commission, Xiangyang, 441022, China

E-mail: dengshan369@sina.com

Abstract. After the occurrence of the barrier lake, the rapid and effective development of hydrological emergency monitoring plays a key role in formulating emergency plans and reducing the losses caused by secondary disasters. This paper introduces the main characteristics of hydrological emergency monitoring of barrier lake, and the overall situation of emergency monitoring of 11.3 Baige Barrier Lake in Jinsha River in 2018. The scheme of hydrological emergency monitoring of barrier lake is designed, and two non-contact hydrological emergency monitoring methods based on radar and LSPIV technology are proposed according to the existing emergency monitoring methods of barrier lake. It has practical guiding significance for hydrological emergency monitoring of Barrier Lake.

1. Introduction

Most of the barrier lakes are formed by sediments caused by earthquakes, landslides or mudslides. The tampon is continuously washed, eroded, dissolved, and collapsed by the water. Once the blockage is destroyed, the lake will overflow and form a flood, which is extremely dangerous. With the continuous occurrence of secondary disasters, the water level of the barrier lake may rise rapidly, and major floods can occur at any time. Once the barrier lake is severely damaged, the consequences are serious [1].

Emergency monitoring is the basis of hydrological emergency response work, providing preliminary basic data and real-time information for hydrological emergency analysis and hydrological emergency forecasting. The main tasks of hydrological emergency monitoring: collecting the basic geometric characteristics of the barrier lake and providing basic information for the research and development of the risk prevention measures in the early stage; in the construction phase of the construction, monitor the inflow from the reservoir area, the change of water level in the upper reaches of the barrier lake and the water level in the reservoir, and provide the basis for the construction organization and dispatch; In the stage of dangerous discharge of barrier lake, monitoring the major towns and water conservancy projects along the river and the river basin will be monitored. It provides decision-making basis for the initiation and termination of early warning at different levels [2].

2. Characteristics and overview of emergency monitoring in the barrier lake

2.1. Characteristics of emergency monitoring in the barrier lake

...
The hydrological emergency monitoring of barrier lake has the characteristics of sudden and emergency, bad working environment and poor working conditions. An objective, correct and scientific understanding of the hydrological emergency monitoring work is the basis for carrying out the hydrological emergency monitoring work. Compared with routine hydrometric measurement, hydrological emergency monitoring has the following characteristics: poor monitoring environment, great potential safety hazards, difficult monitoring, inadequate modern means, long hydrological emergency monitoring front, poor control conditions in the survey area, the monitoring need to be absolute "fast" and relatively "accurate".

In the hydrological emergency monitoring of the barrier lake, the flow velocity of the dam-break flood is very high, the scouring force is very strong, and there are many floating objects. At the same time, it may encounter power outages, communication interruptions, etc. Some stations fail to record the failure of stage meter, and the equipment such as the rush boat, unmanned ship and ADCP can not be used. Usually, stage observation mainly adopts manual observation, total station Prism-free observation, self-recording, etc. Discharge measurement mainly adopts buoy method, radio current meter method, specific area method and so on. The existing hydrological emergency monitoring methods of barrier lake are relatively backward, the observation efficiency is not high, the observation accuracy cannot be guaranteed, and there are some hidden dangers in the life safety of the monitors.

2.2. Overview of the monitoring of the 11.3 Baige Barrier Lake in Jinsha River
At about 17:00 on November 3, 2018, a large-scale landslide occurred again on the right bank of the Jinsha River in Baige Village, Boluo Township, Jiangda County, Changdu County. The landslide blocked the Jinsha River and formed a barrier lake. The stage of the barrier lake continues to rise rapidly, threatening the safety of people's lives and property upstream and downstream. The Bureau of Hydrology, Changjiang Water Resource Commission quickly assembled professional and technical teams to carry out hydrological emergency monitoring and forecasting work, which made outstanding contributions to the successful disposal of the barrier lake [3].

The 11.3 Baige barrier lake of Jinsha River is extremely rare because of its high water level, large reservoir capacity and long duration. Faced with severe dangers, the Bureau of Hydrology, Changjiang Water Resource Commission dispatched a team of experts and seven on-site monitoring teams to control seven monitoring sections on the battlefront of 700 kilometers upstream and downstream of the barrier lake, fully considering various possible situations, and formulated detailed monitoring plans on a cross-sectional basis.

Facing the extreme situations of super-fast rising rate, super-large rising range, super-strong current velocity and super-high sediment concentration, nearly 100 hydrologists raced against the floods, using traditional artificial means such as self-made night-light buoys, total station, combined with modern instruments such as UAVs and radio-wave velocimeters, and so on, difficulty obtained complete once-in-a-thousand-year flood data (see figure 1).

Faced with the difficulties of lack of data, no historical reference and abnormal state, we organized intensively consultation on dam-break flood analysis and prediction. Accurate hydrological forecast and related analysis results provide decision-making basis for emergency disposal of barrier lake and safe operation of downstream cascade reservoirs.
3. **Hydrological emergency monitoring scheme for barrier lakes**

The content of hydrological emergency monitoring of barrier lake can be divided into three parts: monitoring above dam, monitoring on dam body and monitoring under dam (see figure 2).

**Figure 2.** Schematic diagram of emergency monitoring layout for Dam Lake.

### 3.1. Hydrological emergency monitoring above dam

The main monitoring items on the dam are: stage, topography and inflow discharge of the reservoir of the barrier lake.

Stage monitoring in reservoir, before the breakdown of the barrier lake, the stage rises slowly and extensively, mainly considering a large range of self-recording stage gauges, while manual observation water gauges as an alternative scheme; after the breakdown of the barrier lake, the stage above the dam drops rapidly, sometimes there will be mountain collapse, self-recording water level...
gauge probe exposed to the water surface and other phenomena, mainly considering UAV multi-factor integrated monitoring system monitoring. At the same time, a large range self-recording water level meter, artificial water gauge observation, stage video intelligent monitoring and fixed marking method are used as alternatives.

The topographic monitoring of reservoir, which is divided into channel topography and onshore topography, is the key to calculate the water storage capacity of the barrier lake. Channel topography can be measured by submarine boat or unmanned ship with GNSS and echo sounder; onshore topography can be quickly measured by laser scanning unmanned aerial vehicle, and three-dimensional laser scanner is used as an alternative.

The discharge inflow the barrier lake can be measurement in a conventional scheme: the assault boat or the unmanned ship is equipped with ADCP.

3.2. Hydrological monitoring on dam body
The main items of dam monitoring include: the process of collapse, the width of the breach, the surface velocity of the breach, and the stage.

Because of the high risk of dam break, only non-contact scheme can be considered. UAV aerial photography, three-dimensional laser scanner and UAV multi-factor integrated monitoring system are the main consideration in dam break shape and flow monitoring. At the same time, Prism-free distance measurement with total station and intelligent distance measurement with buoy flow measurement are the alternatives for dam break form and flow measurement with buoy flow measurement as flow measurement.

3.3. Hydrological monitoring under dam
The main monitoring items under the dam are the monitoring of stage and discharge at stations below the dam.

The monitoring under the dam is after dam break, the main features are great current impulse, high velocity, high stage rise rate, large increase range and short process. Because of the high risk of monitoring, non-contact methods are mainly used, such as UAV multi-factor integrated monitoring system, Prism-free total station instrument, GNSS buoy, conditional installation of side-scan radar flow measurement system and video intelligent monitoring of stage. At the same time, manual observation of stage and buoy discharge measurement are used as alternatives.

The measurement of flow section under dam can be carried out by GNSS RTK before breaking, and the total station test is the alternative. When the water depth is deep, the measurement of underwater cross section is mainly carried by GNSS and multi-beam underwater measurement system on the charge boat or unmanned ship.

4. Non-contact hydrological emergency monitoring technology
In recent years, with the rapid development of sensors and embedded systems, the real-time flow monitoring technology has made great progress, especially the non-contact flow measuring instrument based on acoustics, optics, radio wave and image has significantly improved the efficiency and safety of hydrology and water conservancy measurement. In view of the current situation and characteristics of hydrological emergency monitoring in barrier lakes, and based on the status quo of non-contact testing technology, this paper introduces the UAV multi-factor integrated monitoring technology based on radar and image methods.

4.1. UAV Multi-element Integrated Monitoring System Based on Radar Wave
Radar wave discharge measurement and stage monitoring are relatively mature in the hydrological industry [4,5]. According to the characteristics of the barrier lake, this paper intends to design a comprehensive monitoring system of stage and discharge carried by UAV. UAV multi-factor integrated monitoring system is divided into air equipment and ground equipment. Air equipment consists of UAV, augmented stability platform, GNSS, wireless radar water level meter, radar velocity
meter and high-definition camera. It is proposed to cooperate with manufacturers to realize real-time monitoring of stage, velocity and topographic aerial photography by using UAV equipped with GNSS and radar stage meter, radar velocity meter and camera integrated equipment, and the monitoring data are transmitted to ground equipment by wireless short transmission. Ground equipment consists of wireless receiver and PC mobile terminal computer. Data communication between air equipment and ground equipment is carried out by wireless mode (see figure 3).

- **Stage measurement**
  After hovering, the UAV elevation is positioned in real time by GNSS RTK, and the altitude difference between UAV and water surface is measured by radar water level meter. GNSS data and radar stage meter data are transmitted to PC for real-time calculation and stage process display.

\[
Z = H - h - c
\]  

In the formula: \(Z\) is the real-time stage; \(H\) is the GNSS elevation; \(h\) is the height difference measured by the radar water level meter; \(c\) is the vertical distance from the GNSS antenna to the probe of the radar water level meter, which is a fixed value.

- **Discharge measurement**
  The UAV is positioned by GNSS RTK to determine the starting distance on the cross section, and the surface velocity is measured by the wave velocimeter. After completing the speed measurement, fly to the second vertical line and begin to measure the speed. All vertical velocity measurements are completed by analogy.

  The discharge measurement software of PC terminal automatically completes the discharge calculation according to the section data imported in advance.

![](image)

**Figure 3.** UAV Multi-element integrated monitoring system based on radar wave.

### 4.2. UAV Multi-element Integrated Monitoring System Based on LSPIV

In the 1990s, Fujita *et al* [6] improved particle image velocimetry (PIV) technology in laboratory hydrodynamics research to be used in the observation of surface flow field and flow estimation of field rivers, which is called large-scale particle image velocimetry (LSPIV). This method takes the natural floating material and water surface model of river surface as the flow tracer, and considers that the motion state of the tracer represents the movement state of the local fluid in the two-dimensional flow field of the measured water surface. According to Lagrange's method for describing fluid motion, if the local particle clusters in an image analysis region divided at time \(T1\) are taken as the research object, assuming that the time interval \(t\) between two frames of image exposure is short enough, it is considered that there exists a matching region without particle inflow and outflow corresponding to the same local particle clusters in the image at time \(T2\), so long as the space of the analysis region is space. By searching the matching region with the greatest similarity in the neighbourhood and getting the distance \(S\) between the two centers, the motion vector of the local fluid micro cellule can be estimated \(V = S / \Delta t\) (see figure 4).
Figure 4. Basic principles of PIV technology.

After the emergency monitoring of Baige barrier lake on "11.3" of Jinsha River in 2018, the Bureau of Hydrological, Changjiang Water Resources Commission used UAV image from the site of the barrier lake, combined with relevant units, used LSPIV technology to analyze the flow velocity of the barrier lake when it burst, which was in good agreement with the field measured data, and also verified the practicability of LSPIV technology in the emergency monitoring of the barrier lake [7] (see figure 5).

Figure 5. LSPIV flow field identification result in the process of Damming Lake.

Compared to non-contact flow measurement techniques such as acoustics and radar, LSPIV features instantaneous full-field flow measurement. It has obvious advantages in quickly acquiring instantaneous flow field, turbulence characteristics, flow pattern, etc., and has the potential of river flow monitoring during high flood period. Therefore, the research on the method of measuring the speed of river surface imaging has important theoretical significance and application value [8].

The application of LSPIV in the barrier lake can be realized by means of a drone, using a high frame rate industrial camera equipped with a drone, real-time transmission of the image to the ground terminal. The surface velocity can be calculated by solving software. Finally, the surface velocity can be converted to the depth average velocity by using the velocity coefficient, and the cross-section flow can be estimated by the Velocity-area method. At the same time, water level recognition can be realized by image perception.

5. Conclusion
The barrier lake is a natural phenomenon with high risk. Once the barrier lake breaches, the hydrological emergency monitoring of the barrier lake is the basis of the emergency disposal work,
which is of great significance to the scientific disposal of the barrier lake. Combining with the Baige barrier lake of Jinsha River 11.3, this paper introduces the characteristics of hydrological emergency monitoring of the barrier lake. A complete hydrological emergency monitoring scheme for the barrier lake is proposed, and the corresponding monitoring methods are introduced. According to the actual situation of emergency monitoring of barrier lake, two non-contact hydrological emergency monitoring methods based on radar and LSPIV technology are proposed. It has practical guiding significance for hydrological emergency monitoring of barrier lake.

Acknowledgments
This work is supported by National Key R & D Program of China (2018YFC1508002), National Key R&D Program of China (2017YFC0405701).

References
[1] Wang J 2011 Hydrological Emergency Practical Technology 2st ed. (Beijing: China Water Resources and Hydropower Press)
[2] Zhang X J 2010 Design of hydrological emergency monitoring scheme for barrier lake Water Resour. Inform. 2010 1-5
[3] Cheng H Y 2019 Hydrology emergency monitoring and forecast on baige barrier lake of Jinsha River on November 3 Yangtze River 50 23-7
[4] Zeng Y C, Shi R G and Chen C 2017 Research and application of radar wave on-line flow measurement and remote centralized control system Hydropower 43 70-74+85
[5] Li X B, Yu D H and Liu S Y 2017 Development and application of radar wave velocity probe in hydrological cableway testing Water Resour. Hydropower Express 38 20-21+27
[6] Fujita I, Muste M and Kruger A 1998 Large-scale particle image velocimetry for flow analysis in hydraulic engineering applications J. Hydraul. Res. 36 397-414
[7] Ruan Z W 2019 Application of Non-Contact Measurement Technology in River and Lake Monitoring (Wuhan: Nanjing Hao Kong Software Technology Co., Ltd.)
[8] Muste M, Kim D and Merwade V 2010 Modern digital instruments and techniques for hydrodynamic and morphologic characterization of river channels Gravel-Bed Rivers 10 315-41