Application of Big Data Analysis in Flood Control of Small Reservoirs - A Case study of Liaoning Province, China

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Abstract. Small reservoirs play an important role in the safety of flood control and economic development. Their operation and management are characterized by a large number of objects and a large amount of information, which requires effective data analysis means support. Based on this, big data analysis technology has been gradually applied and popularized in the operation and management of small reservoirs. In this paper, we first set up a small reservoir flood reporting system based on the data collection and analysis of various aspects such as reservoir capacity, characteristic water level, real-time data of water and rain situation, meteorological data, and presented the results in the paper. Secondly, we analyzed the under-reporting situation during the flood control period of the reservoir, and explored the under-reporting factors and the time when the under-reporting occurred. Finally, we conduct a time series analysis on the situation of water level exceeding the limit of 50 reservoirs during the flood control period, so that we can find the key reservoirs and important time points of flood control more intuitively and provide reference for the smooth development of the management of small reservoirs.

1. Introduction
Small reservoirs play an important role in river flood control, water diversion and power generation. The level of operation management of small reservoirs directly affects the performance of its benefits. In the past, the management of small reservoirs was mainly carried out by manpower, time-consuming and inefficient. In recent years, with the rapid development of information technology and big data analysis technology, machinery manufacturing, aerospace construction and other industries have been rapidly developed\cite{1-2}, and the water conservancy industry has gradually introduced this powerful method.

Since the founding of the initial construction of a large number of small reservoirs in Liaoning province, by 2018, the water conservancy system internal copies of small reservoirs, a total of 685 seats, including 273 small I type reservoir, small II type reservoir in 412, the total capacity of 922.76 million
cubic meters, irrigation capacity of 500.51 million cubic meters, located in the city of the province's 14, on the operations of the reservoir and scheduling management directly affect the surrounding residents' daily life. Due to reasons such as technology and capital source, large data analysis technology in the large and medium-sized reservoir operation management is the first application, through practice, large data analysis technology in the reservoir water level monitoring, forecast, meteorological information network, have played an important role in aspects such as for disaster relief during flood control, greatly improve the scientific and maneuverability of reservoir management[3]. After 2010, Liaoning Province began to gradually apply big data analysis technology in the operation and management of small reservoirs, which improved the management level of reservoirs to a certain extent[4-5].

2. Data collection and processing
Data collection is mainly a combination of manual recording and data collection platform. A full-time reservoir administrator and a temporary reservoir administrator are assigned to each reservoir throughout the province to report the reservoir water level and weather conditions. In terms of facilities, equipment and materials, each reservoir is required to be equipped with basic equipment for measuring water level, and for reservoirs with conditions, equipment for water situation monitoring and rain observation, etc. The competent reservoir authorities shall timely report the information of small reservoirs, material reserves, rescue teams, persons in charge of flood control, danger points and dangerous sections, flood prevention plans, etc. After receiving the information, the information processing departments shall input the information into various systems to ensure the accuracy and timeliness of all information in the system.

3. Results
3.1. Small reservoirs reporting the flood system
Based on the data analysis and summary of water level characteristics, real-time rainfall data, meteorological data, disaster prevention data, regional economy data, public opinion data and other aspects, Liaoning province independently developed the "Liao Xun Communication" APP. Through statistical analysis of the observation data of hydrological precipitation in 14 cities in the province, combined with the forecast results of the meteorological department, a complete flood reporting system for small reservoirs in Liaoning Province was formed.

By collecting the location and flood control capacity of small reservoirs, designing flood level, checking flood level, dead level, flood control limit level, the influence of cultivated land area, population and other data, the system can confirm the working situation and organization information of small reservoirs in real time, as shown in Figure 1. By monitoring the real-time water level of each reservoir, the detailed information about the flood situation of the reservoir is shown in Figure 2. By collecting runoff, rainfall and other meteorological conditions in the reservoir area with the local hydrological monitoring department and meteorological department, important data such as current inbound and outbound flow and peak flow of the reservoir can be monitored in real time, and the reservoir flow curve can be drawn as shown in Figure 3. Since there is no multi-language function, in order to be more realistic, figure 1-3 shows the default Chinese interface of the system. After the real-time flood situation is confirmed, the social and economic impact assessment is made based on the collected cultivated land and population around the reservoir, to provide a basis for flood control decision-making. After the emergency measures are formulated and implemented, the actual risk changes and losses are collected through follow-up to confirm the effectiveness of the implementation of emergency measures, so as to form a complete and effective flood control and emergency reporting system.
3.2. Analysis of flood reporting

Due to a series of subjective reasons such as text message editing errors, shutdown, downtime, mobile phone and system inconsistency, and the objective reasons such as mobile phone signal roaming shifted outside the province, mobile phone repair, mobile phone loss, etc., which hindering the normal operation of the flood reporting system. In view of this situation, since 2017, the small reservoir administration department of Liaoning Province has made records of the flood reporting situation of all reservoirs, made detailed records of the reservoirs that failed to report flood in time, the reservoir administrators, the reasons for not reporting the flood, etc., and analyzed the delay in reporting the flood according to the reasons. The data were collected during the flood control period from June 1 to September 30, 2017, which lasted for 122 days from July 10th to August 20th, the staff reported the flood twice a day, and once a day the rest of the time. The total number of reservoirs is 686, and the number of times of flood should be 112,516. According to statistics, there are a total of 129 times of under-reporting, with an under-reporting ratio of 0.11%. The reasons for not reporting the flood season are shown in Table 1.

| Reason for failure to report flood | Quantity | Percentage (100%) |
|-----------------------------------|----------|-------------------|
| Shutdown                          | 9        | 6.98              |
| Downtime                          | 3        | 2.33              |
| No one heard                      | 11       | 8.53              |
| Unreachable                       | 2        | 1.55              |
| Phone Repair                      | 9        | 6.98              |
| Unknown reason                    | 95       | 73.64             |
| **Total**                         | **129**  |                   |

The number of reservoirs, the number of underreporting and the underreporting rate are shown in Table 2. The underreporting rate is the percentage of the number of underreporting divided by the
number of reservoirs. The number of reservoirs, the number of under-reports, and the under-reporting rate are visualized and shown in Figure 4. In order to make it easier to observe, the under-reporting rate is changed to per thousand.

Table 2. The number of reservoirs and underreports.

| Regional location | City   | Number of reservoirs | Number of underreporting | Rate of underreporting‰ (number of underreporting/number of reservoirs) |
|-------------------|--------|-----------------------|--------------------------|-------------------------------------------------------------------------|
| North             | Shenyang | 17                    | 3                        | 24.03                                                                   |
|                   | Fushun  | 108                   | 40                       |                                                                          |
|                   | Tieling  | 83                    | 7                        |                                                                          |
|                   | Total   | 208                   | 50                       |                                                                          |
| East              | Benxi   | 24                    | 9                        | 20.59                                                                   |
|                   | Dandong | 44                    | 5                        |                                                                          |
|                   | Total   | 68                    | 14                       |                                                                          |
| South             | Dalian  | 183                   | 12                       | 7.02                                                                    |
|                   | Anshan  | 13                    | 2                        |                                                                          |
|                   | Yingkou | 30                    | 2                        |                                                                          |
|                   | Liaoyang| 2                     | 0                        |                                                                          |
|                   | Total   | 228                   | 16                       |                                                                          |
| West              | Jinzhou | 21                    | 10                       | 26.31                                                                   |
|                   | Fuxin   | 43                    | 16                       |                                                                          |
|                   | Panjin  | 1                     | 0                        |                                                                          |
|                   | Chaoyang| 60                    | 9                        |                                                                          |
|                   | Huludao | 57                    | 14                       |                                                                          |
|                   | Total   | 182                   | 49                       |                                                                          |
| Total of the      |         | 686                   | 129                      |                                                                          |

Figure 4. Regional distribution of underreporting

Through the combined analysis of charts, it is concluded that the main reasons for the delays in flood reporting are subjective factors such as no answer and shutdown. Most of the time, the reason is not clear. The underreporting periods are mainly concentrated in the non-main flood seasons such as June and September (the main flood season in Liaoning Province is usually July and August), and spatially
mainly concentrated in the western, eastern and northern parts of Liaoning. Instead, the southern part, which has the most reservoirs, has the lowest underreporting rate.

The underreporting caused by non-flood seasons, we learned from the person in charge, and the survey results showed that such cases were mainly caused by insufficient attention by the warehouse staff. Regarding the spatial distribution of underreporting, after investigation, in addition to human management reasons, another reason is that the reservoir is geographically remote and far away from the signal tower, which often results in unsuccessful transmission of mobile phone information, and the flood reporting system is entered through the mobile information network. Resulting in untimely related flood reporting information in the system.

3.3. Flood forecast and early warning
In order to better carry out the flood prevention work of small reservoirs, the small reservoir management department of Liaoning Province conducted statistics on the situation of reservoirs exceeding the flood limit (exceeding the limit water level during the flood season) in 2017, as shown in Figure 6. Through analysis, it can be seen that the flood of small reservoirs in Liaoning Province in 2017 mainly occurred in early June and mid-to-late August to September. The 50 numbers in the picture refer to fifty reservoirs. Reservoirs with an over-flood limit of more than 1 meter (danger warning) for more than 3 days can be found by labeling: Chaoyang Reservoir in Fushun City, Yingbishan Reservoir in Benxi City, Binglishan Reservoir in Tieling City, and Nantaizi Reservoir in Chaoyang City. The above results are basically consistent with the 2017 forecast by the meteorological department. Based on this, before the start of the flood season in 2018, the provincial small-scale reservoir authority paid special attention to the above four cities, and required to strengthen observation during the flood season and do a good job in flood prevention.

4. Conclusion
Relying on the summary analysis results of reservoir capacity, characteristic water level, real-time water and rain data, meteorological data, disaster prevention work data, disaster data, protection object situation, regional economic and social conditions, structure and unstructured document data, public opinion data and other data. We have established a flood reporting system for small reservoirs in Liaoning Province, and demonstrated in the article. We have analyzed the under-reporting situation during the flood control period of the reservoir. The under-reporting is mostly due to human factors, and most of it occurs during the non-main flood control period. Analyzing the water level monitoring of 50
reservoirs in Liaoning Province, the flooding of small reservoirs mainly occurred in early June and mid-to-late August to September, with very few in July.

For flood control, there are still many shortcomings:

- The flood reporting system is still not stable enough, the instantaneous data processing capacity is slightly insufficient, and the flood reporting information is not intuitive enough. Based on the above situation, we recommend using the APP to directly report the flood, and the reservoir administrator directly fills in the numbers and related information in the APP human-computer interaction interface to improve the timeliness and accuracy of reporting.

- The amount of data is insufficient. Due to limited maintenance funds, reservoir monitoring facilities are seriously inadequate. Many reservoirs only have water gauges, and the lack of monitoring facilities directly leads to the incomplete collection of basic data of the reservoir or the untimely update of the basic data. We recommend that the infrastructure of small reservoirs be further repaired to improve the management level of small reservoirs.

- The flood warning method is not scientific enough. Early warnings are issued by establishing a relationship with the flood risk zone through real-time information of rainfall and reservoir water levels. This method has great limitations in time, especially when the water level changes sharply. Based on this, we suggest that relevant detection points and radar can be added to realize minute-by-minute prediction of the water level change of each river through networking, and to issue flood warning in advance.

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