

Interaction Mechanism between Formation Process of Bank Collapse Disaster Chain and Territorial Space Utilization of Large Reservoirs

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Abstract

Number of reservoirs in China ranks the first in the world. Due to the complex geology, and superimposing rainfall and reservoir water fluctuation, the bank collapse chain is prone to disasters. The Yangtze River Reservoir is key geological disaster prevention area. Studying the process of reservoir disaster is significant because of the limited territorial space utilization. Scientific and technological issues, i.e., the mechanism of bank collapse disaster chain of large reservoirs, the interaction mechanism of bank collapse disaster chain and territorial space utilization, the early identification, monitoring technology and ecological prevention and control technology system of disaster chain, and the territorial space geological safety and control technology system are focused. We consider the material transformation, energy transfer and information transmission in disaster chain; adopt the survey, Space-Air-Ground integrated monitoring, theoretical analysis, numerical simulation and the multidisciplinary research methods; reveal the chain source development, evolution process of secondary and derivative disasters; explore the interaction mechanism of disaster chain and territorial space utilization; construct the system of early identification, monitoring, early warning, control and ecological prevention to achieve Emission Peak and Carbon Neutrality; provide theoretical and technical support for the territorial space geological safety, regulation and utilization of large reservoirs.

Keywords

The Large Reservoirs, Disaster Chain, Disaster-Causing Mechanism, Territorial Space Utilization, Ecological Prevention

1. Introduction

1.1. Research Significance

The large reservoirs in China ranked first in the world as **Figure 1**. Reservoir regulation of natural runoff, flood control, irrigation, water supply, power generation and shipping play a very important role. Its comprehensive economic and ecological environmental protection benefits are huge. Under the complex engineering geological conditions, rainfall and other natural factors, it also superimposed the effects of flooding slope and water level fluctuation of reservoir operation, bringing about the changes of reservoir bank boundary conditions and loading and unloading action, resulting in the geological disasters characterized by frequent occurrence, serious harm and great influence. For example, the water level in the Three Gorges reservoir area rises above 100 m; variation reaches 30 m, which is the largest in the world.

According to statistics, The Three Gorges reservoir area covers 15,000 km², with a coastline length of 5311 km, 2548 geological disasters and a reservoir bank with low stability of 441 km. Bank collapse formed chain disaster, resulting in huge losses. Compared with the general geological disasters in mountainous areas, the geological disasters in reservoir area are more likely to occur, and the disaster process is more concealed, complicated and changeable. In addition, sudden large landslides and collapses in large reservoir areas are easy to cause surges and even form barrier lakes, resulting in long disaster chain and great destructive consequences, and posing a great threat to the utilization of territorial space.

Badong County, restricted by geological disasters, has been selected for three times and relocated twice. The new situation has put new demands on the utilization of territorial space. On the one hand, there should be sufficient territorial space guarantee for resettlement of the reservoir area, port construction, development of the riverside zone, and the guarantee of reservoir functions. However, due to the complex geological environment and frequent geological disasters in mountainous areas, the construction land is seriously insufficient. On the other

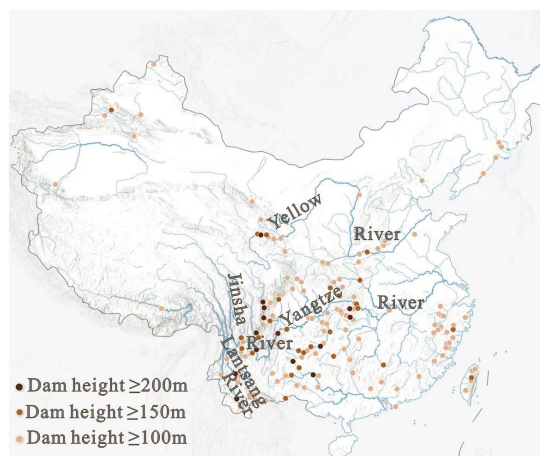


Figure 1. Distribution map of reservoir DAMS in China (Zheng, 2021).

hand, River Basin is a national key ecological function zone for soil and water conservation and biodiversity conservation, with important ecological location and strategic water source of the nation. The Ministry of Natural Resources of The State Council pointed out that ecological, agricultural, urban and other functional Spaces of river basins should be arranged in a scientific and orderly way, ecological protection red line, permanent basic farmland and urban development boundary should be delimited, spatial structure and layout of land should be optimized, and spatial utilization tasks of river basins should be led. The large reservoir area is an important carbon sink space in the natural ecosystem. Under the goal of carbon peak and carbon neutralization, the utilization of national space has a strong typicality, concentration and urgency. Therefore, it is urgent to promote the territorial space geological security, comprehensive regulation and ecological restoration of large reservoirs based on “Production-Living-Ecological” function.

In short, there are many large reservoirs in China, and bank collapse disasters are characterized by secrecy, complexity and chain formation. The chain of bank collapse disasters has a great impact on territorial space utilization, and its interaction mechanism is a difficulty in multidisciplinary integration research. In order to improve the predictability of bank collapse disaster chain of large reservoirs, achieve the purpose of disaster prevention, mitigation and relief, and sustainable utilization of territorial space, it is necessary and urgent to study the geological safety and control technology of territorial space utilization under the new situation, new requirements and new theoretical framework.

According to the characteristics of large-scale reservoir disasters, the main sources of bank collapse disaster chain are bank collapse, landslide and collapse. Secondary disasters are divided into landslide, collapse, debris flow; the derivative disasters include surge, dammed lake and dam break. At present, there is no scientific definition of the scope of territorial space utilization under the disaster chain. In view of the characteristics of large-scale reservoir disasters and territorial space utilization, this study believes that it should be adapted to the scope of geological disaster assessment in reservoir areas, and the scope of study is bounded by the first slope belt or the first watershed.

1.2. Research Status

Although bank collapse disaster poses great threat to economy, life and territorial space utilization, the mechanism of bank collapse disaster type and individual disaster body is relatively in-depth, but the study of bank collapse disaster chain and its mechanism is just starting (Menoni, 2001; Xu et al., 2015; Agha Kouchak et al., 2018; Yin & Peng, 2007). Many technologies and methods have emerged in the early identification, monitoring and spatio-temporal prediction of a single disaster body. The space-air-ground integration technology has become a hot research and application topic today, but the multi-scale and multi-level early identification and monitoring technology system for high vegetation, canyon

terrain and other environmental conditions has not been established. The research on early identification, spatio-temporal prediction and integrated methods of disaster chain is still blank (Das et al., 2011; Chen et al., 2012). Most of the researches on territorial space utilization in large reservoir area focus on the distribution characteristics and change pattern of land use, and a few of them focus on the interaction between geological hazards and land use. However, from the perspective of the formation process of disaster chain, it is still a blank to fully analyze the mechanism of interaction with territorial space utilization (Deng, et al., 2019). At present, the control design of bank collapse disaster remains in the allowable stress design method, and is dominated by many engineering measures. The ecological prevention and control technology under the dual carbon target is still in the stage of exploration and experiment (Xu, 2013; Ran et al., 2020).

2. Key Scientific and Technological Problems

To sum up, the main problems in the research field are as **Figure 2**:

- 1) Compared with the disaster-causing body of bank collapse disaster, the development of chain source of bank collapse disaster and the evolution process and mechanism of chain generated disaster are more complex and uncertain.
- 2) The multi-scale and multi-level early identification, monitoring technology and ecological prevention and control technology system for large reservoirs located in high vegetation, canyon terrain and other environmental conditions have not been established.
- 3) The interaction mechanism between shoreline disaster and territorial space utilization of large reservoirs is still blank, and the interaction between them is unclear and difficult to quantify.
- 4) The geological safety and control technology of land space utilization of large reservoirs under the dual carbon target is still in the exploration stage, and how to reduce carbon and carbon sink becomes an important topic of prevention and control technology in the future.

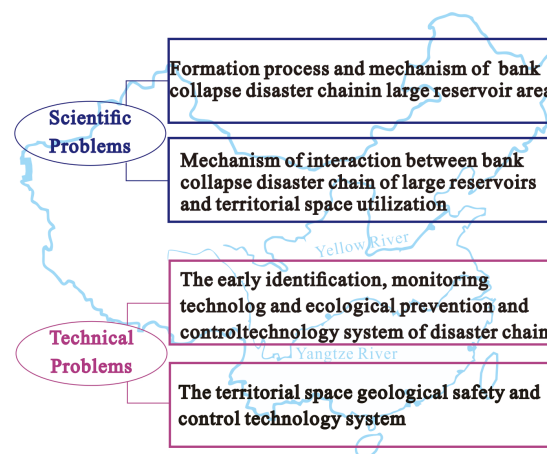


Figure 2. The map of scientific and technical problems.

3. Research Contents

Centering on the aforementioned condensed science and technology issues, this study includes the following four aspects (**Figure 3**):

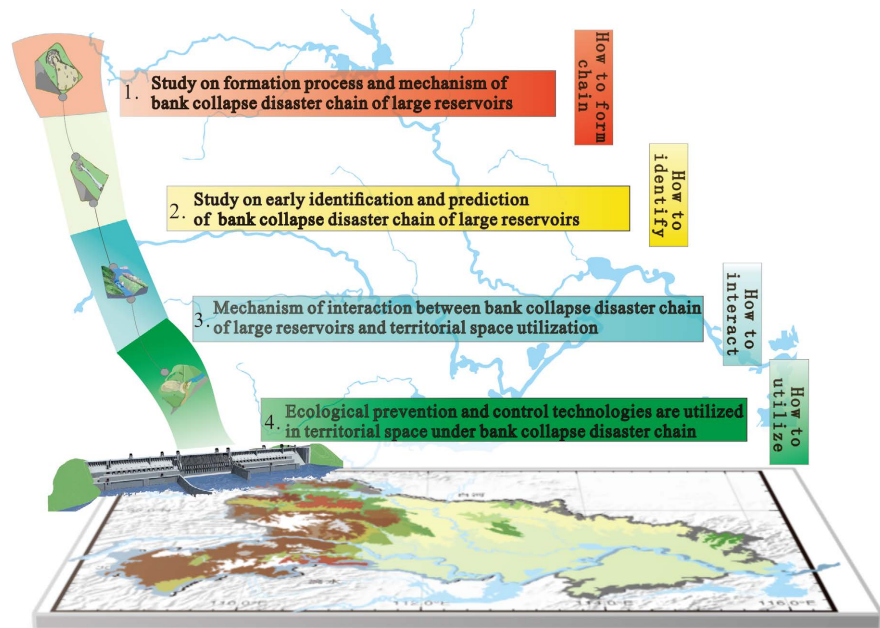


Figure 3. The map of research contents.

1) Study on formation process and mechanism of bank collapse disaster chain of large reservoir

Disaster chain perspective, from the material transformation, energy transfer and information transmission, studies the slope in natural rainfall and water level changes in the internal and external power, the source of bank collapse chain (bank collapse, landslide, collapse) emergence and development, and the resulting secondary disasters (landslide, debris flow), the derivative disasters (surge, barrier lake, dam break) evolution process. The geological, structural and hydrological background of the bank collapse damage ring is studied. Study the following five aspects: the geological, structural and hydrological background of the bank collapse hazard ring; The influences of non-geological factors such as reservoir impoundment, reservoir water fluctuation, rainstorm and territorial space utilization; The dynamic coupling mechanism of stress field and seepage field induced by disaster chain; The principle of progressive or attenuation of disaster chain energy, the relationship between material transformation and energy transfer, and the amplification effect of disaster chain; The mechanism and disaster-causing effect of major landslide blocking river and dam break. Summarize the disaster chain model and mechanism of bank collapse of large reservoirs. Studied on the spatial impact range of the initial, secondary and derivative disasters of the disaster chain. Divide the disaster grade of reservoir land, and establish the risk assessment method of bank collapse disaster chain (**Figure 4**).

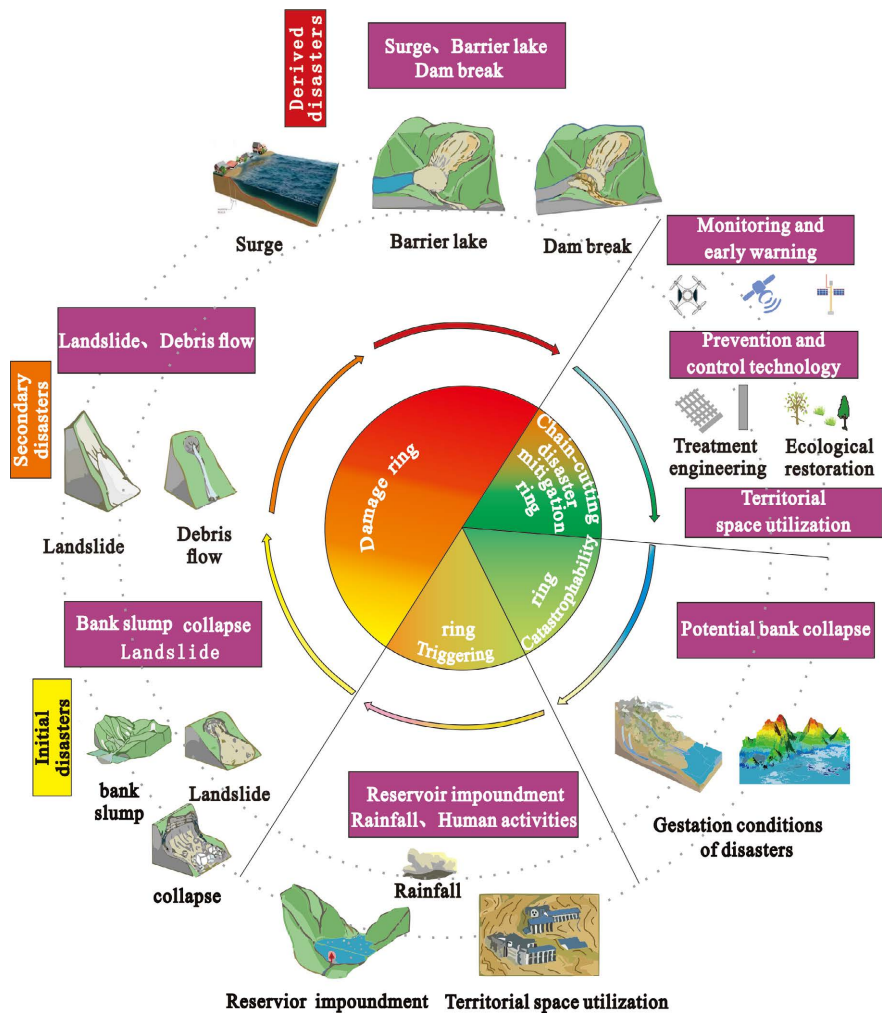


Figure 4. The map of research contents, bank collapse disaster chain, ecological prevention and control.

2) Study on early identification and disaster chain prediction of bank collapse of large reservoirs

From the perspective of disaster chain, research and develop the early identification, monitoring and early warning technology system of the whole chain disaster process of bank collapse. Explore and optimize the space-air-ground integration multi-source three-dimensional observation system based on space-borne platforms, aviation platforms and ground platforms. Study on multi-method, multi-level and multi-scale InSar monitoring technology for discriminant marks of early identification, monitoring and early warning technology, rapid investigation of disaster sources in the reservoir area under canyon type and high vegetation condition. Research the spatial, time prediction method and the framework of monitoring and early warning system based on digital twin technology for bank collapse disaster chain.

3) Study on interaction mechanism between bank collapse disaster chain of large reservoirs and territorial space utilization

Study on the interaction mechanism from the relationship between bank collapse disaster chain of large reservoirs and territorial space utilization. Research the driving process and mechanism of macro-spatial pattern and micro-utilization behavior on the development of disaster chain. Study the influence modes, processes and mechanisms of different geological disaster types on land cover, and delimit the maximum possible impact range. Explore the adjustment of territorial space planning and decision-making ideas after disasters, and reveal the process of government macro-planning for the disposal and restoration of disaster-affected land. Study the impact of potential geological disasters on the formulation of territorial space planning; the evolution process and logic mechanism of residents' land use pattern after geological disaster. Construct a theoretical model of interaction between territorial space utilization and disaster chain.

4) Ecological prevention and control technologies are used in territorial space under the chain of bank collapse disaster

Under the goal of carbon peak and carbon neutralization, study on ecological prevention and control technologies for land space utilization of large reservoirs under the chain of bank collapse disaster; the dual properties of the bank collapse disaster chain of large reservoirs and the complex carbon source and sink in territorial space utilization. Research on the safe, green and economical mode of disconnecting engineering measures and ecological measures; the key technologies of chain-cutting control for different types of disaster chain.

4. Research Objects

After There are many geological disasters in large reservoir areas, which do serious harm and have great influence, the problem of limited land space available, through joint research, reveals the reservoir bank collapse disaster chain mechanism, the interaction mechanism between the use of space and territorial space utilization, build the geological disaster chain early identification, monitoring and early warning system and ecological prevention and control technology, realize the purpose of disaster prevention, mitigation and relief and sustainable utilization of national space under the dual carbon target.

5. Research Methods

By analyzing the operation characteristics of large reservoirs, the distribution of geological disasters and the impact degree of bank collapse disaster chain, plan to select the Three Gorges Reservoir area as the research area, which has the largest reservoir capacity, the national key geological disaster prevention and control area, and the largest impact of geological disasters on territorial space utilization. According to the field investigation, then adjust the study area, and select the typical and representative catastrophic ring.

Through field survey and multi-source remote sensing monitoring, geological model and land cover type were established on the basis of finding out the back-

ground of disaster pregnancy and the status of territorial space utilization. On the basis of experimental test, theoretical study and mechanism, the mechanical model is established. Solid mechanics theory, fluid mechanics theory and dissipative structure theory are used to calculate and simulate the development and evolution process of bank collapse disaster chain, as well as material conversion and energy transfer in the evolution process. The coupling relationship between disaster characteristics and territorial space was established by spatial econometric method. Adopt GIS + BIM digital twin technology to build a disaster chain monitoring and early warning platform. Under the goal of carbon peak and carbon neutralization, researched and develop the geological safety and regulation technology of territorial space utilization under the chain of bank collapse disaster (Figure 5).

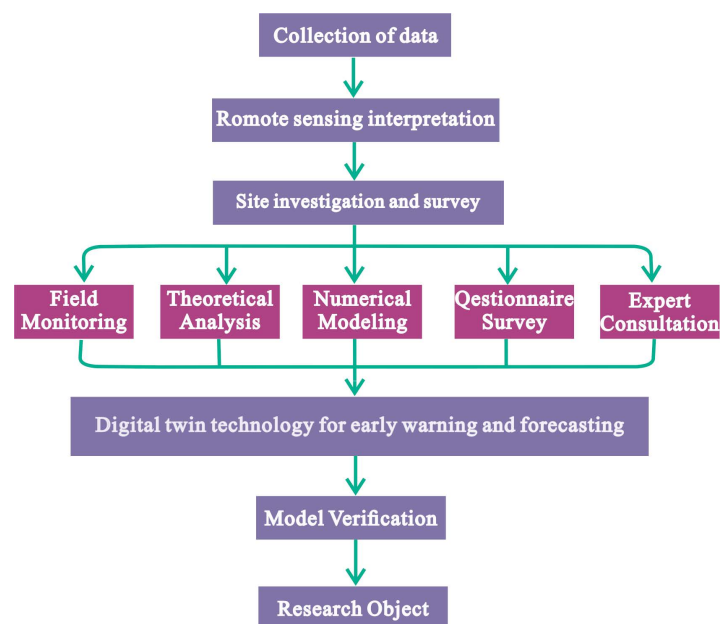


Figure 5. The map of research methods.

6. Technical Route

Focus on scientific problems, aiming at the research target, on the basis of field investigation gestation disasters background, combined with multi-scale, multi-level sky to early identification, monitoring, remote sensing. Apply geology, disaster, dynamics, fluid mechanics and ecology, etc multi-disciplinary methods and theories, combining with the point and face, macro and micro, qualitative and quantitative method. Study the development and evolution process mechanism of bank collapse disaster chain, establish disaster model, research the action mechanism between bank collapse disaster chain and territorial space utilization, and build regional ecological geological environment safety assessment and regulation system based on ecological geology theory. The technical route is shown in Figure 6.

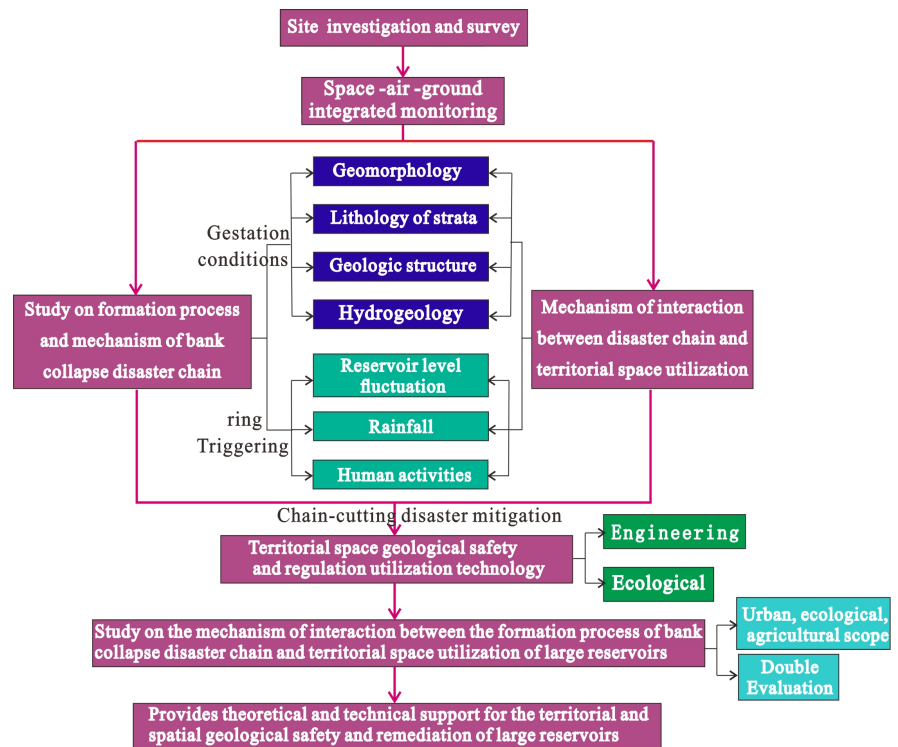


Figure 6. The map of technical route.

7. Conclusion

This paper introduces the research background, content, method, objective, method, technical route and experimental means of the interaction mechanism between the formation process of bank collapse disaster chain of large reservoirs and territorial space utilization. The summary is as follows:

The development of large-scale bank collapse disaster in the reservoir area has a serious impact on regional disaster prevention and mitigation, social and economic sustainable development, and territorial space planning and utilization, so it is of practical and strategic significance to carry out systematic and in-depth research.

Take the main line of research as “gestation mechanism of disaster chain → early recognition → evolution law of disaster chain → monitoring and early warning → risk prevention and control”. From theory to clarify the large space-time evolution process and mechanism of the reservoir bank collapse disaster chain, from technology to solve the early identification, monitoring and early warning technology and based on the whole process of disaster risk prevention and control technology. Forming the integrated evaluation system from early identification of bank collapse, disaster gestation mode, disaster formation mode, disaster process and disaster chain prediction to disaster reduction response.

Construct an early identification, monitoring and early warning system for large-scale reservoir disaster chain based on digital twin technology.

On the basis of analyzing the internal and external dynamics of disaster chain

development, reveal the dynamic mechanism and energy conversion mechanism of chain disasters, develop early identification technology and prevention and control technology for effective utilization of national space with the goal of dual carbon and disaster reduction, and demonstrate and apply it.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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