Research on Construct Scenario-Response Emergency Model of Dam Break

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Abstract. Scientific prediction and prevention of unexpected events are the key issues in emergency treatment. To tackle this problem, according to the common characteristics of dams collapsing, environmental pollution and other unexpected events with energy release, based on the idea of "Scenario-Response" and by constructing the physical model of the dam-break event. To analyzing the various reasons and the principle of disaster of the emergencies, and constructing mathematical intelligent prediction model based on the analysis of the factors in physical model, then analyzing the degree of control caused by the disaster factors through the mathematical intelligent prediction model, at last, proposed a prediction calculation formula for the emergency. Extensive simulation on the Jingjiang section of the Yangtze River realized the scientifically prediction method of dam-break event, and well solved the problem of the prediction and prevention scientifically for the emergency with energy release.

Keywords: Dams collapsing; Scenario-Response Emergency Model; Scientific prediction; Prevention.

1. Introduction

Occurrence of all types of emergencies, such as, earthquakes, typhoons, floods, river levee breaches, high temperature, fire, environmental pollution, traffic accidents, terrorist attacks, and the economic crisis, has brought a great threat and damage to nature and society and each aspect of our life! For those emergencies often has a sudden, serious consequence, a high degree of uncertainty, time constraints, the destruction of large, complex events, long-term potential changes, causing secondary, derivative events, serious impact on life and ecosystems, etc. [1,2]. More and more countries have realized that the need to strengthen the prevention and prediction of emergencies, and maximized avoid the occurrence of disasters. Many efforts have been made to address these difficulties form different angles and different disciplines, but how to detect early, prevent and avoid the occurrence of the events still lacking the advanced scientific research.

In this paper, the research aimed at the common characteristics of reservoir overflow and dam-break, based on the theory of "Scenario-Response", research how to construct the physical-mathematical model of that event, and analysis the impact of event factors on the emergency by the model. Achieving a scientific solution to address the unexpected events prediction, prevention avoidance and other issues.
2. Emergency Analysis

Emergency refers to the sudden occurrence of a major event that endangers the safety of life and property, in special circumstances, due to the drastic changes in the internal conditions of the system and the external environment, the stability and controllability of the system are destroyed, the behavior of the system appears abnormal situation and a class of non-order accident occurring qualitative, is a kind of sudden occurrence under the control of some certain factors, that cause serious harm, loss, and influence to the society, and the negative events need to be dealt with immediately [3,4]. The system includes: a disaster body, ontology and a disaster bearing body.

Emergencies by event origin can be divided into: natural disasters and man-made disasters; according to physical energy-release characteristics into: energy-release events and no energy-release events; according to the scope of the disaster can be divided into: fixed space events and open space events; According to the social attributes can be divided into: political events, economic events and life events; According to the events evolution trend can be divided into: original, secondary and derivative events.

Through analyzing the characteristics of physical energy accumulation, conventional emergencies is mainly due to the disaster causing factors gather energy to event ontology, when the energy reaches the limit, instantaneous release and cause disaster. In the process of energy collection, some events have no energy release, such as: gas tank explosion, high pressure pipe explosion, some events have a slow release of energy, such as: dam break, environmental pollution, etc.

In this case, the research and analysis of the construction of the physical-mathematical model of the events that belong to the same reservoir dam-break events, which is the energy release, and accompanied with complex secondary and derivative events.

3. The Threat of the Model of the Energy Release Event of Dam-break

Dam-break events refer to emergency flood disaster caused by rainfall and threat to the dam of the reservoir then occurs in reservoir water overflow or dam-breach. Those incidents belong to the normal incident, which is effected by a variety of disaster factors, the massive information with uncertainly, at present we mainly based on experience value to get limited prediction and prevention, and control developments. But in order to achieve scientific, efficient and effective prediction , it is need to study the internal principle of disaster causing factors, and construct the physical model and mathematical analyze model, based on the theory of "Scenario-Response", then, scientific analysis and research on events [5,6].

3.1. The Physical Model Construct

The dam-break event is a typical event occurring in the open space with a slow release of energy. The scene simulation model is shown in figure 1, and the corresponding physical model is shown in figure 2.

![Figure 1. Cause analysis of dam-break emergency.](image-url)
3.1.1. Analysis of Model Factor

Some of factors are as follows:

- A hazard-affected body: rainfall, the water upstream and tributary, dam quality etc.
- Disaster causing factor: the upper reaches and tributaries water, reservoir capacity, dam height, dam pressure strength.
- Disaster events: overflow, burst.
- Secondary events: dispersion, piping etc.
- Derivative event: environmental pollution. Epidemic, etc.
- Disaster bearing body: life ecosystem, hosing, crops, breeding industry.
- Disaster behavior: flooded, destroyed, impact.
- Disaster results: the life of casualties, building collapsed, crops flooded, aquatic escape [7].
- Energy releases characteristics: energy release.
- Scope of accident: open range.
- Accident genus: floods, flash floods, landslides, river dam breach, typhoon, tsunami, environmental pollution etc.
- Time attributes: both long-term events, such as heavy rain floods, and other disasters, there are moments of event, such as: flash floods, landslides, river embankment breach and tsunami.
- Disaster reduction: dam heightens, reinforced embankment quality, increase storage capacity, dredge waterways increase storage capacity, clear waterways increase flood discharge, evacuated downstream people.
- Preventive properties: limited prediction, limited prevention, limited control.

3.1.2. Analysis of Disaster Causing Principle

Disaster causing principle: when the tributary imports amount is more than it, the water flow rate is less than the sum of each tributary import flow, the overflow or dam-break event occurred [8], which have a threat and harm to people and things in downstream.

Energy conversion principle: Tributary inflow reservoir, water increases. The water-energy increased, that is, energy accumulation. The sluice reservoir spillway, reservoir water decreased, water potential energy decreased. When the potential energy of water is increased faster than the potential energy reduced speed, the total potential energy of the water in the reservoir will increase. When the total potential energy of the reservoir is greater than the total capacity of the reservoir, the free diffusion of water potential energy will occur, which will lead to disaster.

Analysis of physical equation:

Set the total reservoir capacity M, existing capacity N, the average per second inflow V1, V2,…. Vn cubic meters, the sluice outflow U, the time filled with a reservoir is H. When more than H, overflow or bursts events, H calculated by the formula (1):

\[ H = \frac{(M - N)}{(V1 + V2 + \ldots + Vn - U)} \] (1)
3.2. Mathematical Intelligent Prediction Model Construction

There are three main characteristics of this reservoir model: reservoir capacity, inflow and outflow. The reservoir capacity is fixed, which is determined by the height of the dam, the amount of the inflow and outflow are dynamic measured. According to the characteristic of the reservoir, the mathematical model for the reservoir is shown in Figure 3:

![Diagram of Mathematical Model of Dam-Break Event](image_url)

**Figure 3.** Mathematical model of the dam-break event.

There a reservoir, set its long to be signed L, width W, height H, the sluice is a trapezoid, set upper line A, lower line B, height C. The amount of inflow and outflow is the function of time $t$, inflow amount: $E = f(t)$, outflow amount: $G = g(t)$, the unit is: m$^3$/s. The rising speed of reservoir is a function of time $t$, set as $h(t)$, the unit is: m/s.

There is: inflow-outflow = increase. That is:

$$f(t) - g(t) = \frac{L \times W \times h(t)}{h(t)}$$

After a time $t$, the height of the water level rise:

$$H = \int_{0}^{t} h(t) dt = \frac{1}{L \times W} \int_{0}^{t} (f(t) - g(t)) dt$$

From the above analysis, we can see that if the function $f(t)$, $g(t)$ and $H$ are known, the time $t$ can be calculated. Therefore, the mathematical model has the intelligent features of scientific prediction, and its intelligence is mainly reflected in the changes through the computer dynamic simulation of variable $H$, dynamic prediction of dam break events occurred.

4. Simulation Calculation the Jingjiang River as An Example

Assume that the full length of Jingjiang River Section of the Yangtze River $L = 100$km, the cross-section is trapezoidal, as shown in Figure 4, the average width between the two sides of the embankment $W_1 = 1000$ meters, the width of the button $W_2 = 100$ meters, dam surface form the bottom $H_1 = 30$ meters deep, the current water and dam surface $H_2 = 10$ meters in height (the maximum depth is 20 meters).

4.1. Then Calculate the Following Questions:

1) The upstream is 18 thousand cubic meters per second, each tributary inflow accumulated to 8000 cubic meters per second, the downstream is 2 meters per second. Whether the river would overflow surface? Not, please calculate the height from the water surface to the dam surface.

2) The total amount of the upstream and tributary water arrived how much, river will overflow surface? The amount is called the critical water content.

3) The current water surface and dam surface $H_2 = 10$ meters in height, when the amount of water reaches the critical water content, how many minutes after the river will overflow surface?

4.2. Analysis of Problem Solving:

1) When the water inflow over water outflow, will increase the height of the water surface, at the same time, downstream water volume increased with the increase of the water surface, so the discharge will increase. When inflow and water discharge is equal, the height of the river water is in equilibrium. Then calculate the equilibrium state, the outlet water surface height $H$ (unit m).

By the question, per second, the total amount of water: 26000 cubic meters. The following formula can be deduced from figure 4:
Figure 4. Cross section of the Yangtze River.

\[(15H+100) \times H \times 2 = 26000\]

Calculated:

\[H = 26.29 \text{ M}\]

Reason: the water from the surface height: 30-26.29 = 3.71 M, the river will not overflow the dam, but it is close to the warming line.

2) By the question you know, the critical water overflow is means the maximum of downstream discharge, because the cross-section of the Yangtze River is: \((1000+100)\times 30/2\), speed of 2 m/s. The maximum amount of water discharge in the downstream:

\[W = (1000+10)\times 30/2\times 2 = 33000(\text{m}^3/\text{s})\]

Namely, when the upstream and each branch into the water are more than 3300m3/s, water will overflow dam.

3) The issue is a complex problem, according to several classical cases analysis and discussed below:

First: when the upstream water inlet and tributary waters inlet are in the same place, for there has no buffer section, when the total amount of water reached the critical water content, it also reached the dam surface, and is about to overflow.

Second: Uneven distribution of points in each branch, at this point, accumulate from the upstream of the inlet to downstream tributaries inflow, when the accumulated amount reaches or exceeds the critical water content, the point of this river tributary is the place where the river overflow dam surface. Now supposes that point is 100km from the upstream water inlet.

When the water inflow over water outflow, the height of the water surface will increase, at the same time, the downstream water outflow increase with the rise of the water, therefore, the water discharge will increase. The height of water from the initial 20 meters to 30 meters is a dynamic increasing process.

From the experience, the upstream and each branch into the water are \(f(t) = 33000 + 100\sqrt{t} \text{ m}^3/\text{s}\), outflow amount \(G(t) = 8250\log(t+1) \text{ m}^3/\text{s}\), calculated by Figure 4, when \(H = 20(\text{m}), W = 700(\text{m})\), by the formula(2):

\[H = \frac{2}{L(A+B)} \int_0^T (33000 + 100\sqrt{t} - 8250\log(t + 1))dt\]

Simplify:

\[H = \frac{2}{L(A+B)} (33000T + \frac{200}{3}T^\frac{3}{2} - \frac{8250}{ln10} (T + 1)(\ln(T + 1) - 1))\]

Among them:

\[H=10; L=1000000; A=1000; B=700\]

Can be calculated \(T = 62218\), second = 17 hours 16 minutes 58 second

Therefore, after 17 hours 16 minutes 58 second, the water will overflow surface!
5. Conclusion

Research on Construct Emergency "Scenario-Response" Model of Dam-Break > based on the theory of "Scenario-Response" Model, construct the physical analysis model, from the view of energy accumulate, detailed analyzed the role of each factor in the model of emergency and the physical equation of the event burst; built the mathematical model of dam-break, based on the physical model; according to the mathematical model, the influence of each factor on the emergency events are analyzed in detail, the construction of the prediction physical-mathematic model of the dam-break event, can well solve the dam-break, environmental pollution, epidemic spread and have energy-release of the conventional emergency of scientific prediction, prevention and avoid events and other difficult issues, provide the theoretical support for government to handing emergencies. In this paper, we need to do a lot of simulation calculation while getting the more accurate data, and the demand for manpower and material resources is high, which needs further improvement.

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