# Trial of Visualization of Risk Structure for Effective Operation and Maintenance of Dams

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## 1. Introduction

At dams in Japan, operation and maintenance (O&M) are conducted through daily inspections by patrol and measurements and periodic inspection by experts other than the dam administrator. Recently, efforts of detailed investigation, analysis, testing, etc. for soundness assessments of dams in long-term operation are also being made as Comprehensive Dam Inspections (CDI), [1] in order to prepare the future O&M plan for life extension of each dam. Although the most important purpose of these efforts is to determine the condition of the facility and identify issues for O&M, they can also be considered significant when used as an opportunity to recognize the location of risks that can have undesirable effects on the safety and functions of dams.

In individual dams, siting conditions such as the geology and environment of the site, the dam materials and structure, construction conditions, and operating conditions differ widely. Moreover, there is also a possibility that dams may be affected by large-scale external actions in the form of heavy rain, earthquakes, etc. while in service for many years. In addition, the effect of deterioration of the materials of the dam body over time, although slow, is also a conceivable problem. To enable more rational and effective O&M of dam structures over the long term, it is essential to recognize, as well as possible, the characteristic risks of each individual dam due to combinations of various types of factors and the structure of those risks (scenarios), and to implement appropriate management of those risks.

As one risk management technique in O&M of dam structures, we have been discussed a practical work method which makes it possible to recognize diverse risks and their levels by visualization of the risk structure. As a case study, this article introduces a trial attempt of this method to a model concrete dam where a comprehensive dam inspection was conducted.

## 2. Visualization of risk structure (scenarios)

In this trial, first, we attempted to visualize the structure of the conceivable risks at the model dam. Since no evidences that would clearly affect the safety and functions of the model dam have been reported, we wrote out various events that may have occurred in the past and may have occur in the future on the basis of site conditions (including geological ones) which were recognized and handled at the time of construction, slight changes in condition of the dam reported in past inspections (including the trend of measurement data) etc. and grouped them that are considered to be interrelated. Then, assuming that risk can be

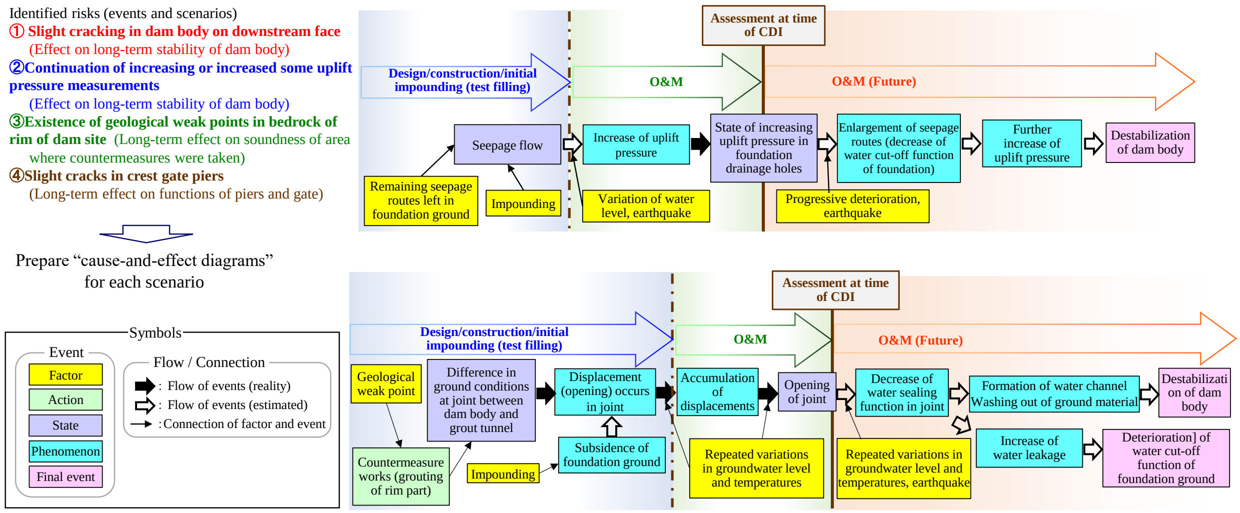
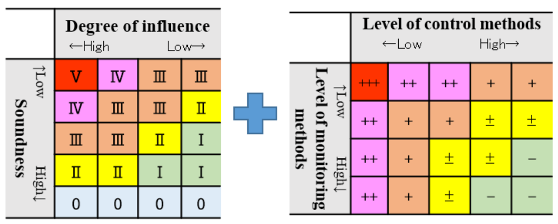



**Fig.-1** Creation of "cause-and-effect diagram" by risk scenario (example in trial) captured by these group units, we prepared multiple "cause-and-effect diagrams" (**Fig.-1**) plotting the internal factors (geology, materials, construction, etc.) that may possibly become causes or inducing factors for various known events, external factors (external actions, etc.), the mutual (cause-effect) relationship between events and the scenarios assumed in the future.

## 3. Assessment of risk levels of scenarios

Next, we attempted a trial assessment of the risk levels of each of the scenarios shown in the "cause-and-effect diagrams," considering the possibility of risk materialization and its final degree of influence on the safety and functions of the dam. It should be noted that quantitative assessments are difficult in the case of dams, because the examples of risk materialization are limited and, as a result, adequate data for a cause analysis are not available. Therefore, in this trial, the level of risk for each scenario was assessed in several levels based on a combination of the "soundness" assessment results (reported in the recent CDI) related to events included in each "cause-and-effect diagram" and the degree of influence in case the risk finally materialized as a result of further progress of a series of related events in the future. The assessment of the "management level" was then added considering the assessment of the "risk level" based on a combination of factors, that is, whether some monitoring methods (e.g., measurements) are available or not, and if so, their reliability, and the status of the control methods (i.e., countermeasures) applied to the facility (**Fig.-2**). The following **Table** shows the levels of risk assessed on a trial basis by this method for each of the scenarios in **Fig.-1**.




(a) Assessment by soundness and degree of influence (basic method)

(b) Addition of management level

**Fig.-2** Method of assessing risk levels

**Table** Assessment of risk levels of scenarios (example in trial)

| Scenarios | Soundness ×Degree of influence | Management level | Levels of risk |
|---|---|---|---|
| ① | Ⅱ | ++ | Ⅱ++ |
| ②* | Ⅲ | + | Ⅲ+ |
| ③ | Ⅱ | ++ | Ⅱ++ |
| ④ | Ⅲ | ± | Ⅲ |

* : Implementation of countermeasures has been completed for ②, which was assessed as having the highest risk level in these four scenarios.

## 4. Risk communication

The visualization of risk structure (scenarios) and risk level assessment must be performed as far as possible on the basis of objective information such as design and construction records, inspection results, etc. However, none of this work can be performed mechanically. Therefore, in this trial, preparation of the "cause-and-effect diagrams" and the assessment of the risk level based on the diagrams were carried out through a process of discussions as "risk communication" (**Photo**) in order to reach a mutual understanding, on the basis of sharing of design- and construction-related materials, inspection records, etc. and joint site confirmation, with the participation of the dam administrator, and experienced persons with different standpoints and fields of expertise, including engineers and experts in various fields such as geology, structures, hydraulic design, etc.

**Photo** Discussions for risk communication

## 5. Conclusion and future development

The method we have tried is expected to be useful in enhancing the quality of O&M of dam facilities, particularly from the viewpoint of facilitating an understanding of the locations of risk and the necessity and importance of action responding to individual risks, through the process of capturing the organic linkage of information such as the trends in measurement data and information on changes in the dam condition, etc., which tend to be perceived at a glance as separate events, and studying their progress along the temporal axis. One of the key to achieving practical effectiveness in these efforts is risk communication and enhancement of its skill. We would like to continue this trial in the future, and compile some technical materials showing how to use this methods effectively in combination with existing approaches such as CDI, so as to contribute to securing even greater safety and realizing long life in dam structures.

## Reference


1) Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Water and Disaster Management Bureau, River Environment Division: Comprehensive Dam Inspection Manual and Commentary" (in Japanese)
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