MONITORING AND EVALUATING DAMS AND RESERVOIRS

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Contents

Summary

The purpose of dam management is to obtain the effectiveness of the dam as greatly as possible by operating the dam safely and appropriately. The dam project should be planned considering other projects or river facilities in its river basin to demonstrate its purpose effectively. Furthermore, it is necessary to execute the investigation carefully from the early stage so as not to generate stagnation or retreat because the dam project is large-scale and needed much cost for construction. Because the appearance of the dam reservoir exerts a big influence on the environment, the mitigation or conservation should be considered to decrease the influence as much as possible. As the dam reservoir is forming by damming of the existing river, the management and operation of the dam should be carried out safely and properly unlike other facilities. In addition, the dam should be operated for a long period of time in proper condition, so the countermeasure for the sedimentation is important for the longevity of dam reservoir,

At this topic level contribution, summary and evaluation of seven themes at article level contribution concerning the environmental impact, hydrological surveys, predictions of the maximum precipitation and the maximum flood, the feasibility study, accumulation of sediments, instrumentation and monitoring, and dam safety are described.

1. Introduction

Vast quantities of dams constructed in the world are functioning properly and satisfying each anticipated purpose by appropriate management and monitoring. However, in existing dams, the longevity is sometimes severe problem representing the aging or the sedimentation. In newly planned dams, mitigation of environmental impact or resettlement of inhabitants becomes the themes to be resolved. In this century, the demand of much more water resources are forecasted in world wide level and the roles of dam reservoirs are expected furthermore. So, we should give much attention with above-mentioned problems.

In this topic level contribution, summary and evaluation of the following themes in article level contribution are described.

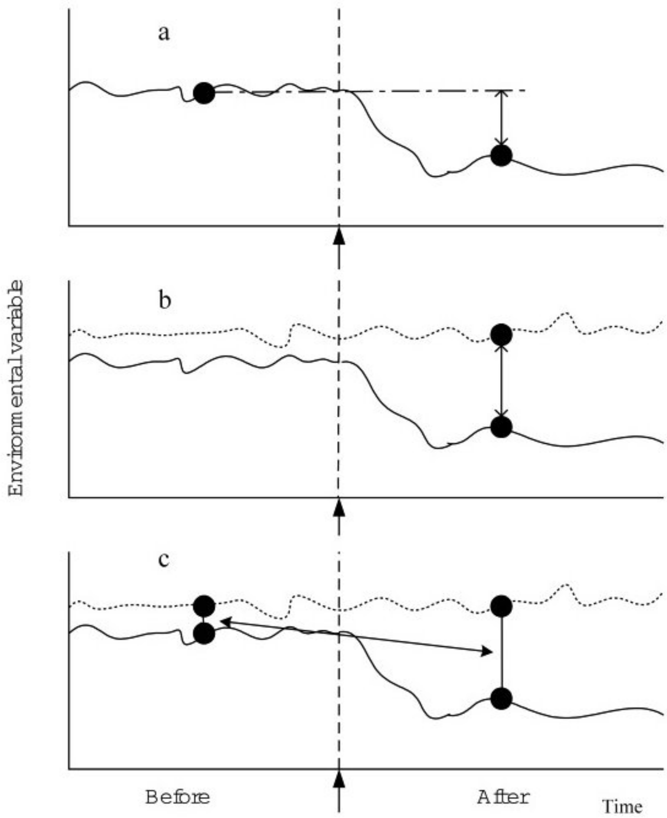
1 Environmental Impact Assessment of Dams and Reservoirs
2 Hydrologic Studies of Dams and Reservoirs
3 Predictions of Maximum Precipitation and Maximum Floods
4 Feasibility Studies for Dams and Reservoirs
5 Accumulation of Sediments in Reservoirs
6 Instrumentation and Monitoring of Dams and Reservoirs
7 Dam Safety

2. Environmental Impact Assessment of Dams and Reservoirs

A dam project results in a large area being submerged under reservoir water and has great impacts on various environments. Usually, the larger the size of the project, the greater the impacts are on the natural and social environments. However, a series of small dams give the impacts to the environment severely compared to the case of one large dam project (Ohsugi, et al. 2004) .

Factors concerning environmental impacts frequently exist in a mutual trade-off relationship. The relationship does not necessarily become apparent immediately after the completion of a project, but gradually by being affected by the peripheral environments over a long period of time. Therefore, monitoring of environmental impacts for a long time after completion is very important. Monitoring the environmental impacts of a project is more effective than predicting the impacts for understanding the reality and thus should be started as soon as the project is completed. On-going surveys of ecosystems in numerous dams and reservoirs should be noted because they may provide useful information for dam projects in future. Uncertain elements should be eliminated as much as possible since there are a number of factors complexly involved in impacts to the environment.

In order to understand impacts to the environment, comparisons of impacts before and after the completion of the dam project must be made. Precise surveys on the habitat and organisms after the dam construction do not reveal the effects of the dam. Furthermore, the effects can be understood only when the states where the effects are received by the dam project are compared with those where no effects are received. In the conditions of two places, the subjects to be compared should be identical except for the factor to be investigated (Yasuda and Ichiyanagi 2003). One method is to compare "before the project", which is a state not affected by the project, and "after the project" (Figure 1). Another method is to compare an affected place with a similar but unaffected place. Application of this method for a dam project is shown in Figure 2. Transitions in an impact site and a control site were monitored to identify the effects. Influences by natural process in terms of both space and duration were eliminated as much as possible. This is usually called the BACI design, and is also effective for eliminating differences of monitoring results by the person in charge of surveys when impacts need to be monitored over a long period of time (Green 1979, Stewart-Oaten, et al. 1986, Underwood 1991, Humphery, et al. 1995).



a; Comparison of "Before the project" and "After the project" at the impact site.
b; Comparison of impact site and control site "After the project".
c; Comparison of "Before the project" and "After the project" at the difference between impact site and control site.
Solid line; change of indicator at impact site.
Dashed line; change of indicator at control site.

Figure 1 Various comparisons.

Dam projects cut off the flow of river water, and obviously affect the environments in the lower reaches. Flexible reservoir management is an practical method for improving the environment in the lower reaches. As shown in Figures 3 and 4, water is temporarily stored by setting a water level for usable storage as a part of the flood storage. The water level for usable storage is higher than the limit water level for flood season when no danger of floods is expected in prediction of the rainfall. Since the usable storage is a part of the flood control capacity, the water level must be lowered to ensure sufficient flood control capacity when flood is anticipated. Therefore, highly accurate rainfall prediction is demanded. The reservoir water is discharged to improve the environment in the lower reaches. Discharge patterns include increase in flow rate to improve landscape and the habitat of fish, and flushing, which aims to stir up the riverbed and clean accumulated silt and dirt (Harada and Yasuda, 2004).

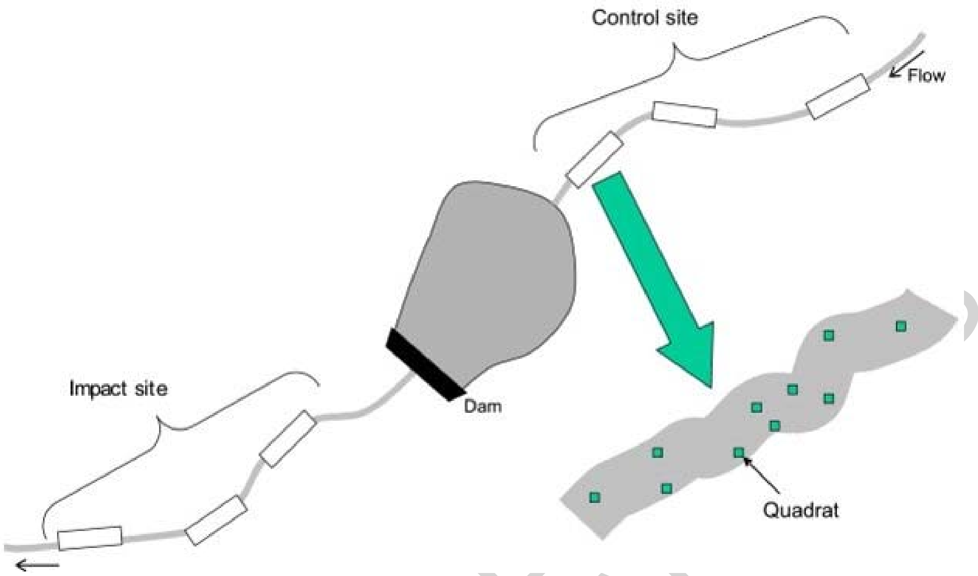


Figure 2 Impact and control sites in environmental impact assessment.

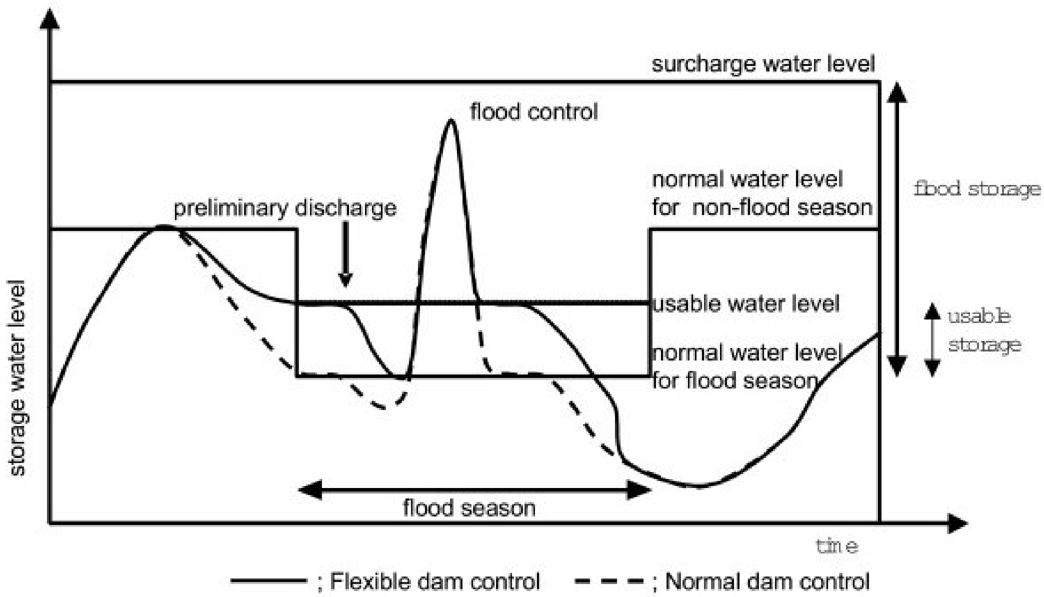


Figure 3 Discharge pattern during water utilization period.

As described before, monitoring is necessary to understand the actual states and execute flexible control of a dam reservoir. Important subjects to be monitored in the lower reaches are to establish the indices to be used to improve the environment. Impacts to animals and plants in the lower reaches, which are, in other words, changes in the habitats of animals and plants, are one of the indices. Changes in physical environment of the river, such as stability of riverbed materials and soil supply, should also be noted. Animals and plants live in physical environments, and the impacts to them can be qualitatively analyzed by investigating the physical environment. Monitoring of the lower reaches enables effective flexible control to be executed.

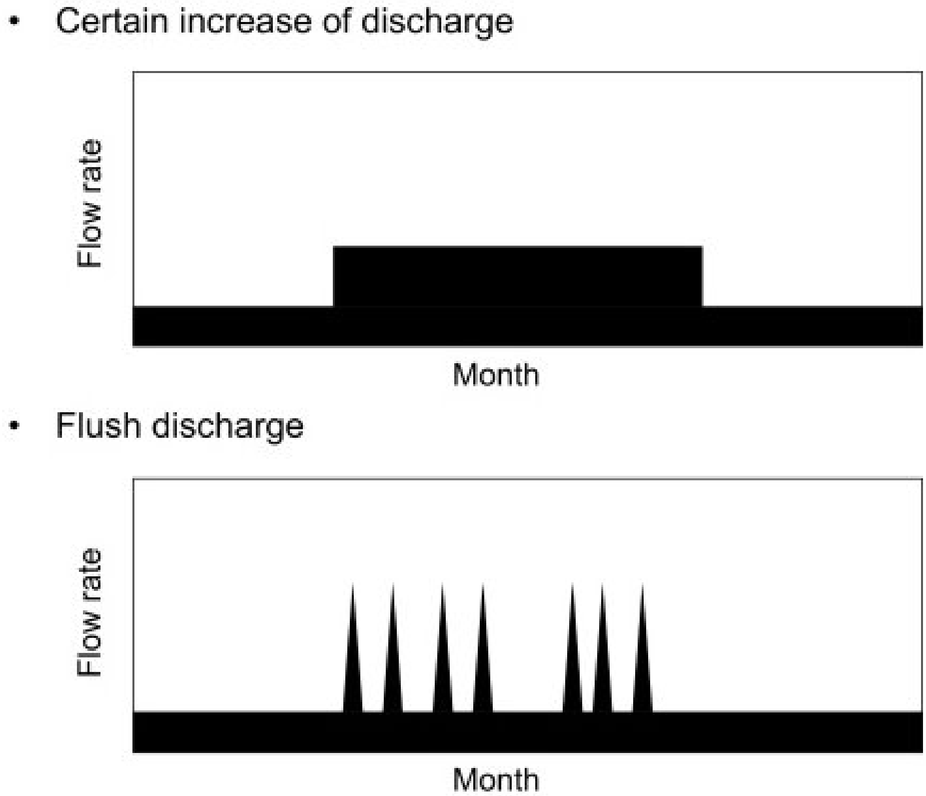


Figure 4 Discharge patterns of inflow water.

3. Hydrologic Studies of Dams and Reservoirs

Runoff analysis estimates the amount of water that flows into a river during a rainfall. The analysis consists of two general processes. The first is to identify the relationship between precipitation and river flow rate based on their data. This is analysis in a narrow sense and is also called identification of a model. The other activity is to estimate the river flow rate from an arbitrary precipitation value using the identified model. The objectives of runoff analysis are classified into 1) flood control and water resource planning, and 2) control of running water.

To plan a dam project, flow rate data of the corresponding river is needed, but there are few records available on flow rates. On the other hand, precipitation data is usually much more abundant than flow rate data.

A runoff model is identified using a period for which both the rainfall and flow rate data are available. Then, the flow rate of the river over a long period of time is estimated by substituting the rainfall data in the runoff model. Flow rates that occur very infrequently, such as flood discharges of 1/100 and 1/200 probabilities, can be estimated for flood control plans by statistically processing and extrapolating the existing flow rate data. However, a small amount of data increases the risk of error during extrapolation. In order to avoid such a risk, a large amount of rainfall data is sometimes statistically processed at first to calculate rainfall values of little frequency, which are then used to estimate the targeted flow rates using a runoff model.

Various measures can be taken against floods and droughts if they can be predicted in advance. Facilities that can control water discharge, such as dams, enable to take such measures efficiently. Prediction of river flow rates is also very important for appropriate dam operation. Runoff analysis is thus needed to predict running water. In such a case, the output of analysis is flow rate. Present discharge data as well as precipitation can be properly used as an input. Precipitation can be monitored using ordinary and automatic rain gauges. Precipitation monitoring gives point data. However, precipitation data needed for planning and management of river and dam is the area rainfall in a basin. Therefore, rain gauges must be installed at sites where the monitored values are the representative precipitation values. At the sites, precipitation must be correctly monitored. It is desirable that the landform is flat and the air current is horizontal. There should be no obstacles nearby, and monitoring over a long period of time should be possible. The gauges should be appropriately maintained to enable long-term monitoring with no missing data.

Water levels are monitored using water gauges and automatic water gauges. Automatic water level gauges are, in principle, accompanied by water gauges, which are the yardstick for the water level. Data on changes in flow rate over a long period of time and flow rate data during floods are needed to draw up water resource development plans and flood control plans. River flow is defined as the product of monitored flow rate at a time and measured cross-section area of the river. Flow rate is usually monitored using a flowmeter or a float. Since flow is difficult to monitor continuously, unlike rainfall and water level, flow at each time is calculated by determining the relationship (H-Q curve) between the water level (H) and the flow rate (Q) from available flow data and then using water level data that is continuous in terms of time.

As recent trends in hydrological monitoring, the study on GFAS (Global Flood Alert System) is carried out for developing countries. Most countries in the world have automatic monitoring systems, although they may not all be considered satisfactory. To predict floods, monitored data must be available by the next day at the latest. Thus, monitored data should be collected more frequently than once every two weeks or every month. The combination of a rainfall prediction system, which uses a satellite, and hazard maps is effective for preventing the disaster from floods. This method can also be used as a flood prediction and alarm system in developing nations that have no telemetric rainfall-monitoring network.

4. Predictions of Maximum Precipitations and Maximum Floods

The natural disasters in the world, have experienced the increasing evolution during the last decades of the 20th century, producing at present a mean of some 40,000 victims per year and mean economic losses of more than 50 billion $ per year. The number of major natural disasters during the period between 1963 and 1992 has been multiplied by 3.5 with relation to the affected people, and by 2.3 in relation to the number of victims (Zupka 1988).

Within the natural disasters, the greater number correspond to floods which suppose about 30% of the socio-economic impacts (32% in relation to the damage with the affected people, and 26% in relation to the significant damage with the number of deaths) (Zupka 1988).

It can be observed that in South Korea they represent some 500M$, Spain 600M$, China 3,000M$, but the most important damages are produced in very developed countries, United States with 3,400M$, and Japan with 7,200M$ per year. Also, it is necessary to quote the significant impacts and economic damages produced by the floods in several developing countries could become the cause of limiting their development.

So then, the experience shows that the damages caused by the floods continue to increase progressively, and in many countries constitute a veritable restraint to the economic and sustainable development. For this, the UN decided in the year 1987 to create the International Decade for Natural Disaster Reduction (IDNDR) for the ten years 1990 - 2000 with the objective of reducing by way of concerted international action, especially in the developing countries, the loss of lives, material damages and the social and economic disorders caused by the natural hazards (IDNHR 1994, UN 1987).

The studies of extreme floods at world level date from the year 1984, when the International Association of Hydrological Sciences (IAHS), published the " World catalogue of maximum observed floods " (Rodier and Roche 1984). These studies show that the maximum floods observed, are limited by an envelope curve, which adapted well to the equation of peak flow and catchment area given by Francou-Rodier (Francou and Rodier 1967):

Analyzing the natural history of the floods, the measures to prevent and reduce the damages produced by the floods, could be classified in two large groups (Berga 2000). They are a) structural actions and b) non-structural actions.

The planning of the flood hazard reduction measures should be carried out as regards the whole of the basin. The actions as a whole should be considered as a system of integrated measures, developing in each case the implanting of combined measures which contemplate the joint application of structural and non-structural measures. It is necessary in many cases to introduce zonings and land-use patterns downstream of the dam, and also implant the flood forecasting and flood warning systems, which are essential for the emergency action plans.

Within the measures in the floods fighting, the role of dams and reservoirs should be emphasized, since the dams constitute a very efficient structural measure, as they are the only solution which permits the storage of large quantities of flood volumes, modifying significantly the flood routing, and being able to reduce the peak flood in an important manner.

The ICOLD Committee on Dams and Floods has studied and analyzed diverse significant cases, which show with quantitative values, the important role played by dams in the flood mitigation (ICOLD 2000). The cases analyzed refer to the flood control in ample areas with important flood problems, in Japan, USA, Brazil, China, Korea, Norway, Spain, etc., in which, in general, are combined the effects of the reservoirs, dams, levees and river canalizations, together with the operation in real time of flood forecasting and warning systems.

In general, in the cases analyzed by the ICOLD Committee on Dams and Floods, the effects in the flood mitigation were very significant, with values varying between 25% to 85% in the reduction of the peak flow. The reduction of the flood volume varied from 10% to 73%, with greater values in the cases in which the flood reservoir capacity was high in relation with the flood volume, and in the cases in which the main purpose of the dam was the flood mitigation.

At the present time close to 20% of the total of the existing large dams have as a purpose that of flood control, be it a single purpose (8%), or as one of its principal objectives. In the future it has been indicated that due to the exponential growth of the damages produced by the floods, it will be necessary to increase the measures of prevention and reduction of damages, for which the implantation and construction of new flood control dams will be necessary, together with measures which control the progressive occupation of the flood plains and the improvement of the reliability of the flood forecasting systems. For this, an increase of the flood mitigation dams is to be foreseen in the future, with extensive flood mitigation plans, as are the cases of Japan, China, Spain and some areas of the USA.

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