1992

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Published in Hydraulic Engineering: Saving a Threatened Resource—In Search of Solutions: Proceedings of the Hydraulic Engineering sessions at Water Forum '92.
Baltimore, Maryland, August 2–6, 1992. Published by American Society of Civil Engineers.

Structural and Non-Structural Alternatives for Accommodating Larger Floods at Dams

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Abstract

This paper provides an overview of structural and non-structural alternatives for accommodating larger floods at dams. The first two alternatives discussed, raising the height of the project and/or lowering the reservoir pool, can be used to prevent overtopping by increasing the available floodwater detention storage in the reservoir. Data gathered by an ASCE task committee survey on modifications that include increased storage by raising project height are summarized and discussed. The third alternative discussed, early warning systems, can provide a low cost alternative to structural modifications. Case studies for the warning systems at the Santee Cooper North Dam and the TVA Blue Ridge Dam are presented.

Introduction

Since the Federal Guidelines for Dam Safety were published in 1979, dam owners have been assessing the safety of their dams in regard to current design criteria. For those projects that were shown to be hydrologically deficient, modifications that would allow the project to safety pass an appropriate design flood were evaluated. Numerous projects have been modified since 1979 to meet present hydrologic design criteria. In order to inventory and evaluate alternatives for safely accommodating new or revised design floods, the ASCE Hydraulics Division Task Committee on Alternatives for Overtopping Protection was established.

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This paper discusses the findings of the ASCE task committee specifically relating to dam safety modifications that include parapet walls and/or raising embankments with original construction materials in order to prevent overtopping. The committee obtained data for their survey through personal knowledge, a literature search, and a survey of the engineering community. The survey involved sending out questionnaires developed by the committee for data collection and cataloging, reviewing, and evaluating alternatives. Although not a part of the survey, two non-structural alternatives that can be used to accommodate larger floods are also discussed.

Structural Alternatives

Increased floodwater detention storage can be achieved structurally by raising the height of the project. Typically, only the sections of the project that would erode and/or fail during overtopping are raised.

The height of nonoverflow sections such as earthen embankments can be increased using construction materials similar to those used during original construction or by adding a concrete parapet wall to the top of the existing embankments. If the project includes a roadway, a 1 to 1.5 m continuous concrete wall that resembles a standard traffic barrier can be used to increase the height of nonoverflow sections without a noticeable change in the project appearance. Tall parapet walls (greater than about 2 m in height) are generally not selected over construction materials such as earth or rockfill due to aesthetic, safety, and vandalism concerns. If original construction materials are used to increase the height of the project, additional material may be required on the downstream embankment slope to maintain a minimum factor of safety for slope stability.

Concrete sections that support facilities such as spillway bays and navigation locks are typically allowed to overtop during large design floods. However, they are often strengthened to resist the additional loads produced by higher reservoir stages or modified to prevent damage from overtopping flows.

Table 1 presents a summary of the structural alternatives that increase reservoir storage reported in the survey. Five projects were reported that used parapet walls to increase the height of the dam. Eight projects were reported that used original construction materials to raise the dam and two used a combination of parapet walls and original construction materials. Except for McCloud Dam in California, the design of these structures provided for passing the full PMF.

Table 1 - Survey Results
Projects with Increased Height

Project	Location	Height Raised (m)	Owner	Notes
Brea Dam	California	0.9	USCOE	1
Butt Valley Dam	California	1.2	PG & E	1
Cherokee Dam	Tennessee	2.4	TVA	1
Clearwater Dam	Missouri	0.9	LRD	1
Fort Loudoun Dam	Tennessee	1.0	TVA	1,3
Beech Dam	Tennessee	1.4	TVA	2
Boone Dam	Tennessee	2.6	TVA	2
Chatuge Dam	N.Carolina	2.0	TVA	2
McCloud Dam	California	1.8	PG & E	2,4
Mud Mountain Dam	Washington	2.1	USCOE	2
Nottely Dam	Georgia	4.6	TVA	2
Pitt Forebay Dam	California	2.0	PG & E	2
Watagua Dam	Tennessee	3.1	TVA	2
Douglas Dam	Tennessee	1.7	TVA	1,2
Nuclear Lake Dam	New York	1.2	NPS	1,2,3

Notes:
1. Parapet Wall
2. Raised with original construction materials
3. Additional spillway capacity also provided
4. 50% PMF modification

Nonstructural Alternatives

Increased floodwater detention storage can be achieved nonstructurally by lowering the reservoir pool. Either a predetermined operational strategy that lowers the pool prior to the arrival of flood inflows, a permanent lowering of the normal pool, or a combination of the two can be used to increase the available floodwater detention storage. If an operational strategy is used, factors such as gate reliability, gate opening time, staff availability, and flood arrival time should be carefully evaluated to ensure that the project will operate when and as needed during an event. Except in situations where there are upstream conditions that provide ample lead time, reservoir operating requirements alone typically cannot be considered a reliable alternative to safely pass larger floods.

A permanent lowering of the normal reservoir pool can, in some cases, provide additional low-cost floodwater detention storage. Adjustments to the normal reservoir pool are often feasible at relatively small nonpower projects with limited shoreline development. Although lower lake levels could impact existing uses such as shoreline development and recreation, offsetting project benefits may be available from additional downstream flood protection, improved water quality, and stable lake levels.

Public opinion concerning lower lake levels and the potential impacts on existing project purposes should be carefully evaluated. Public involvement and education early in the planning process is essential to the success of any alternative that changes existing lake levels. In a recent study of operating priorities for its dams and reservoirs, TVA used a three step process that involved written comments from individuals and groups, public information sessions and intensive planning meetings with small groups structured to represent a broad range of interests to identify critical issues. Figure 1 highlights some of the conflicting forces acting on lake levels over time (Tennessee Valley Authority, 1990).

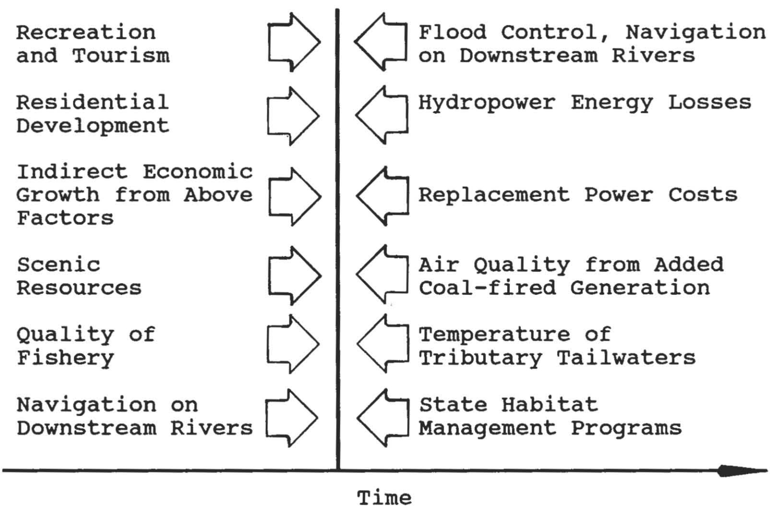

Figure 1. Forces Acting on the Timing of Lake Levels

Early Warning Systems

Early warning and/or dam failure warning systems typically offer a low cost alternative to structural modifications. The survey results indicate that early warning systems are being considered at numerous locations. However, experience with warning systems designed for dam failure situations is extremely limited and mixed. The warning systems at Santee Cooper Project located in eastern South Carolina and the Blue Ridge Dam located in northern Georgia provide the only performance records for existing installations of early warning systems designed specifically for dam failures.

The warning system at the Santee Cooper North Dam was designed to address the possibility of breaching in the event of seismic activity. The warning system alternative was selected because of the prohibitive cost of a new dam ($500,000,000) and the small population at risk. It is estimated that it would take at least ten hours for the flood waters resulting from the postulated dam breach to reach the initial downstream population center which includes about 52 residences on the fringes of the inundation area. The final cost of the warning system is estimated at $5,000,000 with annual maintenance costs of about $50,000. Since the initial testing of the system in early 1987, Santee Cooper personnel have been highly satisfied with its performance. Cooperation among the downstream residents and the various local and state agencies has been good.

Modifications at the Tennessee Valley Authority's (TVA) Blue Ridge Dam included increasing the existing spillway capacity by 60 percent and installing a downstream dam failure warning system. Both economic and environmental considerations led to the selection of the comprehensive dam failure warning system which was completed in 1984 at a total cost of approximately $10.7 million. The cost for the dam failure warning system was approximately $1.1 million. There are about 850 residences at risk below the Blue Ridge Dam. These residences are located in two small towns, one in Georgia and one in Tennessee, and in the rural areas around these communities. Unlike the Santee Cooper project, a significant portion of the residents at risk below the Blue Ridge Dam have maintained a rather complacent attitude about the warning system. Some have signed papers that they do not want a tone alert radio in their home. Others have neglected to have their radios maintained even though maintenance and battery replacement are provided free of charge. The dam failure warning system has been in place for 7 years, and TVA continues to review its overall effectiveness. Although annual maintenance costs to ensure a high degree of reliability for the system were estimated to be $50,000 in 1980, by 1989 the annual maintenance costs had risen to about $250,000. At present, resident apathy, system reliability and increasing annual maintenance costs continue to persist.

A survey completed in December 1987 summarizes the performance records of these two projects and 16 other early warning systems designed primarily for flash floods (Gruntfest, 1987). Although each of these systems was designed for a different situation, many systems exhibited similar problems such as the need for redundancy, lack of maintenance funding, lack of local commitment to the project and the tendency to overrely on warning systems.

Before selecting an early warning system in lieu of structural modifications, failure consequences should be carefully evaluated. In addition to economic consequences, social and environmental consequences such as the population at risk, emergency costs, loss of life and community and emotional trauma should also be considered. A report prepared by the ASCE Task Committee on Spillway Design Flood Selection provides guidance on identifying impacts of dam failure which are not adequately evaluated by current economic analysis practices (American Society of Civil Engineers, 1988).

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