

Practical Lessons from Dam-Break Assessment: A Case Study of Larji Hydroelectric Project, Himachal Pradesh

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Abstract: Dam-break assessment in the Himalayan region is challenging due to steep valleys, rapidly changing downstream conditions, limited historical data, and the potential for extreme floods. This paper presents practical experience from the dam safety assessment of the 126 MW Larji Hydroelectric Project in Himachal Pradesh, India. A UAV-based LiDAR survey, supported by DGPS observations, was used to develop a high-resolution downstream terrain model. This model improved flood-path prediction and enabled predicted flood levels and arrival times to be related to critical infrastructure, including sediment-flushing arrangements, tail-race channels, and powerhouse approaches. A two-dimensional hydraulic model was developed using HEC-RAS 7.0.1, incorporating the actual spillway gate configuration and operating conditions rather than treating the release structure as a generic opening. Three scenarios were assessed: extreme controlled release, barrage failure due to overtopping, and sunny-day failure due to piping or internal erosion. The study highlighted the importance of accurate terrain representation, realistic hydraulic structure modelling, and consideration of multiple failure mechanisms. Ultimately, the assessment demonstrates that integrating advanced surveying, hydraulic modelling, and engineering judgement strengthens dam safety evaluation, emergency planning, and operational preparedness.

Keywords: Dam Safety, Dam-Break Analysis, Himalayan Dams, HEC-RAS, UAV-Based LiDAR, Flood Inundation, Hydropower.

Introduction

Dam-break assessment in the Himalayan region is considerably more complex than a conventional hydraulic modelling exercise. Himalayan hydropower projects are generally situated in difficult terrain characterized by steep, narrow valleys, rapidly changing downstream conditions, and significant downstream infrastructure. In these high-gradient environments, the scarcity of reliable historical hydrometeorological data, coupled with the potential for extreme floods, introduces substantial uncertainty into downstream consequence analysis. Recent extreme events in the Himalayas have underscored the limitations of relying solely on past records, demonstrating that historical experience should not automatically be treated as the upper limit of potential future events.

Traditionally, dam-break assessments are often treated as routine numerical exercises aimed merely at preparing static flood inundation maps to determine "where the water will go." Such conventional approaches frequently overlook the operational

realities of hydraulic structures by treating releases as generic boundaries and relying on a single hypothetical failure scenario. However, the initial hydraulic state and controlled-release behaviour strongly influence subsequent flood-wave development. Furthermore, there is a critical need to extend dam-break analysis beyond basic downstream inundation mapping to encompass owner-side operational safety and preparedness.

The 126 MW Larji Hydroelectric Project in Himachal Pradesh, India, provided an opportunity to examine these challenges through an actual dam-safety assessment. The study combined high-resolution terrain acquisition (UAV-based LiDAR and DGPS), two-dimensional hydraulic modelling (HEC-RAS 7.0.1) with realistic spillway gate operations, and the evaluation of multiple failure mechanisms. The primary objective was not merely numerical simulation, but to understand what can happen downstream and when, thereby establishing a practical basis for both downstream emergency planning and timely operational decision-making.

Methodology

The downstream terrain was surveyed using UAV-based LiDAR and DGPS observations to develop an updated and reliable terrain model for the flood inundation assessment. In steep and confined Himalayan terrain, the quality of the terrain model has a significant influence on the predicted flood pathways. The high-resolution terrain was also used to provide a common spatial basis for relating predicted flood levels and arrival times to critical hydropower infrastructure. When critical project components and their surveyed elevations are incorporated, predicted flood levels and arrival times can be related to operationally important locations, including sediment-flushing arrangements, tail-race channels, and powerhouse approaches.

A two-dimensional hydraulic model was developed using HEC-RAS 7.0.1 (Brunner, 2020). The principal spillway gates were represented using their actual configuration and operating condition rather than treating the release structure as a generic opening or discharge boundary. This approach allowed the pre-failure controlled-release condition and initial hydraulic state to be represented more realistically.

Instead of focusing on a single failure case, the study evaluated three representative dam-break scenarios.

1. Extreme Controlled Release: Simulating pre-failure, controlled-release conditions through the principal gates.
2. Barrage Failure due to Overtopping: Simulating structural failure of the barrage resulting from overtopping.
3. Sunny-Day Failure: Simulating breach resulting from piping or internal erosion under normal conditions.

The analysis examined flood extent, depth, velocity, arrival time, and downstream consequences. This allowed the LiDAR-derived terrain and hydraulic results to be interpreted from two perspectives: downstream risk reduction and dam-owner preparedness.

Results

The assessment revealed several key hydrodynamic and practical observations:

- Topographic Influence: In steep valleys, small changes in terrain significantly influence the direction and concentration of flood flow. High-resolution terrain provides a reliable basis for predicting flow pathways and relating flood levels to critical project infrastructure.
- Failure Mechanism Dynamics: Different failure mechanisms produce substantially different downstream flood behaviour, flood depths, velocities, and arrival times. Consequently, selecting a single breach condition as the representative dam-break scenario does not adequately represent the complete hazard spectrum.
- Gate and Hydraulic Controls: Accurate representation of spillway and gate geometry and operating conditions is critical, as the initial hydraulic state and controlled-release behaviour strongly govern subsequent flood-wave development.
- Limitations of Historical Records: Historical flood records, although important, cannot be treated as the upper limit of future events in a rapidly changing Himalayan environment.
- Role of Engineering Judgement: Advanced software and high-resolution survey data provide better tools, but they do not replace engineering judgement in scenario selection, structural representation, and consequence assessment.

Conclusion

The experience from the Larji Hydroelectric Project reinforces that dam-break assessment in the Himalayas should be approached as an integrated engineering exercise combining modern survey techniques, hydrological understanding, realistic representation of hydraulic structures and gate operations, hydraulic modelling, and engineering judgement, rather than simply a numerical modelling task.

A dam-break assessment should therefore not be viewed merely as the preparation of an inundation map or determining "where the water will go." Its real value lies in understanding what can happen downstream, when it can happen, and using that information to improve dam safety, downstream emergency preparedness, and the dam owner's ability to make timely operational decisions.

References

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