

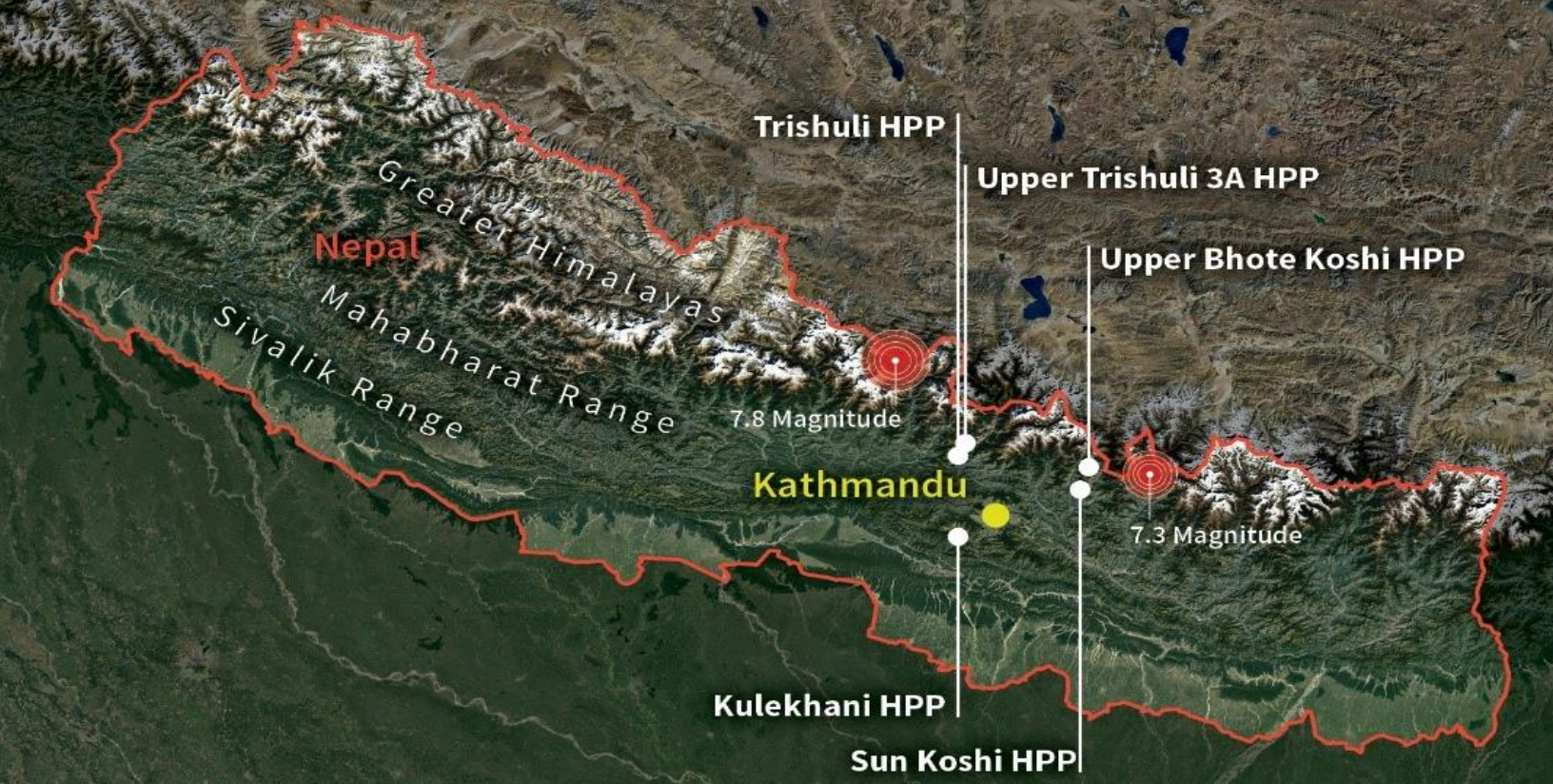


# Enhancing Dam Safety in Nepal

Canadian Consulting Engineering Awards

**HATCH**





# Project objectives, solutions, and achievements

In 2015, Nepal was devastated by the Gorkha earthquake, a magnitude 7.8 event that occurred on April 25, followed by a magnitude 7.3 aftershock on May 12. It is estimated that over 8,700 people died because of the earthquakes and more than 22,500 were injured. Although difficult to estimate, economic losses have been placed anywhere up to 50% of Nepal's Gross Domestic Product. About 115 MW of Nepal's hydropower facilities were severely damaged by another 60 MW impacted, representing over 20% of the available capacity. In addition to these losses, five of Nepal's seven major UNESCO World Heritage sites in the Kathmandu Valley were damaged or destroyed, more than 30 monuments collapsed and 120 others partially damaged.

In the aftermath of the devastating Gorkha earthquakes in Nepal, the World Bank Group turned to the dam safety experts at Hatch to undertake a project designed to assist the Government of Nepal in reducing the risks associated with its plans to develop over 15 GW of hydroelectric power within the next 30 years. The Enhancing Dam Safety in Nepal project entailed the review of the current global state of the art in dam safety management and the state of practice in Nepal. The result was a set of dam safety guidelines tailored to the needs of Nepal that included unique new guidance on how to deal with the natural hazards of a mountainous country such as Nepal.

## Project Objectives

Given the ambitious plans for the expansion of hydropower in Nepal, both the World Bank Group and the Government of Nepal (GoN) recognized an urgent need to develop for specifying the design,



construction and maintenance standards that a dam must satisfy to be “safe”. Currently in Nepal, many of the major hydropower facilities and dams are designed by international consultants from various countries around the world. In the absence of national standards, dam designs vary depending on the judgment and experience of the practitioner and the standards of their home country. While the inconsistent standards that have been used in the construction of Nepal’s dams do not necessarily mean that Nepal’s facilities are unsafe, the risks that an individual dam poses to the downstream public may vary considerably depending on the standard that was selected.

The goals of the World Bank Group and Nepalese government were, therefore, clear. They needed a consultant with internationally recognized dam safety expertise to establish what the current status of dam safety is around the world, determine what the status of dam safety in the nation and develop a set of regulations and standards, tailored to the needs and realities of Nepal. Dam safety standards that would reduce the risks to the public, the nation’s infrastructure, the environment and Nepal’s cultural heritage sites. With these ambitious goals in mind, the Government of Nepal turned to the globally recognized dam safety experts from Hatch and Manitoba Hydro International, supported by TMS, a local Nepalese consultant.

## Solutions

As a first step, the team undertook a comprehensive review of all of the recommendations of the worlds the major dam safety organizations including the Canadian Dam Association, the Australian Committee on Large Dams, the US Federal Energy Regulatory Commission, the International Committee on Large Dams and recent dam safety guidelines that had been prepared by Hatch for the Province of Ontario. Using this information, and discussions with stakeholders in Nepal, a plan

started to take shape. The team formulated industry best practices for dam design and life cycle maintenance based on what should be included in the regulation and what was best included in technical guideline documents. However, a problem became apparent. None of the international organizations provided guidance on how to deal with dam safety issues that are unique to mountainous countries such as Nepal.



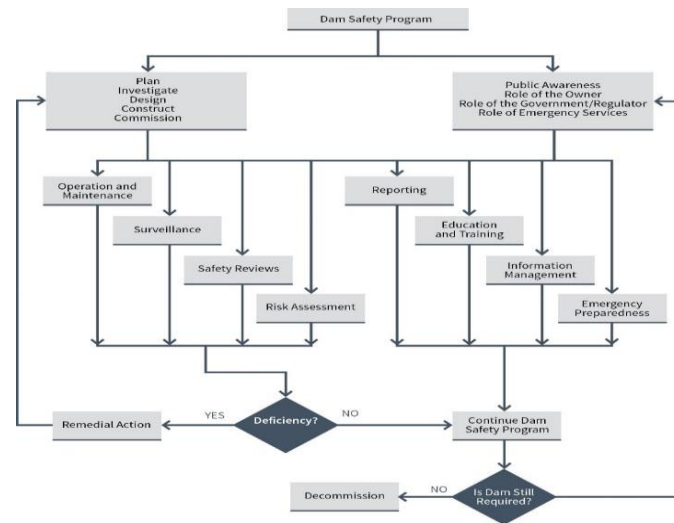
Figure 1: Damage to a Dam

The solution to this problem required the visit a number of damaged hydropower facilities to understand the root causes, nature and impacts of natural hazards. As a result of these visits,

extensive discussions with hydropower owners and operators in Nepal and the application of modern investigative methods such as Probable Failure Modes Analyzes a clear picture emerged. The team determined that the well-known natural hazards presented by flood flows and earthquakes loadings were generally adequately addressed in the design of the nation's Hydro Power Projects. The team determined that it was natural hazards presented by landslides and debris flows that presented the greatest dam safety hazards. To deal with this challenge, the Hatch team undertook extensive assessments and engaged the services of one of the world's experts in natural hazards, Dr. John Reynolds, who worked with the Hatch team to develop first of its kind guidelines for the assessment and mitigation of the risks presented by these hazards.

## Achievements

Hatch exceeded the client's expectation of improving dam safety in Nepal. Hatch took the best the world had to offer and moulded it into practical state of the art guidelines that were practical, sustainable and tailored to the specific needs of Nepal. In addition, new guidelines were developed to address a gap in the state of the art, dealing with the most important natural hazards of Nepal—landslides, rainfall induced debris flows, Glacial Lake Outburst Floods and Landslide Dam Outburst Floods. Finally, Hatch implemented capacity building and training workshops in order to promote systemic change and development within Nepal's dam safety system to support training and capacity building in cooperation with the Ministry of Energy, the Department of Electricity Development, the Nepal Investment Board, the Nepal Electricity Authority, independent power producers and other Nepal engineering organizations.



# Technology Transfer

The team started with a comprehensive review of all of the recommendations of the worlds the major dam safety organizations including the world recognized Canadian Dam Association dam safety guidelines as well as guidelines that had been prepared by Hatch for the Province of Ontario, Parks Canada, El Salvador and Guatemala.

Using this information, and discussions with stakeholders in Nepal, a plan started to take shape. The team formulated translated Canadian best practices for dam design and life cycle maintenance based on what should be included in the regulation and what was best included in technical guideline documents. However, a problem became apparent, the state of the art did not provide guidance on how to deal with dam safety issues that are unique to mountainous countries such as Nepal.

To overcome this challenge Hatch took the best that Canada and the world had to offer and molded it into practical state of the art guidelines that were practical, sustainable and tailored to the specific needs of Nepal. This included new guidelines were developed to address a gap in the state of the art, dealing with the most important natural hazards of Nepal—landslides, rainfall induced debris flows, Glacial Lake Outburst Floods and Landslide Dam Outburst Floods.

Hatch then implemented a series of five comprehensive capacity building and training workshops using the best Canada had to offer to representatives from the Government of Nepal, independent power producers, Nepal engineering organizations, consulting engineers, academics and regulators from across Nepal.



# Contribution to Social and Economic Quality of Life

In 2015, Nepal was devastated by the Gorkha earthquake, a magnitude 7.8 event that occurred on April 25 followed by a series of major aftershocks. Reconstruction plans involved the use of Nepal's waterpower potential to electrify the country and provide needed revenue streams.

However, this would require the development of many new and larger dams in a country in which there were no national standards for dam design and construction. Given this reality, both the World Bank Group and the Government of Nepal recognized that the country's economic goals could only be achieved by developing reliable facilities that could withstand the impacts of the country's natural hazards.

## Regulation of standards

To accomplish this goal, they needed to determine what was the status of dam safety in the nation and develop a set of regulations and standards, tailored to the needs and realities of Nepal. Standards that would reduce the risks to the public, the nation's infrastructure, the environment and Nepal's cultural heritage sites. With these ambitious goals in mind, the Government of Nepal turned to Canada and the globally recognized dam safety experts from Hatch and Manitoba Hydro International, supported by TMS, a local Nepalese consultant.

Over a period of two years, all the nation's goals were achieved. A set of unique standards



were developed that provided guidelines on how to assess and mitigate all types of dam safety issues and realize the environmental and economic benefits that can be realized by taking a life cycle analysis approach considering the likelihood (almost certainty) of a waterpower facility experiencing some sort of major natural hazard event.

The Canadian made dam safety management system that was developed for Nepal will provide tangible social benefits by ensuring that dams are managed safely and maintained in such a way as to protect Nepal's upstream and downstream residents, towns, villages and protection of Nepal's rich cultural heritage. The new systematic approach to the design, construction, and operation of Nepal's waterpower projects will lead to facilities that comprehend the unique conditions that exist in Nepal, ensuring that hydropower projects are constructed in accordance with modern standards and the best of the best principles of dam safety. Implementation of the new dam safety management system in Nepal will also lead to the development of a generation of Nepalese hydropower and dam engineers providing benefits that will extend for generations.

# Complexity

Developing country specific dam safety standards for Nepal presented a significant challenge. In the absence of national standards, dam designs vary depending on the judgement and experience of the practitioner and the standards of their home country. None of the international organizations was able to provide guidance on how to deal with dam safety issues that are unique to mountainous countries such as Nepal.

The solution to this problem required to visit a number of damaged hydropower facilities to understand the root causes, nature and impacts of natural hazards. The team determined that it was natural hazards presented by landslides and debris flows that presented the greatest dam safety hazards. Together Hatch experts and one of the world's leading experts on natural hazards, Dr. John Reynolds, developed a first of its kind guideline for assessing and dealing with landslides and debris flows.

A second challenge in this project arose from the end goal of developing a set of “best practices”. This entailed researching, summarizing, analyzing, and evaluating best

practices developed by numerous other countries. However, these guidelines could not simply be combined to form a guiding document for Nepal.

Beyond the technical challenges, this project also presented communication and team challenges. Hatch successfully delivered a project while effectively transferring Canadian expertise in dam safety to a wide range of Nepalese stakeholders and developing a set of guidelines and a regulation that will form one of the cornerstones of Nepal's reconstruction and march towards prosperity.





# Environmental Benefits

The losses experienced by Nepal because of the Gorkha earthquake alone was staggering. It is estimated that over 8,700 people died and more than 22,500 injured. Economic losses have been placed up to 50% of Nepal's Gross Domestic Product.

In the aftermath of this disaster, the Government of Nepal the World Bank Group entered into reconstruction efforts that centered on the development of waterpower to promote economic growth and sustainability as well as electrifying the nation. Achieving this goal depended on waterpower facilities that could be relied on for decades, a goal complicated by the natural hazards that exist in Nepal.



Figure 2: The Jure Landslide

The guidelines developed by the Canadian experts comprising the Hatch team has led to a new understanding of the importance of accounting for all of the natural hazards that exist in this mountainous country rather than the traditional focus on hydrological floods and earthquake ground motions.

This landmark document is the only such guideline with a comprehensive approach to assessing the potential for natural hazards to occur, individually and in combination. It will provide significant benefits to the safety of future hydropower sites ensuring that they are appropriately sited, designed and constructed avoiding the potential for devastating environmental impacts, destroying aquatic and terrestrial habitat and agricultural lands

Outside of Nepal, these new guidelines will offer benefits to hydropower developers in any mountainous country. Already a description of this new approach has been accepted for publication in the prestigious ICOLD world congress proceedings in Vienna and at the annual Canadian Dam Association Conference.

# Meeting Client's need

The goals of the World Bank Group and Nepalese government were clear. They needed a consultant to establish what the status of dam safety is around the world, determine the status of dam safety in the Nepal and develop a set of regulations and standards, tailored to the needs and realities of Nepal. The problem was, such a document for a country such as Nepal did not exist. With these ambitious goals in mind, the Government of Nepal turned to the globally recognized dam safety experts from Hatch and Manitoba Hydro International, supported by TMS, a local Nepalese consultant.

The results met and exceeded all expectations. In a period of less than two years the Hatch team created first of its kind, world class dam safety guidelines and transferred two decades of Canadian Hydropower experience to a wide range of Nepalese engineers, academics and regulators. These new guidelines offer advice on maintaining the safety of dams through enhanced design practices and how to ensure the safety of existing and future dams throughout their life cycle by means of advice on enhanced operations, maintenance and surveillance practices. Life safety risks were addressed by providing guidance on modern practices for emergency preparedness and action plans. The project also included training dam safety practitioners in Nepal and a roadmap for implementing the new program.



*Figure 3: Hatch's Team Hosted Two Workshop in Nepal*

In addition to and in support of their main goals, several other documents were produced to enhance the learning and growth of those involved in Nepal's dam safety programs. These included training workshops and presentations, a checklist for a review of feasibility studies of hydropower projects, and a conceptual dam and HPP asset management system designed to enhance the safety of existing dams. The integration of these many aspects of dam safety for Nepal that included geotechnical, structural, hydrological, electrical, mechanical, sedimentation, seismic, environmental, social, economic and technological considerations.