An Initiative to Improve Dam and Downstream Community Safety in Vietnam

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Abstract

Viet Nam has one of the largest dam systems in the world, comprising more than 7,000 dams. Approximately 640 of these dams are classified as medium and large dams, and a large percentage of the Vietnamese population is potentially at risk from dam failure flooding, particularly if operation of dams is poorly considered.

In a collaboration between Viet Nam and New Zealand governments since 2012 a disaster risk reduction project to improve dam management and community safety throughout a river basin has been developed by dam safety experts from both countries. Known as the Dam and Downstream Community Safety Initiative (DDCSI) the project has developed a Dam Safety Methodology for dam owners and managers to identify and quantify the natural hazards and assess the risks associated with their dams and develop options to mitigate these risks.

The Dam Safety Methodology will be used to (i) identify and prioritise works and operational improvements needed to improve the safety of a dam, and (ii) identify where Disaster Risk Management can be improved for communities downstream of a dam. This will enable dam managers and owners to target specific improvements to safely manage existing reservoirs or in the planning and design of future projects.

The methodology allows the choice of three levels of assessment – Preliminary, Intermediate and Detailed – depending on the data available and downstream impact of the dam. For dams with greater levels of impact the Intermediate and Detailed assessments include four steps, related to understanding natural hazards, dam potential failure modes, downstream hazard impacts and dam safety and disaster risk management. As well as identifying where structural and operational improvements can be made to a dam, the Dam Safety Methodology provides information on the consequences of a flood release or dam failure event. Such information aids decision making for improved community warning systems, escape routes, land zoning and physical protection works for infrastructure, industry and communities.

The DDCSI Dam Safety Methodology promotes a river basin approach, based on internationally recognised methods and has been published as a series of guidelines in English and Vietnamese. The approach can be used for a single dam or a cascade of dams in a river basin in any country, and indeed across international borders. The Dam Safety Methodology has been successfully tested on three dams of varying size and impact in one of the Ca River tributary catchments in Nghe An province of Viet Nam.

In a continuation of the collaboration between the Vietnam and New Zealand governments, it has been proposed for the Dam Safety Methodology to be implemented over 2016 to 2020 in river basins with a large number of dams in two Provinces of Viet Nam. The Ca River catchment, one of the largest river basin systems in Viet Nam, has been proposed. In these two Provinces, large populations centred on the lowland plains are affected each year by flooding. Six major irrigation and hydro dams are present in this river basin along with a large number of small irrigation dams, all upstream of the fourth largest city in Viet Nam. The most vulnerable dams, or dams with the greatest potential downstream impact, will be addressed first.

1. Background

Viet Nam has one of the largest dam systems in the world, comprising more than 7,000 dams (Table 1). With typography ranging from mountainous inland highlands to densely populated coastal plains, a large percentage of the Vietnamese population is at risk from dam failure flooding. Poorly considered operation of dams can lead to serious and unexpected flooding. Past dam failures have many lives and caused substantial impacts on downstream property and the environment.

Fig. 1. Summary of the dam network in Viet Nam (after World Bank, 2015)

Dam Height	Reservoir Volume	Number of Irrigation Dams	Number of Hydropower Dams
> 50 m	-	3	32
15 to 50 m	> 3 million m^3	551	54
< 15 m	< 3 million m^3	6,648	201

Addressing and improving dam safety has become a priority for the Government of Viet Nam. A national legal framework for dam safety in Viet Nam was first introduced in 2007 with Government Decree No. 72/2007/NĐ-CP. Decree 72 was revised in 2013 to better define responsibilities and practices. Government approval is pending. However implementation of consistent dam safety across the country is challenging due to the limited resources and a lack of tools and procedures to prioritise dam safety works, particularly for small irrigation dams in rural areas (Dam, et al, 2011; VNCOLD, 2011).

This paper describes recent collaboration between the Governments of Viet Nam and New Zealand to develop a Dam Safety Methodology that provides a site specific assessment to:

(i) identify and prioritise works needed to improve the safety of a dam, and
(ii) identify where Disaster Risk Management can be improved for communities downstream of a dam.

The Dam Safety Methodology has been developed under the Dam and Downstream Community Safety Initiative (DDCSI) to meet many of the objectives of Decree 72/2007/NĐ-CP. The methodology allows dam owners and engineers to identify and quantify the natural hazards to their dams, assess their impact and risks and develop options to mitigate these risks. A whole of river basin approach has been taken to identifying natural hazards that could impact dams, their vulnerabilities and the consequences of an unintended release from a dam. This assists in the prioritisation of repairs and upgrades based on risk to the population and damage to economic assets in the river basin.

The Dam Safety Methodology was developed for application to a single dam or a portfolio of dams on a river basin or within a province, district or commune. While this has been an initiative based in Viet Nam, the methodology is applicable in any river basin and, with cooperation, can be applied across country borders. The DSM is applicable to the design of new dams or for safety evaluations of existing dams, and can be applied to all types and sizes of dams.

Section 2 of this paper briefly outlines dam safety and disaster risk management requirements from an international context. Section 3 describes the DSM that has been developed and tested over a pilot period between 2012 and 2015. Section 3 outlines the next project phase which will implement the Dam Safety Methodology for a number of dams in the Nghe An and Ha Tinh Provinces of Viet Nam over the years 2016 to 2020.

2. What is Dam Safety and its Connection to Disaster Risk Management?

2.1 Dam Safety Management

Dam safety practice refers to the safe planning, design, operation and management of dams and their reservoirs for all stages of the dam's lifecycle (Figure 1). ICOLD Bulletin 154 states "*the fundamental dam safety objective is to protect people, property and the environment from harmful effects of mis-operation or failure of dams and reservoirs.*"

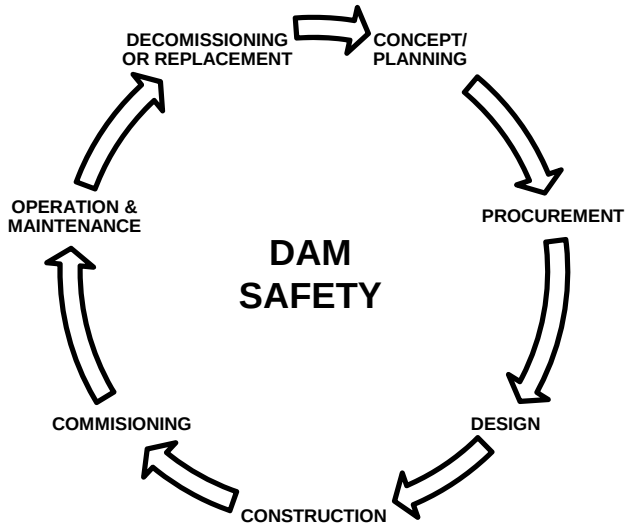

Fig. 1. Dam safety requirements over life cycle of a dam (adapted from ICOLD Bulletin 154).

While modern dam design would be expected to take account of dam safety, older dams are often not designed to the same standards. Operational risks arise when operational procedures are not adequate, or are not being followed. Care and maintenance is not always satisfactory, or is not adequately funded. To counteract these risks, dam safety should be applied throughout the dam life cycle.

Dam safety practice has evolved throughout the world since the 1970's, partly in response to a number of high profile incidents and disasters. The Teton dam failure in the USA in 1976 killed 11 people and led to total damages of US$ 2 billion. Following this disaster, dam safety legislation was introduced in the United States and the United States Bureau of Reclamation (USBR) introduced the Safety Evaluation of Existing Dams (SEED) program and practices. Many features of the SEED programme became the basis for dam safety procedures around the world. Most importantly these events led to the realization that regular maintenance and constant vigilance is required to ensure safe operation of a dam over many years.

More than 95 countries are members of the International Commission on Large Dams (ICOLD), a non-governmental organisation that publishes agreed guidelines and standards of practice for the design, construction and operation of all types of dams. Worldwide there is a general effort to align national dam safety practice with the recommendations published by ICOLD. Many countries, including Viet Nam, have laws (decrees) and regulations requiring dam owners to have dam safety programmes. The laws and regulations provide minimum requirements which are usually well covered by national Dam Safety Guidelines, commonly published by national dam safety organisations. Key differences from country to country tend to reflect their specific legislative and natural hazard context. The Dam Safety Management Systems published in well considered dam safety guidelines apply the principles espoused by ICOLD in their publications.

International dam safety bulletins and guidelines from a number of countries recommend that dam owners have a Dam Safety Management System to provide a structured framework for the safe operation and management of its dams and reservoirs. The typical elements of a Dam Safety Management System are summarised in Figure 2.

The Dam Safety Methodology (described in Section 3.0) provides information to make evidence-based decisions to rectify issues and improve dams or their operating systems and procedures. If no Dam Safety Management System is in place for a dam, the Dam Safety Methodology provides international practice and examples to develop and implement one.

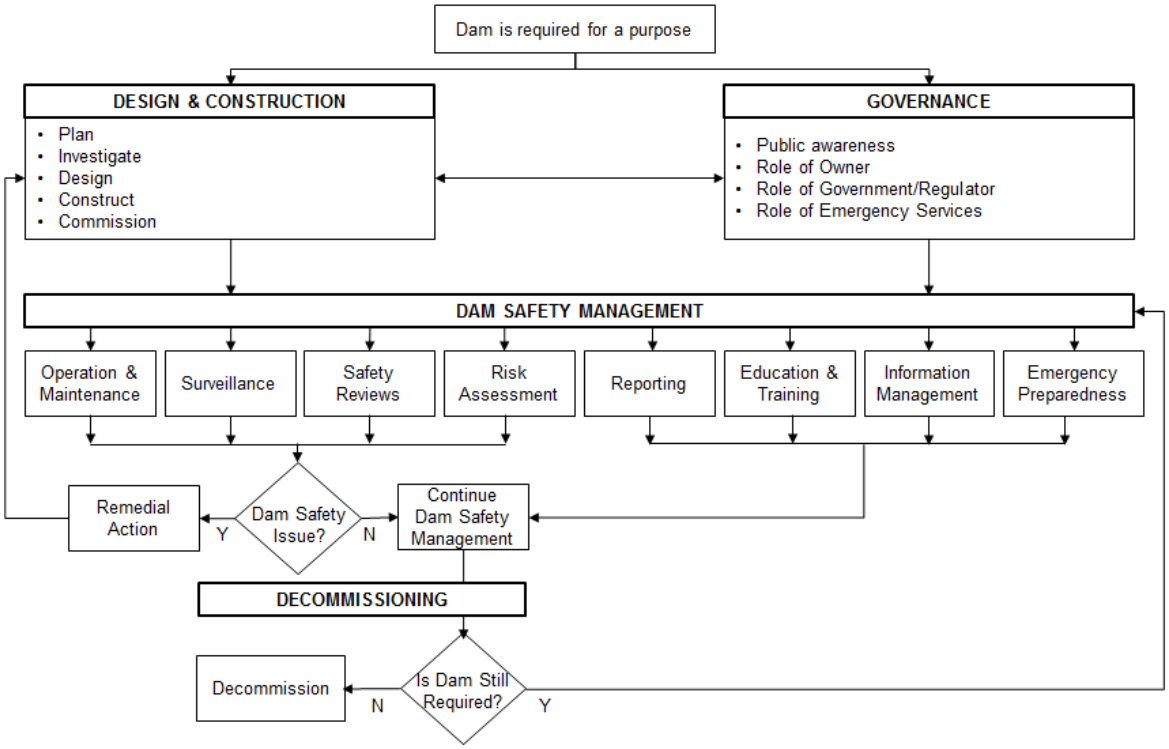

Fig. 2. Elements of a Dam Safety Management System (adapted from ANCOLD, 2003)

2.2. Disaster Risk Management

Disaster Risk Management is the planning and processes in place to manage the risk to communities from potential disaster events through social and physical measures. Potential dam related events that can directly impact on society are uncontrolled reservoir releases (e.g. spillway gates opened without warning downstream communities) or a dam failure with release of the stored contents of the reservoir.

Social measures to manage dam related disasters include: hazard mapping and analysis, vulnerability assessments, land-use management measures to avoid risks in new development, initiation of risk reduction initiatives, evacuation planning, sheltering of displaced people, emergency welfare support/relief, response management plans and infrastructure, response training exercises and drills, early warning systems, public notification. In the Vietnamese context Disaster Risk Management is required to be carried out at all organisations and at all levels of government down to the community level, extending to individual households (Viet Nam Law No. 33/2013/QH13).

Physical measures to manage dam related disasters include include: flood protection embankments; strengthening buildings and infrastructure to mitigate the impact of physical hazards such as flood, storm, earthquake; moving communities or infrastructure away from high-risk areas, reforestation of burnt or cleared slip-prone land.

In Viet Nam, Disaster Risk Management is defined as comprising disaster prevention, response and mitigation (Viet Nam Decision No. 1722007/QD-TTg). The National Strategy emphasises the need for timely response and effective recovery after events, which includes enhanced resilience in reconstruction recovery activities. Disaster Risk Management in Vietnam is intended to “minimize the losses of human life and properties, the damage of natural resources and cultural heritages, and the degradation of environment, contributing significantly to ensure the country’s sustainable development, national defence and security”.

The Dam Safety Methodology (described in Section 3.0) includes a provision to understand and analyse the current Disaster Risk Management practices regarding a dam and whether there are gaps in capability or capacity and opportunities for improvements in planning and practice.

3. Development and Testing of the Dam Safety Methodology

3.1 The Dam and Downstream Community Safety Initiative (DDCSI)

Collaboration over 2012 to 2015 between the Vietnamese and New Zealand organisations listed below developed and trialled a Dam Safety Methodology under the authority of the Ministry of Agriculture and Rural Development (MARD). Known as the Dam and Downstream Community Safety Initiative (DDCSI) the aim of the project was to deliver a nationally applicable process that would allow dam stakeholders to make well informed decisions to undertake structural and operational improvements to dam structures, as well as help to improve Disaster Risk Management practices throughout the river basin.

- Thuyloi University, Hanoi, Viet Nam
- Viet Nam National Committee on Large Dams
- Viet Nam Institute of Geophysics
- GNS Science International Limited of New Zealand
- Damwatch Engineering Limited of New Zealand

The methodology was developed from internationally recognised methods and is published in a guideline that is available free of charge and published as an online download in English and Vietnamese languages (DDCSI, 2015a). The trial of the Guideline produced a case study on three dams in Nghe An Province of Viet Nam, which is also published. This is described in Section 3.3 below.

3.2 Overview of DDCSI Dam Safety Methodology

The Dam Safety Methodology framework is shown on Figure 3. The Dam Safety Methodology is a sequential procedure that systematically assesses natural hazards (floods, earthquakes and landslides), their effect on the dam structure, hydraulic modelling of the unplanned release of water or failure of the dam and mapping of the resulting flood. A thorough assessment of the consequences of a flood release will document potential damages and identify the population at risk from a flood wave.

Level of Assessment

The amount of effort required for dam safety assessment depends on site related parameters. A more detailed assessment may be warranted for dams with larger reservoirs situated upstream of a relatively large population and where the consequences of dam failure would have significant downstream impact. Dams with smaller reservoirs situated upstream of sparsely populated areas, may rely on less detailed methods of assessment. Based on this premise, three different levels of detail of the Dam Safety Methodology can be applied, as summarised in Table 2.

Table 2 – Dam Safety Methodology levels of assessment

Level of Assessment	Description
Preliminary	Rapid assessment based on easily accessible data
Intermediate	Assessment based on existing data and relatively routine analysis methods
Detailed	Assessment based on site specific data, investigations and detailed analysis methods

Preliminary Assessment

The preliminary assessment provides a method to rapidly evaluate the potential downstream impact of a dam failure based on easily accessible information. The outputs from the preliminary assessment include:

- An approximate extent of inundation from a hypothetical dam breach flood
- An estimate of the number of people potentially impacted by the dam breach flood

The preliminary level assessment can be used to:

(i) rapidly evaluate the potential downstream impact of a dam failure based on readily available information (e.g. topographic maps, information on dam type, height and reservoir volume),

(ii) evaluate a large number of dams in a Province, District or Commune to determine their relative downstream potential impacts (this information can be useful to prioritise investment and repair works to those dams with the highest potential downstream impacts, and;

(iii) decide whether a dam requires further analysis at an intermediate or detailed level of assessment.

Once the preliminary assessment has been conducted, further assessment of dams with significant downstream hazard potential should be conducted using the intermediate and/or detailed level of assessment as appropriate.

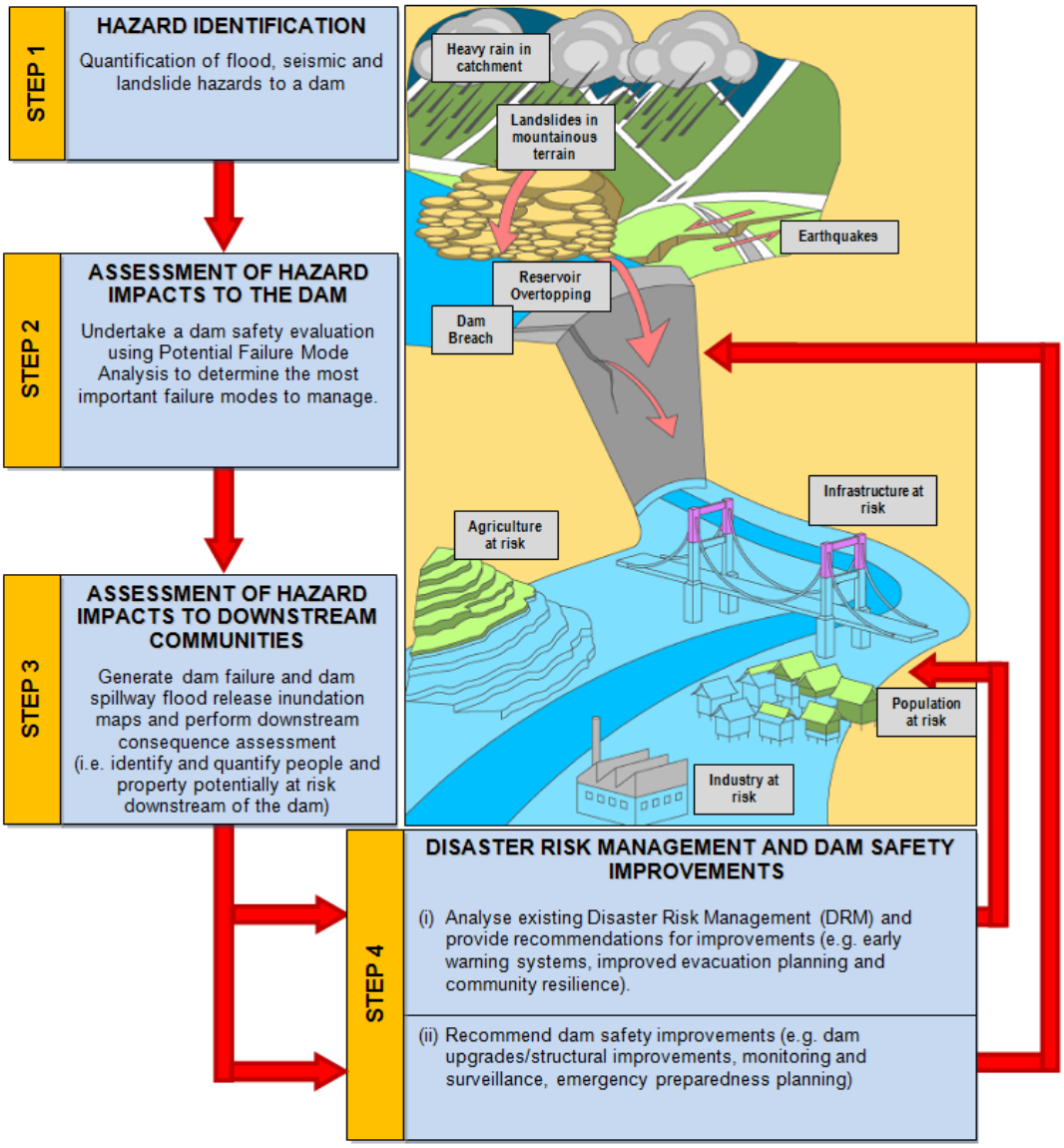

Fig. 3. Illustration of Dam Safety Methodology

Intermediate and Detailed Assessment

Figure 4 provides an outline of the Intermediate or Detailed Dam Safety Methodology. The Intermediate and Detailed assessments have the same overall methodology but vary due to the amount and quality of data, resources and funding needed to conduct the assessment. Overviews of the four steps are are summarised as follows:

- *Step 1 - "Hazard Identification"* provides methods to quantify flood, seismic and landslides hazards to a dam using internationally recognised procedures (e.g. ICOLD Bulletins 124, 142, 148). Floods, earthquakes and landslides are recognised internationally as the primary natural hazards that can endanger the safety of dams. Quantifying these hazards in terms of magnitude and frequency of occurrence allows for informed decisions to be made on their impact on dam safety and methods to mitigate such hazards.

- *Step 2 - "Potential Failure Modes Assessment"* provides methods to perform a dam safety evaluation using Potential Failure Modes Assessment. A potential failure mode is a mechanism or set of circumstances that could potentially result in the uncontrolled release of all or part of the contents of a reservoir. An understanding of potential dam failure modes, and providing avoidance, mitigation or monitoring to prevent or reduce the probability of a potential dam failure mode eventuating, is a cornerstone of effective dam safety management (NZSOLD, 2015; USBR, 2012).

- *Step 3 - "Hazard Impact on Downstream Communities"* provides recommended practice to generate dam failure and dam spillway flood inundation maps using computational hydraulic models. Geographic Information System (GIS) based models are then used to estimate the impacts and losses from the flood events on people, property and agricultural land downstream. By providing information on the consequences of a potential dam failure or spillway release flood, dam owners can understand what design, construction and management actions can be applied to protect people, property and the environment.

- *Step 4 - "Dam Safety and Disaster Risk Management"* provides methods to make informed decisions to improve Dam Safety and Disaster Risk Management practices. The general methodology to understand existing dam safety and disaster risk management systems involved (i) assembling, reviewing existing information on dam safety and disaster risk management, including a site inspection to the dam site if required, (ii) identifying any dam safety issues from surveillance and inspections, review of existing systems and procedures and potential failure modes assessment (see Step 2 above), and; (iii) develop improvements to any dam safety deficiencies or disaster risk management weaknesses identified.

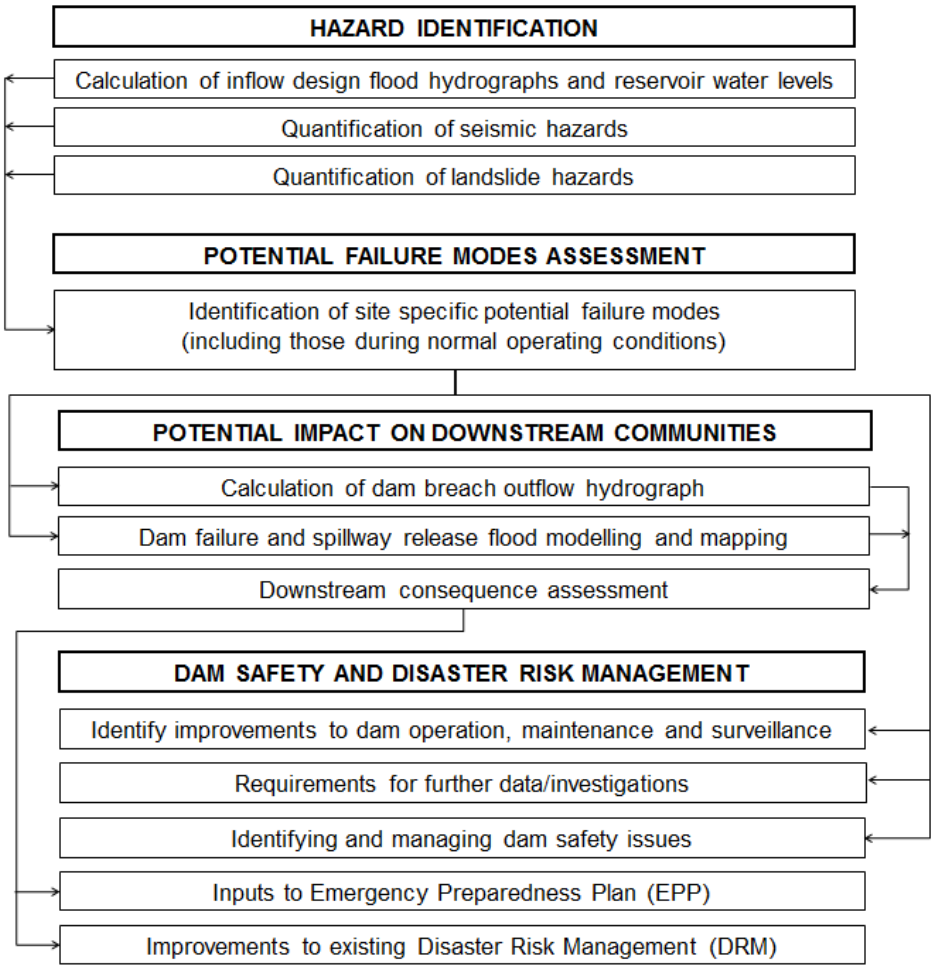

Fig. 4. Overview of the Intermediate/Detailed Dam Safety Methodology

Components of the Intermediate and Detailed assessments can be used interchangeably. For example, if frequent downstream flooding is a significant problem with the dam under consideration, then an overall assessment could be carried out at an Intermediate level, but with Detailed assessment of flood hazards and downstream flood impacts. Alternatively, if there is a known defect with the dam condition then an overall assessment would be carried out at an Intermediate level, but with Detailed assessment for the potential failure modes and dam safety management.

3.3 Case Study

Three large dams on a tributary catchment of the Ca River in the Nghe An Province were selected to trial the DDCSI Dam Safety Methodology. The key parameters for the dams are listed in Table 3 and Figure 5 plots the location of the dams. A preliminary assessment was carried out for Khe Lau reservoir and an Intermediate/Detailed assessment for Sao and Ban Mong reservoirs.

The results from the assessment are published in a Case Study report which is also available online in English and Vietnamese and provides provides an example of application of the assessment process outlined in the Guidelines. The Case Study provides a companion report to the Guidelines.

Table 3. General parameters for case study dams

Name of Dam	District	Commune	Dam Type	Year Built	Catchment Area	Full Supply Level	Reservoir Storage**	Maximum Dam Height	Structure Class***
					km^2	m*	10^6 m^3	m	
Khe Lau	Thái Hòa	Nghĩa Thuận	Earth	1977	4.0	+76.5	1.9	12	III
Sào	Nghĩa Đàn	Nghĩa Lam	Earth	2003	132	+75.7	51.42	31	II
Bản Mồng	Quỳ Hợp	Yên Hợp	Concrete with earth closure	Being built	2,800	+76.4	235.5	44	I

* metres above Mean Sea Level ** at Full Supply Level *** according to Regulation QCVN 04 05:2012/BNNPTNT

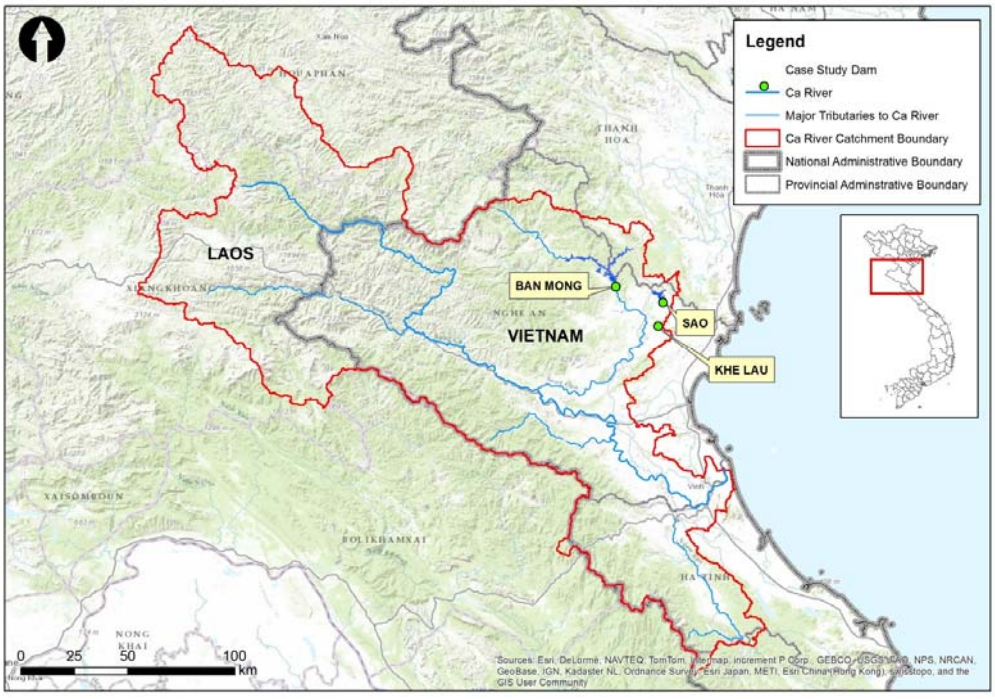

Fig. 5. Location of case study dams and Ca River basin

The Case Study successfully tested the Dam Safety Methodology on three dams broadly representative of the types and sizes of dams throughout Viet Nam. Feedback from stakeholders indicates that the Dam Safety Methodology provides robust, scalable, systems based approach to understanding dam safety and disaster risk management issues for a dam or group of dams.

4.0 Application of the Dam Safety Methodology to Multiple Dams in a Large River Basin

The successful development and testing of the Dam Safety Methodology (as outlined in Section 3.0) led to agreement between the New Zealand Government funder and the Ministry of Agriculture and Rural Development that the project should be extended to an entire (major) river system. The Ca River basin (outlined in red on Figure 5) has been proposed. The project, entitled the "Viet Nam – New Zealand Dam Safety Project" will be carried out from 2016 to 2020 in partnership between the Thuyloi University (formerly called the Water Resources University) Hanoi, Viet Nam National Committee on Large Dams, Viet Nam Institute of Geosciences and Mineral Resources, and GNS Science International Limited and Damwatch Engineering Limited of New Zealand.

The Ca River basin is located in North Central Vietnam and runs through both Nghe An province (population 2.95 million) and Ha Tinh province (population 1.23 million). The catchment is the fourth biggest river basin in Vietnam with a total area of approximately 27,000 km2 of which 65% is within Vietnamese territory. It is estimated that 978 dams are contained within the Ca River basin in Vietnamese territory which vary in size and complexity (905 small dams, 58 medium dams and 15 large dams).

The range of dam stakeholders in the Ca River Basin is both diverse and large in number encompassing farmers, industrialists, dam operators/owners, local officials, Peoples' Committees, downstream communities and national and international non-governmental organisations working with them. Of these, three groups will be the most involved in the proposed project:

- Dam owner/operators;
- Officials responsible for disaster management, evacuation planning and land use planning (and local non-governmental organisation stakeholders who support that work);
- Students of the Water Resources University who will be the next generation of water resource managers in Viet Nam.

The Dam Safety Methodology will be applied progressively to major sub-catchments of the Ca River. The results for each sub-catchment will then be summed to represent the total basin and provide a consistent and evidence-based understanding of dam safety and disaster risk management issues across the Ca River catchment. This will allow dam stakeholders in the two Provinces to identify dams needing rehabilitation and prioritise each one in the assessment portfolio based on potential for greatest harm downstream.

A series of dam safety training courses for dam owner/operators, non-governmental organisations and local officials to build their capacity is an important part of the proposed project, in order to support successful and sustained implementation of the Dam Safety Methodology. These will be implemented across the entire Ca River Basin during the project but also serve as a template for other river basins and Provinces, and into the future. It is estimated that a total of 500 dam safety-related personnel can be trained across the two Provinces.

Crucial to reducing the impact of flooding on downstream communities will be the work the project undertakes in identifying where and how dam owner/operators can best input potential flood release information into dam Emergency Preparedness Plans for these downstream communities. Non-Governmental Organisations, who work with downstream communities around Disaster Risk Management approaches, will be a key stakeholder for engagement by the project around this identification process and best use of flood release information.

A summary of the short, medium and long term objectives of the project are outlined in Table 4.

Table 4. Objectives from project extension

Short Term Outcomes	• Increased stakeholder understanding of dam safety risks and disaster prevention practices. • Refined prioritized list of dam upgrades for Ca River Basin detailing specific areas for remediation.
Medium Term Outcomes	• Greatest risk and impact dams in Ca River Basin targeted for rehabilitation through other capital works projects (e.g. World Bank funded "Vietnam Dam Rehabilitation and Safety Improvement Project" & Government of Vietnam funding) • High hazard dam owner/operators in Ca River basin effectively monitoring and managing dam safety risk. • Improved communication with downstream communities on reservoir water releases. • Relevant Vietnamese agencies undertaking more effective Land Use Planning in Ca River Basin. • Next generation of water engineers, officials and dam owner/operators skilled in Dam Safety Methodology.
Long Term Outcome	• Roll out of DSM to other river basins

5.0 Conclusions

A disaster risk reduction project known as the Dam and Downstream Community Safety Initiative (DDCSI) has been underway in Viet Nam since 2012. The aim of the project is to improve dam management and community safety throughout a river basin. The project has developed a Dam Safety Methodology, based on international recognised methods, for dam owners and managers to identify and quantify the natural hazards and assess risks associated with their dams and develop options to mitigate these risks. The methodology, with three levels of assessment according to the downstream impact of dam failure, includes provision to understand and analyse Disaster Risk Management practices regarding a dam, and whether there are gaps in capability or capacity and opportunities for improvements in planning and practice. As well as identifying where structural and operational improvements can be made to a dam, the Dam Safety Methodology provides information on the consequences of a flood release or dam failure event. Such information aids decision making for improved community warning systems, escape routes, land zoning and physical protection works for infrastructure, industry and communities. The Dam Safety Methodology promotes a river basin approach and has been published as a series of Guidelines in English and Vietnamese. The approach can be used for a single dam or a cascade of dams in a river basin in any country.

With completion of successful testing of the Dam Safety Methodology in a study of three dams in the Nghe An Province of Viet Nam, it is now proposed to implement the same methodology to a large number of dams in two Provinces of Vietnam in the Ca River catchment, one of the largest river basin systems in Viet Nam. In these two Provinces, large populations centred on the lowland plains are affected each year by flooding. Six major irrigation and hydro-power dams are present in this river basin along with a large number of small irrigation dams, all upstream of the fourth largest city in Viet Nam. The Dam Safety Methodology can be used to (i) identify and prioritise works and operational improvements needed to improve the safety of a dam, and (ii) identify where Disaster Risk Management can be improved for communities downstream of a dam. This will enable dam managers and owners to target specific improvements to safely manage existing reservoirs or in the planning and design of future projects. The evidence gathered by using this methodology will be of great use to the Peoples' Committees, officials and non-government agencies involved in Disaster Risk Management at community level.

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