INTERNATIONAL DAM SAFETY PRACTICE AND HOW THIS APPLIES IN VIETNAM

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Abstract

Dam Safety Practice refers to the safe operation and management of dams and their reservoirs for all stages of the dam's lifecycle that follow construction and commissioning. Considering the safety of dams once they commence operation is necessary to protect people, property and the environment from the potentially catastrophic impacts of a dam failure or uncontrolled release from the impounded reservoir.

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 well-known Teton dam failure in the USA in 1976 resulted in the introduction of dam safety legislation and the Safety Evaluation of Existing Dams (SEED) program and practices. These forced recognition that regular maintenance and constant vigilance is required to ensure safe operation of a dam.

Worldwide there is a general effort to align dam safety practice with recommendations of the International Commission on Large dams (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.

In Viet Nam, the Dam and Downstream Community Safety Initiative (DDCSI) is a methodology for dam owners and managers to identify and assess the natural hazards and risks associated with their dams and develop options to mitigate these risks. This should assist in prioritising repairs and upgrades based on risk to the population and damage to economic assets downstream of the dam. It can also be applied at the feasibility stage to inform dam design, operation & maintenance, and emergency preparedness.

The VNCOLD Dam Safety Manual systematically addresses the safety of dams from design, construction, management, maintenance, periodic verification of dam safety level. It also addresses responsibilities allocated to involved organisations and individuals responsible for dams in accordance with Decree 72 ND-CP.

Introduction

Viet Nam has one of the largest dam systems in the world, comprising more than 6,000 dams, with 750 of those classified as medium and large dams (VNCOLD, 2012; Dam, et al., 20121,2). With topography of mountainous highlands in the west and densely populated coastal plains, a large percentage of the Vietnamese population is at risk from dam failure flooding. Poorly constructed dams have failed and errors in operation of dams (including cascade

[1] Dam, T.T., Burritt, R.L., Pisaniello, J.D. (2012). *Adequacy of policy and practices for small agricultural dam safety accountability and assurance in Vietnam. Agricultural Water Management*, Volume 112, Pages 63–74.

[2] VNCOLD. (2012). *Dam Safety Manual.* A report prepared by the Vietnam National Committee on Large Dams (VNCOLD) for the Ministy of Agriculture and Rural Development (MARD). Date: Dec 2012.

operations) have also lead to serious and unexpected flooding. Past dam failures and operational release incidents have taken hundreds of lives and caused substantial economic losses and damage to the environment.

Dam Safety Practice refers to the safe operation and management of dams and their reservoirs for all stages of the dam's lifecycle that follow construction and commissioning. Considering the safety of dams once they commence operation is necessary to protect people, property and the environment from the potentially catastrophic impacts of a dam failure or unexpected release from the impounded reservoir.

Design of dams is covered by design standards and guidelines in many countries. While the specifics may vary from country to country, the fundamental principles for the design of each type of dam has a great deal of commonality across the world.

However the design of each dam is based on the standards and practices current at the time the dam was designed. Over time design practices improve with advances in engineering knowledge and lessons from dam incidents and failures.

The standard of construction depends on many factors including regulation, the level of oversight, the quality control and quality assurance during construction.

Operational dam safety is a more recent addition to dam practice. Dam Safety Practice has evolved throughout the world since the 1970's, partly in response to a number of high profile incidents and disasters. Prior to the Teton Dam failure in the USA in 1976, many countries did not have regulations or guidelines for operational dam safety. Incidents such as the Teton dam failure forced recognition that regular maintenance and constant vigilance (through a structured dam safety monitoring programme) is essential to ensure safe operation of a dam. In the USA, the Teton Dam failure resulted in the introduction of dam safety legislation and the Safety Evaluation of Existing Dams (SEED) program. The primary emphasis of the SEED program was to perform site evaluations and quickly identify dams that posed an increased threat to the public, and to quickly complete the related analyses in order to expedite corrective action decisions and safeguard the public and associated resources[3].

Viet Nam has regulated dam safety with Decree No. 72/2007/NC-CP which was issued by the Government of Viet Nam in May 2007. This decree was revised in 2013 with Government approval anticipated soon. Decree 72 sets out specific requirements for dam safety management which has many parallels with key principles and requirements published in dam safety guidelines from a number of countries..

International Organsiations leading Dam Safety Standards and Practices

The International Commission on Large Dams (ICOLD) is a non-governmental organisation formed in 1935, to lead the profession in setting standards and guidelines to ensure that dams are built and operated safely, efficiently, economically, and are environmentally sustainable and socially equitable[4]. There are currently 95 member countries of ICOLD. Each country has voting rights and is eligible to participate in Technical Committees that coordinate the production of Bulletins describing commonly agreed practice examples and publishing case studies.

Each member country is represented at ICOLD by its own National Body. These National Bodies tend to also be non-governmental organisations with membership from dam owners, design organisations, construction bodies and educational institutes.

Each country is responsible for its own regulation and national standards. Standards documents usually define those practice

[3] http://www.usbr.gov/ssle/damsafety/

[4] http://www.icold-cigb.org/GB/ICOLD/mission_icold.asp

requirements made mandatory by law or regulation. Guideline documents differ in that they may describe recommended good practice in the country which is not covered by law. Key differences from country to country tend to reflect their specific legislative and natural hazard context. This may include exposure to seismic events and typhoons, and operation and maintnenace tasks to be carried out e.g. pre-rainy season.

National Bodies help to disseminate ICOLD Bulletins in their country and in many cases write Guidelines of practice applicable in their home country. Some national bodies may recommend that their country follow Guidelines prepared by other countries. Examples of Guidelines often referred to by other national bodies are those from the Canadian Dam Association (CDA), the Australian National Committee on Large Dams (ANCOLD) and the New Zealand Society of Large Dams (NZSOLD). These may be general Guidelines covering accepted national practice for all dam safety related matters[5,6] or Guidelines on specific topics[7].

In some countries guidelines or manuals on dam safety related matters may be produced by Government agencies, regulators or self-regulating dam owners and engineering organisations. Examples of these are USA organisations such as the Federal Energy Regulating Commission (FERC), United States Bureau of Reclamation (USBR) and the United States Army Corps of Engineers (USACE). Many of the documents produced by these organisations are design practice manuals that describe the most advanced technical knowledge.

International non-Government organisations (NGO's) such as the World Bank may also have policies and procedures that must be followed if they are to be involved in national or regional projects8. These NGO's may also fund initiatives to write Guidelines and practice documents for countries.

Generally technical Guidelines and manuals that recommend good practice are more expansive than the specific laws and regulations relating to dam safety. Compliance reporting is likely to address only a small part of what comprises a good dam safety management programme.

The Vietnamese National Committee on Large Dams (VNCOLD) represents Viet Nam at ICOLD. Vietnamese representatives have held elected office at ICOLD. This participation provides an important link to other countries and allows Viet Nam to understand the relationship between local practice and international practice. VNCOLD through a World Bank project has published a Dam Safety Manual[9].

Principles of Dam Safety

ICOLD has published principles that should apply to the safety of all dams regardless of location or size. The ICOLD Principles from Bulletin 154[10] are listed as follows:

1 "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."

The stored volume of water needs to be retained and all flows through and around the dam controlled within specified limits. "Mis-operation" involves any departure from safe operation of any part of the dam or its safety critical systems.

2 "The prime responsibility for operational integrity and safety of a dam should rest with the Dam Owner."

[5] CDA 2007: Dam Safety Guidelines, Canadian Dam Association

[6] NZSOLD 2015: New Zealand Dam Safety Guidelines, New Zealand Society of Large Dams

[7] ANCOLD 2003: Risk Management Guidelines, Australian National Committee on Large Dams

[8] World Bank 2001: Dam Safeguard Policies, BP 4.37, Annex A - Dam Safety Reports

[9] VNCOLD 2012: *Dam Safety Manual*, Vietnam Water Resources Assistant Project (VWRAP), World Bank Loan No. Cr3880-VN, December 2012

[10] ICOLD 2010: *Bulletin 154 Dam Safety Management: Operational Phase of the Dam Life Cycle*, International Commission on Large Dams

Sometimes a government institution or agency is responsible for the safety of the dam and the public, either directly or through oversight over the safety management activities of the bodies that operate the dam.

3 "The legal and governmental framework for all industrial activities, including operation of dams, provides the overarching structures for operational integrity and safety assurance."

Dam safety guidelines and manuals will always need to recognise laws and regulations.

4 "Effective leadership and management for operational integrity and safety should be established and sustained over the life cycle of the dam."

Dam managers are responsible for the physical lifetime of the dam.

5 "Protection should seek to achieve a balance across competing objectives to provide the highest level of operational integrity and safety that can reasonably be achieved."

The safety measures applied to dams are considered balanced if they provide the highest level of safety to people, property and the environment that can reasonably be achieved throughout the physical lifetime of the dam, without unduly limiting its use.

6 "Measures for controlling risks from dams should ensure that no individual bears an unacceptable risk of harm, and that the risks to society do not exceed the risk tolerance levels of society."

7 "In order to secure the societal value, dams and reservoirs must be sustained in the long term. To ensure sustainability of dams, all reasonably practicable efforts should be made to prevent and mitigate failures and accidents."

- Future generations should be considered in dam safety decisions.
- Safety standards apply not only to local populations but also to populations remote from the dam and reservoir.

8 "Appropriate arrangements should be made for emergency preparedness and response for dam failures and accidents."

Those responsible need to establish in advance arrangements for emergency preparedness and response to a dam breach emergency. Plans may be needed at local, regional and national levels, and where agreed between countries, at the international level.

Implementing the Principles of Dam Safety

To achieve the highest standards of safety that can reasonably be achieved, measures must be taken to:

- Eliminate or reduce predictable hazards or establishment of controls over them to the extent that is practicable. Natural hazards such as floods earthquakes and landslides need to be identified, quantified and understood in order to assess whether mitigation measures at a dam are adequate.
- Eliminate or reduce failure modes, if practicable and if judged to be reasonable in terms of cost and risk reduction benefit. Potential Failure Modes Analysis (PFMA) is a tool that informs dam safety experts of the wide range of potentially catastrophic ways that the dam could fail. The form and nature of the resulting breach is an important parameter in the consequential flood that discharges from the dam. The PFMA also helps identify priorities for rehabilitation as well as improvements to operation, maintenance and surveillance of a dam. PFMA is adopted internationally as a dam safety evaluation tool.[11,12]
- Justify that the capacity of the system and its components exceeds the demands by sufficiently large margins to provide assurance

[11] *FERC. (2005). Engineering Guidelines for the Evaluation of Hydropower Projects: Chapter 14 - Dam Safety Performance Monitoring Program. Federal Energy Regulatory Commission.*

[12] *EA. (2013). Guide to risk assessment for reservoir safety management. United Kingdom Environment Agency.*

of protection. This involves engineering assessment of the dam against the most up-to-date technical knowledge and standards.

- Prevent loss of control over the stored volume and the spillway and other discharges. Control the release of damaging discharges downstream of the dam through controls that are part of the normal, pre-determined operating procedures of the dam.
- Provide the capability to intervene and avert failure in the unlikely event that a failure mode initiates. Identify the development of unsatisfactory conditions through visual and instrument monitoring. Trained operators and engineers with resources to intervene are important resources.
- Mitigate the consequences of events if they were to occur through emergency planning and/or on-site accident management. Knowledge of the flooded area through dam break and flood modelling identifies the population and economic area at risk from flooding. Procedures for effective evacuation to prevent loss of life given dam failure need to be provided. Structural protections (such as flood dykes or levees) to be constructed if appropriate.
- Provide funding mechanisms for the training of operators and engineers, physical upgrades of dams and compensation of the community affected by a failure.

World Bank Policies for Dam Safety Management

The World Bank Operational Policy BP4.37 requires Dam Safety Reports as follows:

1 *Plan for construction supervision and quality assurance*. This report covers the organization, staffing levels, procedures, equipment, and qualifications for supervision of the construction of a new dam or of remedial work on an existing dam.

2 *Instrumentation plan.* This is a detailed plan for the installation of instruments to monitor and record dam behaviour and the related hydro-meteorological, structural, and seismic factors.

3 *Operation and maintenance (O&M) plan*. This detailed plan covers organizational structure, staffing, technical expertise, and training required; equipment and facilities needed to operate and maintain the dam; O&M procedures; and arrangements for funding O&M, including long-term maintenance and safety inspections.

4 *Emergency preparedness plan.* This plan specifies the roles of responsible parties when dam failure is considered imminent, or when expected operational flow release threatens downstream life, property, or economic operations that depend on river flow levels emergency forces and equipment.

Dam Safety Management Systems

International dam safety bulletins and guidelines such as those published by ICOLD, CDA and NZSOLD recommend that dam owners utilise a Dam Safety Management System (DSMS) to provide a structured framework for the safe operation and management of its dams and reservoirs. ICOLD Bulletin 154[13] states that a DSMS should consist of systematic and comprehensive processes in order to ensure that the dam safety risks are properly managed and that all aspects of safety management are integrated or aligned with the organization's overall management structure.

The DSMS provides a formal organized process by which safety of the dam is ensured and maintained throughout its lifetime, from the conceptual phase, through design, construction and operational stage to decommissioning. This is achieved by development of a series of policies, procedures, directives and instructions. Figure 1 illustrates an example of the structure and contents of a DSMS[14].

[13] ICOLD 2010: *Bulletin 154 Dam Safety Management: Operational Phase of the Dam Life Cycle*, International Commission on Large Dams

[14] NZSOLD 2015: *New Zealand Dam Safety Guidelines*, New Zealand Society of Large Dams

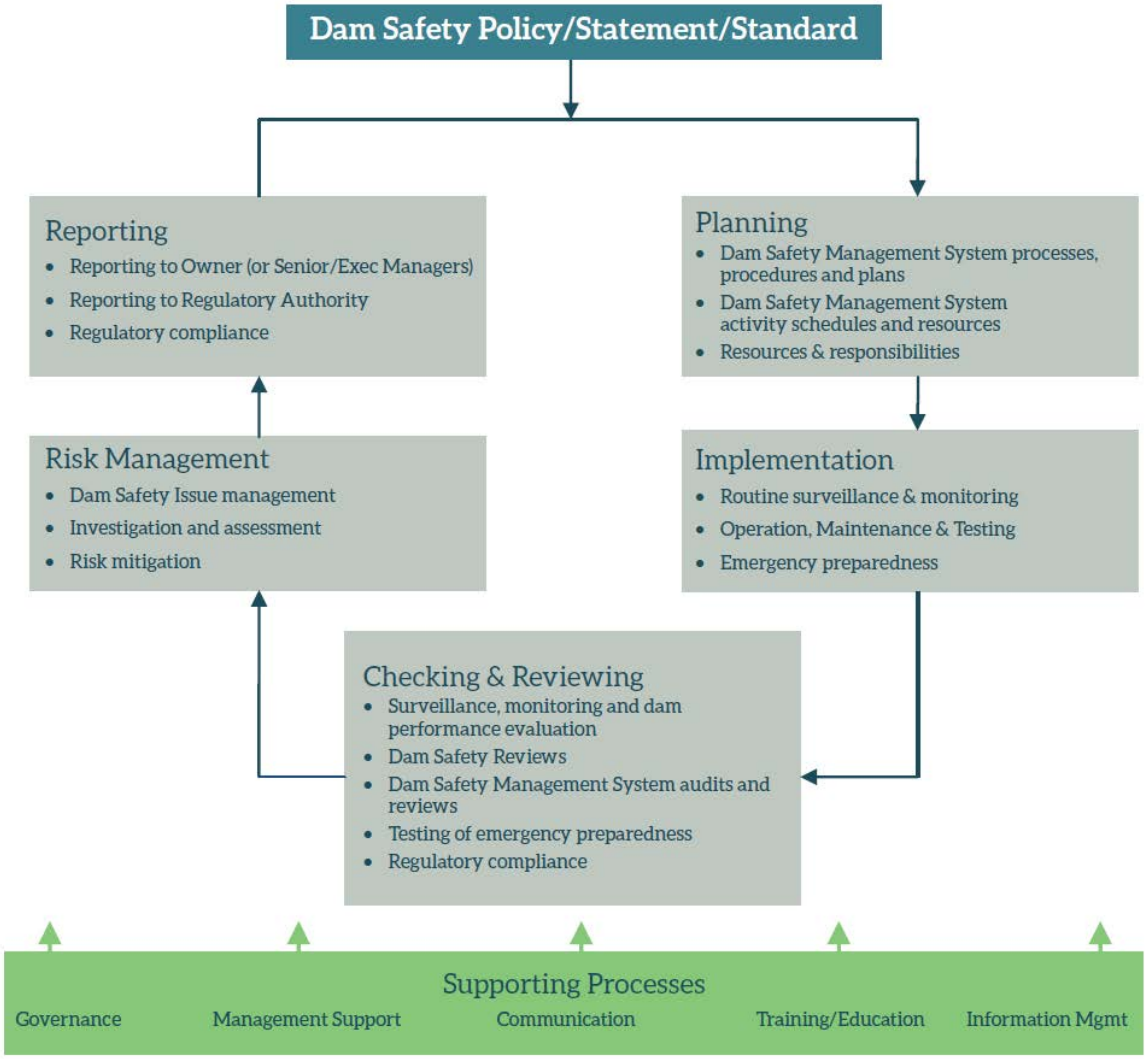

Figure 1: *A Dam Safety Management System (DSMS)*

Elements of a Dam Safety Management System

The DSMS elements recommended by international bulletins and guidelines are typically well aligned in purpose and intent. The NZSOLD Dam Safety Guidelines[15] recommend the elements summarised as follows:

1 Dam Safety Policy

Dam safety should be a primary consideration for any dam owner. A dam safety policy, statement or standard articulates an owner's commitment to dam safety management and linkage to:

- Applicable regulations
- Industry practice
- Public safety
- The protection of third party property, public infrastructure and the environment
- The owner's organisational goals and values

2 Governance

Describing Governance processes will ensure that the owner's decision making, actions and priorities are communicated and that effective implementation of the DSMS is enabled with delegated authority and appropriate resources.

3 People, Training and Education

The owner is responsible for ensuring that appropriately competent personnel are engaged to oversee or implement all elements of the DSMS, and that all involved parties understand and are competent to fulfil their roles and responsibilities. Training and education programmes for all personnel with

[15] NZSOLD 2015: *New Zealand Dam Safety Guidelines*, New Zealand Society of Large Dams

responsibilities for dam safety should be geared towards developing and maintaining appropriate awareness of important dam safety matters.

4 Dam and Reservoir Operation and Maintenance

The DSMS should not be limited to the dam itself, but should include the wider upstream and downstream context including the impounded reservoir and any potential for cascade effects where one dam's operation impacts on another. The owner should understand the parameters within which their reservoir is to be operated for normal, unusual and extreme loading and operating conditions.

The DSMS should include appropriate dam and reservoir maintenance procedures that take into account:

- Operational regimes
- Specific dam and reservoir features and equipment
- Dam potential failure modes
- Dam and equipment consequences of failure

5 Surveillance

Surveillance includes routine visual inspections, instrument monitoring (including deformation surveys), data review and evaluation, and reporting on the safety of the dam.

The objectives of surveillance are primarily to:

- Monitor dam and foundation performance
- Provide a baseline of performance information against which future changes can be assessed
- Ensure that any changes are noted to determine if they may be early indications of potential failure modes for the dam and allow appropriate intervention
- Identify and initiate the evaluation of dam safety issues arising from visual or measured/instrumented surveillance

6 Inspecting Appurtenant Structures and Gate Testing

Appurtenant structures are structures other than the dam itself that are designed and are required for the safe containment and control of the reservoir contents and reservoir discharges under all loading conditions. Appurtenant structures frequently incorporate gates and/or valves, their lifting/operating systems, and their associated power supplies, and control, protection and communication systems.

The DSMS should include appropriate inspection and testing procedures to ensure that appurtenant structures and gates/valves are able to reliably fulfil their dam and reservoir safety functions. Appropriately skilled and experienced mechanical and electrical technical advisers should be consulted in developing regular gate and valve inspection, maintenance and testing plans, and in undertaking performance reviews and assessments.

7 Intermediate Dam Safety Reviews

The purpose of an Intermediate Dam Safety Review (IDSR) is to provide periodic engineering assessment of the dam's performance as indicated by a site examination and an evaluation of surveillance data, maintenance activities and significant events including floods, earthquakes and operational events. For a high hazard dam this usually occurs once a year.

8 Comprehensive Dam Safety Reviews

A Comprehensive Dam Safety Review (CDSR) is a comprehensive, independent review of the design, construction, operation and performance of a dam, and all systems and procedures that affect dam and reservoir safety, against current dam safety guidelines, standards, and industry practice. This includes inspection and testing of gates and/or valves that fulfil dam and reservoir safety functions. Engineering investigations and analyses may, or may not, be necessary to demonstrate continuing safety of the dam. The review should be completed by experienced dam engineers with appropriate experience and competence for the dam type and its complexities.

The CDSR should identify any dam safety issues and deficiencies. The typically

recommended frequency is 5-yearly for dams with high consequences of failure and 10-yearly for dams with low consequences of failure.

9 Emergency Preparedness

Emergency action plans should clearly identify:

- Emergency management roles and responsibilities
- Dam potential failure modes
- Events and dam conditions that may warrant enactment of the plan
- Response and notification procedures
- Details of the potential dam failure consequences in relation to population and property at risk
- Contingency measures

10 Managing Dam Safety Issues and Deficiencies

Dam safety issues are defined as a broad set of issues that affect dam safety, or that arise from implementation of a DSMS, including physical infrastructure issues, dam safety deficiencies (potential or confirmed) and non-conformances.

Dam safety issues and risks should be communicated within the dam owner's organisation to those responsible for decision making and provision of resources. Engineering investigations and analyses are likely to be necessary to demonstrate continuing safety of the dam. The dam may require short term risk reduction measures, including lowering the reservoir, in order for the risk to downstream communities to be acceptable.

11 Audits and Reviews

Audits of DSMS are largely for the purpose of ensuring defined processes and procedures are being followed. Reviews of DSMS are aimed at identifying opportunities for technical and strategic improvements based on recognised dam safety practice.

12 Information Management

Whether paper-based or computer-based, it is vitally important that all dam information is filed and manged in a way that it can be easily located by future users, including those that may not know it exists.

Legal Requirements for Dam Safety Management in Viet Nam

The national legal framework for dam safety in Viet Nam is prescribed through Decree No. 72/2007/NC-CP which was issued by the Government of Viet Nam in May 2007. This decree was revised in 2013 with Government approval anticipated soon. The principles of dam safety management in the revised version of Decree 72 are listed as follows, and have many parallels with the principles outlined in ICOLD Bulletin 154 previously.

1. Dams owners and dam managers are responsible for the safety of the dams that they own and manage

2. Dam safety is the highest priority in the design, construction, and operation, maintenance, reparation and end-use of the dams

3. The dam safety management must be done regularly and continuously in the process of construction, management, and exploitation

4. The responsibilities of the dam owners, dam managers, Ministries, Agencies and People's Committees at all levels must be clearly defined; promoting the sense of community in the management of dam safety.

The revised Decree 72 defines many dam safety requirements such as:

- Providing for classification of individual dams based on reservoir height and volume
- Quality assurance requirements for dam design and construction
- Reporting requirements for operational procedures for reservoirs
- Hydro-meteorological monitoring requirements
- Periodic safety inspection and reporting requirements,
- Requirements to ensure the security of the dam and reservoir
- Requirements for protection of downstream communities due to storm and dam failure events

The roles and responsibilities of various Government agencies are prescribed in a series of Government Circulars. At a central level the Ministry of Agriculture and Rural Development (MARD) is responsible for irrigation dams (including those for water-supply and flood-control) and the Ministry of Industry and Trade (MoIT) is responsible for hydropower dams. The Ministry of Natural Resources and Environment (MoNRE) is responsible for developing inter-reservoir water regulation plans and operating rules in where there is a cascade of dams and reservoirs.

Applying Dam Safety Management Principles in Viet Nam

A disaster risk reduction project to improve dam management and community safety throughout a river basin has been underway since 2012. The Dam and Downstream Community Safety Initiative (DDCSI)[16] is a collaboration between Viet Nam and New Zealand dam safety experts. A methodology has been developed for dam owners and managers to identify and assess the natural hazards and risks associated with their dams and develop options to mitigate these risks. The key steps are:

1 Develop a detailed understanding of natural hazards affecting the river basin, such as floods, earthquakes and landslides.

2 Assess the potential failure modes that could lead to dam failure, following a standard methodology. Assess the operating rules for the dam.

3 Assess the consequences of dam break and flood release, by producing corresponding flood inundation maps and building databases of population, houses and infrastructure at risk from flooding.

4 Knowledge of the consequences of a flood release or dam break 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.

A successful pilot has been completed in the Hieu River basin that flows into the Ca River System in Nghe An Province of Vietnam. The DDCSI Guidelines can be applied on large river basin systems with multiple irrigation and hydropower dams in Viet Nam. The most vulnerable dams, or dams with the greatest potential downstream impact, can be identified and addressed first.

The DDCSI methodology can be used to:

- identify and prioritise works and operational improvements needed to improve the safety of a dam, and
- identify where Disaster Risk Management (DRM) 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. Physical works might include:

- Spillway upgrades to prevent overtopping potential failure modes.
- Filter buttresses and cutoff walls to address seepage and piping concerns through embankment dams.
- Filter collars around culverts.
- Buttressing concrete dams.
- Flood dykes/levees.

Meeting Government Regulations

The VNCOLD Dam Safety Manual[17] has the objective of systematically addressing the safety of dams during design, construction, management and on-going maintenance, and

[16] VN-NZ 2015, *Dam and Downstream Community Safety Initiative Guidelines*, Damwatch Engineering, GNS Science and Thuyloi University Hanoi, 2015.

[17] VNCOLD 2012: Dam Safety Manual, Vietnam Water Resources Assistant Project (VWRAP), World Bank Loan No. Cr3880-VN, December 2012.

periodic verification of dam safety level. It also addresses responsibilities allocated to involved organisations and individuals responsible for dams in accordance with Decree 72 ND-CP.

The Dam Safety Manual and the DDCSI Dam Safety Initiative provide tools for compliance with some aspects of Decree No.72/2013/ND-CP on dam safety management. Examples of common points between assessment methods outlined in the Guidelines and the requirements of Decree 72 are summarised in the table below.

Clause from Decree No.72/2013/NC-CP	DDCSI Guidelines
Chapter II, Article 5, No.4(h) For large dams: Flood maps are developed for downstream areas for design floods, emergency and dam-failure scenarios	Provides simple to detailed methodologies to prepare flood maps for dam spillway release and dam failure events
Chapter III, Article 15, No.2 Appraisals on dam safety	Provides methods to identify site specific: - natural hazards to a dam - dam vulnerabilities and safety issues - identify dam safety issues and determine dam upgrade requirements (structural, technical or institution)
Chapter IV, Article 20 Flood and storm prevention and protection for downstream communities including Emergency Preparedness Plans and warning systems	Provides methods to: - estimate and quantify damages to downstream people, property, infrastructure, agricultural land in emergency flood situations - prepare emergency preparedness plans - to design an effective emergency warning system

Summary

Worldwide there is a general effort to align dam safety practice with ICOLD recommendations. Many countries, including Viet Nam, have laws and regulations requiring dam owners to have dam safety programmes. The laws and decrees provide minimum requirements which are usually well covered by national Dam Safety Guidelines, commonly published by national dam safety organisations. The Dam Safety Management Systems published in well considered dam safety guidelines apply the principles espoused by ICOLD in their publications.

A methodology now exists in Viet Nam for dam owners and managers to identify and assess the natural hazards and risks associated with their dams and develop options to mitigate these risks. This should assist in prioritising repairs and upgrades based on risk to the population and damage to economic assets downstream of the dam.

The VNCOLD Dam Safety Manual[18] has the objective of systematically addressing the safety of dams during design, construction, management and ongoing maintenance, and periodic verification of dam safety level. It also addresses responsibilities allocated to involved organisations and individuals responsible for dams in accordance with Decree 72 ND-CP.

[18] VNCOLD 2012: *Dam Safety Manual*, Vietnam Water Resources Assistant Project (VWRAP), World Bank Loan No. Cr3880-VN, December 2012.