

# Guidance Note on Dam Safety Decision Principles

March 2015



The State of Victoria Department of Environment, Land, Water and Planning 2015



This work is licensed under a Creative Commons Attribution 3.0 Australia licence. You are free to re-use the work under that licence, on the condition that you credit the State of Victoria as author. The licence does not apply to any images, photographs or branding, including the Victorian Coat of Arms, the Victorian Government logo and the Department of Environment, Land, Water and Planning logo. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/3.0/au/deed.en>

ISBN 978-1-74287-510-1 (online)

#### **Accessibility**

If you would like to receive this publication in an alternative format, please telephone the DELWP Customer Service Centre on 136186, email [customer.service@delwp.vic.gov.au](mailto:customer.service@delwp.vic.gov.au) or via the National Relay Service on 133 677 [www.relayservice.com.au](http://www.relayservice.com.au). This document is also available on the internet at [www.delwp.vic.gov.au](http://www.delwp.vic.gov.au)

#### **Disclaimer**

This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

*Cover Photo: Dartmouth Dam, Victoria, Australia*

# Contents

<b>Summary .....</b>	<b>2</b>
<b>1 Introduction .....</b>	<b>3</b>
1.1 Purpose.....	3
1.2 Background.....	3
1.3 Structure.....	3
<b>2 Risk Management and Dam Safety in Victoria.....</b>	<b>4</b>
2.1 Overview of owner and manager obligations .....	4
2.2 Understanding the risk .....	4
2.3 Risk management and engineering standards .....	5
2.4 Considerations for very high consequence dams.....	5
<b>3 Risk Management Process and Roles.....</b>	<b>6</b>
3.1 Holistic risk assessment.....	6
3.2 Risk management role clarity.....	6
3.3 Department-Owner/Manager interaction .....	8
<b>4 Risk Reduction Principles .....</b>	<b>9</b>
4.1 Affordability.....	9
4.2 Progressive improvement .....	9
4.3 Prioritising upgrades.....	10
4.4 Timing of risk reduction measures .....	11
4.5 Risk assessment uncertainty .....	11
<b>5 ALARP Principle and Practice.....</b>	<b>12</b>
5.1 Tolerable risk, the ALARP principle and dams.....	12
5.2 Cost effectiveness.....	13
5.3 Good practice .....	14
5.4 Existing level of risk – Risk Monitoring Zone .....	15
5.5 Societal concerns.....	16
5.6 Other factors in ALARP determination.....	17
<b>6 Systemic Approach to Dam Safety.....</b>	<b>19</b>
<b>7 Investment Decision Making .....</b>	<b>21</b>
<b>8 References .....</b>	<b>23</b>

*The Department of Environment, Land, Water and Planning intends to review this document periodically. Please forward any comments to Siraj Perera, Rural Water Programs and Economic Reform Division, Water and Catchments Group, Department of Environment, Land, Water and Planning, PO Box 500, East Melbourne VIC 3002 or email: [siraj.perera@delwp.vic.gov.au](mailto:siraj.perera@delwp.vic.gov.au).*

## Summary

This Guidance Note aims to assist dam owners and managers make key dam safety investment decisions. It provides guidance on how dam owners and managers can prudently reduce dam safety risk through focussed and proportionate investment.

It provides supplementary advice to existing regulations.

The safety of dams owned by Victoria's water corporations is regulated through Statement of Obligations (SoOs) issued to water corporations by the Minister for Water under the *Water Industry Act 1994*. The SoOs refer to dam safety guidelines prepared by the Australian National Committee on Large Dams (ANCOLD).

The safety of privately owned dams is regulated by Section 67 of the *Water Act 1989*.

The Department of Environment, Land, Water and Planning (Department) is the lead agency for regulating dam safety in Victoria.

Investment decisions about dam safety programs can be complex because of:

- uncertainty in assessing whether current or proposed risk levels satisfy the ALARP ("As Low As Reasonably Practicable") principle;
- uncertainty about appropriate timeframes to achieve adequate dam safety levels;
- uncertainty about whether or not safety levels beyond risk-based criteria should be considered to meet traditional engineering standards; and
- uncertainty about whether dam safety standards and expenditure are proportionate with standards applied to other areas of public safety where catastrophic consequences can occur.

This Guidance Note also intends to provide promote transparent processes for making efficient and appropriate level of investment in dam safety.

# 1 Introduction

## 1.1 Purpose

This Guidance Note aims to assist dam owners and managers make key dam safety investment decisions. It provides guidance about satisfying the “As Low As Reasonably Practicable” (ALARP) principle and clarifies dam safety investment timeframes and appropriate target safety levels. It assumes that the reader is familiar with the broad topics of dam safety, risk management and the ALARP principle.

This Guidance Note supplements existing guiding documentation available to Victorian dam owners and managers including the regulatory instruments, the *Strategic Framework for Dam Safety Regulation*, ANCOLD Guidelines and other publications. While primarily directed toward the Victorian water corporations, many of the principles outlined in this document are relevant to other owners and managers of potentially hazardous dams.

## 1.2 Background

Under the *Water Act 1989* dam owners are responsible for dam safety and accountable for the damage their dams may cause if they fail.

The Minister for Water has powers under the Act to regulate the construction, operation and safety of dams in Victoria. These powers apply to dams owned or operated by public entities such as water corporations, local government, Parks Victoria and to privately owned dams. The Water and Catchments Group in the Department supports the Minister in exercising these powers and responsibilities.

The Minister regulates the safety of dams owned by Victoria’s water corporations through SoOs issued under the *Water Industry Act 1994*. The SoOs are publicly available and can be obtained from the Department’s website.

The Minister for Water regulates the safety of privately owned dams through a licensing regime set out in Section 67 of the *Water Act 1989* and in associated Ministerial Guidelines. The Minister has delegated these licensing functions to Goulburn-Murray Water, Grampians Wimmera Mallee Water, Lower Murray Water and Southern Rural Water.

In 2010 the Department completed an independent review of the regulation of dam safety in Victoria. The review recommended that the Department provide supplementary guidance to dam owners and managers, particularly in relation to the ALARP principle.

The ALARP principle is defined thus:

*“...risks, lower than the limit of tolerability, are tolerable only if further risk reduction is impracticable, or if cost is grossly disproportionate (depending on risk level) to the improvement gained” (ANCOLD Guidelines on Risk Assessment, 2003a, originally from UK Health and Safety Executive, HSE).*

This Guidance Note has been prepared in response to the above recommendation.

## 1.3 Structure

The Guidance Note is divided into six sections covering the following topics:

- **Risk Management and Dam Safety in Victoria** – a discussion on risk management obligations and its application to dam safety in Victoria.
- **Risk Assessment Roles** – to clarify the role of the Regulator, the interaction of the Regulator and dam owners and managers, and the importance of role clarity for all participants in each part of the risk assessment process.
- **Risk Reduction Principles** – for uncertainty in risk assessment, staging of works, prioritisation and timing of remedial measures and continuous improvement.
- **ALARP Principle and Practice** – for cost effectiveness, disproportionality, good practice and societal concerns.
- **Systemic Approach to Dam Safety** – to encourage clear and robust systemic approaches to dam safety management.
- **Investment Decision Making** – a transparent and structured investment decision making approach that is “whole of organisation”.

## 2 Risk Management and Dam Safety in Victoria

### 2.1 Overview of owner and manager obligations

Dam owners and managers are responsible for the safety of their dams.

The SoOs are the primary regulatory instrument for public dams owned by Victoria's water corporations. They impose obligations on water corporations in relation to risk management and dam safety. The SoOs state that owners must have:

*...regard to the ANCOLD Guidelines and have particular regard to:*

- a) prioritising risks posed by the...dams over all dams, components of dams and the types of failure; and*
- b) giving priority to reducing risks to life above other risks; and*
- c) basing the urgency of reducing the risk posed by a dam on the relativity of risks to the tolerability limits as defined in the ANCOLD Guidelines; and*
- d) basing programs for reducing risk on the concept "As Low As Reasonably Practicable" as defined in the ANCOLD Guidelines; and*
- e) where feasible, progressively implementing risk reduction measures to achieve the best outcomes for the available resources.*

Thus ANCOLD Guidelines (Risk Assessment, Dam Safety and other matters) are significant guiding documents for Victorian dam owners and managers regarding dam safety and risk management.

### 2.2 Understanding the risk

**Guidance:** *Dam owners and managers should develop a comprehensive understanding of consequences of dam failure and undertake risk assessments. The details of the risk assessment should be proportionate to the level of risk.*

Dam owners and managers need to develop a comprehensive understanding of dam failure consequences.

The potential consequences of a dam failure include loss of life, economic losses (direct and indirect), losses such as environmental damage and public health impacts, and intangible consequences such as cultural heritage consequences and social trauma.

Owners should complete ANCOLD Consequence Category assessments to gain an understanding of the Population at Risk (or Potential Life Loss, where appropriate) and potential economic consequences associated with failure of their dams.

Existing consequence category assessments that are incomplete or out of date should be updated and completed to an appropriate level of detail as a matter of urgency.

Consequence categorisation allows owners to proceed in an informed way with risk assessment, focussing first on their higher Consequence Category dams.

Dam owners and managers should undertake a Portfolio Risk Assessment (PRA) of all of their dams to determine priorities.

Once Consequence Categories are assigned, ANCOLD (2003a) identifies different levels of risk assessment from 'Screening' to 'Very Detailed'. The first two levels (Screening and Preliminary) are intended to be used to rank risks or to get early indication of issues.

Detailed or very detailed risk assessments should be undertaken for dams with identified Potential Loss of Life or critical infrastructure and/or essential services interdependency (i.e. High or Extreme Consequence Category dams), to assess risk and support the assessment of ALARP. Where dams meet traditional engineering standards, and they are Extreme or High consequence category, a risk assessment will provide owners with substantial benefit by identifying all failure modes and required defences.

Normally a rigorous assessment should be undertaken, however there may be circumstances where this level of assessment is not required. For example, implementing upgrades of smaller High Consequence dams may cost less than undertaking a detailed risk assessment, or in some circumstances a preliminary risk assessment may indicate risks are clearly well below the Limit of Tolerability.

The general principle is that **the more risk** and **the more at risk**, the more prudent it is to undertake a higher level of risk assessment. Risk assessment for these higher risk/consequence dams should be undertaken before other dams.

A key output of the risk assessment process for dams with an identified potential Loss of Life, is an F-N curve which relates F (the probability per year of causing N or more fatalities) to N (the number of fatalities).

Figure 4 in Section 5.4 illustrates an F-N curve with the various risk zones. ANCOLD (2003a) provides detailed commentary on the development of such curves and their use in decision-making.

In addition to societal risk, ANCOLD (2003a) advocates compliance with individual risk. Individual risk requires assessment and evaluation, but most often societal risk will have most influence over life safety considerations.

### 2.3 Risk management and engineering standards

*Guidance: A risk-informed approach satisfying the As Low As Reasonably Practicable principle should be used if meeting the safety standards of a new dam are either impractical or not feasible.*

*A systemic approach should be used to deliver ongoing risk reduction.*

ANCOLD (2003a) states that a traditional or engineering standards based approach to dams engineering is one in which risks are controlled by following established rules for design events and loads, structural capacity, safety coefficients and defensive design measures. In order to meet engineering standards owners would need to demonstrate that their dam(s) meet current design practices for new dams.

For some existing dams, meeting the standards of a new dam can be either impractical or not feasible. In these cases, a risk-informed solution satisfying ALARP and using a systemic approach to ongoing risk reduction may be considered.

### 2.4 Considerations for very high consequence dams

*Guidance: Dam owners and managers should give additional attention to dams with Potential Life Loss greater than 100 lives and/or potential economic losses in excess of \$1 Billion.*

In Victoria there are approximately twenty dams that have a potential loss of life in excess of 100 and/or can cause economic loss in excess of \$1 Billion.

Owners of these dams should give particular attention to:

- the rigour of the risk assessment methodology, including the application of the ALARP principle;
- extent of risk reduction works;
- implementation sequencing and timing;
- the feasibility of satisfying traditional engineering standards; and
- societal concerns (see section 5.5).

The annual dam safety report submitted to the Department by water corporations should provide comprehensive and up to date information on these dams.

## 3 Risk Management Process and Roles

### 3.1 Holistic risk assessment

*Guidance: Dam owners and managers should develop and implement appropriate plans, systems and processes that have regard to the ISO 31000:2009 Risk Management Standard and complemented by the ANCOLD risk assessment processes.*

Dam owners and managers should develop and implement appropriate plans, systems and processes that have regard to the ISO 31000:2009 Risk Management Standard, to ensure that risks to their assets or services are identified, assessed, prioritised and managed. This approach provides an enterprise view of risk. It should be complemented by the dam safety risk assessment process advocated by ANCOLD which focuses on life safety and economic risk. Both the enterprise and the ANCOLD approaches to risk assessment will inform owner decisions regarding prioritisation of risk reduction measures to tolerable levels.

### 3.2 Risk management role clarity

*Guidance: Dam owners and managers should clearly define the roles of the various participants in the dam safety risk assessment and investment process.*

It is important to have a clear understanding of roles of the various participants involved in the risk assessment process. Guidance on the risk assessment process and the roles of identified participants is provided in ANCOLD (2003a), and further illustrated in Figure 1.

The participants identified within the ANCOLD Guidelines (2003a) include:

- the dam owner who is legally responsible for dam safety (e.g. the water corporation);
- the decision-maker (e.g. the Board of the water corporation);
- risk analysts responsible for undertaking risk analysis (e.g. appropriate water corporation staff);
- independent reviewers (for independent advice and quality assurance); and
- the dam safety regulator.

In Victoria, dam owners and managers are responsible for managing the safety of their dams and the principle of “owner responsibility” is clearly present in the regulatory instruments.

Water corporations need to lead the management of dam safety, and initiate the risk identification and assessment process for their dam portfolio, engaging all relevant internal and external expertise and clearly differentiating the decision making role within its organisation.

Figure 1 illustrates a typical risk management process for a dam, and adds to this an overlay of the intersection between the process and the participants to provide some visibility around who is involved in each part of the process.

The boards of water corporations are responsible for determining the appropriate level of investment in dam safety within an agreed organisational process. Independent reviewers can assist owners in this process, however it is important not to blur the role of the independent reviewer and the decision maker.

The Department performs a number of functions including establishing and reviewing the regulatory framework, collating and assessing dam safety management information, promoting good practice, industry benchmarking, and knowledge sharing.



# Risk Management Roles

...generalised interaction with...

## Typical Risk Assessment Process for a Dam

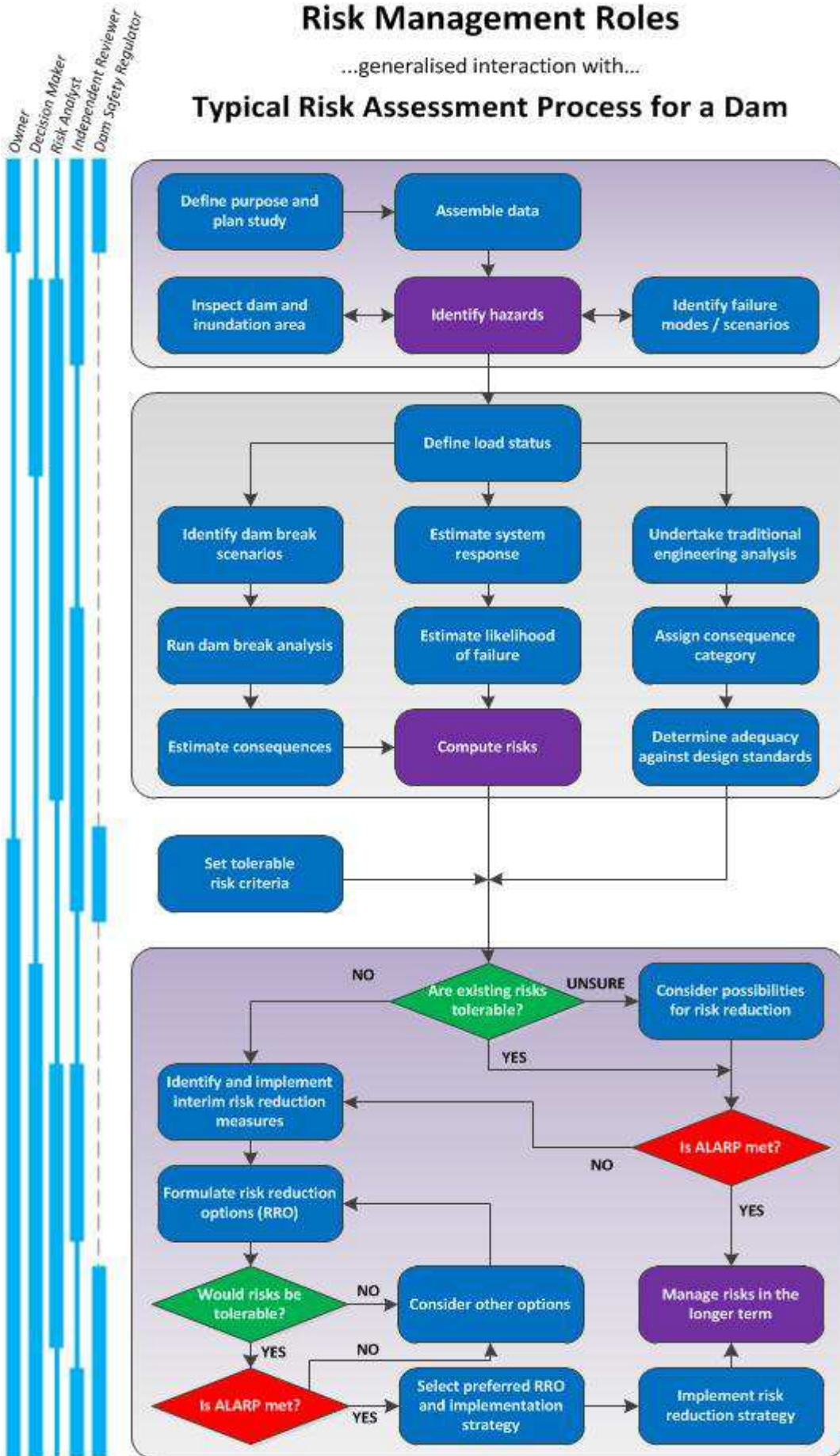


Figure 1 Risk assessment process, roles and interaction (after ANCOLD, 2003a)

### 3.3 Department-Owner/Manager interaction

**Guidance:** *Dam owners and managers should use existing forums to discuss their dam safety challenges and management approaches, and continue to involve the Department in emergency exercises.*

There are a number of forums relating to dam safety and emergency management matters that dam owners and managers can participate in. For example, the Victoria Water Industry Dams Working Group is a key forum for water corporations and the Department to discuss dam safety challenges and management approaches. It is used to discuss state-wide dam safety management issues, share information and evaluate water industry dam safety performance.

The Department has formal processes with owners of large dams and emergency response agencies for managing dam safety emergency situations. Water corporations and owners of potentially hazardous dams should continue to involve the Department during testing and exercising their dam safety emergency plans.

# 4 Risk Reduction Principles

## 4.1 Affordability

**Guidance:** Dam owners and managers should identify a pathway to achieve risk reduction and dam safety objectives whilst maintaining an acceptable pricing pathway.

*Affordability of risk reduction measures is not a consideration for dams with life safety risk above the Limit of Tolerability.*

Dam owners and managers should identify acceptable investment and pricing pathways to achieve life safety and economic risk reduction As Soon As Reasonably Practicable (“ASARP”, New South Wales Dam Safety Committee, 2010). The desired outcome is to achieve portfolio risk reduction within a reasonable timeframe (refer Section 4.4 for details) and an acceptable pricing pathway having regard to practices in similar jurisdictions.

The key question is “how are we, and how will we continue, working to reduce risk at this dam?” In cases where customer impacts would be significant, the economic regulator, the Essential Services Commission (ESC), the Department and other stakeholders should be consulted to explore alternative options and broader impacts.

Investment in dam safety should be managed so that these responsibilities are upheld and that protection of life and property is assured.

Affordability is not a consideration in taking action to reduce the risk of dams (ANCOLD 2003a) with life safety risk above the Limit of Tolerability.

## 4.2 Progressive improvement

**Guidance:** Dam owners and managers may stage risk reduction measures, (known as Progressive Improvement), across their portfolio of dams to reduce risks below the ANCOLD Limit of Tolerability.

The staging of risk reduction measures is widely practised in Victoria and the rest of Australia by dam owners and managers with dams whose F-N curves intersect the area above the Limit of Tolerability.

The approach is to firstly reduce risk in rapid progression to at least below the Limit of Tolerability and then to undertake an assessment of further risk reduction options and implement measures where the additional risk reduction is justifiable. This staged approach is illustrated in Figure 2.

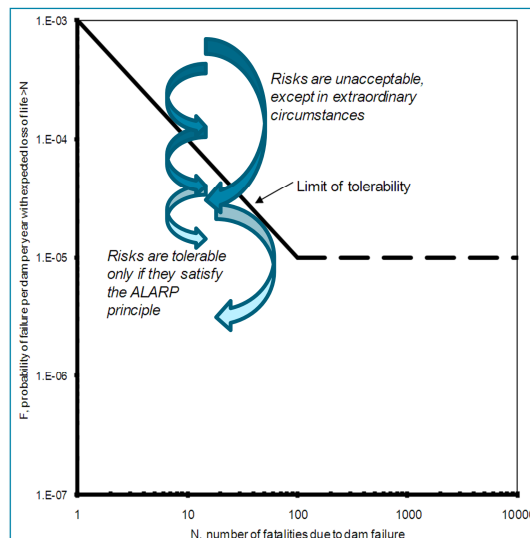


Figure 2 F-N Curve illustrating Progressive Improvement approaches

Guidance Note on Dam Safety Principles

The first stage should if possible, be achieved quickly by interim or intermediate measures. This may be coupled with heightened surveillance around the failure modes of concern and a well exercised emergency management plan. Additional time and investment may be required to implement more enduring risk reduction measures.

Risk reduction may progress to or even beyond the requirements of traditional engineering standards.

Due to the uncertainty inherent in risk assessment and because the consequences of failure and estimates of failure probabilities are subject to change over time, owners should seek to drive risk not “to” but instead “to below” the Limit of Tolerability.

Some owners apply a clearance margin of one third to one half an order of magnitude for failure probability. This approach may be relatively straightforward for an owner if the range and prioritised sequence of risk reduction measures results in a stepped investment profile. In these situations, an owner may be able to package a number of risk reduction measures cost effectively, demonstrate a discontinuity in the risk reduction-cost relationship, and shift the F-N curve clearly into the zone where tolerability can be checked.

### 4.3 Prioritising upgrades

*Guidance: Dam owners and managers may modify an equity-based priority list of portfolio risk reduction measures to account for efficiency and other considerations.*

ICOLD (2005) describes two key and generally competing principles that should be adhered to and balanced during the evaluation of risk. These are:

- **Equity** – the right of individuals and society to be protected, and the right that the interests of all are treated fairly; and
- **Efficiency** – the need for society to distribute and use available resources for the greatest benefit.

Portfolio risk assessment provides dam owners and managers with a view of the risk status of their dams. This approach identifies stakeholders who are most at risk for life safety as well as economic losses. A prioritisation approach based purely on equity would sequence risk reduction measures to reduce life safety risk ahead of economic losses for those most exposed through to those least exposed.

However, owners may consider a number of factors for modifying the equity-based sequence of risk reduction measures. These include:

- manifest signs of inadequacy (incident or identified failure mode emergence);
- expediency around interim improvements that can be rapidly implemented or undertaken during low risk periods (for example, prolonged low reservoir level periods);
- organisational and industry capacity;
- interdependency on essential services or critical infrastructure;
- specific community concerns;
- economic regulator planning cycle (e.g. Water Plan cycle);
- avoidance of excessive deferral duration due to other competing priorities; and
- lack of identifiable mitigation options.

Water corporations should demonstrate “momentum”, (i.e. that risk is reducing at a reasonable rate) while satisfying the economic regulator that the investment in dam safety is both necessary and does not create excessive price shocks for customers. In taking this approach, it is important to test the modified program with the original equity based order and also have regard to the timing for implementing risk reduction measures.

Prioritising the implementation of risk reduction measures for dams with potential Loss of Life below the Limit of Tolerability is addressed through the ALARP processes discussed in Section 5.

## 4.4 Timing of risk reduction measures

**Guidance:** *Dam owners and managers should reduce risks ‘As Soon As Reasonably Practical (ASARP)’.*

*Short term or interim measures should be used for dams that are over an order of magnitude above the Limit of Tolerability for societal risk and for dams with deficiencies that have substantial economic consequences, until a permanent upgrade is implemented.*

For dams above the Limit of Tolerability, the principle of “As Soon As Reasonably Practicable” (ASARP) (NSW DSC, 2010) should be used to help determine the timing of dam safety works and measures.

In practice, the timeframe for implementing a major dam safety upgrade from identification of risk through to investigations, approvals, design, implementation and commissioning can range from a few years to up to about ten years.

Special requirements apply for dams that are over an order of magnitude above the Limit of Tolerability. For these dams, owners should investigate and implement short term or interim measures to reduce risk to within at least one order of magnitude of the Limit of Tolerability. Interim measures may include a combination of non-structural measures (such as drawdown or operating restrictions within a one year timeframe) and structural measures (for example within a two year timeframe). In these cases it is important to ensure that a well exercised emergency plan is in place. In circumstances where it becomes apparent that there is an imminent risk of failure, immediate action is required.

Similar requirements should apply to dams with deficiencies that have substantial economic consequences.

Owners need to be able to show a continuous improvement in the risk position of the portfolio of dams. Some jurisdictions require risk reduction below the Limit of Tolerability to either ALARP or standards within approximately 20 years from when risks are identified. This is a useful benchmark which should be achievable for most Victorian dam owners and managers. However, a case by case consideration is required.

## 4.5 Risk assessment uncertainty

**Guidance:** *Best estimate values with sensitivity analysis should be used in risk assessment. Uncertainty should be acknowledged, assessed and incorporated where possible so that its impacts on decisions are understood.*

The best estimate values of the individual risks, the failure probabilities and the loss of life values, should be used for comparison with the various life safety criteria.

However, it is also important to acknowledge that uncertainty exists in both the estimates of likelihood and consequences of dam failure. Dam owners and managers should consider the level of uncertainty associated with the estimated risks.

For assessment against the Limit of Tolerability, the owner should have confidence that the best estimate is clearly below the limit. The risk analyst should provide an indication of the degree of uncertainty and where it has and has not been propagated. Sensitivity analysis should be undertaken to determine which input parameters have a higher level of sensitivity in the outputs.

The level of uncertainty is likely to be a function of the type of dams and failure modes. As uncertainty increases, there is a case to reduce risks clearly below the Limit of Tolerability. This will depend upon the type of dam and failure mode, and the level of risk assessment, but as an indication, clearance by approximately a half an order of magnitude would appear prudent.

The application of rigorous methods of analysing the uncertainty, such as propagation of uncertainties through the analysis using the Monte Carlo simulation or sensitivity testing of inputs, is encouraged. However, it is recognised that it may be some time before there is demonstrable capability and experience with these approaches in the Australian dam industry.

## 5 ALARP Principle and Practice

### 5.1 Tolerable risk, the ALARP principle and dams

**Guidance:** Dam owners and managers should demonstrate that the “As Low As Reasonably Practicable” (ALARP) principle is satisfied along with three other conditions (ICOLD 2005) listed below, to meet tolerability of risk.

Dam owners and managers should have regard to the matters set out in Figure 3 below and in Section 5.6, to satisfy the ALARP principle.

The dam owner and manager are required to make judgements about tolerable risk. The concept of tolerable risk emerges from the work done by the United Kingdom Health and Safety Executive (HSE), and can be summarised as follows:

*Tolerable risk is defined by ICOLD (2005) and adapted from HSE (2001) as “a risk within a range that society can live with (1) so as to secure certain net benefits. It is (2) a range of risk that we do not regard as negligible or as something we might ignore, but rather as something we need to (3) keep under review and (4) reduce it still further if and as we can.” (Bowles, 2007)*

Each of these four conditions of tolerability has implications for dam safety.

The first condition, “to secure certain net benefits”, requires dam owners and managers to take a systems perspective of their dam assets and test that the wider system, within which a specific dam is a part, benefits from the presence and function of the dam without excessive impact. This evaluation is an important periodic activity for an owner, in consultation with stakeholders, and where the test fails decommissioning may be seriously considered.

The other three conditions of tolerability encourage dam owners and managers to keep close watch on their dams and take a range of measures to understand, reduce and suppress risk, importantly in an ongoing manner.

The ALARP principle is represented as condition (4) “reduce it still further if and as we can.” and is incorporated in Australian common and statute law, is defined by ANCOLD thus:

*“...risks, lower than the limit of tolerability, are tolerable only if further risk reduction is impracticable or if its cost is grossly disproportionate (depending on risk level) to the improvement gained” (ANCOLD, 2003a)*

The ALARP test requires a range of options for risk reduction to be considered. For a risk to be ALARP it must be possible to demonstrate that the cost involved in reducing the risk further would be grossly disproportionate to the benefit gained.

The ANCOLD Guideline states that there is “...no ‘formula’ by which to decide that risks are ALARP. The owner needs to reach a judgment that the sacrifice is grossly disproportionate to the reduction in risk that would be achieved.” The Guideline does, however suggest some “...points that are relevant in making a judgment on whether risks are ALARP....”

The four primary factors identified by ANCOLD are illustrated in Figure 3.

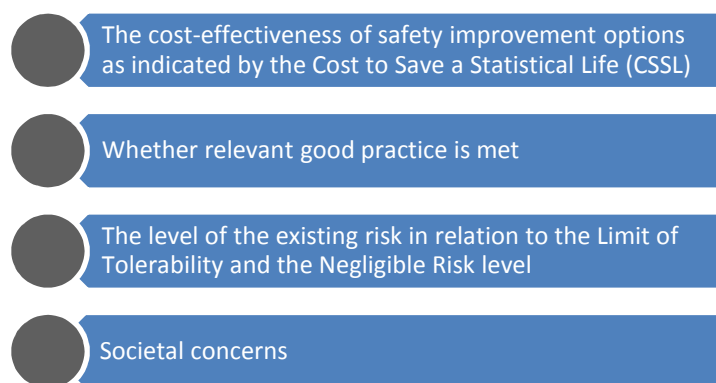


Figure 3 ANCOLD factors for ALARP determination

Determining that ALARP is satisfied is a matter for judgement by the dam owner and manager.

ANCOLD Guidelines also recommend both a “global” and a “component” view of the dam and associated risks be undertaken as part of the process for determining ALARP.

## 5.2 Cost effectiveness

*Guidance: Dam owners and managers should consider cost effectiveness of remedial measures, good practice, the existing level of risk and societal concerns when assessing ALARP.*

The Cost to Save a Statistical Life (CSSL) is a measure of the cost effectiveness of reducing life safety risk and is recommended by ANCOLD as one consideration when assessing ALARP.

ANCOLD (2003a) provides formulae for calculating the CSSL and also “adjusted” CSSL, abbreviated as aCSSL. The adjusted form takes account of the extent to which the cost of risk reduction measures is offset by the expected value of the reduction in monetary loss risks and any reduction in annual operating costs, and should be used for assessing ALARP.

Consistent with the progressive improvement approach, the aCSSL should be calculated for each stage of a dam safety upgrade.

There is no value of aCSSL, at which it can categorically be said that ALARP is justified. Rather, the case in favour of satisfying the ALARP test strengthens progressively as the aCSSL value increases.

ANCOLD (2003a) includes two tables which provide tentative guidance on the ALARP justification based on the aCSSL. Table 8.6 is to be applied to dams which are just below the Limit of Tolerability and Table 8.7 applies to dams just above the “broadly acceptable range”. The thresholds in the tables are a function of the Value of Preventing a Fatality (VPF) and the disproportionality factor.

The VPF is cited in the ANCOLD Risk guidelines as £1M with reference to the 2001 “*Reducing Risks, Protecting People*” (R2P2) report produced by the HSE. Converting £1M to AUD by applying the 2001 exchange rate and then adjusting to 2011 dollars by applying the Wage Price Index (WPI) results in a current (2011) VPF of approximately AUD \$4.5M.

The VPF values adopted by different industries and jurisdictions, in Australia and overseas, vary but tend to be in the range from approximately \$AUD3.0M to around \$AUD9.0M. Values need to be interpreted carefully for application to the dams industry where the risks are involuntary and the benefits are indirect if

they exist at all. In these circumstances the affected person may be more averse to the risks associated with dams, and the VPF figures obtained from other industries may be considered as a lower limit.

A disproportionality factor is used to test whether an investment in dam safety is grossly disproportionate to the benefits associated with an avoided fatality.

The ANCOLD (2003a) guidelines are based on HSE which indicates as generally reasonable a disproportionality factor of 10 for risks just below the Limit of Tolerability and dropping to approximately 3 for risks just above the broadly acceptable level. The HSE framework is widely used and it is appropriate that disproportionality be applied in assessing ALARP.

The application of a disproportion factor in some way accounts for societal dread of single risk events involving multiple fatalities.

The VPF of approximately AUD\$4.5M, and disproportionality factors from the HSE framework (ranging from 3 to 10) demonstrates that the thresholds in Tables 8.6 and 8.7 of ANCOLD (2003a) are conservative. Given this conservatism, there is no need for new threshold values or indexing over the short to medium term.

Experience from recent detailed risk assessments has shown that once the risk profile for a dam has been reduced to below the Limit of Tolerability it is difficult to identify further risk reduction options with aCSSL values that would justify further risk reduction according to the thresholds in Tables 8.6 and 8.7 in ANCOLD (2003a).

Once an owner has achieved risk reduction into the zone where tolerability can be tested, it is unlikely that aCSSL will provide justification for additional risk reduction. Owners are then left to consider good practice, the existing level of risk, societal concerns and other factors in ALARP determination mentioned in Section 5.6.

### 5.3 Good practice

*Guidance: Dam owners and managers should apply good practice, beyond “engineering good practice”, to enhancing dam safety management.*

ANCOLD (2003a) describes good practice as “...an authoritative consensus view across an industry”, and qualifies this statement that “...owners should have in mind, primarily, recognised good practice in Australia.”

Allen et al. (2007) cite examples of owners drawing upon the following as potential sources for upgrade good practice:

- precedent from within the owner’s portfolio;
- precedent from other Australian dam owners and managers who have engaged in risk reduction in similar situations;
- Australian examples of comparable standards based upgrades;
- the judgment and advice of consultants and expert reviewers, national and international; and
- comparison with design criteria for similar new dams.

Currently there is no definitive guide to good practice for dam safety upgrades. Owners in Victoria have interpreted certain dam upgrade practices, structural and non-structural, around dam safety management and risk reduction as “good”. Examples include:

- design practices for embankment dam slope stability or gravity dam sliding stability;
- for embankment dams, raising the dam core and retrofitting corresponding filter zones to the upper sections of embankments to peak flood level;



- incorporating multiple levels of redundancy in spillway gate operating systems; and
- a regularly exercised, comprehensive emergency management plan.

The upper boundary of good practice is poorly defined, for example, to what extent intercepting filters should be retrofitted on embankment dams. For upgrades where there is further benefit and only marginally increased cost to go beyond a good practice risk-based solution and meet traditional standards, it would be prudent for owners to satisfy traditional standards.

However, case by case considerations may render the application of even recognised good practice impractical for certain dams. In these circumstances, owners should initiate discussion with relevant regulators.

Dam owners and managers should adopt a broad view of good practice. Examples of good practice include:

- a comprehensive and robust surveillance and monitoring regime, including instrumentation alarm levels and notification protocols;
- well developed and exercised dam safety emergency plans;
- practices relating to building organisational dam safety management capability and capacity through training of personnel and cross functional resource sharing and benchmarking practices;
- leadership development and organisational resilience practices;
- adopting a “defence in depth” approach to critical operating systems; and
- application of enterprise risk management, sound organisational governance and associated quality assurance.

Dam owners and managers should keep good records of all options considered in their decision making processes. They should also record why certain options were adopted and others were not, in terms of their reasonableness and practicability. This would be an integral part of due diligence obligations.

#### 5.4 Existing level of risk – Risk Monitoring Zone

*Guidance: Dam owners and managers may not require assessment of additional life safety risk reduction measures if a dam falls in the Risk Monitoring Zone, but monitoring of the risk and maintaining the existing mitigation measures should continue.*

The greater the life safety risk the stronger the case for further risk reduction expenditure. This principle has led HSE (2001) to the concept of a disproportionality factor indicating the maximum level of sacrifice that can be borne without it being judged grossly disproportionate.

The greater the risk, the greater the expenditure that can be justifiable before it is considered grossly disproportionate.

The disproportionality factor is used to test whether an investment in dam safety is grossly disproportionate to the benefits associated with an avoided fatality. The factor varies from 10 for risks just below the Limit of Tolerability to approximately 3 for risks “just above the broadly acceptable level”.

ANCOLD (2003a) does not explicitly define broadly acceptable levels of risk but states that for societal and individual life safety risk, levels of risk that are one hundredth the Limit of Tolerability values could be regarded as broadly acceptable.

Two orders of magnitude (i.e. one hundredth of) lower than the prevailing Limit of Tolerability, is proposed for the “Risk Monitoring Zone”. This is illustrated in Figure 4 for existing dams.

The HSE approach is that the level of risk in this zone is so low that it is not worth searching for further reduction in life safety risk.

For dams with F-N curves entirely within the Risk Monitoring Zone additional life safety risk reduction measures may not be required, however, monitoring of the risk (including any inexpensive precautions) should be maintained.

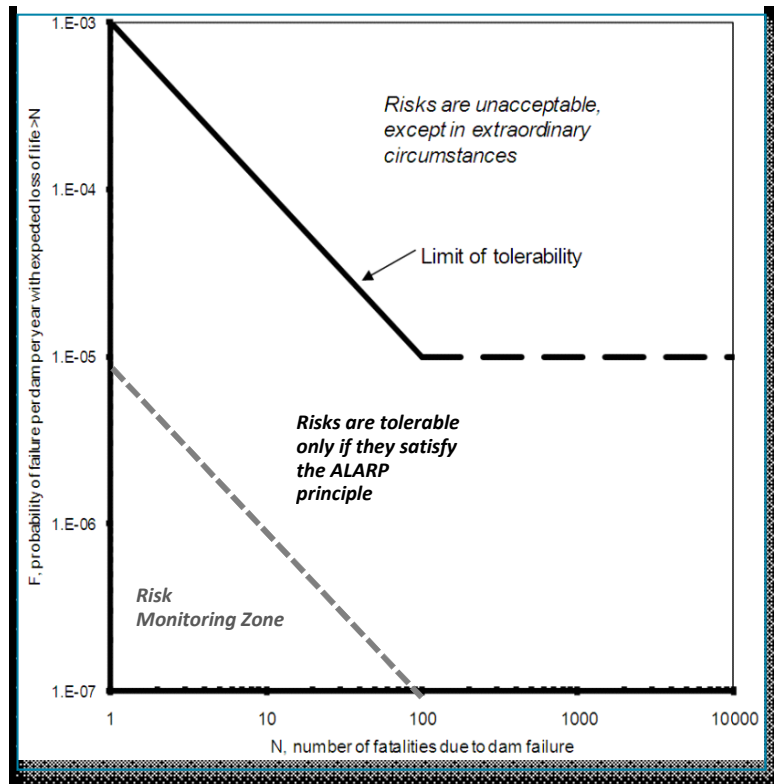


Figure 4 Proposed Risk Monitoring Zone for existing dams

A similar logic can be applied to economic losses - the greater the risk of economic loss, the less weight should be given to the factor of cost of risk reduction measure. There are no accepted industry wide criteria for “economic risk criteria” equivalent to the Limit of Tolerability adopted for societal risk. However, the regulators are likely to take special interest in dams with significant economic costs, particularly where those costs would be borne beyond the organisation by downstream communities and wider society.

## 5.5 Societal concerns

**Guidance:** Dam owners and managers need to communicate risk-informed safety upgrade decisions to affected communities.

Dam owners and managers should communicate with stakeholders who are potentially affected by a dam failure. Dam owners and managers have an obligation to communicate risk-informed dam safety upgrade decisions to affected communities and ensure that the risk is communicated.

Dam owners and managers should engage affected communities and consider their views, as appropriate. However, key decisions concerning dam safety risks and ALARP should be made by the Board of Directors.

There has been little attention paid to understanding community perceptions of dam risk in Australia. Research uncovered was undertaken by CSIRO some two decades ago showed that when compared to 19 other risks such as traffic accidents, medical error and bushfires, dam failure was the lowest short and long-term concern.

It is recognised that societal concern could increase if there was a significant dam safety incident in Australia or overseas.

Societal concerns are likely to be similar for the majority of dams across Australia, however further research is warranted on the community's perception on dam safety risk.

There is a lack of guidance and precedent for incorporating societal concerns for dam failure risks in Australia.

The HSE (2001) includes societal concerns in assessing ALARP. Societal concerns are defined as the:

*“...risks or threats from hazards which impact on society and which, if realised, could have adverse repercussions for the institutions responsible for putting in place the provisions and arrangements for protecting people, e.g. Parliament or the Government of the day. This type of concern is often associated with hazards that give rise to risks which, were they to materialise, could provoke a socio-political response, e.g. risk of events causing widespread or large scale detriment or the occurrence of multiple fatalities in a single event”.*

HSE (2001) further notes that hazards giving rise to societal concerns generally share a number of common features:

- they give rise to risks which could cause multiple fatalities;
- it is difficult for people to estimate intuitively the actual threat; and
- exposure involves vulnerable groups, e.g. children, where the risks and benefits tend to be unevenly distributed.

Societal concerns which should be factored into the assessment of ALARP include:

- dams with very high consequences (e.g., an identified failure mode leading to a potential loss of life of more than 100);
- a highly vulnerable population at risk (such as a pre-school immediately downstream of a dam);
- known and strong interdependence of a dam with critical infrastructure and the provision of essential services; and
- situations where there is a lack of trust from the community that the risk is being adequately managed, perhaps resulting from an earlier dam safety incident.

Strategies to engage with the community on dam safety will require input from communication specialists and in some cases liaison with agencies such as Local Government Authorities and emergency services.

## 5.6 Other factors in ALARP determination

*Guidance: Dam owners and managers should have regard for the factors discussed in this section when determining ALARP.*

There are several other factors that can assist in the assessment of ALARP. These include:

- **Duration that the risk applies** – a greater focus on risk reduction may be prudent for failure modes associated with enduring risks compared to shorter term risks, although ANCOLD stresses that this is not necessarily the case. Short duration of risk here is not to be confused with rare events or low failure probability. In principle though, risk is expressed as an intensity (that is, as likelihood of consequences per annum) and intensity is not affected by duration.

- **Availability of risk reduction options** – in some situations, for some failure modes, it may not be possible to identify additional viable risk reduction options, thus justifying an ALARP determination. Owners will need to be mindful of technological and other developments and review this assessment periodically.
- **Creation of new risks** – risk reduction can itself be risky. In some cases reducing dam safety risks cannot be done without creating new and poorly understood risks. In such a situation, evaluation of ALARP may conclude that it is better to leave things as they are.
- **Adequacy of the Failure Modes analysis** – the determination of ALARP should be based on no less than a contemporary, thorough and expert assessment of potential failure modes. Owners will need to remain informed of any changes to the body of knowledge regarding potential failure modes, which may result in new failure modes being considered or modifications to event trees associated with existing failure modes.
- **Consideration of standards based approaches** – satisfaction of contemporary engineering standards may assist with justifying an ALARP determination. Having met standards, there may be additional simple, low-cost risk reduction measures that could also be considered by dam owners and managers to further reduce risk.
- **Benchmarking** – The Department’s annual state-wide dam safety report and database provide information to benchmark dam safety risks, and this information is improving annually as water corporation data/reporting matures. Such benchmarking may provide helpful information about investment and rate of risk reduction, particularly as risk diminishes over time with increasing investment, and this feedback information could help inform owner investment decisions. In addition, dam safety management systems, processes and procedures could also be benchmarked against established good practice.

## 6 Systemic Approach to Dam Safety

**Guidance:** *Dam owners and managers should develop a dam safety policy statement and make it publicly available.*

Dam owners and managers should clearly articulate how dam safety is to be managed. For water corporations and other organisations, this would comprise a publicly available Board Policy statement.

The policy statement should focus the organisation on the risks inherent in management and operation of dams, and the procedures in place to mitigate these risks. The policy statement should have regard to the *ANCOLD Dam Safety Management Guidelines (2003b)*.

Dam owners and managers should review their dam safety activities to ensure they are comprehensive and effectively delivered across their organisation. Where possible, dam safety activities should be integrated into business systems and workflow procedures, so they are performed routinely, and subject to internal and external audits.

Dam owners and managers should perform periodic and repeatable assessments of their dam safety management performance against the requirements of the *ANCOLD Guidelines on Dam Safety Management*, and where applicable, the *Statement of Obligations*.

A dam safety management performance report would provide dam owners and managers with a clear assessment of performance over time and may assist with prioritisation of interventions to address identified improvement areas.

A key challenge for owners is to retain sufficient internal expertise so to ensure they are able to fulfil owner responsibilities, including decision making, relating to dam safety management and investment decisions.

Dam owners and managers should maintain and enhance organisational capability in dam safety management.

Water corporations recognise the challenges around securing, retaining and developing personnel to undertake dam safety management functions. Many have staff capability development programs in place that include organisational responses to capacity building such as cross functional teaming, succession planning and the use of expert panels to support internal decision making.

Water corporations have consistently engaged in learning forums such as the *Victoria Water Industry Dams Working Group*.

The *National Offshore Petroleum Safety and Environment Management Authority* recently issued an ALARP guidance note to industry. Figure 5 is reproduced and adapted from this guidance note (NOPSEMA, 2014), and illustrates well the journey of risk reduction from intolerable risk, to tolerability testing, to ALARP determination, then to ongoing monitoring and continuous improvement.

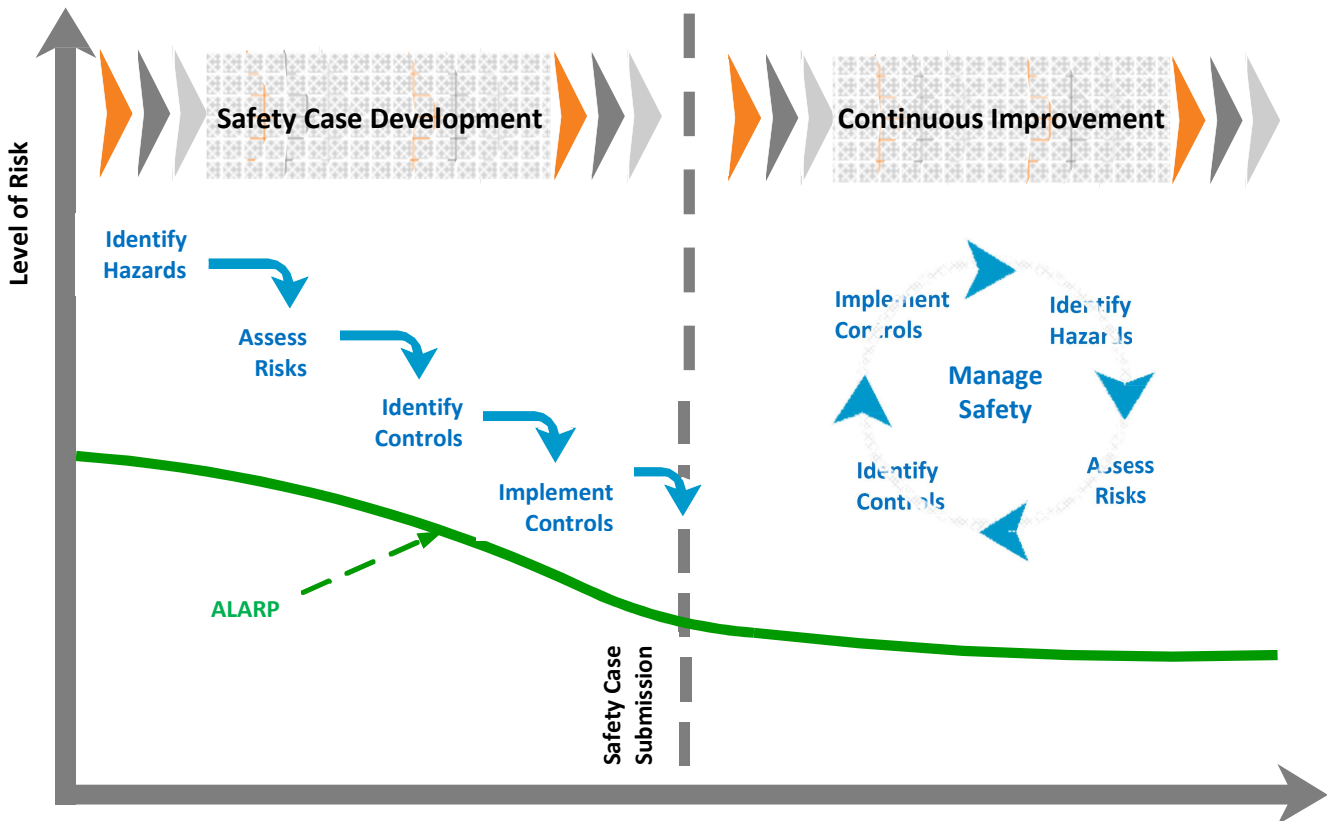


Figure 5 Continuous Improvement in Safety through Implementation of the Safety Case (adapted from NOPSEMA, 2014)

This approach reinforces the concept that in the assessment of ALARP the journey is the destination. Many dam owners and managers in Victoria and around Australia are approaching the equivalent “Safety Case Submission” point for the majority of their portfolios. A safety case should communicate a clear, comprehensive and defensible argument that a system is acceptably safe to operate in a particular environment (Kelly, 2004).

## 7 Investment Decision Making

*Guidance: A structured investment decision making approach will help organisations navigate major capital project selection, and build project portfolio alignment with internal and external stakeholders.*

Managers in organisations, public and private, face the ongoing task of allocating resources wisely to achieve their strategic goals. The task of investment decision making is difficult due to its complexity. Costs, benefits and risks must be balanced across multiple criteria, and stakeholders need to be engaged to differing degrees in investment decisions that inevitably involve trade-offs due to the limited availability of resources (Phillips and Bana\_e\_Costa, 2007). There may also be timing restrictions or limitations on certain projects or groups of projects. Although organisations create functional groups to achieve specific objectives, these same groups may interpret organisational priorities differently and pursue achievement of the objectives of their part of the organisation ahead of the whole.

In the past, organisations have relied on manual methods to develop capital investment priorities and these tend to be subjective and lack the rigour of a structured approach. Organisational strategic objectives may have been considered, but an explicit or measurable link was unlikely to be established between strategic objectives and investment allocation. In addition, these unstructured processes tended to be time consuming and inconsistent resulting in a priority list of capital investment projects that lacked rigour in project ranking and selection. Some organisations may have produced several priority lists, one for each organisational functional group, with no integration or consolidation into an agreed single list of investment priorities. Independent economic regulation in the water sector has prompted water corporations to review their investment decision making approaches so that they are more integrated and linked to the sustainable provision of services at agreed levels and appropriate or acceptable costs.

*Guidance: Organisations need to balance resource allocation across the drivers of value creation (what an organisation wants to do), compliance (what must be done) and risk mitigation (what should be done).*

Organisations that manage dams do not exist for that purpose, rather they exist to pursue greater strategic objectives and a wider organisational purpose of adding value and providing services to communities and stakeholders. The pursuit of adding value represents the starting point for identification of capital projects. Thus, dams in Victoria have been constructed in response to owner organisations, past and present, meeting goals around provision of, for example, sustainable water supply and irrigation protection for communities. Safe management of these dams is then an inherent obligation that owners must comply with, taking account of the risks associated with their dams. Consideration of compliance and risk thus also prompt the identification of capital projects. Resource allocation must then be balanced across these drivers of value creation (what an organisation wants to do), compliance (what an organisation must do) and risk mitigation (what an organisation should do). Projects identified from these drivers should link directly to one or more strategic objectives.

For many dam owners, the Portfolio Risk Assessment (PRA) process represents their risk informed renewal prioritisation methodology to create a capital improvement program, allowing them to prioritise the improvement needs of their dams and to identify those future projects that will secure ongoing dam operations and protection of community interests. Projects addressing reduction of societal risk to below the Limit of Tolerability generally represent “compliance” projects that must be completed. However, for ALARP projects, integrating the outcomes of the PRA with other organisational capital investment programs can be challenging and an overarching investment framework may be required.

The benefits of a structured approach to prioritising projects include a more defensible, efficient and repeatable decision making process along with an overall better selection of projects to be funded based on their contribution to strategic objectives. Other benefits may include increased compliance with legislative requirements, establishment of a performance baseline for future planning efforts and improved communication of strategic objectives across the organisation and with relevant stakeholders. The process itself may be helpful in connecting and aligning the dam safety management part of an organisation with the wider organisation, in collective pursuit of a common purpose and vision.



## 8 References

- Allen, P.;** Barker, M.; McGrath, S.; Topham, C. 2007. *ALARP considerations for dam safety – are we there yet?*. ANCOLD Bulletin No. 137. December.
- ANCOLD** (Australian National Committee on Large Dams), 2012, *Guidelines on the Consequence Categories of Dams*.
- ANCOLD** (Australian National Committee on Large Dams), 2003a, *Guidelines on Risk Assessment*, October.
- ANCOLD** (Australian National Committee on Large Dams), 2003b, *Dam Safety Management Guidelines*. August.
- Bowles, D.S.**, 2007. *Tolerable risk for dams: how safe is safe enough?* US Society on Dams Annual Conference, March 2007, Philadelphia, Pennsylvania.
- DSE** (The Department of Sustainability and Environment), 2007. *Statement of Obligations to water corporations*. Available on the DSE website.
- DSE** (The Department of Sustainability and Environment), 2009. *Dam Safety Regulatory Review*, Technical Committee Report.
- HSE** (Health and Safety Executive, United Kingdom), 2001, *Reducing Risks, Protecting People*, Her Majesty's Stationery Office, London, [www.hse.gov.uk/risk/theory/r2p2.pdf](http://www.hse.gov.uk/risk/theory/r2p2.pdf).
- ICOLD** (International Commission on Large Dams), 2005, *Risk Assessment in Dam Safety Management – A Reconnaissance of Benefits, Methods and Current Applications*, Bulletin No. 130.
- ISO 31000**, 2009. Risk Management – Principles and guidelines.
- Kelly, T.**, 2004, *Safety Case Management: A Systematic Approach*, John Wiley & Sons, Australia.
- MWH & SKM**, 2011. *Development of a Guidance Note on Dam Safety Decision Parameters*. Report prepared for DSE.
- NOPSEMA** (National Offshore Petroleum Safety Environment Authority), 2014, *ALARP Guidance Note*, Revision 5, June
- NSW DSC** (New South Wales Dam Safety Committee), 2010, *Demonstration of Safety for Dams DSC2D*, June.
- Phillips, L. D.**, Bana e Costa C. A., 2007. Transparent prioritisation, budgeting and resource allocation with multi-criteria decision analysis and decision conferencing, *Ann Oper Res* (2007) 154: 51–68.
- Vreugdenhil, R.;** Hill, P.; Perera, S.; Ryan, S. 2011. *Towards Increased Clarity in the Application of ALARP*. ANCOLD (Australian National Committee on Large Dams) Proceedings for Technical Groups, October.
- Water Act**, 1989. Victoria.
- Water Industry Act**, 1994. Victoria.

[www.delwp.vic.gov.au](http://www.delwp.vic.gov.au)