

Strategic Framework for Dam Safety Regulation

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The Department intends to review this document periodically. Please forward comments to Siraj Perera, Water and Natural Resources Group, Department Environment and Primary Industries, PO Box 500, East Melbourne VIC 3002 or email: siraj.perera@depi.vic.gov.au

1. Introduction

1.1. Purpose

This document sets out the strategic framework for regulating Victoria's dams. The framework does not alter current legislation or dam safety regulatory policy, but provides a structure to assist in their implementation and the continuous improvement of dam safety management.

The framework:

- is underpinned by a risk management approach;
- defines objectives and principles to guide the delivery of dam safety regulation (section 2);
- documents current regulatory arrangements, roles and responsibilities (section 3); and
- sets out risk-based processes to direct regulatory resources and effort toward those dams with the potential to cause the largest hazards and risk to the community (section 4 and 5).

It is intended that the framework will assist organisations with regulatory responsibilities, and also dam owners and managers in fulfilling their dam safety and due diligence obligations.

The framework is consistent with the *Victorian Guide to Regulation* (DTF, 2011).

1.2. Background

Dam safety in Victoria is regulated under the *Water Act 1989*¹ (the Act) and the *Water Industry Act 1994*. These acts are administered by the Department of Environment and Primary Industries (DEPI) on behalf of the Minister for Water. The DEPI regulates water corporation dams. The majority of regulatory functions for privately owned dams have been delegated to five licensing authorities (water corporations). DEPI and licensing authorities have powers to undertake emergency action where there is an immediate dam safety risk to the community.

Dam safety regulation in Victoria aims to ensure that the safety of dams is managed so that risk to life, the environment and property is tolerable. Dam safety risk arises from the potential consequences of an uncontrolled discharge of water, as a result of a dam failure. While the likelihood of such events in Victoria is very low, the history of catastrophic dam failure in other countries highlights the importance of good dam safety management.

The Australian National Committee on Large Dams (ANCOLD) *Risk Assessment Guidelines* (2003a) state that tolerable risk is 'A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk that we do not regard as negligible or as something we might ignore, but rather as something we need to keep under review and reduce it still further if and as we can.'

Compared to bushfire, flood, severe storms and climate change, the risk to the community from dam failure in Victoria is relatively low. As this risk is linked to individual structures, it is generally more straightforward to implement measures that reduce the likelihood of the risk eventuating.

Recent estimates indicate that there are over 455,000 dams throughout Victoria (SKM, 2012), the vast majority of which are very small. Dam safety regulation focuses on a small subset of dams which, because of their size and location, warrant a higher level of surveillance and oversight.

¹ While some aspects of the framework are relevant to the regulation of tailings storage facilities, the Department of State Development, Business and Innovation undertakes the majority of regulatory functions for tailings storage facilities under the *Mineral Resources (Sustainable Development) Act 1990* (see section 3.1.3).

1.3. History of Dam Failures

To date there have been two recorded dam failures in Australia that have resulted in loss of life. The first occurred in the 1920s in Tasmania and resulted in 14 fatalities. The second occurred in Queensland in 2008 and resulted in one fatality. During the Victorian floods of 2010 and 2011, spillway outflows of some dams recorded their highest volumes. Over fifty dam safety incidents, mostly associated with small dams, were reported to the DEPI. Most were quickly resolved and third party damage was minimal.

While Victoria and Australia's dam safety record is good, the record of catastrophic dam failures internationally highlights the importance of maintaining effective regulation. In the US, for example, the Federal Emergency Management Agency (FEMA, 2009) noted 28 dam failures from 1874 to 1979, which had collectively resulted in 3,424 deaths. More recently, the failure of a private dam in 2006, Kaloko dam in Hawaii, resulted in seven fatalities.

1.4. Dams and Flooding

Generally, large dams in Victoria were built to provide water security for communities. These dams are not designed or operated for flood mitigation, although some flood mitigation can occur as a result of the flow being attenuated by a dam. There are also a number of retarding basins in urban areas in Victoria built to attenuate flooding associated with higher frequency rainfall events.

Only a small number of dams in Victoria have spillway gates, providing the capability to make flow releases prior to or during a flooding event. Such dams are owned by water corporations. The primary objective of a flood operating procedure is to safely route the flood through the dam's spillway, hence safeguarding the structural integrity of the dam.

Dam operators provide operational and flow data to assist the Victoria State Emergency Service (VICSES) (and the Bureau of Meteorology) in informing and protecting downstream communities during flooding events.

2. Objectives and Principles

The overarching objective for Victoria's strategic framework for dam safety regulation is that:

Dams are regulated so that they are managed to protect the community and environment by the use of good dam safety management practices.

Owner and Manager Responsibility: Under the Act dam owners and managers² are responsible for dam safety and accountable for the damage their dams may cause in the event of a dam failure (*Water Act 1989* sections: 16, 17, 18 and 157). Responsible dam management includes:

- keeping the safety of dams under review and rectifying any deficiencies as soon as possible;
- ensuring that dam safety programs are adequately funded and that dam safety activities are undertaken by suitably qualified and experienced personnel; and
- being prepared to manage dam safety incidents.

Regulatory Oversight: Regulation establishes dam safety performance requirements and emergency management processes and requires that dam managers operate within these parameters over the life of the dam. These are regularly reviewed to incorporate scientific and technological advances and reflect community expectations.

Equity: Dams are built to benefit the community. However, individuals and society have a right to be protected. A dam should be managed to a level of safety so that the risk posed by the dam does not add significantly to the background risk that the community lives with on a daily basis.

Efficiency: Society's resources are distributed and used so as to achieve the greatest benefit. Resources and expenditure on dam safety should be in balance with the level of risk being managed.

Targeted Action: Regulatory activities are prioritised and focused on those dams that could pose significant risks or where the hazards need greater controls.

Consistency: Dams with similar risk levels or potential consequences are subject to comparable dam safety requirements. While there are different regulatory arrangements for water corporation and private dams, outcomes for dam safety are consistent, irrespective of dam ownership or use.

Transparency: DEPI and licensing authorities provide clear and balanced information to the community about dam safety regulation and the risks associated with dams. Managers of significant portfolios of dams make information on their dam safety programs available to the public.

Cooperation: DEPI and licensing authorities maintain a cooperative and inclusive regulatory culture. This includes providing guidance to managers about how to achieve and demonstrate compliance with dam safety obligations, and engaging and fostering partnerships with the water industry, dam managers, and other regulators to strengthen dam safety practice.

² Throughout this document the individual/s or entity that has primary ownership or management and operational responsibility for a dam is referred to as the dam manager.

3. Regulatory Structures and Arrangements

The *Water Act 1989* establishes owner and manager responsibility for dam safety and also contains provisions for dam safety regulation. Regulatory arrangements are currently in place for dams managed by water corporations and privately owned dams (Figure 3-1).

DEPI is the dam safety regulator for water corporation dams and is also the control agency for all dam safety emergency incidents as per the *Emergency Management Manual of Victoria* (OESC, 2011). Five water corporations have been delegated the key dam safety regulatory responsibilities for privately owned dams, through their licensing authority function, with DEPI providing policy input to this process. DEPI and licensing authorities may issue directions concerning dam safety on behalf of the Minister for Water under sections 78 and 80 of the Act.

DEPI is working to extend regulation to incorporate a small number of dams outside current arrangements which are managed by Parks Victoria, DEPI and local government. These include recreational, aesthetic and fire fighting dams as well as a limited number of small retarding basins managed by local government.

3.1. Regulatory Arrangements

3.1.1 Statement of Obligations and Water Corporations

The DEPI is the dam safety regulator for water corporation dams. Water corporations own the majority of large dams in Victoria and are a key focus for dam safety regulation. The water corporation dams have an average age of about 65 years, with the most recent of the major dams, the Thomson dam, having been completed in 1984.

The Minister for Water has issued Statements of Obligations (SoO) to each corporation. These set out various requirements for the performance of their functions in delivering water supply and wastewater services, and are available on DEPI's <http://www.depi.vic.gov.au/water-corporations-statements-of-obligations> and each of the water corporations' websites.

The SoO includes a set of clauses which specify how each corporation should undertake their dam safety program across their portfolio of dams (see Appendix 1). These set out a risk-based approach to the delivery of dam safety programs, and require that corporations report annually to DEPI on the status of their programs. The annual report contains information about the level of safety of the dams, including the results of quantitative risk assessments, and progress towards and proposals for the implementation of works to reduce risks. The Minister for Water may also periodically request independent auditing of the compliance of the corporations against the SoO, through the Essential Services Commission (ESC). DEPI provides the audit scope for this process and reports the results of these audits to the Minister.

Water corporations are also subject to economic regulation by the ESC. Prices that corporations charge for the delivery of water services are subject to approval by the ESC, and this has implications for expenditure on dam safety.

3.1.2 Licensing of Private Dams

Private dams include farm dams and hydro-power and industrial water supply dams. Dam safety regulation is implemented as part of a wider licensing regime under the *Water Act 1989* dealing with the take, use, conveyance and storage of water in Victoria. The licensing authority function is delegated to five of the State's water corporations and DEPI provides policy input and regulatory advice to assist this process.

The licensing authorities (see Appendix 2 for their areas of responsibility) are:

- Goulburn Murray Water;
- Grampians Wimmera Mallee Water;
- Lower Murray Water;
- Melbourne Water; and
- Southern Rural Water.

The authorities issue works licences (section 67) for works on a waterway, bores and dams and monitor compliance against licence conditions (Appendix 2) and safety requirements. These cover the construction, alteration, operation, removal and decommissioning of the works.

Amongst other things, standard licence conditions require that potentially hazardous dams are designed and constructed under the supervision of a suitably qualified engineer, and have surveillance plans and dam safety emergency plans. Licence conditions also require that the licence holder report on the results of the surveillance program to the licensing authority as well as any significant dam safety deficiency. They also require that the licence holder engage a suitably qualified engineer to propose a program to rectify such a deficiency, and carry out any remedial works identified to the satisfaction of the licensing authority.

3.1.3 Regulation of Mine and Quarry Dams

The construction and operation of mine and quarry dams for the purposes of the 'take and use' of water from a waterway, or the storage of water, are subject to licensing framework established under the *Water Act 1989*, in the same way as any other privately owned water supply dams (DSE, 2004).

Department of State Development, Business and Innovation (DSDBI) undertakes the majority of regulatory functions for mine and quarry dams used as tailings storage facilities, settling ponds or process dams. DSDBI is responsible for the administration of the *Mineral Resources (Sustainable Development) Act 1990*. As part of this responsibility, DSDBI manages approvals for the design, construction, operation and decommissioning of these dams, monitors compliance with work plans and licence conditions and undertakes enforcement activity as necessary. DSDBI's policies for the management of tailings storage facilities are set out in the document *Management of Tailings Storage Facilities* (DPI, 2004). ANCOLD has also released updated guidelines on the planning, design, construction, operation and closure of tailings dams (ANCOLD, 2012a)

In some circumstances, tailings storage facilities, settling ponds and process dams may also require a works licence under the *Water Act 1989*, for example where a proposed dam is on a waterway. In such cases, DSDBI will facilitate the approval process for the mining or quarry proposal, and address any matters that the relevant licensing authority has identified as pertinent to the determination of the works licence.

3.1.4 Extension of Regulatory Arrangements

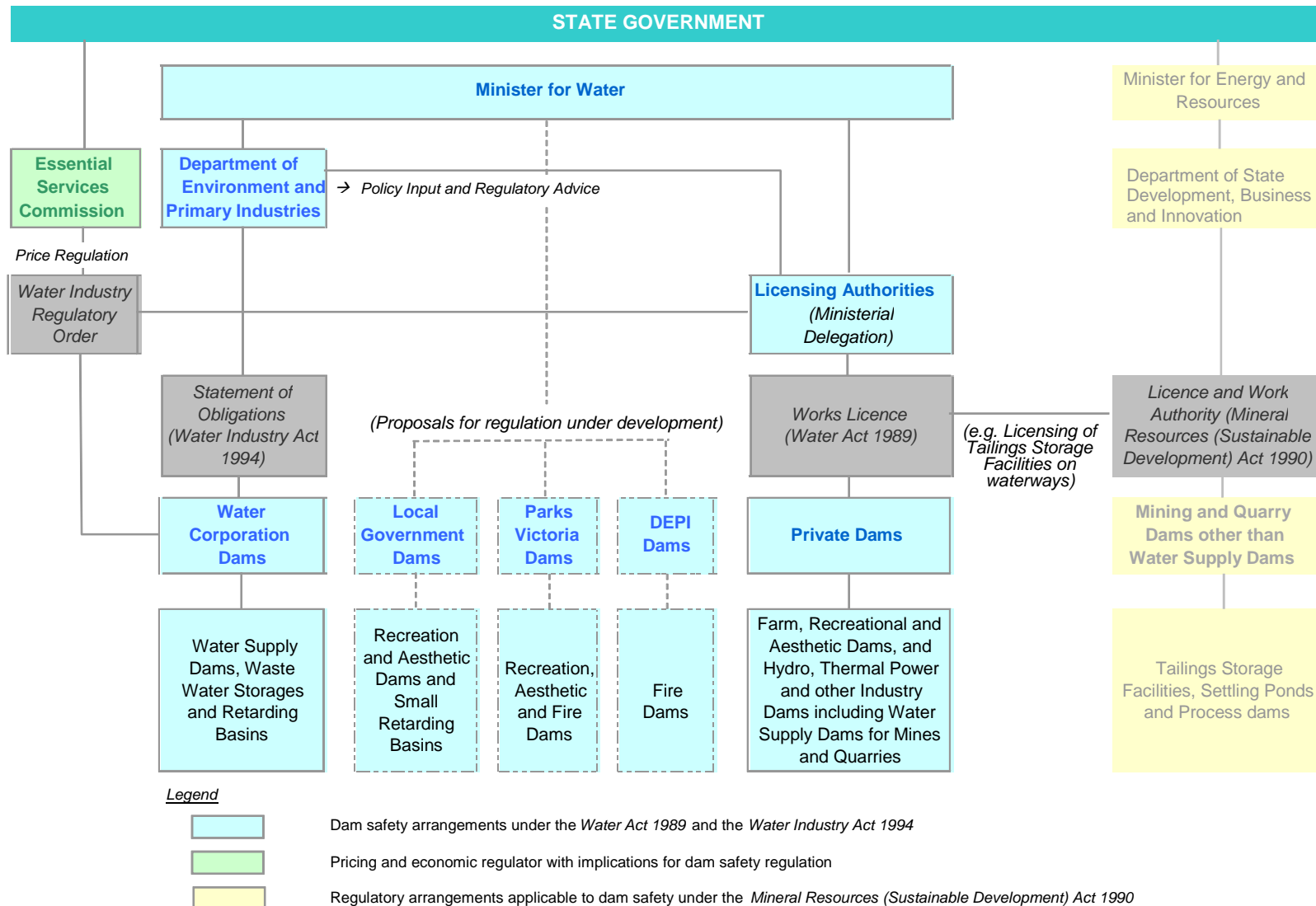
DEPI is currently developing proposals for the inclusion of a small number of dams managed by Parks Victoria, Local Government and DEPI within the regulatory framework (Figure 3-1).

Current estimates indicate that Parks Victoria manages 11 dams and local government 20 dams of interest to dam safety regulation. A survey to identify any potentially hazardous DEPI managed fire-fighting dams is scheduled.

3.2. Dam Safety Advisory Committee

The Dam Safety Advisory Committee was established by DEPI in 2011 and provides independent expert input and advice to DEPI on dam safety regulation. This guidance may extend from policy and research matters to the management or operation of any dam. The Committee is appointed by and reports to the Executive Director, Rural Water and Governance Division, DEPI. The Committee does not exercise any dam safety statutory functions, responsibilities or decision making capabilities.

Figure 3-1 Current and Proposed Dam Safety Regulatory Structures and Arrangements in Victoria



3.3. Australian National Committee on Large Dams (ANCOLD)

ANCOLD is an incorporated voluntary association of organisations and individual professionals with a common interest in encouraging improvements in the safety and operation of dams in Australia. Formed in 1937, it is a member of the international body ICOLD (International Commission on Large Dams). ICOLD's membership consists of 92 countries containing most of the world's large dams. DEPI has actively participated as a member of ANCOLD for many years through the ANCOLD Regulators Forum. The forum includes representation from all states and meets annually.

ANCOLD has produced a series of guidelines (www.ancold.org.au) that are recognised by DEPI as representing the current industry position for dam safety management. The SoO for water corporation dams and the licensing conditions for private dams refer to these documents, as do regulations and guidance material of other jurisdictions across Australia. DSDBI guidelines on tailings storage facilities (DPI, 2004) also reference ANCOLD Guidelines.

The ANCOLD guidelines have provided a reference for improvement and investment in dam safety, and a basis for dam safety performance assessment throughout Australia for many years. They have both influenced and drawn from current international practice in dam safety management, particularly in the adoption of risk management practices over the last few decades. The guidelines cover aspects such as design standards for flood and earthquake loading conditions, and methodologies for risk assessment and decision making. The ANCOLD Risk Assessment Guidelines (ANCOLD, 2003a) are consistent with the Australian/New Zealand Risk Management Standard AS/NZS ISO 31000:2009 (AS/NZS, 2009).

3.4. Comparison with Regulatory Approaches of other Jurisdictions

Throughout Australia, dam safety regulatory arrangements are in place in Victoria, New South Wales, Queensland, Tasmania and the Australian Capital Territory. As yet, there is no dam safety regulation in Western Australia, South Australia or the Northern Territory.

Victoria's mode of dam safety regulation, particularly for the water industry which owns the majority of dams of significance to dam safety regulation, is characterised by a broad oversight approach which sets and monitors objectives for dam safety at a strategic level, while maintaining adequate powers in legislation to intervene if necessary.

In 2010, DEPI undertook a review of dam safety regulation in Victoria, the *Review of the Victorian Dam Safety Regulatory Framework* (2010). This included a comparative analysis of dam safety regulation in the Australian jurisdictions as well as those of a number of other countries (Sih et al. 2011). The comparative analysis also revealed a diverse range of dam safety regulatory, institutional and governance arrangements in the overseas jurisdictions investigated, influenced by dam ownership and usage. For example, in the US, most states have established dam safety regulations to cover private dam owners and owners with small portfolios of dams. In contrast, the United States Bureau of Reclamation and United States Corp of Army Engineers, both of which are federally owned agencies with large portfolios of dams, are self-regulated.

The performance of Victoria's regulatory approach and the supporting institutional and governance arrangements of the water industry was extensively assessed through the Review. The review found that since the introduction of these arrangements in the mid-1990s, there had been a steady improvement in public dam safety, with many of the key risks addressed through well-targeted dam safety upgrade programs. Subsequently, the Review concluded the Victorian approach to regulation had generally proven successful for the delivery of dam safety, with good systems and processes established under the SoO and functioning relatively well across the water sector.

The Review also found that Victoria's regulatory approach was consistent with the governance and institutional arrangements in place for the water industry in Victoria, which were markedly different to those found elsewhere in Australia or overseas. Water services in Victoria are delivered by 19 state-owned water corporations, which are governed by boards of directors, operate on a commercial basis, and are subject to economic regulation. The broad strategic approach to dam safety regulation has provided corporations greater flexibility in balancing dam safety responsibilities against other corporate obligations, and in pursuing efficiency in service and project delivery.

4. Victoria's Regulatory Approach

This section sets out the key processes that DEPI and licensing authorities (Figure 4-1) use to regulate dam safety. Dam safety regulation in Victoria is underpinned by a risk management approach.

Figure 4-1 Regulatory Approach



4.1. Risk Management



Dam safety regulation in Victoria is underpinned by a risk management approach. Resources and effort are focused toward identifying and addressing unacceptable risks, and promoting a sound level of dam safety practice for all dams with the potential to have significant impacts on the community, environment and property.

This approach is consistent with the Australian/New Zealand Standard 'Risk Management - Principles and Guidelines', AS/NZS ISO 31000:2009 and is guided by the ANCOLD series of guidelines on dam safety management.

The ANCOLD *Guidelines on Risk Assessment* (2003a) define risk as a: 'measure of the probability and severity of an adverse effect to life, health, property or the environment.' Dam safety risk is associated with the potential consequences of an uncontrolled discharge of water as a result of a dam failure. Dam safety regulation aims to ensure that dams are managed to a level of safety such that the risk to life, the environment and property is tolerable.

ANCOLD (2003a) states that tolerable risk is: 'A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk that we do not regard as negligible or as something we might ignore, but rather as something we need to keep under review and reduce it still further if and as we can.' This concept of tolerable risk originates from work undertaken by the United Kingdom Health and Safety Executive relating to the regulation of hazardous industries (HSE, 2001).

The risk management regulatory approach to dam safety includes:

- ensuring that dams with the potential to cause significant impacts in the event of a dam failure are subject to regulation;
- promoting a sound base level of dam safety practice by the managers of these dams consistent with the potential consequence of these dams;
- maintaining a higher level of regulatory overview of those dams with the potential to cause loss of life or high economic and environmental consequences should they fail; and
- identifying unacceptable risks and targeting of resources and effort so that dam managers address these risks.

4.1.1. Application of Dam Safety Regulation

There are a wide range of structures such as water supply dams, retarding basins, waste water storages, hydro-electric dams, recreational dams and aesthetic dams that are classified as dams under the *Water Act 1989*. Recent estimates indicate that there are over 455,000 dams throughout the Victorian landscape (SKM, 2012), the vast majority of which are very small. While dam managers are responsible for any damage caused by their dam, regulation focuses on a small subset of dams which may have the potential to cause significant third party impacts should they fail.

4.1.1.1. Water Corporation Dams

DEPI maintains regulatory oversight of over 300 dams managed by water corporations. These are dams that have an ANCOLD Consequence Category of Significant (ANCOLD, 2012b and Appendix 3) or above, or any dam that meets the ANCOLD definition of a large dam (www.ancold.org.au). Water corporations provide an annual status report of the management of these dams through the SoO reporting process. Irrespective of the Consequence Category, water corporations must include all dams they manage in their dam safety management program.

4.1.1.2. Private Dams

Under DEPI *Policies for Managing Works Licences* (DSE, 2010), a private dam is treated as potentially hazardous and is subject to dam safety regulation if it meets the following criteria. The dam:

- has a wall that is 5 metres or more high above ground level at the downstream end of the dam and a capacity of 50 megalitres or more; or
- has a wall that is 10 metres or more high above ground level at the downstream end of the dam and a capacity of 20 megalitres or more; or
- has a wall that is 15 metres or more high above ground level at the downstream end of the dam, regardless of the capacity; or
- is on a waterway and has an ANCOLD Consequence Category of Significant or above.

Of approximately 14,000 dams that are currently licenced, about 700 have been identified as potentially hazardous and are subject to licence conditions relating to dam safety.

4.1.2. Base Level of Dam Safety Practice

Numerous dam failures that have occurred overseas (e.g. ANCOLD 2003b) and a number of near misses in Australia, demonstrate that serious consequences can occur as a result of inadequate design and construction of dams or the lack of an effective ongoing dam safety management program. There are instances where even the failures of relatively small dams have caused multiple fatalities (e.g. Graham, 1999). Therefore dam safety regulation in Victoria requires that all managers of dams with the potential to cause significant impacts have dam safety management programs in place, and demonstrate a sound level of dam safety practice. This includes:

- ensuring new dams are designed and constructed to meet contemporary engineering standards;
- assessing and regularly reviewing the level of safety and performance of dams;
- undertaking works to rectify deficiencies, where the level of safety of a dam is inadequate;
- regular surveillance and monitoring;
- good operations and maintenance procedures;
- emergency preparedness and response; and
- the use of suitably qualified and trained personnel in undertaking dam safety activities.

The ANCOLD *Guidelines on Dam Safety Management* (2003b) provide guidance on dam safety management programs, and set out various levels of practice in accordance with the Consequence Category of the dam (ANCOLD, 2012b). The guidelines envisage less detailed and correspondingly lower cost dam safety management programs where the failure consequences of a dam would be relatively minor, and where dams have similar failure consequences, slightly less intensive programs for lower risk dams compared to higher risk dams.

4.1.3. ANCOLD Consequence Category and Regulatory Overview

The ANCOLD Consequence Category (ANCOLD, 2012b) is a classification of a dam based on a quantitative assessment of the possible impact on surrounding and downstream populations, the environment, property and infrastructure in the event of a dam break. The Consequence Category is not a measure of the chance or likelihood of a dam failing, but provides an initial indication of the level of dam safety practice that should be applied to managing the dam. Dam managers are responsible for completing and reviewing Consequence Category assessments as a basis for developing an appropriate dam safety management program consistent with the ANCOLD Guidelines and other national and international literature on good practice.

The ANCOLD guidelines define the following Consequence Categories (Appendix 3):

- Very Low: this category would apply to those dams where the consequences of a failure would be negligible (for example, small farm dams in remote regions);
- Low, Significant, High A, High B & High C: these categories provide a graded range between the Very Low Category and Extreme Category; and
- Extreme: this category includes those dams where the effects of a failure would have immense consequences in terms of damage to property, infrastructure and the environment and could put many lives at risk with the potential for large loss of life if the dam fails (e.g. large dams with major population centres downstream).

DEPI and licensing authorities use the Consequence Category as a preliminary basis for determining which dams have the potential to pose significant risks and should be subject to a greater level of regulation and dam safety management practice (Table 4-1). In general, dams with High and Extreme Consequence levels are subject to a more detailed regulatory approach which is further explained in section 5. In particular, dam managers are expected to undertake comprehensive dam safety reviews, including quantitative risk assessment, to verify the level of safety of these dams.

While a less detailed approach to dam safety management of Low and Very Low Consequence is generally appropriate, decisions about the level of regulation or action about a particular dam are made considering specific information about the level of safety of the dam and the adequacy of the manager's dam safety practices. For instance, some dams categorised as Low Consequence, while not posing a direct life safety risk, may have the potential to cause third party impacts such as localised damage to commercial and community infrastructure, or localised environmental impacts if poorly managed.

Table 4-1 Broad Regulatory Approach and Consequence Category

CONSEQUENCE CATEGORY	REGULATORY APPROACH	DAM SAFETY MANAGER ACTIONS
High or Extreme	<ul style="list-style-type: none"> highest priority for regulatory overview and monitoring, involving frequent interaction with the managers of dams with significant deficiencies. Water corporation dams with the potential for high loss of life and economic consequences are a particular priority water corporations provide comprehensive annual reporting which is reviewed by DEPI to prioritise regulatory actions supplemented by external audits (section 5) private dam managers may be required to provide annual reporting. Surveillance program results and dam safety information are reviewed as part of the licence renewal process 	<ul style="list-style-type: none"> safety reviews should be undertaken periodically, or where deficiencies are detected, there is a change in dam safety standards, or following a significant loading event. These are overseen by suitably qualified engineers and include both quantitative risk and standards-based assessment. For some small High C dams with low PLL values a standards-based assessment to confirm the safety of the dam may be sufficient and quantitative risk assessment may not be required surveillance, operation and maintenance procedures are developed by suitably qualified engineers having regard to ANCOLD (2003b) dams with deficiencies are upgraded to meet tolerable risk guidelines (ANCOLD, 2003a) DSEPs containing site specific information are in place. These are developed with the input of suitably qualified engineers and regularly exercised
Significant	<ul style="list-style-type: none"> moderate level of regulatory overview and monitoring, with frequent interaction with the managers of dams with significant deficiencies dams with the potential for major economic or environmental impacts are subject to a higher level of regulatory overview. water corporations provide annual reporting, which is reviewed by DEPI to prioritise regulatory actions supplemented by external audits for private dams, surveillance results and dam safety information are reviewed as part of the licence renewal process 	<ul style="list-style-type: none"> safety reviews should be undertaken periodically, or where deficiencies are detected, or there is a change in dam safety standards, or following a significant loading event. These are overseen by suitably qualified engineers and include standards-based assessment quantitative risk assessment may be undertaken, where, for example there is the potential for major economic consequences or the possibility of unacceptable individual risk levels surveillance, operation and maintenance procedures are developed by suitably qualified engineers having regard to ANCOLD (2003b) DSEPs containing site specific information are in place where there is a population at risk downstream
Low to Very Low (meets size criteria in section 4.1.1)	<ul style="list-style-type: none"> generally subject to broad level of regulatory overview with less frequent interaction between dam manager and regulator and a basic level of monitoring large water corporation dams are subject to a similar level of regulatory overview and reporting requirements as Significant Consequence Category dams for private dams, surveillance programs results and dam safety information are reviewed as part of the licence renewal process 	<ul style="list-style-type: none"> safety reviews are undertaken by a suitably qualified engineer utilising standard-based assessment methods where deficiencies are detected, such as through the surveillance program, or following a significant loading event dam managers may utilise simplified surveillance programs and DSEP templates (e.g. DSE, 2011a). These are based on ANCOLD (2003b) dam safety programs for large dams (www.ancold.org.au) should be undertaken to a similar level to Significant Consequence dams
All Consequence Categories	<ul style="list-style-type: none"> DEPI and licensing authorities publish and disseminate information to promote good dam safety practice DEPI and licensing authorities have the authority to issue directions and intervene where there is an imminent risk of a dam failure 	<ul style="list-style-type: none"> new dams are designed and constructed to meet current dam safety standards by suitably qualified engineers Consequence Categories are reviewed periodically or following downstream development dam safety programs are consistent with ANCOLD Guidelines DEPI or licensing authorities are notified when there is a dam safety emergency or a significant deficiency is found works to rectify deficiencies are designed and supervised by a suitably qualified engineer dam safety deficiencies are rectified as soon as practicable. Managers of large dam portfolios may address deficiencies through a progressive dam safety upgrade program.

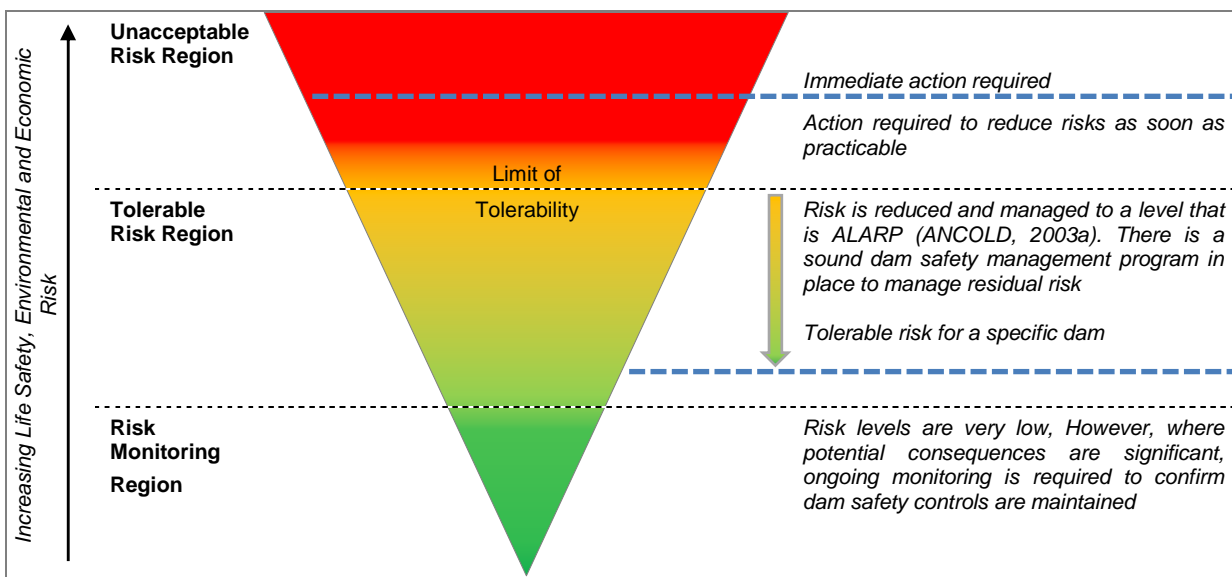
4.1.4. Dam Safety Regulation and Tolerability of Risk Framework

Dam safety regulation utilises the principles of a tolerability of risk framework (Figure 4-2) to provide a basis for evaluating the level of safety of a dam and to assist with targeting regulatory effort and resources. The framework is adopted from the tolerability of risk framework developed by HSE (2001) for the regulation of hazardous industries within the United Kingdom.

While minimisation of life safety risk is the highest priority for regulation, dams also have the potential to pose unacceptable environmental and economic risk. This section provides a general description of the application of the framework, with a more detailed explanation of Victoria's risk-based approach to regulation of High and Extreme Consequence Category dams presented in section 5.

The tolerability of risk framework incorporates the principles of both equity and efficiency. It provides for the protection of society and individuals, while recognising that society's limited resources should be distributed to achieve the greatest benefit, and that expenditure and effort on dam safety should be in balance with the level of risk being managed.

Figure 4-2: Tolerability of Risk Framework (adapted from HSE, 2001 and DSC, 2010)



The upper region of the framework (Figure 4-2) represents the range of risk which is clearly unacceptable. Managers of dams with risk levels that fall within this region are required to develop and implement plans, such as upgrade works, to reduce risks as soon as practicable. This is further divided into two zones, with the upper zone representing the circumstance where a dam is found to pose an exceptionally high level of risk, for example where there is an imminent risk of a dam failure, and immediate action is required to mitigate the risk.

The middle region represents a range of risk which is not insignificant, but that society is prepared to tolerate because it brings with it tangible benefit. As a minimum, dam managers are required to achieve a level of dam safety which is tolerable. In particular, managers of dams with life safety risk should be able to demonstrate that the level of risk of a dam satisfies the 'As Low as Reasonably Practicable' (ALARP) principle or where this is not the case, undertake further measures to reduce the risk.

The ALARP principle is defined by HSE (2001) as: 'That principle which states that risks, lower than the 'limit of tolerability', are tolerable only if risk reduction is impracticable or if its cost is grossly disproportionate (depending on the level of risk) to the improvement gained.'

Approaches to judging whether the ALARP principle has been satisfied in the area of dam safety are described in ANCOLD (2003a). Further guidance for Victorian dam managers on the ALARP principle and making key dam safety investment decisions is provided in the *Guidance Note on Dam Safety Decision Principles* (DSE, 2011b). Key considerations for dam managers in judging whether the ALARP principle has been satisfied include clearly establishing that the level of the risk of the dam meets risk tolerability guidelines (i.e. through quantitative risk assessment as outlined

in section 4.1.5) and that further expenditure to reduce the risk would be grossly disproportionate to the level of risk reduction achieved. Furthermore, the owner should ensure that a sound dam safety management program is in place, so that residual risk will continue to be maintained at tolerable levels, into the future.

Generally, a safety review utilising a standards-based approach undertaken by a suitably qualified engineer would provide an adequate basis for assessing whether dams of Significant Consequence Category or below were performing to a satisfactory level of safety. However, in some instances, quantitative risk assessment may be appropriate for Significant Consequence Category dams, such as where a dam has the potential to cause major economic impacts or where there is uncertainty as to whether the dam poses a life safety risk.

The lowest area of the triangle, the risk monitoring zone, represents very low levels of risk. Examples of dams with risk levels in this region include those that have been upgraded to a very high level, and those that have recently been constructed and fully meet current dam safety standards. Regulatory overview in this case focuses on monitoring these dams to confirm that adequate dam safety management programs are maintained, with a particular emphasis on those dams with large potential for loss of life or catastrophic environmental or economic impact.

4.1.5. Quantitative Risk Assessment

The ANCOLD *Guidelines on Risk Assessment* (2003a) defines risk assessment as: *'the process of reaching a decision recommendation on whether existing risks are tolerable and present risk control measures are adequate, and if not, whether alternative risk control measures are justified or will be implemented,'* and further explain that *'risk assessment involves the analysis, evaluation and decision about the management of risk.'*

The guidelines provide a structured framework and methodology for quantitative analysis of public safety risk and set out the following tolerability of risk guidelines as a basis for judging whether the level of safety of a dam is satisfactory:

- societal risk (limit of tolerability);
- individual risk: and
- the ALARP Principle.

To present information about the societal risk for a dam, an F-N curve is plotted on the Societal Risk Graph (Figure 4-3). The F-N curve represents the cumulative output of analyses of hypothetical dam failure and consequence scenarios. These analyses are undertaken to predict whether the dam will perform to a tolerable level under a wide range of circumstances, from normal operating conditions to floods and seismic events of extreme rarity.

If the F-N plot of the dam intersects the area above the *'limit of tolerability'* line on the societal risk graph (Figure 4-3), this indicates that the level of safety of the dam is inadequate and remediation works are necessary. Implicit in the F-N plot is that the greater the adverse consequences that a dam could cause, the higher the performance requirements it should meet.

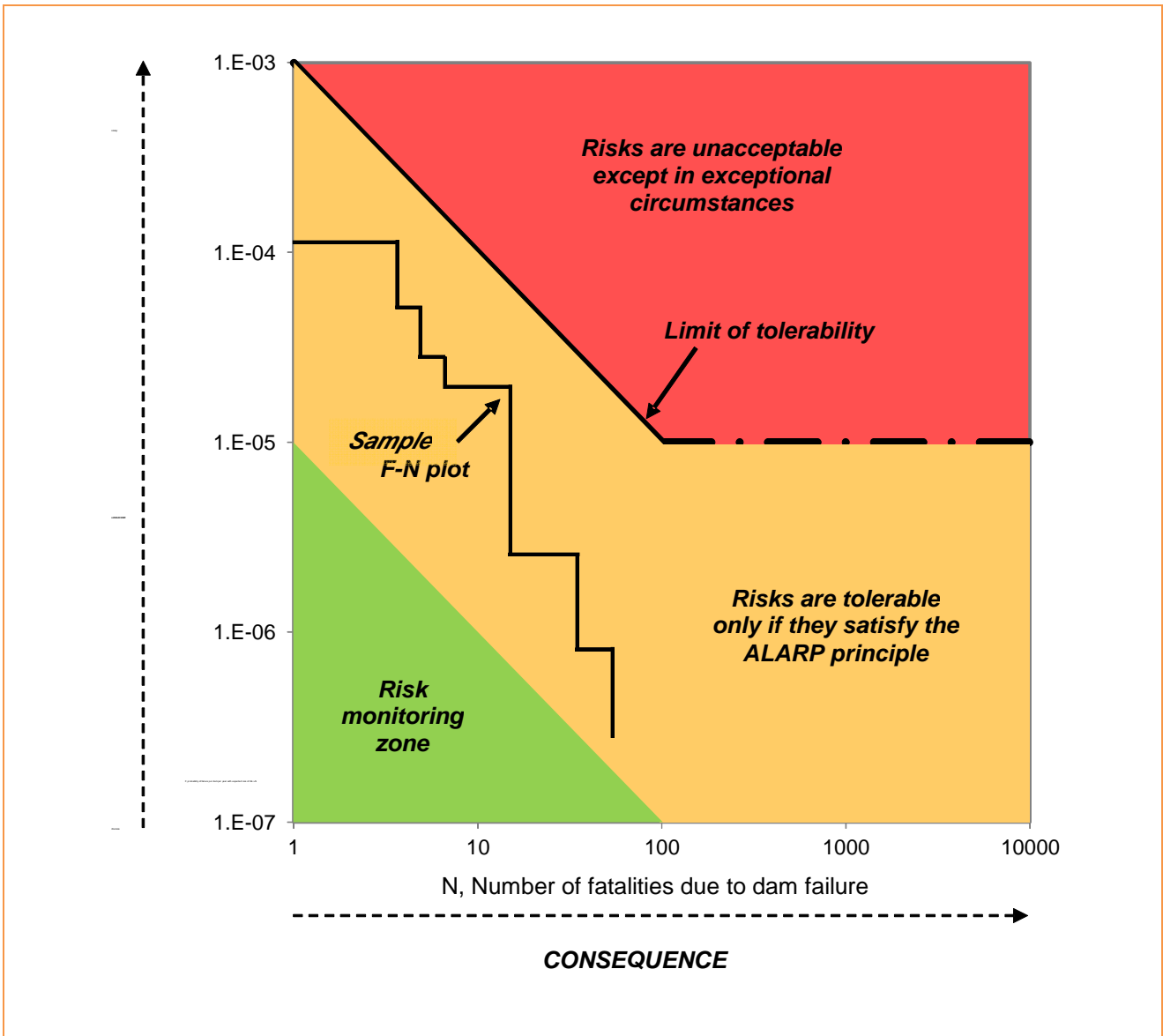
Individual risk represents the risk to the person or group most at risk, and is categorised as unacceptable where the value estimated for an existing dam is higher than the threshold value of 10^{-4} per annum. ANCOLD has developed this guideline using information on average background risk to populations in Australia and has also drawn on work in other countries, such as that by the HSE (HSE, 2001).

Results of risk assessments are used to quantify the seriousness of dam safety deficiencies and to make decisions such as whether short-term risk reduction measures are needed, or whether a longer-term approach can be taken in implementing risk control measures. Risk assessment is also used in developing solutions to repair dams, and in determining the most cost-effective solution where a number of options are available. Where a manager has a large portfolio of dams, quantitative risk assessment may be utilised to assist with prioritising and scheduling dam safety works and capital expenditure. This approach is further explained in *Guidance Note on Dam Safety Decision Principles* (DSE, 2011b).

Ultimately, over the longer term, managers of dams with life safety consequences should continue to undertake risk reduction works until it can be clearly demonstrated that the risk is being managed at a level below the *'limit of tolerability'* that satisfies the ALARP principle, or that the F-N curve of a dam is entirely contained within the risk monitoring zone (Figure 4-3).

While risks of this magnitude may be considered to satisfy tolerability criteria, they must continue to be managed and monitored as part of a dam safety management program and where identified, any further inexpensive precautions should be adopted.

Figure 4- 3 ANCOLD (2003a) Societal Risk Guidelines for Existing Dams with DEPI (2011b) Proposed Risk Monitoring Zone³



³ The horizontal truncation (1.00-05 on the likelihood axis) of the F-N plot recognises the limitations of current analytical techniques and knowledge to evaluate risk with extremely low probabilities of occurrence.

4.2. Awareness, Knowledge and Skills

4.2.1. Awareness and Knowledge



Making clear and balanced information available to dam managers and the community about dam safety risk, due diligence responsibilities of dam managers, regulatory requirements and good dam safety practice is an important task for DEPI and licensing authorities.

DEPI and licensing authorities disseminate information on good practice, regulatory requirements and emergency management arrangements to dam managers and also maintain databases of dams with the potential to cause damage in the event of a dam failure.

DEPI engages with dam managers to raise and maintain their awareness of good practice, regulatory obligations and due diligence responsibilities, through measures such as:

- participating in and contributing to the Water Industry Dams Working Group (WIDWG) and interagency emergency management forums;
- coordinating periodic seminars on various aspects of dam safety;
- providing information on dam safety, duty of care, due diligence and risk management in the director development program for water corporation boards; and
- support and participation in the water corporation's earthquake monitoring network and warning arrangements.

DEPI is also currently working with local government to establish arrangements for ongoing engagement and information exchange with dam managers from local government.

DEPI and licensing authorities will continue to maintain and refine databases on potentially hazardous dams and are currently working to develop a statewide database of private dams. A webpage has been developed to increase public availability of information on water corporation dams which are part of the SoO reporting program <http://www.depi.vic.gov.au/victorian-dam-safety-improvement-program> and DEPI is working with water corporations to further enhance this information.

4.2.2. Skills

DEPI and licensing authorities develop, maintain and regularly review their skills and resources to enable the successful delivery of dam safety regulation. DEPI supports industry initiatives to build and maintain skills in dam safety management.

Effective and efficient dam safety outcomes and the implementation of regulation cannot be achieved without adequate skills and sufficient financial and human resources. The dam safety advisory committee, appointed in November 2011, supplements DEPI's dam safety and technical expertise and provides guidance on the development and implementation of regulatory processes by both DEPI and licensing authorities. DEPI will continue to develop and regularly review its skills and resources to enable a sufficient skill base for the successful delivery of its regulatory program such that regulatory personnel have the:

- training and capacity to oversee dam manager performance and responsibilities and promote good practice; and
- ability and judgement to, where necessary, enforce dam safety compliance as a last resort.

Obtaining adequately skilled personnel, consultants and contractors is a widespread concern and constraint across the dam industry, and may worsen unless proactively addressed. The dams industry in particular is undergoing a major loss of experienced dam engineers as the workforce ages. DEPI will continue to work and support the WIDWG and ANCOLD in initiatives to address skills shortages, such as the National Training Package for the water industry. These include promoting the availability and quality of dam safety training through water industry training providers and tertiary

institutions, and promoting the development of contractual relationships between dam managers to enable the sharing of skills and resources.

4.3. Performance Requirements and Guidance



DEPI and licensing authorities set performance requirements based on current technology, scientific understanding and current industry good practice and provide support and guidance to dam managers to achieve these.

Dam safety performance requirements are set and communicated through regulation and guidelines. These include the SoO for water corporation dams, and for privately owned dams, and licence conditions, based on Ministerial Guidelines (DSE, 2010). Performance requirements form a basis for quantifying and monitoring the level of safety of a dam and how well a dam is being managed.

Where needed, DEPI and licensing authorities provide broad guidance and support to dam managers to assist in understanding and meeting dam safety obligations. In particular, this has been through the publication of dam safety and emergency management guidance notes <http://www.depi.vic.gov.au/dam-safety-management-guidance-notes>.

Dam safety performance requirements are closely aligned with ANCOLD guidelines. DEPI and other regulators in Australia have contributed to the development of these guidelines over many years to achieve a nationally consistent approach to dam safety management.

While continuing to actively participate in the development of the ANCOLD Guidelines, DEPI also separately considers further specific regulatory requirements relative to local circumstances, and provides supplementary guidance on aspects of good practice in dam safety not fully covered in the ANCOLD guidelines. Central to this is DEPI interaction and exchange of information with dam safety practitioners in the water industry through participation in the WIDWG. The dam safety advisory committee also supports DEPI in this task.

Performance requirements cover all key asset/dam safety management good practices over the life of a dam such as:

- design, construction and decommissioning;
- dam safety assessment against contemporary risk guidelines and engineering standards;
- operating procedures and manuals;
- surveillance and monitoring programs;
- incident investigation;
- emergency planning, preparedness (including mapping of inundation zones) and exercises;
- progress of dam safety improvement programs and dam safety investment;
- information management; and
- performance reporting to the regulator, government and the community.

4.4. Performance Monitoring and Assurance



DEPI and licensing authorities monitor and evaluate the performance of dam managers in meeting dam safety requirements.

While the onus of compliance with dam safety requirements rests with the dam manager, DEPI and licensing authorities maintain an overview of performance against dam safety obligations and licence conditions. Where DEPI or the licensing authority identify significant inadequacies in the management of a dam, they will liaise with the dam manager to rectify these.

Water corporation dams form a key focus for dam safety monitoring because of their size, generally higher consequence and their importance to the water sector and the community. Corporations are required to provide detailed annual reporting on their dam safety programs to DEPI (Ryan, 2010). This includes information on:

- the characteristics of the dams;
- safety surveillance, monitoring, operation and emergency preparedness;
- safety incidents;
- the level of safety of the dams; and
- proposals and timing for safety improvement and progress against improvement programs.

DEPI maintains a web-hosted database of all reporting results and engages with water corporation dam managers on the status of their dam safety program and their progress toward achieving dam safety performance requirements. DEPI also produces an annual report of statewide results to enable industry benchmarking and to encourage continual improvement in dam safety practice and risk reduction.

In addition to the annual reporting requirements, the Minister for Water through the Essential Services Commission may also periodically request independent auditing of the compliance of the corporations with specific clauses within the SoO. DEPI provides auditing scope for this process and analyses and reports on the results of these audits to the Minister.

Victoria's privately owned dams that meet the size and consequence categories outlined in section 4.1.1 are classified as potentially hazardous. These are regulated through the conditions of the 'works' licence, which amongst other things, require the licence holder to provide the authority with information such as:

- the design and construction reports;
- dam safety surveillance plan and emergency plans;
- the results of the surveillance programs; and
- notification of any significant deficiencies.

The term of a works licence to operate a potentially hazardous dam is generally five years. As part of the renewal of a licence, the authority may review dam safety information to assess compliance with licence conditions. This may result in instructions to the licence holder to update and improve their dam safety programs and, where required, rectify dam safety deficiencies to the satisfaction of the authority.

4.5. Directions and Enforcement



Where a dam poses an unacceptable risk and the dam manager's response is inadequate, DEPI and licensing authorities, as the Minister for Water's delegates, can issue directions to fix the dam and if necessary will directly undertake the remedial works.

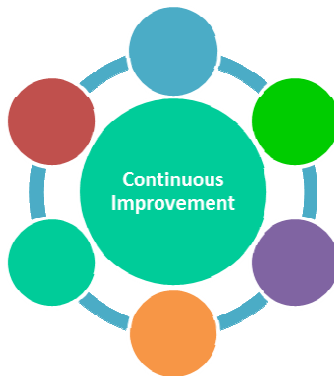
While DEPI's and licensing authorities' preferred approach to dam safety regulation is through cooperation, the *Water Act 1989* has a number of provisions enabling stronger enforcement approaches if warranted. Any decision to use enforcement would consider the level and immediacy of the risk posed by a dam, and the capacity and responsiveness of the manager to undertake effective remedial action.

DEPI and licensing authorities have delegated powers under the Act (sections 78 and 80) to issue directions to managers of both licensed and unlicensed dams. Directions may be issued in emergency situations, or if a dam is hazardous, or is likely to become so. Directions may include requirements such as making improvements to the dam, keeping the dam under increased surveillance and, in exceptional circumstances, removing the dam.

Where there is immediate risk to the community, environment or property, and dam managers are uncooperative or ineffective in undertaking appropriate action, DEPI and licensing authorities may decide to undertake remedial works and then recover the cost of these works. These powers are provided under sections 81 and 151 of the Act.

In certain circumstances, dam managers may also be subject to prosecution and penalties under section 75 of the Act.

4.6. Continuous Improvement



DEPI and licensing authorities work in partnership with dam managers, industry groups and other stakeholders to encourage and assist continued improvement, innovation and consistency in dam safety practice.

This is achieved through supporting and participating in existing industry forums such as the WIDWG. DEPI is working to extend these networks and enable effective information exchange with all managers and owners of potentially hazardous dams.

DEPI promotes and contributes to national standards on dam safety and their consistent application through regulation. This is pursued through working with industry, other Australian regulators and dam safety practitioners to support ongoing effort, research and investment in the review, update and implementation of the ANCOLD guidelines. Key to this is DEPI's participation and contribution to the ANCOLD Regulators' forum.

Dam safety regulation's primary focus to date has been water corporation dams. This is because of their size, generally higher consequence of failure and importance to the community. DEPI and licensing authorities are now working to further extend the implementation of dam safety regulation in Victoria to include all potentially hazardous dams and to ensure its consistent application. This includes current initiatives to develop arrangements for regulatory coverage of dams operated by Parks Victoria and dams and retarding basins managed by local government. DEPI will also continue working with licensing authorities to extend the use of risk management processes in managing and regulating private dams, particularly to managers with portfolios of High or Extreme Consequence Category dams.

4.7. Emergency Management



DEPI and licensing authorities provide guidance to dam managers and support agencies about emergency preparedness, and ensure effective incident control in escalating situations.

Victoria's multi agency framework for emergency management is established under the *Emergency Management Act 1986*. This sets out most of Victoria's emergency management structures and assigns roles and responsibilities.

The *Emergency Management Manual Victoria* (EMMV) published by the Office of the Emergency Services Commissioner contains the key policy and planning documents for emergency management in Victoria. The EMMV identifies DEPI as the Control Agency responsible for water and wastewater service disruption and dam safety. Water corporations and the VICSES are listed as support agencies for these types of emergencies.

The following state arrangements from the EMMV apply to dam safety emergencies:

- State Emergency Response Plan (EMMV Part 3);
- State Emergency Relief and Recovery Plan (EMMV Part 4); and
- Emergency Management Agency Roles (EMMV Part 7).

These documents can be found on the website of the Office of the Emergency Services Commissioner at <http://www.oesc.vic.gov.au/emergencymanual>.

As the Control Agency responsible for water and wastewater service disruption and dam safety, DEPI has an emergency notification and response protocol with water corporations on water, wastewater and dam safety incidents (DEPI, 2014). This covers arrangements for dams managed by water corporations and private dams licensed by the five licensing water corporations.

Under the protocol, DEPI requires that water corporations:

- notify DEPI through the State Duty Officer of any dam safety emergencies with a risk level of medium or high, or with the potential to escalate to this level; and
- directly manage the emergency response at the dam site, assuming the role of incident controller, until the emergency is either resolved or the situation escalates to a level which requires DEPI to make a replacement appointment.

DEPI is currently revising the emergency notification and response protocol to clarify emergency processes and roles and responsibilities for private dams, and also for public dams that are managed by entities other than water corporations.

The VICSES is the Control Agency for flooding. DEPI, VICSES and other agencies have produced a protocol to set out emergency arrangements for the management of flooding consequences downstream of dams and responsibilities for the notification of downstream communities. This protocol is appended to the *State Flood Emergency Plan* (VICSES, 2012) and can be found at <http://www.ses.vic.gov.au/prepare/em-planning/state-plans>. The protocol applies to floods passing through a dam which are within the operational capacity of the dam but have the potential to cause downstream impacts, floods caused by environmental releases or floods caused or exacerbated by a dam failure. The document clarifies roles and responsibilities of various agencies (e.g. VICSES, VICPOL, DEPI, and BOM) and also those of dam managers, particularly water corporations.

Further emergency management requirements are set out in the SoO for water corporations, and for private dam managers within licence conditions. In addition, DEPI and licensing authorities produce guidance material to assist in the preparation of dam safety emergency plans and liaise with the managers of major dams to promote regular review and exercising of dam safety emergency plans (DSE, 2011a). DEPI also engages in ongoing dialogue with other agencies

with dam safety emergency responsibilities including the Fire Services Commissioner and Victoria Police to maintain and improve clarity in roles, responsibilities and procedures.

The Victorian Emergency Management Reform White Paper released in December 2012 (Victorian Government, 2012) sets out a broad roadmap for key reform initiatives on emergency management in Victoria. These include supporting the community to become more resilient, establishing new governance structures and independent assurance arrangements. The reform initiatives are being progressively implemented.

5. Regulatory Overview of High and Extreme Consequence Dams

High and Extreme Consequence dams with the potential to cause loss of life are a high priority for regulatory overview and monitoring. Dams managed by water corporations are a key focus for regulation in this respect. Typically, these dams also have the potential to cause large environmental and economic impacts.

Under the SoO, water corporations are required to report annually to DEPI on the risk profiles of their dams, progress in completion of risk reduction works and their proposals for further dam safety improvement works. To comply with dam safety obligations, corporations are expected to undertake detailed safety reviews for High and Extreme Consequence dams utilising both quantitative risk-based and standards-based assessment, to provide a comprehensive understanding of the level of safety of these dams. Standards-based assessments can provide a useful reference in understanding risks and, where appropriate, justify decisions.

DEPI uses this information, as well as results from periodic external audits, as a basis for monitoring the adequacy of the corporations' dam safety programs and for prioritising and targeting its regulatory activities. In particular, DEPI evaluates the results for individual dams to determine the level and type of regulatory response, particularly if the dam does not yet meet tolerable risk guidelines (section 4.1.5).

The Victorian dam safety regulatory regime includes a risk-informed approach so that such decisions are made in a systematic and consistent way and that regulatory actions and resources are efficiently prioritised. This is similar to the decision-making risk framework used by the United States Bureau of Reclamation (USBR, 2011). While the level and type of response is proportionate to the severity of the risk, regulatory overview is maintained across all dams with the potential to cause significant impacts in the event of a dam failure.

Victoria's risk-informed approach involves categorisation of High and Extreme Consequence dams into the five escalating levels of regulatory response below:

- (a) immediate (e.g. a dam failure is imminent, an active failure mode may be in progress or a risk value greater than two orders of magnitude above the 'limit of tolerability' has been obtained);
- (b) very high (e.g. level of societal risk is very high);
- (c) high (e.g. level of societal risk is high);
- (d) moderate (e.g. risk is within the tolerable area); and
- (e) monitor and review (e.g. risk level in the risk monitoring zone, Figure 4-3).

For (a), (b) and (c) above, risks are unacceptable except in exceptional circumstances.

For (d) and (e) above, risks are tolerable if they satisfy ALARP.

The criteria summarised in Table 5-1 are applied to determine the appropriate level of regulatory response.

Table 5-1 Prioritisation Criteria

PRIORITISATION CRITERIA	
Dam safety risk status	<ul style="list-style-type: none"> • information indicating that a dam failure is imminent or in progress • level of societal risk and individual risk (section 4.1.5) • results of standards-based assessments • whether the risk is associated with a single failure mode • magnitude of potential public safety, societal, economic and environmental consequences • the annualised likelihood of the consequence occurring

Table 5-1 Prioritisation Criteria, continued

PRIORITISATION CRITERIA	
Dam manager's risk management program	<ul style="list-style-type: none"> • adequacy of dam safety assessment information, including frequency of dam safety reviews • level of uncertainty in the information provided • level of surveillance and monitoring and compliance with ANCOLD guidelines • emergency preparedness <ul style="list-style-type: none"> – site specific DSEPs with current inundation map – regular review and exercising of DSEP • operation and maintenance procedures • training and use of appropriate expertise for dam safety activities • design details, scheduled date and budgetary details for dam safety improvement works • track record of manager of multiple dams in timely completion of risk reduction works

While the safety status of the dam is a key criterion in assessing the level of regulatory response, the adequacy of the dam manager's risk management processes is also important in deciding on the most effective course of action.

When dam managers implement actions to reduce risk such as upgrade works, or as better information is provided on the safety status of a particular dam, the level of regulatory response is re-evaluated accordingly.

Table 5-2 outlines the various actions that a dam manager may take to address a particular situation and possible responses by the regulator for each regulatory response category. The table is intended as a guide rather than as a prescriptive list, because it is not possible to envisage the best course of action in every circumstance. It should also be noted that in the majority of cases the dam manager will have taken a proactive approach and the regulatory response will reflect how well the dam manager is dealing with the situation.

Examples of possible scenarios and regulatory approaches are provided in Appendix 4. These are compilations of various situations which may have arisen and do not apply to any specific dam.

While the majority of dams with the potential to cause very high consequences are owned by water corporations, DEPI is working to apply the above approach to other dam managers, to enable a consistent level of regulatory overview for all High and Extreme Consequence Category dams.

5.1. Risk assessment results showing very high risks

In the majority of cases where risk analyses have generated very high risk results, there have been no indications of active failure modes in progress. Typically, a particular dam would have operated satisfactorily for many years. However, assessment against current standards and using contemporary risk analysis methods may have identified a significant design or construction flaw in the dam that needs to be addressed in the short to medium-term to ensure its ongoing safe operation. In many circumstances, this risk can be significantly lowered in the short-term by imposing an operating restriction (lowering the level of water in the dam) or minor structural works, until longer-term measures can be carried out.

Sometimes, a very high risk result may be obtained where a screening or preliminary level risk assessment is used when initially assessing the safety of the dam. In this case, more conservative parameters may have been selected for the risk analysis due to the higher level of uncertainty associated with less detailed investigations. Typically after obtaining a high risk result, more investigations and data gathering will be undertaken, and following input of this information into the risk analysis, a much lower (though rarely below the 'limit of tolerability') result may be obtained.

Table 5-2 Manager and Regulator Response for High and Extreme Consequence Dams

LEVEL	POSSIBLE SCENARIOS	POSSIBLE DAM MANAGER ACTIONS	POSSIBLE REGULATORY RESPONSES
1.Immediate	<ul style="list-style-type: none"> the societal risk is over two orders of magnitude above the 'limit of tolerability' the annualised likelihood of failure is very high (e.g. >0.1) and dominated by a single failure mode the societal risk is low but there is an urgent risk of damage to critical infrastructure of state-wide importance, major disruptions to essential services or catastrophic environmental impacts a dam failure may be imminent or in progress 	<ul style="list-style-type: none"> implement interim risk reduction measures such as operating restrictions or short-term structural works provide board with regular status reports notify DEPI and other key organisations review and exercise dam safety emergency plan seek expert advice increase monitoring and surveillance ensure risk assessments are completed to a detailed to very detailed level expedite planning for major risk reduction works undertake major risk reduction works as a priority if a dam failure is imminent or in progress, activate the dam safety emergency plan, including stakeholder notification processes, and take immediate actions to prevent dam failure 	<ul style="list-style-type: none"> liaise with the dam manager at very frequent intervals to monitor risk and progress of interim and major risk reduction works ensure overview by senior management review adequacy of dam manager's emergency management arrangements and monitoring and surveillance require an independent engineering review facilitate permit approvals and access to resources and expert advice if required, issue formal directions to dam managers to repair the dam or directly undertake works activate internal emergency management processes if a dam failure is imminent (section 4.7) as a last resort, be prepared to ensure alternative arrangements for incident control if the situation escalates beyond the owner's capacity
2. Very High	<ul style="list-style-type: none"> the societal risk is over one order of magnitude above the 'limit of tolerability' but there are no indications that dam failure is imminent the annualised likelihood of failure is high the societal risk is less than one order of magnitude above the "limit of tolerability" but there a may be a high risk of damage to critical infrastructure of state-wide importance, major disruptions to essential services or catastrophic environmental impacts 	<ul style="list-style-type: none"> implement interim risk reduction measures such as operating restrictions or short-term structural works provide board with regular status reports notify DEPI and other key organisations review and exercise emergency arrangements seek expert advice increase monitoring and surveillance ensure risk assessments are undertaken to a detailed to very detailed level expedite planning for major risk reduction works complete major risk reduction works as soon as practicable, usually within a few years of the identification of the risk 	<ul style="list-style-type: none"> liaise with owner at frequent intervals to monitor risk and progress of interim and major risk reduction works ensure overview by senior management review adequacy of dam manager's emergency management arrangements and monitoring and surveillance require an independent engineering review facilitate permit approvals and access to resources and expert advice if required, issue formal directions to dam managers to repair the dam or directly undertake works

Table 5-2 Regulatory Response for High and Extreme Consequence Dams, continued

LEVEL	POSSIBLE SCENARIOS	POSSIBLE DAM MANAGER ACTIONS	POSSIBLE REGULATORY RESPONSES
3. High	<ul style="list-style-type: none"> the societal risk is at or within one order of magnitude above the 'limit of tolerability' the individual risk is at or above 10^{-4} per annum the societal risk is slightly below the 'limit of tolerability', but the level of confidence in the risk assessment is low the societal risk is below the "limit of tolerability" but there may be an unacceptable risk of damage to critical infrastructure of state-wide importance, major disruptions to essential services or catastrophic environmental impacts there is uncertainty about the level of safety of the dam the dam safety management program is inadequate 	<ul style="list-style-type: none"> consider interim risk reduction measures notify DEPI provide board with regular status reports confirm adequacy of monitoring and surveillance seek expert advice ensure risk assessments are undertaken to a detailed to very detailed level, particularly for dams at the upper range of consequence levels review and exercise emergency arrangements reduce risk to below the 'limit of tolerability' as soon as practicable: implementation of works may take several years from the initial identification of the risk (e.g. DSE, 2011b) for managers of multiple dams this may involve a progressive portfolio approach to implementing risk reduction works update dam safety program to ensure consistency with ANCOLD guidelines and other good practice 	<ul style="list-style-type: none"> engage in regular dialogue with the dam manager to communicate dam safety obligations monitor risk levels and adequacy in progress toward completing dam safety works to reduce risks to tolerable levels monitor adequacy of emergency management arrangements and monitoring and surveillance
4. Moderate	<ul style="list-style-type: none"> the societal risk is clearly below the 'limit of tolerability' and economic and environmental risk is low the individual risk is clearly below 10^{-4} per annum the annualised likelihood of failure may be very low, but potential life safety, environmental or economic consequences may be of a catastrophic level (e.g. greater than 100 loss of life or economic losses in excess of \$1 Billion) a sound dam safety management program is in place 	<ul style="list-style-type: none"> verify whether risks are ALARP ensure at least a detailed level of assessment for ALARP evaluation and very detailed in the case of dams with the potential for large consequences consider the feasibility of satisfying traditional engineering standards for very high consequence dams where cost-effective options are identified, undertake further risk reduction work to achieve ALARP: timeframes for completion may be in the range of up to twenty years from the identification of the risk continue to manage and monitor risk at tolerable levels and reduce risks further if possible periodically review and exercise emergency plans 	<ul style="list-style-type: none"> engage in regular dialogue and information exchange with owner to communicate dam safety obligations continue to monitor dam safety levels and adequacy of dam safety programs through normal reporting processes require owner to review Consequence Category periodically
5. Monitor and review	<ul style="list-style-type: none"> the societal risk is within the risk monitoring zone and economic and environmental risk is low a sound dam safety management program is in place 	<ul style="list-style-type: none"> consider the feasibility of satisfying traditional engineering standards for very high consequence dams continue to manage and monitor risk at tolerable levels periodically review and exercise emergency plans 	<ul style="list-style-type: none"> continue to monitor dam safety levels and adequacy of dam safety programs through normal reporting processes typically, a lower frequency of dialogue and information exchange with owner

6. Glossary and Acronyms

The following glossary of terms is taken from various documents including the *Guidelines on Risk Assessment* (ANCOLD, 2003a) and *Guidelines on Dam Safety Management* (ANCOLD, 2003b).

TERM	DEFINITION
ALARP	As Low As Reasonably Practicable Principle. That principle which states that risks, lower than the 'limit of tolerability', are tolerable only if risk reduction is impracticable or if its cost is grossly disproportionate (depending on the level of risk) to the improvement gained (HSE, 2001).
ANCOLD	Australian National Committee on Large Dams.
BOM	Bureau of Meteorology
Consequence	In relation to risk analysis, the outcome or result of a risk being realised. Includes flood impacts in the downstream as well as upstream areas of the dam resulting from failure of the dam or its appurtenances, as well as indirect impacts over an indefinitely large area.
Consequence Category	A classification of adverse consequences resulting from a dam failure (ANCOLD, 2012b).
Dam Manager	The individual/s or entity that has primary ownership or management responsibility for a dam. Dam managers or owners of public dams in Victoria include Water Corporations, Local Government, Parks Victoria and the Department of Sustainability and Environment. For private dams included in a works licence, the dam manager is the holder of the licence. For private dams without a licence the dam manager is the owner of the land.
DEPI	Department of Environment and Primary Industries, Victoria (former DSE).
DPI	Department of Primary Industries, Victoria.
DSC	Dams Safety Committee. The New South Wales dam safety regulator.
DSDBI	Department of State Development, Business and Innovation, Victoria.
DSE	Department of Sustainability and Environment, Victoria (now DEPI).
DSEP	Dam Safety Emergency Plan. A continually updated set of instructions and maps that deal with possible emergency situations or unusual occurrences at or related to a dam or reservoir.
Emergency Management	The organisation and management of resources for dealing with all aspects of emergencies. Emergency management involves the plans, structures and arrangements which are established to bring together the normal endeavours of government, voluntary and private agencies in a comprehensive and co-ordinated way to deal with the whole spectrum of emergency needs including prevention, response and recovery (OESC, 2011).
EMMV	Emergency Management Manual Victoria. The EMMV contains the key policy and planning documents for emergency management in Victoria.
ESC	Essential Services Commission. Victoria's independent economic regulator of essential services supplied by water and sewerage, electricity, gas, ports and rail freight industries.
Failure of a Dam	In the general case, the inability of a dam system, or part thereof, to function as intended. Thus, in terms of performance to fulfil its intended function, the inability of a dam to perform functions such as water supply, prevention of excessive seepage or containment of hazardous substances. In the context of dam safety, failure is generally confined to issues of structural integrity, and in some contexts to the special case of uncontrolled release of the contents of a reservoir through collapse of the dam or some part of it.

Hazard	Threat or condition, which may result from either an external cause (e.g. earthquake, flood, or human agency) or an internal vulnerability, with the potential to initiate a failure mode. A source of potential harm or a situation with a potential to cause loss.
HSE	Health and Safety Executive. The national independent watchdog for work-related health, safety and illness in the United Kingdom. It is an independent regulator and acts in the public interest to reduce work-related death and serious injury across Great Britain's workplaces.
ICOLD	International Committee on Large Dams. This is a non-governmental international organization which provides a forum for the exchange of knowledge and experience in dam engineering. ICOLD has National Committees from 90 countries with approximately 10, 000 individual members.
Incident	An event which could deteriorate to a very serious situation or endanger the dam.
Individual risk	The increment of risk imposed on a particular individual by the existence of a hazardous facility. This increment of risk is an addition to the background risk to life, which the person would live with on a daily basis if the facility did not exist.
Large Dam (ANCOLD)	<p>A large dam (www.ancold.org.au) is defined as one which is:</p> <ul style="list-style-type: none"> (a) more than 15 metres in height measured from the lowest point of the general foundations to the 'crest' of the dam, (b) more than 10 metres in height measured as in (a) provided they comply with at least one of the following conditions: <ul style="list-style-type: none"> (i) the crest is not less than 500 metres in length (ii) the capacity of the reservoir formed by the dam is not less than 1 million cubic metres (iii) the maximum flood discharge dealt with by the dam is not less than 2,000 cubic metres per second (iv) the dam is of unusual design. <p>No dam less than 10 metres in height is included.</p>
Likelihood	A qualitative description of probability and frequency.
MDBA	Murray Darling Basin Authority. The Commonwealth statutory body created by the <i>Commonwealth Water Act 2007</i> with responsibilities for planning the integrated management of the water resources of the Murray Darling Basin including the management of River Murray operations assets.
PAR	Population at Risk. All those persons who would be directly exposed to floodwaters assuming they took no action to evacuate.
PLL	Potential Loss of Life. The part of the population at risk that could lose their lives in the event of a dambreak.
Risk	Measure of the probability and severity of an adverse effect to life, health, property, or the environment. In the general case, risk is estimated by the combined impact of all triplets of scenario, probability of occurrence and the associated consequence. As a special case, average (annualised) risk can be estimated by the mathematical expectation of the consequences of an adverse event occurring (that is, the product of the probability of occurrence and the consequence, combined over all scenarios).
Risk analysis	The use of available information to estimate the risk to individuals or populations, or property or the environment, from hazards (qv). Risk analyses generally contain the following steps: scope definition, hazard identification, and risk estimation.

Risk assessment	<p>The process of reaching a decision recommendation on whether existing risks are tolerable and present risk control measures are adequate, and if not, whether alternative risk control measures are justified or will be implemented. Risk assessment incorporates, as inputs, the outputs from the risk analysis and risk evaluation phases.</p> <p>Consistent with the common dictionary definition of assessment, viz. “To analyse critically and judge definitively the nature, significance, status or merit of [risk]”, risk assessment is a decision-making process, often sub-optimal between competing interests, that results in a statement that the risks are, or are not, being adequately controlled. Risk assessment involves the analysis, evaluation and decision about the management of risk and all parties must recognize that the adverse consequences might materialise and owners will be required to deal effectively with consequences of the failure event.</p>
Risk management	The systematic application of management policies, procedures and practices to the tasks of identifying, analysing, assessing, controlling and monitoring risk.
Societal risk	The risk of widespread or large scale detriment from the realisation of a defined hazard, the implication being that the consequence would be on such a scale as to provoke a socio/political response, and/or that the risk provokes public discussion and is effectively regulated by society as a whole through its political processes and regulatory mechanisms. Such large risks are typically unevenly distributed, as are their attendant benefits. Thus the construction of a dam represents a risk to those close by and a benefit to those further off, or a process may harm some future generation more than the present one. The distribution and balancing of such major costs and benefits is a classic function of government, subject to public discussion and debate.
SoO	The Statements of Obligations (SoOs) are regulatory instruments issued by the Minister for Water to water corporations and licensees. The SoOs impose obligations on the water corporations and licensees in relation to performance of their functions and the exercise of their duties.
Standards-based Approach	The traditional approach to dams engineering, in which risks are controlled by following established rules as to design events and loads, structural capacity, safety coefficients and defensive design measures.
Suitably Qualified Engineer	A person eligible for membership of the Institution of Engineers Australia who is able to demonstrate competence in the design, construction supervision and surveillance of dams.
Tolerable risk	A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk that we do not regard as negligible or as something we might ignore, but rather as something we need to keep under review and reduce it still further if and as we can (HSE, 2001).
VICWATER	Victorian Water Industry Association.
VICSES	Victoria State Emergency Service. A volunteer based organisation responding to emergencies and working to ensure the safety of communities around Victoria. It is the lead agency when responding to floods, storms and earthquakes and operates the largest network of road rescue in Australia.
WIDWG	Water Industry Dams Working Group. A forum consisting of representatives from Victorian water corporations, VicWater and the Department of Environment and Primary Industries.

7. References

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Appendix 1: Statement of Obligations Emergency and Dam Safety Clauses

5-2 Managing Incidents and Emergencies

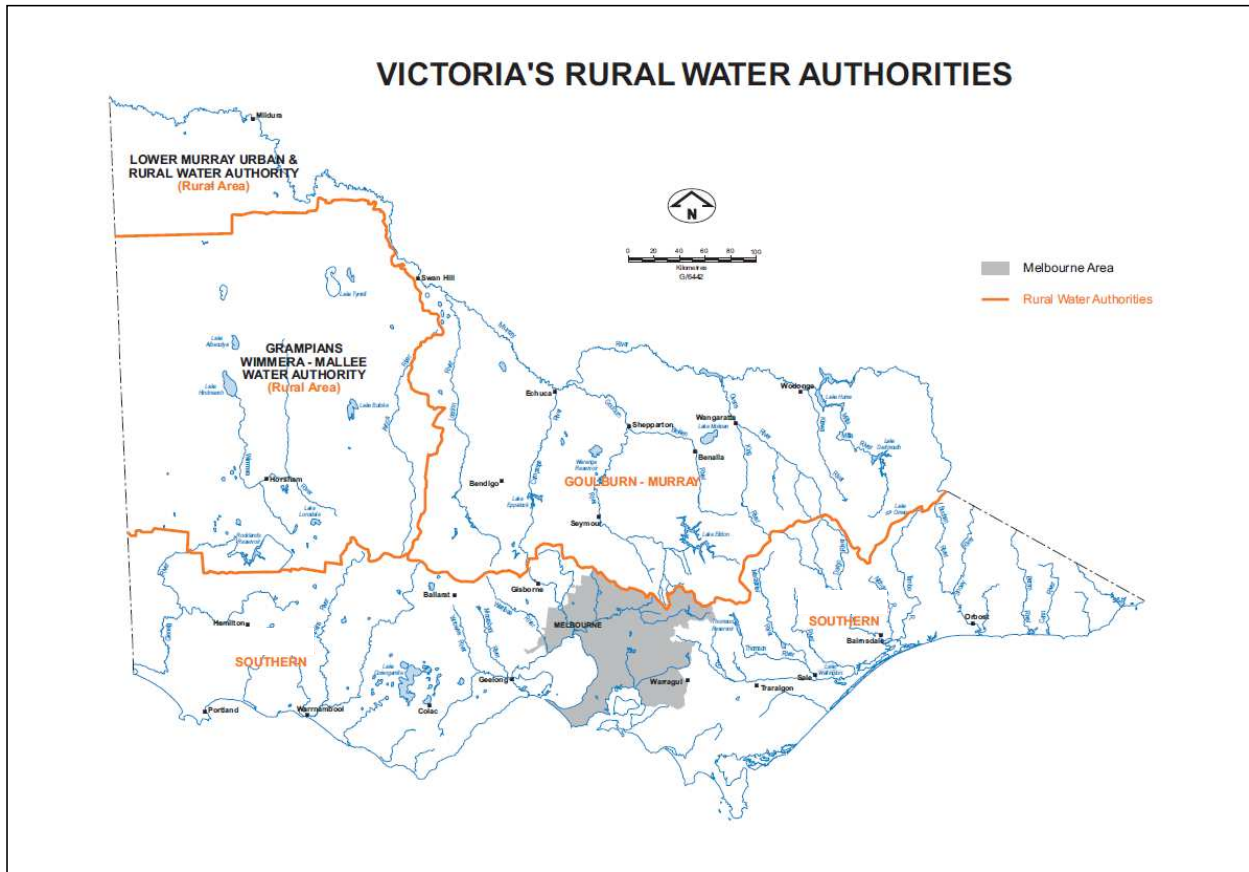
.1	<p>The Corporation must develop an emergency management plan for incidents and emergencies covering all hazards and measures, including:</p> <ul style="list-style-type: none"> a) the continuity of services; b) incidents resulting in waste discharges to the environment; c) a dam safety incident; d) a major Information and Communications Technology (ICT) incident; e) potential security risks, including but not limited to terrorist attacks; f) risks to water quality; and g) (for Melbourne Water only) flooding in any waterway in Melbourne Water's waterway management district or water which flows into or out of works operated by Melbourne Water. <p>The emergency management plan must have regard to the Australian Inter-Service Incident Management System. (subject to paragraph (g), applicable all)</p>
.2	<p>In addition to the obligation at 7-2.4 the Corporation must make available to the public its policy on:</p> <ul style="list-style-type: none"> (a) Pre-release of water from its dam; and (b) Surcharge of water level in its dams. <p>(applicable all)</p>
.3	<p>The Corporation must undertake such periodic training and exercises as may be necessary to ensure that its emergency management plan and business continuity plan are tested and can be implemented effectively. (applicable all)</p>

5-3 Dam Safety

.1	<p>The Corporation must develop and implement processes to identify, assess, manage and prioritise improvements to, and periodically review the safety of, dams, including retarding basins and wastewater storages, operated by the Corporation. (applicable all)</p>
.2	<p>In developing processes under sub-clause 5-3.1, the Corporation must have regard to the ANCOLD Guidelines and have particular regard to:</p> <ul style="list-style-type: none"> (a) prioritising risks posed by the Corporation's dams over all dams, components of dams and the types of failure; (b) giving priority to reducing risks to life above other risks; (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; (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. <p>(applicable all)</p>
.3	<p>The Corporation must develop and implement a dam safety monitoring and surveillance program for each dam operated by the Corporation, consistent with the ANCOLD Guidelines. (applicable all)</p>
.4	<p>The Corporation must prepare and give to the Secretary by 30 June each year a report that contains:</p> <ul style="list-style-type: none"> (a) a prioritised list of proposed dam safety works identified under sub-clause 5-3.1 and the dates by which the Corporation proposes to complete each of those works; (b) a summary of the risk profile of: <ul style="list-style-type: none"> (i) dams operated by the Corporation at the date of the report; and (ii) each dam on which the Corporation proposes to undertake safety works, after those works are complete; and (c) a summary of the overall risk reduction profile of the Corporation's dams. <p>(applicable all)</p>
.5	<p>If for any reason the Corporation is unable to undertake any proposed dam safety works identified under sub-clause 5-3.1 within the time advised, it must promptly prepare and give to the Secretary a report which explains why the Corporation is unable to undertake those works and includes any other information requested by the Secretary. (applicable all)</p>

Appendix 2: Licensing Authorities and Standard Licence Conditions

Figure A2.1 Areas of responsibility of licensing authorities



Licensing authorities issue works licences (section 67, *Water Act 1989*) for works on a waterway, bores and dams. Table A2-1 lists standard dam safety conditions as set out in *Policies for Managing Works Licences* (DSE, 2010). Additional conditions may be applied to specific works licences by the relevant licensing authority depending on the attributes and surrounds of the dam.

Table A2-1 Standard conditions for works licences, dam safety clauses (DSE, 2010)

for licences to construct a potentially hazardous dam

18. The dam and associated works must be designed and constructed under the direct supervision of an engineer eligible for membership of the Institution of Engineers Australia who is able to demonstrate competence in the design, construction supervision and surveillance of dams.
19. The licence holder must ensure that the engineer responsible for design and construction of the dam holds professional indemnity insurance for an amount of \$[insert text here] million with an undertaking to maintain the cover for at least seven years following the construction of the dam.
20. The license holder must notify the Authority at least five business days prior to work commencing on the dam, and must also notify the Authority if work is to cease for an extended period during construction.
21. The dam and associated works must not be made operational until the Authority acknowledges receipt of a completed and acceptable dam-safety surveillance plan and an emergency management plan.
22. The dam and associated works must not be altered, removed or decommissioned without a works licence that authorises alteration, removal or decommissioning.

Table A2-1 Standard conditions for works licences, dam safety clauses, continued

for licences to construct or operate a potentially hazardous dam

23. The licence holder must lodge a copy of a dam-safety emergency management plan with the Authority and the relevant municipal council.
24. The licence holder must provide the Authority with the results of any surveillance program within 12 months of the issue of this licence and thereafter at any other time requested by the Authority.
25. The licence holder must, if directed by the Authority, amend the surveillance program and emergency management plan at any time.
26. If a deficiency is found in the structure of the dam that is not minor in nature, the licence holder must immediately advise the Authority of the nature of the deficiency and engage a suitably qualified engineer to propose a program to rectify it.
27. The licence holder must carry out, to the satisfaction of the Authority, any remedial works identified by a suitably qualified engineer.

Appendix 3: ANCOLD Consequence Categories

The *Guidelines on the Consequence Categories for Dams* (ANCOLD, 2012b) sets out two methods for assigning a Consequence Category. The first, shown in Table 4, uses estimates of the population at risk (PAR) and environmental, economic and social damage if a dam failed. The guidelines state that ‘the PAR includes all those persons who would be directly exposed to flood waters assuming they took no action to evacuate.’ The second method (Table 5), which is a more detailed approach, is based on undertaking an assessment of the potential loss of life (PLL) that could be caused by a dam break. The PLL is defined by the guidelines as ‘the part of the population at risk that could lose their lives in the event of a dam break.’

In relation to the assignment of consequence categories, it is important to take note of this reference from the ANCOLD Consequence Guidelines – “However the complexity of determining the various parameters that make up each Consequence Category means that only experienced dam engineering professionals should interpret and use these Guidelines when making decisions that could impact on community safety, community cost and services, infrastructure, natural environment, heritage, and the owner’s and other businesses.” In undertaking a consequence category assessment the information provided in the below tables should not be used without taking into account the full guidance provided in the Guidelines.

Table A3.1 ANCOLD Consequence Categories based on Population at Risk (Table 3 ANCOLD, 2012b)

Population at Risk (PAR)	SEVERITY OF DAMAGE AND LOSS (E.g. health and social, environment, infrastructure and business cost)			
	MINOR	MEDIUM	MAJOR	CATASTROPHIC
<1	Very Low	Low	Significant	High C
≥ 1 to 10	Significant (Note 2)	Significant (Note 2)	High C	High B
≥ 10 to < 100	High C	High C	High B	High A
≥ 100 to <1,000	(Note 1)	High B	High A	Extreme
≥ 1,000		(Note 1)	Extreme	Extreme

Note 1: With a PAR in excess of 100, it is unlikely damage will be minor. Similarly with a PAR in excess of 1,000 it is unlikely damage will be classified as medium.

Note 2: Change to “High C” where there is the potential of one or more lives being lost.

Table A3.2 ANCOLD Consequence Categories based on Potential for Loss of Life (Table 4 ANCOLD, 2012b)

Potential Loss of Life (PLL)	SEVERITY OF DAMAGE AND LOSS (E.g. health and social, environment, infrastructure and business cost)			
	MINOR	MEDIUM	MAJOR	CATASTROPHIC
<0.1	Very Low	Low	Significant	High C
≥ 0.1 to <1	Significant	Significant	High C	High B
≥ 1 to < 5	(Note 1)	High C	High B	High A
≥ 5 to <50		High A	High A	Extreme
≥ 50		(Note 1)	Extreme	Extreme

Note 1: With a PLL equal to or greater than one (1), it is unlikely damage will be minor. Similarly with a PLL in excess of 50 it is unlikely damage will be classified as medium.

Appendix 4: Regulatory Overview of High and Extreme Dams: Examples

The following F-N plots and Table 6 provides examples of various risk scenarios and what type of decisions and actions the regulator and dam owners may take under these circumstances. The examples are compilations are various situations that have arisen, but do not intentionally represent a particular dam. It should be noted that many different situations may arise, so it is difficult to be prescriptive about what scenarios could occur or the most appropriate course of action.

Figure A4.1 Example F-N plots

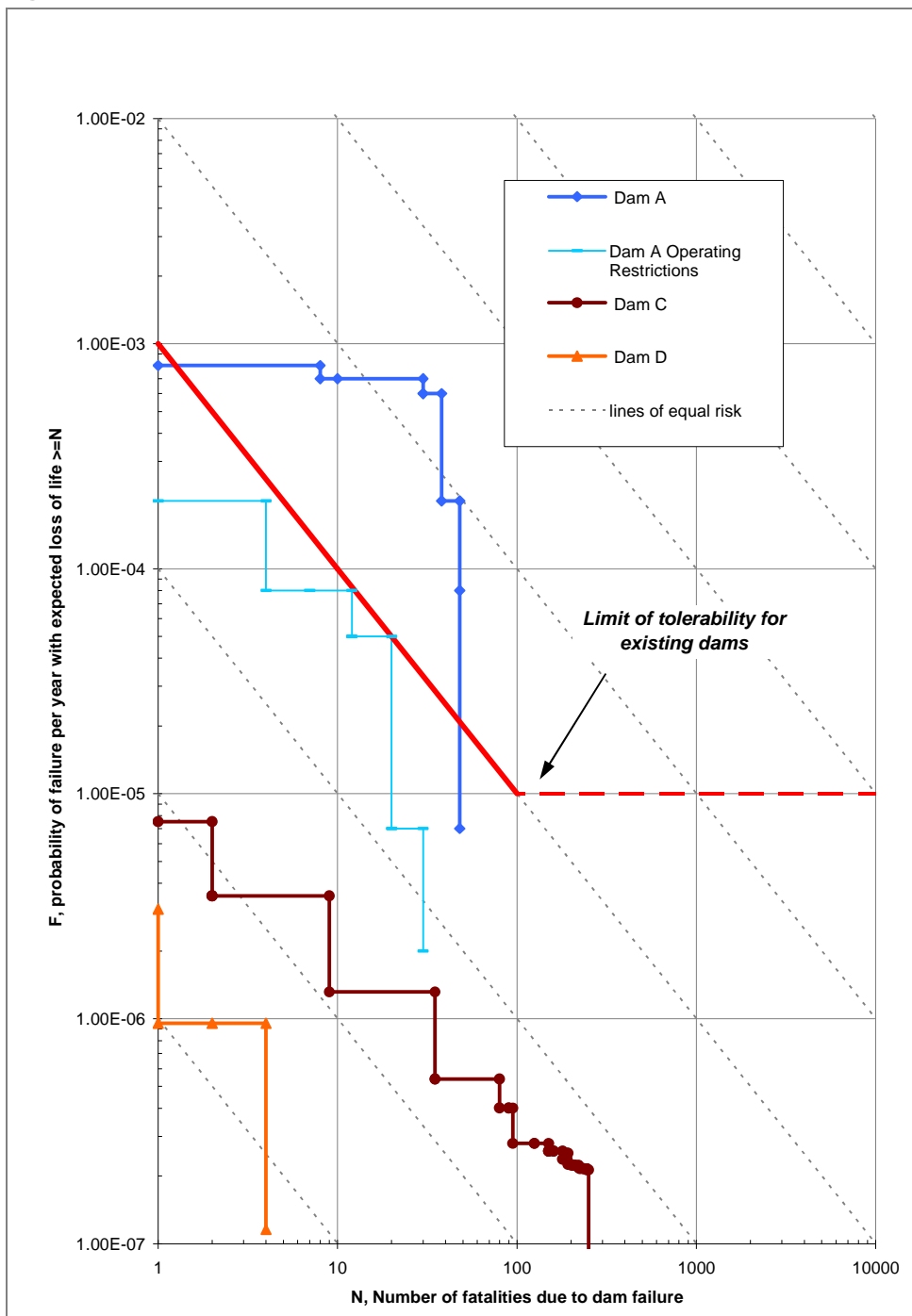


Table A4.1: Examples for Management and Regulation of High and Extreme Dams

DAM	RISK SCENARIO	LEVEL	OWNER ACTIONS	REGULATORY RESPONSE
Dam A: Consequence Category High A	<ul style="list-style-type: none"> Dam A has a 25 m high earthen embankment Constructed in the 1930's, the dam lacks filters. Minor seepage has occurred at the toe of the dam for many years, but recently rates have increased. Seepage water has remained clear a subsequent dam safety review and detailed risk assessment has found that the societal risk is over one order of magnitude above the limit of tolerability. The increased risk profile of the dam is largely driven by a single failure mode related to the internal erosion in the embankment and also significant downstream development over the last two decades the owner has a comprehensive surveillance and monitoring program in place and there is no indication that dam failure is imminent 	Very High	<ul style="list-style-type: none"> the owner has established a technical review panel to oversee the situation. This includes external expert dam safety advice interim works to establish an operating restriction of one metre below FSL have commenced. This is expected to reduce seepage rates and risk levels considerably. After the completion of the work the risk level of the dam will be re-evaluated heightened surveillance and monitoring is in place. emergency management arrangements have been reviewed and confirmed with stakeholders and a dam safety emergency management exercise has been undertaken the owner has commissioned detailed design works and cost estimations for the upgrade of the dam which will involve the installation of full height filters. The construction phase is scheduled to commence in two years the board is provided with regular status reports 	<ul style="list-style-type: none"> following notification of the deficiency, DEPI had regular briefings from the owner and the dam safety engineer to confirm that there is no immediate risk of dam failure the owner has provided a number of reports on proposals and progress of interim and long-term risk reduction works this has included operating restrictions, increased emergency management arrangements and monitoring and surveillance DEPI is monitoring the owner's completion of interim risk reduction works and will review proposals and timelines for the completion of dam safety improvement works following finalisation of the operating restrictions DEPI is providing guidance and facilitating permit approval processes senior management are being provided with regular status reports DEPI has confirmed that emergency management arrangements and monitoring and surveillance have been recently reviewed and are satisfactory
Dam B: Consequence Category High B	<ul style="list-style-type: none"> Dam B is a 20 metre high concrete gravity dam the societal risk is low (loss of life < 1). There are no houses in the inundation zone but recreational fishing and occasional camping occurs downstream economic consequences are potentially major as the dam is a critical regulating structure for a high value irrigation area. A safety review has concluded that while there are no indications of a short-term dam failure scenario, the annualised failure probability of the dam is unacceptable 	High	<ul style="list-style-type: none"> a dam safety upgrade is scheduled to commence within four years. Preliminary design work has been completed with works to include strengthening of the dam by installation of anchors into the foundation and replacement of the spillway gates the board is provided with regular status reports. the dam is to be the subject of the owner's annual dam safety emergency exercise the adequacy of current operation, surveillance and monitoring procedures and emergency management arrangements have been reviewed and confirmed by the owner's dam safety engineers 	<ul style="list-style-type: none"> DEPI has had regular briefings with the owner and dam safety engineer. A safety review of the dam has confirmed that there is no short-term risk of dam failure. DEPI is monitoring risk levels and progress in completing dam safety works so that risks are reduced as soon as practicable to tolerable levels DEPI has confirmed that emergency management arrangements and monitoring and surveillance have been recently reviewed and are satisfactory

Table A4.1: Examples for Management and Regulation of High and Extreme Dams, continued

DAM	RISK SCENARIO	LEVEL	OWNER ACTIONS	REGULATORY RESPONSE
<p>Dam C: Consequence Category Extreme</p>	<ul style="list-style-type: none"> • Dam C was built in 1920 and has a 50 m high earthen and rockfill embankment • there is a large, growing regional centre 3 km downstream of the dam • extensive upgrade works ten years previously included installation of full height filters to protect against internal erosion and piping • a portfolio risk assessment following the upgrade indicated that the risk is well below the limit of tolerability and the annual failure probability is low • seepage rates and piezometric pressures are low and have shown consistent trends since the upgrade • with an extensive piezometer network and seepage monitoring, it is expected that any indications of internal erosion would be detected early • if the dam was built according to current construction standards the spillway capacity would be larger • a hydrological study concluded that the dam can pass a flood of an AEP of 1:100,000, however modelling methodology and data availability has improved since the study was completed 	<p>Moderate</p>	<ul style="list-style-type: none"> • the owner will undertake a detailed risk assessment to establish whether the case for ALARP can be clearly justified or if further works could achieve significant risk reduction • if further improvements are justified, works will be scheduled as part of the owner's portfolio dam safety improvement program • if the case for ALARP is established, the owner will continue to manage and monitor risk at tolerable levels through a comprehensive dam safety management program. This will include periodic reviews of the safety level of the dam and annual reporting to the regulator • the owner regularly reviews and periodically exercises the emergency management plan 	<ul style="list-style-type: none"> • following discussion with DEPI the owner has commissioned a detailed risk assessment of the dam to verify whether the societal risk meets the ALARP principle or whether additional works (specifically spillway works) may be justified to achieve further risk reduction • due to the extensive downstream development, the owner is required to undertake detailed monitoring and surveillance of the dam and provide an annual report to regulator on the current safety status of the dam • DEPI reviews the safety status of the dam through the owner's annual report. The owner's dam safety program is also subject to periodic regulatory audits
<p>Dam D: Consequence Category High C</p>	<ul style="list-style-type: none"> • Dam D is a 30 m high concrete gravity dam constructed in the 1970's in a rural area • while there are a number of houses downstream of the dam, a dam safety review and detailed risk assessment have concluded that the probability of failure and the societal, economic and environmental risk is very low 	<p>Monitor and review</p>	<ul style="list-style-type: none"> • The owner manages and monitors risk at tolerable levels through a comprehensive dam safety management program compliant with ANCOLD guidelines • The owner regularly reviews and practices the emergency management plans • The safety level of the dam is periodically reviewed, including reassessment of the consequence level. Results are reported to the regulator through annual reporting requirements 	<ul style="list-style-type: none"> • Under regulatory requirements the owner is required to undertake detailed monitoring and surveillance of the dam and provide an annual report to regulator on the current safety status of the dam • DEPI reviews the safety status of the dam through the owner's annual report. The owner's dam safety program is also subject to periodic regulatory audits

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