Queensland Government

Department of Regional Development, Manufacturing and Water

Dam Safety Management Guideline

Version 03.1 August 2024

rdmw.qld.gov.au

Acknowledgement of Traditional Owners

We respectfully acknowledge the Aboriginal and Torres Strait Islander peoples as the Traditional Owners and Custodians of this Country – the lands and seas on which we meet, live, learn, work and play. We acknowledge those of the past, the Ancestors whose strength has nurtured this land and its people, and we recognise their connection to land, sea and community. We pay our respects to them, their culture and to their Elders past and present.

This publication has been compiled by Dam Safety Team of the Department of Regional Development, Manufacturing and Water.

Interpreter statement:

The Queensland Government is committed to providing accessible services to Queenslanders from all culturally and linguistically diverse backgrounds. If you have difficulty in understanding this document, you can contact us within Australia on 13QGOV (13 74 68) and we will arrange an interpreter to effectively communicate the report to you.

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Summary

This guideline is an approved guideline under s572 of the *Water Supply (Safety and Reliability) Act 2008* (Act[1]).

- It is to be used in the process of applying dam safety conditions (DSC) to a referable dam, that has been issued by a duly authorised delegate of the chief executive pursuant to s354(2) of the Act, to ensure suitable dam safety standards are applied under the Act.
- Development permit conditions imposed under the provisions of the Act and the *Planning Act 2016*[2] can 'call up' or reference relevant sections of these guidelines as a way of undertaking particular activities.

This guideline describes the components of an effective dam safety management program for a referable dam. It will help owners of referable dams to comply with DSC applied by the chief executive.

While this guideline is intended for the management of referable dams in Queensland the principles described are applicable to all dams and similar water infrastructure.

This guideline does not address aspects associated with failure impact assessments, safety assessments and emergency action plans; these are described in separate published guidelines.

Content is generally consistent with the Australian National Committee on Large Dams' (ANCOLD) Dam Safety Management Guidelines (2003) but also considers developments in other Australian and international jurisdictions.

This guideline has been developed by the dam safety team of the Department of Regional Development Manufacturing and Water with input and review from dam owners and industry stakeholders in Queensland. It reflects their knowledge and experience.

While the primary audience for the guideline is dam owners and operators the contents are intended to be informative guidance for all stakeholders.

[1] https://www.legislation.qld.gov.au/view/pdf/inforce/current/act-2008-034
[2] https://www.legislation.qld.gov.au/view/pdf/inforce/current/act-2016-025

How to use this guideline

Section	Description	Intended readers
Dam safety conditions	A list of template dam safety conditions (DSC) typically considered by the chief executive. Contains references to relevant sections of this guideline.	Primarily owners and operators of referable dams or their employees and consultants. Also, a general description to guide dam owners wishing to quickly identify minimum management requirements for a particular dam.
Introduction	The purpose of, and responsibilities associated with, dam safety management. A comparison between this guideline and the corresponding ANCOLD guideline is provided.	Primarily owners and operators of referable dams or their employees and consultants. Also, other dam owners, decision makers and those wishing to understand the context and justification of dam safety management.
Background	Background information including the components of dam safety management, description of a referable dam and auditing and quality compliance.	
Dam safety management program components	Detailed description of the required components of a dam safety management program, for the purposes of complying with DSC applied by the chief executive.	Primarily dam safety management personnel responsible for the management of a referable dam.
Supporting components	Detailed description of supporting components to enable an effective dam safety management program.	
Dam safety components described in other guidelines	References to other guidelines which describe dam safety management aspects such as failure impact assessment and emergency management.	
Auditing of dam safety management by the regulator	How the regulator audits dam owners to assure compliance to dam safety conditions.	
References	References to scientific literature and industry guidelines are provided.	
Appendices	Appendices are provided to support the guideline, including a comprehensive selection of checklists for dam safety management program components.	

Dam safety conditions[3]

The DSC listed in this section are template conditions the chief executive will typically consider applying to a referable dam.

The final conditions applied in any given case may differ to the template conditions, to take into account the consequences of a potential dam failure, the characteristics of the dam and particular issues identified at the dam (e.g. deficiencies).

An objective of imposing DSC is to ensure dam owners will develop a suitable dam safety management program and can demonstrate its effectiveness.

DSC may be applied when:

- A development approval under the *Planning Act 2016* is given for the construction of a new referable dam or upgrade of an existing referable dam.
    - The development application in most cases need to be made to the Department of State Development, Manufacturing, Infrastructure and Planning (DSDMIP) through its State Assessment and Referral Agency (SARA) group as the assessment manager. See **Appendix L.**
- An existing dam is determined to be referable- through the failure impact assessment (FIA) or referable dam notice (RDN) process.
    - Where an existing dam is newly determined to be referable under the *Water Supply (Safety and Reliability) Act 2008* (Act), the chief executive may develop and decide DSC under s354 of the Act. A notice may be issued requiring a dam owner to supply specified information about their referable dam to assist in deciding the DSC to be applied.

The chief executive also has the power to change any imposed DSC, under s356 of the Act.

- This recognises that dams are generally long-term structures; planning and development over time can alter the consequences of failure and design standards and management practices can change over time. By having the capacity to change DSC, requirements can be kept appropriate over the life of the dam.

DSC must be relevant and reasonably required, but not be an unreasonable imposition upon the dam owner. Dam owners can seek internal reviews of, and appeal against, DSC imposed by the chief executive (Chapter 7 of the Act).

Table 1 provides a list of template DSC that would typically be considered for a referable dam. The list does not restrict the chief executive's power to apply a different DSC at any time in accordance with the provisions of the Act.

The department recommends each DSC be read in conjunction with the relevant section of this guideline.

[3] Dam owners may also need to comply with requirements additional to DSC. For example, requirements relating to failure impact assessments, emergency actions plans, emergency event reports, flood mitigation manuals and transfers of dam ownership.

Table 1 Dam Safety Conditions (see footnotes and this guideline for explanation of terms)

No	Title of condition and text	Condition timing	DSMG reference	When applied[4]
1	Dam safety management program			
	(a) The dam owner is responsible for the safety of the dam.	At all times	Section 3.1	All dams
	(b) The dam owner must have a Dam Safety Management Program for the dam that complies with the *Queensland Dam Safety Management Guideline*.			
	(c) The dam owner is responsible for implementing the Dam Safety Management Program for the dam.			
2	Documentation			
	(a) Any documentation prepared in order to comply with these dam safety conditions must be stored securely by the dam owner in accordance with the *Queensland Dam Safety Management Guideline,* until such time as the dam is decommissioned.	At all times	Section 3.2	All dams
	(b) The documentation must be made available to the Regulator.	Within 5 business days of a written request for access being received by the dam owner		
3	Data book			
	(a) The dam owner must maintain a Data Book for the dam in accordance with the *Queensland Dam Safety Management Guideline*.	At all times	Section 3.3	All dams
4	Annual safety statement			
	(a) The dam owner must provide[5] an annual statement to the Regulator about the safety status of the dam, the management practices for the dam and how the dam owner has implemented these dam safety conditions.	By 1 October of each year	Section 3.4	All dams
5	Safety Assessment			
	(a) If a safety assessment using the *Queensland Guidelines on Safety Assessments for Referable Dams* results in an assessment that an upgrade is required to address an intolerable risk, an upgrade project plan in accordance with those Guidelines must be provided to the chief executive.	By 1 October of each year	Safety Assessment Guidelines (RDMW, 2023)	All dams

[4] See Appendix B for description and justification of thresholds for DSC application. Note that 'all dams' refers to all referable dams.
[5] Unless otherwise specified, electronic submissions to the Dam Safety Regulator are suitable.

No	Title of condition and text	Condition timing	DSMG reference	When applied[4]
6	Design and construction			
	(a) Any new construction, including remedial works or decommissioning, must be designed and its construction supervised by a suitably qualified and experienced RPEQ[6] and described in a design report.	At all times	Section 3.6, 4.5	All dams
	(b) The dam owner must ensure that technical reviews of the dam project occur in accordance with the *Queensland Dam Safety Management Guideline*.	At all times		
	(c) The dam owner must ensure a design report for the proposed works, including drawings, is produced and a copy provided to the Regulator.	At least 30 business days prior to the commencement of construction of the works		
	(d) The dam must not be altered or decommissioned without the dam owner giving prior written notification to the Regulator, except in an emergency situation.	At least 30 business days prior to the commencement of construction of the works		
	(e) In an emergency situation, the dam owner must notify the Regulator of the undertaking of the relevant works.	As soon as possible		
	(f) The dam owner must provide notification to the Regulator once construction works have been completed.	Within 5 business days following completion of works		
	(g) The dam owner must ensure an as-constructed report, that includes as-constructed documentation and drawings for the works, is produced and a copy provided to the Regulator.	Within 60 business days following completion of works		
7	Operation and Maintenance			
	(a) The dam owner must develop and implement an operation and maintenance manual for the dam (including surveillance and monitoring) in accordance with the *Queensland Dam Safety Management Guideline*.	Before construction of the dam is complete	Section 3.7	PAR≥10 or High C and above
	(b) The dam owner must ensure that aspects of the operation and maintenance manual critical to dam safety are kept current.	At all times		
	(c) The dam owner must ensure that appropriately trained and experienced personnel operate and maintain the dam in accordance with the operation and maintenance manual.	At all times		

[6] References to a 'suitably qualified and experienced RPEQ' refer to the provision of engineering services compliant with the *Professional Engineers Act 2002*, whereby engineering services are conducted by, or under direct supervision of, a registered professional engineer of Queensland (RPEQ). Section 4.1 provides advice on the capabilities expected of suitably qualified and experienced engineers beyond RPEQ such as being able to demonstrate competence in the design, construction supervision and surveillance of dams.

No	Title of condition and text	Condition timing	DSMG reference	When applied[4]
8	Engineering Inspections			
	(a) Comprehensive inspections of the dam must be conducted by a suitably qualified and experienced RPEQ and in accordance with the *Queensland Dam Safety Management Guideline*. A Comprehensive Inspection Report is to be prepared following the inspection and a copy provided to the Regulator.	First comprehensive inspection report by a date to be specified, then at intervals not exceeding 5 years apart[7]	Section 3.8	All dams
	(b) Annual Inspections of the dam must be conducted by a suitably qualified and experienced RPEQ and in accordance with the *Queensland Dam Safety Management Guideline*. An Annual Inspection Report is to be prepared following the inspection and a copy provided to the Regulator.	Once every calendar year[8]		PAR>100 or Category 2 FIR
	(c) The Regulator must be invited to attend engineering inspections.	At least 10 business days prior to inspection		All dams
9	Safety review			
	(a) A safety review of the dam must be conducted by an independent, suitably qualified and experienced RPEQ in accordance with the *Queensland Dam Safety Management Guideline*. A safety review report is to be prepared and a copy provided to the Regulator.	First safety review report by a date to be specified, then at intervals not exceeding 20 years apart[9]	Section 3.9	PAR≥10 or High C and above
	(b) The dam owner must ensure technical review of the safety review occurs in accordance with the *Queensland Dam Safety Management Guideline*.			
10	Deficiencies, Incidents or Failures			
	(a) The dam owner must notify the Regulator of any identified deficiency, incident or failure for the dam, in accordance with the *Queensland Dam Safety Management Guideline*.	Within 48 hours of becoming aware of the deficiency, incident or failure	Section 3.10	All dams
	(b) The dam owner must engage a suitably qualified and experienced RPEQ to propose a program to assess the deficiency, incident or failure.	Within 20 business days of the deficiency, incident or failure occurring		
	(c) The dam owner must carry out, to the satisfaction of the Regulator, any remedial works.	As agreed with the Regulator		

[7] Safety reviews incorporate the comprehensive inspection for that particular time period.
[8] Comprehensive inspections incorporate the annual inspection for that particular year.
[9] Investigations and design analyses supporting a major dam upgrade project might potentially be accepted by the Regulator as a safety review. The dam owner should liaise with the Regulator about this issue.

No	Title of condition and text	Condition timing	DSMG reference	When applied[4]
	(d) The dam owner must provide notification to the Regulator once any remedial works have been completed.	Within 5 business days following completion of works		
11	Other			
	(a) As defined by the Regulator			
12	Definitions			
	• ***Dam owner*** has the same meaning as in the Act. • ***Dam project*** means works for the dam including stages of specification, investigation (including safety review and safety assessment), design, construction, remedial works and decommissioning. • ***Queensland Guidelines on Safety Assessments for Referable Dams*** means the guideline relating to the safety assessment of dams made by the chief executive under section 572 of the Act. • ***Queensland Dam Safety Management Guideline*** means the guideline relating to managing a referable dam made by the chief executive under section 572 of the Act. • ***Registered professional engineer*** has the same meaning as in the *Professional Engineers Act 2002*. • ***Regulator*** means the chief executive of the department responsible for administering the provisions of the Act relating to referable dams and flood and drought mitigation. • *The **Act*** means the *Water Supply (Safety and Reliability) Act 2008.*			

Version history

Version	Date	Comment
1	February 2002	Original approval

2	October 2020	Significant changes include:
		• Changes to how a dam is made referable, reflecting legislative amendments
		• Dam safety conditions
		  • Table of template dam safety conditions typically applied to dams included, with sections in the guideline applicable to each condition referenced
		• Safety review
		  • Review process can consider acceptance criteria or risk management criteria
		• Operation and Maintenance (surveillance and monitoring)
		  • Section incorporates standard operating procedures (SOP), detailed operation and maintenance manuals (DOMM) and surveillance and monitoring
		• Annual statement of compliance
		  • A dam safety condition requiring an annual statement of compliance to regulatory requirements as part of wet season preparedness
		• Consideration of the Paradise Dam Commission of Inquiry Recommendations, in particular sections:
		  • Aspects of design and construction
		  • Project procurement
		  • Technical review
		  • Auditing
		• Content included
		  • Technical review
		  • Recommended skills for dam safety personnel
		  • Project procurement
		  • Quality assurance
		  • Change of ownership
		  • Auditing
		• Content removed
		  • Emergency Action Plans (EAP) and Emergency Event Reports (EER) now refers to the EAP Guideline
		  • Failure Impact Assessments (FIA) now refers to the FIA Guideline
		  • Reduction of FSL now refers to the AFC Guideline

3	February 2024	Changes include: • Reshuffle of major headings to provide clearer links to contents that describe safety conditions. • Adjustment of template dam safety conditions to reflect updates to supporting regulatory guidelines and a clarification of the obligation to invite the regulator to attend engineering inspections. • Revision of guidance on components of a dam safety management program and satisfying dam safety condition 1.

Version	Date	Comment
		• Revision of guidance on technical review, deficiencies and project procurement. • Updates to templates and department titles.
3.1	August 2024	Minor amendments to template dam safety conditions.

Disclaimer

Dam owners can be liable for loss or damage caused by the failure of or escape of water from a dam. s364 of the *Water Supply (Safety and Reliability) Act 2008* (Act) states:

‘Nothing in this chapter affects the liability of a dam owner or operator for any loss or damage caused by the failure of a dam or the escape of water from the dam’.

The provisions of the Act will override this guideline in the event of there being any inconsistency between the Act and this guideline.

No responsibility is accepted for actions taken or any losses sustained based on reliance on an interpretation of this guideline to the exclusion of the relevant legislative provisions.

Dam owners and their agents are reminded that they must obtain their own legal and specialist technical and engineering advice about whether their actions will meet the requirements of the relevant legislation and are appropriate in their particular circumstances.

This guideline contains extensive checklists and matters to consider as part of a dam safety management program. There is a risk that these checklists are incomplete, as there may be other issues to consider that may be unique to a particular dam.

It is the responsibility of each dam owner to consider whether there are any matters beyond those contained in this guideline which may be of relevance to their dam.

Glossary

Term (Abbreviation)	Description
Acceptable Flood Capacity (AFC)	The flood event the dam spillway must have the capacity to pass without causing failure of the dam. AFC is derived from the PAR and failure consequence category using methods described in RDMW (2023a). AFC is often expressed as a flood with a specific annual exceedance probability (AEP). AFC has particular relevance to standards-based assessments when flooding as a cause of failure is considered in isolation. A risk-based assessment of a dam does not consider AFC nor flood capacity expressed as a percentage of AFC.
Act	*Water Supply (Safety and Reliability) Act 2008*[10]
ANCOLD	The Australian National Committee on Large Dams Incorporated (ANCOLD Inc.) is an incorporated voluntary association of organisations and individual professionals with an interest in dams in Australia. ANCOLD was formed in 1937 as the Australian national committee of the International Commission on Large Dams (ICOLD), a non-government organisation established in 1928, and is one of 100 member countries. ANCOLD's mission is to be the industry body, representing its Members and Associates, disseminating knowledge, developing capability and providing guidance in achieving excellence for all aspects of dam engineering, management and associated issues. Amongst other things, this organisation publishes guidelines that are often adopted by states for dam engineering. Refer to the ANCOLD website.
Bywash	See spillway.
Catchment	A catchment is an area where water is collected by the natural landscape to a surface location or storage.
Category 1 failure impact rating	Has the same meaning as in the Act. A category of referable dam under the Act that has been determined to have a population at risk of 2 or more persons but not more than 100 persons.
Category 2 failure impact rating	Has the same meaning as in the Act. A category of referable dam under the Act that has been determined to have a population at risk greater than 100 persons.
Certification	See RPEQ.
Chief executive	The chief executive of the department responsible for administering the provisions of the Act relating to referable dams. Sometimes referred to as the 'dam safety regulator' of Queensland. Reference to the chief executive includes reference to delegates under the Act.

[10] https://www.legislation.qld.gov.au/view/pdf/inforce/current/act-2008-034

Term (Abbreviation)	Description
Consequence Category	The 'Consequence Category' approach (which is consistent with ANCOLD 2012) quantitatively identifies the severity of dam failure consequences including life safety, damage to property and infrastructure, economic, health, social and environmental effects. Based on these identified consequences a Consequence Category from 'Very Low' through to 'Extreme' is assigned. See Appendix A.
Dam	Has the same meaning as in the Act. A dam means: • works that include a barrier, whether permanent or temporary, that does or could impound water; and • the storage area created by the works The term includes an embankment or other structure that controls the flow of water and is incidental to works mentioned above (these are often referred to as 'associated works' and can include features that influence dam safety). The term does not include the following: • a rainwater tank • a water tank constructed of steel or concrete or a combination of steel and concrete • a water tank constructed of fibreglass, plastic or similar material See the definition of 'referable dam' for further exclusions relevant to referable dams under the legislation and to FIA.
Dam crest flood (DCF)	The flood event that causes reservoir levels to reach the lowest point of non-overflow section of a dam.
Dam operator	The person/s or organisation responsible for the operation of a dam and works associated with the dam.
Dam owner	Has the same meaning as in the Act. An owner of a dam is the owner of land on which the dam is constructed or is to be constructed. Such an owner is any of the following, and includes the occupier of the land: • The registered proprietor of the land (relevant for freehold land). • The lessee or licensee under the *Land Act 1994* of the land (relevant for non-freehold land that is, State land). • The holder of a mineral development licence or mining lease under the *Mineral Resources Act 1989.* • The person or body of persons who for the time being, has lawful control of the land, on trust or otherwise. • The person who is entitled to receive rents and profits of the land.
Dam project	Works on an existing or new dam, including stages of specification, investigation (including safety review or safety assessment), design, construction, remedial works and decommissioning.
Dam Safety Condition (DSC)	Conditions applied by the chief executive to a referable dam that the referable dam owner must comply with to ensure a suitable dam safety management program is applied. A set of DSC are applied according to the consequences of dam failure, the characteristics of the dam and particular issues identified at the dam.

Term (Abbreviation)	Description
Dam safety management program	A dam safety management program is a systematic approach to managing dam safety including the required organisational structures, accountabilities, policies and procedures. It is the primary means of ensuring that dam failure risks are managed throughout the life cycle of the dam including design, construction, operation, maintenance and decommissioning. See Section 3.1.
Deficiency	See Section 3.10.
Decommissioning	Removal or modification of a dam in order to remove the risk of dam failure. It is usually undertaken when a dam is no longer needed, or it is not practical to remedy deficiencies.
Department (or DRDMW or RDMW)	Department of Regional Development Manufacturing and Water. Previously responsible departments were: • Department of Natural Resources Mines and Energy (DNRME) • Department of Energy and Water Supply (DEWS) • Department of Environment and Resource Management (DERM) • Department of Natural Resources and Water (NRW) • Department of Natural Resources and Mines (NRM) • Department of Natural Resources, Mines and Water (NRMW)

Development	Under the *Planning Act 2016*, development is any of the following:
	
	• carrying out–
	  ○ building work; or
	  ○ plumbing or drainage work; or
	  ○ operational work; or
	• reconfiguring a lot; or
	• making a material change of use of premises

Development assessment	Assessment of a development application against relevant policies, guidelines and state codes.
Development condition	A condition that a development permit is subject to. When the chief executive of DRDMW accepts a failure impact assessment, DSC may be recommended to be applied as development conditions by the decision maker pursuant to the *Planning Act 2016*. They may also be applied by the chief executive after the development permit has been decided and thereby amend that permit. In either case, the DSC are taken to be conditions attaching to the permit.
Development permit	A development permit is the part of a decision notice for a development application that authorises the carrying out of assessable development to the extent stated in the decision notice.
DSMG	Dam Safety Management Guideline (this document).
DOMM	Detailed Operation and Maintenance Manuals
Emergency action plan (EAP)	Has the same meaning as in the Act. An EAP provides guidance for actions required as a result of any hazardous situations or emergency events occurring at a dam. There is a legislative requirement for all referable dams to have an approved EAP. See RDMW (2023).

Term (Abbreviation)	Description
Failure	Has the same meaning as in the Act. The physical collapse of all or part of a dam, or the uncontrolled release of any of its contents.
Failure impact assessment (FIA)	Has the same meaning as in the Act. An assessment undertaken to determine the consequences of failure of a dam, for the purposes of deciding whether to categorise a dam as a referable dam under the Act. The assessment is described in DNRME (2018).
Failure impact rating (FIR)	Following a failure impact assessment, a category 1 or 2 failure impact rating is allocated depending on the maximum population at risk assessed based on assumption of failure of a dam. Dams with category 1 or 2 failure impact ratings are referable dams under the Act.
First fill	The period between when inflows into a dam commence to when operating levels are reached. The period of first filling of a dam is often associated with elevated risk of dam failure.
Flood of record	For a dam, the highest observed reservoir water level that has occurred since commissioning. Inflow events that surpass the flood of record are often associated with elevated risk of dam failure.
Freeboard	Vertical distance between a stated water level and the top of the non-overflow section of a dam.
FSL	Full supply level; level of the water surface when the water storage is at maximum operating level, when not affected by flood.
Good practice	A practice that has been proven to work well, produce good results and is therefore recommended. It is a successful experience, which has been tested and validated, in the broad sense, which has been repeated and deserves to be shared so that a greater number of people can adopt it. ANCOLD (2022) provides a discussion on “recognised good practice”. Further description also is available in DELWP (2015).
Hydraulic modelling	Hydraulic modelling is a mathematical representation (usually resolved numerically and solved computationally) of a watercourse, which is used to simulate and analyse the watercourse's hydraulic behaviour. Hydraulic modelling can also be conducted using physical models in which a scaled representation of a watercourse is constructed. Physical models tend to be near-scale models of particular structures.
Hydrodynamic modelling	Similar description to hydraulic modelling, considers the time dependent variations in hydraulic behaviour such as the rise and fall of flood flows.
Hydrological modelling	A hydrological model is a simplified, conceptual representation of the watershed and catchment flow sections of the hydrologic cycle. Hydrologic modelling is typically applied to estimate runoff into a water body as a result of rainfall and runoff on a catchment.
ICOLD	International Commission on Large Dams. Refer to the ICOLD website.

Term (Abbreviation)	Description
In-camera	A confidential meeting or "in private" portion of a meeting. Refers to portions of technical review workshops where technical reviewers discuss matters in private without the participation or observance of dam owner, project team or observers.
Incident	An event that does not endanger the integrity of the dam and downstream property or life, but which could, in other circumstances, deteriorate into a serious situation. It can be described as a ‘near miss’.
Independent	Not burdened by the economic, corporate or operational concerns of a dam owner or a dam project, with no financial or other interest in the outcome, and with no real or perceived conflict of interest that hasn’t been declared and accepted.
Inspection	A careful examination of all physical aspects of a dam. See Table 24, Appendix F.
Notice	A written notice provided to the dam owner by the chief executive under the Act.
Operation and maintenance manual	A manual that documents all aspects of operation, maintenance, surveillance and monitoring. It may encompass separate documents such as standing operating procedures (SOP) and detailed operation and maintenance manuals (DOMM). Irrespective of terminology of the documents themselves, the manual is expected to describe the program components, be current, and demonstrate that appropriately trained and experienced personnel can operate and maintain the dam appropriately.
PAR	Population at risk. The number of persons calculated using methodologies described in a failure impact assessment (DNRME, 2018), whose safety will be at risk if the dam or the proposed dam after its construction fails. PAR are persons who are not at risk by a flood event but are at risk when the same flood event is accompanied by a dam failure event, subject to water depth increments and flood hazard thresholds and other criteria and exclusions. Also described as incremental PAR. PAR has the meaning given to population at risk under s346(3) of the Act.
PLL	Probable loss of life (or Potential loss of life). The part of the population at risk (PAR) expected to lose their lives if a dam failure event occurred. PLL is calculated using methodologies described in industry literature including ANCOLD (2012 and 2022).
Probable maximum flood (PMF)	The flood resulting from probable maximum precipitation coupled with catchment conditions that are optimal for generating maximum runoff. It is a hypothetical flood estimate relevant to a specific catchment whose magnitude is such that there is negligible chance of it being exceeded.
Procurement	Procurement is the process to identify, engage and deliver services. For dams, procurement must consider the range of uncertainties, which manifest as risks, and how they are apportioned between parties.

Term (Abbreviation)	Description
Project team	The project team is the entity (or entities) engaged by the dam owner to undertake a dam project. Depending upon stage of project, the project team is responsible for investigation, design, construction, or other associated obligations associated with the delivery of a dam project. The project team solves technical challenges and is responsible for technical delivery and certification.
Referable dam	Has the same meaning as in the Act. A referable dam is one that would, in the event of failure, put a population of two or more people at risk. Referable dams are regulated under the Act for dam safety purposes. The Act defines a referable dam as a dam or proposed dam after its construction, for which: • a failure impact assessment is carried out under the Act and • the assessment states the dam has or the proposed dam after its construction will have a category 1 or 2 failure impact rating and • the chief executive has under the Act, accepted the assessment. A dam also becomes referable when: • the chief executive reasonably believes the dam has a category 1 or 2 failure impact rating and gives a referable dam notice (RDN) under the Act to the owner and • the owner does not submit a failure impact assessment disputing the RDN within the time specified in that RDN. The following cannot be considered to be a referable dam: • a dam containing or proposed dam that after its construction will contain, hazardous waste • a weir, unless the weir has a variable flow control structure on the crest of the weir (noting that a weir typically will not have PAR, see weir definition)
RDN	Referable dam notice Described in s342A of the Act, a referable dam notice (RDN) is given to a dam owner when the chief executive reasonably believes a dam would, if it were failure impact assessed, have a category 1 or category 2 failure impact rating.
Risk	Measure of the probability and severity of an adverse effect to life, health, property or the environment. ICOLD (2005) defines risk as “In the general case, risk is estimated by the combined impact of all triplets of scenario, probability of occurrence and the associated consequence. In the special case, average risk is 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)”.

Term (Abbreviation)	Description
RPEQ	Registered professional engineer of Queensland It is a requirement of the *Professional Engineers Act 2002* that professional engineering services in Queensland—or professional engineering services carried out interstate or overseas for a Queensland-based project—are carried out by a registered professional engineer of Queensland (RPEQ). The only exceptions are if an unregistered person carries out a professional engineering service under the direct supervision of a RPEQ who takes full professional responsibility for the service, or the service is carried out only in accordance with a prescriptive standard. Certification of dam safety works in Queensland typically require engineering services to be undertaken and, therefore, require RPEQ sign-off. See Section 4.3.
Regulator	See chief executive.
Reservoir	An artificial lake, pond or basin for storage, regulation and control of water.
Safety review	An assessment of the integrity of a dam by assessing known and credible failure modes and mechanisms against safe acceptance criteria (engineering standards, dam safety guidelines) or risk management criteria. It considers all previous, as well as the need for further, engineering studies and investigations. See Section 3.9.
Spillway	A weir, channel, conduit, tunnel, gate or other structure designed to permit discharges from the reservoir when storage levels rise above FSL. There can be more than one spillway at a dam (primary, secondary and auxiliary spillways). If the rate of flow is controlled by mechanical means (such as gates) it is considered a controlled spillway. If the geometry of the spillway is the only control, it is considered an uncontrolled spillway. Sometimes called bywash at small embankment dams.
Spillway adequacy	See acceptable flood capacity (AFC).
Standing Operating Procedures (SOP)	The protocols and responsibilities for operation of a system in the dam. Note that SOPs are described as part of the operation and maintenance program.
Storage capacity (or volume)	The volume of water ordinarily stored upstream of a dam during normal operations of that dam. Note that for detention basins, which are typically dry except during inflow events, storage capacity is often described as a storage capacity curve (storage volume vs water level).
Suitably qualified and experienced RPEQ	Section 4.1 provides advice on the capabilities expected of ‘suitably qualified and experienced’ dam safety management personnel beyond RPEQ such as being able to demonstrate competence in the design, construction supervision and surveillance of dams.

Term (Abbreviation)	Description
Technical review	Technical review provides detached advice and scrutiny to a dam project that is unlikely to be influenced by the time and commercial constraints under which owner and project team usually operate. Technical review should commence early and continue throughout the life of a project. Matters for review should include but may not be limited to regulatory, safety and operational requirements, the principal components of the dam and its critical design parameters. See Section 4.5.
Testing	Testing and sampling procedures to confirm critical design parameters.
Weir	Has the same meaning as in the Act. A barrier constructed across a watercourse, below the banks of the watercourse, that hinders or obstructs the flow of water in the watercourse. Weirs typically do not cause a substantial difference in water level (upstream to downstream) when the water is about to overflow the banks. This means that the weir typically only generates in-bank afflux if it were to fail, so habitable property is not incrementally impacted, there is no PAR, and the structure is not referable. A structure that extends outside the banks of the watercourse, or stores water outside the banks of the watercourse, or causes significant afflux when levels are close to the height of the banks, is unlikely to meet this definition of a weir even though it may be named a weir. There may be circumstances where such a structure does have PAR and is referable. A weir with a variable flow control structure on its crest may require a failure impact assessment. Note that a non-referable structure may still be a public and/or workplace safety hazard, especially if there are itinerant populations downstream (for example recreational water users). Such hazards are the responsibility of the owner of the structure. See failure impact assessment for more information.

1. Introduction

1.1 Dam safety in Queensland

Dams in Queensland fulfil important roles including water supply, hydropower generation, process water management, flood and environmental management and recreation. They provide valuable benefits to their owners and the wider community.

Dams need to be safe[11]. As well as storing water, dams are also storing potential energy that, if released in an uncontrolled manner, can result in loss of life, damage to property and environmental harm.

Dams whose failure would threaten personal safety are regulated by Queensland Government for dam safety purposes; these dams are called 'referable dams' (DNRME 2018).

Referable dam owners need to be committed to dam safety and have an effective dam safety management program, incorporating a culture of dam safety and delivered through day-to-day operations.

A dam safety management program minimises the risks of a dam failing and protects life, property and the environment.

1.2 Purpose

The Queensland dam safety management guideline:

- Is an approved guideline under s572 of the *Water Supply (Safety and Reliability) Act 2008* (Act).
- Describes the components of a dam safety management program.
- Provides advice on how to meet the regulatory responsibilities associated with the ownership of a referable dam in Queensland.
- Clarifies the application of Dam Safety Conditions (DSC) by the chief executive to ensure a suitable dam safety management program is applied under the Act.
- Assists dam owners by describing good practice in dam safety management through the full life of a dam so that risk to life, property and the environment is kept to within tolerable levels.
- Development permit conditions imposed under the provisions of the Act and the *Planning Act 2016* can 'call up' or reference relevant sections of these guidelines as a way of undertaking particular activities.

The dam owner's dam safety management program needs to be comprehensive and thorough to reflect the potentially catastrophic risk being addressed.

1.3 Identification of dam safety requirements

If considering the development or upgrade of a dam, consider the following process for identifying dam safety requirements (Table 2).

[11] The term 'safe' is a familiar one in public discussions. However dams, like any constructed infrastructure, have inherent uncertainties and as such there is always an element of risk to the community. Safe, as used in this guideline, can be considered as meeting a risk that is acceptable to society. RDMW (2023a) provides further guidance.

Table 2 **Dam safety checklist; a process for identification of dam safety requirements**

Step	Dam safety requirement	Reference
1	Is the dam referable and subject to regulation? • Failure impact assessment (FIA) to identify if the dam could threaten the personal safety of two or more persons if it were to fail.	FIA Guidelines (DNRME, 2018)
2	How safe is the dam? • Assessment to identify minimum design standards, especially for spillway capacity.	Safety Assessment Guidelines (RDMW, 2023a)
3	What are the DSC for the dam? • Based on consequence of failure, conditions applied to management of a dam by the chief executive.	Table 1
4	Is each DSC satisfied? • This guideline describes how to satisfy each DSC.	Table 1
5	Does the dam have an approved emergency action plan? • An emergency action plan (EAP) describes the response to a dam safety emergency. • An EAP is to be prepared, submitted and be approved by the chief executive prior to dam construction.	EAP Guidelines (RDMW, 2023)
6	Other dam safety related regulatory requirements? • The Act details those dams which require a flood mitigation manual. Presently there are only three dams with this requirement in Queensland.	Act

1.4 Responsibility for dam safety

Responsibility for the safety of a dam rests with the dam owner.

Dam owners can be liable for loss or damage caused by the failure of, or escape of water from, a dam. s364 of the Act states:

‘Nothing in this chapter affects the liability of a dam owner or operator for any loss or damage caused by the failure of a dam or the escape of water from the dam’.

Life safety risk is the primary concern associated with dam failure. Dam failure can also lead to disruption to community services, extensive economic losses and major environmental damage. A dam failure can have catastrophic consequences from which the owner, and others, may never be able to recover.

An effective dam safety management program reduces dam safety risks to be as low as reasonably practicable and assists the dam owner to comply with its dam safety conditions.

This guideline has been prepared to assist the dam owner to develop an effective dam safety management program to comply with its dam safety conditions. In publishing this guideline the chief executive does not seek to supplant the responsibilities of the dam owner to ensure dam safety risks are tolerable, rather to establish the regulatory framework and process to support and encourage good practice.

The dam safety regulator is considered an informed source of knowledge in dam safety matters and is frequently asked to provide opinion or comment. This is provided within the constraints of the regulator’s resource availability and time and is not intended to replace rigorous technical investigations to support or refute the opinion or comment.

1.5 Other relevant guidelines

1.5.1 Queensland State regulatory guidelines

This guideline only addresses matters relating to dam safety of water dams in Queensland.

This guideline does not address aspects associated with failure impact assessments, safety assessments and emergency action plans. The description, development and approvals associated with a flood mitigation manual are not included in this guideline.

Separate guidelines are available on the department website applicable to water dams developed by the department:

- Queensland Dam Safety Management Guidelines (this guideline)
- Guidelines for Failure Impact Assessment of Water Dams (DNRME, 2018), for establishing if a dam is referable
- Guidelines on Safety Assessments for Referable Dams (RDMW, 2023a), for establishing safety standards for referable dams and timeframes to address intolerable risks
- Emergency Action Plan for Referable Dam Guideline (RDMW, 2023), for the development of an Emergency Action Plan (EAP) for a referable dam

Referable dams are to meet the requirements outlined in the guidelines issued by the chief executive. The guidelines are subject to review to strive to reflect contemporary good practice.

1.5.2 Use of ANCOLD guidelines

ANCOLD is an Australian based voluntary association of organisations and individual professionals with a common technical interest in dams. ANCOLD focuses on disseminating knowledge, developing capability, and providing guidance in achieving excellence for all aspects of dam engineering, dam management, and associated issues.

ANCOLD prepares and issues guidelines that represent good engineering practice. They are widely applied across Australia for large and small water and tailings dams. The department is a member organisation of ANCOLD and actively contributes to the development of many of these practice guidelines.

Queensland's regulatory requirements often reference ANCOLD guidelines as sources for information on suitable practices to achieve dam safety standards. Concepts developed by ANCOLD are adopted in the guidelines, providing a degree of consistency in dam safety management across Australia.

The contents and intent of this guideline generally reflects that of the corresponding ANCOLD guideline: Guidelines on Dam Safety Management (ANCOLD, 2003). While the concepts, principles, contents layout and definitions of this guideline seek to be consistent with ANCOLD (2003) there are differences due to the need to be consistent with specific state legislative purposes and decisions.

A summary of key differences is provided in Table 3.

Table 3 Comparison with ANCOLD guidelines

Aspect	Dam safety management guideline	ANCOLD guidelines (ANCOLD, 2003)
Applicability	Only applicable to water dams in Queensland.	Applicable to all dams and similar structures.
DSEPs (called EAPs in Queensland)	Emergency Action Plans are comprehensively described elsewhere in guidelines and legislation.	Dam Safety Emergency Plans (DSEP) are considered within ANCOLD 2003.
Operation and Maintenance	Described in a single section.	Additional sections on surveillance and monitoring.

Aspect	Dam safety management guideline	ANCOLD guidelines (ANCOLD, 2003)
program (including surveillance and monitoring)		
Technical review	Comprehensive description	Limited description
Additional content	• Recommended skills for dam safety personnel • Project procurement • Change of ownership • Quality assurance • Auditing • Requirement for an annual statement of compliance	Limited description

2. Background

2.1 What is a referable dam?

A dam is referable if it meets the requirements of a referable dam under section 341 of the Act and threatens the personal safety of two or more persons if it were to fail. A referable dam is regulated for dam safety purposes in accordance with the Act.

A description of methodologies to identify a referable dam, including exclusions and legislative considerations, is provided in the Failure Impact Assessment guidelines (DNRME, 2018). This also describes situations when a dam is deemed as referable by the chief executive.

2.2 How is a referable dam regulated?

Currently the responsible regulator is the chief executive of the department.

The regulatory approach applied by the chief executive considers:

- Establishing minimum standards to apply to referable dams through the issue of guidelines, policies and DSC.
- Ensuring that dams with the potential to threaten personal safety in the event of a dam failure are subject to regulation.
- Applying regulatory requirements to referable dams based on the potential level of consequences should they fail.
- Identifying unacceptable risks and targeting of resources and effort so that dam owners address these risks.
- Promoting good practice in dam safety management.

2.3 Responding to changing risks at a dam

There are a range of activities, inspections, investigations, analyses and supporting documentation relating to referable dams that may reveal previously unknown risks or challenge an owner's understanding of the risk position of their dam.

How these risks are identified, investigated and addressed is part of an effective dam safety management program. In this regard, any concerns that there may be a worsening of the risk position of a referable dam may constitute a deficiency and be subject to safety condition DSC10: Deficiencies, incidents and failures (Section 3.10).

Remedial actions to address changes in the risk position of a referable dam may also be subject to safety condition DSC6: Design and Construction (Section 3.6) or safety condition DSC9: Safety Review (Section 3.9). Section 3.10.3 describes circumstances where remedial investigations or studies are subject to safety conditions.

2.4 Standards for asset management and quality assurance

An objective of imposing DSC is to ensure dam owners have an adequate dam safety management program for their referable dam(s) and can demonstrate its effectiveness. DSC, and other legislated dam safety obligations for referable dams in Queensland, can be mapped to the key elements of the ISO55001:2014 asset management standard. Alignment to ISO55001:2014 provides opportunities for dam owners to guide the establishment, implementation, management and continual improvement of their dam safety management program.

The dam safety management program is supported by policies, processes, procedures and documentation that may be subject to a quality assurance system. The ISO9001:2015 standard is often used by dam owners to guide the adequacy of systems used for planning, checking and reviewing their dam safety management program.

2.5 Consequence categories

Consequence categories are used in many jurisdictions as a basis for determining dam safety management requirements such as design criteria and operation, maintenance and surveillance requirements.

A consequence category is derived through a process of collecting information about the consequences of potential dambreak and identifying the severity of these consequences.

The 'Consequence Category' approach (which is consistent with ANCOLD 2012) is a classification of adverse consequences resulting from a dam failure. It quantitatively identifies the severity of dam failure consequences including life safety, damage to property and infrastructure, economic, health, social and environmental effects[12,13]. Based on these identified consequences a Consequence Category from 'Very Low' through to 'Extreme' is assigned:

- Dams with 'Low' or 'Very Low' consequence category have relatively minor regulatory obligations.
- Dams with 'High' or 'Extreme' consequence category are subject to rigorous regulatory obligations.

Appendix A contains further information on Consequence Categories. This in turn informs thresholds for application of DSC, which are described in **Appendix B**.

2.6 The regulator may choose to publish regulatory submissions

On occasions the department receives regulatory submissions which are considered of value to the public or to the dam industry. Examples include reports describing a new or unexpected incident or deficiency at a dam, a response to an emergency event or information which, when collated, provides key insights into dam safety management across the full portfolio of referable dams.

If the department considers a particular regulatory submission to be of public interest, or that dam safety outcomes may be enhanced if that submission were to be made available, then the department may choose to publish a redacted version of the submission.

Prior to publication the department will contact the dam owner to discuss the decision to publish, outline the reasons why the submission is to be published, and share the redacted version intended to be published.

[12] Note that Consequence Category considers a broader range of dam failure consequences compared to a failure impact assessment (DNRME 2018, which only considers the number of PAR).
[13] The Consequence Category is not a measure of chance or likelihood of a dam failing; only consequence (failure is assumed).

3. Dam safety management program components

This section provides a detailed description of the components of dam safety management. References are made to appendices that contain supporting information and checklists. Each component of the program is referenced to a corresponding DSC (Table 1).

3.1 DSC1: The dam safety management program

A dam safety management program is a systematic approach to managing dam safety including the required organisational structures, accountabilities, policies and procedures. It is the primary means of ensuring that dam failure risks to life, property, the environment, and public welfare are managed throughout the life cycle of the dam, which includes design, construction, operation, maintenance and decommissioning.

A dam safety management program provides a structured approach for the development, coordination and control of activities undertaken to ensure that these dam failure risks are reduced so far as is reasonably practicable. The dam safety management program should align the dam failure risk management activities with the dam owner's organisational objectives.

An effective dam safety management program incorporates components listed in Table 4. Elements relevant to all other DSC (Sections 3.2 onwards) and obligations in the Act (Section 5) represent additional components of an effective dam safety management program. See Section 2.4 for supporting background discussion.

Table 4 Components of a dam safety management program

Aspect of dam safety management	Dam Safety management program component
Context of the organisation	☐ A quality system, appropriate to the size and complexity of the dam (or the portfolio of dams), to support dam safety across the organisation. ☐ Consideration and incorporation of dam safety, where appropriate, into objectives, plans and processes across the organisation. ☐ The legal and regulatory obligations with respect to dam safety are considered and incorporated into the quality system to support relevant personnel's awareness of requirements and enable the organisation to maintain compliance. ☐ Awareness of the potential impact the dam (or the portfolio of dams) has on the community in terms of life safety risk is promoted throughout the organisation.
Leadership	☐ A governance framework, appropriate to the size and complexity of the organisation, to ensure relevant oversight of dam safety activities. ☐ A commitment to achieving good practice dam safety management by setting clear objectives, allocating adequate budget and appropriate resources and applying dam safety related decision-making criteria. ☐ Documented roles and responsibilities for personnel with a role in dam safety, including the identification of skills, training and qualifications required.
Planning (and risk management)	☐ Documented dam safety objectives and a schedule of key dam safety activities. ☐ A documented risk framework and register, appropriate to the size and complexity of the dam (or the portfolio of dams), which considers dam safety. This should include a description of how the risk framework is used to

Aspect of dam safety management	Dam Safety management program component
	trigger dam safety actions (such as conducting further investigations, commissioning upgrade works, emergency response, etc).
Support	☐ There is a documented description of skills, training and qualifications required for roles in dam safety, supported by a justification that there are sufficient resources to support dam safety, evidence of a training program and consideration of succession planning (see also Section 4.1 and 4.2).
Delivery	☐ Any matters that are required to support operation, maintenance and emergency response. ☐ Any matters that are required to support capital works programs (including criteria, processes, controls, monitoring and performance evaluation).
Performance evaluation	☐ Any matters that are required to support surveillance, monitoring. ☐ A review and/or audit process, appropriate to the size and complexity of the dam owner's organisation, to evaluate: ☐ the appropriateness of documented processes to satisfy legal and regulatory obligations and organisational requirements. ☐ the application of and adherence to those documented processes.
Improvement	☐ Any matters that are required to support incident reporting. ☐ Corrective actions and improvements are incorporated, where necessary, as a result of the review and/or audit process.

3.2 DSC2: Documentation

Appropriately managed documentation provides proof that dam safety management program components are in place and being adhered to. For the purposes of regulation, any documentation prepared in order to comply with the DSC must be securely stored and be made available to the chief executive if required.

- The level and extent of the documentation required depends on the size, consequence category and risk status of the dam.
- Documentation preparation and requirements for program components are detailed in following sub-headings of this section.
- All documents should be retained by the dam owner until such time that the dam is decommissioned.
- Should a change of ownership of a dam occur, all relevant information is to be transferred to the new owner (see Section 4.7 and s366 of the Act).

It is important to maintain careful record keeping and preservation of all dam information:

- Dam information should be filed and managed in a way that it is secure and can be easily located by future users at short notice.
- Dam information should be appropriately backed up and stored, with multiple backup redundancies.
- Dam owners should securely store all documents associated with the dam and ensure they are readily available for reference, inspection and auditing purposes.
- A robust information management system (see also Section 2.4) safeguards an owner against the risks of institutional knowledge being lost through staff turnover. Activities that are planned using reliable knowledge and good records could save the owner considerable time and money. For example, when investigating a dam safety deficiency, historic records may avoid the need for intrusive and unnecessarily costly dam investigations.

3.3 DSC3: Data book

A data book is an organised, planned and maintained collation of information that provides:

- A history of dam performance, preserving historical design, construction, dam surveillance and dam inspection information for future engineering investigations
- Supports the operation and maintenance plan (including surveillance and monitoring)
- Provides evidence of compliance with DSC, informed by the dam safety management guidelines
- Contains or references relevant documentation including as-constructed drawings, etc

It can be a hardcopy book, a digital repository or other organised and controlled record. It includes a table of contents, index or similar that enables easy navigation.

The data book is updated as new information becomes available such as additional investigations, inspections outcomes, design reviews, risk assessments, remedial works, dam incidents and notable events.

A checklist of the data book contents is provided in **Appendix C**.

3.4 DSC4: Annual statement of compliance (wet season preparedness)

DSC require a dam owner to provide an annual statement of compliance on the safety status, management practices and implementation of the DSC of the dam by 1 October of each year. This aligns with wet season preparedness and the annual review of the EAP (see RDMW, 2023 and s352P of the *Act*).

The statement of compliance is an opportunity to check the components of the dam safety management program to ensure the dam is safe and in good working order for the upcoming wet season. Any lessons learnt from previous events, training exercises etc should also be considered and incorporated into the program if appropriate.

Appendix H contains a template for submission of an annual statement of compliance and EAP review. Note that the dam safety regulator normally issues a reminder prior to 1 October of each year that contains a similar submission template.

For dam owners with a dam portfolio a single submission of statement of compliance for all dams may be appropriate.

Further information is available in the EAP Guidelines (RDMW, 2023).

3.5 DSC5: Safety assessments and addressing intolerable risks

RDMW (2023a) describes the process to establish minimum dam safety standards for referable dams, including timeframes for addressing intolerable risks.

3.6 DSC6: Design and construction (including investigation, commissioning and decommissioning)[14]

Investigation, design and construction phases influence safety over the life of the dam. The standards to which a dam is designed and constructed should suitably reflect the consequences of dam failure, the characteristics of the site, suitable materials and construction practices and the loading conditions applicable to the site.

Relevant dam safety issues that a dam owner should consider include:

[14] Note that some of the more detailed considerations described in this section may only be fully applicable to large and more complex dams.

- The investigation, design and construction of dams requires suitably qualified and experienced personnel who are familiar with principles, technical guidelines, articles and manuals relevant to the type of dam and their role. See Section 4.1.
- Ensuring that adequate resources are allocated to address technical issues, manage the dam in a safe manner and meet dam safety regulatory requirements.
- Knowing the consequences of dam failure and the failure impact rating of the dam.
- Other relevant issues, irrespective of whether they have specific dam safety implications, including:
    - environmental impacts
    - the economic viability of the dam
    - long-term operational maintenance management implications
    - community impacts

3.6.1 Investigation

It is important that investigation programs are properly resourced, planned and managed to address all unknowns that could affect dam safety:

- No two dams are the same. Each has a unique set of hydrological, topographical, geological, geotechnical and environmental characteristics.
- Dam engineering is not an exact science; it frequently involves uncertainties beyond prevailing knowledge and relies heavily on mathematical principles, physical laws, experienced judgement and known safe practices.
- Many historical dam failures have been attributed to a lack of understanding of flood intensities and how site conditions change following dam construction and reservoir formation. These two aspects, hydrology and geology, are particularly critical for dam safety.
- The more that is known about site conditions and foundation materials, the less conservative a design needs to be. Any uncertainties should be addressed through further investigation where practicable. This should result in a better understanding and apportionment of project risks and lower costs.

All investigation work needs to be properly recorded, including interpretations of the work completed.

Documentation describing investigations must be retained (Section 3.2).

ANCOLD (2020) provides further guidance.

3.6.1.1 Geological and geotechnical investigations

Geological and geotechnical investigations of the site and foundation material can range from a broad scoping level to localised and detailed investigations. Investigations should:

- Be thoroughly planned to ensure that all matters that may affect dam safety are identified, investigated, documented and appropriately resolved.
- Identify any potential difficulties with the site, such as existing signs of slope instability, adversely orientated joints, weak foundation materials extending beyond the depths of the completed fieldwork, the presence of potentially liquefiable materials, open joints, foundations discontinuities, etc.
- Not be limited to the dam site alone; the geology, topography and depth of water held in the storage area should be considered to ensure that major leakages, slope instabilities and significant reservoir-induced seismic activities that could compromise the safety of the dam are considered in the design.
- Identify the sources and suitability of construction materials for a new/upgraded dam.
- Generally be ongoing through the construction period as the foundations become fully exposed, or the extent of any foundation work such as grouting, is required.
- Be compliant to relevant Australian standards.
- Samples and analyses should be securely stored for future use and reference.

Staged investigations are typically carried out, with progressively more detail investigated at each successive stage subject to the outcomes of the previous stage.

Locations of all test pits and drill holes should be accurately recorded and shown on construction plans. They should be permanently sealed / rehabilitated either as part of the investigation program or during construction.

Investigative reports need to be updated and amended as construction proceeds. When construction is complete, a full and comprehensive report provides a reference for ongoing surveillance of the dam and future safety reviews.

3.6.1.2 Hydrological investigations

Hydrological investigations relate to the analysis of rainfall and runoff in order to establish the likelihood of extreme discharge events at a dam. The investigations are often challenged by the rarity of occurrence of extreme flooding at a dam site and subsequent lack of reliable historical information.

Hydrological investigations typically involve:

- Establishing ambient extreme rainfall conditions in the catchment.
- Developing an appropriate rainfall-runoff model to estimate catchment inflows.
- Calibration of the model with historical flood data where possible.
- Using the model, develop design flood events across a range of probabilities for use in the design process.

Due to the inherent uncertainties associated with the hydrology of extreme flood events the following should be considered:

- Application of stochastic methods to better understand the variability of predictions
- Sensitivity testing to better understand how model parameter selection influences predictions
- Comparisons to any information associated with extreme rainfall and runoff outside the dam site catchment
- Paleo-climatic evidence
- Comparisons to theoretical limits of rainfall
- Scientific literature
- When dealing with uncertainty and in the absence of detailed or reliable information, conservatism in approach is recommended. In particular:
    - Assume FSL at the start of a flood event unless there is a compelling and justifiable alternative.
    - Consider future climate conditions (see also discussion in RDMW 2023a).

3.6.1.3 Hydraulic investigations

Design should give proper consideration to the erosive force of water and the capacity of the riverbed to withstand such force. This may include testing and simulation using computational (i.e. computational fluid dynamics, or CFD modelling) and hydraulic modelling (i.e. physical modelling at appropriate scale), as well as geotechnical investigations (and the interaction between those disciplines).

3.6.2 Design

The design of a dam generally seeks to achieve optimal physical arrangements for the various components of a dam to achieve safety, suitability of purpose, reliability and usability. All designs must include a thorough evaluation of dam safety risks and the measures to control them, with a focus on providing affordable and resilient backup features and systems to support primary features and systems.

RDMW (2023a) describes the process to establish minimum dam safety standards for referable dams.

Section 4.5 describes technical review for a dam design.

Resources associated with dam design should have relevant capabilities and skills, see Section 4.1.

Dam design should consider key elements listed in Table 5.

Table 5 Key elements to consider in dam design

Category	Checks
Compliance with good practice	All dam structures must be designed to suit the loads to be applied to them in accordance with: • Departmental and ANCOLD guidelines • any other relevant Australian Standards • compliance and information notices issued by the chief executive • accepted contemporary engineering practices • adequate technical review
Physical characteristics	• dam type • location and alignment • size and shape • additional works
Geology and geotechnical information	• material properties and availability • foundation properties and treatment (to support dam structure and control seepage) • regional and site geological characteristics understood, models developed
Hydraulic aspects	• AFC and/or DCF • type of spillway, means of flow control, and energy dissipation • design of scour resistance for discharge channels • hydrological characteristics • hydraulic design and water loadings • stream diversion requirements • flood mitigation capacity
Seepage	• controlled from dam (including filters, drains and pressure relief wells) • controlled from reservoir basin and rim
Outlet works[15]	• Outlet capacity for environmental and other discharge requirements • Provision for safe operation and maintenance • Reservoir lowering during a dam safety emergency
Stability	• structural capacity of principle elements • ability to withstand flood loadings • ability to withstand seismic loadings
Testing	• Testing program to ensure design parameters are achieved during construction (see also Table 6)
Construction methods and sequencing	• including watercourse diversion requirements during construction • earthworks and foundation/abutments works • filters and drains • conduits • tendons and post-tensioning • construction materials meet site and design requirements • ongoing operations during works on existing dam

[15] And inlet works for offstream storages.

Category	Checks
	• dam safety during construction, including flood warning and emergency response and sequencing to minimise flood risks • workplace safety during construction
Operational aspects	• operational complexity and reliability • requirements for ongoing surveillance and monitoring • technical capability and availability of operations personnel • emergency management
Mechanical and electrical	• essential equipment and systems have adequate backup • gates and valves
Environmental aspects	• fish passage and the implications of this to the outlet works design and arrangement • environmental impacts including the effects of storage and barriers • effect on upstream and downstream areas • magnitude of downstream releases
Surveillance	• inspection and approval of foundation treatment prior to placing of dam materials • long-term monitoring and instrumentation

3.6.3 Construction

During the various phases of dam construction the following dam safety aspects should be considered:

Table 6 Aspects of construction relevant to dam safety

Construction phase	Aspects relevant to dam safety
Planning and programming	• Appropriate management plans developed and implemented • Allocation of appropriate on-site staff / resources • Consideration of changing dam safety risk during construction activities • Quality control and technical review • Scheduling and sequencing of construction activities • Important hold points clearly defined and subject to inspection and review • Reporting and documentation
Emergency management	• A clear understanding of potential hazards during construction • A forecast tool to predict the likelihood and timings leading up to a hazard occurring at a dam • Clear escalation triggers to ‘make good the site’
Communication	• Communication and coordination between design and construction personnel, both on-site and off-site, are essential for quality control. This helps ensure that construction personnel are aware of the design intent, new field information acquired during construction is documented and incorporated into the design, design assumptions are confirmed and the dam is constructed according to the design intent.
Inspections	• Foundation inspection to thoroughly identify and document all the characteristics of the foundations of a dam. Once the

Construction phase	Aspects relevant to dam safety
	foundations have been fully exposed and prepared there may be a need to amend the design requirements. • Inspections by the designer (not just the construction manager) are necessary to confirm any amendments. If unanticipated conditions, such as geological features, are encountered, the designer must be involved in determining appropriate design changes. • Certification of inspection of construction activities, for example at critical milestones or if assumptions associated with critical design parameters change, should be considered to ensure that design intent is met. Certification should be undertaken by the designer, providing confidence the intent of design is maintained. A construction inspection schedule should be clearly outlined in the construction specification prepared as part of the design report. See Section 4.3.
Testing	• The materials used to construct a dam and the dam as-built should be subjected to inspection and physical testing to confirm the values adopted for critical design parameters. Testing and sampling procedures to confirm other critical design parameters should also be considered. • Those responsible for the dam's design and construction should organise and oversee such testing and systematically record their findings. • Quality control, sampling and testing should be in accordance with relevant standards and guidelines, and outlined in construction specifications, such that it provides confidence that the parameters used for design will be met. • Special consideration should be given when innovative techniques or materials are to be used, such as testing prior to installation.
Design review	• If site conditions change as construction proceeds, changes to design may be required. Access to, or engagement with, the dam design team can optimise the necessary adjustments.
Technical review	• Consideration of technical review during construction
Skills	• See Section 4.1.

3.6.4 Commissioning and first fill

A commissioning schedule is to be put in place before the dam is brought into full operation. The dam designer should be involved throughout the commissioning process to ensure that the performance of the dam and its appurtenant structures are consistent with the design philosophy and intent.

The commissioning schedule includes procedures and practices, surveillance programs, operation and maintenance manuals and any design and construction reports completed before, during, and after the construction of the dam.

The period of first filling of a dam is often associated with elevated risk of dam failure. It is therefore important that specific monitoring and/or special inspections be considered.

It is important that commissioning procedures are appropriate to the dam and enable the designer, and later the dam owner, to regularly monitor its performance during and following reservoir filling.

Complex or high consequence dam projects may benefit from a clear plan for first fill to (say) FSL and then subsequent filling subject to surveillance and inspection.

3.6.5 Decommissioning

When a dam is no longer needed, or is not practical to remedy deficiencies, the dam owner may decommission the dam. From a dam safety perspective the intent of decommissioning is to ensure that there is no remaining PAR.

For referable dam decommissioning a plan is required to be prepared and submitted to the regulator in accordance with dam safety conditions (those associated with conducting remedial works and decommissioning).

Decommissioning a dam requires significant parts of the dam structure to be removed or modified to make it incapable of storing water; either temporarily or permanently.

Before decommissioning, a dam safety decommissioning plan is prepared that outlines proposed actions, including:

- A time sequence of studies and works associated with the decommissioning
- A description of how all dam safety issues associated with the decommissioning are addressed, including:
    - provision for safe release of stored water
    - provision for treatment and safe disposal of any resulting silt or contaminated soil
    - demonstration that any failure of remaining dam sections do not present a risk to public safety
    - assessment of altered hydraulic character of spillways and streams
    - provision for consultation with downstream residents and landholders
    - provision to minimise impact on downstream residents

In addition to dam safety issues, there are numerous environmental, economic, and social issues to be considered. The owner should research any associated requirements when planning the decommissioning, particularly to ensure sustainable, minimally erosive storage basin conditions prior to dam removal. The owner should also identify and inform all appropriate authorities.

3.6.6 Reporting

Reporting encompasses documentation of all phases, provided at key milestones, of a dam project.

Irrespective of terminology of the documents themselves, reporting is expected to describe project design and construction and demonstrate that the final works have been completed in accordance with the design intent.

The DSC describe a design report for the proposed works (where works refers to the dam project) and an as-constructed report.

- A design report for the proposed works is initially compiled prior to any construction.
- The as-constructed report is compiled following completion of construction. This report describes any design amendments made during construction or references an updated design report.

The reporting includes (or refers to documents prepared earlier that includes):

- Design report
    - Drawings
    - Summary of principal data
    - Hydrological and hydraulic data and analyses
    - Spillway hydraulics
    - Foundation conditions and treatment
    - Properties of construction materials
    - Testing
    - Embankment design and stability analyses
    - Stress and stability analysis of concrete structures and other structural components
    - Instrumentation
    - Construction specifications
    - Technical review

- Certification

- As-constructed report
  - Reference to design report contents and any amendments
  - Construction documentation
  - As-constructed drawings
  - Technical review
  - Certification

Interim reports may include a sub-set of these contents. **Appendix D** provides a checklist.

Section 4.3 provides further information on certification obligations.

3.7 DSC7: Operation and maintenance (including surveillance and monitoring)

3.7.1 Operation and maintenance

Proper operation and maintenance is essential for the continued viability and safety of a dam and its associated structures over the life of the dam. Appropriate operation and maintenance reduces dam safety risks through avoidance of:

- activities are not undertaken inappropriately or in an unsafe manner
- 'out of date' procedures being applied
- problems not being addressed because dam safety inspections are not performed or are not carried out by appropriate people
- critical equipment not being checked, then not being operational when needed
- poor maintenance that can result in abnormal deterioration of the dam, reduced life expectancy of the dam and increased risk of dam failure
- failure to open gated spillways at the appropriate time, which can cause overtopping of the gates and subsequent failure of the dam
- failure to close gated spillways or outlet works which may empty a reservoir
- poorly trained operations and maintenance personnel

An operation and maintenance manual is to include:

- A description of protocols and responsibilities for operation of a system in the dam (e.g. water releases by outlet works or gate operations). These are beneficial to dam owners because they provide information on procedures for a dam, which in turn helps to ensure:
  - Long-term adherence to operating procedures and across changes in ownership and operating personnel.
  - Tasks are completed in a safe, correct and repeatable manner by providing operating protocols for personnel to follow.

- Detailed instructions on how and when (including frequencies) to operate and maintain individual pieces of equipment for a dam and its associated structures (e.g. valves and motors for gates). Also a description that identifies the location of all equipment.
  - Operations and maintenance conducted in accordance with detailed instructions ensure that equipment and instrumentation is operated and maintained in a correct and appropriate manner, and critical equipment is regularly tested. Equipment operated incorrectly can adversely affect the primary function of the dam and its value.
  - Instructions should reflect operating complexity, location of the dam and distribution of responsibilities between maintenance and operational personnel.

- The recording and work assignment system that is capable of issuing and tracking work orders issued to operational staff and others (such as external contractors), then recording the outcomes.

- This system plays an important role in verifying work undertaken on the dam for dam safety purposes.
- Work orders can originate from the requirements of the operation and maintenance program.
- A separate maintenance management system may exist with the dam owner's organisation for this purpose.

- The above points supporting effective surveillance and monitoring activities (including physical engineering inspections described in Section 3.8).

The manual should be available prior to the first filling of the reservoir.

Referable dams also require an emergency action plan (EAP) in place that describe operations at the dam during an emergency. For dams requiring a prescribed flood mitigation manual (FMM), the FMM describes gate operations during flood events. See Sections 5 and 4.9.

Appendix E provides further information on issues to consider when developing a procedure, a contents checklist and discussion on level of attendance.

3.7.2 Key elements of surveillance and monitoring

Surveillance is the ongoing examination of the physical condition and operation of a dam. The routine monitoring of existing dams and reacting quickly to inadequate performance or danger signals are critical aspects for dam safety. Careful routine monitoring and quick response can prevent failures, including those caused by poor construction.

Surveillance programs must be capable of detecting problems or unsafe conditions at an early stage so that timely and effective corrective measures can be applied and safety of the dam is not compromised. Note that the complexity required for these processes depends on the dam.

Key elements of a surveillance program are listed in Table 7. The following sections provide additional details of the core components of the program:

- Physical inspections, from routine inspections by operational staff (described in this section and Table 24, **Appendix F**) through to comprehensive inspections by engineers (engineering inspections, Section 3.8)
- Collection and monitoring of dam instrumentation (monitoring, Section 3.7.3)
- Evaluation and interpretation of the data (surveillance evaluation, Section 3.7.4)

Table 7 Key elements of a surveillance program

Element	Description
Objectives	• Provide a baseline of performance information against which future changes in performance can be assessed • Identify any unusual behaviour, regardless of how insignificant, because this may be the forewarning of a newly developing unsafe condition • Initiate the evaluation of dam safety concerns arising from visual or measured / instrumented surveillance • Adapt the level of surveillance in response to changing conditions and circumstances (i.e. seasonal, operational, time or event based changes)

Nature and extent	• Each dam has its own surveillance program that is appropriate to:
	  • The type of dam, its size and complexity, and storage capacity
	  • The PAR and other potential consequences of dam failure
	  • The level of risk associated with the dam
	  • The value of the dam to the owner

Element	Description
	• More intensive surveillance may be required during and after an event (such flood or earthquake), when a potential dam safety deficiency exists or during first filling. • Generally, larger and more complex structures with unique design features require more detailed and comprehensive surveillance programs. • The surveillance program should be planned during the design and construction phases and in response to emergent problems. • Suitably qualified and experienced personnel should be consulted on the nature and extent of suitable surveillance programs.
Processes and procedures	• Surveillance processes and procedures should be well defined and functional and involve competent trained personnel. • Documentation should be controlled and readily available to, and understood by, those responsible for the implementation of surveillance activities.
Commencement	• To obtain a historical context for defects, surveillance should commence as early as possible in the life of the dam to detect the development of any problem or unsafe trends and provide full background information on a dam's performance.

3.7.3 Monitoring

Monitoring is the collection, presentation, and evaluation of information from measuring devices installed at or near dams. Key elements are described in **Appendix G**.

3.7.4 Surveillance evaluation

Surveillance evaluation is an assessment of the safety of a dam, in terms of its condition and operation, based on data obtained from on-site dam safety inspections and monitoring. Evaluation is an important step where decisions are made affecting the safety and operation of a dam.

Dam owners should ensure that the system used to collect and process the monitoring data has the capability to detect the occurrence of 'obviously different' data, which can be caused by:

- data recording and transfer errors
- instrumentation malfunction
- abnormal behaviour of the dam

These situations should be investigated immediately. If the change is attributed to abnormal behaviour, the owner should initiate further investigations to explain the abnormality and ensure that it does not indicate a worsening dam safety situation. Such abnormalities can be a trigger for remedial action and/or activation of an emergency action plan.

Surveillance evaluation is typically conducted as part of an annual or comprehensive dam safety inspection, although evaluation may be undertaken at more frequent intervals or at times of concern. Evaluation should be conducted by a suitably qualified and experienced RPEQ.

As part of the surveillance process there should be an established procedure for the follow-up and resolution of unmanageable observations or situations, whether confirmed or unconfirmed. This may include actions to be taken when alert thresholds are exceeded or when an abnormal or extraordinary loading condition is experienced. The procedure should clearly identify the escalation process so that issues can be dealt with appropriately as soon as possible.

Further guidance on surveillance evaluation is provided in ANCOLD (2003).

3.7.5 Documentation

The operation and maintenance manual documents all aspects of operation, maintenance, surveillance and monitoring. It may encompass separate documents such as standing operating procedures (SOPs) and detailed operation and maintenance manuals (DOMM).

Irrespective of terminology of the documents themselves, the manual is expected to describe the program components, be up to date, and demonstrate that appropriately trained and experienced personnel can operate and maintain the dam appropriately.

Appendix E provides a contents checklist.

3.8 DSC8: Engineering inspections

An important activity in a dam safety management program is the frequent and regular inspection for abnormalities in conditions and for deterioration of the dam. Early detection of unsafe conditions can prevent failure of a dam.

Three types of inspections can be considered:

1. Routine inspections[16], typically conducted daily / weekly by dam operators as part of their duties
2. Annual inspections, conducted by a suitably qualified and experienced RPEQ
3. Comprehensive inspections, which incorporates the annual inspection for that particular year, is conducted at least every five years by a suitably qualified and experienced RPEQ and, where appropriate, additional technical specialists

Components and requirements are summarised in **Appendix F** (Table 24). Appendix F also provides further information on each type of inspection as well as reporting requirements.

Annual and comprehensive engineering inspections are part of the DSC (Table 1). Routine inspections are informed by the operation and maintenance manual.

In addition, special inspections may be necessary when a possible deficiency at the dam is identified or the dam has been through abnormal loading conditions (including first fill or following a flood of record). These are often carried out urgently and may only address specific features of the dam.

The regulator is to be invited, with adequate notice, to attend dam inspections.

3.8.1 Independence of personnel conducting inspections

There are a number of considerations to using personnel independent of the dam owner's organisation to conduct inspections:

- A fresh set of eyes to inspect a dam may reveal previously unidentified concerns
- Perceptions of bias or conflict of interest is avoided when using independent personnel
- A skilled engineer who does inspections across multiple dams may be available both internally and externally depending upon the dam owner's organisation
- The skill of conducting the inspection remains with the dam owner, which reduces risks if an emergency were to occur, if conducted internally
- Costs to undertake inspections

The dam owner should take these issues into account when deciding who should conduct inspections.

3.9 DSC9: Safety review

3.9.1 Approach

The safety standard of a dam can become deficient over time, or be identified to be deficient over time, due to:

[16] Note that routine inspections are visual surveillance and not necessarily an engineering inspection.

- changes to consequence category resulting from downstream development
- changes to safety standards
- advances in knowledge and analysis techniques (for example the methods of assessing design flood events)
- identification of latent conditions not previously recognised
- deterioration of dam materials, including foundations
- changes in dam management practices
- other developments, such as a new dam upstream or downstream development, that may influence the adequacy of the dam

It is therefore necessary to periodically demonstrate adequate dam safety.

A safety review is a procedure for systematically assessing the safety of a dam after its original construction. It is a fresh engineering assessment of all elements. It typically incorporates:

- Collection of background information
    - review of historical operational performance
    - review of surveillance reports
    - consideration of the need for additional investigations
- Comprehensive inspection
    - see Section 3.8
- Review and update of design, construction and operation
    - review of failure impact assessment consequence[17]
    - review of loads and credible failure modes
    - detailed review of all structural, hydraulic, hydrologic and geotechnical design aspects against current practices[18]
    - consideration of the need for additional analyses
- Comparison of dam performance to current dam safety criteria
    - using standards and/or risk-based methodologies (further described in RDMW 2023a)

The level of sophistication of safety review varies depending on the characteristics and complexity of the dam, the magnitude of any potential deficiencies and their consequences and currency of available knowledge of the dam.

Many matters considered as part of dam design and construction are considered applicable to a safety review (Section 3.6).

Technical review of a safety review must occur (Section 4.5).

The safety review of a dam can be complex and often requires a team of experts. Resources associated with the review should have relevant capabilities and skills, see Section 4.1.

Section 4.3 provides further information on certification obligations for safety review.

3.9.2 Frequency of review

Frequency of safety review is specified in the DSC (Table 1). This is typically a maximum 20-year interval, but note that ANCOLD (2003) suggests 10-to-20-year intervals are considered appropriate.

[17] Particular attention should be given to changes in land use that may have occurred since construction of the dam that may affect the hazard that the dam poses. Changes to consider include mining, urbanisation and clearing of the catchment area both upstream and downstream of the dam.

[18] Adopted design assumptions and standards must be reviewed and compared with current good practice, for example:

- Foundation integrity (bearing, seepage) applied must be reviewed and compared with current good practice
- Spillway design must be reviewed and compared with current accepted engineering standards
- Embankment and outlet structures must be reviewed and checked they can withstand appropriate loadings (including seismic) in accordance with current engineering good practice
- Filtering effectiveness for preventing piping must be reviewed against modern accepted criteria

A safety review may also be initiated in response to issues such as:

- an absence of design and construction documentation
- a regulatory requirement
- detection of abnormal behaviour or incident
- changes in acceptable design and construction standards
- proposals to raise or modify a dam
- changes in standing operating procedures
- a change in consequence category may require a safety review to be conducted

Investigations and design analyses supporting a major dam upgrade project can be considered a safety review. The dam owner should confirm with the regulator that the extent of investigations and analyses suffice as a safety review.

3.9.3 Reporting

A report must be produced to document the safety review. Contents should include (see also Appendix D, noting that safety review reporting is similar to design reporting):

Table 8 Contents of safety review report

Section	Description
Statement of dam safety	• A statement on the safety of the dam indicating if the dam is in a satisfactory condition and capable of meeting current design criteria.
Consequence analysis	• A statement of the consequences of failure and if a revised failure impact assessment is required.
Comprehensive inspection report	• The comprehensive inspection report (see Section 3.8).
Available documentation	• A review of available documentation used in the safety review.
Description of dam	• A detailed description of the dam including its history of design, construction and historical performance.
Parameters and assumptions	• Parameters adopted and assumptions made (and their basis) for review analyses.
Methodology and results	• A description of the methods of review analyses and results (numerical and physical).
Acceptable flood capacity assessment and/or risk assessment	• An assessment of the standards that the dam is required to achieve and whether the dam currently achieves these standards (or reference made to a valid separate assessment).
Identification of deficiencies	• Identification of any deficiencies in the dam including criticality ratings for these deficiencies[19].
Discussion	• Comments should be made regarding adequacy of the dam safety surveillance program and operation and maintenance procedures. Such comments and conclusions should reflect prevailing knowledge in hydrology, hydraulics, soil mechanics, geology, structural analysis, identification and assessment of failure modes, and design criteria relating to dams.

[19] A deficiency may be insufficient knowledge about a particular aspect of a dam.

Section	Description
Recommendations	• Recommendations for remedial work, emergency action, and/or further studies which should be undertaken and timings for these.
Conclusions	• Conclusions should be developed regarding the adequacy of the main elements of the dam, that is, foundations, main wall, spillway, outlet works, associated equipment and monitoring system.
Technical review	• Documentation of technical review process and outcomes.
Certification	• Section 4.3

3.10 DSC10: Deficiencies, incidents and failures

3.10.1 Definitions

Deficiencies, incidents and failures are escalations of threats to dam safety (see Table 9).

Table 9 Definitions of deficiencies, incidents and failures

Threat to dam safety	Examples
Deficiency A factor or feature that potentially threatens the safety of a dam. Deficiencies may be detected by surveillance inspections and evaluations or dam safety reviews or following incidents. They may also be detected during engineering investigations and analyses. A deficiency is also an increase in societal risk to an unacceptable risk, which is a risk that is greater than one order of magnitude above the tolerable societal risk threshold, and identified by a safety assessment. A dam owner must be able to demonstrate that dam safety deficiencies, whether they are potential or confirmed, are being addressed in a responsible manner. An effective dam safety management program contains elements aimed at detecting and responding to deficiencies before they escalate to an incident. Dam safety deficiencies can be very complex and take time to investigate, assess and resolve effectively and safely. Through appropriate investigation and/ or assessment, potential dam safety deficiencies may be resolved as either not a dam safety deficiency or a confirmed dam safety deficiency.	• inappropriate or deficient design or construction • time based deterioration or breakdown of material • damage to dam (e.g. landslides, erosion, earthquake etc.) • a consequence analysis investigation indicates a material change in societal risk position • a safety review indicates a significant shift in the likelihood of a potential failure mode
Incident	• rapid or unexpected change in seepage

Threat to dam safety	Examples
An event that does not endanger the integrity of the dam and downstream property or life but which could, in other circumstances, deteriorate into a serious situation. It can be described as a 'near miss'.	• overtopping of earth embankment without failure • excessive beaching • excessive embankment erosion • spillway / bywash erosion or blockage • excessive cracking or displacement in concrete dams and spillways • sliding, rotation or settlement of the dam • actual or suspected earthquake damage • malfunction of gates, fuse plugs or crest bags
Failure The physical collapse of all or part of a dam or the uncontrolled release of any of its contents.	• collapse or erosion of embankment dam from overtopping • collapse or erosion of spillways • internal erosion or piping through earth embankments or abutments • failure of release conduits • sliding or overturning of concrete dams • deterioration of maintenance deficiencies

3.10.2 Detection

Detection considers the following:

- Effective surveillance, inspections and monitoring (Section 3.7).
- Prompt investigation and information gathering for analysis.
- An assessment of the consequences of a worsening situation and its likelihood.
- An assessment (i.e. evaluation against prescriptive and/or risk-based criteria) to determine the severity of a deficiency.

3.10.3 Remedial action

Remedial action is required when a dam no longer meets an acceptable level of safety to bring it to a satisfactory standard for the continuing life of the dam.

The type of remedial action required, and its urgency, is determined by the nature of the deficiency (or incident or failure). Key elements, including descriptions of short, interim and long-term remedial actions, are described in Table 10.

Remedial actions should be developed by a suitably qualified and experienced RPEQ or team, supported by other appropriate specialists as required.

Remedial actions should be consistent with good practice standards.

Impacts to the community may be a consideration.

Remedial actions, especially long-term actions, can be very complex and take time to investigate, assess and resolve effectively and safely. They may be subject to DSC6 and DSC9:

- Any remedial investigations or studies that directly influences the risk position of a referable dam is considered to be subject to safety condition DSC9: Safety Review (Section 3.9).
- Any remedial investigations or studies likely to contribute to design and/or construction of a new dam or a major upgrade or augmentation is considered to be subject to safety condition DSC6: Design and Construction (Section 3.6).
- If in doubt, contact the regulator.

Table 10 Key elements of remedial actions

Element	Description

Type of remedial action	Short term actions include:
	• Preventative measures to stop the situation from worsening
	• Activation of EAP (including evacuations)
	• Installation and operation of warning systems
	• Modification of operating procedures including lowering of reservoir levels by controlled release and increased surveillance
	Interim actions include:
	• Lowering reservoir levels whilst preparing for and implementing long term actions
	Long term actions include:
	• Structural changes to a dam, including:
	  ○ dam crest raising
	  ○ spillway enlargement
	  ○ auxiliary spillway or fuse plug/gate
	  ○ post tensioning
	  ○ scour protection
	  ○ filter upgrade (for embankment dams)
	  ○ weighting zones (for embankment dams)
	  ○ foundation treatment including grouting and slurry trenches
	• Changes to operating procedures
	• Decommissioning of a dam

Public safety	Dam safety should be considered when determining remedial works. When remedial works are undertaken, the safe passage of flood events should be considered. • The dam owner has a duty of care to act in a timely manner if downstream consequences, particularly public safety risks, are increased • In life threatening situations, remedial actions may require short-term actions including the evacuation of persons at risk, modification to operations or controlled release of storage • For a referable dam, these initial actions may be addressed in an EAP
Urgency	The urgency with which remedial works are completed needs to reflect the nature of the identified dam safety deficiency and the level of risk it presents. • In some instances, it may be prudent to stage the remedial works to provide an interim reduction in the risk level • The chief executive may impose timeframes for rectification of specific deficiencies through guidelines, safety conditions or emergency direction notices • When dealing with a large portfolio of dams, where an owner has conducted a dam safety evaluation across the entire portfolio, it is recognised and generally accepted that it is not possible for an owner to address all identified dam safety deficiencies at one time
Documentation	All investigation, design, and construction activities undertaken as part of the remedial works must be documented and included in the dam records.

Element	Description
Notification	Any requirement for remedial action is to be reported to the chief executive.

3.10.4 Communication

It is important to notify stakeholders if there is an escalation of a deficiency, incident or failure. Key elements are described in Table 11.

DSC (Table 1) provide direction on notification and reporting of deficiencies and incidents that are not sufficiently threatening to trigger an EAP activation.

Table 11 Key elements of communication

Element	Description
Timing	DSC provide minimum frequencies
Reporting	As per the DSC, which require the dam owner to report safety related incidents and failures to the chief executive. The purposes of this reporting are to: • alert the chief executive to a potentially dangerous situation • enable the chief executive to better understand the safety status of the dam • provide learning to assist in avoidance of similar occurrences at other dams
Response	The occurrence of an incident may trigger the need for a Special Inspection (Section 3.8) or EAP activation.
Documentation	Dam owners should ensure that permanent records of such events, including dam safety inspections and evaluation reports, are kept in the data book.

4. Supporting components

4.1 Skills of dam safety management personnel

Management of dams requires the use of suitably qualified and experienced personnel. They should be familiar with all relevant basic principles, technical guidelines, articles and manuals.

Dam owners must ensure personnel (including technical advisors) engaged in dam safety related investigations and studies have appropriate qualifications, registrations and adequate knowledge and experience relevant to the type of dam and the task required.

Dam owners should ensure that the operating personnel involved in the day-to-day dam activities are experienced and/or trained in relevant aspects of dam management. While the chief executive does not currently mandate competencies for dam operators, employment of appropriately qualified operators for dams is recommended and considered good practice.

Engineering services in Queensland must comply with the *Professional Engineers Act 2002*, which requires a registered professional engineer of Queensland (RPEQ) to undertake or directly supervise an engineering service. Attributes in addition to RPEQ are recommended for personnel responsible for dam safety management. The DSC (Table 1) refer to such personnel as a "suitably qualified and experienced RPEQ".

Inputs are often required from non-engineering technical specialists, such as geologists. Supervising these inputs in the context of meeting the *Professional Engineers Act 2002* should be considered.

Appendix J provides a matrix of skills for dam safety management personnel. ANCOLD (2003) also provides guidance on knowledge required for personnel involved in dam safety programs.

4.2 Training and education

Dam owners should develop a program for keeping the skills of their dam operation staff up to date with modern standards, practices and technology through training programs, courses, and 'on the job' training. Succession planning is important to maintain knowledge and competence over the life of a dam, as is the availability of sufficiently skilled resources to carry out required tasks.

Dam owners, particularly those managing high risk consequence dams, should consider providing their personnel with regular refresher training in dam surveillance and inspection techniques and maintain a register of staff competency. **Appendix J** describes skills for dam safety personnel which includes continuing professional development.

Development of skills to operate and manage new infrastructure should be considered as part of the project delivery.

4.3 Certification

Certification is considered a formal statement of obligation and responsibility for public safety to the community, especially when it addresses dam safety. It provides critical technical assurance. It is a requirement for:

- Engineering inspections
- Safety reviews
- Design and construction (including completion of construction)
- Inspection of construction

Certification is done by a suitably qualified and experienced RPEQ who is engaged in all aspects of the dam project.

They are required to provide certification of a range of technical assurance elements including compliance to legislation and dam safety conditions, adherence to good practice, reliability of information and data used, appropriate documentation of decision making and quality of process.

Their certification does not necessarily require them to conduct all engineering services (or directly supervise all engineering services), so long as those services are done by other suitably qualified and experienced RPEQs.

Appendix K provides templates to consider when preparing a certification.

4.4 Project procurement

Procurement is the process to identify, engage and deliver services. For dams, procurement must consider the range of uncertainties, which manifest as risks, and how they are apportioned between parties.

It is important for dam owners to note that only a very small proportion of risk can be assigned to other parties in the delivery of dam investigations, renewals, and capital projects. The dam owner retains and is accountable for the management of dam safety. Therefore, it is vitally important that the dam owner is fully engaged in the planning and implementation of any procurement process to identify and manage business and dam safety risks.

Generally, dam projects do not always fully identify or realise the full range of risks and associated costs until after construction activities commence. This is largely due to uncertainties associated with the as-constructed details of existing structures, sourcing appropriate materials, site geology and flood management. Other factors such as construction works on an operational dam, complexities in construction sequencing, limited access and stakeholder management also contribute to project complexity. There can also be a tendency for ‘optimism bias’; an assumption that risks will not be realised and that the project can proceed without fully addressing those risks.

Procurement models range from those where a project is allocated to a single entity (e.g. construct only, design and construct delivery models) to those where multiple entities, including the dam owner, share responsibility for project delivery (e.g. alliance delivery model). Choice of delivery model will depend upon a multitude of factors that include project complexity, the ability to reasonably apportion risk, and the skills and the resources of each party to manage the identified risks.

4.4.1 Key Project Roles

In managing project development and delivery, dam owners need to consider how the following roles are addressed and resourced in the project team across the project phases (Table 12).

Table 12 Key project roles in project development and delivery

Role	Role Description
Owners Project Sponsor	A key executive with the appropriate delegation to oversee the planning and delivery of the project and provide timely decision making.
Owners Engineer	A source of expertise for the owner to provide input into project decisions to allow the consideration of whole of life impacts, operations and maintenance, residual risks and impacts of design changes. Employed or contracted by the owner directly.
Independent Technical Reviewers	Independent review to provide detached advice and scrutiny that is unlikely to be influenced by the time and commercial constraints faced by the owner, consultant and contractors.
Design Manager / Project Technical Lead	A key individual or individuals to drive the delivery and the quality of the design deliverables. Dam projects are bespoke multi-disciplinary projects requiring not

Role	Role Description
	just coordination of deliverables but a detailed understanding of how they interact.
Designers Representative	Management of on-site design inputs including the release of hold points, requests for information and design change management. This role is key to allowing the designer to certify that the design has been delivered in accordance with the design intent.
Independent Verifier / Expert	A specialist resource engaged by the owners to undertake independent checks on the design or construction to address high risk activities or manage quality outcomes.
Construction Manager	Management of the construction interface between owner, designer, and the contractor.
Superintendent / Commercial Advisor	Management of the project commercials including variations, schedule performance and progress claims.

4.4.2 Selection of a Procurement Model

The choice of procurement and project delivery model depends upon the project complexity, the ability to reasonably apportion risk, and the skills and resources of each party to manage the identified risks.

Specific to dam projects, aspects to consider when developing a procurement model include those listed in Table 13.

Table 13 Aspects to consider for selection of project procurement model

Category	Recommendation
Project Scope Definition	• Key project outcomes and the owners' requirements for the completed works need to be clearly defined. • Existing and historical site data needs to be collected, collated and checked including as-built details, services, electrical and mechanical equipment, existing materials and historical details such as ground investigations and flood data. • A geology and/or geotechnical model is required for the site and careful consideration given to the adequacy of the available data for the proposed works. Further investigations may be required to reduce uncertainties. • Sufficient design work to develop a robust reference or tender design needs to be completed prior to engaging a delivery partner even where collaborative delivery models such as Alliances are to be used.
Approvals	• An assessment of the required project approvals is required before any approach to the construction market. Approval delays and conditions present significant schedule and commercial risks for the owner. • Where feasible approvals should be obtained before contract award, noting that some approvals are to be obtained by the construction partners. • Alliances or fast-tracked projects may require the appointed project team to negotiate and gain the necessary approvals.
Owners Input	• To the extent practicable, the entity that is ultimately to own or operate the dam after its commissioning should have an opportunity to influence its design and construction; and if there is an alliance, it should be part of that project structure. • The ultimate dam owner should have the skills to be a capable participant in the project delivery that matches the identified areas of risk. • Safety in Design and ongoing operations, maintenance and surveillance are long terms considerations that need to be adequately addressed with the owners' operational teams during project delivery.
Budget and Finance	• Due to the complex nature of dam projects, risks may be realised during the course of the project that incur additional time and cost to address. This should be considered and incorporated into the procurement model. • Scope definition and budget allocation may change as investigations are conducted (especially geology). Irrespective of the thoroughness of investigations there may not be a complete understanding of latent site conditions until after construction commences. • Management of dam safety risks, flood events and day to day operations need careful consideration and often impose constraints impacting construction productivity, especially for upgrade projects. These impacts need to be evaluated in the development of the project budget. • Sufficient contingency should be provided to account for any additional expense associated with the emergence of risks.
Risks	• Risks should lie with the party that can best control the risks. In many instances this is likely to be the dam owner. • Fairness and capability are considerations when allocating risks. • Unreasonable allocation of risks to parties who are not well positioned to manage them can result in overly conservative costings and/or poor project delivery (and corresponding dam safety risks). • Progressive identification, management and allocation of risks should be practised throughout a project.
Risk Management	• Technical aspects should be the priority when making procurement and project delivery decisions.

Category	Recommendation

	• Investigation works conducted prior to project design and construction, especially with regard to site geology, increase the understanding of risks and improves project outcomes.
	• In light of the likely emergence of risks, flexible timeframes and management of variations should be factored into the selection of procurement model and contractual arrangements.
	• When making procurement and project delivery decisions, contractual arrangements between parties should clearly set out how each party is to identify, document and respond to the emergence of risks.
	• A detailed dam safety management plan should be prepared and implemented for project works to manage life safety risks including:
	  ○ diversion and coffer dams for flood management
	  ○ partially completed structures such as embankments or spillways
	  ○ work on an existing dam or spillway
	  ○ first filling and commissioning
	• Contractual arrangements should ensure that identifying and delivering an appropriate technical solution is the focus of the project team.

Resources	• Within the constraints of probity, early engagement with industry participants, including potential construction contractors, is recommended. • All parties should have suitably skilled staff engaged during procurement. • The owners team should be involved throughout the procurement activity and have adequate engineering expertise to assess proposals as an informed client. • Technical review should occur throughout all phases of the project to achieve the technical integrity of proposed design elements and to question the appropriateness of procurement process relative to project risks. Early engagement of technical review is preferred.
Verification / Certification	• It is the intent of these Guidelines that any construction or upgrade works are certified by a suitably qualified and experienced RPEQ. • While certification of specific disciplines may require multiple RPEQ (e.g. electrical, mechanical etc) it is expected that a key technical lead is appointed to oversee the various certifications and assess that the design intent has been met. • Owners need to carefully consider the engagement of the certifying engineers team and develop an agreed scope for site supervision to allow sign off at the end of the project. • See also Section 4.3.
Project Culture	• Outstanding project outcomes are the product of a project team working together respectfully to deliver shared goals and manage risks. The procurement process and selected delivery method contribute to the ability to build such a team. • The owner has the ability to drive a positive work culture and associated behaviours during the selection of project partners. This can assist to minimise conflicts and disputes and increase the chance of success for the project team.

4.5 Technical review

4.5.1 Roles and responsibilities in a dam project

A dam project can include one or all components of specification, design, construction and commissioning, with consideration for ongoing management.

As shown in Figure 1, roles in a dam project can be broadly categorised as dam owner (risk owner and budget owner with authority to define and modify the scope of the project), project team (the entity or entities engaged by the dam owner to undertake a dam project) and technical reviewer (engaged by the dam owner but acting independently of both dam owner and project team).

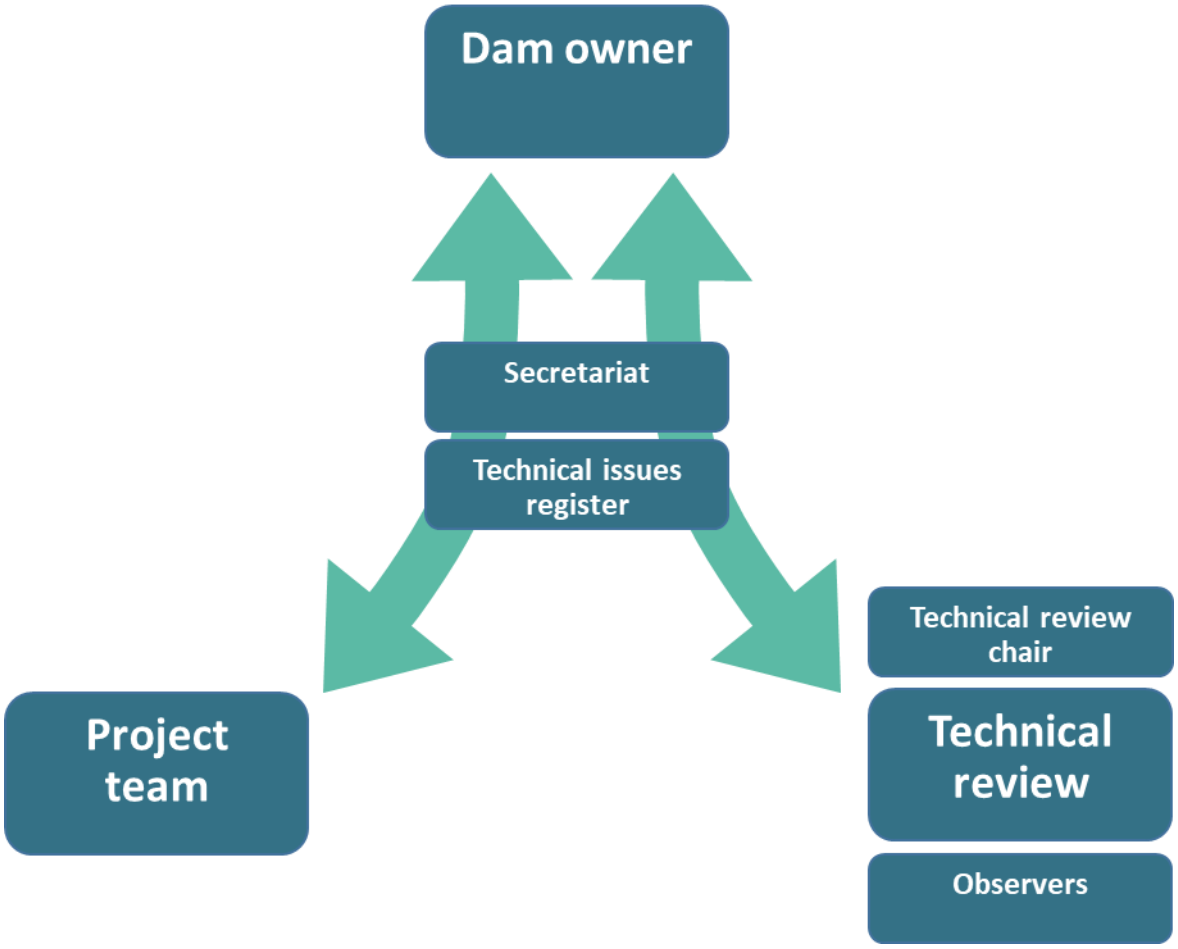

Figure 1 Roles and responsibilities in a dam project of relevance to technical review

4.5.1.1 Dam owner

The dam owner is the risk owner, budget owner and has authority to define and modify the scope of the project. Reporting between project team and technical review is controlled by the dam owner.

The dam owner should have technical capacity to identify and discern emerging issues, leadership skills to enable effective interaction between project team and technical reviewer, and communication skills to articulate technical matters to senior decision makers.

The dam owner should have a suitably sized, skilled and experienced workforce engaged to deliver the project and oversee the technical review process.

The dam owner should be the entity that is ultimately to own or operate the dam after the dam project. This implies the involvement of the ultimate owner of the life safety risks, and any other ongoing long-term liabilities associated with a dam.

The dam owner should have a person or position that is the point of contact for general technical matters for both the project team and technical review. The point of contact should have appropriate technical capacity to understand and interpret any matters or concerns being raised.

The dam owner should also identify a project sponsor or similar (person, position or group) who has capacity to make decisions on behalf of the dam owner's organisation. This point of contact should have an awareness of the risks associated with the project and have authority to action any

recommendations. The project sponsor does not necessarily have a direct involvement in the day-to-day activities of the project.

4.5.1.2 Project team

The project team is the entity (or entities) engaged by the dam owner to undertake a project or a particular stage of a project (for example, responsible for investigation (including safety review or safety assessment), design, construction or other associated obligations for the delivery of a dam project). The project team reports to the dam owner.

The project team solves technical challenges and is responsible for technical delivery and certification.

The project team needs to be technically competent and cannot rely on technical reviewers to certify a project.

An individual RPEQ is required to certify the dam project. This individual should be identified and nominated early, fully participate in the dam project and be clearly identifiable as being the person responsible for certifying the dam project.

4.5.1.3 Technical review

The role of technical review, that is expert and independent of owner, designer and constructor, can be a valuable, affordable resource to promote better dam design and construction, especially where novel or innovative methods are proposed. Such a review can provide detached advice and scrutiny that is unlikely to be influenced by the time and commercial constraints under which designers and contractors usually operate. The technical reviewer reports to the dam owner separately from the project team.

Technical review should commence early and continue throughout the life of a project.

Matters for review should include but may not be limited to regulatory, safety and operational requirements, the principal components of the dam and its critical design parameters. The structural integrity and the identification and mitigation of risks associated with its failure are addressed as a priority, with life safety considerations highest priority.

The purpose of technical review is to constructively challenge assumptions, methodologies and decisions in order to achieve project outcomes that are reasonable and consistent with current practice.

The purpose of the technical review is to review. It does not have a responsibility to solve technical challenges and is not responsible for project outcomes; this is the responsibility of the dam owner and project team.

The technical review does not provide a project audit or certification of the project.

The technical reviewer is engaged by the dam owner but acts independently of both dam owner and project team and is not burdened by their economic, corporate or operational concerns.

Technical reviewers should have integrity and question their own scope and schedule, as well as that of the project and its participants, if considered justifiable and necessary.

Technical reviewers should have authority to co-opt others with appropriate expertise to conduct peer review of matters beyond the collective expertise of the panel members or where obtaining additional views is considered advisable (see also State of Queensland, 2020, State of Queensland 2020a and Nielsen et al, 2021).

Specific skills and attributes for a technical reviewer are described in Section 4.5.2.

4.5.1.4 Technical review chair

A panel chair or spokesperson can be assigned when there are two or more technical reviewers. Specific skills for a technical review chair are described in Section 4.5.2.

The chair is required to identify and prioritise reviewer feedback and, where required, escalate or highlight significant concerns to the dam owner. The chair should energetically follow up on any issues that have not received a satisfactory response.

It is the responsibility of the chair to ensure reviewers maintain appropriate behaviours of integrity, impartiality and independence.

The chair coordinates formal feedback from the reviewers, during workshops and also in preparation of written reports, and is the point of contact and technical review spokesperson with the dam owner.

4.5.1.5 Secretariat

The secretariat provides managerial support to the technical review and is the owner of the technical issues register. They oversee:

- Logistical arrangements for meetings and workshops including travel and accommodation arrangements.
- Timely circulation of documentation prior to and following meetings and workshops including agenda and technical issues register.
- Sharing formal documentation (including the technical issues register, reports, memorandums and meeting/workshop minutes if taken).
- Data and document quality control.

The secretariat is required to be present at all meetings and workshops.

The secretariat should be efficient and capable of facilitating effective relationships between dam owner, technical review and project team. Technical knowledge of dams is not required.

4.5.1.6 Observers

Observers attend technical review meetings and workshops. They are often representatives from regulatory bodies, project sponsors and other key stakeholders.

Including observers in technical review can provide benefits:

- An opportunity for stakeholders to witness a process that is being relied upon to provide technical assurance for the dam project.
- Familiarity with the project and review process can facilitate efficient and effective decision making.
- Technical review workshops provide a unique training opportunity, to hear from industry experts and learn what the key risks and concerns are for particular aspects of a dam design or construction.

Observers do not have a direct technical review role. Their inputs or opinions may be sought by workshop participants.

The regulator observes the technical review process when considering if the technical review is compliant to regulatory obligations (see also Section 4.5.6).

Inclusion of other observers may concern some dam owners, especially if content being discussed is sensitive or if an overwhelming number of observers impact a workshop.

Clear direction of the role of observers in terms of reference can mitigate these concerns. For example, restricting active participation in meetings, providing a specific time allocation to allow observers to raise questions or queries, or use of online meetings protocols (with muting) could be considered.

4.5.2 Skills of technical reviewers

4.5.2.1 Expertise

Technical reviewers must have relevant technical expertise, preferably at a level equal to or broader than the corresponding subject specialist in the project team under review. The technical skills should

reflect the technical challenges of the project. Skills, and individual reviewers, may change as the project proceeds.

Technical reviewers require communication and interpersonal skills to capably raise relevant issues and concerns, encourage constructive debate and resolve differences of opinion appropriately.

Additional capability for the technical review chair role is required to identify and prioritise reviewer feedback and, where required, escalate or highlight significant concerns to the dam owner.

Appropriate leadership and management of the review members is necessary to ensure that technical issues are appropriately prioritised, a balanced perspective is maintained and bias is avoided.

Appendix J provides supporting guidance on skills for technical reviewers.

4.5.2.2 Integrity

A technical reviewer has integrity and is guided by the following principles (adapted from ACSE, 2017 and BPEQ, 2019):

- Honesty in all aspects of communication
- Accountability in the conduct of review
- Professional courtesy and fairness in working with others
- Acting without discrimination or prejudice
- Good stewardship on behalf of others
- Recognition of obligation to health, welfare and community safety

4.5.2.3 Expert judgement and cognitive bias

The purpose of technical review is to confirm that technical matters have been appropriately addressed, evaluated and justified objectively and without bias.

NUREG (2018) cites a series of behaviours, often not deliberate or intentional, that can influence the judgement of experts. These are collectively referred to as cognitive bias, which manifest from "*mental shortcuts that usually involve focusing on one aspect of a complex problem and ignoring others. These rules work well under most circumstances, but they can lead to systematic deviations from logic, probability, or rational choices*". Further discussion is also provided in Nielsen et al (2023).

NUREG (2018) highlights that these common cognitive biases are "*inherent to all expert judgments and are not deliberate. They are simply the way that scientists and engineers commonly process information and offer our technical judgments*". It also highlights that "*the most effective way of countering cognitive biases is simply to make the experts aware that they exist and to encourage the experts to counter them*".

4.5.3 Size, approach and timing for technical review

4.5.3.1 Size and approach

The size and scope of a technical review team will depend upon:

- project complexity
- the need for specific subject matter specialists
- use of innovative or new design, construction or material
- dam failure consequences

Indicative technical review size and scope, based on population at risk (PAR), is as follows.

- If PAR < 10: evidence of technical review of design at completion of construction[20]
- If PAR < 100: one to two independent technical reviewers subject to project complexity

[20] For example, technical review associated with a small, low consequence, earth embankment dam may be an internal review by the same organisation who conducted the dam project.

- PAR > 100: several independent technical reviewers, each with specific technical specialties, forming a technical review panel. The panel is engaged at regular intervals during the project via (preferably) face to face panel sessions

It is reasonable to anticipate 5 to 10% of the costs associated with the technical inputs of a project (e.g. those costs allocated to engaging specialist staff for engineering design, construction management costs, etc.) to be allocated to a technical review process.

RDMW (2023a) also suggests considering a comparison to good practice and precedent.

4.5.3.2 Timing

Technical review should commence early and continue throughout the life of a project. This includes consideration of technical review during preparation for project procurement as well as specification, investigation, design, construction and commissioning.

Frequency of engagement of technical reviewers should reflect project complexity and be sufficient to be effective.

4.5.4 Governance and management

4.5.4.1 Relative skills of dam owner, project team and technical reviewer

As highlighted in Section 4.5.2, technical reviewers must have relevant technical expertise, preferably at a level equal to or broader than the corresponding subject specialist in the project team under review.

However, as noted in Section 4.5.1:

- The dam owner is the risk owner, budget owner and has authority to define and modify the scope of the project. They should have technical capacity to identify and discern emerging issues.
- The project team solves technical challenges, is responsible for technical delivery and certification, and cannot rely on technical reviewers to certify a project.
- The technical reviewer constructively challenges assumptions, methodologies and decisions but does not have a responsibility to solve technical challenges and is not responsible for project outcomes.

When identifying key roles in a dam project it is worth reflecting upon the differing responsibilities and who is the best choice for each. For example, project outcomes may benefit from engaging the person with the most relevant technical expertise as the lead of the project team or as an owner's engineer (supporting the dam owner), rather than as a technical reviewer.

4.5.4.2 Communication Channels

Clear lines of communication should be established between roles, including:

- Ensuring the dam owner has a single point of contact for general technical matters for both the project team and technical review.
- Ensuring the dam owner has an identified project sponsor who has capacity to make decisions on behalf of the dam owner's organisation.
- The certifier for the project team is identified and that matters that may impact the certification are directed to them.
- The technical review chair is identified (if review team is of sufficient size).
- The secretariat, who manages the technical issues register, plays an important role in maintaining appropriate communication protocols.

It is important that workshops and meetings, where project team present and discuss matters with the technical reviewers, are appropriately recorded with subsequent actions, concerns, questions and responses formally captured in the technical issues register.

4.5.4.3 Independence and conflicts of interest

Technical review acts independently. It should not be burdened by the economic, corporate or operational concerns of either the dam owner or project team. There should be no real or perceived conflict of interest that hasn't been declared and accepted by the dam owner. There should be no financial or other interest in the outcome of the project.

Situations may occur where a technical reviewer is, or has in the past, performed another role with the dam owner or project team and could be a potential conflict of interest.

As highlighted in NUREG (2018), the relatively small and close-knit nature of specialist technical communities makes it likely that technical reviewers, dam owners and project teams will know each other and may even be working together in other circumstances. Therefore, there should be no unrealistic expectations about separation and distance.

These situations do not necessarily mean a conflict of interest will occur, rather there is a risk it could occur. Technical reviewers should rely on their principles of integrity before accepting the role and clearly state any potential or perceived conflicts of interest prior to engagement.

If the identified technical reviewer cannot be easily replaced or, if the benefits of their engagement outweigh the risks, the dam owner may need to accept that a risk exists and manage and mitigate that risk accordingly.

Any issues should be declared at the outset of the project to provide transparency. Decisions need to be clearly justified and documented and a conflicts management plan prepared and followed if required. Discussing the matter with the regulator is also advised.

4.5.4.4 Disputes

Resolution of disputes or disagreements between technical reviewer, dam owner and/or project team is the responsibility of the dam owner. A pre-prepared escalating response process should be considered as part of the governance structure (see also Nielsen et al, 2021).

If a dispute cannot be resolved by the dam owner, the technical review process may ultimately be impacted to the point where it is no longer adequate (see Section 4.5.6).

A technical reviewer should be able to raise any matters of concern relating to the project to the regulator. Any contractual arrangements between dam owner and technical reviewer should consider the technical reviewers' capacity for open disclosure to the regulator.

4.5.4.5 Selection criteria

Selection of technical reviewers should consider the specific objectives for the review and the relevant areas of expertise required to achieve them, noting that these objectives may change during the life of a dam project. It should also consider the key risks associated with the dam (for example, the reviewers required for a concrete arch dam may differ markedly from those required for an earth embankment dam).

Selection criteria should consider the following attributes as essential for technical reviewers:

- Professional conduct in line with the code of conduct of leading professional bodies.
- Formal tertiary qualifications in engineering or relevant science, or professionally recognised construction supervision capabilities.
- Relevant technical expertise.
- Dam safety knowledge and experience of relevant Queensland legislation, policies and guidelines, and industry guidelines including ANCOLD.
- Interpersonal and communication skills, including ability to convey technical matters clearly and logically in team settings and written form.

Section 4.5.2 provides further advice on skills for technical reviewers.

When selecting a group of reviewers to form a panel, there should be an appropriate balance of knowledge and experience across relevant project disciplines so that there is credible and effective review of the specific methods and technologies under investigation.

Challenges can arise when there are multiple reviewers from a single organisation. This raises concerns of real or perceived conflicts of interest, and the potential for those individuals to collaborate externally and come to review meetings “pre-prepared”. There may however be recognised subject matter experts from one organisation who are eminently suitable for the reviewer roles; in these circumstances may be a need to carefully manage conflicts of interest (Section 4.5.4.3).

Good behaviours, communications and trust between individuals across the dam project (dam owner, project team and reviewers) may offset risks and contribute significantly to positive project outcomes. Selection should consider how well individuals will work as a team.

A lack of diversity within a technical review team can increase the likelihood of cognitive bias behaviours. Diversity of technical background, age, gender, behavioural characteristics and cultural background within the review team should be considered.

4.5.4.6 Technical issues register

A technical issues register is a catalogue of questions raised, responses from the project team (or the dam owner if more relevant and appropriate) and commentary on their resolution. It can be a multi-cycle, live document that is used for tracking technical review matters over multiple workshops and project phases.

The secretariat is responsible for the register.

Specific issues in the register should only be closed by the technical reviewer once they are satisfied with the response from the project team. The register then becomes a formal record of the resolution of the issue, with reference to evidence supporting the resolution and the date it was resolved.

Suggested columns / entries for the technical issues register:

- Id of issue
- Date of issue
- Question asked by technical reviewer
- Response by project team
- Resolution (as determined by technical reviewer)
- Reference / link citing evidence of outcome

4.5.4.7 Document control

A centralised location for documentation is recommended with appropriate backup, security and accessibility.

4.5.4.8 Training and education opportunities

Technical review workshops for major dam projects are an opportunity to observe a project team present their work to a panel of industry recognised subject matter experts. Project team members are normally well prepared for the workshops, the quality of presentation and supporting documentation is high, and review discussions are often highly technical and informative.

Junior engineers should be encouraged to observe technical review workshops. It provides a unique opportunity to hear from industry experts and to learn what the key risks and concerns are for particular aspects of a dam design or construction.

Observation alone may not always provide benefit; it may be worthwhile considering a mentoring scheme or similar whereby junior engineers observe workshops and then prepare a report or presentation on what they saw and heard and its relevance.

See further commentary on observers in Section 4.5.1.6.

4.5.5 Scope

4.5.5.1 Preparations and Terms of Reference

The dam owner's preparations prior to commencement of technical review should consider the matters described in Sections 4.5.1 to 4.5.4.

A terms of reference should be prepared that reflects the dam owner's expectations of the review process and complies with industry and regulatory requirements. A template terms of reference is provided in **Appendix I**.

4.5.5.2 Technical review preparation meeting

The preparation meeting (or series of meetings) should consider the activities in Table 14.

Table 14 Recommended activities for technical review preparation meeting

Activity	Discussion
Initial project review	An initial project review clarifies the scope of technical review and familiarises the reviewer(s) with the project. The project review is an opportunity for the reviewer to raise queries to the dam owner relating to: • The appropriateness of review scope, schedule and resources, including any suggestions for improvement. • The overall project governance, delivery model and risk management strategies. • Available information and the need for any additional investigations.
Physical site inspection	Technical reviewers should physically visit the site at least once.

In-camera discussion	The first preparation meeting is an opportunity for a private discussion between the technical reviewers to reflect upon the dam project and how effective the key stakeholders, especially dam owner, project team and technical review, are. Any concerns, or potential for emergent concerns, should be discussed.
	
	These include:
	
	• Risks:
	  ○ What are the key risks associated with the dam project that technical reviewers need to be mindful of as the project proceeds?
	  ○ Who owns the risks in the project and can those owners manage those risks?
	  ○ Are there any gaps in the knowledge base for the project that may be questioned as unacceptable at this stage in the project?
	• Capabilities:
	  ○ Is the technical review suitably capable? Is there a need to co-opt more technical reviewers?
	  ○ Is the dam owner suitably capable? Should engaging an owner's engineer be considered?
	  ○ Is the project team suitably capable? Is there a clear individual who will certify the dam project?
	• Communications:
	  ○ Are all roles and responsibilities clearly defined?
	  ○ Are communication / reporting lines clear, as well as escalation pathways?
	• Secretariat:

Activity	Discussion
	○ Is the secretariat, technical issues register, logistics of meetings and workshops and data and document storage acceptable? ○ Is the timing, scope and proposed workshop agendas acceptable? • Confirm the terms of reference: ○ Are any real or perceived conflicts being effectively managed? ○ Is the dispute resolution process clear and fair?
Declaration of independence, conflicts of interest and cognitive bias	The technical review chair should host a discussion that steps through the recognised challenges to independence, conflicts of interest and commonly cited cognitive bias behaviours associated with technical decision making. The discussion should commence with a review of the technical review role and responsibilities (Section 4.5.1.3). Each person in the workshop should then consider if there is a potential for a lack of independence, a conflict of interest or a cognitive bias issue (Sections 4.5.2.3 and 4.5.4.3) and what steps could be taken to counter it. Examples of questions that could be asked during this discussion and any additional discussions as the project proceeds: • Are all assumptions transparent and defensible? • Are there any assumptions based upon an individual's opinion, or past experience, that cannot be easily explained or justified? • Are all risks reasonably identified and quantified and is there potential for an underestimation of the uncertainty of these risks? • Does the dam project have a preferred solution and why is that solution preferred? • Is there any new information or learning that could impact the project outcomes? • Are there any previous dam projects which are being used to guide this dam project? • Is the background and experience of a particular person influencing the project? • Are the participants views their own, or are they representing the opinion of their affiliate organisations? • Are there any technical reviewers who may issue direction to the project team which could be construed as a design constraint (i.e. a tendency to "fix the problem")? • How engaged are stakeholders in the success of the dam project? • Are the technical reviewers comfortable delivering bad news? The discussion should be minuted and any concerns should be described, along with any mitigation measures proposed to counter them. Any participants in the technical review process who consider they may have a perceived, potential or real conflict of interest, a concern associated with their independence, or any potential biases, should declare their conflict.

4.5.5.3 Workshops

Technical review workshops are held at regular milestones and critical stages of a project. They are intended to be a collaborative and engaging forum to share information and raise questions.

Relevant documentation for the workshops should be distributed by the secretariat 1 to 2 weeks prior to the workshop. An agenda is recommended to track workshop activities.

Prior to the workshop the technical reviewer should diligently review all material provided.

Workshops should be chaired by the dam owner and consider the activities in Table 15.

The technical issues register, which is essentially an action list, should be regarded as the most important document and point of truth. Other recordings of decisions or actions, such as minutes taken during workshops by the secretariat, should only be regarded as a confirmation that agenda items and any other matters took place during the workshop, and that general discussions on particular topics took place. Decisions and actions from the technical reviewer should be confirmed separately either in the technical issues register or technical review reports.

Table 15 Recommended activities for technical review workshops

Activity	Discussion
Review the technical issues register	At the outset of each meeting a review of the technical issues register should highlight changes made since the last workshop (those matters resolved and new matters raised, etc).
Project team presentation, followed by Q&A	The project team presents technical content. Technical content should include responses to previously raised and outstanding issues in the technical issues register, especially if any questions raised could impact future analyses. New technical content will reflect the current stage of the dam project. Questions subsequently asked by the technical reviewer should elicit a response from the project team, possibly with further actions beyond the workshop, which the technical reviewer can subsequently re-assess.
Observer participation	Optionally, a time allocation to allow observers to raise questions or queries to participants.
In-camera discussion	A discussion with the technical reviewers that considers the content presented, whether the proposed activities address the project requirements and risks, and whether any concerns or questions are to be raised.
Feedback session	Led by the technical reviewer chair, technical review feedback is provided to the workshop attendees. The secretariat updates the technical issues register (subject to final approval from the technical reviewer).
Close	Agreement of actions and confirmation of timing, contents and actions required prior to next workshop.
Post workshop	The secretariat confirms the technical issues register changes with the technical review chair and distributes. The secretariat finalises documentation and agenda for next workshop with the technical review chair and dam owners and distributes. The project team continues works on the dam project.

4.5.5.4 Reporting

Reporting is required to demonstrate an effective technical review process has been conducted. It describes the review process, how it has challenged assumptions, methodologies and decisions, and whether all queries have been appropriately resolved by the project team. Where necessary, suggestions for action by project team or dam owner are provided.

The report contents (Table 16) should focus on the activities described in the technical issues register.

There may be several periodic reports provided at critical project milestones; the recommended report contents in Table 16 may not necessarily be needed in each of these reports.

The technical reviewer reports to the dam owner.

Table 16 Suggested technical review report contents

Section	Discussion
Executive summary	A simple language description of the technical review process and its outcomes. The executive summary should be brief and considered as a summary for decision makers.
Technical review team	A list of the technical reviewers in the team, their affiliations and relevant technical skills. A statement of any real or perceived conflicts of interest identified and what mitigation measures were applied to offset. Outcomes of discussion on cognitive bias.
Project stage and basis for review	A list of the technical documents provided that were considered in the technical review. A list of the workshops held, their dates, and a brief summary of their purpose and outcomes. A statement that a site visit was conducted or, if a site visit was not conducted, reasons why and mitigations considered to offset.
Summary of the technical issues register	A description of the technical issues register, key issues raised during the technical review, how they were addressed, and whether they have raised concerns regarding the underlying assumptions made in the dam project.
Conclusions and recommendations	A list of key actions for the dam owner and project team to consider. A summary describing the technical reviewer's opinion of project progress and adequacy of outcomes.
Signoff	All technical reviewers should sign the report.
Addendum / appendix with technical issues register	The technical issues register, or a link / reference to the register.

4.5.6 Regulatory compliance

As part of its role of regulatory oversight:

- Unless agreed otherwise, the regulator is to be provided all documentation associated with the technical review process. This includes any terms of reference, charter or contractual arrangements between dam owner and technical reviewer.
- An invitation is to be extended to the regulator to observe the technical review process.

- The regulator is to be notified of any changes to the technical review participants or their roles within the technical review team.
- The contractual arrangement between dam owner and technical reviewer must allow the technical reviewer the option to inform the regulator of any concerns relating to a dispute with the dam owner.

The regulator may reflect upon the matters listed in Table 17 when considering if technical review is adequate.

Table 17 Checklist of matters considered to assess technical review adequacy

Topic	Matters to consider
Competency and behaviour of technical reviewers	• Reviewers are independent and technically capable to undertake their role. • The review team is sufficiently competent to address the technical challenges of the project, and no additional team members are required.
Competency of dam owner	• The dam owner is sufficiently competent to address the technical challenges of the project.
Competency of project team	• The project team is sufficiently competent to address the technical challenges of the project. • There is a single person who is the certifier and they are RPEQ.
Governance	• Appropriate governance, including the roles and reporting of dam owner, project team and technical reviewer, have been followed. • Reviewers are independent and any real or perceived conflicts of interest have been declared, discussed and can be managed.
Terms of Reference	• The terms of reference aligns with the published template. • Reporting lines are clear in the organisation structure. • The secretariat's role has been clearly defined and a capable resource is allocated. • Observers, including the regulator and others for educational purposes, have been considered and invited. • Adequate document control has been established.
Timings	• There is a sufficient frequency and duration of workshops. • Relevant documentation is being provided at least 1 to 2 weeks prior to workshops. • Sufficient time has been allocated to allow technical reviewers to consider evidence and provide feedback.
Preparation	• Potential for independence, conflicts of interest and cognitive bias was discussed early and measures to manage any identified risks were implemented into the scope. • A comprehensive literature review and data mining exercise was undertaken to ensure all relevant information has been identified and provided.
Process	• The technical review is conducted in a manner consistent with good practice and this guideline. • There is access to all available and relevant information (i.e. all that was shared commonly with the project team) • There has been sufficient time and resource allocation for the review. • There is appropriate commencement and completion of review. • Observer roles are being respected.
Outcomes	• The review process has no unresolved disputes. • Reviewers have not provided design inputs.

Topic	Matters to consider
Reporting	• There is documented evidence of the review process (i.e. questions asked and satisfactory responses provided with supporting evidence in a technical issues register). • All comments and concerns were documented, addressed and resolved. • Critical decisions are documented, with adequate explanation and justification. • Any contentious or disputed decisions were resolved and appropriately documented. • Reporting aligns with the technical issues register.
Regulatory oversight	• The regulator has received the terms of reference. • The regulator has been invited to attend all technical review workshops. • The regulator has access to all information that the technical reviewers were provided.

4.6 Dam security

Vandalism and security breaches (including terrorism and cyber security) can affect dam safety. These activities cannot be controlled but should be considered and addressed by dam owners.

The vulnerability and criticality of the dam and its components should be considered in determining security arrangements. Particular attention should be given to unauthorised operation of equipment. A balance should be retained with the need for effective dam operation and public access expectations.

The following actions could be considered when developing a dam security plan:

- fencing of vulnerable areas
- installation of CCTV and security cameras
- use of sensors and security lightings
- enclosure of critical control systems in secure buildings
- adopting appropriate operational computer security controls
- signage that includes emergency contacts
- maintaining contact with local police of the environment
- cyber security awareness, risk reduction strategies and protective measures

4.7 Change of ownership

On change of ownership of the dam, the DSC and all documentation must be transferred to the new owner within 10 business days after the change in ownership.

In accordance with s366 of the Act, the former owner must also, within 10 business days after the change in ownership, give notice to the regulator of the change.

The notice must state the name, description of the dam and property, the date of the change in ownership and contact details for the new owner.

4.8 Emergency powers

The chief executive has the power, by notice, to issue a direction to a dam owner to take emergency measures under s359 of the Act.

An emergency direction notice is only issued if the chief executive is satisfied or reasonably believes:

- there is a danger of the failure of:
    - a referable dam or

- another dam (whether or not a failure impact assessment has been carried out for the dam), if the chief executive reasonably believes the dam would have a category 1 or category 2 failure impact rating if an assessment or another assessment were carried out for the dam; and

- action is necessary to prevent the failure or minimise its impact

A s359 notice is a compliance notice under the Act and attaches to the land, other than leased State land, binding the owner of that land and subsequent owners. Any person bound by this notice must comply with it unless the person has a reasonable excuse.

In addition, the chief executive has power under s359A of the Act to take reasonable steps to prevent or minimise the impact of any dam failure if the chief executive is satisfied or reasonably believes:

- there is danger of the failure of a dam, and
- the failure is likely to pose a risk to safety or health of the public or an individual, and
- immediate action is necessary to prevent or minimise the impact of the failure.

Any reasonable expenses incurred by the chief executive or an authorised officer in doing anything under s359A may be recovered as a debt.

Emergency powers have not been exercised by the chief executive to date. In practice it is likely that QFES or other emergency responder with similar authority would be better placed to exercise their powers (with the dam safety regulator providing advice), especially if they are already operational and have officers close to the dam.

4.9 Flood mitigation manuals and flood event reports

Under the Act, a referable dam may be prescribed by the Minister to require flood operations be undertaken in accordance with an approved flood mitigation manual. Flood mitigation manuals describe how operational releases are made from the dam during flood events, or in response to the declaration of a temporary full supply level. A flood event report is required if a flood event occurs and a flood mitigation manual is used.

The Act provides further information.

5. Dam safety components described in other guidelines

5.1 Failure impact assessments (FIA)

The mechanism for determining the failure impact rating, and hence the referable status of a dam, is a failure impact assessment (FIA).

See the FIA Guidelines (DNRME, 2018).

5.2 Emergency action plans (EAP)

Legislation requires a referable dam to have an approved EAP. An EAP ensures that there are protocols and procedures in place for the dam owner and disaster management groups to manage and minimise the consequences of dam emergency events and coordinate emergency responses and warnings.

See the EAP Guidelines (RDMW, 2023).

5.3 Emergency event reports (EER)

Legislation requires an EER to be prepared whenever an emergency event occurs. The EER provides important feedback to the chief executive about, amongst other things, the adequacy and effectiveness of the EAP associated with the dam.

See the EAP Guidelines (RDMW, 2023).

5.4 Reduction of full supply level (FSL)

Reduction of full supply level for dam safety purposes is described in RDMW (2023).

6. Auditing of dam safety management by the regulator

The chief executive conducts dam safety site audits according to an internal audit management strategy and plan.

Dam safety site audits are conducted to:

- Monitor compliance with regulatory requirements through identification of any shortfalls in the dam owner's dam safety management programs and any areas of non-compliance to specific legislative requirements including DSC.
- Address dam safety status and general condition.
- Provide an opportunity for the regulator to physically inspect the dam and liaise with dam owner and operator.
- Audits consider both dam projects (including design and construction) and ongoing management of dams.

The typical scope of a dam safety site audit is as follows:

1. Desk-top review of submissions, previous audits and compliance history
2. Site Visit:
    - Interview dam owner's representative and operational staff
    - Completion of an on-site checklist
    - Brief physical inspection of dam
3. Audit Report
4. Specific scope items for a particular dam

Items typically covered during a dam safety site audit include:

- Dam safety management program
- Recordkeeping
- Status and compliance to legislation and DSC:
    - FIA
    - Safety Assessments
    - EAP, including Annual Reviews and EERs
    - Engineering inspections
    - Safety review
    - Other DSC
- Response to recommendations from previous investigations:
    - Engineering inspections
    - Safety reviews
    - Audits
    - Other reviews
- Competence of dam personnel
- Dam inspection

Dam safety site audits are not intended to identify physical dam deficiencies, but this may happen as a result of the site inspection. Inspections to identify potential physical dam deficiencies is a separate activity (Section 3.8).

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Appendix A Consequence categories

Consequence categories are used in many jurisdictions as a basis for determining dam safety management requirements such as design criteria and operation, maintenance and surveillance requirements.

A consequence category is derived through a process of collecting information about the consequences of potential dambreak and identifying the severity of these consequences. Consequences relevant to the process are:

- Risk to human life
- Damage and loss

For determining a rating for Severity of Damage and Loss consideration is given to each of:

- infrastructure costs
- impact on dam owner's business
- health and social impacts
- environmental impacts

Separate consequence categories are assigned for:

- failures that occur without any associated natural flooding – the Sunny Day Consequence Category
- failures that occur in association with a natural flood – the Flood Consequence Category

ANCOLD (2012), with a minor correction published on the ANCOLD website in October 2015, sets out two methods for assigning a Consequence Category.

The first method (Table 18) uses estimates of the PAR and 'Severity of Loss and Damage' if a dam were to fail. 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 19), 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 failure. 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'.

The same criteria for Severity of Damage and Loss applies across both methods.

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 addition, ANCOLD (2012) predates the simulation modelling methods often used to predict PLL and notes that no one particular methodology is suggested for determination of PLL.

Table 18 Consequence categories based on PAR

Population at risk	Severity of damage and loss			
	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: PAR refers to incremental PAR (see definition in Glossary).
Note 2: 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 3: Change to 'High C' where there is the potential of one or more lives being lost.

Table 19 Consequence categories based on incremental PLL

Incremental Potential Loss of Life (PLL)	Severity of Damage and Loss			
	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 (Note 2)	High A	Extreme
>=50		(Note 1)	Extreme	Extreme

Note 1: With an incremental PLL equal to or greater than one (1), it is unlikely damage will be minor. Similarly, with an incremental PLL in excess of 50, it is unlikely damage will be classified as medium.
Note 2. Where PLL is in the range ≥ 5 to <10, the Category level can be reduced to High B

Appendix B Thresholds for application of dam safety conditions

The following table provides justification for the thresholds that would typically be considered when applying a DSC to a particular referable dam. The thresholds do not restrict the chief executive's power to apply any DSC at any time to a referable dam in accordance with the provisions of the Act.

Table 20 Thresholds typically considered for application of DSC

Threshold applicable to DSC	Justification
PAR>100 or Category 2 failure impact rating (FIR)	• The threshold considers category 2 FIR which is comparable to the High A (medium severity) ANCOLD consequence category.
PAR≥10 or ANCOLD High C consequence category and above	• This threshold is based upon ANCOLD consequence categories, Table 3 (ANCOLD 2012) and reproduced in Appendix A. • A PAR threshold is available because it is not considered reasonable that the 'severity of damage and loss' be assessed for all referable dams in Queensland. • The threshold is based on a 'medium' severity, which gives a 'High C' category. Note that the threshold is the more conservative of High C and PAR≥10.
All dams	• Many DSC are considered appropriate to all referable dams.

Appendix C Data book checklist (not exclusive)

Category	Checks
General	☐ Table of contents
Background information	☐ statistical summary of the main features of the dam ☐ spillway rating curve ☐ reservoir storage curve ☐ aerial photograph of the dam (if available) ☐ historical events (prior to construction, during construction and subsequent operation) ☐ record of incidents at the dam ☐ historical reports of inspections, reviews, etc. ☐ relevant correspondence
Geological information	☐ regional information ☐ site information ☐ seismicity ☐ relevant correspondence
Hydrologic information	☐ significant historical floods ☐ design floods ☐ current inflow design flood ☐ relevant correspondence ☐ failure impact assessment ☐ consequence assessment
Foundation information	☐ description ☐ foundation properties ☐ strength properties ☐ design and analysis ☐ treatments ☐ construction records, changes and modifications ☐ instrumentation ☐ known deficiencies (for example, seepage, etc.) ☐ relevant correspondence
Dam structure	☐ description ☐ design criteria ☐ design and analysis ☐ treatments ☐ construction materials ☐ construction records, changes and modifications ☐ instrumentation ☐ deficiencies (for example, cracking) ☐ relevant correspondence ☐ as constructed drawings
Other features—spillway, outlet works, mechanical systems	☐ description ☐ design and analysis ☐ details of relevant control systems and operating principles ☐ as constructed drawings
Rapid stability assessment	☐ details of stability calculations and parameters so that an assessment can be made of changed conditions

Appendix D Design and construction reporting checklist

Reporting is expected to describe project design and construction and demonstrate that the works have been completed in accordance with the design intent (see Section 3.6.6).

D-1 Design report

Category	Checks
General	☐ Design parameters adopted, assumptions made and the basis for these parameters and assumptions (including identification and addressing failure modes) ☐ Design methods, standards and loads adopted, and the design data gathered and developed (i.e. plans, reports of investigations) ☐ Results of any analyses and investigations (numerical and physical) ☐ Operational and maintenance intentions used in developing the design or necessitated by the constraints of the design ☐ Operating criteria and limitations assumed in design, such as gate operating rules and outlet works operation protocols ☐ Describe the expected performance and condition of the structure ☐ Describe the instrumentation and monitoring requirements for the dam ☐ Items requiring surveillance during first filling and subsequent operation with appropriate frequencies
Drawings	☐ Plan of the dam and appurtenant works drawn on a contour plan of the site ☐ Arrangements, elevations and sections showing details of the structures, the proposed foundation levels and sub-surface geological features ☐ Datum, scales etc. clearly defined ☐ Consideration of building information modelling
Summary of principal data	☐ Type of dam ☐ Type of foundation cut-off (if any) ☐ Type of spillway ☐ Height of dam (as defined in the Water Supply (Safety and Reliability) Act 2008) ☐ Length of (as applicable) embankment(s) or non-overflow structure(s) ☐ Spillway crest(s) • type, number and dimensions of spillway and any crest or sluice gates ☐ Elevations of (as applicable): • original stream bed or lowest natural surface at toe • base of cut-off • spillway crest(s) • top of dam • FSL • top of flood storage (if any) • maximum flood level ☐ Volumes of (as applicable): • excavation for foundations, cut-off and spillway • fill in each embankment zone and total

Category	Checks
	• concrete in spillway, if separate • concrete in dam wall and appurtenance ☐ Reservoir storage capacity: • to FSL • in flood control storage • in surcharge storage ☐ Reservoir surface area at FSL ☐ Catchment area ☐ For the maximum design flood: • estimated recurrence interval • peak inflow rate • peak spillway discharge ☐ For outlet works: • number and dimensions of outlet pipes and conduits • number, sizes and types of guard and regulating valves and gates • discharge and drawdown capacity ☐ List of reports prepared by any person or organisation in the course of investigation and design
Hydrological and hydraulic data and analyses	☐ Failure impact assessment (including dam break analysis and consequence assessment) ☐ Topographic map of the catchment or description of the terrain including elevations ☐ Area of the catchment and of each sub-area controlled by other storages or lakes ☐ Summary of stream flow, flood flow or rainfall records on which the hydrological analyses are based ☐ Adequacy of spillway and means of assessment ☐ Tables or curves of reservoir area and storage capacity versus water surface level ☐ Summaries, as applicable, of hydrological analyses leading to the determination of flood frequencies, probable maximum flood, reservoir capacity, outlet capacity, spillway capacity and freeboard above maximum flood level ☐ Recurrence interval of maximum flood adopted for the design of spillway and outlets, as applicable ☐ Particulars of proposed reservoir operation including operation of outlets and spillway crest gates during floods ☐ Fetch of reservoir and estimated wave height and run-up ☐ Drawdown capacity
Spillway hydraulics	☐ Description of and results from hydraulic model testing of final spillway arrangements (numerical and/or physical) ☐ Hydraulic data including formulae and coefficients used in determining capacity of spillways and outlets ☐ Summary of assumptions and methods adopted for the design of energy dissipaters for spillways and outlets ☐ Discharge rating curves for spillways and outlets ☐ Tailwater rating curve(s) for spillways and outlets ☐ Scour assessment

Category	Checks
Foundation conditions and treatment	☐ Map and description of the general geology of the dam site and reservoir area showing major faults and identifying any other potentially hazardous features requiring special consideration ☐ Report on any underground mine workings in the vicinity of the dam or reservoir and any provisions considered necessary to accommodate these workings ☐ Records of foundation exploration holes, pits, excavations and other sub-surface investigations indicating: • nature and depth of material on which the dam, spillway, outlets and other appurtenant works are proposed to be founded • summaries of results of laboratory and in-situ tests for determining the engineering properties of the foundation materials indicating the number of tests, sampling locations and extreme as well as average values ☐ Nature and extent of any proposed foundation treatments such as: • cut-off through pervious strata • provisions for drainage • curtain, blanket or consolidation grouting • measures to consolidate, decrease permeability or otherwise modify the properties of the foundation or remedy defects • grout records
Properties of construction materials	☐ For earthfill, filter materials, pervious materials, transition materials and rockfill: • approximate locations of the borrow areas and quarries and estimated volumes of reserves of each material • numbers of exploration holes, pits and excavations in each proposed borrow area and quarry • summaries of results of laboratory tests for determining the engineering properties of each type of material, and of results of geological examinations and tests on rock materials, indicating the number of test samples and extreme as well as average values ☐ For concrete aggregates, if not obtained from sources of materials previously described: • approximate locations of proposed sources and estimated volumes of reserves of aggregates • number of exploration holes, pits and excavations in each proposed source • summaries of results of laboratory tests for determining the engineering properties of each type of material, and of results of geological examination and tests on rock materials, indicating the number of test samples and extreme as well as average values
Testing	☐ Testing program to ensure design parameters are achieved during construction
Embankment design and stability analyses	☐ Details of each design case considered ☐ Summaries of the properties of the material in each zone of the embankment and the foundation adopted for the stability analyses including density and shear strength parameters both as placed and saturated as appropriate and the justification for the adopted properties ☐ Basis for the estimates of the pore pressures in the impervious zones adopted for each design case examined

Category	Checks
	☐ Particulars of the methods of stability analyses used, formulae used in the analyses or references in technical literature, and the upstream and downstream water levels used in each design case ☐ Minimum values of the factor of safety obtained for each design case and the locations of the critical slip surface for each case drawn on a cross-section of the embankment or results of any other method of assessment of the stability of the embankment
Stress and stability analysis of concrete structures and other structural components	☐ Stability methods adopted ☐ Uplift criteria ☐ Details of each design case considered ☐ Summaries of the properties of concrete and foundation materials adopted for the analyses ☐ Assumptions as to loads, including combinations of loads due to water, dead weight, uplift, earthquake, silt or other solids and temperature change when appropriate ☐ Limiting stresses ☐ Methods of analysis ☐ Results of any structural model studies ☐ Results of analyses including safety factors and stresses in the structure and foundation or the results of any other method of assessment of the stability of the structure
Instrumentation	☐ Layout and description of embedded instruments and other devices installed to observe the behaviour of the works including, as applicable, pore pressures and uplift, leakage, embankment settlements, foundation deformations, alignment, deflections, stresses, strains, temperatures, contraction joint openings, seismic and mechanical vibrations ☐ Pore pressure and uplift values assumed for the design of the associated structures at instrument locations ☐ Recommendation for frequency of observations/readings ☐ Which failure modes instrumentation are monitoring for and their relevant trigger levels
Construction specifications	☐ Clauses dealing with: • foundation treatment and grouting • sources of construction materials • methods of treatment and placement of materials • acceptability criteria ☐ Inspection and testing programs ☐ Construction schedule and sequence of construction operations, if specified ☐ Stream diversion plan with respect to safety during construction
Technical review	☐ Documentation of technical review process and outcomes
Certification	☐ Minimum certification requirements are defined in the DSC for the referable dam

D-2 As-constructed report

Category	Checks
General	☐ How the original design intent and objective has been met or otherwise ☐ Designed and actual construction methods (including results of testing) ☐ Describe the expected performance and condition of the structure ☐ Necessary changes that have been made during the design and construction of the dam and how the original design intent has been maintained ☐ Items requiring surveillance during first filling and subsequent operation with appropriate frequencies ☐ Key contractors and personnel ☐ Protocols and storage of data and samples[21]
Reference to design report contents and any amendments	☐ Referenced as required ☐ Any design changes made during construction (with details of the decision)
Construction documentation[22]	A complete record of the construction is maintained and compiled to assist in determining solutions to any safety problem that may arise during the life of the dam. This record is to be a component of, or referenced from, the design report. As a minimum, this record should include: ☐ construction processes ☐ foundation mapping ☐ foundation treatment ☐ material preparation and placement ☐ filters, cut-offs ☐ core materials ☐ joint preparation ☐ material test results and comparison with assumed design parameters[23] ☐ instrumentation data including precise instrument locations and initial instrument readings ☐ construction inspection reports ☐ systematically compiled and comprehensive photographs and/or videos of the construction, with particular coverage of significant events ☐ Description of quality control practices adopted during construction ☐ Description of any incidents that occurred during construction
As-constructed drawings	☐ As-constructed drawings indicating the actual lines, levels and dimensions to which the structure is built ☐ Drawings highlighting where as-constructed outcomes differed from the original design ☐ Drawings are sufficiently detailed so that, in the event of any safety concerns, information can be quickly obtained to resolve
Technical review	☐ Documentation of technical review process and outcomes

[21] Safe storage of documentation, data and test samples is vital. Where information such as geological core is required to be retained, then this should be undertaken in a manner that ensures the core remains useful for further reference or investigations.
[22] A construction report can be a separate document, especially for large or complex structures, and not necessarily prepared by the design team. If this is the case, reference to the construction report should be made and a summary prepared from it.
[23] Test results should be presented in such a way that they conform to recognised standards. The documentation provides the designer with the information required to confirm design criteria are being met and will be valuable for future design reviews (such as safety review, special inspections or future upgrade works).

Category	Checks
Certification	☐ Minimum certification requirements are defined in the DSC for the referable dam (see also Appendix K)

Appendix E Operation and maintenance program checklist

E-1 Development and implementation

Table 21 Development and implementation of an operation and maintenance program

Aspect of program	Description
Clearly defined, functional, established and documented operations procedures	☐ What are the roles and duties? ☐ Who is responsible for completing the duties? ☐ When and how often must they be completed? ☐ How will they be evaluated, documented, and quality checked? ☐ How and to who will issues be escalated and addressed? ☐ What events could trigger the need for intensive surveillance?
Clear description of range of operating criteria	☐ Operating criteria are known and described ☐ The dam is operated within these criteria ☐ The dam is maintained so that it can perform within established criteria ☐ Regulatory requirements are met
Is a procedure required?	Prior to determining whether a procedure needs to be developed, consider the consequences of incorrect or no function: ☐ What costs would be incurred? ☐ What resources would be required to remedy the situation? ☐ What time would it take to remedy the situation? ☐ What are the safety implications? ☐ What are the environmental implications? ☐ If today was my first day in the job, would I know: • Enough about the organisation and its different functional areas to perform the required tasks? • With whom I should communicate and what inputs I need, where they come from, how I access them, and whether I need someone's assistance? • What to do with the output of my job and to whom I should direct it? • If the adverse consequences of performing the task incorrectly are minimal, the task may not need to be documented?
Implementation	☐ Define responsibilities for actions critical to the safety of the dam ☐ Identify procedures for particular daily activities and ensure that these activities are done safely and consistently ☐ Ensure appropriate people are notified when unforeseen or unusual events occur
Equipment work instructions	☐ Work instructions detail location of the equipment, the way in which equipment should be operated and outline the steps involved in performing a task. • For example, a work instruction may be developed for the use of the gantry crane for placement of bulkheads gates
Maintenance schedules	☐ Maintenance schedules detail the asset, description of task, frequency of maintenance and special requirements for servicing and maintaining the equipment and instruments. • For example, a maintenance schedule should be developed for maintaining and servicing all mechanical and electrical equipment

Aspect of program	Description
Equipment data sheets or manufacturer's manuals	☐ Technical information needed for maintenance, repair, and overhaul of equipment.
Documentation control and availability	☐ Documentation should be complete, accurate and up to date and cover all procedures, facilities and equipment. ☐ Controlled documentation that is readily available to, and understood by, those responsible for the implementation of surveillance activities • Copies must be easily accessible to all dam operators for day-to-day use on site, especially where dam operations are controlled and operational decisions are made (particularly for flow control) • For procurement and administrative reasons as well as emergency situations it is advisable to hold a copy in the dam owner's office. ☐ Regularly reviewed and updated to reflect changes in processes or requirements, to allow improvements in the effectiveness of surveillance activities, and to ensure that the procedures remain effective over time. ☐ Equipment data sheets or manufacturer's manuals needed for maintenance, repair, and overhaul of equipment. ☐ As a minimum, program should be reviewed annually and updated if needed.
Recording and work assignment system	☐ Checklists detailing who is responsible for work, supervising responsibilities, record keeping requirements, etc. ☐ Logs of details of the work, date and time to complete, etc. ☐ Relevant document storage and backup facilities.
Record actions and events	☐ Provide a permanent record of actions taken to operate the dam ☐ If action results in an undesirable outcome, program may assist in determining the reason so that amendments can be made ☐ Enable reviews of an organisation's operations to improve efficiency

E-2 Issues to consider

Not all of the following procedures are applicable to each dam. The requirement for individual procedures needs to be decided case-by-case, i.e. failure consequence.

Table 22 Checklist of issues to consider for an operation and maintenance program

Category	Issue	Reason for inclusion
Personnel training and procedural issues	☐ Operator training, including site and task specific training (e.g. confined space)	To ensure suitably qualified and experienced people are available to operate the dam
Critical operating procedures	☐ Normal operating criteria	To ensure the dam is operated and maintained in accordance with known operating limits
	☐ Test operation of critical equipment	To reduce the risk of the equipment not operating as planned. Such a procedure should provide for:

Category	Issue	Reason for inclusion
		• an annual pattern of test operation of gates or other crest control devices[24] • regular testing of backup power supplies • regular testing of sump pumps • regular testing of communications
	☐ Pump operation plan for water harvesting that includes monitoring	To minimise the risk of overtopping of the dam through over-pumping
	☐ Notification of spillway discharge	To ensure emergency planners are aware of significant spillway discharges during flood events
	☐ Spillway gate flood operations	To ensure spillway operations proceed in accordance with agreed procedures which maximise the safety of the dam and minimise disruption to flood affected communities. Items to include: • water level monitoring procedures • discharge control and flood release protocols including monitoring and warning of areas of impact prior to releases (for campers, etc.) as required in the emergency action plan • coordination of releases with other dams or downstream tributaries (where appropriate) • communication security and failsafe procedures • reference to EAP and/or flood mitigation manuals
	☐ Bulkhead gate installation, penstock drainage, trash screen removal and installation	To ensure the safety of operations and maintenance personnel
	☐ Confined space access	To maximise the safety of people in and around the dam
Monitoring and surveillance	☐ Water level monitoring procedures and the monitoring of inflow events	To ensure dam hydrology and spillway performance can be reviewed
	☐ Instrumentation surveillance and data recording	To ensure appropriate monitoring and surveillance is carried out and the data are rapidly analysed and reviewed
	☐ Owners routine dam safety inspection including checklists and reporting requirements	To ensure routine dam safety inspections are carried out consistently and to appropriate standards and frequencies
	☐ Dam safety annual inspections (if required by safety conditions)	To ensure inspections are carried out consistently and to appropriate standards and undertake works as recommended
	☐ Dam safety five yearly comprehensive inspection (if required by safety conditions)	To ensure inspections are carried out consistently and to appropriate standards and undertake works as recommended

[24] This should include test cracking gate under full load and raising and lowering gate under no load over full travel.

Category	Issue	Reason for inclusion
	☐ Requirement for inspection before, during and after flood events or after seismic events	To ensure the emergency action plan and any remedial works are triggered before, during and after such events
	☐ Inspection, testing and maintenance of mechanical and electrical equipment	To ensure mechanical and electrical equipment can be operated as designed whenever necessary
Log book	☐ Maintenance of dam log book	To ensure operations and maintenance activity and associated decisions are recorded
	☐ Log book should include major events	To record major and exceptional events and conformance with procedure such as: • equipment testing • major planned and unplanned maintenance and special one-off jobs at the dam • testing of gate functions • painting programs • EAP activation, flood discharges and reservoir levels • incident details • reports dispatched and received • notification of receipt of changes to documentation

E-3 Contents checklist / template

Table 23 Checklist of operation and maintenance manual contents

Category	Checks
Preliminary pages	☐ cover sheet ☐ title page ☐ table of contents ☐ revision sheet ☐ any necessary certification and/or verification required by the dam owner ☐ an aerial photo of the dam if possible
Formatting	☐ ensure hardcopies and/or electronic copies are easily accessible and easy to make revisions, additions and updates ☐ start each procedure on a new page ☐ use a standardised format for each procedure ☐ give each procedure a title that is short and adequately identifies the task ☐ use lists rather than narration to outline instructions and information whenever possible
Areas of responsibility	All areas of responsibility in the administration, operation and maintenance of the dam should be clearly indicated. Some of the operational aspects of dam ownership and operation that should be addressed include: ☐ operation of equipment at the dam ☐ reservoir inflow and flood forecasting ☐ authorising spillway flood releases ☐ authorising irrigation releases

Category	Checks
	☐ authorising emergency releases ☐ recording reservoir data ☐ routine inspection ☐ maintenance ☐ modification ☐ correct method of opening and closing guard gates ☐ dam safety and surveillance
Operating personnel responsibilities	☐ The operating personnel responsibilities should be specifically identified and should include regularly scheduled duties personnel are required to perform
Organisational arrangements and procedures	☐ Administrative and operational relationships between the various operating and end user organisations should be detailed, both formal and informal agreements should be referenced ☐ Organisational arrangements in the form of flow charts can be beneficial, for example, agreements on allocation of responsibility for operation ☐ Write procedures clearly and concisely. ☐ Each procedure should identify the step-by-step actions or groups of actions in sufficient detail to describe the task in a logical manner
Appendices / attachments	☐ Where appropriate, include drawings, sketches, graphs, manufacturer's instructions, marked photographs, numbering of valves and switches, etc. in appendix or text to increase understanding and reduce the chance of error ☐ Where appropriate, if a procedure requires a form or forms to be filled out to confirm that a task described in the procedure was undertaken, copies of the form should be attached to the procedure

E-4 Level of attendance

The owner should ensure that the level of operator attendance for the dam is appropriate for the consequence category of the dam as well as the:

- ☐ consequences of the dam failure
- ☐ proximity of the population at risk and the available warning time
- ☐ remoteness of the dam and ease of access during flood events
- ☐ reliability of remote sensing and transmission of warning trigger data to offsite control centres
- ☐ availability of backup operations personnel
- ☐ other activities conducted at or near the dam by the dam operator
- ☐ need to trigger emergency action plans
- ☐ complexity of gate operations and associated need for skilled operators
- ☐ preparedness of operations staff
- ☐ inspection post seismic or flood events compared with monitoring as flood event evolves

For example, the level of attendance for a particular dam with a Category 1 failure impact rating that has simple operating requirements, a distant population at risk and a long warning time, may involve regular (i.e. every couple of days) visits and inspections. In contrast, a dam with a Category 2 failure impact rating with complex operating requirements and a high population at risk in close proximity may require qualified dam operators in residence and/or an appropriate electronic surveillance, control, and communication system. The reliability of electronic systems should be considered in determining the level of attendance during flood events.

Further, a dam owner may wish to assign the operation of a dam to a nominated operator (the dam owner still retains responsibility for dam safety). If this occurs, the dam owner should ensure the nominated operator:

- ☐ is aware of the potential damage which could result from the different modes of failure relevant to the dam
- ☐ is aware of the designers operating criteria and operates the dam in accordance with the operation and maintenance program
- ☐ is aware of what constitutes an abnormality
- ☐ participates in dam safety inspections and the surveillance program
- ☐ is empowered to initiate the emergency action plan should the need arise

Appendix F Dam safety engineering inspections checklist

This appendix considers annual and special inspections for physical integrity of the dam and comprehensive inspections that assess the overall safety management of the dam. It describes the information about the structure that needs to be gathered during the inspection, gives examples of the defects and problems that may be encountered, provides guidance on the formulation of recommendations on remediation and repair strategies and reporting.

This advice contained in this appendix is intended to describe a minimum standard of inspection and reporting. It would be expected that engineers experienced in the management and performance of dams would provide a dam owner with comment and insight into the issues that are influencing the safety of a dam and advice on the management of the dam as an asset.

Common causes of dam failure are included here, however the list is not exhaustive. Each dam is different and may present its own unique problems. Anyone who inspects a dam should be aware of any unique or unusual characteristics, have knowledge of a wide range of potential problems and look for all potential modes of failure.

Where a dam contains unusual or particularly complex features the inspection and report should reflect additional emphasis on these aspects.

F-1 Summary of inspections

Table 24 Summary of dam safety engineering inspections

Category	Routine inspection	Annual inspection	Comprehensive inspection
DSC	Not specified (but informed by DSC relating to operation and maintenance)	Specified	Specified
Purpose	To check for expected behaviour and identify any deficiencies of the dam through visual observation.	To identify physical deficiencies of the dam by visual examination and review of surveillance data against prevailing knowledge.	To undertake a full and thorough inspection of the dam, review of surveillance data and the dam owner's whole dam safety management program.
Inspectors	The dam owner or field operators as part of their normal duties at the dam who are experienced and trained to recognise deficiencies in dams.	Suitably qualified and experienced personnel to undertake inspections that require technical evaluation and interpretation. It may be necessary to involve a team of engineers to cover all necessary expertise.	
Recommended Frequency[25]	Daily to monthly, depending on consequence category: • Very Low to low: monthly • Significant: twice-weekly to weekly	Annually (as per DSC) or more frequent	Five yearly (as per DSC) or more frequent

[25] Subject to the advice of a suitably qualified and experienced RPEQ, a reduction in the frequency of inspections may be considered for dams that are well monitored, in remote locations, when there is an extended period of low storage level, or if the consequences of reduced frequency are determined to be low. This is subject to the regulatory requirements specified in the dam safety conditions.

Category	Routine inspection	Annual inspection	Comprehensive inspection
	• High: daily to tri-weekly • Extreme: daily		
Inspection checklist	• Inspections should follow a checklist of items. • The checklist for each dam / inspection should be tailored to the specific nature, features, characteristics, identified credible potential failure modes and performance history of the dam. • Inspection checklists should be developed in conjunction with a relevant technical specialist(s). • The checklist should not be too prescriptive; the inspector should be encouraged to inspect other areas and features that may have a bearing on dam safety. This principle should be emphasised in the training of inspectors. • Photographs of general and specific features from repeatable locations provide an effective long-term record of inspection observations. Video recording of features or unusual events can also be particularly valuable.		
Reporting	Dam owner's internal checklist, reporting and documentation (as per operation and maintenance manual).	• Dam status and all defects or unsafe conditions • For any defects describe a strategy for taking remedial action, including preliminary costing and, if several defects or conditions are found, prioritisation of actions • Identify personnel who are accountable for progressing recommendations and a check made to ensure works are carried out in future	Assess and document all aspects of the dam safety management program: • ongoing appropriateness of the consequence assessment • dam status and all defects or unsafe conditions • for any defects describe the strategy for taking remedial action, including preliminary costing and, if several defects or conditions are found, prioritisation of actions • deficiencies identified in the dam safety management program and its documentation • a strategy for overcoming the deficiencies, including prioritisation of actions if several deficiencies are identified • identify personnel who are accountable for progressing recommendations and a check made to ensure works are carried out in future • dam safety training completed by the dam owner personnel since last comprehensive inspection
Additional notes	Routine inspections should be carried out by someone involved in the day-to-day running of the dam. Much of the inspection and observation should be incorporated in the daily work routine of such	The inspection should assess all physical aspects of the dam. An annual inspection requires preparation of checklists, mechanical equipment and access (i.e. confined and difficult areas).	Guidance on these inspections follows in subsequent checklists in this appendix**.** This inspection should incorporate: • an annual inspection • test operation of all equipment and systems

Category	Routine inspection	Annual inspection	Comprehensive inspection

	officers via the operation and maintenance manual:
	• timing and frequency of inspections
	• who should be involved
	• reporting requirements, including for any abnormal observations
			• when considered necessary, major function checks and maintenance inspections. For example:
			  • spillway apron dewatering
			  • conduit dewatering
			  • driver inspection of intake works
			  • conduit video inspection

F-2 Annual inspections

Table 25 Annual inspections checklist

Category	Description
Description	Annual inspections to identify physical deficiencies of the dam by visual examination and review of surveillance data against prevailing knowledge.
Personnel	For safety reasons it is advisable to have two or more personnel on each inspection. Workplace practices may require additional personnel for confined spaces, heights, etc.

Recording Inspection Observations	Inspections require the accurate location, recording and photographing of areas of interest. The objective is to permit observation and comparison of the state of a dam through time. It is necessary to record:
	☐ extent of such areas (i.e. length, volume, width and depth or height)
	☐ a brief description of any anomalous condition, i.e.:
	  • quantity/quality of drain outflows, seepage and its source(s)
	  • location, type and extent of corrosion or deteriorated concrete
	  • location, length, displacement and depth of cracks
	  • extent of moist, wet or saturated areas
	  • changes in conditions

Areas for Inspection: Monitoring	A surveillance evaluation should be integrated into an annual inspection. The surveillance evaluation report should: ☐ assess the available pressure, movement and seepage monitoring data by analysis of the impact (if any) of all monitoring results ☐ assess the seepage from the storage (a plan should be provided showing position, quantity, and quality of seepage) ☐ report on the recent movement survey for the dam ☐ report on the foundation and embankment pressures being experienced by the dam (a plan showing the position and purpose of the individual piezometers should be provided) An assessment should be made of the behaviour and presence of seepage, movement and pressure monitoring being carried out at the dam.
Areas for Inspection: Operation	A review of the way in which the dam has been operating since the last annual inspection and how it is intended to operate until the next annual inspection is carried out. The report should comment on the impacts of the operation on dam safety including rainfall records, release records, record of flows in the spillway and maintenance and repairs carried out. It is appropriate to report on the compliance with operation and maintenance program and assess relative to good practice. The following areas may also be considered in an inspection:

Category	Description
	☐ a test operation of all equipment ☐ evaluation of all surveillance data ☐ major function checks and maintenance inspections. For example: • spillway apron dewatering • conduit dewatering • diver inspection of intake work • conduit video inspection ☐ the foundations, abutments, and reservoir rim should all be inspected regularly ☐ an inspection should be made far enough downstream to ensure that there are no problems that affect the safety of the dam (such as scour / erosion potential) ☐ the reservoir surface and shoreline should also be regularly inspected to identify possible problems. Whirlpools can indicate submerged outlets (Large landslides coming into the reservoir could cause waves overtopping the dam or water quality problems, suspect areas should be quantitatively monitored.) ☐ upstream development and other catchment characteristics, which might influence reservoir water or silt inflows, should be noted in major inspection reports to anticipate possible problems or modifications in the dam ☐ downstream development in flood plains should also be regularly assessed

F-3 Comprehensive inspections

Table 26 Comprehensive Inspections Checklist

Category	Description
Description	Comprehensive Inspection focuses on the dam safety management program and documentation for the dam. It is an assessment of the appropriateness, the effectiveness and application (including the owner's response to recommendations) of the dam safety management program and documentation for the dam including: ☐ Operation and Management program ☐ EAP ☐ Data Book ☐ Design Report/Safety Review ☐ Surveillance and inspection program and records The comprehensive inspection should incorporate the annual inspection for that particular year (Table 25). This assessment should take into account the safety conditions for the dam.
Personnel	A suitably qualified and experienced RPEQ must carry out comprehensive inspections. More than one engineer may be required. In assessing and reporting on these aspects of the dam the inspecting engineer needs to assess the current dam safety management program and documentation for the dam against that required in the DSC and this guideline.[26]
Operation	It is appropriate to report on the compliance with the operation and maintenance program. It is also desirable to assess the program relative to good practice and the requirements of this guideline.
Inspection	Comprehensive inspections should incorporate a review of the annual inspection program and annual inspection records for the dam as well as evaluating the dam owner's response to the conclusions and recommendations from inspection reports.

[26] The dam owner should consider the merits (or otherwise) of engaging an independent RPEQ to undertake an inspection (as opposed to a dam owner's RPEQ).

Category	Description
Addressing previous and ongoing recommendations	Comprehensive inspections should incorporate a review of progress in addressing previous recommendations from prior investigations. This includes identifying those personnel who are accountable for progressing the recommendations.
Emergency Preparedness	Comprehensive inspections should incorporate an assessment of the emergency preparedness of the owners and operators of the dam. The owners EAPs and documentation should be assessed relative to the requirements of the EAP Guidelines (RDMW, 2023).

F-4 Special inspections

Table 27 Special Inspections Checklist

Category	Description
Description	A special inspection is recommended in the following cases regardless of the regular inspection schedule: ☐ whenever a concerning specific defect is observed in the dam ☐ during and immediately after the first reservoir filling or augmentation ☐ during and after a period of rapid draw down ☐ before a predicted major rainfall, or filling ☐ during (if possible) and after heavy flooding (or severe windstorm) ☐ following an earthquake, sabotage or overtopping; immediately and then regularly for several months to detect any delayed effects

F-5 Report preparation

Table 28 Preparation of an Inspection report checklist

Category	Description
General	The aim of the annual, comprehensive and special inspection reports is to document the findings of each inspection and to detail the required actions to be taken by the owner as a result of the inspection. These reports should be presented in a precise and readable form and be signed by a relevant and nominated person. Detailed data that is used to assess aspects of the dam should be attached as appendices and not included in the body of the reports. Captioned and dated photographs should be used extensively in the reports.
Information on the dam	The inspection report should include the following background information on the storage: ☐ ownership details including any change of owner ☐ details of the safety conditions for the dam ☐ a brief description of the dam including: • location (latitude and longitude) • nearest town • principal dimensions and design water levels • construction type • current water levels • history, including inspection history ☐ a thorough and critical review of: • Data book • Operation and maintenance program

Category	Description
	• EAP • Operation and maintenance plans and log books for the dam • Safety Review status for the dam
Documenting the Inspection	The inspection report should address the preparation for the inspection in the following areas: ☐ outline of the preparation for the inspection ☐ the preparation of checklists ☐ data gathering ☐ special provisions (i.e. drainage of stilling basins or aerial inspection) ☐ review of previous inspection, including identification of action items and their current status ☐ review of operation and design information ☐ review of surveillance and monitoring data ☐ composition of the inspection team including: • details of the inspecting engineer or consultant including RPEQ reference as appropriate • details of owner's representative • details of operations staff involved in the inspection ☐ photographic record of the inspection. All photographs should be dated and annotated to reflect the features recorded
Conclusions and recommendations	Each inspection report must include an overall assessment of the state of the dam and recommend action to remedy defects or ensure continued appropriate management practices. These should include: ☐ comments on the implementation of recommendations from previous reports ☐ conclusions on the safety of the dam ☐ recommendations on additional evaluation, investigation or testing ☐ recommendations on rehabilitation, repair and operational modifications relating to issues that were noted during the inspection ☐ a summary sheet outlining the recommended action, the responsible person and the appropriate time frame ☐ the dam owner should sign the report and endorse the recommendations prior to circulation If observed defects are considered serious, advice from a suitably qualified and experienced RPEQ should be sought. Depending on the significance of the potential consequences, the advice should be documented in the report.
Circulation	Copies of the inspection report should be circulated to the following: ☐ the dam owner ☐ the individual responsible for operation of the dam ☐ copies of the comprehensive inspection report should also be circulated in accordance with the safety conditions for the dam
Sample Contents Page	☐ General ☐ Inspection team and signature page ☐ Conclusions and recommendations ☐ Information on the dam ☐ Inspection ☐ Monitoring ☐ Review of data book, operation and maintenance program and EAP (for comprehensive inspections) ☐ Embankment (if needed) ☐ Spillway ☐ Outlet Works (if needed)

Category	Description
	☐ Concrete (if needed) ☐ Weir ☐ Captioned and Dated Photographs

F-6 Requirements for specific elements

This section outlines defects observed in each of the following elements of dams.

- Earth embankments
- Spillways and bywashes
- Discharge control structures and outlet works
- Concrete dams
- Weirs

Owners should address the requirements for each element of their dam.

F-6-1 Requirements for earth embankments

Table 29 Checklist for requirements for earth embankments

Category	Description
Description	There are several types of dam construction included in the earth embankment category: • homogeneous compacted earth fill dams • homogeneous compacted earth fill dams with toe drains • zoned compacted earth fill dams • diaphragm rockfill dams • central core rockfill dams • sloping clay core dams These dams generally include an impermeable zone of clay fill or concrete and a supporting rock or earthfill zone to provide strength. Filter zones provide internal drainage of the structure. These dams can fail by: • internal erosion of embankment material by seepage and transport of embankment material through sinkhole cracks, animal burrows, compaction flaws in embankment, compaction flaws in conduit surrounds, flaws in the abutments (known as a piping failure), incompatible filter / fill materials • bulk removal of material and loss of height and section through slumping, beaching, tree roots, gully and sheet erosion • overtopping
Report	The report should document the inspection by including comments on the condition of the dam embankment with regard to: • erosion / scour • vegetative growth • seepage • slump formation • beaching • deterioration of rip rap • cracking Following are some illustrations of deficiencies to look for when inspecting embankment dams.

Figure 2 Illustration of deficiencies associated with embankment dams: seepage

- A water flow or sand boil on the lower portion of the downstream slope or toe area, especially at the groins
- Leakage around conveyance structures such as outlet works, spillway conduits, or penstocks
- Blocked toe drains and relief wells
- An increase in the amount of water being released from toe drains and relief wells. (Remember to take into account changes in the reservoir level, or the effects of rainfall on the downstream face and abutments)
- Wet areas or area where the vegetation appears greener or more lush on the embankment slope or toe area
- Turbidity or cloudiness of the seepage

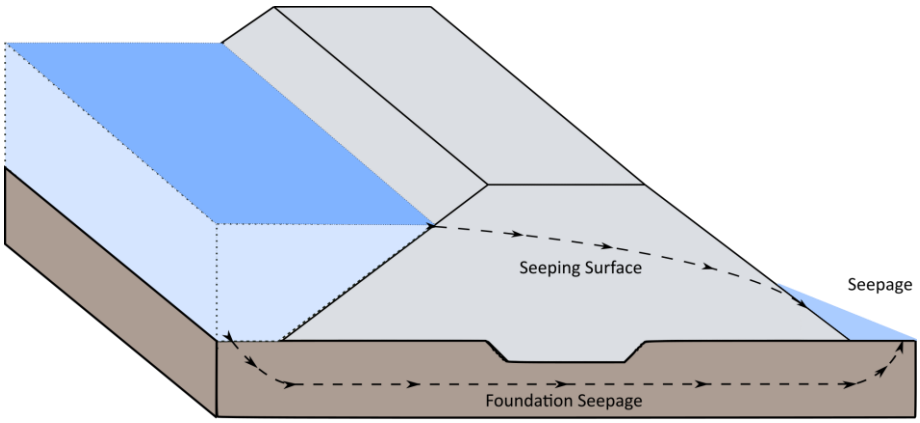


Figure 3 Illustration of deficiencies associated with embankment dams: cracking

- Desiccation Cracking: A random honeycomb pattern of cracks usually found on the crest and the downstream slope
- Transverse Cracking: Cracks that are perpendicular to the length of the dam usually found on the crest
- Longitudinal Cracking: Cracks that are parallel to the length of the dam. Longitudinal cracks may be associated with stability problems in the slopes

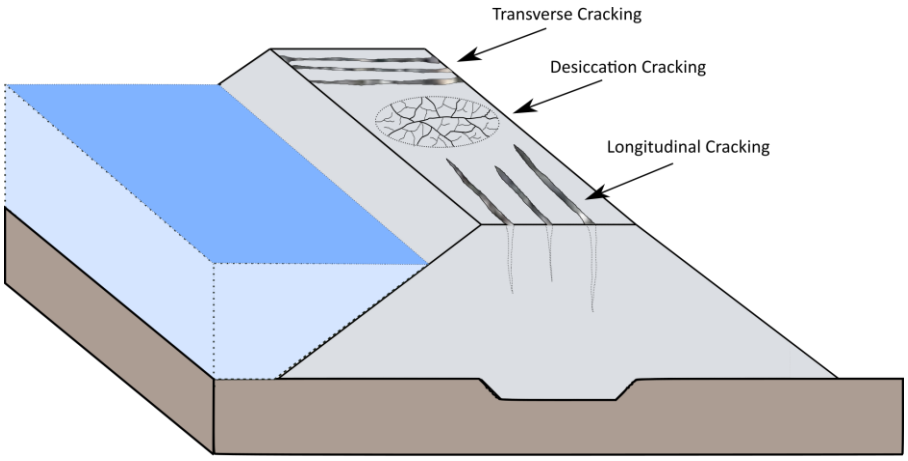


Figure 4 Illustration of deficiencies associated with embankment dams: instability

- Slides on the upstream and downstream slopes
- Bulging, especially at the toe of the dam
- Misalignments in the crest and embankment slopes found by sighting along fixed points

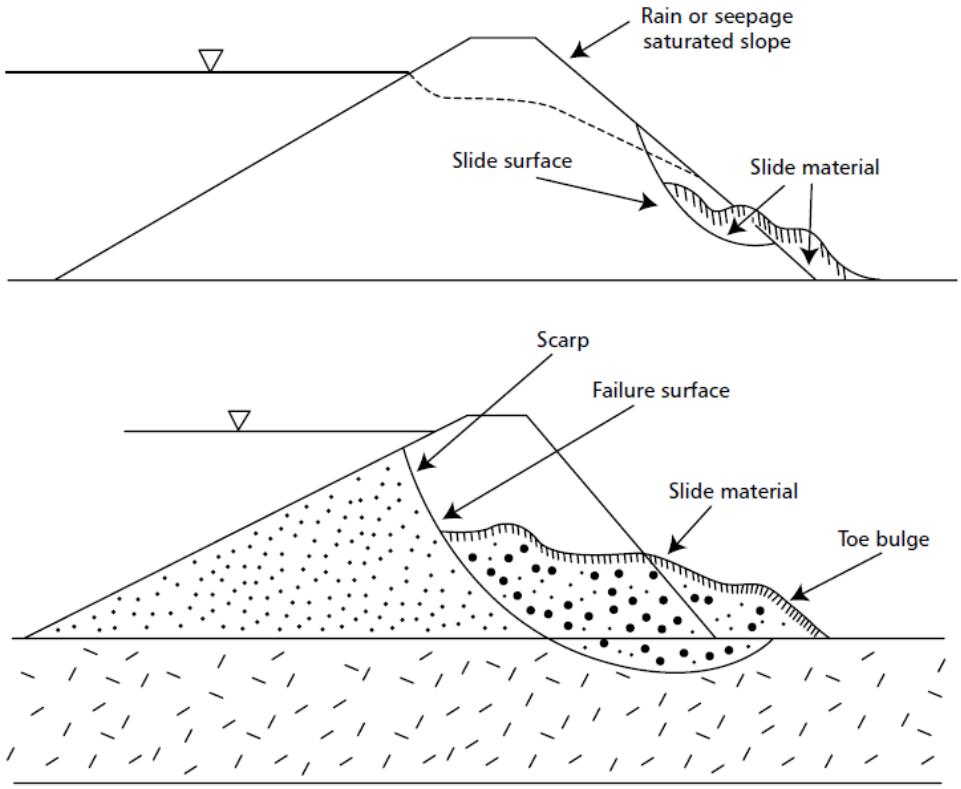


Figure 5 Illustration of deficiencies associated with embankment dams: depressions

- Sinkholes found by checking and probing each depression. Remember, sinkholes have steep, bucket-like sides while minor depressions have gently sloping, bowl-like sides. These are initiated by settlement or migration of materials in the embankment.

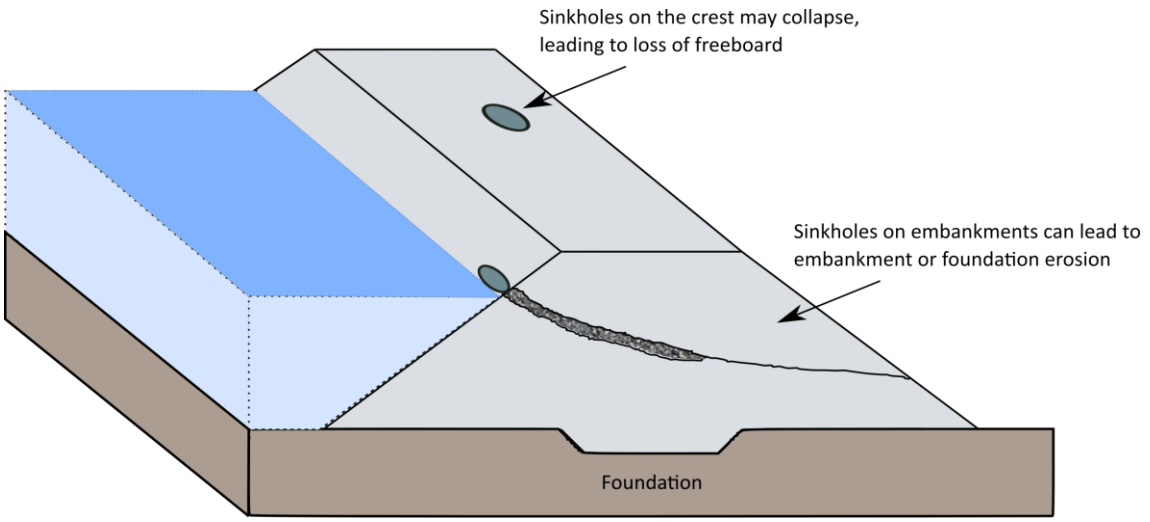
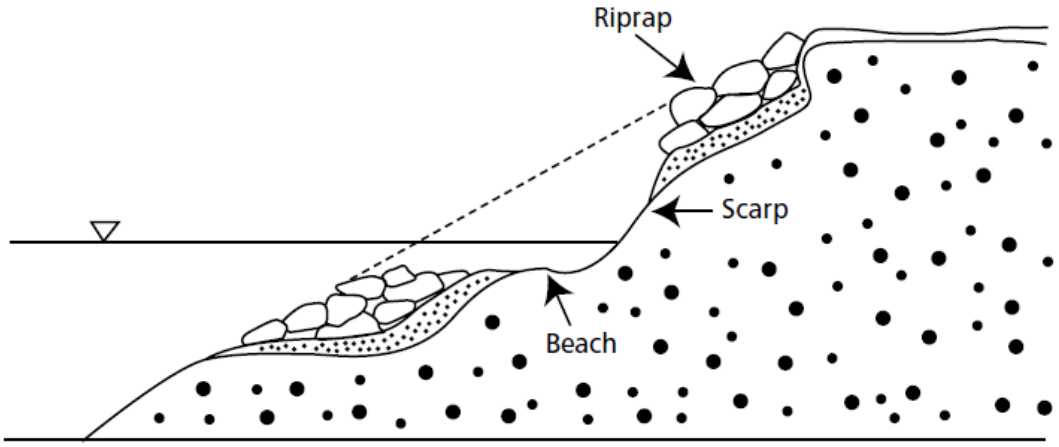


Figure 6 Illustration of deficiencies associated with embankment dams: maintenance concerns

- Inadequate Slope Protection: Check for bald areas or areas where the protection is sparse or damaged
- Surface Runoff Erosion: Check for gullies or other signs of erosion. Make sure to check the low points along the upstream and downstream shoulders and groins since surface runoff can collect in these areas
- Inappropriate Vegetative Growth: Check for excessive and deep-rooted vegetative growth, especially trees that are within 6m of or on the embankment
- Debris: Check for debris on and around the dam, especially debris that could clog or choke outlet-works or spillway inlets
- 'Animal Burrows': Check for damage caused by burrowing animals and termite mounds



F-6-2 Requirements for spillways and bywashes

Table 30 Checklist for requirements for spillways and bywashes

Category	Description
Description	Spillways are designed to withstand high flows that have the capacity to overtop and erode embankments and to undermine concrete and rockfill structures. Spillways that are not able to adequately contain the extreme flows through the dam may contribute to failure of the dam by overtopping. Spillways can fail by erosion of the structure from downstream, by erosion that results from failing to contain the flows within the spillway section, by erosion of support for any structural elements through weaknesses and by uplift pressure under the spillway slab. Spillway flow needs to be directed back to the stream safely. Poorly directed flows through the spillway can erode the toe of the dam embankment and initiate failure. Poor alignment and spillway profile is also a potential problem. Spillways and bywashes should be inspected immediately after spill events to monitor any damage and to determine erosion and scour patterns. Comments on damage sustained after spill events should be included in the surveillance report.
Report	The surveillance report should include an assessment of, and recommendations on the dam spillway or bywash with regard to: ☐ erosion of the downstream slope ☐ slumps in sidewalls

Category	Description
	☐ potential for blockages caused by fencing, debris build up, or vegetative growth ☐ profusion and integrity of grass cover to the downstream slope ☐ blockages in the underdrainage of concrete spillways A recommendation for any remedial works to ensure the spillway and bywash is capable of fulfilling its function.

F-6-3 Requirements for concrete dams

Table 31 Checklist for requirements for concrete dams

Category	Description
Description	Possible causes of concrete dam failure include: ☐ overturning or sliding due to erosion of the foundation or abutments during overtopping resulting from inadequate freeboard ☐ abutment or foundation failure due to overstressing ☐ structural failure of concrete unable to sustain imposed loads ☐ Uplift pressures within the joints of spillway floor slabs
Inspection and report requirements	When inspecting the crest, faces and galleries and gallery drains of concrete dams and weirs any of the following defects should be noted, documented and photographed and an assessment made of any changes in their severity since last inspection: ☐ seepage and leakage ☐ cracking concrete deterioration ☐ disintegration ☐ spalling ☐ efflorescence ☐ drummy concrete ☐ popouts ☐ pitting ☐ scaling ☐ surface defects ☐ displacement ☐ misalignment ☐ differential movement in cracks ☐ conditions of joints When inspecting the areas upstream and downstream of a concrete dam and weirs any of the following defects should be noted, documented and photographed and an assessment made of any changes in their severity since last inspection: ☐ cracking, bulges and slides ☐ sinkholes ☐ wet areas ☐ lush vegetation ☐ erosion of the abutment areas following spills ☐ localised scour

F-6-4 Requirements for weirs[27]

Table 32 Checklist for requirements for weirs

Category	Description
Description	Weirs are designed to withstand overtopping by all river flows. Consequently, weirs need to not only be stable and safe against the hydraulic forces applied and to retain water but must also be able to retain integrity in an erosive environment. Whilst a regular time-based inspection regime is appropriate, it is more important to inspect and document the deficiencies and remedial requirements after each river flow event.
Common causes of failure of weirs	☐ excessive and progressive downstream erosion, both from within the stream and through lateral erosion of the banks ☐ erosion of inadequately protected abutments ☐ hydraulic removal of fines and other support material from downstream protection (gabions and aprons) resulting in erosion of the apron protection ☐ deterioration of the cutoff and subsequent loss of containment ☐ additional aspects specific to concrete, rockfill or steel structures
Inspection and report requirements	☐ details of any testing of flow control structure ☐ adequacy of flow control structure ☐ Mechanical / electrical equipment ☐ disruption to the downstream banks - as an indication of erosion ☐ water levels in the downstream pond - as an indication of seepage ☐ deepening of the downstream pond as a result of erosion ☐ erosion of abutment protection ☐ corrosion or other deterioration of the sheetpile or other cutoff material ☐ cracks and open construction joints in the downstream apron - as an indicator of hydraulic removal of fines and also uplift and deformation ☐ magnitude of each river flow event since last report ☐ comment on the relative upstream and downstream water levels ☐ any repairs and maintenance resulting from each flow event ☐ comments on the operation of mechanical equipment (i.e. gates, bags) during flow events

F-6-5 Requirements for discharge control structures and outlet works

Table 33 Checklist for requirements for discharge control structures and outlet works

Category	Description
Description	Dams with inadequate and failed outlet pipes experience loss of serviceability by emptying or by being unable to release as required. Leaking along the dam/conduit interface and from the outlet conduit are common sources of internal erosion failure. Deterioration and failure of the outlet structure, collapse or deterioration of the outlet pipework or valves or failure of associated control systems could cause the loss of outlet capability.
Discharge conduit	The discharge conduit should be inspected internally if possible (proper regard for workplace health and safety requirements is essential). If access to the conduit is not possible, video inspection should be carried out. The following aspects of the conduit should be assessed and reported on: ☐ sources of leakage should be photographed, marked on a plan and the flow rate estimated

[27] Typically a weir does not have PAR and is not a referable dam.

Category	Description
	☐ misalignment should be measured, and marked on a plan ☐ deterioration of pipe and joint material should be photographed ☐ fouling of the intake structure ☐ extent and depth of corrosion
Valves	All valves should be exercised at each inspection and an assessment made on the condition, the ease of operation, maintenance history and ease of access. The report should contain comments on the appropriateness of labelling of valves. The full range of gate settings should be checked. The person performing the inspection should slowly open the valve, checking for noise and vibration. Certain valve settings may result in greater turbulence. Listen for noise like gravel in the system. This indicates cavitation may be occurring.
Structures	All structures associated with the dam should be assessed for serviceability. Intake structures may need to be inspected by divers for fouling and deterioration. Valve pits and boxes inspected for concrete deterioration and settlement. Intake structure steelwork inspected for corrosion and misalignment and damage. Baulks and gates exercised and inspected for corrosion and damage. Outlet structures inspected for concrete deterioration corrosion and misalignment and damage. Dams incorporating mechanical gate structures should be reported on by an appropriately experienced mechanical engineer.
Electrical, mechanical and control systems	Mechanical equipment including spillway gates, sluice gates, valves, stoplogs, pumps, flash boards, relief wells, emergency power sources, siphons, and electrical equipment should be operated at least once a year and preferably more often. Testing should cover the full operating range under actual operating conditions. Each operating device should be permanently marked for easy identification, and all operating equipment should be kept accessible. All controls should be checked for proper security to prevent vandalism. All operating instructions should be checked for clarity and maintained in a secure, but readily accessible location. All control systems associated with operation of the dam should be reported on by an appropriately experienced electrical engineer. The report should include assessment of the operation of all functions of the control system through the full range of responses and alarms. The report should incorporate an assessment of the condition and the maintenance and operation history of the system and of the existence and appropriateness of the operation plan for the controlled system. The report should make recommendations on the future maintenance requirements.

Appendix G Key elements of dam monitoring

Element	Description
Need to monitor	Monitoring is needed to: ☐ Detect deterioration in the performance of the dam ☐ Detect trends or behaviour to establish compliance with design expectations • If the trends indicate non-compliance with design expectations, investigation and potentially remedial action should be initiated ☐ Resolve dam design issues that could not be fully investigated during design and construction stages. • A monitoring strategy to confirm design expectations by establishing a correlation with actual behaviour. • Note that some behaviour responds slowly over many years while others may not become evident for many years. The dam owner should identify issues to be monitored, incorporate appropriate instrumentation into the dam and specify the frequency of observation. Locations of monitoring equipment should be targeted. For lesser consequence dams, it may be concluded that there is no need for any instrumentation and physical inspections are sufficient. Interpretation of data is an essential component of monitoring that should be undertaken by trained and experienced dam safety engineers.
Processes to monitor	Examples of behaviours that may lead to failure modes that are monitored include: ☐ Reservoir level ☐ Dam and foundation seepage and/or leakage rates ☐ Dam/abutment internal water pressures and phreatic surfaces ☐ Foundation uplift pressures ☐ Dam deformation and displacement
Instrumentation	All instruments must be correctly installed (i.e. location and method), calibrated, and maintained at appropriate intervals to ensure the ongoing collection of reliable data. Documentation and drawings of instrument location, purpose, calibration and maintenance should be accurate, regularly reviewed, safely stored, and available to operational staff, technical advisers and reviewers. Technological advances in instrumentation types and systems occur over the life of the dam. ☐ Original instrumentation may be augmented or replaced by new systems over time ☐ Additional instrumentation may also be installed when a potential dam safety deficiency is being investigated and assessed
Monitoring frequency	See Section G-1 and Table 34.
Communications and storage	Remote telemetry of data from the dam to a control centre can streamline monitoring, especially during critical periods (such as during a flood event). Backup facilities should be available for checking remote monitoring and accessing operational data for the dam during critical periods.

Element	Description
	Alert levels can be built into electronic devices and may be supported by an on-demand display of previous readings for a given instrument. Whatever method is used to record observations and readings, all records must be carefully stored as part of the long-term surveillance record.
Backups and redundancies	Instrumentation can provide critical information during an emergency event. Monitoring of key processes, such as reservoir water levels, should incorporate backup systems and redundancies for both the instrument and its communications.
Responsibility for setting the monitoring program	RPEQ

G-1 Dam monitoring frequency guide

Factors influencing the frequency of monitoring include:

- The conditions, type and size of the dam
- The instrumentation installed at the dam
- The consequence category
- Risk profile of the dam
- Key failure modes and indicators of those modes
- The nature of the behaviour being monitored
- The stage of maturity of the dam (for example, monitoring may be more intense during the construction and first filling stages than during the operational phase)
- The occurrence of any problems or events (for example special events, such as record floods and earthquakes, may require more intense monitoring)
- Monitoring frequency can vary over time depending on the dam's performance, the discovery of deficiencies or changing risks

The following table is adapted from ANCOLD (2003), Table 5.3, which provides monitoring frequencies as a guide for dams that are 'in service' and have no known issues.

Table 34 Guide for frequency of dam monitoring[28]

Monitoring	Consequence Category				
	Very Low[29]	Low	Significant	High	Extreme
Rainfall	Monthly	Monthly	twice weekly to weekly (tc)	daily to tri weekly (tr)	daily (tr)
Storage Level	Monthly	Monthly	twice weekly to weekly (tc)	daily to tri weekly (tr)	daily (tr)
Seepage	Monthly	Monthly	twice weekly to weekly (tc)	daily to tri weekly (tr)	daily (tr)
Chemical analysis of seepage[30]			consider	consider	consider
Pore pressure[31]		Consider	3-monthly to 6-monthly	monthly to 6-monthly	monthly to 3-monthly
Surface movement, control[32]				5-yearly to 10-yearly	5-yearly
Surface Movement, normal		Consider	consider	2-yearly	yearly
Internal movement/stresses			consider	2-yearly	yearly

[28] The frequencies quoted assume manual reading of the instrumentation. Where automated readings are available more frequent reading would be appropriate. TC refers to 'telemetry to be considered'. TR refers to 'telemetry recommended'.
[29] The frequencies listed for very low hazard category dams are suggestions; the dam owner should determine appropriate monitoring.
[30] Recommended annually for concrete dams, tailings dams and embankments constructed from, or on, potentially dispersive materials where specified by the designer or safety reviewer.
[31] The frequency of reading and location of the monitoring instruments are at the discretion of the suitably qualified and experienced RPEQ.
[32] A control survey uses monuments that are remote from the dam site to check the location of the survey monuments at the dam site.

Monitoring	Consequence Category				
	Very Low[29]	Low	Significant	High	Extreme
Seismological[33]				consider (tr)	consider (tr)
Post-tensioning[34]			10-yearly	5-yearly to 10-yearly	5-yearly

[33] The frequency of reading and location of the monitoring instruments are at the discretion of the suitably qualified and experienced RPEQ. Seismological instruments, where installed, are recommended to be incorporated into state-wide seismic networks.
[34] Preferably all cables, but at least a significant representative sample, to be monitored.

Appendix H Annual statement of compliance and EAP review template

Dam owners have the option of completing this notice and submitting via damsafety@rdmw.qld.gov.au or the Dam Safety Portal.

Chief Executive
Attention: Dam Safety Director
Dam name and ID: <insert name> <insert ID>
Subject: Annual statement of compliance and EAP review

Dear Sir

In accordance with s356A and s352P of the *Water Supply (Safety and Reliability) Act 2008* an annual statement of compliance and emergency action plan (EAP) review has been completed.

The review has identified that (indicate with a tick) the dam safety management program (DSMP):

☐ Complies with relevant legislation and guidelines, including safety assessment and failure impact assessment
☐ Complies with all dam safety conditions applied to the dam
☐ Data book and relevant documentation is up to date, available and appropriately managed
☐ Operation and maintenance manual is up to date
☐ Equipment is in good working order
☐ Instrumentation, surveillance and monitoring equipment is in good working order
☐ Interpretation of instrumentation data is performed
☐ Engineering inspections have been performed and documented (details provided below)
☐ Deficiencies, incidents and/or failures have been noted and addressed
☐ Scheduled actions to address recommendations from external audits and inspections are being addressed (details provided below)

The review of the EAP has identified that:

☐ Hazards, triggers and corresponding response actions remain appropriate.
☐ Inundation information suitably shows population at risk (PAR).
☐ Notification and warning arrangements, including frequency, prioritisation and content, are appropriate.
☐ Contact details are complete and up to date.

The annual review has found that (indicate with a single tick):

☐ Amendment of the EAP is not required
☐ Amendment of the EAP is required, and an updated EAP will be submitted for assessment and approval.

For your records we can provide the following additional information (indicate with a tick):

☐ Emergency Alert polygons have been prepared and lodged with the SDCC Watch Desk.
☐ An event or training exercise involving use of the EAP occurred within the last year.

Additional relevant information pertaining to the DSMP, the EAP and our wet season preparedness is as follows:

- <insert points here as preferred>

Yours sincerely,

<insert signature block>

Appendix I Template terms of reference for technical review

I-1 Introduction

The role of technical review, that is expert and independent of owner, designer and constructor, can be a valuable, affordable resource to promote better dam design and construction, especially where novel or innovative methods are proposed.

Such a review can provide detached advice and scrutiny that is unlikely to be influenced by the time and commercial constraints under which designers and contractors usually operate. The technical reviewer reports to the dam owner separately from the project team.

Technical review is required for all referable dam projects in Queensland and is subject to regulatory oversight.

This terms of reference describes the structure and functionality of the technical review specifically for this dam project. It is subject to periodic review and may require adjustment as the dam project develops, technical issues emerge, or industry guidance or regulatory requirements are revised.

I-2 The dam project

<Provide a description of the dam project, considering:

- Key features of the dam project
- The reason for the dam project (new dam, upgrade, safety review, etc).
- Timeframes and scheduling (start date, end date of project phases)

Critical elements and risks associated with the dam project include:

- List particular features of the dam project, especially those may be complex or challenging.
- List particular risks anticipated to be significant for the dam project.>

I-3 Purpose of technical review

The primary objective of the technical review is to review investigations, design, specifications and construction methodology so that:

- Dam safety risks are properly identified, assessed and mitigated where unacceptable.
- Investigations, assessments and analyses undertaken by the project team align with industry good practice.
- Any significant flaws are identified early.
- Adopted parameters, assumptions and quantifications of uncertainties are reasonable and do not introduce unacceptable residual risks for the dam project.
- There is confidence that all technical documentation and reporting adequately details the dam project as it proceeds through the project phases.
- Dam project outcomes meet dam owner's expectations.

To achieve these objectives the technical review is expected to:

- Interrogate the project team's investigations, analyses, designs and construction methodologies, ask targeted and reasonable questions.
- Constructively challenge technical assumptions, methodologies and decisions associated with the dam project.
- Through their expert knowledge and industry involvement, consider whether relevant dam design codes, guidelines and engineering standards have been adhered to.
- Enhance the integrity of the review process by maintaining neutrality on real and perceived conflicts of interest.

The purpose of technical review does not include verifying, certifying or approving the dam project. This is contractually the responsibility of the project team and their nominated registered professional engineer of Queensland (RPEQ).

I-4 Selection

Specific to this dam project the following technical competencies are required:

- <List technical competencies of reviewers for this particular dam project (eg geology, geotechnical, concrete dam design, construction methodologies, local knowledge, etc).
- Also list additional technical competencies that may be required in future.>

Selected technical reviewers need to satisfy the following minimum criteria:

- Professional conduct in line with the code of conduct of leading professional bodies.
- Formal tertiary qualifications in engineering or relevant science or professionally recognised construction supervision capabilities.
- Relevant technical expertise.
- Dam safety knowledge and experience of relevant Queensland legislation, policies and guidelines, and industry guidelines including ANCOLD.
- Interpersonal and communication skills, including ability to convey technical matters clearly and logically in team settings and written form.
- <Any other selection criteria here.>

Additional competencies considered in the selection of technical reviewers are:

- Peer recognition of the relevant area of expertise and demonstration of a successful career track record.
- Personal reputation, integrity and ethical behaviour displayed throughout their professional career.
- Absence of any real or perceived conflict of interest or bias that hasn't been declared and accepted by the dam owner.
- High-level interpersonal skills, with the ability to prepare written technical reports and other communications clearly, logically and in a timely manner.
- How well individual technical reviewers will work as a team.
- Diversity of technical background, age, gender, behavioural characteristics and cultural background within the review team.
- <Any other selection criteria here.>

Based on guidance provided in RDMW (2023[35]), the dam failure consequences and the degree of complexity, a technical review team consisting of <*number*> individuals has been chosen. <*Provide justification / explanation if the number of reviewers, their affiliations and independence from the dam owner and project team differs from that recommended in RDMW (2023)*>.

I-5 Roles and responsibilities

I-5-1 Dam owner

The dam owner is the risk owner, budget owner and has authority to define and modify the scope of the project.

Reporting between project team and technical review is controlled by the dam owner.

Key stakeholders from the dam owner's organisation engaged in the dam project are:

- The point of contact for general technical matters for both the project team and technical review is <*person and/or position*>. <*Briefly describe how the person has the skills for the role*>.
- The project sponsor, who has an awareness of the risks associated with the project, capacity to make decisions and escalate important matters, is <*person, position or group*>. <*Briefly describe*

[35] The Queensland Dam Safety Management Guidelines, https://www.resources.qld.gov.au/__data/assets/pdf_file/0007/78838/dam-safety-management.pdf.

what authority the project sponsor has to escalate concerns or action any recommendations>. The project sponsor will maintain periodic communications with the technical reviewer and be available to the technical reviewers should any concerns arise. <*provide communications protocols if applicable*>.

I-5-2 Project team

The project team is responsible for undertaking the dam project. It solves technical challenges and is responsible for technical delivery and certification.

The project team reports to the dam owner.

The nominated representative for the dam project, who will certify the dam project according to the certification obligations described in RDMW (2023) and is aware of obligations of the Professional Engineers Act 2002, is <person>. <*Briefly describe how the person has the skills for the role and their affiliations*>.

I-5-3 Technical reviewer

The technical reviewer is responsible for the objectives outlined in Section I-3.

Based on the selection criteria in Section I-4 the following technical reviewers have been identified:

- <Provide a list of the technical reviewers in the team, their affiliations and relevant technical skills. If relevant, include a statement of any real or perceived conflicts of interest identified and what mitigation measures were applied to offset.>
- <If a technical review team, identify the technical review chair.>

I-5-4 Secretariat

The secretariat provides managerial support and is the owner of the technical issues register.

Responsibilities include:

- Logistical arrangements for meetings and workshops including travel and accommodation arrangements.
- Circulation of documentation being reviewed prior to meetings and workshops.
- Preparation and circulation of agenda and minutes (if taken).
- Appropriate storage and sharing of formal documentation (including the technical issues register, reports, memorandums and meeting/workshop minutes if taken).
- Data and document quality control.
- Ensuring that appropriate processes are adhered to.
- <Any other responsibilities here>.

The secretariat is to be present at all meetings and workshops.

The nominated secretariat is:

- <List individual’s name and their affiliations>.

I-5-5 Observers

The Queensland Dam Safety Regulator (regulator) is a stakeholder for matters of clarity in regulatory requirements and observes the technical review process when considering if the technical review is compliant to regulatory obligations.

Other observers, who are invited to attend technical review meetings and workshops but do not actively participate in discussions, are:

- <List other observers, including those nominated to observe technical review for training purposes>.
-

I-6 Governance

I-6-1 Organisational structure

<Describe the organisational structure for the technical review process, showing directions of communications and reporting responsibilities. The structure should include communication channels between dam owner, project team and technical review>.

I-6-2 Independence and conflicts of interest

The technical reviewers are responsible for declaring any known conflicts of interest, either financial, direct or perceived, by populating and signing a conflict of interest declaration at the commencement of their engagement.

It is the responsibility of the technical reviewer to notify the dam owner's point of contact should any changes from the initial declaration occur throughout the project duration.

<Provide here, or as an appendix or attachment, a template conflict of interest declaration.>

<If required, include any confidentiality obligations. Note that a technical reviewer should be able to raise any matters of concern relating to the project to the regulator. Any contractual arrangements between dam owner and technical reviewer should consider the technical reviewer's capacity for open disclosure to the regulator>.

I-6-3 Disputes

Disputes internal to the technical review are to be managed by the technical review chair in the first instance.

If an internal dispute cannot be resolved, or a dispute arises between technical review and project team, the dispute is escalated to the dam owners point of contact.

If a resolution is unable to be reached, the dispute is escalated to the project sponsor.

As outlined in RDMW (2023), technical reviewers have authority to co-opt others with appropriate expertise to conduct peer review of matters beyond the collective expertise of the panel members or where obtaining additional views is considered advisable. Under these circumstances the technical review chair is to liaise with the project sponsor.

If a resolution of any of the above cannot be reached, or if a dispute arises between technical review and project sponsor, the dispute may impact the adequacy of the technical review process. Under these circumstances any or all parties are to contact the regulator.

The contractual arrangement between dam owner and technical reviewer must allow the technical reviewer to discuss with the regulator any concerns relating to a dispute with the dam owner. Failure to disclose an unresolved dispute may impact the technical review process to the point where it is no longer adequate and it is non-compliant to Queensland's dam safety regulatory framework.

I-7 Methodology

I-7-1 Project familiarisation

The technical review team will participate in a project familiarisation. This will include:

- A presentation workshop from the dam owner and project team on the dam project, outlining the technical matters to be addressed, risks and objectives of the project.
- A site visit to the dam site will be conducted.
- A technical review preparation meeting.

<Provide further details considering the contents of Section 4.5.5.1 and 4.5.5.2.>

I-7-2 Workshops

Technical review workshops will be held at the following stages of the project:

- <Describe and justify the frequency and timing of the workshops.>

Relevant documentation for the workshops will be distributed by the secretariat <*1 to 2 weeks*> prior to the workshop. This will include the agenda, minutes of the previous workshop (if taken) and supporting documentation.

The technical issues register is available to all participants throughout the project. It is accessible at the following location: <*Provide link to online document or specify that a version will be circulated as part of relevant workshop documentation provided by the secretariat*>.

Prior to the workshop the technical reviewer should diligently review all material provided.

The agenda for each workshop will generally be as follows:

- <Describe the workshop agendas, considering contents in Section 4.5.5.3>.

The secretariat will circulate an updated technical issues register <*1 to 2 weeks*> following the workshop.

I-7-3 Reporting

Reporting is required to demonstrate an effective technical review process has been conducted. It describes the review process, how it has challenged assumptions, methodologies and decisions, and whether all queries have been appropriately resolved by the project team. Where necessary, suggestions for action by project team or dam owner are provided.

Technical review reports will be submitted to the dam owner's point of contact at the following stages of the project:

- <Describe and justify the frequency and timing of reporting.>

The reports will contain the following:

- <Describe report requirements, noting Section 4.5.5.4 and preference to focus on the activities described in the technical issues register>.

I-8 Document management

Documentation used during the technical review process will be stored in a secure location and made accessible to all relevant parties including dam owner, project team, technical reviewer, regulator and observers (as appropriate).

<Describe the document management system and access / security requirements.>

Appendix J Recommended skills for dam safety management personnel

The following tables provide a matrix of recommended skills for dam safety management personnel (further discussion on the contents are provided in Nielsen, 2021).

- Table 35 describes the recommended skills. The skills are separated into attributes of professional conduct, dam safety knowledge and experience, education, technical expertise and leadership and management.
- Table 36 describes the roles associated with dam safety management. Alternate role titles with similar skills are suggested.
- Table 37 cross-references the roles in Table 36 with the recommended skills listed in Table 35.

In some instances a team may be required that, together, contain the recommended attributes for a particular task or role. A person may also have more than one role.

The attributes and roles listed should be considered as a guide rather than a requirement.

Table 35 Recommended skills for dam safety management personnel, arranged by attribute

Attribute	Skills for dam safety management[36]
Professional conduct	1) Professional conduct in line with the code of conduct of leading professional bodies • Identify and recognise areas of competency, limits of personal knowledge and skills • Awareness and understanding of latest advances in dam engineering and surveillance practice • Continuing professional development, 150 hours over 3 years (such as is required by RPEQ and Engineers Australia)[37]
Dam safety knowledge and experience	1) Knowledge and experience of relevant Queensland legislation, policies and guidelines, and industry guidelines including ANCOLD • Understanding of dam safety management programs • Understanding of issues affecting the safety of dams for various types of structures • Understanding of monitoring, inspection and surveillance practices • Practical experience in dam operations, preferably in Queensland
	2) Familiarity with the specific dam • Structural components, operational requirements, etc • Familiar with documentation and reporting requirements • Knowledge and experience of dam's design and construction • Ongoing awareness of deficiencies
Education	1) Engineer or relevant science • Formal tertiary qualifications in engineering or relevant science or professionally recognised construction supervision capabilities

[36] In some instances a team may be required that, together, contain the skills recommended for an attribute group.
[37] Continuing Professional Development (CPD) is considered anything that helps expand knowledge and maintain up-to-date technical skills. It includes direct training activities (such as training courses, seminars and conferences) as well as indirect activities (such as learning on the job, personal reading and mentoring activities).

Attaining recommended CPD hours is a requirement for maintaining RPEQ status. A similar CPD target is recommended for all dam safety personnel (not just engineers), noting however that a reasonable proportion of those hours are often the responsibility of the individual to undertake and record and not the employer / dam owner.

Attribute	Skills for dam safety management[36]
	• If an engineer, then compliant with the Professional Engineers Act 2002 which requires a registered professional engineer of Queensland (RPEQ) to undertake or directly supervise an engineering service in which they have registered their proficiency
	2) Technician or associated • Suitable qualifications and demonstration of competence to operate and conduct annual inspections of dams (e.g. Certificate II, III, IV or Diploma in Water Industry Operations)
Technical expertise	1) Engineering design • Coordination between design and construction teams • Geology and geotechnical engineering • Catchment hydrology and hydraulics • Spillway hydraulics • Design of embankment, concrete dams • Risk analysis • Specific technical specialisation
	2) Engineering construction • Coordination between design and construction teams • Construction methods • Quality control • Material selection and placement • Foundation preparation and grouting • Embankment construction • Concrete construction • Decommissioning • Specific technical specialisation
	3) Operational skills • Assemble evidence to form the basis for sound engineering decisions • Identify and assess critical indicators in connection with the ongoing safe operation of a dam • Review information critically • Make decisions on actions taken during a safety incident, including understanding when to escalate a technical issue • Dam safety surveillance training is current
	4) Inspection and monitoring skills • Reliably conduct and document inspections and monitoring • Recognise warnings of a developing dam deficiency • Record and assess deficiencies • Dam safety surveillance training is current
	5) Disaster management • Disaster management and coordination of emergency response • Experience preparing effective emergency management plans, including stakeholder engagement
	6) Failure impact and consequence analysis • Hydrologic (including rainfall analysis) and hydrodynamic modelling • Identify potential dam failure modes and assess consequences • Consequence analysis

Attribute	Skills for dam safety management[36]
	7) Risk analysis • Understanding of risk principles • Awareness of risks associated with various types of structures, investigation and analysis methods, etc. • Experience undertaking remedial action on dams • Ability to plan dam safety upgrades to ensure risks remain tolerable and legislative/good practice requirements are met
Leadership and management	1) Health and Safety • Demonstrate appropriate knowledge and application of WHS legislation, hazards and safe systems of work relating to the operation and maintenance of dams, including working in confined spaces and working at heights
	2) Interpersonal and communication • Lead and manage teams • Communicate with technical and non-technical people to support decision making • Discuss ideas and technical issues affecting dam safety with other engineers and specialists • Prepare written documents in a concise and succinct manner, appropriate to the intended audience, so that technical issues are effectively communicated • Able to explain purpose and reason for dam safety decisions
	3) Project management, quality assurance and planning • Business planning • Procurement and contracts • Project management • Risk management • Record keeping • Quality assurance

Table 36 Role descriptions applicable to dam safety management

Role (s)	Description
Dam operator • Also: routine inspector	• Located at the dam to operate the dam and conduct routine inspections • Performs day to day activities at the dam such as making releases, reading instrumentation • Acting in accordance with Operation and Maintenance Manual requirements and generally in accordance with a prescriptive standard • Capable of identifying emerging issues and can escalate
Dam safety engineer • Also: senior inspector	• Engineer or technician supporting a comprehensive dam inspection • Engineer or technician supporting dam safety management program • Generally acting under direction of senior dam safety engineer and generally in accordance with a prescriptive standard
Senior dam safety engineer • Also: engineering inspector, dam safety decision maker, principal engineer, senior flood operations engineer	• Engineer coordinating a comprehensive dam inspection • Engineer delivering dam safety management program • Responsible for engineering decisions relating to dam safety • Responsible for technical decision making during an emergency event
Flood engineer • Also: flood operator, flood officer, dam duty operator	• Responsible for interpreting rainfall and flood predictions and analysing operational options
Hydraulic modeller	• Responsible for assessment, submission and certification of failure impact assessments (FIA) • Responsible for developing dam failure inundation maps
Emergency event coordinator • Also: operations manager	• Responsible for coordinating responses during an emergency event
Construction supervisor	• Responsible for delivering construction for a dam project in accordance with specifications
Design engineer • Also: dam engineer	• Subject matter specialist providing engineering inputs to a dam project or safety review (design, construction and/or other)
Technical specialist • Also: geologist, relevant scientist	• Subject matter specialist providing technical inputs to a dam project or safety review (design, construction and/or other) who is not an engineer
Lead design engineer • Also: technical reviewer, risk assessment lead	• Specialist to manage a dam project or safety review (design, construction and/or other) • Specialist to conduct technical review

Table 37 **Recommended skills for dam safety management personnel, allocated to each role (green R is recommended skill, yellow U is useful skill, blank is skill not required)**

Role Note that in some instances a team may be required that, together, contain the recommended attributes for a particular task or role. A person may also have more than one role.	Professional Conduct 1	Dam safety knowledge and experience 1	Familiarity with dam 2	Education		Technical expertise							Leadership and management		
				Engineer or relevant science 1	Technician or associated 2	Design 1	Construction 2	Operational 3	Inspection 4	Disaster management 5	Consequence analysis 6	Risk 7	Health and Safety 1	Interpersonal / communication 2	Project management 3
Dam operator (routine inspector)	R	U	R		R				R				R		
Dam safety engineer (senior inspector)	R	R	R	R					R				R		
Senior dam safety engineer (engineering inspector, dam safety decision maker)	R	R	U	R		U	U	U	R				R	R	
Flood engineer (flood operator, dam duty operator)	R	U		R		U		U		U	R				
Hydraulic modeller	R	U		R							R				
Emergency event coordinator (operations manager)	R	R	U	U	R			U		R	R		U	R	R
Construction supervisor	R	R		U	R	U	U						R	U	R
Design engineer (dam engineer)	R	R		R		R	U		U			U	U	U	R
Technical specialist (geologist, scientist)	R	U		R		R	U					U		U	U
Lead design engineer (technical reviewer, risk assessment lead)	R	R	U	R		R	R	U	R	U	U	R	R	R	R

Appendix K Certification templates

K-1 Engineering inspections

This <Annual / Comprehensive / Special> engineering inspection of **Dam** was prepared by **Company** and certified by **Name.**

Particulars of the dam are as follows:

- Description:
- Name
- Dam ID
- Watercourse or offstream storage name
- Locality (nearest city/town)
- Location (lot on plan, local government area)
- Latitude and longitude
- Dam owner:
- Current failure impact rating of dam:
- Population at risk:

Evidence that was considered in the course of this inspection is as follows:

- <Provide list here>

As at the <day of month, year> I state the following:

- I have inspected the site.
- I am competent to conduct the inspection and am performing this engineering service in accordance with the *Professional Engineers Act (2002)*.
- The inspection complies with the relevant dam safety conditions for this dam which have been applied under the *Water Supply (Safety and Reliability) Act 2008*.
- The inspection has been conducted in accordance with relevant and current guidelines and standards that are considered good practice and appropriate for this dam.
- I am satisfied that the inspection was appropriately thorough for this type of inspection and this dam.
- The inspection report is based on information that is not false or misleading and is supported by evidence gathered, where practical, during the inspection.
- I am satisfied that the report sufficiently describes the evidence I have used to justify my conclusions and recommendations.
- I am satisfied that the inspection process was conducted with due regard for quality of process and technical review.

Signature

Name (RPEQ registration number)
Postal address
Contact number(s)
Email address

K-2 Safety review

This safety review of **dam** was prepared by **company** and certified by **name.**

This <annual / comprehensive / special> engineering inspection of **dam** was prepared by **company** and certified by **name.**

Particulars of the dam are as follows:

- Description:
- Name
- Dam ID
- Watercourse or offstream storage name
- Locality (nearest city/town)
- Location (lot on plan, local government area)
- Latitude and longitude
- Dam owner:
- Current failure impact rating of dam:
- Population at risk:

Evidence that was considered in the course of this safety review is as follows:

- <Provide list here, which should include the certified comprehensive inspection report>

As at the <day of month, year> I state the following:

- I have inspected the site.
- I have thoroughly researched and identified all relevant information.
- I am competent to conduct the safety review and am performing this engineering service in accordance with the *Professional Engineers Act (2002)*.
- The safety review complies with the relevant dam safety conditions for this dam which have been applied under the *Water Supply (Safety and Reliability) Act 2008*.
- The safety review has been conducted in accordance with relevant and current guidelines and standards that are considered good practice and appropriate for this dam.
- I am satisfied that the safety review was appropriately thorough for this type of dam and its failure consequences.
- The safety review report is based on information that is not false or misleading and is supported by evidence gathered, where practical, during the safety review.
- I am satisfied that the report sufficiently describes the evidence I have used to justify my conclusions and recommendations.
- I am satisfied that the safety review process was conducted with due regard for quality of process and technical review.
- I am not the owner, an employee of the owner, the operator, or an employee of the operator of the dam being assessed.

Signature

Name (RPEQ registration number)
Postal address
Contact number(s)
Email address

K-3 Design report

This certification of the design of **dam** was prepared by **company** and certified by **name.**

Particulars of the dam are as follows:

- Description:
- Name
- Dam ID
- Watercourse or offstream storage name
- Locality (nearest city/town)
- Location (lot on plan, local government area)
- Latitude and longitude
- Dam owner:
- Current failure impact rating of dam:
- Population at risk:

Evidence that was considered in the course of this design is as follows:

- <Provide list here>

As at the <day of month, year> I state the following:

- There is sufficient information to inform the design.
- I am satisfied that the information and analyses applied are appropriate, suitably accurate and suitably informed by inspections and physical testing to establish the values adopted for critical design parameters.
- I am competent to conduct the design and am performing this engineering service in accordance with the *Professional Engineers Act (2002)*.
- The design complies with the relevant dam safety conditions for this dam which have been applied under the *Water Supply (Safety and Reliability) Act 2008*.
- The design has been conducted in accordance with relevant and current guidelines and standards that are considered good practice and appropriate for this dam.
- I am satisfied that the design was appropriately thorough for this type of dam and its failure consequences.
- The design report is based on information that is not false or misleading and is supported by evidence gathered, where practical, during the design process.
- I am satisfied that the report sufficiently describes the evidence I have used to justify the design outcomes.
- I am satisfied that the design was conducted with due regard for quality of process and technical review.

This is a referable dam and may place the community at risk if it were to fail. I recognise my ethical obligations in accordance with the Board of Professional Engineers Code of Practice to safeguard the health, welfare and safety of the community. I am satisfied that construction can start.

Signature

Name (RPEQ registration number)
Postal address
Contact number(s)
Email address

K-4 Inspection of construction

This certification of the inspection of construction of **dam** was prepared by **company** and certified by **name.**

Particulars of the dam are as follows:

- Description:
- Name
- Dam ID
- Watercourse or offstream storage name
- Locality (nearest city/town)
- Location (lot on plan, local government area)
- Latitude and longitude
- Dam owner:
- Failure impact rating of dam:
- Anticipated population at risk:

The construction activities I inspected are as follows:

- <Provide list here>

Evidence that was considered in the course of this inspection is as follows:

- <Provide list here>

As at the <day of month, year> I state the following:

- I am performing this engineering service in accordance with the *Professional Engineers Act (2002)*.
- The construction activities inspected comply with the relevant dam safety conditions for this dam which have been applied under the *Water Supply (Safety and Reliability) Act 2008*.
- The construction activities inspected have been conducted in accordance with relevant and current guidelines and standards that are considered good practice and appropriate for this dam.
- I am satisfied that dam construction activities inspected are in accordance with the intended design requirements.
- I am satisfied that construction is being conducted with due regard for quality of process and technical review.
-

Signature

Name (RPEQ registration number)
Postal address
Contact number(s)
Email address

K-5 As-constructed report

This certification of the construction of **dam** was prepared by **company** and certified by **name.**

Particulars of the dam are as follows:

- Description:
- Name
- Dam ID
- Watercourse or offstream storage name
- Locality (nearest city/town)
- Location (lot on plan, local government area)
- Latitude and longitude
- Dam owner:
- Failure impact rating of dam:
- Anticipated population at risk:

Evidence that was considered in the course of this project is as follows:

- <Provide list here>

As at the <day of month, year> I state the following:

- I am performing this engineering service in accordance with the *Professional Engineers Act (2002)*.
- The construction activities comply with the relevant dam safety conditions for this dam which have been applied under the *Water Supply (Safety and Reliability) Act 2008*.
- The construction has been conducted in accordance with relevant and current guidelines and standards that are considered good practice and appropriate for this dam.
- I am satisfied that construction was appropriate for this type of dam and its failure consequences.
- I am satisfied that dam construction meets the intended design requirements.
- The designer was consulted throughout construction.
- The as-constructed report is based on information that is not false or misleading and is supported by evidence gathered, where practical, during construction.
- I am satisfied that the report accurately and comprehensively describes the evidence I have used.
- I am satisfied that construction was conducted with due regard for quality of process and technical review.
- I am satisfied that the information and analyses applied are appropriate, suitably accurate and suitably informed by inspections and physical testing to establish the values adopted for critical design parameters.

This is a referable dam and may place lives at risk if it were to fail. I recognise my ethical obligations in accordance with the Board of Professional Engineers Code of Practice to safeguard the health, welfare and safety of the community. Considering the above, I see no reasons why the dam should not be used to store water.

Signature

Name (RPEQ registration number)
Postal address
Contact number(s)
Email address

Appendix L Steps for preparing development applications[38]

Under the provisions of the Planning Act 2016, a dam owner will need to obtain a development permit for construction of, or any upgrade to, a dam that is or will be referable (as operational works).

The development application in most cases needs to be made to the Department of State Development, Infrastructure, Local Government and Planning (DSDILGP) through its State Assessment and Referral Agency (SARA) group as the assessment manager.

L-1 Assessment framework

L-1-1 State Assessment and Referral Agency (SARA)

SARA is responsible for delivering a co-ordinated, whole-of-government approach to the state's assessment of development applications. The chief executive of the Planning Act, the Director-General of the Department of Infrastructure, Local Government and Planning (DILGP) is the assessment manager or referral agency for development applications where the state has a jurisdiction (see also DILGP, 2017).

Schedule 10 of the Planning Regulation 2017 prescribes that operational work that is the construction of a referable dam is an assessable development. An applicant for a referable dam development is therefore required to make an application to SARA in accordance with the development assessment process summarised in Figure 7.

Development applications for a referable dam are assessed by SARA against State code 20: Referable dams under SDAP. Accordingly, applicants are advised to demonstrate compliance with the relevant provisions of the code in order to assist in minimising requests for further information, and to speed up the assessment process.

L-1-2 State Development Assessment Provisions (SDAP)

The provisions provide assessment benchmarks for the assessment of development applications where the chief executive administering the Planning Act, is the assessment manager or a referral agency.

An operational works development application for a referable dam development are assessed by SARA against SDAP's State code 20: Referable dams.

L-1-3 Other approvals

In addition to requiring a development application for operational works for a referable dam, an applicant may be required to meet additional statutory requirements under the Planning Act (and other legislation) for further aspects of the development.

Additional development applications or permits may be required to be made to a local government, SARA or another entity as prescribed under the Planning Regulation. This guidance material does not cover such additional statutory requirements.

Under the Water Supply (Safety and Reliability) Act 2008, a dam which is referable is required to have an approved EAP. This is addressed in RDMW, 2023.

[38] More information on referable dam development permit requirements is available at DNRME 2018.

L-1-4 Pre-lodgement

Prior to submission of a development application, owners should undertake pre-lodgement discussions regarding the proposal.

These discussions should include the dam safety team of the department to discuss whether the dam is likely to be referable. Where there is doubt, technical details of the development and potential DSC may need to be provided by the owner.

A pre-lodgement meeting with SARA is also recommended prior to lodging the development application for a referable dam. This meeting assists an applicant in understanding the requirements for technical assessments against the code based on the individual circumstances of the proposed development.

To determine if there are any additional approvals (e.g. material change of use, building works, reconfiguration of a lot, other permits, etc.) that may be required to support the operational works application to SARA, it is strongly recommended that the applicant consults with the relevant local government. This consultation may occur before or in conjunction with the pre-lodgement meeting with SARA.

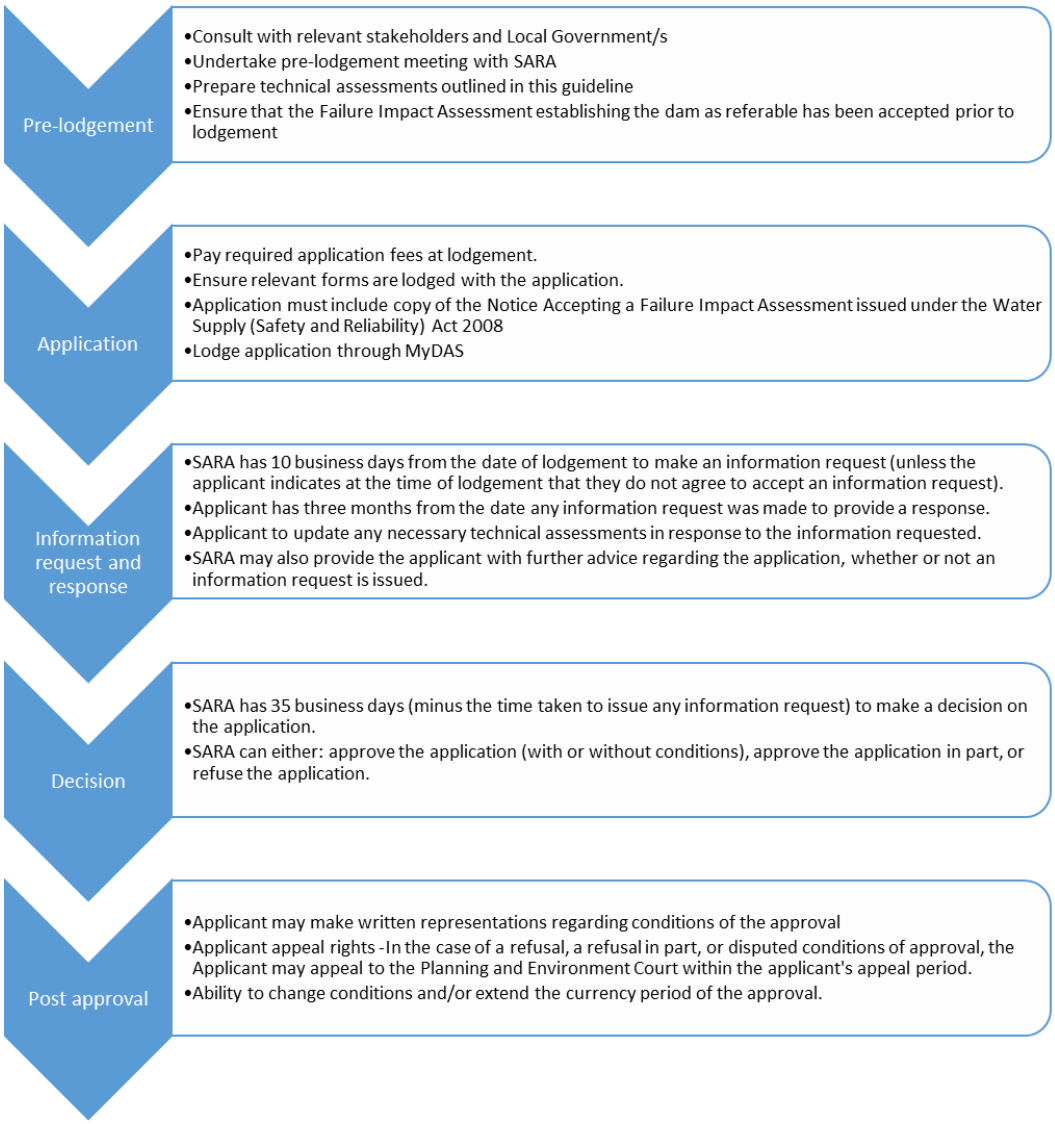


Figure 7 Development assessment process for referable dams

L-2 Assessment criteria

This part of the appendix provides additional information to assist applicants with demonstrating compliance with the performance outcomes of the code. Because dams can be complex structures and extremely variable in their size, type of construction, operation and failure consequences, no definitive acceptable outcomes are provided for in this code. Note that if a development application does not comply with one or more of the performance outcomes in the code, then it is assessed by SARA against the purpose statement in the code.

Each section is written to correspond with the relevant provision in the code and provides context around the provision of supporting information, and actions that may be required to demonstrate compliance. This includes the methodology to be applied for technical assessments that may be required.

Development applications for referable dams are assessed against the requirements of departmental guidelines, including referenced documents. Dam owners should ensure that they use relevant guidelines prepared by the department when developing their proposal. For issues not covered by departmental guidelines, guidelines developed by ANCOLD can be used.

Applicants are reminded that the supporting actions contained in this section cover the minimum standards required to respond to the criteria and additional assessments may be required dependent on individual project and site circumstances.

L-2-1 Meeting performance outcomes: referable dams

Performance outcome 1 (PO1) design and construction of referable dams

Performance outcomes

- PO1 The dam is designed and constructed in a manner which:

- Is in accordance with appropriate dam engineering practices and standards
- Minimises the potential for dam failure
- Minimises any of the impacts resulting from a failure of the dam
- Is appropriate for the site conditions where the dam is located

Acceptable outcomes

- No acceptable outcome is prescribed

Supporting actions

The following actions support an applicant in demonstrating compliance with PO1:

The applicant should demonstrate that the risk of dam failure is mitigated through the adoption of suitable design and construction practices and standards for the site conditions encountered and to an extent commensurate with the level of failure consequences.

In particular, applicants are expected to demonstrate in their supporting documentation that:

- appropriate investigations have been completed to establish site conditions, and
- the proposed works comply with current engineering standards and accepted practices.

Following is a list of issues that applicants should consider while preparing an application. The list is not exhaustive. Careful consideration should be given to the proposal and its potential impacts to determine which issues are relevant to the application. It is expected that consideration of these issues are site and dam type specific.

Potential design issues:

- consequence assessment
- hydrologic and hydraulic data and analyses
- spillway adequacy

- foundation conditions and treatment
- suitability of construction materials
- embankment design and stability analyses
- instrumentation installed
- construction specification

The supporting documentation submitted should also include:

- a summary of the principal data about the dam
- plans of the dam and associated works drawn on a contour plan of the site
- arrangements, elevations and sections showing details of the proposed structures, including foundation details

Performance outcome 2 (PO2) Management and maintenance of referable dams

Performance outcomes

PO2 The dam will be managed and maintained in a manner which:

- Is in accordance with appropriate dam engineering practices and standards
- Ensures the ongoing safe operation of the dam
- Minimises the risks of dam failure
- Is appropriate for the site conditions where the dam is located

Acceptable outcomes

- No acceptable outcome is prescribed

Supporting actions

The following actions support an applicant in demonstrating compliance with PO2.

The applicant should indicate how the risk of dam failure will be mitigated through the adoption of management and maintenance practices and standards suitable for the magnitude of consequences were the dam to fail.

Referable dams are generally required to perform satisfactorily over an extended life period. Therefore, responsible operation of the dam and maintenance to prevent deterioration of the structure are important to its continuing performance

In particular, the applicant should consider the following while preparing the application:

- monitoring systems to detect the development of any abnormal behaviour at the dam
- operational and maintenance procedures for the safe management of the dam
- regular inspection requirements for the dam, including by suitably qualified and experienced RPEQ

The on-going dam management requirements are generally be reinforced through conditions attaching to any development approval.

L-2-2 Meeting the purpose of the code

The purpose of the code is to reduce the risk to the community from the failure or other impacts of referable dams by ensuring appropriate safety standards are utilised in the design, construction, management and maintenance of dams.

Development will comply with the code if it can be shown to meet the code's purpose statement. The purpose provides the overall context for the code and holistically defines what the code seeks to manage and/or protect. For this reason, if a development application does not comply with one or both of the performance outcomes described above, the applicant should instead demonstrate how the purpose of the code can be achieved by the proposal.

L-3 Review

On referral from DSDILGP, the dam safety group will provide relevant comments on the application, including any recommended DSC that should be attached to the development approval.

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