NEW ZEALAND
DAM SAFETY GUIDELINES

THE NEW ZEALAND SOCIETY ON LARGE DAMS

New Zealand Dam Safety Guidelines

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PREFACE

The New Zealand Society on Large Dams (NZSOLD) Dam Safety Guidelines have the following objectives:

- Definition of the outline guidelines to enable the safety of existing dams to be investigated and identified in a consistent and adequate manner within New Zealand.
- Facilitation of the provision of consistent evaluations of dam safety deficiencies leading to the construction of improvements which contribute to dam safety.
- Provision of guidelines on the issues to be taken into account in the design and development of new or refurbished structures.
- Consistency with the requirements of the Resource Management Act (RMA), and other pertinent legislation.
- Provision of an interface with existing and future regulatory frameworks (e.g. RMA)

In the revision of these guidelines, NZSOLD is facilitating the transfer of information and standards of practice among professional engineers and others involved in the process of maintaining dam safety. Responsibility for interpreting, verifying and applying these guidelines lies with those engaged in dam safety work, whether owners, designers, contractors or regulators. These guidelines are not intended as design specifications or an instruction manual for untrained persons. Engineers, experienced in the design and construction of dams, are qualified to judge the suitability of a standard or guideline for a particular purpose.

These guidelines will be of use to those not fully experienced in dam safety issues, as well as serving to guide Owners, Licensing Authorities, and Constructors, and others, who share in the responsibility of achieving safe dams.

The use of criteria other than those indicated by the guidelines may be appropriate to accommodate conditions arising at some projects. Advances in knowledge and improved techniques continue world-wide and these Guidelines should be interpreted and applied accordingly.

From time to time, portions of these guidelines will be amended or revised. The user is responsible for ensuring that the most up-to-date version is being used. The current version is issue #2, dated November 2000.

NZSOLD welcomes any contributions from the users of these guidelines. This is a live document, and will benefit from the experience and knowledge of the users.

LEGAL NOTICE

NZSOLD, its officers, managers, and members who participated in the development of the guidelines:

- Do not make any representations, express or implied, as to the accuracy, completeness or appropriateness for use in any particular circumstances, of any of the information provided, requirements identified, or recommendations made in the guidelines.
- Do not accept any responsibility for the use or application of, or reliance on these guidelines or any procedures, information, or documents developed in accordance with these guidelines, for any purpose or reason whatsoever.

REGISTRATION OF PURCHASE

To: Technical Secretary
The New Zealand Society on Large Dams
P O Box 12241
Wellington
NEW ZEALAND

Dear Sir

I have received a copy of the "Dam Safety Guidelines", and wish to be kept up to date with any amendments or revisions.

Name: _____

Address: _____

_____

_____

Company: _____
(*if applicable*)

Date of Receipt of Manual _____

Yours sincerely

This form is to be completed and forwarded to The Technical Secretary, NZSOLD, so that the recipient can be advised of amendments or revisions to the guidelines.

NZSOLD also welcome any contributions to the future improvement of the guidelines.

PART I - INTRODUCTION

I.1 Purpose

Dam Safety Assurance is essentially about "avoiding the uncontrolled escape of the stored contents".

This document aims to provide sound guidelines for all those involved in designing and developing new dams, evaluating and upgrading existing dams, and maintaining and operating all dams. The emphasis throughout is on measures to achieve safe construction and operation of dams, irrespective of type or size. These Guidelines are aimed at Technical Advisers, Owners, Licensing Authorities and Constructors, and others owning of responsibility and a duty of care for dam safety. All parties share responsibilities in achieving safe dams, and none more strongly than the Owner or Developer, on whom responsibility ultimately rests for safe operation and maintenance of the facility once it is operational.

The need for such a document to suit New Zealand conditions has been recognised by the New Zealand Society on Large Dams (NZSOLD) and others within the dam industry. Clearly, as various dam failures and incidents around the world have shown, some with substantial loss of life and environmental damage, there is a need to exercise due care at all levels in achieving dam safety. There is a need to embody the level of advice necessary for full implementation of safety procedures by measures such as these Guidelines. Benefits which will accrue from the promotion and achievement of adequate dam safety practices include environmental protection, public confidence, and the commercial benefits to the owner of constructing and maintaining in a safe and insurable condition, what is usually a significant investment.

There is a wealth of technical literature related to dam design and guidance on dam safety. NZSOLD's aim is to provide a comprehensive document relating to the specific requirements of New Zealand's environmental and safety legislation.

I.2 The Special Nature of Dams

Dams with their related structures and the storage reservoirs they form, have a special nature because of their scale, the water forces at work and the use of natural ground to form the major part of the reservoir containment. Most other man-made works are built of high strength manufactured materials, involve controlled geometry, do not involve large storage of fluid contents, and generally do not use the foundation other than to support the works themselves. In the case of dams, however, account has to be taken of:

- dam site topography which usually cannot be altered significantly because of cost
- dam site and regional geology which greatly influences water retention and structural safety
- the most appropriate materials to build the dam from and the dam structure arrangements to assure a safe operable dam
- the nature of the materials stored behind the dam which, because of density and toxicity (e.g. mine tailings), may require an even higher level of safety than normal
- the management of flood risk and bypassing of floods while the dam is being built
- the earthquake forces which the dam with its stored contents may experience
- the potential floods which may pass through the reservoir and how these may be taken past the dam and returned to the river without risk of dam overtopping (unless specifically designed for overtopping), or erosion damage
- the surveillance, maintenance, and operational procedures (which may include the operation of flood gates) to ensure the dam works as intended

- the management of sediment passage down the river
- the management of other risks such as volcanic activity

It is the close interaction between the natural ground and man made structures, together with water (or other fluid contents) stored at a higher level, which most strongly characterise the special nature of dams. From the time it is first stored and for the whole life of the dam, the retained fluid has the potential to escape through any geological or man made weakness. Dams age and deteriorate through ongoing geological and chemical processes and also may be found to be less safe than is desirable through technological advances which improve knowledge of dam and foundation behaviour, and earthquake and flood risk. Dam failures resulting in the uncontrolled escape of the stored contents can be catastrophic and preservation of safe conditions requires never ending vigilance. Even canals which are on elevated topography or involve high embankments have the potential to cause significant damage and these too are classed as dams. Similarly, relatively modest closure embankments or "saddle dams" filling a gap in the rim of a reservoir, can have high damage potential and must also be considered as dams.

As well as all dams constituting a special class of structure, each dam will have unique characteristics, particularly in terms of site geology and geometry. The variations in geology, building material types, geometry, earthquake and flood risk and the like, mean that it is not practicable to develop a standardised code-type design for dams. Each dam must be treated individually, taking all relevant factors into account. These Guidelines aim to assist that process.

It should be noted that retarding basins and canals containing large volumes of water with damage potential if there is an uncontrolled escape, may also act as dams, and should be treated accordingly.

River stopbanks are generally not regarded as dams and government agency advice is that they will be specifically excluded from any dam safety legislation that is written.

I.3 Wider Considerations

Dams with their associated reservoirs can have substantial environmental effects and any existing dam or new project must comply with environmental legislation and associated licensing or consent requirements. It is not the intent of these Guidelines to address all of the environmental issues associated with a new dam development or consent renewals for an existing dam. However, particularly in the case of future owners, it should be recognised at the outset that dam developments have effects extending beyond the immediate confines of the dam and inundated areas. For example;

- reservoir slope stability, may become a dam safety issue due to the risk of overtopping caused by large volumes of reservoir water being displaced by slope failures [most New Zealanders will be aware of this issue through the Clyde Dam].
- groundwater level changes may affect stability and land use around the reservoir margins and possibly adjacent to the downstream river, as a result of changed water levels.
- trapping of river bedload in the reservoir can result in upstream shoaling and loss of reservoir storage. Bed load stripping downstream of the dam due to a loss of upstream supply is another possibility which must be considered.
- flora/fauna effects may occur in storage basin, downstream, and in passage around and through the dam.
- minimum flow maintenance downstream of the dam to ensure the survival of flora and fauna, and to reduce causes of stream bed deterioration.
- Social development/changes to downstream use given the changed flood situation.

I.4 Legislative Aspects

New Zealand does not have specific dam safety legislation or administration as some other developed countries do. The two Acts which take safety and construction into account are the Resource Management Act (1991) (RMA) and the Building Act (1991) (B.Act) with its accompanying Building Regulations (1992). Another Act which may be relevant to the design of Tailings dams is the Hazardous Substances and New Organisms Act (1996) (HASNO Act). In an emergency situation, the Civil Defence Act (1989) may also apply to a dam.

Part II discusses legislative aspects in more detail.

There are some broader legal obligations under New Zealand law which owners and designers in particular need to appreciate. The following summary is drawn from a paper by R J Sommerville at the NZSOLD 1995 Symposium on "Dams – The Implications of Ownership":

- the law applies strict liability on the initial owner or creator of a dam but for subsequent owners principles of negligence apply;
- extreme phenomena or Acts of God tend to be seen by the Courts as risks to be foreseen and taken into account to a satisfactory standard, which places an onerous burden on those responsible for the creation of a dam;
- liability for negligent acts may be traced back to an owner or operator, which requires the owner or operator to maintain tight control over the actions of advisers or employees; and
- codes of practice or guidelines (such as these) are likely to be seen by the courts as outlining minimum practice procedures.

The Resource Management Act (1991) governs the development or continued use of dams from the resource allocation viewpoint. This Act is administered by Regional Councils. The Building Act (1991) and Building Regulations (1992) impose compliance via "producer statements" of design and construction of new projects (or alterations to existing works). An annual warrant of fitness is also required for existing 'buildings' (and a dam is a building under the Building Act) which contain equipment or potentially restricted access affecting the safety of people using the building. Some dams or dam components will require a warrant of fitness under the Act. This Act is administered by District or City Councils.

These Guidelines follow or are compatible with international dam safety practice as embodied in legislation or in the procedures of administering authorities of the relevant countries. They are modified to meet New Zealand conditions, particularly in the Potential Impact categories adopted for safety recommendations.

I.5 Scope of Guidelines

These Guidelines are in four parts, this PART 1 INTRODUCTION, and those listed below. Parts II and III are descriptive, relatively concise and provide an overview of issues. Part IV, The last part is in the form of Appendices which provides further detail, most of which is technical in nature. The parts are as follows:

• PART I INTRODUCTION	Outlines the objectives of the document, the special nature of dams, and the need for consideration of the wider issues and legal implications
• PART II REGULATORY ASPECTS	Introduces the parties involved in developing, maintaining and operating dams and outlines their responsibilities, and then briefly describes the principal legislation affecting dam development and safety

- PART III TECHNICAL ASPECTS — Describes dam Potential Impact categories, then provides technical guidelines for safe dam development, mainte nance and operation, related wherever appropriate to the hazard category of the dam – reference is made to Appendices for greater detail
- PART IV APPENDICES — Provide the detail referred to in PART III and also contain:
  - definition of technical terms
  - relevant extracts from key legislation
  - references which may be of use to those wishing to undertake wider reading

It is important to appreciate that these Guidelines focus on aspects which should be considered and procedures which should be followed. They do not constitute a design or operations manual and for implementation, reference must be made to appropriately qualified technical personnel, other appropriate technical references and detailed methods of investigation and analysis. NZSOLD does not warrant that the Guidelines are necessarily all embracing or will cover every conceivable situation: ultimately the Owner and Advisers to the Owner must decide what is appropriate.

I.6 Terms Used

Efforts have been made throughout to minimise the use of technical terms and where no specific description is given, the common interpretation of the word can be taken. A list of technical terms used is included as a preface to the Appendices in Part IV.

There are six terms, however, which are crucial to dam safety and are referred to or implied throughout these guidelines. Because of their importance they are introduced here.

Potential Impact: Potential Impact is related to the consequences (effects) of the dam failing, if it should release its stored contents. If a dam is assessed as having a high Potential Impact, it does not mean that the dam is unsafe. Indeed a high Potential Impact dam should have a higher level of safety than other dams.

Hazard: This term is used to describe a source of potential harm or a situation with a potential to cause loss. Factors such as earthquakes, floods, and possible deficiencies in the dam or its foundations, which may lead to unsafe behaviour of the dam can be considered hazards. Unsafe behaviour may result in the Potential Impact being realised.

Criteria: This term refers to the numerical values or other standards adopted by the world-wide dam industry for aspects of dam design and performance. It is important to note that technological advances or empirical evidence may lead to criteria changing with time.

Dam: A structure, man made or created naturally, which will withhold a body of water, or other fluids, such as tailings or sludge.

Dam Safety: Relates to the wider issue of reservoir safety and the effect on people and property downstream.

Special comment

The circumstances of **Potential Impact, Hazards and Criteria** may, and in fact generally do, change with time. This means that the function or art of designing, building and operating a dam is a living process. All those associated with dams, particularly Owners and Administrators need to recognise this fact in their forward planning and responses from time to time.

PART II - REGULATORY ASPECTS

II.1 Parties Involved and Responsibilities

II.1.1 General

Those involved in the dam industry fit into five main categories as follows:

(i) the dam Owner or Developer (ownership may change from time to time) who operate and maintain the dam

(ii) the Licensing Authority or Authorities who issue and administer statutory consents

(iii) the Technical Advisers whose roles include investigation, design, evaluation and technical advice

(iv) the Constructors or Contractors who undertake construction and maintenance roles to specifications by others (in some cases a Contractor may also operate the dam on behalf of the Owner)

(v) the Public, who may be affected directly or indirectly by the dam and who have certain rights, particularly under environmental and licensing legislation.

The respective roles and relationships between the parties are usefully introduced in terms of the dam life cycle. While the effective life of a well constructed and maintained dam may be almost indefinite in terms of the normal human life cycle, nonetheless at some point in time due to natural forces or changing needs, the dam will reach a terminal point in its life.

Table II-1 summarises the life cycle and key activities within it, and illustrates typical participant roles.

II.1.2 Dam Owner

While the Dam Owner (who may also be the initial developer) may not be technically qualified and may play a relatively subordinate role in a new development or in appraisals of an existing dam, the Owner nonetheless occupies the most important role. It is the Owner who holds the various statutory permits for the dam and is legally responsible for maintaining the dam in a safe condition and for operating it safely.

The Owner usually relies on Technical Advisers for investigations, design, safety reviews and the like, and on suitably qualified Construction Contractors for construction or rehabilitation. In these situations, the Advisers and Contractors act as agents for the Owner and will carry an appropriate level of responsibility and liability for their actions under the terms of the contract for their services. However, it is important for the Owner to recognise that in the event of a problem arising, the Authorities will look first to the Owner and the Owner must fully understand all Owner liabilities, the limits of the liability which the Owners agents can accept, and the level of additional risk or insurance to be carried.

The owner is legally liable for damage after a dam failure and may be culpable in loss of life situations.

A responsible attitude towards safety by Owners is essential to protect others and avoid negligence situations. It is also a prudent means of protecting the value of the investment. The Owner holds the purse strings and initiates all of the activities associated with dam development and continued safe operation. By understanding and requiring guidelines such as these to be implemented, the Owner will be taking positive initiatives to ensure that the dam is safely developed, maintained and operated. Further, the Owner will be exposed to significantly reduced liability and negligence risks if the guidelines are implemented.

Table II-1. Review of Dam Life Cycle and Participant Roles.

STAGE - ACTIVITY	OWNERS	TECHNICAL ADVISERS	AUTHORITIES	CONSTRUCTORS	PUBLIC
CONCEPTION					
- Need	Establish				
- Site	Obtain				
- Functional Criteria	Determine				
- Feasibility	Commission	Execute			
- Alternatives	Commission	Execute			
- Assessment of Environmental Effects	Commission	Execute			Participate
- Consents	Apply for	Support	Evaluate/Grant		
GESTATION					
- Detailed Design	Commission	Execute			
- Construction	Commission	Supervise		Execute	
- Certification	Commission	Execute	Receive		
BIRTH AND GROWTH					
- Commissioning	Commission	Test, certify		Execute	
- Performance Review	Apply for Authorise	Control	Evaluate/Grant	Execute	
- Fine Tuning	Authorise	Execute			
MATURITY AND AGING					
- Surveillance	Execute	Assist	Monitor?		
- Maintenance	Execute		Monitor?	Assist	
- Periodic Reviews	Commission	Execute	Monitor?		
- Consent Renewals	Apply for	Support	Evaluate		Participate
- Rehabilitation	Commission	Design/ Supervise/ Certify	Monitor	Execute	
DEATH					
- Consents	Apply for	Support	Evaluate/Grant		
- Decommissioning	Commission	Design/ Supervise/ Certify	Monitor	Execute	Participate

II.1.3 Approving and Administering Authorities

Apart from the Police and Civil Defence Organisations who may take control of a dangerous situation, there are three statutory Territorial Authorities who administer legislation relating to dam safety. These are:

- the relevant Regional Council
- the relevant District Council or
- the relevant City Council

Both Regional and District Councils have responsibilituies under the RMAct for the provision of resource consents and the application of constraints and approvals through the planning document preparation process.

Regional Councils are responsible for granting and maintaining resource consents[1] relating to land use, discharges and use of water. In considering environmental issues, the Regional Council will be concerned with dam safety in relation to potential environmental impact. District and City Councils are responsible for permitting existing and future structures via Code Compliance Certificates and will be most concerned with physical arrangements. It is important for Owners to be aware that these Authorities do not accept responsibility on behalf of the Owner for their actions, although under the Building Act, the District Council is liable for claims arising from latent damage for up to 10 years after issue of the initial Code Compliance Certificate. Regional Councils clearly have a duty of care to their ratepayer – constituents and a duty under the Resource Management Act to ensure that any adverse environmental effects are avoided, remedied, or mitigated

II.1.4 Technical Advisers and Contractors

Technical Advisers and Constructors or Contractors cover a wide scope of activities in the dam industry. Various aspects of investigation, evaluation, design and construction demand a high level of specialist expertise, particularly in the case of high Potential Impact or technically complex dams. Typical skills and related roles include:

- engineering geology and geotechnical engineering skills for appraisal of foundation and dam constituent materials and their behaviour
- hydrological and hydraulic engineering skills for assessment of river flows and hydraulic design of spillways and other hydraulic structures
- seismological and seismotectonic skills for appraisal of earthquake risk and selection of design criteria
- environmental assessment and engineering skills to identify issues and effects and achieve environmentally appropriate solutions
- dam and related structure engineering skills for design and detailing of the key structures and mechanical equipment, and establishment of maintenance and operating procedures
- skills in evaluating and managing construction risk, particularly floods during construction
- project management and quality assurance skills to ensure approved designs are translated into effective construction
- construction competence, experience, and integrity to ensure all works are built to the standards required - on larger or more complex projects, this will require selection of a range of specialist Construction Contractors for different parts of the works
- peer review and appraisal capability to overview Technical Advisers' work or undertake periodic surveillance and safety reviews of existing dams

These roles or services are generally filled from outside the Owners' own forces although Owners who have a number of dams, may retain technical and construction capability in house. The parties filling these roles play a key part in achieving safe and effective dams and often carry heavy responsibility for their advice or services. It is vitally important that they and the Owner understand the extent of their roles and the boundaries of their responsibilities. For example, it is not practical or reasonable to expect the Designer of a dam to certify the adequacy of its construction if the

[1] A Resource Consent is a document which authorises a person to undertake any activity which would otherwise not be permitted under the Resource Management Act. In relation to dams the relevant parts of the Act are Sections 14 (for a "water permit" to take, use, dam or divert a stream) and 15 (for a "discharge permit" to release water back into the stream.; Section B (Land use consent for constructing a dam in a water course). Section 9 may also apply.

Designer has not had adequate representation during construction or control over decision making on site. It is therefore usual practice and a recommendation of these Guidelines, that continuity of key Technical Advisers be maintained through design, construction and commissioning.

Other technical (or for smaller dams 'quasi-technical') roles include dam operation and routine surveillance. Generally these roles are fulfilled by the Owner's permanent staff, or in the case of a small simple dam, by the Owner personally. Services may be contracted out in the case of larger dams or operating facilities : again it is vital that requirements are fully understood and the participants have effective procedures in place.

II.1.5 Public

While the public interest is cared for in the broader sense by environmental and building legislation and its enforcement by the Authorities, the Public has the opportunity for direct involvement through the consents process whether the consents are for a new development or renewal of previous consents. Members of the public most likely to become involved are those directly affected by the dam and its operation, and wider interest groups advancing a particularly environmental, social, cultural, or political perspective.

Members of the public with a direct interest often include those to whom the dam (or more appropriately the stored contents), represents a potential hazard to life and property. Public safety is of primary importance and one of the reasons behind these Guidelines. The other participants in the dam industry must at all times recognise their duty of care to the Public and act de facto as agents for the well being of the Public.

II.2 Statutory Requirements

II.2.1 Introduction

The current New Zealand legislation relating to dam safety is:

(i) The Resource Management Act (1991) which regulates the use of the resource or an activity and grants consents or permits for use or management of the water and land involved. Conditions relating to dam safety may be applied to the consents or permits and key aspects are discussed in II 2.2

(ii) The Building Act (1991) supplemented by the Building Regulations 1992, which aims principally to provide buildings which are safe for occupants, and therefore is not particularly well suited to dams. Nonetheless, a dam is a building and under this Act a new dam requires a building consent and certification upon completion. If a new or existing dam contains certain systems (e.g. lift or fire sprinklers) it will also require an annual warrant of fitness under the Building Act. However, an existing dam (building) is otherwise exempt from this Act unless the Territorial Authority establishes that it is a dangerous building, when various measures can be taken.

(iii) The Hazardous Substances and New Organisms Act (1996) which controls potentially harmful substances, such as could be included in or stored in some dams, (e.g. as sludge or tailings dams).

(iv) The Civil Defence Act (1989) which provides for the declaration of local, regional or national emergencies by authorised personnel and the taking of specific action to deal with the emergency. Emergency action planning for dams is not mandatory, but is prudently integrated with the emergency services. Note that the supply of an emergency preparedness plan may be required by the conditions of the respective resource consents, in order to mitigate the effects of the dam.

(v) The Health & Safety in Employment Act (1992) which obliges employers to ensure the safety of employees in the work place, which could extend to areas downstream of the dam.

It should be noted that these Guidelines have no legal status except where they may be included in whole or part as conditions of consents and compliance certificates by Approving and Licensing Authorities.

The typical sequence for a new dam development, illustrating where legislative requirements related to safety are applied, is outlined on Figure II-1. Virtually all of the sequence would apply to an existing dam undergoing an upgrade as part of a whole scheme upgrading, or to correct safety deficiencies.

II.2.2 Resource Management Act Consents

Resource Management Act consents are in two principal categories:

- water permits (e.g. to dam divert, take for use, discharge)
- land use consents (e.g. for siting, altering, using materials)

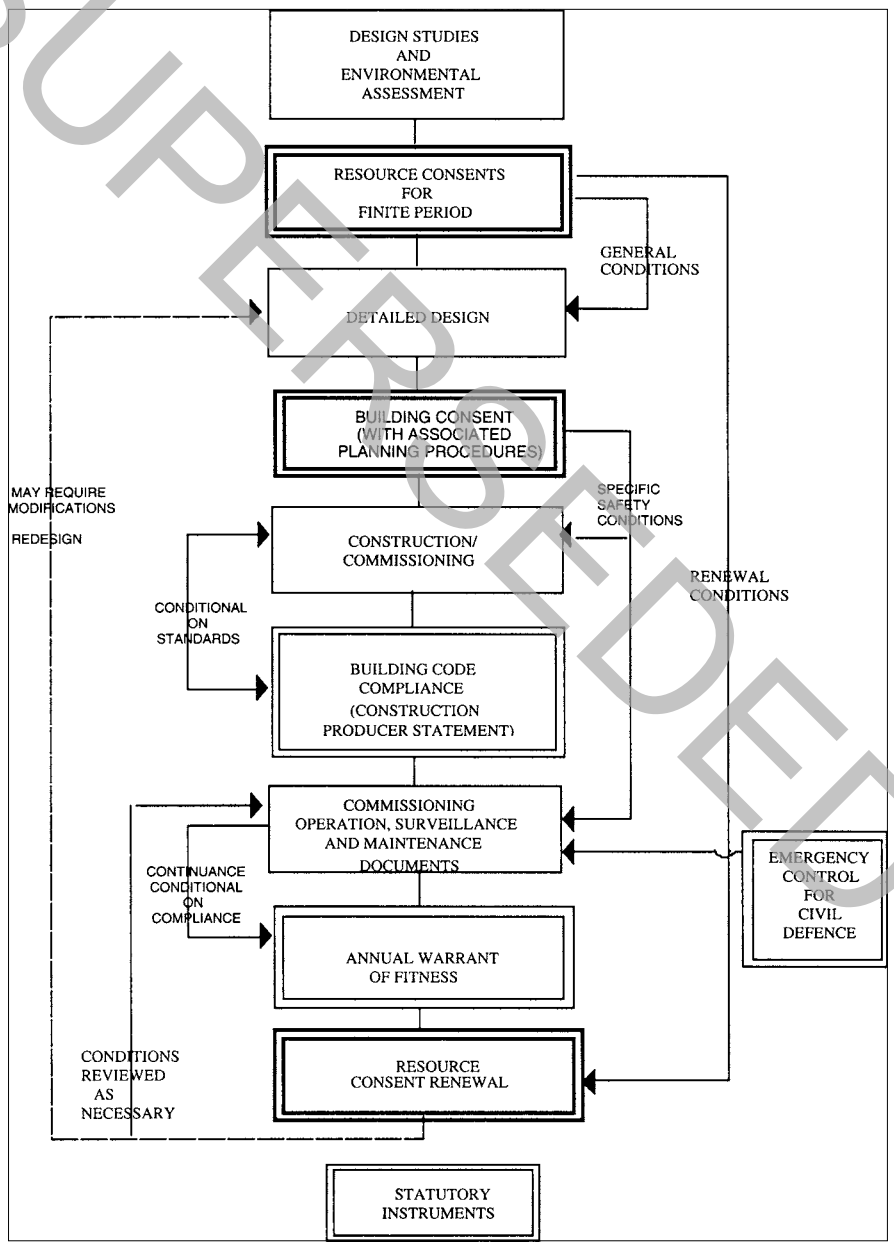

Figure II-1. Legislative Requirements in Dam Development and Operation.

This document does not outline all of the issues relating to the RM Act but highlights aspects relevant to dam safety. A key step in the process is establishing actual or potential effects, and avoiding, remedying or mitigating them to the satisfaction of the consenting authority. Effects include:

- any potential effect of high probability, or
- any potential effect of low probability but high potential impact.

Clearly the uncontrolled release of contents from dams could have a high potential impact. Any potential effect of significance and high probability clearly has to be avoided, remedied or mitigated.

Schedule IV of the Act lists matters to be considered including the risks and effects of natural hazards, or use of hazardous substances and installations, and where any discharge of contaminants may occur, the nature of the discharge and the sensitivity of the receiving environment to adverse effects.

An assessment has to be made of the risk to the environment "likely" to arise. The following points are made:

(i) the terms "hazard" and "risk" are not defined in the Act, but are generally understood to have the meanings:
   - that hazard is related to the potential for damage; and
   - that risk is related to the probability and consequence of that potential being realised.

(ii) "hazardous substances" are not defined in the Act, but are covered by the Hazardous Substances and New Organisms Act (1996) and stored natural water would not normally be considered a hazardous substance under this Act - naturally acidic or potentially corrosive water stored in a volcanic area could conceivably be hazardous and tailings liquor would be in that category, but still developing regulations (1999) should clarify the situation.

(iii) "natural hazards" are not defined but generally are taken to be earthquake, flood, volcanic activity, and the like - landslides probably come under this term.

(iv) "likely" is clearly a relative term and some suggest that this word is equivalent to foreseeable.

It is an offence under the Act(s. 15) to allow the uncontrolled release of a contaminant and naturally occurring stored water discharged in an uncontrolled manner into natural water comes into this category. **It is vital therefore that the consents clearly prescribe the conditions under which any uncontrolled release of contents from the dam is permitted.** This is highly relevant to consents for flood management during dam construction and the in-service capacities of spillways.

Dam safety planning for new projects starts with the schedule IV assessment of potential effects, their probabilities and how to design for them to a standard society will accept via the RM Act process. Section III.1 discusses hazards and risks in more detail. It is important to recognise the hazards and risks which apply during construction of the dam as well as the long term in-service condition.

Section 108 (5a) of the Act enables conditions to be set on the design of building structures. A dam is a building under the Building Act which is discussed in the next section. Basically the RM Act governs with respect to land use and the Building Act governs construction and subsequent use. Precedent law has established that the more stringent of conditions imposed under the two Acts will prevail.

It should be noted that any offence under the RMA is dealt with under criminal court proceedings. A successful prosecution against a person, no matter how minor or inconsequential

the offence may have been, will result in a criminal record and lead to the loss of certain personal rights, such as right of entry to certain countries. Furthermore, an employer cannot indemnify an employee against any proceedings, but can meet costs and pay fines.

As discussed in detail later within this document, the safety issues associated with dams, particularly higher hazard dams, can be quite complex. **It is therefore a recommendation of these guidelines that, for new structures,in the case of High Potential Impact dams as defined in section III of this document, any consent hearing committee or commissioners should be assisted by a senior dam engineering specialist with appropriate experience in dam design and construction , and be able, by that experience, to appreciate hazard and risk issues. Where dams are being reconstructed or the like, the risks should be well known already.**

II.2.3 Building Act Requirements

The Building Act defines a dam as a building by way of a negative exemption in the third schedule, which states:

> *"A building consent shall not be required in respect of…… Any dam that retains not more than 3 metres depth and not more than 20,000 cubic metres volume of water, and any stopbank or culvert."*

What the Building Act does require for new dams are:

(a) that, excepting repairs as defined in the third schedule, item (a), buildings constructed, altered or demolished, are subject to a building consent;

(b) as a pre-requisite to the consent, a Project Information Memorandum (PIM) from the Territorial Authority, relating to planning and landuse issues;

(c) a Producer Statement (Design) to establish compliance with the Building Code which accompanies the Building Act;

(d) A Producer Statement or statement (Construction) to confirm compliance of construction with the specified design;

(e) A Code Compliance Certificate issued by the a Territorial Authority, following satisfactory completion of the building work;

(f) a Compliance Certificate for continued use of the building where certain systems are included in the building (for dams, principally lifts and emergency fire / lighting systems), plus an associated annual warrant of fitness.

As far as most dams are concerned:

(i) the Building Code contains few *acceptable solutions* relevant to dams and generally the designer has to demonstrate use of *alternative solutions* to the satisfaction of the Territorial Authority (may require Peer Review as a consent condition);

(ii) few dams have systems requiring a Code Compliance Certificate and Annual Warrant of Fitness;

(iii) dams are exposed to risks during construction (mainly flood risk) which do not apply to typical buildings;

(iv) existing (i.e. pre-1991) buildings or dams are not subject to the Act unless the Territorial Authority deem them to be *dangerous, or earthquake prone.*

The Building Act does require the following, which may be relevant to (new) dams:

- under the Building Regulations, Clause B1, Structures, the performance criterion requires that buildings, building elements or siteworks, are to have a low probability of rupturing, becoming unstable, losing equilibrium or collapsing during construction or alteration throughout their lives (low probability is not, however, defined);

- under Building Regulations, Clause E1, Surface water, the performance criterion requires that surface water resulting from a storm having a 10% probability of occurring annually and which is concentrated by the building or siteworks shall be disposed of in a way that avoids the likelihood of damage or nuisance to other property (likelihood is not defined).

Generally, because dams are unusual and unique buildings, the Building Act does not cover them particularly well within the objectives of the Act and dam safety objectives. Territorial Authorities are likely to rely on peer review for the consent and code compliance processes as provided for in these Guidelines. If the Building Act were to be extended to be more specific and appropriate to dams, it would include a Compliance Schedule requirement for dams. A Compliance Schedule format which the dam industry considers would be appropriate and could be agreed between dam owners and the Territorial Authority, is outlined in Appendix H as a Performance Schedule.

II.2.4 Hazardous Substances and New Organisms Act Requirements

Certain dams could contain a hazardous substance having an intrinsic property of : *a capacity to oxidize, corrosiveness, toxicity, ecotoxicity.* The Act is a framework type backed by regulations, still being drafted at the time of issue of this (1999) Guidelines revision. Section 142 of the Act covers the relationship with other Acts. This section requires any RM Act function to comply with the HASNO Act requirements but would enable a RM Act consent to impose more stringent conditions. It is likely, therefore, that hazardous substances issues will be dealt with in the RM Act process, albeit recognizing HASNO Act requirements.

II.2.5 Emergency Services Situations

If the Authorities charged with civil defence responsibilities determine that an emergency exists (e.g. a dam is found to be on the verge of collapse), then the necessary declaration can be made. If there is a District civil defence plan, then the initiation can be at District level, but otherwise it will be at the Regional level, or even at National level. The latter might apply in the event of a major volcanic eruption, but otherwise, national emergencies are unlikely for dams. The Police can also initiate the process in the event of others not taking action.

Under a civil defence emergency, the key points relative to dams is that the powers include, to *"carry out or require to be carried out works ..... and the removal and disposal of dangerous structures and materials,"* as well as resource and rehabilitation activities. There is no upper limit to the powers to "carry out works."

II.2.6 Health and Safety Aspects

Employer obligations under the Health and Safety in Employment Act cover all employee activities including investigation work, construction work and all operations, maintenance and surveillance work. While the Act applies for the greater part to activities not directly related to dam safety, the Owner (Employer) of a dam has to ensure that the dam as a workplace is safe for operational employees, as well as for other persons who enter the site.

The penalties under the Act for breach (e.g. where a person, *"knowing that failure to take any action is reasonably likely to cause serious harm to any person, fails to take the action")* include:

- imprisonment to a term of not more than 1 year
- a fine of not more than $100,000
- both

Thus if an Owner is alerted to a potentially dangerous situation, and an employee is then seriously harmed through failing to protect the employee, the Owner may face serious legal consequence.

This section has been added for completeness, but is not directly relevant to the uncontrolled release of a dam's contents.

PART III - TECHNICAL ASPECTS

III.1 Classification of Dams

III.1.1 Introduction

The destructive forces unleashed by an uncontrolled escape of water or other contents stored behind a dam has the potential to harm people, property and the local environment. The consequential losses can include loss of life, socio-economic losses, financial losses and environmental losses.

The risk that a dam poses is related to both the consequences of failure and the likelihood that a failure could occur. Measures can be taken to reduce the risk to an acceptable level and that is what dam safety is about.

Many countries which operate dam safety programmes have established a classification system with between 3 and 5 categories that relate to the consequences of dam failure. These Guidelines follow this general policy and a classification system based on the Potential Impact of the dam failure has been adopted.

The potential impact classification can change during the life of a dam due to the nature and occupation of the valley downstream, or of valley use upstream. For a tailing dam the potential impact classification may change during various stages of development, operation, and closure. Consent renewals may, from time to time, require a review of the potential impacts and dam requirements to maintain acceptable safety.

There are many factors which can affect the potential impact of dam failure. These can include:

- the dam height (the higher the dam, the higher the potential energy of the water and the faster the water may escape);
- the volume stored behind the dam (the bigger the storage the bigger the damage potential);
- the nature of the stored materials (e.g water versus mine tailings or toxic wastes)
- the shape and hydraulic characteristics of the downstream valley which affects the nature and extent of potential flooding;
- the downstream conditions, particularly habitation or public areas and the valley environment which would be exposed to the effects of dam failure;
- the effects to a community of depriving them of the stored water which may be critical for water supply.

Other factors may affect the likelihood of a dam failure if they are not correctly dealt within the investigation, design, construction or operational phases of the dam's life. These may include:

- difficult or unusual foundation conditions;
- construction materials;
- proximity to active faults;
- catchment use (e.g. forestry operations with associated risk of debris)
- proximity to volcanic hazards; and
- landslides in the reservoir area.

It is the damage potential that is important in assessing the potential impact classification. The other factors that may affect the likelihood of a dam failure are important and need to be adequately addressed to minimise the risk the dam and its reservoir create.

The following sections describes the Potential Impact Classification of dams adopted in these guidelines.

III.1.2 Potential Impact Classification

These Guidelines adopt the definitions of Potential Impact category as given in Table III.1. The categories are based on the incremental losses which a failure might give rise to. Incremental losses are those additional losses that might have occurred for the same natural event if the dam had not failed.

The consequences (life, economic losses) with the higher rating determine the Potential Impact Category.

Potential impact classifications adopted for these Guidelines cannot be prescriptive and will be a matter for the consent authorities and owners to establish.

These Guidelines and the following sections are intended for dams where the potential impacts of failure include loss of life and damages beyond the owners property. Dams which would be classified in the very low category are generally outside the scope of these Guidelines. However these dams should be reviewed on a regular basis to ensure that land use changes have not altered the Potential Impact Category.

Very Low Potential Impact dams are likely to be those that are exempt under the Building Act, being those dams that retain not more than 3 metres depth, and not more than 20,000 cubic metres volume of water. The dam height would generally be less than 4 metres.

Low Potential Impact dams are likely to have dam heights less than 10 metres, and less than 6 metres if the storage exceeds 50,000 cubic metres.

Medium Potential Impact dams are likely to have dam heights in the 10 - 20 metre range, but not exceeding 15 metres if the stored volume of water exceeds 1,000,000 cubic metres.

If the dam height and storage exceeds those for other categories then a high potential impact classification is probable.

The dam height and reservoir volume parameters while useful for an initial screening of potential impact classification should not control the potential impact classification where the consequences of a dam failure are not consistent with such an initial screening. For example, a 10 - 15 metre high dam whose failure can lead to fatalities should be classified with a high potential impact. Similarly, a 25 metre high dam whose failure would not cause fatalities and where damages are moderate can be classified as Low Potential Impact. There are actual dams in New Zealand where the above two examples apply.

Flood detention dams could have a low potential impact under earthquake loads, but a high potential impact under flood loads, particularly if failure under floods lead to incremental fatalities.

Table III.1 Potential Impact Categories for Dams in Terms of Failure Consequences.

Potential Impact Category	Potential Incremental Consequences of Failure	
	Life	Socio-economic, Financial, & Environmental
High	Fatalities	Catastrophic damages
Medium	A few fatalities are possible	Major damages
Low	No fatalities expected	Moderate damages
Very Low	No fatalities	minimal damages beyond owner's property

III.2 Principal Dam Components and Related Safety Issues

Most people unfamiliar with dams, and potential new Owners or Developers, may think of the dam primarily as comprising the barrier across the valley which creates the reservoir storage. However, the complete dam comprises several parts, the number and type depending on the particular dam and its function. In the context of dam safety, the dam also includes the reservoir and its margins.

The principal components, their functional requirements, and typical areas where risk or safety issues occur, are summarised as follows:

(i) The Reservoir

The reservoir behind the dam will generally have a fluctuating water level which temporarily increases as floods pass through it and falls in cases where the stored water is drawn off for use. Initial reservoir filling and water level changes can make reservoir margins unstable where they are steep and/or have unfavourable geology. If the reservoir is full and there is a major reservoir landslide, the displaced water may cause major damage downstream and also cause the dam to fail.

(ii) The Main Dam Structure

The main dam structure creates the barrier which holds back the stored water. The dam cannot be treated in isolation from its foundations or the adjacent natural ground (or abutments) with which it acts in an integrated manner. Similarly the dam and spillway design need to be integrated to ensure that flood flows do not overtop the dam, except where the dam has been specifically designed to be overtopped without damage to the crest, abutments, or the downstream face.

The dam (and its foundations) must have adequate strength to withstand the applied forces and be sufficiently water tight to maintain the storage and prevent seepage from eroding the fabric of the dam (it is unlikely there will be no seepage).

As well as issues associated with the interaction of dam and its foundation, areas of risk affecting safety can be extensive and include:

- not correctly assessing material properties or not correctly placing materials during construction, thereby leading to lower strength than required
- material types, thickness and disposition being inadequate to control seepages, leading to excessive pressures or internal erosion
- earthquake forces and their effects on the dam being underestimated leading to underestimation of stability
- inadequate provision for long-term weathering and chemical degradation of materials leading to unacceptable loss of strength and unsatisfactory seepage control
- incorrect interpretation of the foundation and assessment of its compatibility with the formed dam and its behaviour following construction and reservoir filling.
- Inadequate provision for the effects of discontinuities at interfaces between the formed dam and its foundations and abutments and at embedded structures.
- Inadequate provision for temporary loadings (e.g. porewater pressures) during construction and commissioning.

(iii) Foundations including Abutments

The areas of ground on which the dam is located (sometimes called the dam footprint) and the areas of ground adjacent, form part of the total water barrier. If the foundations do not adequately support the basic dam structure, or are themselves weak or prone to high seepage flows and forces, then they can create an area of high risk.

As for the dam structure, areas of risk can be extensive and include aspects such as:

- geological defects in rock structures which are points of weakness and/or of high seepage flow potential, leading to poor structural performance and potential instability due to seepage
- weaknesses in the abutments making them vulnerable to slope failures
- weaknesses in the foundation that are susceptible to liquefaction during earthquakes
- potential long term chemical degradation of grouting undertaken to arrest foundation seepage or accelerated weathering or leaching at rock defects
- difficulties in interpretation of the nature and structure of foundations and their behaviour following reservoir filling. Lack of adequate investigation or interpretation may result in instability and excessive leakage.
- lack of information, inadequate identification or provision for seismic forces and movements

(iv) Conduits

The principal conduit is usually that used to divert river flow past the dam during construction. Other conduits may be required for drawing off water for its ultimate use. The conduits are often built as tunnels on large dams

Conduits, particularly those taken through the dam structure or foundations, create safety risks if the conduit openings can admit high pressure leakage into the surrounding fill or foundation. If seepage can track along the conduit in an uncontrolled manner, it can lead to erosion and a "piping" type failure. Many small dams have failed through inadequate protection against seepage associated with conduits.

(v) Spillways

The spillway system has to carry the flood flows safely past the dam and can take several forms. These include the use of a separate auxiliary spillway which operates only in floods which are very large, or have very low frequency. In some situations, particularly where the reservoir is not permitted to rise significantly during a flood, flood gates are installed and opened progressively to bypass the incoming flood flow.

Spillways and flood gates constitute a high risk part of the dam, with failure of the spillway system putting the dam or abutments at risk of severe erosion damage possibly leading to collapse. Areas of spillway risk include:

- flood sizes being underestimated with consequential undersizing of components

- Secondary effects such as debris blocking the intakes. This is often important for smaller structures with less spillway capacity.
- energy control arrangements at the end of the spillway being inadequate, causing erosion and structural collapse by undermining
- spillway chute details allowing high energy flow to create destabilising uplift pressures at structural joints or cavitation damage for high head spillways
- flood gates not operating as intended and auxiliary spill paths for this eventuality not being adequate

(vi) Construction Diversion — Provisions for diverting the river or catchment flows past the dam during construction may comprise coffer dams, diversion channels, conduits or tunnels. The diversion provisions require due attention to the community standards set in the consent process under the RMA. A detailed risk assessment is appropriate for each stage in the construction process, and to assess the effect of any procedural amendments. Additional protection may be required to protect the owner's or constructor's interests.

(vii) Tailrace/ Downstream — Often the short section downstream of the dam is significant to structural integrity especially with respect to slope stability and flood control/erosion.

(vii) Other Structures — Other structures include, intakes on the upstream side of the dam, and powerhouses or pump stations often built into the downstream foot of the dam.

In certain cases, damage to the structures can lead to consequential damage to the dam or endanger spillway capacity. The risks will depend on each situation but must be evaluated and protected against.

Prospective Owners who wish to have a wider understanding of how dams work are referred to the US FEMA Owner's Guidance Manual (see Guideline References at the end of Part IV)

III.3 Investigation, Design, Construction and Commissioning of New Dams

III.3.1 Introduction

This section relating to new dams, outlines recommended principles and procedures to achieve a safe dam. The outline is substantially in generalised and checklist form, but more detail and supplementary references are contained in the Appendices of Part IV.

The key components and principal safety issues which can arise in a dam development are outlined and then the recommended procedures are described. Procedures are first covered in general terms and then in relation to each of the three dam Potential Impact categories of Table III-1.

III.3.2 General Requirements

There are some fundamental principles which should be applied through the investigation, design, construction and commissioning stages to achieve an adequate level of safety. Design and Build contracts are dealt with in section B8 Of the document. The same principles apply, but more care may be required to ensure that the design concepts are not corrupted by later amendments in the construction or commissioning process. The principles are:

(i) the competence and experience of the Owner's agents relative to the nature and dam potential impact category of the dam, must be appropriate in all areas

(ii) there must be a co-operative and trusting relationship between the Owner and Technical Advisers, and the lead Technical Advisers or Designers must be given full control over decision making in critical areas

(iii) the Owner must agree to apply the appropriate level of funding for investigations, design and construction to reduce the chances of critically important issues (particularly related to foundations) being not sufficiently well assessed or under protected

(iv) the Designer/Technical Adviser has a duty not to compromise unduly due to financial pressures from the owner, developer or contractor

(v) a thorough evaluation of dam safety risks and the measures to control them must be made, with focus on providing affordable "fallback" arrangements to support primary defences

(vi) appropriate quality assurance procedures should be implemented at all stages including use of peer review for higher potential impact dams, and some critical aspects of medium potential impact dams

(vii) continuity of key technical advice should be maintained throughout all stages of the dam from development, through design, construction and commissioning, to reduce chances of critical points of design philosophy and intent being misinterpreted during construction or commissioning

III.3.3 Investigations

Pre-design and design investigations, depending on the situation, will encompass:

- defining topography
- defining hydrology, particularly flood characteristics
- defining geology and site specific foundation conditions and properties
- determining the properties of construction materials
- determining seismic and volcanic hazards and earthquake forces
- testing proposed construction techniques
- determining the potential impact and environmental effects
- local knowledge of previous designs in the vicinity

The degree to which each area of investigation is taken depends on the potential impact , scale of project and value of the investment to the Owner. The following subsection discusses this aspect in more detail. However, the importance is stressed of undertaking an adequate level of geological and foundation investigation by suitably qualified Specialists, working closely with appropriately qualified dam Designers. Many dam safety issues and incidents and also dam failures, are attributable to inadequate investigation and/or application of sufficiently well qualified personnel. Even small or low potential impact dams can have high likelihood of foundation related problems.

Dam investigations also include the aspect of seeking the most cost effective project solution, but this aspect and environmental aspects are not discussed as they do not relate directly to dam safety.

III.3.4 Design

Dam design can be complex, require a range of specialist disciplines, and involve considerable effort in identifying the most cost effective design. From the dam safety viewpoint, the key points which must be addressed are:

- evaluation of the potential impact of the dam, all associated risks, and the levels of security to be adopted for design in each area

- ensuring that the design team is suitably well qualified and led and is operating within appropriate quality assurance procedures
- using industry accepted state of the art analysis and design procedures appropriate to each area of design
- adopting a conscious defensive engineering approach in areas of greatest risk
- translating designs into clearly understood construction specifications and drawings, backed by an appropriately extensive design report which records all design data, philosophy and assumptions, and defines areas requiring re-evaluation or confirmation during construction
- formatting of the EAP, operating and maintenance manuals, commissioning, monitoring and documentation
- the design must be buildable. The construction sequence/method can influence the design.

III.3.5 Construction

The quality of construction is all-important to dam safety. The dam components will not have the level of safety targeted or adopted by the designer if construction materials or workmanship do not equal or exceed the design specifications. Even a small change of detail, e.g. in an area of potential high seepage forces, can severely prejudice the functional safety in the area of the detail and have wide reaching implications.

The following requirements are necessary from the dam safety viewpoint:

- the Constructors must be suitably experienced and committed to achieving the standards of work specified
- the level of supervision of the works, quality assurance procedures and Designer/Technical Specialist continuity, must be appropriate to the scale and complexity of the dam. Where appropriate, a peer review should be included
- the Owner must recognise that inherent uncertainties may remain after design investigations and only be revealed during construction, and have funding in place to deal with costs arising from additional requirements identified during construction
- any area identified in the design process as requiring confirmation by the Designer during construction, must be totally under the Designer's control, and no design change, however small, shall be made without the Designer's review and formal approval
- a suitably detailed design report and drawings showing the as-built structure of all components of the dam and foundation shall be developed as an on-going and integral part of the construction supervision process, and be prepared after completion of each component so that there is a reliable record to refer to at all times in the future
- foundation and construction material testing shall be undertaken with quality assurance methods
- an Emergency Action Plan shall be put in place (and modified as construction progress dictates) during the construction and commissioning works

III.3.6 Commissioning

Commissioning the dam provides the first test of the design and construction and may not be fully completed for some time due to the time required to fill the reservoir, establish stable seepage conditions and provide a flood which realistically tests spillway performance. Experience has shown that inherent safety problems are often disclosed during commissioning and the initial year or so of full operation. Strategies which maximise the opportunity to monitor performance against expectations are therefore critically important from the dam safety viewpoint.

Commissioning to achieve and maintain safety should involve the following as a minimum:

- carrying out the commissioning of the dam and respective components in accordance with preplanned written procedures after final construction inspections by the responsible Designer and respective Technical Specialists and recommendation by the Designer that commissioning may commence
- acquainting all those involved in executing and monitoring the commissioning of their roles and responsibilities including how to react in the case of measured performance not complying with expectations or safe limits
- continuing commissioning and initial performance surveillance as necessary until the responsible Designer is able to certify to the Owner that the dam can be considered fully operational within written operating and maintenance procedures (in some cases, to be practical, some items may require review within the operating regime - e.g. where the spillway has not been fully tested during basic commissioning)
- completing commissioning with a suitably comprehensive commissioning report which documents all activities, performance and changes made to works if any, so that there is a permanent record for future evaluations
- explicit review and monitoring of all seepages must be interpreted against the sealing methods, and foundations issues

III.3.7 Procedures Related to Potential Impact Classification

The extent of procedures required to develop an adequately safe Low Potential Impact dam do not need to be as rigorous or as detailed as those for a complex High Potential Impact dam, nor would they normally be considered affordable. However, the same principles apply. Table III.2 summarises specific (minimum) guidelines for dams in High, Medium and Low Potential Impact categories as defined in Table III-1. More detailed guidelines are contained in Appendix B.

III.4 Operation, Maintenance and Surveillance

III.4.1 Introduction

Effective and ongoing operation, maintenance and surveillance procedures are essential to ensure the continued viability and safety of a dam and its appurtenant structures. Poor operation, maintenance and surveillance will invariably result in abnormal deterioration, reduced life expectancy and possibility of failure. The proper operation, maintenance and surveillance of a dam provides protection for the Owner and the general public. Furthermore, the cost of good operation, maintenance and surveillance procedures is small compared with the cost and consequences of a dam failure which could include major repairs, loss of life, property damage and litigation.

For Very Low Impact dams, Owners etc. are referred to the NZSOLD publication: Guidelines on Inspecting Small dams.

The objectives of operation, maintenance and surveillance are to ensure that the dam is used to maximum effect whilst maintaining an adequate standard of safety and preparedness for continuing operation.

The benefits of good operation, maintenance and surveillance are quick identification of any corrective action required to promote the safety and extend the useful life of the dam.

III.4.2 General Requirements

All dams and reservoirs should be operated and maintained by their Owners in accordance with accepted safe practice. Operating, maintenance and surveillance procedures should be developed and documented by the Owner for the safe operation of the dam under normal and adverse condi-

Table III-2.
Summary of Minimum Procedures for Development of New Dams related to Potential Impact Classification.

Refer to TableE III-1 for Potential Impact Definition.

ASPECT	LOW	MEDIUM	HIGH
Designer and Technical Team Proficiencies	• prior dam design experience of advantage but not essential • designer should have good all-round civil engineering ability and experience • specialist geotechnical experience desirable for larger or more important structures in this category • specialist support is required for electrical & mechanical aspects • emergency response	• lead designer should have had prior specific experience in Medium Potential Impact dam design of similar type as leader of, or major contributor to design • specialist geotechnical experience should be employed for foundation and materials aspects • hydraulic structures should be designed by an engineer with relevant prior experience	• lead designer should have had specific experience in High Potential Impact dam design of similar type as leader of or major contributor to design • specialist personnel with appropriate qualifications and prior experience should be employed in all areas of investigation and design
Quality Assurance	• appropriate in-house systems • peer review desirable for larger or more important structures in this category.	• peer review of design and construction is desirable and strongly recommended if the design team's prior experience is not extensive • formalised planning and checking of all work should be carried out	• external peer review through design and construction should be applied • all work should be completed in accordance with specific quality assurance procedures, generally to ISO 9001 or similar
Investigations	• foundation investigation should involve pitting and hand boring at the dam site, general appraisal of land stability and obtaining all local knowledge • foundation drilling desirable for larger or more important structures in this category. • local knowledge • hydrological appraisal based on regional hydrological characteristics	• geotechnical appraisals should include: - air photo interpretation - appraisal of local and regional geology - pitting plus drilling of the dam site - pit and/or bore investigations of borrow areas for earth dams - in-situ and laboratory testing for permeability and strength as appropriate to conditions • consideration of potential landuse changes • hydrological appraisals should examine local factors such as rainfall intensity, infiltration characteristics, and run off characteristics	• geotechnical appraisals should be all embracing including: - engineering geological evaluation - comprehensive site investigations - assessment of reservoir slope stability - site specific seismic risk evaluation • hydrological appraisals should examine all relevant factors and employ a range of techniques for flood estimation • where reservoir storage is used for flood routing, specific reliable topographical survey of the relevant part of the reservoir should be undertaken

ASPECT	LOW	MEDIUM	HIGH
Design Standards and Methods	• standard procedures should be used for hydraulic structures design • precedent or empirically based design may be acceptable for the dam where the site appears to present no problems, and the dam less than 10m high • under static loading, and where dam stability is analysed, calculated factors of safety for the dam should be greater than 1.5 under the worst loading condition • a design report should be prepared stating clearly data obtained and employed, design/checking methods and assumptions made	• precedent or empirically based design should only be used for dams less than 15 m high, free of foundation difficulties • where precedent or empirically based design is used for the dam, proportioning and detailing should be suitably conservative (e.g. with generous internal drainage for earth dams) • actual or potential foundation and abutment problems identified in investigations should be dealt with specifically • design should consider long term, rapid drawdown and seismic loading cases regardless of the design method with appropriate factors of safety • construction practicality • design report should be accompanied by peer reviewers' report and endorsement.	• procedures should be comprehensive for all aspects and use state of the art methods and industry accepted factors of safety appropriate to the particular issue being considered and its effect on dam safety • design report to be fully comprehensive and supplemented by the peer reviewer's report endorsing the final design
Construction	• the Contractor(s) should have prior relevant experience in the classes of work involved • full time representation by technical personnel will not normally be required but inspections by a responsible engineer should be made at not less than the following points: - after foundation preparation and before starting dam construction	• the Contractor(s) should have had prior relevant company experience which is still held by operating personnel, and in particular, the work should be managed by a representative who has been actively involved in directly comparable similar work • for larger earthfill type dams full time supervision and control testing of earthworks is recommended and should be mandatory where the design is specific and is not based on an empirical approach which has conservative safeguards built into the design	• the Contractor(s) should have had relevant prior experience in significant or High Potential Impact dam construction or directly comparable work, have that experience still available to be brought to bear, and have on-site management with prior relevant dam construction experience at a senior level • the designer should be represented full time on site by adequately qualified personnel with access to specialists who can be called on to advise on specific aspects

ASPECT	LOW	MEDIUM	HIGH
Construction continued	- during construction of any conduits taken through the dam - during initial earthfill or concrete works - at any other point as necessary to enable a producer statement on completion • a brief construction report should be prepared, generally in support of the final producer statement	• inspections should be as outlined for Low Potential Impact dams and the designer should normally be responsible for confirming the quality of construction using suitably qualified personnel - however, to enable the final producer statement, each area will generally require more than one inspection - where there is not full time supervision, the work will likely require two or more inspections per week • the designer or any other person responsible for confirming the quality of construction should have adequate authority to order additional work necessary for safety • for dams with specific design or difficult foundations, a suitable level of instrumentation should be carefully considered • an appropriate construction report should be prepared, generally to accompany the producer statement, and be supported by sketches or drawings which illustrate any departures from the original design details	• there must be effective means for the designer to ensure that the design interest is always being realised and authority to order additional work necessary for safety • full time supervision and control testing of construction should be a mandatory requirement • peer review should be integrated effectively • comprehensive instrumentation for monitoring during commissioning and operations should be implemented • a detailed construction report and comprehensive as-built drawings should be prepared (due to the work involved, these data are likely to follow after the final producer statement)
Commissioning	•specific procedures are unlikely to be needed other than careful visual inspections by the owner during reservoir filling and testing of components • designer should observe and report on the results of reservoir filling and include a report in the producer statement. Unexpected results should be reported to the owner and appropriate advice obtained if necessary	• the designer should prepare a list of items for the owner to inspect carefully during commissioning together with limits for any instrumentation or measurements and procedures for reacting in the event of untoward behaviour • where behaviour has not met expectations or problems have been encountered, a report on commissioning should be prepared	• comprehensive procedures should be prepared related to the dam type, components and risks with an appropriate level of direct observation and ongoing review of results by the responsible designer • commissioning should be under the control of the designer with regard to matters of safety until the dam is satisfactorily operational and be completed by a comprehensive commissioning report

NOTE: In some cases the boundary between Medium and High Potential Impact may not be clearly definable and for dams at the upper end of the Medium range, most of the procedures for High Potential Impact dams may be warranted.

*Post-commissioning operational aspects must also be addressed, as discussed in Section III.4.

tions. The operating, maintenance and surveillance procedures should be regularly reviewed by the Owner, Operations Staff and their Technical Advisers to ensure they continue to meet the needs of the Owner, users and downstream communities as well as safety criteria.

A change in hydrology due to a change in precipitation (or the evaluation thereof), or increased run off due to land use change should be kept under review or more simply, it may be due to a significant increase in the length of record.

The scope of operating, maintenance and surveillance procedures should be set out in an operations, maintenance and surveillance manual appropriate to the Potential Impact Classification of the dam. Generally, Low Potential Impact dams which do not threaten life or property need less intensive surveillance and less rigorous operating procedures than Medium and High Potential Impact dams.

The most important activities in a dam surveillance programme are the frequent and regular inspections for abnormalities or deterioration in conditions and the collection, recording, analysis and evaluation of monitoring data. The frequency of inspections and recording monitoring data varies according to the task and the hazard category of the dam. Special inspections will be required after unusual events such as earthquakes, major floods, rapid drawdown or volcanic activity.

Details of these activities are set out in III.4.3 to III.4.5 and in Appendix E.

Operation, maintenance and surveillance will involve a wide range of personnel depending on the task and the Potential Impact Classification of the dam. In the case of a Low Potential Impact farm or irrigation dam for example, this will normally involve only the Owner except for low frequency inspections by an appropriate dam specialist. In all cases the Owner, Operator, Caretaker, Technician or Technical Specialists should be appropriately qualified, and must be trained to follow the requirements of the operations, maintenance and surveillance manual, including how to recognise warning signs and initiate appropriate action.

Typically for a Medium or High Potential Impact dam, the operations, maintenance and surveillance manual will cover the following principal areas:

- summary description of dam with selected drawings and references to other documents (e.g. as-built drawings)
- procedures for operating functional components
- owner's health and safety requirements
- routine equipment and structure maintenance procedures
- equipment overhaul requirements
- inspection and monitoring requirements
- evaluation procedures, definition of unacceptable behaviour and actions to be taken
- emergency procedures

Monitoring and inspections are a fundamental part of the process and these range from routine daily observations to special safety review inspections. Tables III.4.1 and III.4.2 show recommended levels of dam safety monitoring inspection and typical frequencies for inspections.

It is often the case for new dams that the monitoring system established and the associated frequencies of readings, are particularly comprehensive in areas of potential concern. The intermediate and comprehensive reviews may consider decreasing readings of specific observation points which have shown benign results over a sufficiently long period. It is advisable, however, to retain the points in case they are needed in the future.

Table III.4.1.
Dam Safety Inspections.

Type of Inspection	Inspector	Purpose
Routine	Operations Personnel (may be Owner)	The confirmation of satisfactory behaviour or identification of deficiencies by field and operating personnel as part of their duties at the dam.
Intermediate	Technical Adviser, Dams	The confirmation of satisfactory behaviour or identification of deficiencies by visual examination of the dam and review of surveillance data against prevailing knowledge. Equipment is not necessarily operated.
Comprehensive (e.g. safety review refer III.5)	Technical Adviser, Dams and Specialists (where relevant)	The confirmation of satisfactory behaviour or identification of deficiencies by a thorough onsite inspection; by evaluating data; and by applying current criteria and state-of-the-art knowledge. Equipment should be test operated to identify deficiencies.
Special	Technical Adviser, Dams and Specialists	The examination of particular features of a dam for some special reason (e.g. after earthquakes, major floods, rapid drawdown, volcanic activity).
Emergency	Technical Adviser, Dams and Specialists	The examination of a particular feature of a dam which has been identified as having a possible deficiency or which has been subject to abnormal loading conditions.
Compliance Certificate	Independent Qualified Person	For high and Medium Potential Impact classification dams, the preparation and or auditing of the compliance certificate annually to ensure that the dam safety assurance performance is within acceptable criteria, and that the approved procedures are in place, and applicable.

Table III.4.2.
Typical Frequency of Inspection.

Potential Impact Classification	Inspection Type (Refer Table III.4.1)				
	Comprehensive Review	Intermediate Review	Routine	Special	Emergency
High	On first filling * then 5 yearly	Annual **	Weekly to Monthly	As required	As required
Medium	On first filling * then 5 - 7 yearly	Annual**	Monthly	As required	As required
Low	On first filling * then 10 yearly	1 to 2 year intervals	Monthly to 4 Monthly	At owners discretion	As required

* as part of commissioning - refer III.2
** could include a compliance certificate as per Appendix H

For Low Impact dams where regular intermediate reports are carried out and made available to the consent authorities, the comprehensive dam safety review may be met by augmenting the intermediate report every ten years. For Very Low Potential Impact dams, a 10 yearly review of the potential impact is prudent.

III.4.3 Procedures for High and Medium Potential Impact Dams

Generally the procedures will be similar for both High and Medium Potential Impact Classification dams, with the level of detail reduced as the Potential impact classification of the dam reduces. Setting aside operational procedures related to the functional operation of the dam, the procedures will address the following main areas:

- operational and maintenance aspects which affect dam safety and related equipment maintenance
- routine monitoring
- specific inspections
- how equipment (including emergency and backup systems) is to be activated
- Emergency Action Plan

Operational and maintenance aspects affecting safety are usually related to spillways which have mechanical flood gates and/or energy dissipating discharge valves. The procedures need to make clear how equipment is to be activated and maintained to ensure flood passage risks are controlled.

Routine maintenance of components to preserve them in an acceptable condition is a fundamental part of the whole dam safety process. The periodic inspections provide a sharper focus in the process, through persons not in routine contact with the dam providing an external and critical overview. It is important that the maintenance aspects of any inspection recommendations be acted upon promptly, particularly where they could have a serious impact on safety if left unattended.

Routine monitoring of dam performance to confirm continued acceptable behaviour, is based on visual observations and measuring key parameters via instrumentation planned as part of design, or installed as a result of subsequent safety reviews (refer Appendix E for typical details, including recommended frequencies of observations and measurements). The recorded data, when evaluated on an ongoing basis, enables behavioural trends to be tracked and give early warning of adverse behaviour. The requirements are strongly influenced by the dam type (e.g. concrete, compacted fill, gravity, buttress, etc.). Typical items instrumented or monitored include;

- profiles and condition, deformations, seepages or damp areas (visual)
- reservoir water levels which relate to dam loads and flood behaviour
- local rainfall which relates to background seepages
- drainage and distinguishable seepages which relate to control of leakage water flow
- clarity of seepage flow which relates to potential erosion of embankment or foundation material.
- water pressures within the dam and foundations which relate to structural behaviour
- movement or deformation of the dam surface and internal structure which relates to structural behaviour
- stresses within the dam which relate to structural behaviour
- seismic acceleration which relates to structural behaviour

Routine monitoring must be accompanied by an effective system of evaluating results and taking action where necessary. The operations, maintenance and surveillance manual should contain maximum values for critical items (e.g. seepage values, water pressures, deformations) set by the Technical Advisers. If critical values are reached, the matter is referred immediately to the appropriate Technical Advisers for review and action.

An EAP is to be developed and routinely tested for High and Medium Potential Impact dams

III.4.4 Procedures for Low Potential Impact Classification Dams

Specific instrumentation such as water level and pressure measuring equipment is usually not considered to be necessary for Low hazard dams. Nonetheless some Owners may take conservative precautions and include a level of instrumentation more in line with that for a Medium category dam if a failure of the dam could have serious operational or financial consequences: i.e. the level of surveillance and instrumentation is dictated by asset protection rather than public and environmental safety. Generally, Low Potential Impact dams have simple operational arrangements which do not impact on safety and adequate operational and surveillance procedures will generally comprise:

- regular inspections by the Operator or Owner of the general condition of the dam and the consistency of aspects such as identifiable seepage
- routine maintenance of dam surfaces and spillway paths
- periodic (e.g. 1 to 2 yearly) inspections by an appropriate Technical Specialist

III.4.5 Emergency Action Planning

Dams should be designed, constructed, operated and maintained to minimise the risk of dam failure. Nevertheless, incidents can occur either naturally or precipitated by phenomena such as floods, earthquakes, sabotage or mal-operation which could create an emergency situation with respect to dam safety. For this reason emergency action planning should be undertaken for High and Medium Potential Impact Classification dams to minimise the adverse effects of such incidents. The plan should list actions that the Owner, Operations Personnel and relevant Government and Local Authorities should take if an incident or emergency develops. The process of developing an emergency action plan may involve some or all of the following actions:

- identify safe access routes to the dam for the conditions anticipated
- determine the inundated area from assessments of the possible effects of a dam failure (e.g. by dam break analysis)
- determine and identify those conditions that may initiate an emergency and specify the actions to be taken and by whom
- identify all agencies and individuals who would be involved in the emergency action plan, and co-ordinate the development of the plan with those parties
- identify communications systems between parties and individuals
- identify all special equipment and resources required and their location
- test and revise the plan at regular intervals

More detailed guidelines for emergency action planning are contained in Appendix F.

III.4.6 Personnel and Training

Safe management of dams is a frame of mind and involves all the people concerned from the Owner (or senior owner representative), through Managers to Operations Staff. Education and training must therefore be conceived along the lines of developing awareness of the need for ongoing vigilance, surveillance and maintenance in addition to giving instruction in the 'nuts and bolts' mechanics of the relevant and desirable procedures. The training and awareness raising must be related to the specific characteristics and Potential Impact Classification of the dam.

Clearly, the personnel involved must understand and fulfil their respective roles and be suitably trained in their areas of responsibility. This is particularly the case for Managers, Caretakers and Operational staff who may be recruited into their positions without prior specific experience. Appendix E provides recommendations.

III.4.7 Data Recording

All data relevant to dam safety obtained under routine operation, maintenance and surveillance, should be processed and recorded so that it is available for future safety reviews and forensic evaluation as necessary. This information should form part of the dam "data book". For High Potential Impact dams, special care should be taken to achieve security of the records using, for example, fireproof archiving and having at least two sets of data stored in two different places.

III.5 Safety Reviews of Existing Dams

III.5.1 Introduction

Modern practice in developed nations is to subject existing dams to a periodic safety review or audit. Such reviews are necessary to establish the safety condition of older dams designed and built in times when dam technology was not as highly developed as it is today, and where often there are poor records of design philosophy and construction details. Ongoing safety reviews are also of benefit for more recent and well documented dams as they enable an independent check on the appropriateness of all arrangements and the opportunity to take into account the effect of any new standards or state of knowledge (e.g. changed appreciation of flood or earthquake risk or changes in downstream landuse which may increase the Potential Impact of the dam).

The safety review is a formalised evaluation of the dam with the main objective being to ensure that the standards for safety are achieved and action is taken, where necessary, to achieve acceptable safety standards. The review involves an examination of dam arrangements, performance and surveillance systems on the basis of various criteria, including the following:

- the adequacy of the dam structures and spillway systems in the light of current knowledge and practice and longer length of data record
- the adequacy of operating and maintenance practices and instructions that affect dam safety
- the adequacy of the surveillance system in place
- the adequacy of the processing and reacting to previous surveillance data
- the adequacy of the Emergency Action Plan
- the expected performance of the dam in terms of its realistic hazards and consequences.

It is also important to consider potential long term changes in the catchment and downstream of the dam. For example:

- Forestry upstream can result in cyclic changes in runoff/floods with resultant spillway implications.
- Urbanisation downstream can occur after the dam reduces the flood hazard. The increased development will increase the consequence of any potential hazards.

The scope of the Safety Review will vary depending on whether the review is a "first time" review of an old dam for which there are poor records, a follow-up review after corrective action has been taken, or ongoing reviews of modern or modernised dams which are very well documented. Generally, Low hazard category dams do not warrant a detailed Safety Review except to check periodically whether their status has changed to a higher category.

The generally accepted frequency of Safety Reviews for High and Medium Potential Impact dams is at 5 or 7 yearly intervals. Unscheduled safety reviews may be necessary to respond to abnormal surveillance observations or data particularly where this corresponds with unusual events (e.g. flood or earthquake). The Owner is normally the party who commissions a safety review. However, any other party with a legal right to do so, may also request a safety review to verify the dam's safety.

The periodic technical evaluations should highlight the need for any modifications to maintain an appropriate level of safety.

Current legislation does not make safety reviews mandatory although they are often required as a consent condition and many of the larger Owners in New Zealand have voluntarily adopted safety review procedures. It is definitely in the Owner's interests to undertake safety reviews and they are most strongly recommended.

III.5.2 General Requirements

The requirements will vary depending on the type, age and Potential Impact Classification of the dam and whether the review is a first time or repeat review.

The so-called SEED (standing for Safety Evaluation of Existing Dams) manual produced by the U.S. Department of Interior, Bureau of Reclamation, gives comprehensive guidelines, naturally orientated towards U.S. practice and legislation. This manual is frequently used outside the US as a base for safety reviews, but is not necessarily appropriate in its entirety for New Zealand situations. However, it contains some basic general requirements which are important, such as:

- establishing and maintaining "data books" which document the details of the dam's composition, history, operation and performance
- the qualifications of the review team
- the general procedures for conducting the review

The data books are important and place an obligation on the Owner to maintain and safeguard records. Fully comprehensive data books will typically include:

- investigation data and reports
- design documents and design report
- as built drawings, construction photographs and construction report
- commissioning report
- operation, maintenance and surveillance manual
- surveillance records and relevant operational records
- incident reports and records of any changes to components or operations
- previous inspection and review reports

Often much of this data is almost non-existent in the case of older dams, and either as a precursor to the first safety review, or as part of it, considerable effort has to be put into collating whatever data may be available.

The independence and qualifications of the reviewers is an important requirement. The team members for the first two critical reviews should not have had any direct prior design, construction or operator involvement in the dam and be in a position to undertake the review independently without prejudice. Membership of the team will vary depending on the situation. Large / complex hydro dams usually require:

- a specialist civil engineer able to evaluate the civil engineering aspects and components
- a specialist mechanical engineer able to evaluate relevant mechanical components such as spillway gates
- a specialist geotechnical engineer or engineering geologist to evaluate foundation and related aspects
- an electrical engineer to evaluate the power supply, alarms, and the remote indication and control systems

Particularly in the case of reviews of older dams where wider expertise may be necessary to evaluate aspects which are poorly documented, the team is often widened to include:

- hydrological and hydraulic expertise
- dam analysts
- rock mechanics specialists
- at least one member of the team, or the team as a whole, must evaluate the relevant operating, maintenance and emergency planning facility aspects

Most dams require a suitably experienced and qualified civil engineer with back up specialist support for specific areas.

In conducting the safety review, it is important that the operations and maintenance personnel for the dam be available to accompany the review team and provide or obtain answers to relevant questions asked by the team.

Subsequent to major work on site, with a safety implication, the reviewers should be chosen such as they are not reviewing their own work.

III.5.3 Procedures for Dams of High and Medium Potential Impact Classification

As is the case for Operations, Maintenance and Surveillance, in Section III.4, the Safety Review requirements are similar in principle for both High and Medium Potential Impact Classification dams but the scope of the review and spread of specialist skills applied will reduce with reducing risk. It is virtually impossible to prescribe in a reference document exact requirements covering individual reviews and, in the absence of a single dam safety authority as applies under New Zealand conditions, the skills and experience of the dam industry should be drawn upon for specific advice. Owners and Statutory Administrators who do not have sufficient expertise directly available, are recommended to obtain advice from persons recognised in the industry as having appropriate expertise, when setting up briefs for safety reviews. These Guidelines, including the detail of Appendix G, can be drawn upon.

The safety review procedures involve the following:

- selection and briefing of review team
- appraisal of available information in data books
- physical inspection of the dam and associated structures
- testing and confirming the operation of mechanical equipment impacting on safety
- evaluating operating, maintenance and surveillance procedures and records including clarifying matters of detail with operations staff
- assessing the adequacy of the dam and its components to withstand current design standards with adequate margins of security related to hazard (refer to Sections III.2 and III.3)
- preparing a report covering the review work, which contains recommendations where necessary, for specific more detailed studies, remedial action, or improved routine procedures
- evaluating emergency procedures, facilities and equipment

III.5.4 Procedures for Dams of Low Potential Impact Classification

As stated in the introductory section, formalised safety reviews are not common for Low Potential Impact dams. However, the Owner may require a detailed safety review from an asset management or reinsurance viewpoint, particularly where failure of the dam (e.g. a hydro diversion intake or canal) could lead to major losses of revenue. If the recommended biennial inspections are undertaken by suitably qualified personnel, significant aspects related to safety should be identi-

fied, as a matter of course. Where a specific and independent safety review is undertaken, the procedures will be much the same as outlined for the higher potential impact category dams with the scope or level of detail determined by the Owner's level of concern about asset protection and the extent to which the hazard is "low".

III.6 Repair, Rehabilitation or Removal

Repair of any part of the dam, associated structures or equipment, will usually result from unexpected damage or a need to correct an unsafe condition detected during routine monitoring, or as a result of a safety review. The term rehabilitation is generally used to cover a significant upgrading of the facility to increase its economic lifespan, and modernise facilities to make them more cost effective and technologically appropriate. In some situations, the spur for rehabilitation may be a safety review which shows the need for major repair.

Whether the issue is one of repair or rehabilitation, the procedures which need to be followed are those outlined in Section III.3 for the design and construction of new dams. Repair or rehabilitation of an existing dam, does, however, raise a particular issue of flood risks during the work and how these are to be controlled with adequate safety. These Guidelines therefore recommend the procedures outlined in Section III.3 including particular attention to flood management during construction.

Where a dam is found to be in a potentially dangerous condition, temporary measures should be taken to improve safety until permanent repairs can be made. The Owner, once notified of a dangerous condition (i.e. which has the potential to lead on to "creation of an adverse effect on the environment") or having identified it, is legally obliged under s17 and s338 of the RMA to remedy or mitigate the effect. Failure to act can lead to fines up to $200,000 and $10,000 per day for continuing offences and up to 2 years imprisonment for Owners or Directors of Bodies Corporate. Statutory defences are available based on strict liability and dependent upon remedial actions. Temporary measures may involve lowering or drawing down the reservoir under an emergency consent granted by the Regional Authority. Significant reduction in risk may be provided by measures such as increased surveillance measures, directed at the identified hazard.

Removal of a dam, or decommissioning which has the same effect as removal, may occur because the dam has outlived its usefulness, or it requires safety works which the Owner cannot afford or which render uneconomic the operation associated with the dam. Unless emergency action is agreed by the Regional Council as being necessary, planned removal will require resource consents and an assessment of environmental effects. Again procedures should generally follow those of Section III.3 with focus on controlling risks during the removal or decommissioning work and leaving them acceptably low on completion.

III.7 Safekeeping of Records

A basic, yet often neglected, aspect of dam safety is the requirement for safekeeping of records. This requirement applies to all dams, irrespective of the hazard category particularly since a hazard category may change with time. The term records applies to all data relating to the dam as indicated for data books in Section III.5.2.

The minimum requirement for safekeeping of records should be that a duplicate of each is made, with the working copy kept at the nearest operations centre to the dam and originals in different buildings or in a fireproof strongroom. All records should be properly described in an index listing and archived in the appropriate location for quick retrieval.

III.8 Emergency Action Planning Guidelines

The Emergency Action Plan (EAP) is a formal plan that identifies emergency conditions at a dam and prescribes the procedures to be followed to minimise property damage and loss of life. The need for such a plan is demonstrated when an unexpected event creates a condition which may adversely affect the integrity of the dam or threaten life and property. All High and Medium Impact category dams should have an Emergency Action Plan.

The plan should detail the site specific procedures which an Owner, Operator, (or Contractor) and Relevant Authorities should implement if an emergency situation develops.

To develop an emergency action plan, the following items should be considered:

- identify and ensure safe and expedient access routes to the dam for the emergency conditions anticipated
- determine the potentially inundated area from relevant dambreak flood profiles downstream of the dam. Situations considered may include fair weather dam failure, design flood, with and without dam failure, as well as other extreme scenarios
- prepare inundation maps which clearly depict the flooded areas depicting flow velocities and depth
- identify all jurisdictions, agencies, and individuals who would be involved in the EAP. Co-ordinate the development of the EAP with these parties. This interaction should include discussion of evacuation (destinations, priorities, and procedures), post-flood actions (recovery and clean-up), and other measures necessary in the event of an emergency
- identify primary and secondary communications systems, both internal (between persons at the dam) and external (between dam personnel and outside entities).
- identify all special tools, equipment, keys and where they can be located if required in an emergency
- list and prioritise all persons and entities involved in the notification process, and draft a Notification Flowchart
- develop a draft of the EAP
- hold meetings with all parties (including public) included in the notification list for review and comment on the draft EAP
- make any revisions, obtain the necessary plan approval, and disseminate the EAP to those who have responsibilities under the plan
- test and revise the EAP at regular intervals
- review the notification chart at regular intervals

Appendix F provides more detailed guidelines for the preparation of Emergency Action Plans.

An essential ingredient for the emergency action plan is the participation of all parties, with potential involvement, in the preparation, implementation and testing of the plan.

Where a dam is under construction, the issues and environmental factors will vary with the progress of the project. The EAP needs to be updated to account for these changes, and the current foreseeable hazards and consequences.

PART IV - TECHNICAL TERMS

Definitions

Acceptable Risk - The level of risk (the combination of the probability and the consequence of a specified hazardous event)which the public are prepared to accept without further management. Acceptability of risk may be reflected in government regulations. It will be determined in court judgements.

Annual Exceedance Probability (AEP) -

Probability that an event of specified magnitude will be equalled or exceeded in any year.

Abutment - That part of the valley side against which the dam is constructed.

Appurtenances - Structures and equipment on a project site, other than the dam itself. They include but are not limited to, such facilities as intake towers, powerhouse structures, tunnels, canals, penstocks, low-level outlets, surge tanks and towers, gate hoist mechanisms and their supporting structures, and all critical water control and release facilities. Also included are mechanical and electrical control and standby power supply equipment located in the powerhouse or in remote control centers.

Base of dam - General foundation area of the lowest portion of the main body of a dam.

Catchment - Surface area which drains to a specific point, such as a reservoir, also known as the watershed or watershed area.

Certificate of Dam Compliance -

A certificate of dam compliance (or annual warrant of fitness) is a non compulsory certificate prepared by an independent qualified person, based on a compliance schedule prepared for the specific dam and its appurtenant structures. It is a warranty that the dam is being operated within agreed procedures, and is performing within the limits set for individual indicators.

Consequences of failure -

Impacts in the downstream as well as upstream areas of the dam resulting from failure of the dam or its appurtenances.

Consequence category -

Scale of adverse consequences that would be caused by failure of a dam.

Dam - Barrier which is constructed for the purpose of enabling the storage or diversion of water, or water containing any other substance, that could impound 30,000 m^3 or more and is 2.5 m or more in height. The height is measured vertically to the top of the barrier, as follows:

(i) from the natural bed of the stream or watercourse at the downstream toe of the barrier, in the case of a barrier across a stream or water course.

(ii) from the lowest elevation at the outside limit of the barrier, in the case of a barrier that is not across a stream or watercourse.

"Dam" is herein defined to include works (appurtenances) incidental to, necessary for, or in connection with, the barrier.

For purposes of these guidelines, this definition may be expanded to include "dams" under 2.5 m in height or which can impound less than 30,000 m^3, if the consequences of failure would be unacceptable to the public, such as:

- Dams with erodible foundations where a breach could lower the reservoir more than 2.5 m
- Dams retaining toxic substances

Dam safety inspection - An inspection of the dam to observe its condition. Inspections are carried out much more frequently than Dam Safety Reviews.

Dam Safety Review - Comprehensive formal review carried out at regular time intervals to determine whether an existing dam is safe, and if it is not safe, to determine required safety improvements.

Emergency - In terms of dam operation, any condition which develops naturally or unexpectedly, endangers the integrity of the dam and downstream property or life, and requires immediate action.

Emergency Action Plan (EAP) - Document which contains procedures for dealing with various emergencies, as well as communication directories and inundation maps showing upstream and downstream water levels and times of arrival of floods which would result from the failure of the dam or its appurtenances.

Extreme event - Event which has a very low annual exceedance probability (AEP).

Extreme Loads - The rare loading imposed by extreme events such as earthquakes, floods and landslides.

Failure of dam - In terms of structural integrity, the uncontrolled release of the contents of a reservoir through collapse of the dam or some part of it; in terms of performance to fulfill its intended function, the inability of a dam to perform functions such as water supply, prevention of excessive seepage or containment of hazardous substances.

Foundation - Rock and/or soil mass that forms a base for the structure, including its abutments.

Freeboard - Vertical distance between the water surface elevation and the lowest elevation of the top of the dam or other containment structure.

Full Supply Level (FSL) - Maximum normal operating water surface level of a reservoir. Also called maximum normal level (MNL).

Hazard - Threat; condition, which may result from an external cause (e.g. earthquake or flood), with the potential for creating adverse consequences.

Incremental Consequences of Failure - Incremental losses or damage which a dam failure might inflict on upstream areas, downstream areas, or at the dam, over and above any losses which might have occurred for the same natural event or conditions, had the dam not failed.

Inflow Design Flood (IDF) -

Most severe inflow flood (volume, peak, shape, duration, timing) for which a dam and associated facilities are designed.

Inspection - See "Dam safety inspection".

Maximum Credible Earthquake (MCE) -

Largest reasonably conceivable earthquake that appears possible along a recognized fault or within a geographically defined tectonic province, under the presently known or interpreted tectonic framework.

Maximum Design Earthquake (MDE) (or Safety Evaluation Earthquake (SEE)) -

The MDE is used for new design, and the SEE is used for evaluation of existing dams. The earthquake that would result in the most severe ground motion which a dam structure must be able to endure without the uncontrolled release of water from the reservoir.

Maximum Normal Level (MNL) -

See "Full Supply Level".

OMS manual - Manual which documents procedures for safe operation, maintenance and surveillance of a dam.

Outlet works - Combination of intake structure, conduits, tunnels, flow controls and energy dissipation devices to allow the release of water from a dam.

Owner - Person or legal person, including a company, organization, government unit, public utility, corporation or other entity, which either holds a government license to operate a dam or retains the legal property title on the dam site, dam and/or reservoir, and which is responsible for the safety of the dam.

Probable Maximum Flood (PMF) -

Estimate of hypothetical flood (peak flow, volume and hydrograph shape) that is considered to be the most severe "reasonably possible" at a particular location and time of year, based on relatively comprehensive hydrometeorological analysis of critical runoff-producing precipitation (snowmelt if pertinent) and hydrologic factors favourable for maximum flood runoff.

Probable Maximum Precipitation (PMP) -

Greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of year, with no allowance made for long-term climatic trends. The PMP is an estimate of an upper physical bound to the precipitation that the atmosphere can produce.

Regulatory Agency - Usually a government ministry, department, office or other unit of the national or provincial government entrusted by law or administrative act with the responsibility for the general supervision of the safe design, construction and operation of dams and reservoirs, as well as any entity to which all or part of the executive or operational tasks and functions have been delegated by legal power.

Reliability - Likelihood of successful performance of a given project element. It may be measured on an annualized basis or for some specified time period of interest. Mathematically, *Reliability = 1 – Probability of failure*.

Reservoir - Water body impounded by one or more dams or dikes, inclusive of its shores and banks and of any facility or installation necessary for its operation.

Reservoir capacity - Total or gross storage capacity of the reservoir at full supply level.

Return period (mean return period) -

Reciprocal of the annual exceedance probability (AEP). Over a long period of record, the return period equals the average elapsed time between occurrences of an event equaling or exceeding a specified magnitude.

Risk - Measure of the probability and severity of an adverse effect to health, property, or the environment. Risk is estimated by the mathematical expectation of the consequences of an adverse event occurring (i.e. "the product of the probability of occurrence and the consequence"). See also Acceptable Risk

Safe dam - Dam which does not impose an unacceptable risk to people or property, and which meets safety criteria that are acceptable to the government, the engineering profession and the public.

Spillway - Weir, channel, conduit, tunnel, gate or other structure designed to permit discharges from the reservoir.

Spillway crest - Uppermost portion of the spillway overflow section.

Tailing dam - Dam constructed to retain tailings or other waste materials from mining or industrial operations.

Tailwater level - Level of water in the discharge channel immediately downstream of a dam.

Toe of dam - Junction of the downstream (or upstream) face of dam with the ground surface (foundation). Sometimes "heel" is used to define the upstream toe of a concrete gravity dam.

Top of dam - Elevation of the uppermost surface of a dam proper, not taking into account any camber allowed for settlement, curbs, parapets, guard rails or other structures that are not a part of the main water-retaining structure. This elevation may be a roadway, walkway, or the non-overflow section of a dam.