# APPENDIX A

# LEGAL OBLIGATIONS AND LIABILITIES OF THOSE ASSOCIATED WITH THE NEW ZEALAND DAM INDUSTRY

## A.1 Existing Legislation

The sources of legislation placing obligations on those associated with the dam industry are:

- Civil law
- Resource Management Act 1991
- Building Act 1991
- Civil Defence Act 1985
- Health and Safety in Employment Act 1992
- Local Government Act 1974

## A.2 Requirements under Civil Law

**Ryland v. Fletcher**

The House of Lords established the following principle of law:

> *"we think that the true rule of law is that the person who for his own purposes brings on his lands and collects and keeps there anything likely to do mischief, must keep it in at his peril, and if he does not do so, is prima facie answerable for all damage which is a natural consequence of its escape"*

This provides a clear basis for liability of the person responsible for the dam existing in the first place. The water (or other stored material) is kept at the peril of the person responsible for keeping it there, and that person will be liable if the stored material escapes. Fault is not a necessary element for liability to be established. The risk is implicitly accepted by bringing a known dangerous substance onto the land.

**Negligence**

For operators and subsequent owners of dams, the principles of negligence apply, rather than strict liability under the Ryland v. Fletcher principle. The basic principle is that in operating a potentially dangerous structure such as a dam, reasonable care must be exercised to ensure that damage to others is not caused by a failure of the dam.

The focus will be on whether action taken during design, construction and operation of the dam was reasonable in the circumstances to ensure against such a failure occurring.

A formal set of guidelines emphasising accountability and review of all aspects of dam design, construction and operation is required by the owner, to ensure there is the strongest chance of picking up any mistake before it can contribute to a dam failure.

The New Zealand Dam Safety Guidelines can be used as the minimum standards for conforming.

**Civil Liability resulting from Damage due to Natural Causes**

The owner or operator of a dam could be civilly liable for damage caused by processes which arise as a natural consequence of the existence of the dam. If the damage was the reasonably foreseeable result of the activity of damming the river, etc., then the owner / operator could be argued to be liable.

The owners / operators need to undertake comprehensive studies regarding the natural effects of the construction and operation of the dam. All reasonable steps then need to be taken to eliminate or minimise the risk.

## A.3 Requirements under the Resource Management Act (1991)

The Resource Management Act provides for criminal offences in the event of breaches of its provisions.

The Court of Appeal has allowed that "*a failure to properly investigate and take appropriate preventative steps amounted to allowing an escape*"

Section 341(1) makes the criminal provisions of the Resource Management Act strict liability offences, the defence to which is proof of absence of fault. It is important to operate lawfully with all relevant consents applying to a dam, its maintenance and operation.

Section 341(2) sets out the specific nature of statutory defences.

The courts have stated that in order to establish a defence, the defendant must have exercised all reasonable care by establishing a proper system to prevent commission of the offence and by taking all reasonable steps to ensure the effective operation of the system.

When considering natural disasters, the courts will assess that the threshold above which a natural occurrence could be said to have been unforeseeable or impossible to provide against to be extremely high.

### Mitigation of Effects

Under the Resource Management Act, there is an obligation upon the defendant to adequately mitigate or remedy the effects of the event and if possible to avoid the event occurring.

### Personal Liability of Directors

Directors are unable to hide behind the body corporate if the corporation is charged with an offence against the Act which was authorised, permitted, or consented to by that Director.

Directors have a responsibility to ensure that there is a published set of safety guidelines which are followed and designed to prevent the sort of occurrence which could give rise to a criminal prosecution under the Resource Management Act.

Senior managers may all share in the responsibility.

### Remedies by Litigants

Litigants who identify potential damage with no precautions in place may consider options ranging from "Quia timet" injunctions brought to prevent the possibility of future damage or injury, to enforcement orders under the Resource Management Act.

## A.4 New Zealand Building Act (1991)

### Application to Dams

The New Zealand Building Act in its present form (1997) includes significant dams as buildings by way of 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."*

The indirect reference to dams intimates that the drafters did not have dams in mind during the preparation of the act.

The Building Act generally accepts the original design standard as satisfactory for the life of a structure, whereas the Resource Management Act places an obligation on the owner continually to reassess the ability of the dam structures to resist foreseeable events so as to mitigate against a catastrophic release of stored material.

Because of the unique nature of dams, there is a lack of established design and building codes for dams that are typical of those applied in the building industry.

**Compliance during Construction and Commissioning**

The Building Act currently allows for safety compliance during construction and commissioning of a building to be detailed in the plans and specifications submitted to the territorial authority at the time of the application for a building consent.

Under the building Act a new dam is a building and requires a building consent and certificate upon completion.

If a new or existing dam contains structures with features for public access such as lifts, fire sprinklers, etc., then an annual warrant of fitness is required.

Part IX of the Building Act which relates to dangerous buildings, has provisions to take action when it is apparent that a dam is in a dangerous condition or is being operated in a dangerous manner.

# APPENDIX B - DESIGN

## B.1 Introduction

This Appendix expands upon the recommendations of the main text of the Guidelines, by providing a higher level of detail and discussion of technical aspects. Specific design and analysis methods suited to each dam, are left to Designers, and the focus of these expanded guidelines is on issues to be considered. A list of references which contain various design recommendations is provided under Guideline References in Appendix G.

## B.2 Dam Types and Related Factors

There are various types of concrete and earth/rockfill dams, which are well described in reference literature. The point of this section is to highlight key factors related to each type to help guide the Designer in the right direction.

As outlined in the main text, canals and ‘saddle’ dams more than 3 m high are considered to be dams. Current legislation excludes river flood protection banks, usually called “stopbanks” in New Zealand, although they constitute an elongated flood detention dam with a relatively low design flood compared with other dams. Owners and Designers of stopbanks should consider applying these Guidelines to stopbank design.

Main uses for dams are:

- community and irrigation water storage dams and conveyance (canals)
- flood detention (special purpose dams and stopbanks)
- water storage and elevation (dams) and conveyance (canals) for hydro power generation
- storage of mine tailings and other wastes
- pollution control and water treatment
- recreation

The use and associated life of the dam can have a significant bearing on design requirements and standards, and need to be taken into consideration appropriately for each dam. Most text books and references tend to approach dam design from the perspective of dams which generally have a consistently high reservoir level except when the reservoir storage is depleted in a rapid drawdown situation. However, flood control and tailings dams usually vary from the usual condition and warrant a modified approach. By way of example:

- Tailing dams: These may have a short operating life and be rehabilitated to a “walk away” situation which is quite different from the operating condition. The short operating life may warrant one set of design criteria and the rehabilitation condition will usually require different criteria. The environmental hazard of potentially toxic materials in the dam structure or stored behind the dam, may warrant a much higher level of material and seepage control than is required in a dam involving chemically neutral materials.
- Flood detention dams: The short exposure time to high reservoir levels will usually mean that seepage pressures are substantially different from those in a “normal” dam and may lead to design details which also are different. The low level conduit for normal flow at valley floor level has to operate at all times, which may mean passing bed load with erosion potential. Thus care needs to be taken in design to cater for longevity and practical repair of the conduit if ever needed in the future.

These examples illustrate the need to identify and appreciate specific factors and avoid inappropriate application of "text book" design.

Noteworthy factors which should be recognised for different dam forms are as follows:

- Embankment dams
  - layering of earthfill, leading to concentrated near horizontal seepage and unsafe internal pressure is always a possibility and the lower the level of supervision, the higher the likelihood
  - certain NZ materials such as loess and central North Island low density pumiceous deposits, are substantially more vulnerable to erosion or piping than other materials and demand extreme care
  - care to be taken with materials in Karstic areas
  - the quality of foundation for seepage control and durability of rockfill used in faced or central core rockfill dams requires close attention
  - testing material for dispersivity
- Rollcrete and concrete gravity dams
  - design needs to appreciate the adverse effects that weak or deformable foundations, and uncontrolled heat of hydration may have on concrete stresses within the dam
  - directional earthquake forces critical for most dams
- Concrete buttress dams
  - foundations need to withstand concentrated buttress forces, particularly under earthquake loading
  - temperature effects are also important
  - capable of withstanding high hydraulic gradient
- Concrete arch dams
  - foundations and abutments need high competence to carry gravity loads and horizontal thrusts
  - competent arch dam design, particularly under directional earthquake loading and to modern standards, is highly complex and requires a high level of specialisation in arch dam analysis
  - capable of withstanding a high hydraulic gradient
  - foundation defects can be critical to dam stability



## B.3 Assessment of Hazards and Risks

Evaluation of hazards, potential impacts, factors affecting risk, acceptable levels of risk, and means of limiting risk, are a part of or prerequisite to effective design.

There is a need to distinguish between the hazards applicable during the construction period, and the relevant hazards post construction.

Basic potential impact assessment must make a reasonable evaluation of the flood wave and downstream inundation resulting from dam failure and/or overtopping due to conceivable reservoir landslides. Conservative estimates will likely be acceptable for small dams with modest storage or dams in remote areas where there is little habitation. Where there is human habitation, significant property, or high environmental values downstream, an industry accepted computer analysis of the effects of dambreak should be undertaken.

The factors which are likely to contribute most to potential dam failure must be evaluated at the appropriate level relative to the potential impact category defined in the main text. The most important are:

- site and regional geology including landslides
- tectonic movements and seismic forces/potential

- flood characteristics
- internal and foundation erosion

There are others which are more remote, such as volcanic eruption.

As well as establishing the basic potential impact classification, and areas of greatest risk, it is necessary to establish acceptable risk levels. The starting point is industry practice as set out in literature and accepted precedents. The consents processes may set minimum requirements (which for example may be much more stringent for a tailings dam than an equivalent water supply dam). The Designer should also seek the Owner's minimum requirements from the commercial viewpoint, which may possibly be set between the Owner and Insurer.

## B.4 Personnel and Quality Assurance

The basic requirements for technical personnel have been set out in the main text. It needs to be appreciated that dam engineering is a mixture of science and art. Although physical laws and mathematical principles play important roles, significant reliance is also placed on experience and engineering judgement. No matter how complete investigation and design methods may be, they can in no way replace the exercise of competent and experienced judgement.

Another factor of importance is continuity between design and construction to ensure design intent is correctly interpreted and proper account is taken of the effect of any site conditions being different from those assumed in design. Such changes may not be obvious to people other than the Designer or Design Team. Quoting from the Federal Guidelines for Dam Safety, "The design function can never be considered finished as long as the dam remains in place: design involvement should continue throughout construction and operation of the project." This statement goes even further into operation but it is generally recognised that persons different from the Original Designer may address design issues once the project is fully operational.

During Design/Build projects, the owner needs to be assured that the original designers maintain a watching brief and are consulted on all changes up until the commissioning is complete .

The investigation and design of dams must address a variety of knowns and unknowns, and sufficient funds must be allocated to ensure that dam safety is not compromised by inadequate practices. Proper investigation and design requires that all critical issues are identified, investigated and resolved to acceptable risk levels, following industry guidelines.

Allowing or ensuring sufficient time for thorough investigation and design is another important factor sometimes overlooked in the pressure to make progress once a final decision to proceed is made. Designers and Owners must be realistic about the time needed.

Quality assurance procedures have been addressed briefly in the main text (Section III). Requirements are outlined more fully as follows for different dam potential impact categories:

**(a) Low Potential Impact**

A formal review of the Designer's work, by an independent experienced engineer, is not considered essential. However, the Designer should have in place appropriate in-house systems to regularly review the work and ensure that the investigation and design processes properly address all engineering issues relating to the project. In some cases it may be appropriate to seek support of Technical Specialists to address specific engineering issues, particularly during the initial conceptual phases of the project.

**(b) Medium Potential Impact**

A formal engineering review of the Designer's work, by an independent experienced engineer, is desirable. Formal in-house systems for the planning, checking and reviewing of all work should be in place.

If the design team has limited experience in the investigation and design of Medium Potential Impact dams, a formal engineering review process should be incorporated within the design service agreement. The process should include an early initial review, to ensure that the design concept is appropriate for the proposed site and available construction materials, and regular design reviews at appropriate intervals during the design.

**(c) High Potential Impact**

A formal engineering review of the Designer's work, by an independent experienced engineer, should be a mandatory requirement. The review process should be thorough and on similar lines to that outlined above for the investigation and design of Medium Potential Impact dams. In-house systems for the planning, checking and reviewing of all work should be in accordance with a Quality Plan, satisfying the requirements of ISO 9001.

A limited experience team should be supplemented with suitably experienced staff.

While peer review is a cornerstone of Quality Assurance, the Quality Plan and adherence to the plan is of prime importance. Plans will vary in scope and detail depending on the project, but should include:

- a detailed design brief setting out objectives or performance criteria, data sources and assumptions, engineering design criteria, standards, methods of analysis, and the like
- means of handling design changes
- description statement of personnel responsibilities and interdisciplinary interfacing
- communication and documentation requirements

To achieve the most effective and co-operative peer review during design, there are some basic principles which should be followed. These include:

- commencing peer review early in the design process before the Designer has developed design proposals which are difficult or costly to modify
- encouraging good and regular communication between the Reviewer and Designer
- briefing the Reviewer to assess and question in depth and provide opinions on areas considered to need improvement from the safety viewpoint, but not to usurp the design which must remain the Designer's responsibility
- having a mechanism agreed between all the parties for resolving any areas where the Designer and Peer Reviewer may have strongly opposing views and the Designer does not support the Reviewer's proposals (usually applies where the Reviewer proposes a more expensive way of achieving the particular objective)

## B.5 Investigations and Data Assembly

All investigations and assembly of data ready for design must be to a level which is appropriate to the Potential Impact category, site characteristics and commercial value of the dam. Areas normally requiring investigation or measurement relative to dam safety, are:

- flood hydrology
- site and reservoir engineering geology and foundation characteristics
- site (including reservoir) and regional seismicity

A point to note is that flood estimation needs to take into account the best possible appreciation of future catchment changes (e.g. deforestation in the case of a remote dam or increasing urbanisation in the case of a flood detention dam).

Several of the references listed at the end of Appendix H provide detailed guidance on investigation techniques and many more references exist through technical books, papers and conference proceedings. The following paragraphs set out key points but do not necessarily constitute an all-embracing checklist.

**(a) Low Potential Impact**

- flood hydrology - Generally less rigorous methods of flood estimation will be acceptable, such as use of published regional flood estimation techniques and adoption of triangular shaped hydrographs
- geology and foundations - Techniques will generally include examination of published geological maps, canvassing local knowledge, inspection for signs of surface instability, pitting of dam footprint and borrow areas, and hand boring. Some basic testing should be undertaken such as in-situ strength measurement of foundations to confirm the extent of any subexcavation needed, in-situ soakage tests to gain an appreciation of foundation seepage potential where this may be of concern, compaction and associated strength tests on fill to confirm what is required to achieve adequate fill standards, and grain size, Atterberg limits and permeability testing of fill where relevant for design of through-seepage control measures. If there is any indication of potential difficulties via local knowledge, signs of previous slumping at the dam site or around the reservoir, weak foundation material continuing beyond the depth of pits and hand bores, volcanic ashes or loess type materials being present, or any other finding giving possible concern, then a suitably experienced specialist engineering geologist or geotechnical engineer should be employed to assess the situation using more comprehensive investigation procedures as necessary.
- seismicity - Low potential impact dams will normally only warrant simplified seismic design, unless the commercial consequences of failure dominate decision making. In the case of earthfill type dams, analysis is unlikely to be necessary. Site specific seismic evaluations will not generally be warranted and national earthquake code zoning data can be utilised - however, published geological maps should be examined to ensure that the dam is not directly over or immediately adjacent to an active fault.

**(b) Medium Potential Impact**

- flood hydrology - Flood estimation should use two or more recognised techniques before applying appropriate judgement and, wherever suitable data is available, flood records should be taken into consideration.
- geology and foundations - Generally, dams in the Medium Potential Impact category should not be designed on an empirical basis although precedent information of relevance may be used to advantage. Thus geological and foundation data should be sufficient to permit rational design of the dam. This will require consideration of the items listed for Low Potential Impact dams, but to a higher level including:
  - engineering geological mapping and interpretation including assessment of reservoir stability
  - boreholes in the dam foundation area with in-situ permeability testing
  - appropriate strength tests on foundation and (for embankment type dams) fill materials
  - consideration of the risk of fill materials being dispersive with appropriate testing
  - consolidation tests where foundation settlement may be of concern to performance and dam detailing
- seismicity - In the case of earth and rockfill dams competently designed for static conditions, the seismic design case is unlikely to be critical and published data can generally be used to infer ground accelerations for any seismic design or analysis. For concrete dams at the lower end of the category, ground accelerations derived from

published data should also be acceptable where pseudo-static analysis/design methods are being used along with appropriate factors of safety, but the approach for High Potential Impact dams should be employed for Medium Potential dams near the top end of the category.

**(c) High Potential Impact**

- flood hydrology - All available techniques should be used to ensure the most thorough assessment of design floods up to the Probable Maximum Flood (PMF)
- geology and foundations - Techniques will be much as described for Medium Potential Impact dams but be to a higher level of comprehensiveness, with focus on key issues identified by expert Advisers. More extensive and longer duration investigations may apply such as:
  - observation wells
  - test tunnels or drives
  - large scale in-situ tests
  - seismic and other non-destructive testing
  - reservoir slope stability investigations
- seismicity - A site specific seismic risk study should be undertaken, the level of detail depending on the hazard and value of the investment, response spectra being developed for design of various elements

## B.6 Design Standards or Criteria

Much of dam design relates to achieving appropriate physical arrangements for the various components and careful detailing to cater for hydraulic and seepage forces which apply. Standards or criteria for details cannot be easily summarised but there is a wealth of advice available in recognised texts, technical papers and ICOLD Bulletins (see Guideline References). The need to treat seepage issues and protection with extreme care cannot be overemphasised.

The process of consultation leading to the approval of consents to dam, divert and / or take water will consider not only the potential impact of the dam but also the individual characteristics of the dam in its environment.

Some aspects of selecting design loads and surveillance criteria are related to the Potential Impact Category. It is common practice to select the inflow design flood (IDF and Maximum Design Earthquake (MDE) on the basis of the potential impact category. It is common practice to select an IDF and MDE with lower annual exceedance probabilities for the higher potential impact categories to ensure acceptable risk to society.

The performance criteria to ensure dam safety and reservoir integrity are that the dam should

- be able to safely pass the Inflow Design Flood
- be able to withstand the Maximum Design Earthquake without uncontrolled release of the reservoir.

The following discussion and guidelines are offered for general factors of safety, earthquake design, flood protection and freeboard.

**(a) General Factors of Safety**

Potential failure mechanisms for dams under different loading conditions are usually assessed in terms of minimum factors of safety. The minimum factors of safety can vary depending on whether they relate to embankment dams, concrete dams or concrete faced rockfill dams.

For embankment dams, the dam, foundation and abutments need to be stable under construction, operating conditions and full or partial drawdown. Minimum factors of safety are typically as given in Table B.6.1, which is from CDA (1999).

**Table B.6.1.**
**Factors of Safety, Static Assessment.[(a)]**

| Loading conditions | Minimum factor of safety | Slope |
|---|---|---|
| Steady state seepage with maximum storage pool | 1.5 | Downstream |
| Full or partial rapid drawdown | 1.2 to 1.3[(b)] | Upstream |
| End of construction before reservoir filling | 1.3 | downstream and upstream |

(a) The factor of safety is that factor required to reduce the mobilized shear strength parameters in order to bring a potential sliding mass into a state of limiting equilibrium, using generally accepted methods of analysis.

(b) Higher factors of safety may be required if drawdown occurs relatively frequently during normal operation

For concrete dams and their foundations, sliding resistance is important to withstand the load combinations that could occur. After extreme loads the dam and foundation must have sufficient stability to safely retain the reservoir. Typical minimum factors of safety for concrete gravity dams are indicated in Table B.6.2.

**Table B.6.2.**

**Commonly Accepted Values for Strength and Sliding Factors for Gravity and Buttress Dams.**

| TYPE OF ANALYSIS[(a) (f)] | LOAD CASE | | | |
|---|---|---|---|---|
| | USUAL | UNUSUAL (post earthquake) | EARTHQUAKE (MDE) [(b)] | FLOOD (IDF) |
| Peak Sliding Factor (PSF) No tests | 3.0 | 2.0 | 1.3 | 2.0 |
| Peak Sliding Factor (PSF) With tests [(c)] | 2.0 | 1.5 | 1.1 | 1.5 |
| Residual Sliding Factor (RSF)[(d) (e)] | 1.5 | 1.1 | 1.0 | 1.3 |
| Concrete Strength Factor[(g)] | 3.0 | 1.5 | 1.1 | 2.0 |

(a) PSF is based on the peak shear strength. RSF is based on the residual or post-peak strength.

(b) The stated value under the MDE load case is based on pseudostatic analysis. Performance evaluation of the dam should also take into account consideration of the time dependent nature of earthquake excitations and the dynamic response of the dam.

(c) Adequate test data must be available through rigorous investigation carried out by qualified professionals.

(d) If PSF values do not meet those listed above, the dam stability is considered acceptable provided the RSF values exceed the minima.

(e) The minimum values of RSF may be reduced for low consequence dams provided data is available to support such a reduction.

(f) For low consequence dams, if they are judged to be performing satisfactorily, based on an inspection and review of available data, and if conditions are expected to be no less favorable in the future, stability analysis may not be necessary.

(g) These values are recommended where test data is not available.

The sliding factor in Table B.6.2 is defined as:

$$SF = \frac{\text{Available shear strength}}{\text{Net Driving Force}}$$

The design of concrete dams will need to also consider other factors such as the position of the resultant force on sections through the dam, normal (perpendicular) stresses at the heel and toe of the dam and shear stresses at construction joints and within the dam body. Recognised texts on the design of arch, conventional concrete gravity dams and roller compacted concrete dams cover these issues.

**(b) Earthquake Design**

Industry practice especially for medium and high potential impact dams is to design for two levels of earthquake. These are the Maximum Design Earthquake (MDE) and the Operating Basis Earthquake (OBE). The MDE is the maximum level of ground motion for which the dam should be designed or analysed. It is required that at least the impounding capacity of the dam be maintained when subjected to that seismic load. Selection of MDE is based on the potential impact classification and for high potential impact dams the MDE is usually either the Maximum Credible Earthquake or a 1 in 10,000 AEP event if probabilistically derived. For medium and low potential impact dams it is common to select an MDE with ground motions less severe than the MCE or 1 in 10,000 AEP event.

The Operating Basis Earthquake is usually selected on a probabilistic basis and typically represents ground motions that have an annual exceedance probability of about 1 in 150. The performance criteria under the OBE is that only minor damage is acceptable.

Following the OBE, there should be either no damage, or minor repairable damage.

Under and after MDE level shaking, including after shock shaking, some damage is allowable, but it must not lead to a catastrophic failure. The main shaking may lead to cracking, increased seepage pressures within the dam body and reduced strength. Post earthquake static safety should be checked as well as aftershock shaking which typically is one magnitude less than the MDE and can occur a day or so later. There is unlikely to be time to take any preventative action between the main shock and the after shock.

For appurtenant structures it is usual practice to design critical elements that are essential for the safe retention of the reservoir to the same MDE as for the dam. Non-critical structures whose failure would not lead to dam breach are usually designed to OBE or structural loading code requirements.

For embankment dams where liquefaction in the foundation or dam body is not a concern, pseudo-static methods are common to assess slope stability. Where seismic coefficients in the range of 0.1 to 0.15*g* have traditionally been used the required minimum factor of safety has typically been in the order of 1.2 to 1.3. These simplified methods rely heavily on the lessons learned from the performance of dams during past earthquakes (ANCOLD 1999). For higher potential impact dams it is likely that safety factors under the MDE using a pseudo-static approach will be less than

1.0. Depending on the dynamic characteristics of the dam materials and foundation, simplified or more rigorous deformation analysis will be required to demonstrate adequate ability to safely retain the reservoir.

The art of seismic design for embankment dams also relies on good defensive design details as much as stability factors and deformation analysis. These aspects are covered in ICOLD and ANCOLD Guidelines and include amongst other factors:

- Providing ample freeboard and crest width
- Providing well designed and constructed filters downstream of the core
- Providing ample drainage zones
- Flaring the embankment core at abutment contacts
- Using well graded and densely compacted sand/gravel/fines or highly plastic clay for the core if the option is available.

Special details will be required if there is danger of movement along faults or seams in the foundation.

In assessing the capability of an embankment dam or foundation to resist earthquake motions the potential for liquefaction must be addressed. Where possible, liquefiable materials shall be avoided or removed. If liquefaction is possible then the post-liquefaction static and after shock stability of the dam will need to be evaluated with and without remedial measures to ensure dam failure does not occur.

**(c) Flood Protection**

The potential impact consequence of a dam failure in flood is usually the main determinant in selecting the design flood. Industry trends are towards recognising and evaluating the incremental consequences i.e. what is the incremental damage or hazard over and above pre-breach conditions. For example, where the flood build up is slow and there is plenty of time for effective warning and evacuation downstream would occur in any event, there may be little or no threat to life beyond a certain outflow size. The Incremental Damage Flood or IDF term is used. Another approach recognised by New South Wales is the Imminent Failure Flood (IFF) when the dam is on the point of collapse. Depending on the dam type, the structure may sustain overtopping before reaching the IFF level.

For low potential impact dams the minimum IDF is usually between a 1 in 100 and 1 in 1,000 AEP.

For medium potential impact dams the minimum IDF is usually between a 1 in 1,000 and 1 in 10,000 AEP.

For high potential impact dams the minimum IDF is usually between 1 in 10,000 AEP and the PMF. The PMF is usually selected if a large number of fatalities would result from failure of the dam. If collapse of the dam has little incremental damage potential the design flood may be reduced.

ICOLD, ANCOLD, NSW Dam Safety Committee, and the Canadian Dam Association all have guidelines that cover the selection of design floods.

There appears to be no universally accepted standard for selecting the size of flood for construction diversion facilities and the choice is generally based on risk or optimisation of diversion capacity versus construction costs and damage costs. ICOLD Bulletin 48a discusses these aspects.

The probability of exceeding the diversion design flood for various ratios of exposure time (L) divided by flood return period (T) is indicated in Table B6.3

**Table B6.3.**

**L/T versus Probability of Exceedance.**

| Exposure Time/Flood Return Period *L/T* | Probability Flood Return Period Being Exceeded % |
|---|---|
| 1/5 | 18 |
| 1/10 | 9.5 |
| 1/20 | 4.9 |

ICOLD Bulletin 48a comments that:

> *"with concrete dams, flooding of the working area will not cause the works to be abandoned and so the diversion ... can be designed for floods of quite high frequency, say the ten-year flood.*
>
> *Earth dams are entirely different, as they may be completely destroyed if overtopped. For larger structures, taking several years to build, a return period of 50 years or more might be used in designing the diversion works."*

The total volume of the diversion flood must be evaluated in addition to the peak inflow for flood routing studies if diversion systems rely on partially constructed dams to attenuate diversion flood peak flows by reservoir storage. Flood volume probability of exceedance must also be considered to ensure adequate safety.

**(d) Freeboard**

The freeboard for an embankment dam and concrete dams with erodible abutments should limit the percentage of waves that could overtop the dam to an amount that would not lead to dam failure. This will include extreme wind speeds under normal operating conditions and lesser value of wind speed under flood conditions. Freeboard should also be sufficient to ensure the dam is not overtopped subsequent to an earthquake.

## B.7 Design Issues

### B.7.1 Introduction

This section serves to highlight key design issues from the dam safety perspective. Reference must be made to design literature for methods of design and detailing.

One point which needs stressing at the outset for higher potential impact dams, is the importance of monitoring systems built into the dam for surveillance purposes. The Designer should be conscious throughout the design process of monitoring requirements.

### B.7.2 Temporary Works

For dams built under tendered contract, temporary works are generally made the Contractor's responsibility except for diversion arrangements.

Notwithstanding the fact that it is industry practice to accept the low probability risk of a large flood occurring during the construction period, diversion arrangements should be carefully considered in relation to the risks of overtopping and the expected consequences of the dam being overtopped at any stage of construction. The risks of overtopping may be high while the dam is low but the consequences may be minor. Conversely, the consequences may be significant as the dam reaches full height, but the risks may be low due not only to the fact that the time exposure is short, but also the upstream storage capacity available. In some cases temporary auxiliary spillway paths to one side of the dam may be warranted to supplement the diversion facility.

Any temporary works which in any way alter the permanent construction from the design/specification for permanent works, must be reviewed/approved by the designer.

### B.7.3 Spillways

The following points are highlighted relating to design of spillways with their associated energy dissipating arrangements:

- wherever it is practicable and advisable an auxiliary flow path should be provided clear of the dam to give extra protection for extreme events and/or for failure of the main spillway to take all of its design flow - this is more relevant for embankment dams
- auxiliary spill paths should be located and/or protected where necessary so that erosion damage to the flow path is not sufficient to cause an excessive flood peak and the environmental consequences of the erosion are acceptable The location should prevent any damage to the dam.
- for all spillways, the likelihood and consequences of spillway blockage should be carefully evaluated - this is of particular importance in the case of small dams with small spillway inlets and flood detention dams - usually where there is likelihood of blockage, the only option is to provide an auxiliary spill path.
- for gated spillways, design needs to consider the possibility of one or more gates not operating as intended during maximum floods, and whether in the event of all gates being inoperable, there is a likelihood of dam failure (e.g. earth dam) or an acceptable level of reparable damage (e.g. concrete dam) - additionally there must be a facility allowing effective dewatering of each gate for maintenance and repair. Emphasis required on the provision of adequate backup facilities to ensure that the likelihood of total malfunction are minimal. (e.g. multiplicity of gates, back up power supplies, etc.).
- tailwater conditions which affect the design and performance of energy dissipation arrangements need careful evaluation taking into account the potential for long term changes due to downstream conditions
- some structures warrant hydraulic model testing to ensure adequate energy dissipation under extreme floods, and that eddy currents do not pose a hazard to the dam.
- in applying the usually adopted design criteria and details, particular attention needs to be focused on controlling cavitation for high head spillways, and protecting spillway chutes against the possibility of high uplift pressures caused by high velocity flow entering joints



### B.7.4 Dam Structure

Design of the body of the dam covering strength, seepage and deformation aspects for all loading conditions, is very well covered in readily available literature. Points worthy of emphasis from the safety viewpoint are listed as follows:

- wherever it is practicable and economic, secondary lines of defence should be incorporated in design arrangements
- particular care must be taken in providing protection in areas where adjacent materials have strongly contrasting permeabilities
- consideration needs to be given to possible changes in material characteristics or performance of critical elements within the expected life of the dam (e.g. physical degradation of materials or blockage of drains due to precipitates)
- to the greatest practicable extent, design arrangements should provide access for future main-

tenance or repair - this is particularly relevant where the design adopts an assumed level of performance to be verified by monitoring, and has a backup plan for implementation if performance is not as expected

- for low potential impact dams where the costs of comprehensive supervision to specified standards may be excessively costly relative to the works and it is decided only to make intermittent inspections, design details need to be suitably conservative in areas where the consequences of poor construction are greatest (e.g. layering of earthfill).
- again for low potential impact dams of earthfill type, where empirical or semi-empirical design is utilised, details should err on the conservative side in recognition of uncertainties inherent in empirical design
- some seepage is inevitable. Control measures must be designed to prevent erosion and be appropriate to both the risks and potential impacts with particular attention being paid to control of preferred seepage along penetrations through the dam. The Drainage capacity is to be sufficient to carry seepage under unusual conditions - e.g. post earthquake.
- drains and stand pipe piezometers should be positioned so that they may be cleaned out (or new piezometers drilled).

### B.7.5 Reservoir Drawdown Arrangements

Depending on the dam type and hazard potential, it may be prudent to incorporate measures to draw the dam the reservoir down a certain amount after a severe earthquake. Potential loss of freeboard from earthquake deformation of a high potential impact embankment dam is the kind of situation that may justify some drawdown. Dams generally have drawoff facilities for water supply or hydro generation which can contribute to drawdown and others have gated spillways which can be used. However, typical water supply embankment dams with free overflow spillways will have limited drawdown capacity. Certain dams may warrant incorporation of a lower level drawoff so that the total drawdown capacity enables failure risks to be minimised.

### B.7.6 Mechanical Equipment and Related Structures

All mechanical equipment and supporting structures which impact on dam safety must be designed to standards consistent with the potential impact category and as an integral part of the dam as a whole. The following specific recommendations are made:

- where equipment has a finite life, design must include maintenance considerations and provision for replacement without affecting dam safety beyond an acceptable level during the replacement work. Bulkheads are essential to allow inspection and maintenance of critical gates and their components.
- for gated spillways, simple operating instructions and well trained operators are important factors to ensure the safe passage of extreme floods.
- all equipment essential for the dam's safety, such as flood gates, drainage pumps and valves, uplift relief devices, fire protection systems, control and alarm systems, and others, should include precautionary measures to ensure functioning under emergency conditions - precautionary measures could include the duplication of installations including power supply, local control in addition to remote control, automatic triggering of safety devices, and manual emergency operation
- equipment essential for safe operation should be connected to at least two independent power sources
- the placement, where feasible, of manual facilities, essential services etc., should, if possible, be such that rupture of water carrying conduits cannot threaten their integrity, otherwise automatic shut off devices should be installed for protection (i.e. provide a fail-safe operation)

- all structural arrangements should facilitate ready access for the inspection, maintenance, repair or replacement of defective equipment - due attention should be paid to the necessity for access under emergency conditions and exceptional circumstances (e.g. storm, failure of electricity supply, severe winter conditions, etc.).
- redundancy is desirable in instrumentation as some failure can be expected during the life of a dam.

### B.7.7 Reservoir

There is a tendency sometimes to focus on the dam and not pay much attention to the reservoir. Generally in the case of Low potential impact dams, assessment of impacts on safety or the environment (e.g. landscape scars or stream flow discolouration due to slips) will be a judgement-based issue, dealt with more from the environmental effects perspective at the land use consents/water permits stage. For higher potential impact dams, the following key items need to be addressed from hazard and safety viewpoints:

- whether there is any part of the reservoir (e.g. a narrow ridge on the perimeter) which may present a higher likelihood of failure than the closure dam
- wave impact upon any communities adjacent to the reservoir
- whether any old landslides may remobilise or new slips develop under any of the possible reservoir conditions, to the extent that the dam could be overtopped and/or the reservoir blocked
- whether any of the reservoir surrounds in the proximity of the spillway may fail and block the spillway or impair its function
- what management regime must be implemented to prevent bed load or debris from affecting spillways if prevention is assumed in spillway design



### B.7.8 Monitoring Systems

The design of monitoring systems should take advantage of available technology and be appropriate to the potential category of the dam. Design of systems needs to address:

- the significance to the structural integrity of the dam and related structures of the value of the item being monitored
- the usefulness of the item being monitored as an indicator of any potentially adverse behavioural change of the structures
- the ease and reliability of the system to provide reliable data at appropriate time intervals and ensure rapid interpretation of results
- providing redundancy in the monitoring system to cater for possible instrument failure and allow cross-checking of readings
- the desirability of obtaining a long term record of external factors (e.g. rainfall, runoff, seismic activity) to enable periodic review of design assumptions
- establishment of the limiting criteria for items monitored, beyond which action is taken to review and ensure the continued integrity of the dam

### B.7.9 Contingent Redesign

The Designer must remain alert through construction to any change in conditions or properties from those assumed for final pre-construction design. Redesign for contingent situations clearly must be to the same standards as the original design but most importantly must be addressed in a thorough manner, to ensure that any detailed changes made do not inadvertently create a risk elsewhere. It is essential that the Owner/Developer understand the likelihood of contingent redesign with its associated costs and have appropriate contingency funding in place. Even small design changes must not be considered in isolation. Often significant reductions in dam safety result from a sequence of relatively minor seemingly unrelated modifications. The feedback loop is crucial.

## B.8 Design and Build Contracts

Owners, developers and regulators need to ensure that the administrative and contractual arrangements for the design and construction of any major dam pay particular attention to dam safety. The technical and managerial conditions for dam safety made in these Guidelines need to be built-in to all arrangements for the design and construction of dams.

Two examples of conditions detrimental to dam safety are "conflicts between commercial and dam safety interests" and "lack of authority for design". The possibility of these being present are particularly obvious in the case of design and build projects, but may be present in other arrangements.

Design and build types of contract can take many forms. They are well suited to works where the end product can be accurately defined and its achievement is within the contractor's control. They can also be used for the construction of less well-defined works, provided provision is made for the lack of certainty. In dam construction, there is often significant uncertainty about the final extent of foundation work required to meet design requirements.

The contract provisions adopted to cover uncertainty may range from, on the one hand: "full recovery by the contractor of all additional costs and time required to meet changes", to, on the other hand: "all risks being recognised and met entirely by the contractor without increase in price or time".

There are obvious flaws in both these extreme positions. In the first, an employer would be concerned about whether or not the changes made are really necessary or are cost effective. In the second case, the concern would be that commercial pressures might govern the response to the conditions found, to the detriment of dam safety.

So stated, they set the boundaries. In practice, intermediate solutions to the particular circumstances would be sought and built into tender documentation and contract agreements. The aim should be to minimise or regulate the potential conflicts between the interests of the parties, and ensure that those that remain do not adversely affect dam safety.

Common to all arrangements made for the design and construction of dams is the need to provide for inspection and approval by the employer, and for the contractor to follow best practice in the control of quality, cost and time.

Of particular note are provisions for river control – permanent spillways and diversion during construction. Spillways and diversions can be major structures and significant cost elements. The design of these structures has to meet safety needs. The balance between safety and cost, especially for the short term diversion arrangements, require an element of judgement. The decision making procedures and standards in these areas must be clearly set out.

The main requirements for dam safety are:

(a) The Designer's experience and expertise should be relevant and appropriate. If the owner or employer's own experience in this field is limited, the owner or employer should obtain expert advice before making a selection or accepting a pre-qualification.

(b) In selecting a Designer, the owner should give greater consideration to ability and performance than to price, bearing in mind that the loss through deficiencies can far outweigh any savings otherwise made.

(c) In a design and build type contract, the design element is of paramount importance for dam safety. The selection of the designer should be subject to the employer's approval. Minimum requirements for selection should be specified. The designer's decisions and the design should be seen by the employer to meet dam safety requirements as noted in the following items.

(d) The Designer's contract or the element of the contract relating to design should require that design selection and technical decisions be in accord with these NZSOLD Guidelines, relevant consent conditions and in general, to current international best practice.

(e) In the design and build case, the owner should administer and supervise the contractor's design and construction. Particular care should be taken to prevent conflicts between commercial and dam safety interests.

(f) The parties should recognise and provide for the fact that in all cases dam design does not end with the provision of drawings and specifications, but continues through construction. Essential design decisions and confirmations are required in regard to foundations, foundation treatment and construction materials. The designer must be fully involved in the construction phase of the work and allowed access and facilities for inspection, testing and verification. In this respect designer means the engineer or engineers principally involved in the design and not others of the same organisation.

(g) In accordance with these Guidelines, administration of design, construction, or design and build contracts, should include specified quality procedures that are documented in accordance with current best practice in quality control. In a design and build contract the Designer should give written confirmation that the design meets current best practice ***and*** that the dam has been constructed in accordance with the design intentions.

(h) For High and Medium Potential Impact categories of dam the owner or employer should employ expert advisers to review the designers work and make suggestions where necessary or where improvements can be made. Such advisers are sometimes called Peer Reviewers. The word "peer" in its strict sense means "of equal standing". In this context it is recommended that the reviewers be experts or of high standing in their respective fields and not simply another like design company.

(i) For Low Potential Impact dams, no review or a lesser standard of review may be appropriate. Owners with their designer's advice, or regulatory authorities should decide whether review is justified and if so how it should be provided. The reason for this lesser standard in this case is that the cost of review should be appropriate to the case.

(j) In all cases, designer's have a duty to others (and themselves) to engage or request a second opinion for problems that are particularly difficult or beyond their own experience.

## B.9 Design Stage Documentation

Section III.3 of the main text states that one of the key points to address in achieving dam safety is "translating designs into clearly understood construction specifications, 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".

There is value in getting the Peer Reviewer involved at an early stage. For difficult sites the same can be said for contractors, as the construction sequence can have a significant impact upon design. The documentation must be reviewed to ensure that it is "buildable".

From the dam safety perspective, construction drawings and specifications must clearly describe the particular requirements to be achieved in areas critical to safety. For example, if the design assumes a high degree of homogeneity for an earth dam, specifications for filling and bonding of fill layers must be comprehensive and explicit. The kinds of earthworks specifications used for general filling elsewhere will not be adequate. The same principle applies to concrete dams, for example where temperature control is of critical importance. While it is not customary practice, consideration should also be given to including a commentary in the construction documents, which highlights the critical areas, the related reasons for the specifications adopted, and the possible consequences of failing to meet the specified requirements. The Designer should also outline the minimum Quality Assurance procedures to be followed (refer Appendix C for more detail).

The design report which backs the construction documents, signals completion of the main part of the design process, although design activities are not fully complete until the dam is complete to the Designer's satisfaction. The scope and contents of the design report will vary depending on the type, significance and hazard category of the dam and will likely be only a few pages long for a straightforward low hazard dam. The matters which should be contained in the design report include:

- a description of setting, dam purpose, and Owner objectives
- the potential impact assessment
- a description of the key variables (hydrology, geology, geotechnical aspects, seismicity, dam operation etc.) backed by appendices describing data acquisition and results
- the design philosophy, criteria and methods adopted in each area, with justification
- the monitoring proposals and discussion of areas where future confirmation of dam safety will be critically dependent on monitoring
- highlighting of areas which require particular attention and review during construction
- points of importance to be addressed in separate commissioning requirements

## B.10 Refurbishment

For any alteration, rehabilitation or repair works to existing structures or facilities, the original design documents and all available construction and operation records must be carefully reviewed to obtain a thorough appreciation of the original design principles and structural integrity of the existing works.

Before commencing detail design work for any refurbishment works, those sections of the works that are to be modified should be carefully surveyed and documented and added to the dam records

Consideration of the consequences of the refurbishment on other components is essential (e.g. raising the crest to provide more freeboard can lead to an increased loading).

The design of any refurbishment works should address the safety related requirements listed above in previous sections. If the refurbishment works require substantial modifications, or if the basic design assumptions have changed significantly since the original design, the complete structure should be reanalysed.

Refurbishment works offer good opportunities to upgrade old or install new monitoring equipment as an effective means of improving dam safety. The issues outlined in Section B7.7 should be addressed before any upgrading or installation of monitoring equipment.

# APPENDIX C - CONSTRUCTION

## C.1 Introduction

This Appendix builds on the general discussion of the main text of the Guidelines and addresses those aspects of the construction process which are most important to achievement of dam safety. While sometimes commissioning work overlaps with construction or may be regarded as an integral part of construction, commissioning is covered in Appendix D. The focus in Appendix C is on issues, qualifications, procedures and systems, not methods of construction.

Key aspects covered are:

- personnel and roles
- quality assurance
- dealing with changed conditions
- documentation requirements

## C.2 Personnel and Roles

### C.2.1 Introduction

The main text (Table III-2) highlights the basic experience requirements of the Contractor (or Constructor) for each dam Potential Impact category, the Owner's obligations and Designer requirements, including continuity through construction. This section discusses in more detail the roles, qualifications and responsibilities of the personnel involved in construction. Depending on the size, type and Potential Impact category of the dam, the following key personnel are involved in construction:

- the Owner
- the Designer supported by Technical Specialists and Peer Reviewers
- the Supervisor with supporting personnel
- the Contractor
- the Approving Authority

### C.2.2 The Owner

Generally the Owner will delegate construction administration to the Supervisor who may be a representative of the Designer. The most important Owner functions related to dam safety are:

(i) taking industry advice as necessary, to ensure that all parties engaged to investigate, design, construct, commission and operate the dam are suitably qualified and have their roles and authorities properly defined

(ii) to provide at all times the necessary funding to achieve the required quality of inputs in a timely manner

Relating to the second point, it is often said that cash flow is the life blood of the Contractor. If the Contractor is deprived of cash and/or sees the Supervisor or Owner as being unrealistically "hard-nosed", there is a possibility that short cuts will be taken with standards being compromised, possibly to a dangerous level (e.g. through completely unseen defects in the mass of the dam).

### C.2.3 The Designer and Technical Support (including Peer Review)

Continuity of Designer input through construction is considered to be an essential requirement in the case of Medium and High Potential Impact dams and highly desirable for Low Potential Impact dams. The same applies to Specialists or Reviewers. This continuity is important in enabling actual site conditions to be evaluated against the pre construction inferences about foundation conditions and to ensure correct interpretation of design documents and intent. The role of the Designer and Technical Support is to help ensure that the dam is built in accordance with the approved safe design including any necessary changes from the original design.

The Designer and Technical Support roles form part of an overall Quality Assurance system as discussed in Section C.3. The various parties involved in the construction stage should take particular note of the key areas where the Designer, with Support where necessary, needs to be actively involved on site. These areas should be made clear in contract documents and/or supervisory instructions particularly for small dams which do not have full time supervision.

### C.2.4 The Project Manager (including Support Personnel)

The Project Manager is defined here as the person responsible on behalf of the Owner for ensuring that the detail of the construction work is carried out in accordance with the contract design and specifications. The Project Manager will normally also be responsible for contractual administration and fill the role of Engineer to the Contract. Depending on the project, the Project Manager may have a support team ranging from clerks of works and field technicians to full time specialists.

In the case of Low Potential Impact dams, where full time supervision might not be employed, the Designer will usually also be the Project Manager. On larger higher Potential Impact dams, the Project Manager will normally be an appointee of the Designer's company with the contract for detailed supervision being directly with the Designer. It is a recommendation of these Guidelines that the Project Manager always be the Designer or a Designer appointee, to provide the highest possible level of continuity and communication, and avoid potential conflicts of view and approach which may otherwise arise and thereby risk inappropriate action being taken in areas of critical importance. If the Owner chooses not to follow this recommendation, then the Designer should participate in selection of the Project Manager and be confident that the Project Manager will fill the role to the required standards.

The qualifications and experience of the Project Manager are important. Generally the Project Manager should have had relevant prior experience on a dam of similar type or on types of construction which substantially aggregate to the work involved in the dam. The direct prior experience requirements may be less stringent if the supervisory team includes personnel with individual expertise in specialist areas. Communication skills and ability to deal co-operatively with the Contractor are also important. If confrontational situations develop and remain unchecked, the risks of something going wrong will be increased. The ability to understand and follow design specifications is also important so that any features or changes which may impact on design assumptions or criteria can be recognised and brought to the Designer's attention.

In Design/Build contracts the Project manager is preferably an "Independent": employee of the contractor, with sufficient technical expertise to liaise with the designer and the "coal face" contractor.

As the Potential Impact category of the dam increases, so should the qualifications of the support staff in the team.

### C.2.5 The Construction Contractor

The Construction Contractor clearly has a vital role to play in achieving a safe dam. In all cases the Contractor must be suitably qualified in terms of personnel, resources, attitude and prior relevant experience. General guidelines have been set out in the main text and Section C.4 outlines in some detail Contractor perspectives related to dam safety.

### C.2.6 The Approving Authority

Generally the Approving Authority should only become directly involved in construction inspections in cases where it is not satisfied that the level of on-site supervision is fully comprehensive or that reliance cannot be placed on the Quality Assurance systems employed. The Approving Authority should ensure there is adherence to any conditions included in the consents. Low Potential Impact dams with intermittent inspection is a likely situation where the Authority may make inspections to satisfy itself that the works appear to be proceeding appropriately. Such inspections are a matter for each Authority, but inspection points would most likely correspond with areas where the Designer will also take the greatest interest, e.g.

- foundation preparation
- penetrations through the dam
- initial dam construction
- pre-commissioning inspection

## C.3 Quality Assurance

### C.3.1 Introduction

Without an appropriate level of Quality Assurance through a quality management system or plan, there will be possibility of design requirements and/or standards not being met, with adverse impact on safety. The scope and level of quality assurance systems applied during the construction stage will vary with the Potential Impact Classification and degree of protection built into the design, but for higher Potential Impact dams should involve:

- Designer - continued application of the principles and intent of NZS 9001
- Contractor - a system complying with the intent of NZS 9002, Quality Systems for Production and Installation, and NZS 3905.2, Guide to Quality System Standards for Construction

### C.3.2 Key Requirements

Some of the key requirements for achieving Quality Assurance have been covered under Section C.2 and the recommendations made there and in C.3.1 above, substantially cover the situation for low Potential Impact dams. In the case of higher Potential Impact dams it is worth highlighting what are seen as key requirements in achieving an appropriate level of quality assurance. These are:

- Designer Continuity - (as discussed) (reference Design /Build)
- Peer Review - (as discussed)
- Constructor or Contractor Selection - A selective approach is recommended, which deliberately focuses on the Constructor or Contractor's track record, and availability of key personnel. This may be by a formal prequalification process involving specific questions and a formalised evaluation system, or by direct selection of potential bidders through general knowledge backed by enquiries as necessary
- Teams and briefings - It is vital that the members of Designer and Contractor teams be thoroughly briefed on their duties and responsibilities and that the teams be selected in full recognition of the individual characteristics of the Project. This may mean, for example, putting specialists full time into the supervisory team at certain stages or providing a larger

supervisory team than “the norm” because of particular issues of extreme importance.

- **Design Change Procedures** - Any change, however minor, departing in any way from the approved initial design, must be developed, checked and approved by the Designer before implementation. Site staff may need to propose changes to suit circumstances, but only the Designer can authorise changes. Small changes in detail constitute a design change and very small changes may have an effect which only the Designer can fully appreciate.

  Contractor initiatives are another source of potential design change and should not be discouraged if they help expedite or lower the cost of the work while maintaining or enhancing safety. However, systems must again provide for full evaluation by the Designer and approval of the change through the Designer.
- **Designer authority to make changes** - The contracts between the Owner and the Designer and inter alia with the Constructor or Contractor, must allow the Designer authority to make such design changes as are necessary during construction to achieve the necessary level of safety and performance. Situations can arise, particularly during opening up of foundations, where the need for changes become evident.
- **Offsite manufacture** - The quality system must make appropriate arrangements for confirming the quality of off site manufacture including the effects of transportation. Even standard suppliers’ items need thorough consideration when imperfections or failure could adversely affect safety.
- **Record keeping** - Comprehensive record keeping is essential for future diagnosis and to enable the necessary certification under the Building Act. Section C5 addresses record keeping in more detail.



### C.3.3 Critical Areas

All areas of critical importance to meeting design intent and achieving safety should be identified before construction and be highlighted in the Designer/supervisor’s quality plan. Areas and items which most commonly fall into this category are:

- foundation preparation, including such items as shaping, strength, surface texture, foundation defects and dealing with seepage
- quality and consistency of key materials whether they be concrete, earthfill, filter or drainage
- bedding, jointing, backfilling and protecting any penetrations through the dam
- developing correct procedures for key areas of construction, particularly compacted earthfill
- installing, protecting and reading instrumentation
- installing embedded items for critical mechanical equipment, installing stressed anchors and the like, and erecting and testing equipment including controls and backup systems
- adequate protection of the works during construction

These areas provide key inspection points in the case of Low Potential Impact dams which are not under full time supervision.

## C.4 Construction Contractor's Perspective

### C.4.1 Introduction

Few references are found in dam literature about the Construction Contractor's perspective and virtually none focusing on dam safety. This section aims to describe what the Contractor's perspective is or should be. Focus is deliberately on higher Potential Impact dams but the underlying philosophies apply as well to Low Potential Impact dams.

The Construction Contractor's role is integral with that of the Designer in achieving dam safety. The objectives of the Owner can only be achieved with a Contractor who adopts a professional and responsible approach to the construction and participates as part of the overall project development team. In particular this requires the development and maintenance of an open and active working relationship with the on site supervisory team. To achieve this, a conscious effort may be needed in the early stage of the project but it is absolutely critical to the overall success of the project and the early effort will pay handsome dividends.

### C.4.2 Organisation

Dam construction, particularly on larger more complex dams, can involve multi-disciplinary activities, all of which are important if not critical to achieving the designer's intent. Therefore personnel with the skills to match the range and complexity of activities is essential. In selecting project staff, the construction company must ensure that a well structured site team is provided with a balance between field supervisory/production staff and engineering/planning/technical management. It is imperative that the key aspects of the project are identified and appropriately qualified and experienced staff selected. If the Contractor cannot provide personnel from within existing staff, then recruitment should be adopted. Construction personnel tend to be a transient human resource and high calibre project staff can usually be attracted to a challenging project. It is false economy to skimp on staff numbers or quality.

It is essential that the contractor provide support to the project team throughout the contract but particularly during the early establishment and startup phase. This can best be achieved by supplementing the project team with some experienced personnel to assist with key early tasks such as planning, programming, temporary works design and site infrastructure establishment. Early effort in getting the job up and going and on a sound footing will help significantly in achieving a successful result.

Working and living conditions are often harsh and it is important that both the contract and the site team is continuously monitored throughout the contract to ensure that performance is meeting expectations. Early identification of problems is essential if time delays or poor quality performance are to be avoided.

The Contractor's senior site management must also be competent to liaise and work with the Local Authorities, the Supervisor and in particular the site supervisory team, without which a quality and safe project will be very difficult to achieve.

It is important that all senior site managers become fully familiar with the contract, the drawings and the specifications. Any apparent anomalies and ambiguities, doubts on interpretation of requirements or concerns on the practicality or achievability of the specified requirements should be raised as soon as possible to mitigate any adverse effects that could arise.

### C.4.3 Contract Administration

Sound contract administration is an important aspect of a successful project and must not be underestimated. Although only indirectly related to achievement of a quality and safe dam project, if not properly undertaken, it may have consequential adverse impacts on the technical and field supervisory management of the project.

Regular liaison between the Project Manager, his staff, the Contractor, and contract staff is essential to good contract administration.

Regular review of the implementation of the designers specifications and standards by the designer, throughout the programme, is essential.

It is necessary to have formalised procedures which are understood and adhered to by all site staff for activities such as document control including contractual correspondence, drawings, meeting minutes, site instructions, variation orders and the like. It is important to maintain drawing registers and to ensure that obsolete or superseded drawings are removed from use. Systems should be in place for ensuring that all information required by those performing the work including subcontractors and suppliers is transmitted promptly and in a controlled manner.

It is essential to have proper procedures for the procurement of materials which ensures that the materials and components to be incorporated in the works are in compliance with the specifications.

Subcontractors are often major contributors to a dam project and proper selection and management procedures must be adopted if their contribution is to be successful. The head Contractor must actively manage and control the activities of the subcontractor and ensure that the subcontractor fully understands and fulfils allocated responsibilities.

Proper procedures and suitably qualified staff must be available to handle the changes, variations, measurement of the work and financial management (progress claims, V.O's etc.) and the financial reporting of the project.

### C.4.4 Engineering

Dam design and engineering is a complex discipline and the construction engineer must have a sound knowledge of the engineering principles involved and the appropriate construction practices. It is imperative that the Contractor's project engineer has sufficient knowledge and experience to be able to handle the technical aspects of the construction and has adequate authority within the Contractor's organisation to be able to control the work to the extent necessary to ensure that the appropriate quality standards are achieved. On larger projects where the project engineer is not the contract manager it is important that the contract manager gives full support on technical matters and matters of quality to ensure that standards of workmanship and specification compliance are not compromised for reasons of production expediency.

Large dam construction usually involves complex engineering methods and techniques. It is essential that proper planning is undertaken well in advance to ensure that technically sound solutions are developed, that the necessary resources are available to undertake the work and that the personnel undertaking it are adequately skilled, trained and informed of the methods and techniques to be adopted. Good field supervision is vital to control the work.

Construction engineering tasks related to construction standards/safety and personnel safety, which commonly arise on a dam project and require special attention, are:

- river diversion and cofferdam design and operation
- materials selection and management
- concrete mix design, concrete production and testing

- falsework and formwork design and supervision to ensure structural adequacy and a safe working environment and
- heavy lifts involving cranes and special rigging

Note, however, that any engineering design for permanent works, and temporary works that affect the quality of the permanent works must be within the Designer's guidelines and approval. The use of specialist design consultants to supplement the in-house skills of the Contractor in addressing these sorts of engineering tasks is normal practice in New Zealand and must be identified and allowed for by the Contractor in preparing the tender.

The Health and Safety in Employment Act (1992) places special responsibilities on the Contractor which will be significant through the dam construction period. There must be a project specific safety plan.

Knowledge of – or ability to apply – all statutory codes of practice and standards and general experience and knowledge of good work practices is essential. Sound engineering judgement is vitally important on a major engineering construction site such as a dam and only comes with experience – a factor to be considered in selecting the project manager.

Construction programming is also vital to the success of the project and must be used as a management tool to assist achieving a quality product. The programming must take account of the climatic conditions and its impact on sensitive activities, e.g. earthworks, concrete placement. If a meaningful programme is not developed and adhered to then programme accelerations in the latter stages of the contract can often only be achieved by sacrificing quality and standards. Regular short term programmes should be produced for sections of the work in conjunction with the field staff for their use in managing their activities. Regular updates of the project's master programme are also essential and must highlight all critical activities which impact on work quality including receipt of important design information, materials, equipment and the like, with sufficient lead time to allow appropriate planning and preparation by the Contractor to allow the orderly and controlled progression of the work.

Good engineering, planning and programming is essential to achieving a high quality and safe dam.

### C.4.5 Inspection and Records

It is now common practice and often a contractual requirement that the Contractor undertakes most of the day to day inspection of the work. Passing the responsibility for quality control down to those responsible for undertaking the work is a fundamental principle of modern Quality Assurance management systems and is proving to be very effective in raising quality achievement levels. It is important that the contractor fully understands any contractual requirements in this regard and adequately allows for the work involved. Inspection of the work to verify its compliance with the contract requirements is essential if a safe dam is to be achieved.

Records of inspections, as built details, test results etc. are all important aspects of quality compliance which a Contractor must be aware of and must provide procedures, systems and personnel to undertake.

## C.5 Records

Construction records are of extremely high value as background to future safety evaluations of the existing dam and planning of any amendments or improvements. They form an important part of the dam data book referred to in Section III.5.2 of the main text. The level of detail will of course vary with the size, complexity, function and Potential Impact category of the dam.

Record keeping should encompass the following:

(i) day-to-day construction issues - If a comprehensive quality management system is employed (as should be the case), there will be a comprehensive paper trail of day to day details including relevant progress/profile surveys. While the data may be consolidated into a report, it is recommended that the raw data be kept in safe bulk or electronic filing wherever practicable. Photographs are an essential ingredient of this part of the record.

(ii) surveillance data - Often the Designer will require data gathering during construction of matters having a present or future impact on dam performance and safety (e.g. rainfall, river flows, seepages, construction pore pressures and stresses). This data must be recorded accurately and be fed back to the Designer promptly with a request for instructions so that appropriate action, if any required, may be taken.

(iii) geological logging - Particularly for higher Potential Impact dams and dams where the geology is not straightforward, all openings and prepared foundation areas should be logged, photographed, mapped and interpreted in a report to a level of competence fitting the particular dam.

(iv) construction report - The construction report should provide an accurate summary of construction with focus on the relationship between actual and originally assumed conditions, any changes from the original design and why they were made, and any particular problems which arose and how they were dealt objectively with. The report should be prepared with a conscious attempt by the writer to anticipate what a forensic team might be interested in 30 or so years hence. Clarity of expression is also important.

(v) as-built drawings - As-built drawings are essential to provide a clear depiction of what was actually constructed, and require a comprehensive system of recording sketches and drawings as construction proceeds, from which the as-builts can be prepared. Accurate representation of the excavated ground profiles should be prepared prior to their being covered by items of dam construction. This aspect is of key importance and accurate foundation profiling must be kept to the fore in planning and construction surveying.

The safekeeping of the records is of vital importance as outlined in Section III.5.2 of the main text.

# APPENDIX D - COMMISSIONING

## D.1 Introduction

This Appendix provides guidelines for the commissioning stage which often is of critical importance in the dam safety process. While commissioning may involve detailed testing of the functionality, of equipment (e.g. for a hydro development), this Appendix focuses on commissioning aspects relevant to dam safety, particularly for high Potential Impact and Medium Potential Impact dams.

## D.2 Personnel and Roles

The personnel involved in the commissioning process and their usual roles are summarised as follows:

- Owner - who is customarily reliant on Advisers for their advice on commissioning and must give freedom to them to act appropriately if dam safety is in question during commissioning
- Designer - who normally advises on and monitors commissioning, and is given authority by the Owner to manage the process and initiate action to preserve safety where necessary. In certain situations, the Owner may appoint a separate Project Manager to oversee all activities but all decisions by the Project Manager should fully recognise advice from the Designer
- Contractor(s) or Constructor(s) - who implements commissioning under instructions and must be equipped and prepared to act appropriately and rapidly in the event of unsatisfactory performance of the dam or components during commissioning
- Authorities - who ensure, usually by delegation to the Owner and/or Designer and by the terms of consents, that adequate procedures are followed; and in the case of Civil Defence or Police, for higher Potential Impact category dams, are on standby in case of emergency
- Technical Specialists and Peer Reviewers - who provide specialist inputs as required in support of the Designer or, in the case of Peer Review, to the Owner (or Project Manager)
- Operating Personnel - who, in the case of large and operationally complex dams, participate in commissioning to learn about the dam and its safe and effective operation during the commissioning process

The categories of personnel and numbers involved will vary depending on the dam and, in the case of a straightforward low Potential Impact dam, commissioning may only directly involve the Owner and the Designer. It is essentially a matter for the Designer, with overview from Authorities responsible for consents, to determine the necessary procedures, personnel and controls. For High Potential Impact dams commissioning proposals/procedures should also be subject to Peer Review. It is strongly recommended, however, that in all cases, continuity of Designer input be maintained through commissioning (and prior construction) to ensure that performance levels are consistent with design philosophy and intent.

## D.3 Planning and Procedures

Commissioning should not proceed until all necessary planning has been completed, procedures have been established and communicated to the responsible personnel involved. The planning must be represented by written commissioning instructions, prepared by the Designer and communicated to relevant personnel.

From the dam safety perspective, and dependent on the Potential Impact category, commissioning procedures should address the following:

- definition of all parties involved and their responsibilities, the names of key personnel including backups, and 24 hour contact arrangements for emergency situations
- the stage of completion of dam and reservoir components which must be achieved before initiating commissioning
- the rate of reservoir level rise, including any hold points where the level can be controlled reasonably and it is important to review dam and/or reservoir performance on a stage basis
- the monitoring to be undertaken during reservoir filling, including the testing of installed equipment important to safety (e.g. flood gates) and spillways
- the recording and communication of monitoring data, its interpretation, and conditions under which rapid or emergency action must be initiated
- an outline of action to be taken in the event of an emergency situation developing (this may match the EAP discussed in Appendix F)
- a full set of surveillance records taken over a number of months, consistent with the progress of construction, or stable over the time period

A typical contents list for the commissioning procedures document (in this case for a water supply dam) is given opposite.

Readiness is a critical aspect of planning. Commissioning should not proceed until the Designer or the Owner's Project Manager has carried out appropriate readiness checks and is satisfied that commissioning may proceed.

Prerequisites for commencing reservoir filling may, depending on scale and complexity, include:

- completion of minimum works on the dam, structures and reservoir area
- installation and "dry" testing of equipment, controls, telemetry and alarms
- installation of all instrumentation and establishment of monitoring systems
- provision on site of materials and equipment to deal with possible emergency needs (e.g. diggers, bulldozers, filter material stockpiles)
- preparation of the monitoring procedures and communication of them to relevant personnel including Civil Defence and Police
- confirming that statutory requirements are met
- other items not directly related to safety

As part of a formal Quality Assurance system, detailed readiness checklists may be prepared and utilised for various components and activities.

## D.4 Typical Commissioning Issues

The following issues are typical of higher Potential Impact classifications and more operationally complex dams. In the case of more straightforward Low Potential Impact dams, commissioning substantially involves close visual examination of the dam and conduits during reservoir filling and for some months thereafter. An early test of the spillway may be prudent, then check the performance during the first flood or floods.

**COMMISSIONING PROCEDURES**

**CONTENTS**





Often the first filling of the reservoir (or canal) is a critical condition for dams, setting aside extreme flood and earthquake events. The filling provides a test of its actual performance of the structure and defence mechanisms, and safe practice is to take all reasonable measures to monitor the behavior of the dam and its components. Monitoring of instrumentation and visual observations are key elements in commissioning. When the Wheao hydroelectric scheme headrace canal failed, there was damage to the power station and costly repairs. Setting aside the design issues which contributed to this failure, it is generally recognised that had a fully comprehensive commissioning procedure been in place, the failure may have been avoided and corrective work would then have been relatively modest.

One issue which can arise is a desire by the owner to expedite the dam being brought to an operational stage, particularly where the project is of a commercial type (e.g. hydroelectric development). The parties involved must put dam safety first and not attempt to commission faster than is judged appropriate by the Designer. The Owner should recognise that this is in the Owner's interests in any case, because of the commercial consequences of an avoidable failure.

Areas typically addressed during commissioning include:

- a routine of suitably frequent walkover inspections particularly to check for emerging seepages and any surface deformations
- measurement of seepage points to monitor,
  - changes in seepage quantities with reservoir rise or local rainfall which may affect abutment seepage, and absolute values relative to design estimates
  - seepage clarity as an indication of adequate filtering and absence of piping mechanisms
  - location and distribution of seepages beyond designed interceptor drainage and what such seepages mean in terms of dam and abutment performance
- measurement of settlements and lateral deformations and comparison with predictions and acceptable limits
- measurement of concrete stresses and temperatures where such are important in concrete dams, and comparison with design limits
- checking the hydraulic performance of spillway components at the first available opportunity
- incorporation of peer review for High Potential Impact dams

In special circumstances, there may also be a need for close monitoring of reservoir slope stability during commissioning.

The duration of commissioning and the frequency of routine measurements are relevant issues.

While commissioning should reach a point where all signs are positive and the dam can be considered operational for practical purposes, stable pore pressure, stress and deformation conditions may not be reached for a year or more after top reservoir level is reached. It may be some time before there is a large enough flood to test the spillway. The commissioning should include a specific spillway test, where appropriate. A commissioning mode level of surveillance may need to be extended for some time.

The frequency of observations and measurements will vary depending on the situation, but frequently it is daily and even round the clock for the first few days or weeks, and may move towards weekly observations as stable patterns develop, then accept even longer intervals for instrumentation readings once the dam is deemed operational.

Each case needs to be judged by the Designer responsible for the dam, with support from Peer Reviewers and Technical Specialists as appropriate.

## D.5 Control

The need for effective control by the Designer or an appointed Project Manager acting on advice, has been stated. This aspect cannot be over emphasised and control must be exercised in a thorough manner. Control starts with proper planning but must incorporate ongoing evaluation of all data gathered and feedback to those implementing the commissioning. The control must provide for rapid and effective responses to situations which warrant or demand action to preserve safety. This may put pressure on the Designer and Owner to take action which is adverse to commercial objectives, but the parties must be prepared to face up to actions necessary for safety.

It is vital that there are clear and workable arrangements for rapid evaluation of data, decision making and initiating action to preserve safety (and the asset).

## D.6 Handover and Reporting

Handover marks the point where the dam has been taken through commissioning to a point where the Owner is assigned full responsibility for operating the dam. It may be the case that handover has associated conditions relating to ongoing review of monitoring data until conditions stabilise or spillways are tested (spillway tests should be undertaken before the handover).

The Designer must define the handover point and any associated conditions and convey them clearly to the Owner. Apart from the Designer being satisfied with the general condition and performance of the dam and its component parts, the Designer must ensure that the Owner is made fully conversant with operating, maintenance and surveillance requirements, and that adequate training of the Owner and/or Operating Personnel has been achieved in these areas (refer Appendix E).

The commissioning process must be recorded in a commissioning report completed as soon as is practicable after handover. This report provides an important permanent record of initial performance compared with design expectations, together with any changes in details or expectations made during the process. The report will constitute a benchmark for ongoing surveillance and safety evaluations and may fill a vitally important role in subsequent detailed examination of any problem area which may develop. The report should be as comprehensive as possible with its possible future long term use clearly in focus.

A typical contents list for a commissioning report (again in this case for a water supply dam) is given overpage.

**COMMISSIONING REPORT**

**CONTENTS**

# APPENDIX E
# OPERATION, MAINTENANCE AND SURVEILLANCE

## E.1 Introduction

This Appendix builds on the guidelines for operations, maintenance and surveillance contained in the main text, the focus remaining on matters related to dam safety. Operating and maintenance requirements from functional or asset management perspectives, which would also be included in a complete operating system, are not included. While the surveillance aspects of this Appendix have much in common with those outlined for Commissioning in Appendix D, this Appendix relates to ongoing operations once the dam has been commissioned.

The detail of this Appendix is mainly relevant for Medium and High Potential Impact category dams, but elements are also applicable to Low hazard category dams. Owners of Low Potential Impact dams and their Technical Advisers should assess the following recommendations and adapt appropriate parts for use on their dam. Large parts of these recommendations may be relevant where the asset represented by the dam is of high value and the commercial consequences of dam failure are significant.

It is worth noting that operations, maintenance and surveillance all contribute to the safe performance of the dam and its appurtenant structures.

## E.2 Personnel and Training

Safe management of dams is a frame of mind and involves all the people concerned down 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 category of the dam.

The Owner is responsible for operating the dam safely and also sets requirements from the viewpoint of protecting asset value. Generally, Owners will not be fully conversant with the technical requirements of operations, maintenance and surveillance to maintain safety. Thus they will rely on advice from the Designer in the case of a new dam or Technical Specialists in the case of existing dams which do not already have formalised procedures. It is important that the Owner ensures that the advice is given by appropriately qualified personnel, who will have received "training" through past experience.

Training will depend on the circumstances, ranging from the Designer training the Owner/Operator of a small Low Potential Impact dam, to Operators of major High Potential Impact dams being taken through structured training courses, seminars, audits and refresher courses. Techniques may embody:

- attendance at relevant seminars (including overseas, e.g. ANCOLD courses)
- membership of NZSOLD and attendance at their seminars
- development of 'in house' procedures and implementation of them in practice
- interaction with other dam owners and getting the benefit of their experience
- keeping up to date through acquisition of the latest guidelines and training materials. Training materials are available from NZSOLD.

**Table E.1.**
**Proficiencies Required for Personnel Involved in Dam Safety Implementation.**

| GROUP | PRINCIPAL AREAS OF PROFICIENCY |
|---|---|
| Owner Manager Administrator | • Awareness of environmental and financial responsibilities relating to dam safety<br>• Understanding significance of hazard and risk<br>• Support of quality assurance principles |
| Technical Advisers | • Geotechnical principles<br>• Design principles including structural, geotechnical, hydrologic and hydraulic<br>• Construction techniques<br>• Operation and maintenance procedures<br>• Surveillance processes<br>• Response to dam safety issues<br>• Emergency planning<br>• Emergency response |
| Operations and Maintenance Personnel * | • Safe operations procedures<br>• Maintenance practices<br>• Surveillance principles, particularly monitoring<br>• Emergency planning<br>• Need for vigilance |
| Technical Advisor, Dams Field Personnel * | • Awareness of visual signs of dam safety deficiencies<br>• Procedures for operating mechanical items<br>• Emergency response including alerting others<br>• Surveillance principles, including monitoring<br>• Need for vigilance |
| Key Emergency Personnel*/Civil Defence | • Awareness of the potential impact<br>• Emergency planning and response |
| Territorial Authorities/Regional Councils | • Awareness of Planning, Resource and Building Consent implications |
| Public at Risk | • Emergency awareness and response<br>• Awareness of the potential impact |

(* e.g. probably the Owner in the case of a low potential impact dam)



## E.3 Scope and Structure of Manual

The manual describing procedures for operations, maintenance and surveillance, is a vital document and is customarily referred to just as the "Operations (or Operating) and Maintenance" Manual or O & M Manual. The latter abbreviation will be adopted for the following discussion.

The scope of the O & M Manual will vary for each situation but a general scope can be outlined. Table E.2 which follows, sets out main contents which should be included in the manual from the dam safety perspective. Further detail on key aspects is contained in subsequent sections.

It is also important to note that the O & M Manual must be easy to understand and user-friendly for those who are to implement it on a routine basis, whether the medium is printed text, via computer software, or both. There is a risk otherwise that important aspects will be overlooked because of human reaction to complex instructions. It is recommended that basic instructions and forms be as brief and simple as possible, with background information and detail in well referenced appendices.

**Table E.2.**
**O & M Manual Contents from Dam Safety Perspective.**

| ASPECT | NOTES |
|---|---|
| INTRODUCTION | • sets out scope and objectives |
| DAM STRUCTURE AND PURPOSE | • describes what the dam is and does referencing to other documents as appropriate (e.g. Design and Safety Evaluation reports, consent conditions etc.) |
| APPURTENANT STRUCTURES | • describes the function of appurtenant structures, such as spillway, intake, penstocks, powerhouse etc. references to other documents as appropriate (e.g. design and safety Evaluation reports, consent conditions, etc.) |
| KEY ASPECTS RELATING TO SAFETY | • sets out the particular aspects of importance on this particular dam related to reservoir safety. This includes not only those aspects relating directly to the dam (such as structural, geological and dam safety parameters) but also features of the appurtenant structures (such as gates, valves, electrical controls and communication systems). Part I includes the Health and Safety Act requirements. |
| MANAGEMENT STRUCTURE AND PERSONNEL | • describes how the dam is run and its appurtenant structures is run and who is responsible for what. |
| OPERATIONS AND MAINTENANCE REQUIREMENTS | • describes how the dam and its appurtenant structures is to be operated and what is to be maintained and to what standards to maintain functional safety |
| LEGISLATIVE REQUIREMENTS | • describes the procedures to be followed to meet operational and safety legislative requirements. This covers water use consent conditions, (under RMA ), warrant of fitness, including compliance schedule, (under Building Act) and health and safety (under Health & Safety in Employment Act) issues. |
| SURVEILLANCE AND EVALUATION | • sets out surveillance items, frequency, reporting requirements, acceptable limits for values measured and how data is to be evaluated and reacted to (including unusual events) |
| PLANT AND EQUIPMENT | • details the maintenance and testing procedures and frequencies and documentation to meet the requirements of the building warrant of fitness under the Building Act. |
| EMERGENCY ACTION PLAN | • sets out the plan and procedures to follow in the event of an emergency<br>• can be a stand alone document |

## E.4 Maintenance and Surveillance - Scope and Frequency

### E.4.1 Operation

Features and equipment for the passage of water through the dam and its appurtenant structures must carry out their normal functions without leading to the uncontrolled release of the reservoir water. Uncontrolled release of the reservoir is interpreted as an event during which there is no control over the quantity of water and its rate of discharge from the reservoir.

It should be noted that in general the failure of a turbine or a penstock for example will not result in the uncontrolled release of reservoir water as the quantity and the size of the opening and the capacity of the inlet control rate of discharge. The Building Code covers the design and performance of these features. Normal operating circumstances, which may result in the uncontrolled release of reservoir water, include where discharge is likely to cause erosion, which puts the safety of the dam and therefore the reservoir in jeopardy. In this case procedures should be in place to meet the general requirements of these guidelines.

### E.4.2 Maintenance

Maintenance can be separated into four areas:

- mechanical equipment impacting on operational safety (gates, pipelines, valves)
- electrical equipment to operate the same mechanical equipment or which telemeters data used in safety management or forms part of the emergency communications systems.
- the dam and its appurtenant structures
- the reservoir and its margins

Mechanical and electrical equipment require appropriate maintenance and testing. The aim of the testing programme is to demonstrate the equipment is in good working order and is capable of normal and emergency operation. In addition it is necessary for operators to be familiar with the performance of this equipment, especially if it otherwise infrequently used and if modifications or repairs have been carried out. During testing any associated issues of environmental concerns, and legal consents will have to be addressed by appropriate planning and consent processes.

The standard of maintenance and frequency and type of test will be according to the equipment function in terms of dam safety and normal operations. The Owner will decide his maintenance and testing regime for equipment controlling normal operations using usual commercial criteria. a typical testing programme for gates and valves involved in dam safety of medium and high potential impact dams is provided in Table E.3.



**Table E.3.**
**Guideline Gate/Valve Testing Schedules.**

| GATE/VALVE FUNCTION | UNBALANCED HEAD TEST | BALANCED HEAD TEST | BACK-UP POWER SUPPLY TEST |
|---|---|---|---|
| Passage of floods | Annually<br>15% minimum opening.<br>Initiated by back-up power supply | Six yearly.<br>Full range.<br>Initiated by back-up power supply | Monthly.<br>Battery & motor start-up checks.<br>150 mm min. opening |
| Reservoir evacuation only | Six yearly.<br>15% min. opening.<br>Initiated by back-up power supply | Six yearly.<br>Full range (in dry).<br>Initiated by back-up power supply | Monthly<br>Battery & motor start-up checks.<br>Nil gate opening |
| Machine intake | Six yearly | Annually | N/A |
| Bulkheads and stoplogs | Twelve yearly | N/A | N/A |

Back-up power supply tests also form part of the gate tests. They concentrate on confirming satisfactory field operation. Control room function tests should also be checked for satisfactory performance. These include the testing of local operation, remote operation, automatic operation, over velocity tripping of intake gates and automatic re-pumping to counter gate drift. Gate hoisting ropes should be visually inspected annually, for defects such as broken strands, corrosion, deformation and loss of lubricant. Specifically selected ropes, representative of each gate installation, shall receive a six yearly non-destructive test.

Communications equipment should be tested and maintained as part of the exercising of Emergency Action Plans.

Typical aspects addressed under routine maintenance and assurance of functionality, include:

- undertaking regular system checks
- operating equipment deliberately if it has not operated frequently in service
- lubricating moving parts and keeping oil levels topped up
- controlling or repairing corrosion
- repairing and replacing worn or damaged equipment
- operating ancillary equipment such as standby generators and ensuring batteries are charged and suitable fuel is always available

Maintenance of dam components and the reservoir, will generally be on an as-needs basis. Any specific issues will be included in the compliance schedule. Routine items which are commonly addressed as part of operational safety include:

- clearing dead timber from the reservoir margins and the dam face which might block spillways and dealing with weed islands if there is a likelihood of these impairing the spillway function
- repairing rip rap damage or surface erosion on the dam face
- keeping surface drains, and drainage systems generally, in good condition
- draining seeps and arresting or repairing significant reservoir slumps and slides
- ensuring that trees and like growth do not establish on the dam or designated abutment areas to prevent root penetration and obscuring of seepages and slumps
- repairing cracks and erosion damage in spillway concrete

## E.5 Surveillance - Scope and Frequency

The following text refers to routine surveillance carried out by the Owner or the Owner's Operators, and excludes external inspections (refer E6). It is this routine inspection and surveillance and its evaluation which is of greatest importance, as it can detect potential problems early and enable them to be dealt with more safely and cost effectively, giving the dam owner the opportunity to remedy, alleviate, or mitigate the problem. External inspections and major safety reviews are usually too infrequent to enable early detection. Refer to E7 and Appendix G.

The total surveillance requirements have provision for:

- regular surveillance (ongoing)
- intermediate inspections (annual)
- five-yearly reviews, or following an unusual event

Apart from evaluating the data and responding to it, as discussed in the next section, it is important that the data be logged systematically and in a form which makes it easy to utilise and record permanently. If the recording is not systematic, trends may be disguised and data may be difficult to interpret reliably.

Graphical presentation is important. The perception of significant trends or changes may be obscured by a mass of records of benign conditions. Monitoring schedules should be reviewed periodically (at least at Safety Reviews) to reduce them to essentials.

There is a need for quality assurance procedures with acceptable standards for the maintenance of instrument accuracy and measurement accuracy in data interpretation.

Tables E.4 and E.5 provide a list of typical inspection and surveillance items and indicative measurement frequencies for Medium and High Potential Impact dams. Designers or Technical Advisers will set actual requirements to suit the particular dam, in accordance with the compliance requirements.

## E.6 Data Evaluation and Reactions

Surveillance will not serve its purpose unless the data gathered is evaluated against some acceptable criteria, warning signs are recognised promptly, and appropriate action is taken. In specific cases some may be detailed in the Compliance Schedule. In general for high and medium impact potential dams and their appurtenant structures the data is to be reviewed monthly for the determination of trends and detection of anomalies. There must be an adequate system for evaluation and action. Should a dam safety issue arise the Owner is likely to be required to demonstrate that all possible steps were taken in the analysis and response to the collected surveillance data.

Apart from reacting appropriately to visual signs, either on a common-sense basis or as more specifically laid out in the O & M Manual, the Manual should set maximum values (usually incorporating a margin of safety) for key parameters measured (such as seepages, uplift pressures, and pore pressures. The Manual should require the observer to compare the value measured against the limits set, and then state how to react if the value is exceeded. In same cases, the Manual may require some immediate preventative action such as lowering the reservoir, but generally there will be a referral system to the Technical Advisors nominated in the Manual as having responsibility for evaluation and advice.

## E.7 Unusual Events

Surveillance and evaluation of performance should also be carried out following unusual events which may lead to emergencies and special procedures as covered under Emergency Action Plans. In the normal course of operations, unusual events should be evaluated to determine whether there has been any damage requiring correction, special safety measures needing to be implemented, and to assess behaviour compared with design.

Unusual events customarily anticipated in surveillance schedules, include:

- large rainfalls or floods
- earthquakes
- landslides into the reservoir
- windstorms
- volcanic eruption

## E.8 Intermediate Inspections

Dam safety inspections are required to verify throughout the operating life of the structure the structural integrity of the dam and appurtenant structures, assuring protection of human life and property. Inspection types and frequencies are developed to suit particular cases and may be varied according to conditions. In general these inspections are conducted annually and in the case of medium and high impact structures, carried out by someone outside the owner’s staff. For low impact structures the owner may conduct them. Each inspection must be reported. Verification that

**Table E.4.**
**Guideline Surveillance Schedules. (A) Inspection Guidelines.**

| | INSPECT FOR: | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FEATURE: | Alignment | Animal Burrows | Cracks | Debris | Deterioration | Erosion | Human Activity | Leakage | Muddy Water | Seepage | Settlement & Slides | Vegetation | Weathering |
| **EMBANKMENT DAMS** | | | | | | | | | | | | | |
| Upstream Slope | M | M | M | | | M | M | | | | A | A | |
| Downstream Slope | M | M | M | | | M | M | W | W | M | A | A | |
| Abutments | | M | M | | | | | W | | M | A | A | |
| Crest | M | M | | | | M | | | | | A | A | |
| Seepage Areas | | | | | | | | W | W | M | | | |
| Internal Drainage | | | | | A | | | W | W | | | | |
| Relief Drains | M | | M | | A | | | W | W | | | | |
| | | | | | | | | | | | | | |
| **CONCRETE DAMS** | | | | | | | | | | | | | |
| Upstream Face | | | M | | A | | | | | | A | | A |
| Downstream Face | | | M | | A | | | W | | M | A | | A |
| Abutments | | | M | | A | | | W | | M | A | A | A |
| Crests | M | | M | | A | | | | | | A | | A |
| | | | | | | | | | | | | | |
| **SPILLWAYS** | | | | | | | | | | | | | |
| Approach Channel | | | | W | | | | | | | | | |
| Stilling Basin | | | | | | M | | | | | | | |
| Discharge Channel | | | | W | A | | | | | | A | A | |
| Control Features | | | | W | A | | | | | | | | |
| Erosion Protection | | | | | | | M | | | | M | | |
| Side Slopes | | | M | | | M | | M | | | A | A | |
| | | | | | | | | | | | | | |
| **INLETS, OUTLETS AND DRAINS** | | | | | | | | | | | | | |
| Inlet & Outlets | M | | | W | A | | | M | | | | A | |
| Stilling Basin | M | | M | W | A | | | | | | | | |
| Discharge Channel | | | M | W | | | | | | | | A | |
| Trashracks | | | | W | | | | | | | | A | |
| Emergency Systems | | | | | A | | M | | | | | | |
| | | | | | | | | | | | | | |
| **GENERAL AREAS** | | | | | | | | | | | | | |
| Reservoir Surface | | | | | | | | A | | | | | |
| Shoreline | | | | | | | | | | | A | A | |
| Mechanical Systems | | | | | A | | | | | | | | |
| Electrical Systems | | | | | A | | | | | | | | |
| Upstream Watershed | | | | | | | A | | | | | | |
| Downstream Floodplains | | | | | | | A | | | | | | |
| | | | | | | | | | | | | | |
| Lists features to be inspected at a dam and the problems or deficiencies to be looked for. | | | | | | | | | | | | | |

W = Weekly, M = Monthly, A = Annually

the inspection has been carried out and the report produced is part of the building warrant of fitness. Unless specifically required by the regional Authority the report is kept by the Owner but must be produced upon request.

The inspection report describes observations and interpretations and gives recommendations. The focus of the report is on matters relating to dam safety and actions required to be taken by the Owner to assure legal requirements are met. The Owner may take the opportunity to include in the report matters relating to asset management and health and safety. To accommodate recommenda-

**Table E.5.**
**Guideline Surveillance Schedule. (B) Instrumentation and Monitoring Guidelines.**

| | MEANS OF PROBLEM DETECTION | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **FEATURE:** | Visual Observation | Movements | Uplift & Pore Pressure | Water Levels & Flow | Seepage Flows | Water Quality | Temp Meas | Crack & Joint Meas | Seismic Meas | Stress-Strain Meas |
| **EMBANKMENT DAMS** | | | | | | | | | | |
| Upstream Slope | M | A | M | C | | | | | C | |
| Downstream Slope | M | A | M | | W | A | | A | C | |
| Left/Right Abutments | M | A | M | | W | A | | | C | |
| Crest | M | A | M | | | | | A | C | |
| Internal Drainage System | | | M | | W | A | | | | |
| Relief Drains | M | | M | | W | | | | | |
| Reprap & Slope Protection | M | | | | | | | | | |
| Tailings dam drainage | | | | | | C | | | | |
| | | | | | | | | | | |
| **CONCRETE DAMS** | | | | | | | | | | |
| Upstream Face | M | A | | C | | | M | A | C | A |
| Downstream Face | M | A | M | | | | M | A | C | A |
| Left/Right Abutments | M | A | M | | W | | | | C | A |
| Crest | M | A | M | | | | M | A | C | A |
| Internal Drainage System | | | M | | W | | | A | | |
| Relief Drains | M | | M | | W | | | | | |
| Galleries | M | A | | | | | | A | C | A |
| Sluiceways/Controls | M | | | C | | | | | | |
| | | | | | | | | | | |
| **SPILLWAYS** | | | | | | | | | | |
| Approach Channel | M | A | | C | | | | | | |
| Inlet/Outlet Structure | M | A | M | D | W | | | | | |
| Stilling Basin | M | | | D | | | | A | C | |
| Discharge conduit/Channel | M | | M | D | | | | A | | |
| Control Features | M | | | | | | | | | |
| Erosion Protection | M | | | | | | | | | |
| Side Slopes | M | A | M | | | | | | | |
| | | | | | | | | | | |
| **OUTLETS & DRAINS** | | | | | | | | | | |
| Inlet & Outlets | M | A | M | W | | | | A | C | |
| Stilling Basin | M | | | | | | | | | |
| Discharge Channel | M | A | M | W | | | | A | | |
| Trashrack/Debris Control | M | | | | | | | | | |
| Emergency Systems | M | | | | | | | | | |
| | | | | | | | | | | |
| **GENERAL AREAS** | | | | | | | | | | |
| Reservoir Surface | M | | | | | W | | | | |
| Mech/Elect Systems | M | | | W | | | | | | |
| Shoreline | A | | | | | A | | | | |
| Upstream Watershed | A | | | | | A | | | | |
| Downstream Floodplains | A | | | | M | A | | | | |
| | | | | | | | | | | |
| Lists features to be observed at a dam and the suggested instruments or observation techniques to be used. | | | | | | | | | | |

W = Weekly, M = Monthly, A = Annually

tions, which are not essential to safety, a procedure sometimes adopted is to categorise recommendations into:

- urgent
- necessary
- desirable
- optional

or similar.

Inspections should be systematically organised so that the status of all critical aspects of the dam can be accurately recorded and evaluated. Field inspection checklists should be assembled as a part of the operation, maintenance and surveillance procedures. Reference to previous inspection reports should be made during or prior to the inspection. Generally, the intermediate inspection reports should include:

- observations during the inspection
- what has occurred since the previous inspection e.g. incidents, action arising from previous recommendations
- a review of monitored data and other information
- an evaluation and interpretation of the structural performance of the dam and related structures/equipment including a comparison of the conditions with those of the previous inspection
- appropriate photographs
- recommendations and action list

Dam safety inspections for low potential Impact structures should include:

- observations during the inspection;
- what has occurred since the previous inspection, e.g. incidents, action arising from previous recommendation;
- appropriate photographs; and
- recommendations and action list.

# APPENDIX F
# EMERGENCY ACTION PLAN

## F.1 Requirement for an Emergency Action Plan (EAP)

An Emergency Action Plan (EAP) is integral with the Operations and Surveillance procedures, considers all the potential hazards, and puts in place actions to isolate, prevent, protect life, or, mitigate losses.

An Emergency Action Plan should also be prepared prior to the construction of Medium and High Potential Impact earth dams. The documentation should also be prepared for similar category concrete dams if there is a potential for abutment erosion as a result of overtopping during construction of a concrete dam. The documentation will assist in identifying how to handle flood volumes and peak discharges during construction.

Situations which could give rise to an emergency include:

- Volcanic eruption (lava flow, ash, etc.)
- Major earthquake
- Major flood
- Major landslide into the reservoir, or from abutments
- Inadequate spillway ( or diversion in the case of a dam under construction)
- Spillway blockage or inoperable gates
- Dam structure progressively failing due to seepage forces or piping
- Accidental damage
- Sabotage

An EAP should exist for all High and Medium Potential Impact Dams.

The hazard and risks will vary depending on the status of the dam and the plan requirements will vary accordingly. Legislation requires emergency action plans for the following stages of the life of a dam:

- Construction above medium impact level
- Commissioning
- Operation
- Alteration or decommissioning

## F.2 Development of an Emergency Action Plan

**An EAP should describe the actions to be taken by the dam owner and operators ( or contractors when a dam is under construction) and relevant agencies in an emergency. The EAP should assign responsibility for each action to an individual and/or backup. The dam owner is responsible for co-ordination of input to the EAP from other agencies and affected parties**

The steps in developing an EAP are generally as follows:

- Identification of those situations or events that would require initiation of an emergency action.
- Identification of the performance or surveillance indicators which will lead to an emergency being initiated.

- Specification of the actions to be taken, and by whom.
- Identification of all sources, agencies, and individuals who are able to supply information for input into the EAP.
- Identification of all jurisdictions, agencies, and individuals who will be involved in implementing the EAP.
- Identification of primary and auxiliary communications systems, both internal (between persons at the dam) and external between dam personnel and external agencies).
- Identification all persons and agencies involved in the notification process, and draft a notification flow chart. Include who should be notified, in what order, and what other actions are expected of downstream agencies.
- Assess if each territorial, Regional and Central Government agency involved and having its own general emergency plan requires amendments to their plan to include actions required as a result of a dam emergency.
- Develop a draft EAP.
- Discuss fully with all the parties included on the notification list, seeking review and comment.
- Make any revisions, obtain any necessary regulatory approval, and circulate the EAP to those who have responsibilities under the plan.

## F.3 Contents of an Emergency Action Plan

**The EAP should include the following procedures and information**

- **Purpose of the Emergency Action Plan**
- **Responsibilities**
- **Emergency identification and evaluation**
- **Preventative actions (where available)**
- **Notification procedure**
- **Notification flow chart**
- **Communication systems**
- **Access to site**
- **Response during periods of darkness**
- **Response during periods of adverse weather**
- **Sources of equipment**
- **Stockpiling supplies and material**
- **Emergency power sources**
- **Inundation maps**
- **Warning systems (if used)**

**Purpose of the Emergency Action Plan**

The Plan is designed to limit damage to the dam and areas downstream, and prevent loss of life. It should take into account conceivable failure scenarios applicable to the dam, the potential downstream consequences, and what realistically may be achieved to safe guard lives at risk and generally minimise damage.

The outcomes are:

- The identification of emergency conditions which could endanger the integrity of the dam and which require immediate action.

- Prescription of procedures which should be followed by the dam owner and operating personnel to initiate emergency procedures at the dam.
- Provides timely warning to appropriate emergency management agencies for their implementation of protection measures for downstream communities.

**Responsibilities**

This section should specify the person(s) or organisation(s) responsible for the surveillance, maintenance and operation of the dam and the person(s) and or agencies responsible for implementing various stages of the EAP.

**Emergency Identification and Evaluation**

If detected early enough, potential emergencies can be evaluated and preventative or remedial actions taken. The EAP should contain clear procedures for taking action when a potential emergency is identified. Notification of emergency situations requires that a responsible contact person initiates the remedial action and decide if and when an emergency should be declared and the EAP executed. Clear guidance should be provided in the EAP on the conditions which require that an emergency be declared.

Once an emergency situation has been identified and evaluated, it should be classified as to its urgency so that the appropriate action can be taken.

**Preventative Action**

This section should detail preventative actions, taken both prior to and following the development of emergency situations, to prepare for any emergency. It should detail provisions for surveillance and detection of an emergency situation and should clearly indicate what can be implemented in a timely manner. An important factor in the effectiveness of the Emergency Action Plan is the prompt detection and evaluation of information obtained from instrumentation and/or physical inspection and surveillance procedures.

The time factor from the onset of an emergency to awareness of imminent damage and its effect on the workability of the EAP should be detailed. Timely implementation of the EPA is a crucial element in its effectiveness and appropriate effective warning systems are imperative for downstream emergency authorities to minimise loss of life and property damage.

The following factors should be outlined in this section of the EAP:

- Surveillance, Monitoring and Warning Systems
- Alert and alarm levels for surveillance and monitoring systems
- Adverse Time Response
- The nature of the material that may potentially be released in a failure
- Alternative Source of Power and Communication
- Emergency Supplies and Resources
- Co-ordinating Information (e.g. weather forecasts, stream flow)
- Actions to lower the reservoir or limit inflows and outflows
- Actions to remedy, alleviate or mitigate the potential impact

**Notification Procedures**

Notification procedures must be clear and easy to follow. The EAP should set out a list of all persons to be notified in the event that an emergency is declared, and their order of priority.

For each type of emergency situation, the EAP should clearly indicate who is to make a call, to whom it is to be made, and in what priority.

Early notification to the N.Z. Police allows them to prepare for a mobilisation of forces before the emergency is declared. They can then determine if they have sufficient resources, or will need to call in the Civil Defence

The number of persons to be notified by each responsible individual should be kept to a minimum, and briefing of the news-media should be pre-planned to the greatest possible extent.

**Notification Flow Chart**

A notification flow chart is a diagram showing the hierarchy of notification during an emergency. It is a pictorial representation of the notification procedure. The EAP should contain a notification flow chart clearly summarising the notification procedure for each of the emergency conditions considered. Included are: N.Z. Police, Civil Defence, Owner, Contractors, Technical advisers, Territorial Local Authorities and media. The flow chart should include individual names and position titles, office and home telephone numbers, with alternative contacts and means of communication. Copies to be available to all individuals having responsibilities under the plan, and prominently posted at the dam, and local emergency operations centre.



**Communications Systems**

Full details of the internal and external communications systems as they apply to the EAP should be included.

**Access to the Site**

The description of access should focus on primary and secondary routes and means for reaching the site under various conditions (e.g. foot, boat, helicopter, bulldozer), and the expected response (travel) time.

**Response during Periods of Darkness**

The EAP should cover the response to potential or actual emergency conditions during periods of darkness including those caused by power failures.

**Response during Periods of Adverse Weather**

The EAP should address emergency response under adverse weather conditions including extremes of cold, snow, or storms.

**Sources of Equipment**

The location and availability of equipment and contractors that could be mobilised in case of an emergency should be included.

**Stockpiling Supplies and Materials**

The location and availability of stockpiled materials and equipment for emergency use should be addressed.

**Emergency Power Sources**

Details on the location and operation of emergency power sources should be included.

**Inundation Maps**

Inundation maps are needed for District Planning, Resource Consent Management, N.Z. Police, Civil Defence and Territorial Local Authorities to develop management and evacuation plans. Flood hazard maps may already exist for the affected flood plains. Where the EAP scenario gives a flood peak < 2% probability event ( 1 in 50 year return period), then the existing flood hazard maps may suffice. They should be prepared wherever communities or significant numbers of dwellings are located in the flood plain. These maps will outline the area inundated in sufficient detail to locate dwellings, services and other significant features. Indication of flood wave travel times will be noted on the maps.

**Warning Systems**

Warning systems are sometimes used to provide warnings to residents, camp grounds, and parks that are close to the dam. Full details should be contained in the E A P and cover N.Z. Police, Civil Defence, Territorial Local Authority, Own Company, Contractor, and media.

**Appendices**

Additional items may be covered in the appendices to the EAP:

- General site plans may be useful
- Drawings showing the potential breach location used in the inundation study
- Tables showing the variation in flood stage with time at key locations in the flooded area
- Recording of Emergency situations
- EAP training and Review

## F.4 Maintenance and Testing of an Emergency Action Plan

**The dam owner is responsible for issuing the EAP to those affected, as well as for maintaining and updating all registered copies of the EAP.**

**The dam owner should test the EAP.**

As updates or amendments are produced, they should be forwarded to each holder (as listed in the EAP) and acknowledged by the recipient. Telephone numbers and names of contact persons should be updated on a regular basis, at least annually. It is helpful to place the EAP in a loose-leaf binder so that outdated pages can be easily removed and replaced with updated information, to ensure a complete, current and workable plan. A list of plan holders should appear in the EAP.

Testing is an integral part of the EAP to ensure that both the document and the training of involved parties are adequate. Tests can range from a limited table top exercise to a full scale simulation of an emergency and can include multiple failures (domino effect).

## F.5 Training

**The dam owner should provide training to ensure that dam personnel involved in the EAP are thoroughly familiar with all elements of the EAP, the availability of equipment, and their responsibilities and duties.**

**This familiarity should be extended to appropriate members of the N.Z. Police, and Civil Defence Officers.**

Technically qualified personnel should be trained in problem detection and evaluation and appropriate remedial (emergency and non-emergency) measures.

This training is essential for proper evaluation of developing situations at all levels of responsibility which, initially, is usually based on observations on-site. A sufficient number of people should be trained to ensure adequate coverage at all times. Simulated exercises may prove useful in this training.

## F.6 Inundation Studies

**An inundation study should be carried out for all dams that clearly require EAP's, and for dams where it is not obvious whether or not an EAP is needed, or where the consequence of classification of dam is in doubt.**

**The inundation study should be based on assumptions that will indicate all areas that could be flooded for the most severe combination of reasonably possible conditions.**

Various dam failure scenarios are normally studied; these cover rapid failure times, large breach sizes and conservative antecedent conditions. The potentially inundated area should be determined and the following conditions considered:

- Fair weather dam failure (piping, earthquake, volcano) at full supply level.
- Design flood with and without failure.
- Inundation maps showing the flooded areas should be prepared. A number of computer programmes are available which can be used successfully to provide the analysis.

Regional Councils have a responsibility for regional scale natural hazard information including flood hazard maps. Where an impact of failure is similar to flood sizes already mapped then existing information may suffice,

**Key Emergency People**

An easy to find section provided for key emergency contacts

**Inspection**

A special dam inspection together with appropriate monitoring needs to be carried out as quickly as possible with ongoing surveillance until the emergency is over. A schedule of appropriate inspectors for the dam should be attached as an appendice.

## F.7 Risk Assessment

A risk assessment will assist in the development of the consequences of potential hazards associated with the structures, and the likelihood of their occurrence. The risk assessment will assist in the selection of options to remedy, alleviate or mitigate potential impacts as a result of a structural failure of a structure retaining a body of material. The production of a fault tree and an event tree is helpful in representing the effects of various hazards.

# APPENDIX G - SAFETY REVIEWS

## G.1 Introduction

This Appendix provides expanded guidelines for safety reviews. Almost by definition, safety reviews are applicable to dams with Medium or High Potential Impact, and the recommendations are more applicable to such dams. However, Low Potential Impact dams may warrant assessment to preserve the asset value or earning potential of the dam and require periodic review to assess whether their hazard may have moved into a higher category.

The Appendix focuses on key points but does not cover all details. Reference should be made to other documents as appropriate, using for example the reference list at the end of these Guidelines.

## G.2 Personnel

The following lists the key personnel involved, outlines their roles or responsibilities and recommends basic skill or experience requirements:

- Owner - Whether or not safety reviews are statutorily required (by consent conditions), the Owner must take steps to understand the requirements for safety reviews, plan and budget for their implementation and ensure that they take place. After taking advice as necessary, the Owner must draw up the brief, in accordance with the Compliance Schedule requirements facilitate the review, and most importantly, act on recommendations considered necessary to secure an appropriate level of public safety, avoidance of damage to other property, and protection of environmental security.
- Statutory Authorities - Under "warrant of fitness" conditions, Regional Councils will have a responsibility to confirm that safety reviews have been undertaken to satisfactory standards, then ensure that recommendations essential to safety are implemented
- Operators - On behalf of the Owner, Operators will be responsible for providing all available data and relevant information to the Safety Review Team, facilitating inspections including Health and Safety aspects, operating equipment as necessary, and responding fully and frankly to any questions put to them.
- Safety Review Team - The Technical Specialists making up the Team will carry out the review and report in accordance with the Owner's brief, Compliance Schedule requirements, and to the highest standards of professional practice. Each Specialist must be suitably experienced and senior in the area to be covered, and while "grey hairs" are of considerable value, it is important that each person is technologically up to date because a fundamental part of safety reviews is to assess the dam in the light of current technology. For more complex dams involving several facets, it may be necessary or advisable to involve more than one engineer to ensure adequate coverage of issues. There may also be a need for closely defined specialist inputs in areas such as seismology and earthquake risk. Owners and

Regulators need to appreciate that if the Team is not suitably qualified, the review may not disclose important issues. Members of the original design team may assist by clarifying matters, but should not be included in the Safety Review Team to ensure that an independent and unprotective evaluation is made.

- Peer Reviewers - While a safety review is a form of peer review, some organisations require peer review of the Safety Review Team's work. This applies particularly in the first round where there is a lack of original data. The need for such a review depends on circumstances and affordability, but such peer review is recognised as a sound concept. The Peer Reviewer (or reviewers) in this case needs to have suitably wide experience at least equal to that of the Team and generally will be drawn from the most senior practitioners available.

## G.3 Scope of Review and Related Issues

### G.3.1 General

The main text summarises the key areas typically considered in a review. Setting aside the difficulties which arise in an "initial" review as discussed in G3.2, the following outlines a more detailed typical scope and related issues:

- fundamentals
  - assessment of hazards and risk taking into account any existing or proposed catchment changes upstream or downstream
  - appraisal of general design standards against modern practice, involving site specific assessment of seismotectonics, flood risk and volcanic risk
  - assessment of the site condition of the existing structures
  - evaluation of design data and construction methods
- hydrology and spillway provisions
  - appropriateness of design flood(s)
  - ability to pass design flood(s)
  - spillway performance characteristics, risks of blockage or malfunction, and stability
  - acceptability of freeboard
  - consequences of no change to spillway
- structural aspects
  - appropriateness of dam design details for loadings and seepage conditions taking foundation features and performance data into account
  - performance under design earthquake(s) and flood(s)
  - structural integrity of ancillary structures impacting on safety under all design loading conditions
- equipment
  - structural adequacy
  - functionality and security of operation
  - reliability
- reservoir
  - slide potential
  - seiche risk
- downstream
  - environmental changes affecting potential impact classification

| | |
|---|---|
| | - river bed changes affecting structural or spillway performance |
| • operational, maintenance and surveillance aspects | - compliance with essential aspects of Appendix E guidelines and implementation of any previous safety review recommendations |
| • reporting | - see G.4 |
| • emergency | - prescribe procedures in an emergency plan |
| preparedness | - assign responsibility |
| | - identify all parties involved |
| | - identify cause, effect, and mitigation |
| | - locate resources |

The Safety Review Team will assess a finer level of detail within these areas.

As a matter of good practice, and to help achieve effective communication or understanding, it is recommended that the Owner or an appointed representative take part in the inspection, and/or that meetings be held during the course of the evaluation, or after supply of a draft review report.

Care is required in setting up the contractual relationship between the owner and the safety reviewer, to ensure the review is complete, and the report is without bias from the Owner, or manager of the facility. In appropriate or draconian liability provisions may unduly influence the judgment and candor of the reviewers to the extent that they may only take an ultra conservative approach and recommend unnecessary additional studies and investigation to cover the slightest uncertainties. The brief needs to clearly separate the annual performance compliance from other asset management aspects the owner may wish examined.

### G.3.2 Initial Reviews

This term applies to old or existing dams reviewed for the first time, which frequently have limited data available on their development history and may also have limited operational records. The key problem with such dams is the lack of data and "where to start".

In principle, the first step should be to try to establish a data book (or books) which provide the best available knowledge of the dam. The extent to which the Owner does this as a prelude to the review or as part of it, is a matter of choice and circumstances.

An almost inevitable consequence of initial reviews, unless the situation is very straightforward, is that they will involve at least two stages. The first stage will be aimed at putting issues in perspective as can best be judged on available information, and determining areas of uncertainty for further examination. It may be that a potential safety deficiency is identified straight away, in which case appropriate action must be taken. The second stage will often require forensic investigation and monitoring to assess areas of uncertainty. In such cases a realistic lead time to the "Warrant of Fitness" date will be required.

It is important that Owners appreciate the probable need for forensic investigation and its associated cost, and that Consent Authorities appreciate that it may take some time to arrive at realistic conclusions in the case of initial reviews. . Notices to Rectify should reflect the practicality of achieving compliance from a time and cost basis balanced with risk exposure.

### G.3.3 Low Potential Impact Dams

Brief and generalised recommendations are outlined in the main text for Low Potential Impact dams. Legislation may not require a "warrant of fitness" for a Low Potential Impact dam, but it is not in the Owner's interests or society's interests, to ignore dam safety on the basis of the Potential Impact being low. Furthermore, environmental changes may cause a Low Potential Impact dam to be rated in the Medium Potential Impact classification These Guidelines deal with issues of dam safety. For all classifications of dam, the owner will need to take particular precautionary measures to protect commercial and public relations interests.

There are many dams with a low risk to life or property, notably for community water supply or hydro generation, where the consequences of failure would have serious social or economic effects. Thorough safety reviews of these dams are definitely in the Owner's interests and may well be required to maintain insurability. In such cases an appropriately scoped safety review should be undertaken, based on the foregoing and following advice. These dams are Medium Impact Dams by definition.

## G.4 Review Conclusions and Reporting

The extent and standard of reporting should be such as to:

- confirm that the brief has been met fully or exceeded
- comprehensively describe the inspections, findings, forensic work, and related inferences or conclusions
- be easily understood by the Owner and subsequent Reviewers
- present conclusions and recommendations clearly
- confirm compliance requirements have been met and / or what is required to fulfill compliance.

Key conclusions and recommendations which require the most careful consideration are:

- the assessed condition of the dam and appurtenant structures to function satisfactorily in a safe manner according to recognised criteria
- determination of those issues associated with the dam, its appurtenant structures or the catchment which have a potential impact on dam safety
- determination of the most plausible modes of failure for the dam, or its appurtenant structures, and their potential dam safety impact
- an assessment of the dam's performance with respect to these potential modes of failure
- assessment of the Operations and Maintenance procedures (or equivalent documentation) for dam safety application
- areas of uncertainty requiring further assessment
- any areas requiring immediate action with accompanying advice
- prioritisation of recommended actions

## G.5 Follow-up Action by Owner

The responsibility for acting on the recommendations of the safety review rests with the Owner. The Consent Authority will provide a level of external control and overview. The Owner should take advice as necessary on how best to implement the recommendations. Where the cost implications are high, it may be in the Owner's interests to undertake a higher level of investigation and review before implementing the full detail of recommended works. It may not be necessary to undertake significant works, where an acceptable level of reduction in the potential impact of the issue can be brought about by softer options, such as increased surveillance, and improved emergency preparedness procedures. Where a high level of risk is perceived to apply while matters are being investigated or designed, the Owner should implement such reasonable temporary measures as can be effected to improve the situation after discussion with the Consent Authority (e.g. increasing the frequency of surveillance, lowering the water level or providing temporary auxiliary spillway capacity).

The Consent Authority may issue a Notice to Rectify. Such notice may be to decommission the dam. This would require consents to be sought under the Resource Management Act.

# APPENDIX H - PERFORMANCE SCHEDULES

## H.1 Introduction

This Appendix outlines how dam safety Performance Schedule requirements can be implemented consistent with the Building Act requirements for Compliance Schedules, and aims to illustrate how these Guidelines as a whole may be drawn upon to establish detailed performance compliance procedures. Note that under s44 (2) of the Building Act, every compliance schedule...... "shall specify the inspection, maintenance and reporting procedures to be followed by independent qualified persons in respect of the systems specified in subsection (1) of this section.......". The procedure for each dam will be unique and will also vary depending on the status of the dam, and the consequence of failure.

Performance schedules for the construction stage may be warranted when particular flood hazards and risks apply, during commissioning when the body of the dam and its appurtenant structures are first being tested against design expectations, for normal operation of the dam, and during any repair or demolition. The latter situations are the exception rather than the norm, and clearly need to be treated on their merits, especially if the dam is deemed dangerous and needs rapid intervention such as immediate lowering of the reservoir operating level. Monitoring and emergency action plan requirements during construction, commissioning, repair or demolition are aspects of Plans and Specifications to be considered and incorporated in the building consent and resource consent. Therefore this Appendix focuses on compliance for new dams and dams under normal operation, where a compliance regime is appropriate ( higher impact dams generally)

## H.2 Qualifications of Personnel

The Building Act requires independent qualified persons to undertake or certify compliance requirements. CS-16 of the Handbook enables the dam owner to exercise these functions subject to confirmation of competency for most situations, but requires a person or persons independent of the owner's organisation or employ for annual compliance inspections or special safety inspections and the like.

Where an owner is certified under ISO 9000, and employs experienced technical staff operating independently of the operational and maintenance section, then the annual compliance inspection may be undertaken by those staff, and subjected to both the ISO 9000 external audits, and the five to seven yearly comprehensive dam safety reviews.

Certification under ISO 9000 is not necessary, but may be helpful to owners of High or Medium Impact Potential dams.

Certain systems may be inspected by the owner, or anyone else on the owner's behalf, but some systems need specialist inspection. An independent qualified person (IQP) is a person (or firm) approved by the regional council as qualified to inspect certain compliance schedule items and ensure that necessary maintenance occurs. "Independent" means that the person has no financial interest in the building. [Quoted from BIA pamphlet 1999].

An owner with appropriate processes and procedures in place, certified by a third party, such as meeting ISO 9000 requirements, may be accepted as requiring fewer items subject to IQP inspections. Fewer items may be required for specific systems, or a lower frequency of inspection. The performance schedule and need for specialist inspections may be issued by the regional council (RC).

Appendix E of these Guidelines provides an outline of proficiencies requirements for personnel involved in ongoing dam operation. Appendix G gives guidance on safety reviews, with implied personnel skills. The following paragraphs expand on qualifications from the viewpoint of meeting the Building Act type requirements.

### (i) Operation and Maintenance

Generally personnel involved in dam operation and maintenance will have received on-the-job training within an appropriate owner structure and/or training in a similar environment. Recognised technical or trade qualifications will usually be required for managers or team leaders of dams requiring full time personnel. Clearly there will be a greater demand for the likes of hydropower dams and dams with gated spillways. On the other hand, flood detention dams and water supply dams involving ungated overflow spillways and gravity supply intakes with downstream control, will require more intermittent involvement of operations and maintenance personnel.

### (ii) Routine Monitoring and Surveillance

Personnel responsible for routine monitoring or surveillance will have received as a minimum, adequate and specific on-the -job training and overview from appropriately qualified seniors. For higher impact dams, generally a recognised technical qualification relevant to the activity, will be required.

### (iii) Engineering Overview and Response

Personnel involved in assessing routine monitoring data, determining its significance and actioning appropriate response, require appropriate training and experience in dam engineering. Almost without exception, this will involve those responsible having gained an appropriate tertiary degree in engineering and a level of practical experience in dam engineering relevant to the complexity of the dam and its potential hazard or impact. As a general guideline, a minimum of 2 years of relevant practical experience would be expected for dams at the lower end of the complexity/ hazard spectrum and a minimum of 5 years of experience for dams at the higher end of the spectrum. Depending on the technical issues associated with the dam, and the experience and qualifications of those involved, a team of appropriately qualified personnel or access to specialists, may be required.

### (iv) Periodic Inspection

Annual inspections by owner employed personnel for compliance certification will also generally require the qualification and experience levels described in (iii) above. In most situations the inspection will adequately be undertaken by one suitably qualified engineer, but in certain cases, input or limited support may be required from others qualified in disciplines outside the inspecting engineer's areas of expertise.

For the less frequent full safety reviews (e.g. 5 yearly), the personnel involved should have the same basic qualifications as outlined under (iii) above, but the total relevant practical experience should be around 5 years minimum for less significant dams, and 10 years minimum for more significant dams. generally those involved should have a profile within the dam industry and be recognised as having a high level of experience and competence. The reviewer or reviewers must be able to cover competently all the technical areas on which evaluation of dam safety depends, and reviewers may need to draw on support from others not directly involved in inspections, such as specialists in evaluating flood hydrology. Selection of the reviewer or review team may require the owner to seek advice from senior members of the dam engineering profession on suitable candidates and/or selection procedures.

## H.3 Performance Compliance Elements for Existing Operational Dams

When writing performance schedules due account should be taken of the following:

(i) All systems and data recording relevant to a performance schedule are in accordance with industry practice and comply with ISO 9000 procedures or are consistent with such procedures.

(ii) Appropriate management and operational structures are in place with roles clearly defined for all activities, including access to qualified specialists where directly employed owner resources do not have the necessary level of expertise.

(iii) The competence and level of required training for personnel involved in operating and maintaining dams is defined for each dam.

(iv) Data is available which confirms the competence and level of training of personnel involved in maintaining dam safety

(v) An appropriate scope and frequency is set for routine monitoring and surveillance, with criteria and response mechanisms set for excessively adverse or potentially dangerous results.

(vi) Reaction to any unusual event has been at the earliest practicable and appropriate time.

(vii) The Owner's actions taken or being taken in response to previously identified deficiencies or uncertainties requiring resolution, are appropriate.

(viii) An appropriate emergency action plan is in place, has been subjected to an annual confirmation or update, and all other related requirements have been met. This plan includes provision for emergency inspections.

(ix) Comprehensive and appropriate operational and maintenance procedures related to dam safety are in place and are being observed, including testing of equipment important to safety, which may not be exercised during normal dam operation.

(x) Annual inspections including review of the prior 12 months' activities and data have been undertaken. Note that, for performance compliance purposes, this may either take the form of an audit by the independently qualified person or persons, or be undertaken by the same.

(xi) Comprehensive (five to seven yearly) safety reviews and their scope are programmed for implementation by independent qualified persons.



## H.4 Compliance during Construction and Commissioning

The following require establishment, implementation and certification:

**A Construction Stage**

- Before the dam reaches a significant impact category, appropriate systems, management structures, personnel skills and monitoring systems related to possible construction hazards (mainly flood during construction) **and** an appropriate emergency action plan.

**B Commissioning Stage**

- Before permanent filling of the reservoir commences, an appropriate commissioning plan with associated monitoring shall be put in place together with an appropriate emergency action plan related to commissioning hazards.
- After the reservoir has reached the normal maximum operating level and been held at that level for a sufficient period to test the performance as defined in the commissioning plan, and appurtenant structures have been tested, appropriate certification of completion of commissioning (including analysis of results and the taking of any actions necessary to achieve safety) and preparation of operational compliance requirements for the following twelve months operation.

## H.5 Emergency Action Plans

These plans are an important element of Building Act and Resource Consent condition compliance. Appendix F gives detailed guidance on plan formulation and implementation. Plans are required:

(a) not less than one month prior to the dam reaching medium impact level, assuming a flood which may fill the available storage;

(b) not less than one month prior to commencing permanent filling of the reservoir and commissioning;

(c) for the operational stage of the dam after completion of commissioning and evaluation of commissioning results, with an annual update thereafter as necessary; and

(d) for alteration work or demolition.

For more straightforward dams, one comprehensive plan submitted at the time of the consent application, may be sufficient to cover the first three stages.

For larger, more complex structures that take some time to construct and commission the improved knowledge of the site, structure and conditions during construction may lead to refinements in design and proposed operation and maintenance procedures. In such circumstances the EAP for each stage should be prepared incorporating such improved knowledge.

It should be noted that for consents required under the Resource Management Act, the effects of dams must be considered. Emergency Action Plans, at least in outline form, may also be required in support of an application for a resource consent.

An emergency action plan (EAP) is required for the operational stage of the dam after completion of commissioning and evaluation of commissioning results. An update, at least annually or more frequently if necessary, should be done. Such an update may make changes to methods or only reflect changes to personnel and contact details.

The EAP should incorporate the improved knowledge of site, structure and operation gained through construction, commissioning and subsequent operation phases. Only in the case of a relatively simple structure would it be expected that the EAP for the operational and maintenance period could be written prior to commissioning.

## H.6 Operation and Maintenance

### H.6.1 General

It is important in the first instance that operational features are correctly identified for compliance under general application of the Building Act or whether they fit under provisions applying to dams. To fall under the latter, the operation must lead to the uncontrolled release of the reservoir water or uncontrolled impacts on the margins of the reservoir as described in Appendix E.

For compliance within the dam safety perspective, documentation, procedures, maintenance and surveillance practices shall be in place as applicable elsewhere in these documents.

### H.6.2 Hydraulic Structure Gates and Valves

Dams incorporating gates and valves have a higher operating and maintenance demand and accordingly requirements for such equipment are highlighted.

To meet a compliance regime, the gates and valves that contribute to reservoir safety must be capable of functioning as required. This requires not only a physical inspection of equipment but also a demonstration of its capability. Guidelines for the physical inspection and for testing performance are provided below.

(a) Inspection

The physical inspection of any gate or valve should include:

(i) Structural condition - inspect for defects in structural members/ connections, signs of corrosion and cavitation, condition of cables and wires, anchorage points, lifting super structure and crane conditions etc.

(ii) Operational condition - inspect for mechanical and electrical operational aspects such as state of lubrication, security of power supply, backup supply, operator access, condition of controls, ease of operation, instructions, protection from weather etc.

(b) Tests

A typical testing schedule is contained in Appendix E. Tests should be specific to gate function and type. Fully documented records of gate use during a normal hydraulic operation are adequate to demonstrate satisfactory performance. Typical records of gate / valve test include:

- Documentation. To include : gate/valve identification, date of test, inspectors, hydraulic conditions, results and test.
- Gate performance. Water entry conditions, flow past gate, outlet conditions, energy dissipation, air entrainment, water and air demand surges, etc. under transient conditions, etc.
- Equipment performance. Motor load, power demand, unusual noises, hydraulic systems, east of operation, control systems including gate opening indicator, etc. for both the main and backup power sources.
- Operator performance. Familiarity of operators, to operate, and with backup power source(s) or gate operation.
- Communications. Robustness of communication systems.

## H.7 Surveillance (or Inspection)

### H.7.1 General

Meeting a compliance regime requires that relevant surveillance and inspections found in Part III Technical Aspects and Appendix E, Operation, Maintenance and Surveillance in these Guidelines are being followed. It is important that the systems in place are relevant to the dam Potential Impact category, its condition and any specific operational regime. This decision will incorporate the input of professional expertise from both the owner and IQP personnel involved in compliance issues.

### H.7.2 Construction and Commissioning Surveillance

Important aspects of surveillance at these stages is the prior planning of the surveillance system. Preparation based on expected behaviour and contingencies for unexpected but foreseeable events. Compliance requires documentation and demonstration of the appropriate levels of these aspects.

### H.7. 3 Regular Surveillance (or Inspections)

Regular surveillance is a routine activity. Compliance requires a demonstration that the owner's established surveillance system accurately records safety performance of the dam and that appropriate actions are being taken when potential deficiencies or adverse data trends are identified.

### H.7.4 Intermediate (e.g. Annual) Inspections

A compliance regime requires a report on a detailed engineering site inspection for dam safety deficiencies and includes a review of surveillance and operations information applicable to the dam and its appurtenant structures to assess the current safety performance. The report is also to review the owner's surveillance systems. These include:

- Regular surveillance
- Data analysis and recording
- The appropriateness of reactions to reported potential deficiencies and adverse trends resulting from owner regular surveillance
- Timely response to actions recommended as a result of intermediate inspections, safety reviews, and emergency inspections.
- Records of regular dam safety plant and equipment testing
- Competence of owner personnel involved in dam safety inspection

Any recommendations arising from the report must indicate a reasonable time frame in which actions should be undertaken.

The report should be limited to dam safety issues, i.e. those that are relevant to threats to life, safety or other property and not detail maintenance items nor matters that are covered by other compliance schedules, e.g. lifts. Generally, the annual inspection will be the basis for owner issue of the annual warrant of fitness.

### H.7.5 Emergency and Special Inspections

Emergency and special inspections after unusual events as indicated in Appendix F must also be defined in the compliance schedule. Actions to be taken should be prescribed to the extent practicable.

### H.7.6 Comprehensive Inspection (e.g. 5–7 yearly)

A performance compliance regime requires a report prepared by the review team involved in the detailed evaluation of prior performance, operation, maintenance, and inspection systems relating to preventing the uncontrolled release of stored contents. The standard against which reporting is to be made is current standards and technical knowledge pertaining to dam safety. The comprehensive inspection will need to address whether the compliance requirements should be updated and address whether the dam can be considered safe in terms of the current accepted guidelines and standards for dams, until the next comprehensive inspection.

The report is to cover the same areas as the annual inspection but in more detail. Appendix F provides more detail on comprehensive inspections to match the more comprehensive scope.

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