# Appendix A - Summary of Written Acceptable Flood Capacity Assessment Requirements

## Summary of Written Acceptable Flood Capacity Assessment Requirements

The Acceptable Flood Capacity Assessment must be certified by a registered professional engineer as accurate and reasonable. The following information must be included in a written Acceptable Flood Capacity Assessment report:

### Executive Summary/Introduction

A general description of the dam and the result of the Acceptable Flood Capacity Assessment including:

- Name of dam;
- Location of dam (i.e. longitude and latitude);
- Real property description of the land on which the dam structure is located
- Photographs of the existing dam or dam site
- Name of the owner of dam (i.e. name of individual or company).
- Dam owner contact details (i.e. postal address, street address, phone number, facsimile, email);
- Status of dam (i.e. existing or proposed dam or proposed work);
- Date dam construction completed to current arrangement;
- Development permit and water licence details (if any);
- Date last failure impact assessment accepted by the chief executive;
- The maximum population at risk;
- The failure impact assessment category for the dam;
- Type of dam (i.e. homogenous earthfill dam, zoned earth and rockfill dam, concrete dam or other);
- Height and storage capacity of the dam;
- Dam capacity to Full Supply Level (in megalitres);
- Spillway description (Type & Dimensions);
- Spillway discharge rating curves and any applicable operational rules (for gated operations) used in determining the AFC;
- Existing Flood Discharge Capacity for the dam at the dam crest level or a level with the design freeboard;
- AEP of the Existing Flood Discharge Capacity
- Acceptable Flood Capacity (AFC) for the dam;
- Spillway Design Flood and, if it is less than the AFC, details as to how it was assessed and the impacts of floods in excess of the Spillway Design Flood;
- Identified current flood discharge capacity as a percentage of AFC.

## Data and methodology used

The Acceptable Flood Capacity Assessment shall include a summary of the data on which the assessment is based and the details of the methodology used (small dams standard/ fallback option /risk assessment) including, but not limited to the following:

| **Risk assessment** | **Small Dams Standard/Fallback Option** |
|---|---|
| • Description of methodology for determining design rainfalls and results;<br>• Description of methodology for determining spillway capacity floods and the results of routing the floods through the storage;<br>• Description of methodology for assessing consequences of failure<br>• Basis of the risk assessment process, methodology, parameter values and uncertainties including documentation as to:<br>  o Demonstrate the appropriateness of the assessment;<br>  o How the risks were identified and assessed;<br>  o What systems are applied to ensure the risks are properly controlled? | • Description of methodology for determining design rainfalls and consequent flood magnitudes;<br>• Details of the operating procedures adopted in determining the AFC;<br>• Details of consequences of dam failure for Sunny Day and Flood failure conditions<br>• PAR for each failure case considered;<br>• Interpolations. |

Details of the review of the appropriateness and accuracy of the data (including the details of dam break analyses for "Fallback Option") must be also included in the assessment.

*Note that although consideration of the current consequences would be sufficient for this assessment, it is strongly recommended that all likely future downstream developments be taken into account in assessing AFC.*

## Assessment

Details of the assessment including, but not limited to the following:

| **Existing Dams** | **Proposed dams** |
|---|---|
| • Dam Crest Flood (DCF) for the existing arrangement, with the assigned Annual Exceedance Probability (AEP), to ANCOLD *Guidelines on Selection of Acceptable Flood Capacity for Dams,* Appendix 1.<br>• For dams with hazard category of *Extreme* or *High A*, PMF, based on Book VI, ARR (Nathan & Weinmann, 1999) procedures, with FSL the pre-flood reservoir condition, and including information on the assigned values for all influencing parameters such as temporal and spatial patterns and losses.<br>• For dams with hazard category of *High B* or *High C*, 'PMP Design flood' based on Book VI procedures with the reservoir at FSL at the start of the flood event or sequence of flood events.<br>• The assessed hazard category, and potential consequences, noting any changes to potential consequences since the previous review report-both total and incremental consequences are to be reported including the potential for loss of life.<br>• Assessment of the allowance for freeboard with reasons<br>• Note of any changes to dam management, operating rules, conditions and surveillance procedures since the previous review report.<br>• Information on EAPs in place.<br>• Identified hydrologic deficiencies including assessment against Guideline criteria<br>• Estimated risks of failure and assessment of their tolerability.<br>• Capacity to accommodate future climate change (i.e. what is in reserve?) | • Assessed hazard category and consequences – total and incremental - are to be reported including the potential for loss of life.<br>• Hydrologic assessment against deterministic criteria. (needs further definition)<br>• DCF and PMF and/or PMP Design flood, as for review of existing dams, and appropriate.<br>• Proposals for freeboard provisions with reasons for the nominated freeboard.<br>• Proposals, including assessed risks, for flood management during construction<br>• Proposed dam management operating rules, conditions and surveillance procedures.<br>• Provisions, if any, for future climate change. |

### Risk reduction proposals for existing dams (following the completion of an assessment for the dam)

Risk reduction measures only need to be considered as part of the risk assessment process when considering whether ALARP has been satisfied.

- Risk reduction options considered and comparative assessments against existing arrangement.
- Proposed DCF, PMF and/or PMP Design Flood, with assigned AEP, as appropriate for each of the options considered.
- Assessed hazard category and potential dam failure consequences, after implementation of risk reduction measures.
- Details of any structural measures to be relied on for risk reduction including changes to spillways or dam embankments etc.
- Details of any proposed non-structural measures to be relied on for risk reduction including changes to dam management, operating rules and flood warning systems, conditions and surveillance procedures.
- Proposed freeboard provisions and basis for these for each of the options considered.
- Proposals, including assessed risks, for flood management and construction management during construction.
- Interim EAPs, both during planning and during construction.

### Registered Professional Engineer details.

The Acceptable Flood Capacity Assessment is to incorporate a certification from a Registered Professional Engineer (RPEQ). This certification shall include:

- Name of the certifying RPEQ.
- Registration number.
- Contact details (including postal address, street address, telephone number, facsimile, email as appropriate).
- A statement that this AFC assessment is reasonable and accurate and has been done in accordance with the NRW Guidelines on Acceptable Flood Capacity for Dams;
- Signature of RPEQ.
- Date.

# Appendix B - Methodology for Demonstrating Compliance with ALARP.

**Methodology for demonstrating compliance with ALARP.**

The **ALARP principle** requires that risks should be ‘as low as reasonably practicable’. The methodology for demonstrating risks are ALARP is to be applied to all assessments where the “risk assessment procedure” is used for determining Acceptable Flood Capacity.

This requirement is to reduce risks to life to the point where further risk reduction is impracticable or requires action that is grossly disproportionate in time, cost, trouble and effort to the reduction in risk achieved. This principle forms the balance between equity and efficiency, with the balance deliberately skewed in favour of equity.

To decide whether risks are ALARP, it is necessary to consider the possibilities for further risk reduction beyond the limits of tolerability and their relative ease or difficulty (the sacrifice) of implementing them and to balance these against the benefits of implementing them. To demonstrate this, for the purposes of these guidelines, it is necessary to formulate risk reduction options and to prepare concepts and realistic cost estimates to undertake the risk reduction measures.

Each case will depend on the circumstances of the dam under consideration, but further risk reduction measures considered should not only include major modifications to the dam structure but should also include modifications or additions of individual pieces of equipment and/or components of individual structures where such measures are likely to have a significant impact on the overall risk of dam failure. In assessing the costs of these further risk reduction measures, only the incremental costs associated with risk reductions beyond the limit of tolerability should be considered[9].

By undertaking the activities detailed in these guidelines and incorporating the outcomes in their decision recommendations, the analysts can assist the decision-maker, who has to make the final judgement that risks are ALARP.

A particular owner’s ability or inability to afford a risk reduction measure – that is, the owner’s financial circumstances - is not a consideration in deciding whether life safety risks are ALARP.

The methodology outlined below presents a cost-benefit framework for determining whether the ALARP upgrade improvements are required. This methodology assumes that a number of engineering calculations have already been performed to determine the probability of a flood event or other hazard (e.g. seismic, wind, piping) causing dam failure based on the probability of the event over the life of the dam and the expected loss of life during the event. The answers to these calculations are then applied to the methodology presented below.

A range of potential ALARP spillway capacity upgrades (including any necessary structural upgrades to accommodate additional headwaters and flows) should be considered in the assessment. The levels of these upgrades must then be used to develop a cost benefit curve for the spillway upgrade options, so that the point at which costs equal benefits can be identified. This optimal ALARP upgrade standard should then be compared with and plotted on the same graph as the limit of tolerability to demonstrate the upgrade point with which dam owners are required to comply.

The methodology requires the probable loss of life due to dam failure[10] and probable property damage over the life of the dam due to dam failure to be determined, for both the project that just satisfies the tolerable risk criteria without consideration of ALARP[11] and a range of further potential ALARP spillway upgrades.

The probability of loss of life due to dam failure over the dam’s life is calculated by examining the

[9] Where the overall dam upgrade project is to proceed as one overall project, the project costs associated with an ALARP component of the project should only include that proportion of the overall establishment costs associated with the upgrade of the works beyond the ‘tolerable limit’.

[10] Note that probability of expected loss of life due to dam failure over the life of the dam may also be expressed as the probability of death and dam failure occurring at the same time.

[11] The minimum tolerable spillway standard prior to the consideration of ALARP is the spillway capacity which just allows the risk profile to meet the limit of tolerability criteria.

population at risk, the fatality rate[12] and the probability of dam failure during a flood event (or the flood event plus a proportional increase in discharge capacity equal to the level of ALARP upgrade being examined) over the nominated design life of the dam[13] for the particular catchment. The probability of expected loss of property due to dam failure over the dam's life is calculated by examining the property at risk, the expected damage during a flood event and the probability of dam failure during that flood event (or the flood event plus a proportional increase in discharge capacity equal to the level of ALARP upgrade being examined).

The first calculation in the methodology should be applied to the dam arrangement that just satisfies the tolerable risk criteria without consideration of ALARP, as follows:

$$E(LOL_{dam\ life}) = [\sum (F_i \times PAR_i)] \times P(FE)$$

which simplifies to:

$$E(LOL_{dam\ life}) = E(LOL) \times P(FE)$$

Where:

$E(LOL_{dam\ life})$ = total expected LOL over the life of the dam.
$E(LOL)$ = expected total LOL during a failure event;
$F_i$ = fatality rate for each separate community,(*i*), in the particular catchment (This rate should be calculated for each community as some communities may be subject to different levels of flood severity and different flood vulnerabilities);
$PAR_i$ = total PAR in each separate community during the failure event corresponding to the fatality rate $F_i$ in the particular catchment;
$P(FE)$ = probability of dam failure during a flood, seismic or other event over the life of the dam;

The calculation is also applied separately to the proposed ALARP upgrade standard. That is:

$$E(LOL_{dam\ life})^* = [\sum (F_i^* \times PAR_i^*)] \times P(FE)^*$$

which simplifies to:

$$E(LOL_{dam\ life})^* = E(LOL)^* \times P(FE)^*$$

Where:

$E(LOL_{dam\ life})^*$ = total expected LOL over the life of the ALARP upgraded dam.
$E(LOL)^*$ = expected total LOL during a failure event at the ALARP upgraded dam;
$F_i^*$ = fatality rate at ALARP upgraded dam for each separate community, (*i*), in the particular catchment (note that this is necessary as some individual communities comprising the PAR may be subject to different levels of flood severity and different flood vulnerabilities);
$PAR_i^*$ = total PAR in each separate community during the failure event corresponding to the fatality rate $F_i^*$ in the particular catchment;
$P(FE)^*$ = probability of dam failure due to a nominated flood, seismic or other event greater than the minimum tolerable spillway standard over the life of the ALARP enhanced dam;

Once the expected loss of life is determined based on a dam complying with the tolerable risk level and the various levels of ALARP upgrade, the incremental reduction in the probability of loss of life from dam failure as a result of the ALARP upgrade being performed may be calculated. This requires the difference in the total expected loss of life calculated in the first step to be calculated, as follows:

$$E(LOL_{dam\ life})_{Incremental} = E(LOL_{dam\ life}) - E(LOL_{dam\ life})^*$$

Where:

$E(LOL_{dam\ life})_{Incremental}$ = incremental reduction in total expected LOL over the life of the dam due to the ALARP upgrade being performed

12 The 'fatality rate' is the appropriate fatality rate in Graham's loss of life formula (Graham, 1999) assuming 'no warning time' unless a strong case to the contrary is made.
13 To be taken as 150 years from the completion of the spillway upgrade.

Similarly, the expected property damage can be considered by determining the incremental flood damage due to the failure of the dam during an event and the changes to the operations and maintenance costs due to the upgrade.

$$E(Damages_{dam\ life})_{Incremental} = E(Damages_{dam\ life}) - E(Damages_{dam\ life})^*$$

Where:

$E(Damages_{dam\ life})_{Incremental}$ = Incremental damages due to the dam failure event

$E(Damages_{dam\ life})$ = the expected total damages resulting from the event without dam failure

$E(Damages_{dam\ life})^*$ = the expected total damages resulting from the event with dam failure

The expected damages are to be based on the NRW *Guidance on the Assessment of Tangible Flood Damages* (NR&M 2002c).

This incremental reduction in the estimated loss of life over the life of the dam, attributable to the ALARP upgrade being performed is then used to determine the expected total benefit ($E(TB_t)$) resulting from the ALARP upgrade. This is done by multiplying the VOSL by the incremental reduction in the estimated over the life of the dam due to the ALARP upgrade being performed, as shown below.

$$E(TB_t) = E(LOL_{dam\ life})_{Incremental} \times VOSL$$

It is presumed that the expected total benefit will be achieved in the year the upgrade is completed (ie, time = t). This is the case as the reduction in the probability of dam failure as a result of an increase in the level of AEP flood event that the upgraded dam can endure, will occur in the year that the upgrade work is completed. This benefit is not accrued in prior or subsequent years, as the timing of the total benefit is taken to align with the reduction in risk and the completion of work.

A societal discount rate of 6%, as noted in Queensland Treasury Guidelines (Qld Treasury, 2000 and Qld Treasury 1997) is to be adopted when determining the net present value of cash flows. The expected total cost of the upgrade should also be ascertained in current year dollars using the same societal discount rate. This will necessarily require the dam owner to consider the timing of cash flows associated with the upgrade and apply a similar 6% discount rate. The discounting calculations are presented below.

$$E(TB_0) = E(B_t) / (1+r)^t$$

*and*

$$E(TC_0) = [E(C_t) / (1+r)^t] + [E(C_{t-1}) / (1+r)^{t-1}] + [E(C_{t-2}) / (1+r)^{t-2}] + \ldots + [E(C_{t-n}) / (1+r)^{t-n}]$$

Where:

r = societal discount rate
t = the time period in which the benefit will be received and the costs will be incurred
$E(TB_0)$ = expected total benefit in current year dollars
$E(TC_0)$ = expected total cost in current year dollars

These expected total benefits and costs may then be compared to establish if the ALARP upgrade is likely to produce total benefits in excess of total costs (ie, a cost benefit ratio of less than unity). If the net benefit is positive then the project should go ahead. The cost- benefit decision calculation is presented below:

If: $E(TC_0) / E(TB_0) \leq 1 \rightarrow$ ALARP spillway upgrade required
$E(TC_0) / E(TB_0) > 1 \rightarrow$ ALARP spillway upgrade not required

This calculation illustrates that where the analysis produces a cost to benefit ratio of less than or equal to one (ie, benefits at least match the costs), then the ALARP upgrade would be required. An example of how this methodology should be applied appears in the example presented below.

Through this process, the cost benefit curve can be plotted so that the appropriate level of dam upgrade may be identified.

From a social economic perspective, the appropriate level of upgrade beyond the limit of tolerability would be where the marginal benefits of the total spillway upgrade equal the marginal costs of the total spillway upgrade. This is the point at which total net benefits are maximised. This point may be determined by graphing the cost benefit curve, of total expected benefits against the relative increase in flood discharge capacity based on the calculations performed for the range of ALARP spillway upgrades.

When relying on 'risk assessment', dam owners are required to undertake upgrades at least to the 'tolerable risk' line. The extent to which the spillway needs to be further upgraded depends on whether the point at which the total benefits equal the total costs lies beyond the limit of tolerability or not.

### ALARP upgrade options to be considered

There are a wide range of potential upgrade options to be considered as part of the upgrade process to reduce the risks below the tolerable risk level. Such options that might be considered include (but may not be limited to):

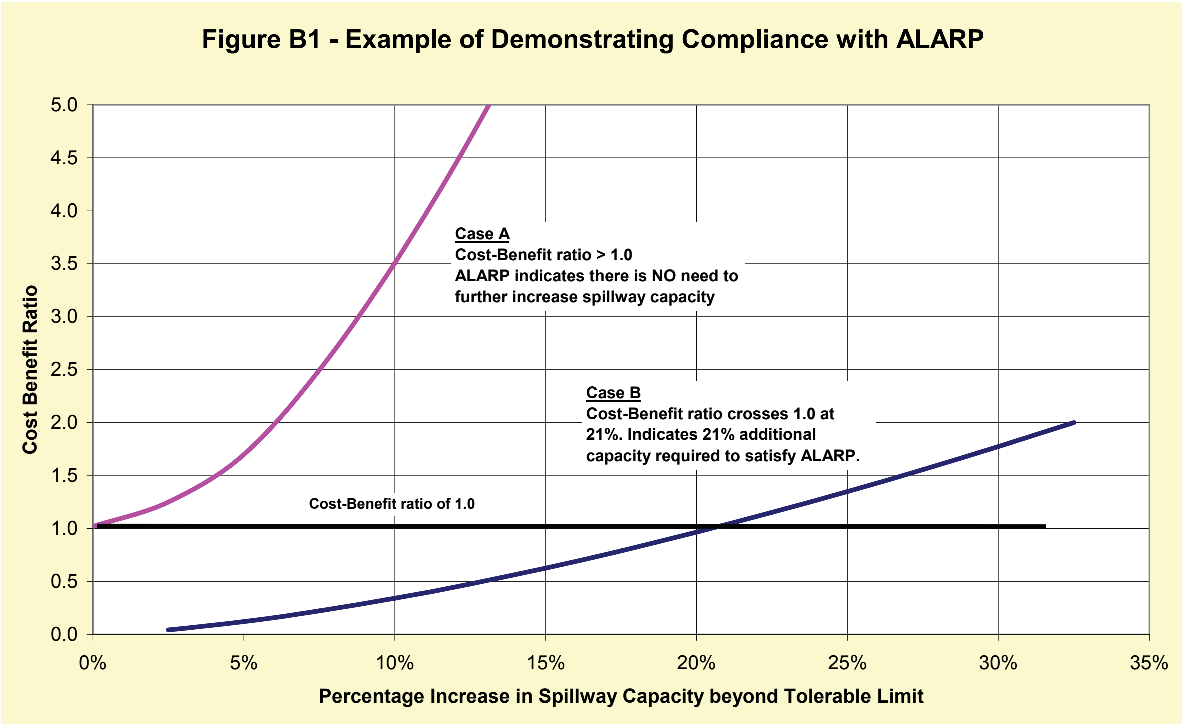
- Widening or deepening an existing spillway
- The addition of spillway gates or some other flow control structure
- Modifying the operating systems/rules for the structure so that risk of failure is reduced
- Structural modifications to the dam to enable it to safely pass overtopping flows
- Additions/modifications to dam embankments and foundations to reduce the risk of failure
- The addition of additional spillways such as higher level auxiliary spillways or fuse plug spillways
- Raising or modifying non-overflow dam sections to reduce the risk of failure
- Diversion of some of the catchment around the dam
- A combination of any or all of the above.

The required accuracy of the necessary estimates for these options will be dependent on the sensitivity of the outcome. The accuracy need not be high where the result is clear-cut one way or the other.

The actual ALARP upgrade options to be considered in each particular case will be dependent on the circumstances at each individual dam and advice may need to be sought from an RPEQ experienced in dam engineering. Non-structural options can only be considered if it can be clearly demonstrated that such options can be relied on in the long term and are under some degree of control by the dam owner.

## Example

An example of the ALARP methodology is provided below to illustrate the practical application of calculating the life benefits achieved by upgrading the size/capacity of a spillway by 10% beyond the limit of tolerability standard. The assumptions made below are presumed to have been provided through engineering studies and calculations




Assumptions:

*P(FE)* = 0.04878 (= probability of a 1 in 3000 year AEP event occurring over a 150 year life of the dam)

*P(FE)** = 0.02107 (= probability of a 1 in 7045 year AEP event [equivalent to a 10% increase in spillway capacity] occurring over a 150 year life of a dam

*F* = 0.15 (for medium severity flooding where houses would be damaged during flood events)

*PAR* = 10 (obtained from Failure Impact Assessment studies)

*VOSL* = $5m AUD (2004 dollars)[14]

*r* = 6%

*t = 5* (ie, upgrade will be completed in year 5)

*E(TC)* = $250,000 (ie, expected total cost of ALARP upgrade over five years as follows: year 1: 5%; year 2: 5%; year 3: 15%; year 4: 35%; year 5: 40%)

*Probability of death given dam failure*

*Under tolerable safety standard*

$$E(LOL_{dam\ life}) = [\,(F_i \times PAR_i) + (F_k \times PAR_k) + (F_m \times PAR_m)] \times P(FE)$$
$$= [0.15 \times 10] \times 0.04878 = 0.07317$$

*After ALARP spillway improvement*

$$E(LOL_{dam\ life})^* = [\,(F_i^* \times PAR_i) + (F_k^* \times PAR_k) + (F_m^* \times PAR_m)] \times P(FE)^*$$
$$= [0.15 \times 10] \times 0.02107 = 0.03160$$

[14] Assumed based on a figure within the strong to very strong ANCOLD justification range for risks just above the broadly acceptable risk.

*Incremental reduction in probability of death given dam failure*

$$Incremental\ E(LOL_{dam\ life}) = E(LOL_{dam\ life}) - E(LOL_{dam\ life})^{*}$$
$$= 0.07317 - 0.03160 = 0.04157$$

*Expected Benefit of ALARP spillway upgrade*

In year 5:

$$E(B_t) = \text{Incremental } E(LOL_{\text{dam life}}) \times VOSL$$
$$E(B_5) = 0.04157 \times \$5{,}000{,}000 = \$207{,}850$$

*At time zero:*

$$E(B_0) = E(B_t) / (1+r)^t = \$207{,}850 / 1.06^5 = \$155{,}990$$

*Expected indexed Cost of ALARP spillway upgrade at time zero*

$$E(C_0) = [E(C_t) / (1+r)^t] + [E(C_{t-1}) / (1+r)^{t-1}] + [E(C_{t-2}) / (1+r)^{t-2}] + \ldots + [E(C_{t-n}) / (1+r)^{t-n}]$$
$$= \$100{,}000 / 1.06^5 + \$87{,}500/1.06^4 + \$37{,}500/1.06^3 + \$12{,}500/1.06^2 + \$12{,}500/1.06$$
$$= \$198{,}500$$

*Cost-Benefit Analysis*

$$E(C_0) / E(B_0) = \$198{,}500 / \$155{,}900 = 1.27$$

In this example, for this potential project, as the costs of undertaking the additional upgrade outweigh the benefits, the dam owner would not be required to increase the minimum safety of the spillway by 10% above the tolerable limit to sustain a larger AEP flood event. Had the benefits outweighed the costs however, the upgrade would have been required.

Such cost -benefit assessments should be undertaken for a range of upgrades beyond the limit of tolerability, so that the optimal level of ALARP upgrade could be identified. If this was done and a cost-benefit curve of the type shown in the Figure B1 for 'Project Type A' might result.

To achieve compliance with the minimum safety standard, dam owners are required to undertake upgrades until the optimal upgrade point is reached (being the point at which benefits equal costs). Thus, for the Project Type A example, where no point is below a Cost-Benefit ratio of 1.0, no further upgrade would be required to satisfy ALARP. However, if a cost-benefit curve like 'Project Type B' resulted, a additional 21% upgrade would be required in order to satisfy ALARP.

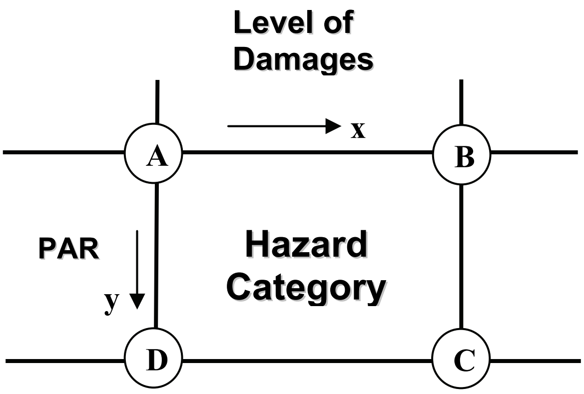
## Appendix C - Methodology for Interpolating Required AEP within a particular Hazard Category using Fallback Procedure

## Methodology for Interpolating Required AEP within a particular Hazard Category using Fallback Procedure

The following methodology can be applied for interpolating the required AEP of the Acceptable Flood Capacity within a specific Hazard Category for the Fallback procedure.

The following interpolation procedure is to be applied within any 'Severity of Damage and Loss' and 'Population at Risk' cell of Table 2:

(a) Once the consequences of failure (level of damage) and the PAR have been assessed using the provisions of Section 3.3, determine the appropriate Hazard Category and determine the Annual Exceedence Probabilities (AEPs) to be applied at each of the points A, B, C and D using the AEPs set out in Table 2. (Note the points A, B, C and D are not to be confused with the hazard category in Table 2)




(b) Determine the 'x' and 'y' coordinates for the most critical failure case.
x = the relative severity of damage and loss relative to the boundaries of the damage scale
y = the log of the PAR

Where 'x' and 'y' are calculated as follows:

$x = [\log_{10}(\text{Damage})-\log_{10}(\text{Damage @ A})]/[\log_{10}(\text{Damage @ B})-\text{Log}_{10}(\text{Damaged @ A})]$

$y = \log_{10}(\text{PAR}/10)$

Where the values of damages at A/D and B/C have been interpolated from the ranges of damages contained in ANCOLD 2000b for:

1. Estimated Costs
2. Service and Business relating to the Dam
3. Social
4. Natural Environment

With the lowest AEP selected corresponding to the worst combination of 'x' and 'y' values being adopted.

Note for 'Major' levels of damage, the maximum value of the 'x' coordinate shall be taken to correspond to twice the level of damages at the boundary between 'medium' and 'major'.

(c) Using the following relationship, determine for each combination of 'PAR' and 'Level of Damages' the required AEP of the design flood and select the smallest AEP as the required AEP of the AFC.

$\text{Log(AEP)} = \alpha_1 + \alpha_2 x + \alpha_3 y + \alpha_4 xy$

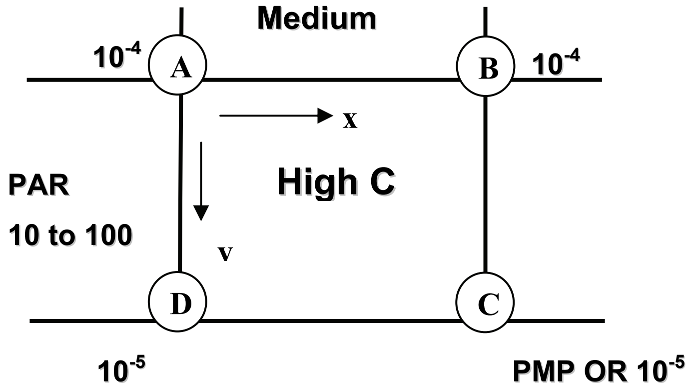
Where

$\alpha_1$ = the log (AEP) of the design flood at point A
$\alpha_2$ = the log (AEP) of design flood at point B – $\alpha_1$
$\alpha_3$ = the log (AEP) of design flood at point D – $\alpha_1$
$\alpha_4$ = the log (AEP) of design flood at point C – $\alpha_1$ – $\alpha_2$ – $\alpha_3$

By way of example for the case of

- a PAR of 29 and serious damage or destruction of 10 houses producing a 'Medium' level of residential damages[15].
- A catchment area of less than 100km$^2$

Because the catchment area is less than 100 km$^2$, Table 2 indicates the notional AEP of the Probable Maximum Precipitation is 1.0x10-7 and the Hazard Category is 'High C'.




Point 'A' corresponds to a PAR of 10 and, from Appendix D of ANCOLD *Guidelines on Assessment of Consequences of Dam Failure* (ANCOLD, 2000b), a level of damages equivalent to the destruction of four houses.

Point 'B' corresponds to a PAR of 10 and a level of damages equivalent to the destruction of forty-nine houses.

Point 'C' corresponds to a PAR of 100 and a level of damages equivalent to the destruction of forty-nine houses.

Point 'D' corresponds to a PAR of 100 and a level of damages equivalent to the destruction of four houses.

From Table 2 of this Guideline, the AEP of the AFC at point 'A' and 'B' is 1.0x10-4 and the AEP of the AFC at points 'C' and 'D' is the probability of the PMP or 1.0x10-5 (whichever is greater) i.e 1.0x10-5.

Thus …

At point A    y = log(10) = 1, x = 0, required AEP = $1.0\times10^{-4}$
At point B    y = log(10) = 1, x = 1, required AEP = $1.0\times10^{-4}$
At point C    y = log(100) = 2, x = 1, required AEP = $1.0\times10^{-5}$
At point D    y = log(100) = 2, x = 0, required AEP = $1.0\times10^{-5}$

At the point of interest x = (log 10-log 4)/(log 49- log 4) = 0.366

$y = \log_{10}(29/10) = 0.4624$

$\alpha_1 = \log_{10}(1.0\times10^{-4}) = -4$

[15] Under the ANCOLD Guidelines on the Assessment of Consequences of Dam failure (ANCOLD 2000b) a 'Medium' level of residential damages corresponds to 'Destroy 4 to 49 houses or damage to a number'.

$\alpha_2 = \log_{10}(1.0x10^{-4}) - \alpha_1 = -4 - (-4) = 0$

$\alpha_3 = \log_{10}(1.0x10^{-4}) - \alpha_1 = -5 - (-4) = -1$

$\alpha_4 = \log_{10}(1.0x10^{-5}) - \alpha_1 - \alpha_2 - \alpha_3 = -5 - (-4) - (-1) - 0 = 0$

Which gives a required AEP of the Acceptable Flood Capacity of

$$\text{Log(AEP)} = \alpha_1 + \alpha_2\, x + \alpha_3\, y + \alpha_4\, xy$$

$$= -4 + 0 * x -1\, y + 0 * x\, y$$

$$= -4 - 1 * 0.4624 = -4.4624$$

Therefore the required AEP is $1x\ 10^{-4.4624} = 3.45\ x\ 10^{-5}$