The need for private dam safety assurance policy – demonstrative case studies 10 years later

Pisaniello and McKay research and examine private dam safety and suggest methods to address areas of concern

Abstract

Farmers in Australia have often overlooked the common law obligation to review/design dams in line with current standards because of high engineering consulting costs. This leaves them vulnerable to litigation if their dam fails and the downstream community susceptible to unacceptable risk levels. The seriousness of this problem was demonstrated by a case study undertaken 10 years ago in the dam safety policy-absent State of South Australia. The paper presented here follows up previous research by testing whether giving more time, awareness and encouragement to farmers addresses the problem to any extent. This has been tested in the "still" policy-absent State of South Australia and the "now" policy-driven State of Victoria. In each of the two States, 10 hazardous private reservoirs have been investigated for spillway adequacy in line with state-of-the-art practice. The investigation follows the release of an innovative Australian developed cost-effective spillway design/review procedure which was available and promoted in both States to minimise cost burdens to dam owners and encourage better dam safety management. The case studies clearly demonstrate that farmers require more than awareness and encouragement in order to ensure they properly look after their dams.

Introduction

In Australia, as in most countries, owner obligation exists under common law to take reasonable care of dams according to current prevailing standards. Hence, owners should review their dams, and take appropriate action where necessary, to minimise the risk of failure and avoid liability for possible consequences of failure (McKay & Pisaniello, 1995).

Unfortunately, no dam can be made 100 per cent safe as there is an incomplete understanding of the uncertainties associated with natural and human factors, materials behaviour and construction processes. Therefore, there is a risk of failure at every dam. The adverse consequences at some dams are such that risks need to be checked and, if necessary, reduced to modern acceptable standards. Also, owners must ensure uncertainties are balanced against competent technical judgement.

However, farmers in Australia often overlook the common law obligation to review/design dams in line with current standards because of high engineering consulting costs. This leaves them vulnerable to litigation if their dam fails and the downstream community susceptible to unacceptable risk levels. This problem was demonstrated 10 years ago in South Australia, as reported in Pisaniello and McKay (1998a). The research reported here follows up and extends the previous research by (1) testing in South Australia, whether giving more time, awareness and encouragement to farmers has addressed the problem to any extent, and (2) comparing the situation to Victoria which recently became a dam safety policy-driven State.

How dam safety is now managed in Australia

Most government dam-owning agencies have assumed the responsibility of evaluating public dams in terms of risk in accordance with current guidelines, and subsequently have either undertaken or are in the process of implementing appropriate action to reduce the risks to modern acceptable standards (Pisaniello and McKay, 1998b, p.263).

Unfortunately, there is a policy vacuum in Australia on private dam safety policy, except partially in NSW (*Dams Safety Act, 1978*), Victoria (*Water Act, 1989*) and Queensland (*Water Act, 2000*), but even their policies are not pervasive (for example they only address the problems associated with hazardous dams, usually the larger, more significant on-stream dams, without giving due consideration to the problems associated with the multitude of smaller off-stream catchment dams nor the supervision over the management of these structures). In Queensland, a dam will generally only be "referable" (that is, made subject to the dam safety provisions of the *Water Act 2000*) if it is more than eight metres in height *and* 250 ML in storage capacity and, following a 'failure impact assessment', it is found to have a downstream population at risk (PAR) of two or more people (see Part 6 of the *Water Act 2000*). Dams smaller than this can also be failure impact assessed, but only if it is reasonably believed by the Chief Executive (CE) responsible for the *Water Act 2000* that the dam's PAR is two or greater [per s 483(2) and (3)]. If the assessment proves correct, then the dam may be declared referable. In effect, smaller, yet hazardous dams which pose a downstream threat to only one "apparent" person and/or to significant downstream property, government infrastructure or the environment may go unsupervised in Queensland. Based on Pisaniello and McKay (1998b), this 'referable' criterion in Queensland appears too lenient and discretional compared to world standards. Overseas practices have blanket-regulated dams as small as 1.8 metres (Michigan) and with a minimum storage capacity of only 25 ML (UK) following experience with a number of disastrous small dam failures.

Another concern is that since most private dams are relatively small in size, they seemingly represent a "low" hazard to their immediate downstream inundation area, hence, the community accepts them designed to the lowest of standards. Unfortunately, when these dams are considered cumulatively in a large catchment of, say, a large, highly hazardous public reservoir, then they each represent quite a significant incremental flood hazard as their cumulative failure can significantly increase the risk of failure (via the "domino effect") of the public reservoir downstream. The effect of additional flooding in the connecting river systems can also be severe. This was demonstrated in a recent flood study of the Kangaroo Creek Dam in the Torrens catchment of South Australia (Lange Dames Campbell (SA) Pty. Ltd. & Snowy Mountains Engineering Corporation, 1995).

Webster & Wark (1987) report that owners of private dams are wary of any controls which are likely to add significantly to their costs. Consequently, private owners, in general, are either ignoring, underestimating or simply remain unaware of the risks and hazards associated with their dams and are frequently guilty of not maintaining the structures. Too often owners look only at the benefits gained from their dams and not the hazards the dams could generate. As a consequence, potential hazards to neighbouring residents and properties exist, placing people and community infrastructure at unnecessary risk. This was demonstrated by Pisaniello and McKay (1998a), and the case studies reported in this paper further demonstrate the potential seriousness of this problem.

Victoria is the only Australian State to acknowledge and attempt to address the problem of generally low/significant hazard, off-stream farm dams. It has addressed farm dam safety by firstly recognising it to be a problem (together with the recent issue of equitable water allocation and capacity sharing), and then "partnering" with the farming and downstream community to execute a law reform process. A Farm Dams Irrigation Review Committee established in early 2000, released a discussion paper *Sustainable Water Resources Management and Farm Dams* seeking submissions from the community. The paper addressed capacity sharing issues for off-stream dams and recommended that potentially hazardous dams be regulated. From the responses received, over 70 per cent were in favour of regulating potentially hazardous dams (Victoria State Government, 2001). As a result Victoria recently incorporated dam safety provisions to its *Water Act 1989*. In particular, section 67 now applies to significant "off stream" dams and requires owners to obtain a licence to operate their dams. Under section 71, licence conditions include dam safety requirements (for example, standards of construction, surveillance, operation and maintenance). Rural Water Authorities set up around the State have been assigned the responsibility of administering the Act and the licensing requirements (Department of Natural Resources and Environment (DNRE) Victoria, 2002).

A further significant step in Victoria has been the publication of the booklet *Your Dam, Your Responsibility – A guide to managing the safety of farm dams* (DNRE Victoria, 2002). This targets the smaller yet hazardous dams usually ignored in most jurisdictions and informs dam owners of their responsibilities and potential liabilities. The publication also advises the multitudes of non-hazardous dam owners that, even if a dam does not require an operating licence, it is in the farmer's best interest to ensure the dam is safe and well maintained otherwise the life of the asset could be severely diminished. The publication details, in simple language, and illustrates the necessary processes to keep any farm dam in a good safe condition. It provides a template dam safety emergency plan that is simple to understand and comply with.

However, even in Victoria (as well as the other States) there is still a need for a mechanism to minimise review costs to private owners and, in turn, encourage better dam safety management. Such a mechanism has been developed in the form of a regionalised cost-effective spillway design/review procedure.

Overall, States that fail to establish some form of safety assurance policy on the management of potentially hazardous private dams are, in effect, unconsciously devaluing the lives of people living downstream of these dams compared with the lives of those living downstream of public dams to which attention has or is being given.

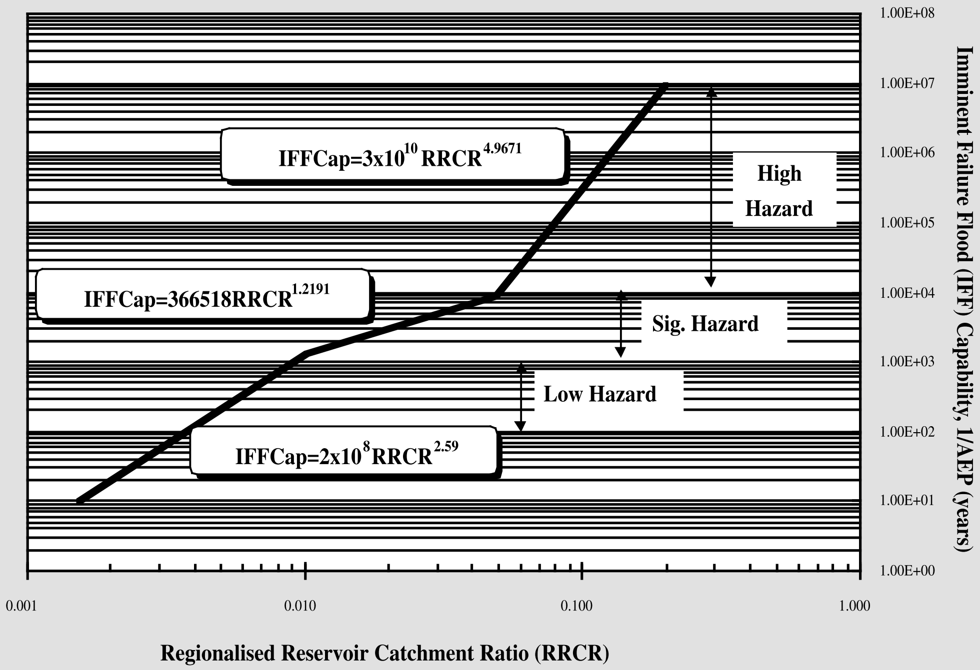
Encouraging better private dam safety management via a cost-effective spillway design/review procedure

Dam owners should review the spillway flood capabilities of their dams and upgrade if necessary, to avoid liability for possible failure consequences (McKay & Pisaniello, 1995). To encourage dam owners to do this, a simple and cost-effective flood capability design/review procedure has been developed. This procedure was first developed by Pisaniello (1997) and is now applicable in south eastern Australia. The procedure (illustrated in Figure 1) is in line with current best practice, thereby promoting consistency and uniform standards. Full details of the procedure are available in Pisaniello et al (1999), Pisaniello et al (2000) and Pisaniello and McKay (2003).

The procedure involves using regionalised relationships based on simple hydrological/hydraulic variables for predicting reservoir flood capability (illustrated in Figure 1 for South Australia). The procedure is;

- applicable to reservoirs on small rural-type catchments (up to around 20 km^2);
- is compatible with any design flood standards, and
- is based on easily derived variables only (example spillway width and height, reservoir area, catchment area), deeming it quick to use yet accurate in its output.

Figure 1. Reservoir Flood Capability Design/Review Mechanism incorporating ANCOLD (1986 and 2000a) Criteria: South Australia (after Pisaniello et al. 1999).



$$RRCR = \frac{SC}{97.805 \cdot CA^{0.7747}} \cdot \sqrt{\frac{\sqrt{RA} \cdot SH}{1000 \cdot CA}} \cdot \frac{\log\left\{\dfrac{97.805 \cdot CA^{0.7747}}{5.2404 \cdot CA^{0.7453}}\right\}}{\log\left\{\dfrac{5.2404 \cdot CA^{0.7453}}{4.0985 \cdot CA^{0.7799}}\right\}}$$

where:

SC = spillway overflow capacity (m3/s)

CA = catchment area (km2)

RA = reservoir area when Full (km2)

SH = max. spillway overflow height (m)

ANCOLD (1986) criteria on Recommended Design Floods (RDF) for dams, which for the most-part coincide with ANCOLD (2000a) 'fallback' acceptable flood capacity criteria (see Table 1), have been incorporated into Figure 1 to establish the principal design/review tool. The Hazard Category in Table 1 is determined using ANCOLD (2000b) which provides a more quantitative assessment of hazard (compared to ANCOLD 1986) based on a matrix of both population at risk (PAR) and severity of damage and loss. These parameters can be determined from the 'dam failure flood affected zone' which is readily estimated using a simplified procedure for smaller dams as outlined by ANCOLD (2000b).

Table 1. ANCOLD (1986) and ANCOLD (2000a) "Fallback" Recommended Design Flood Exceedance Probability Standards

Incremental Flood Hazard Category*	Annual Exceedance Probability
High	PMF to 1 in 10,000
Significant	1 in 10,000 to 1 in 1000
Low	1 in 1000 to 1 in 100

* Determined using ANCOLD (2000b) *Dam Failure Consequence Assessment Guidelines*

Acceptable flood capacity determined from Table 1 can be compared to the actual Imminent Failure Flood (IFF) capability of an existing dam (obtained from Figure 1) to determine whether its spillway is adequate. If the spillway is not adequate, the process can then be applied in reverse (that is, "design mode") to determine an appropriate size spillway. Pisaniello et al (2000) demonstrates the simple application of the procedure with a simple worked example. It should be noted that ANCOLD (2000a) now refers to IFF as the Dam Crest Flood (DCF).

The main benefit of the procedure is its simplicity, which dramatically reduces the great effort and resources that are normally required for conducting a state-of-the-art reservoir flood capability evaluation and/or design. For example, the consultant fee for undertaking such an evaluation and/or design for an embankment dam on a relatively small catchment is normally around AU$10,000. The procedure has the potential for reducing this fee to around AU$200. This fee is nominal when compared to the actual dam construction cost of around $1000 per ML (Boehm, 2002). This is important as it:

- encourages all private dam owners to provide for flood capability review of their dams on their own initiative which is important in States where dam safety assurance policy is either absent or of low level (for example, South Australia and Western Australia);
- provides many owners of small, low hazard dams with an affordable means of preserving their asset against the high incidence of flood failure. The risk of failure of public reservoirs due to cumulative failure of small dams is also reduced;
- encourages the "proper" flood design of all new private dams which in the case of most farm dams, is otherwise left to construction contractors who lack the expertise to provide satisfactory service in this area; and
- addresses the concern for government that an adequate private dam safety assurance policy may place unacceptably high cost burdens on rural communities.

The availability and benefits of the mechanism have been widely promoted over the last three years throughout South Australia and Victoria using promotional brochures and mailouts, and the relevant government agencies have been informed.

Spillway adequacy case studies in South Australia and Victoria

In South Australia, concern over the need for private dam safety assurance policy has been expressed by many over the past 20 years. For example, Pisaniello and McKay (1998a) makes reference to a Flood Warning Consultative Committee report of 1990. More recently, a flood study of the Kangaroo Creek Dam, in the Torrens catchment of South Australia (LDC & SMEC, 1995), found that the peak inflow to Kangaroo Creek would increase fourfold if all the small dams in the catchment failed at the same time (reasonable assumption for an extreme flood event), compared to the flow estimated if the dams remained intact. In such an event, the design flood of Kangaroo Creek Dam would be exceeded. The study thus recognised the need for "controlling the standard of construction of farm dams and their spillways."

A poorly designed spillway as it undercuts and weakens the dam wall: the potential exists for the wall to collapse at any time, particularly during a significant overflow event.

In contrast, Victoria is the only State to acknowledge and address the problem of generally low/significant hazard off-stream farm dams. As a result of the recent law reforms, the amended *Water Act (1989)* sees the dam owner responsible and liable for damage caused by their dams. Under the *Water Act (1989)*, all dams require a licence to 'take and use' water and, at the same time, potentially hazardous dams require an operating licence that contains conditions relating to surveillance and dam safety. Administration of these laws has been in progress for the last two years.

Case studies procedure

As part of case studies for an ARC Discovery Project investigating private dam safety management practices in South Australia and Victoria, the modern flood capabilities were determined of a sample of 10 hazardous private reservoirs in each State. A brief outline of the procedure is as follows:

- The 10 dams in each State were selected on the basis that they be 'referable' in size and rated as either 'significant' or 'high hazard' in accordance with ANCOLD (1986 and 2000a) guidelines. In South Australia, the 10 dams included five of the same dams investigated 10 years ago (Pisaniello and McKay, 1998a) in order to test whether time eventually sees farmers take necessary action, given they were previously informed of the deficiencies and the need for remedial action.
- Each of the dam sites were visited and spillway/embankment sizes were measured using appropriate survey equipment. Catchment and reservoir areas were determined from 1:10,000 and 1:25,000 scale topographic maps and aerial photos.
- The sample dams were all embankment-type structures and had typical spillways that were free flowing and weir-type in nature. The maximum wall heights of the dams ranged from 5m to 11m; their storage capacities ranged from 50 ML to 250 ML; and the size of their catchments ranged from 0.5 km^2 to 6 km^2.
- The spillway design/review procedure, already described, was used to determine the Dam Crest Flood (DCF) capability of each dam, being the flood which, when routed through the reservoir results in a peak storage level equal to the lowest elevation on the non-overflow crest (as recommended by ANCOLD (1986 and 2000a) for embankment dams).
- The DCF capability of each dam was determined for both an upper bound and lower bound 'start' storage level case:
  - — Upper bound case – initial storage level assumed 100 per cent full.
  - — Lower bound case – initial storage level assumed 33 per cent full.

The lower bound case was checked to eliminate uncertainty. The case study results are illustrated in Tables 2 and 3.

Case studies results and analysis

The results of the case studies were analysed by comparing them against ANCOLD criteria (illustrated in Tables 2 and 3) for South Australia and Victoria respectively.

ANCOLD (1986 and 2000a) guidelines recommend that unless normal operating conditions indicate otherwise, a 100 per cent full 'start' storage level should be assumed when assessing spillway flood capability of embankment dams. The comparisons in Tables 2 and 3 demonstrate that regardless of the 'start' storage level assumed, many hazardous private reservoirs with inadequate spillway capacities do exist in both South Australia and Victoria. The risk of failure from overtopping is consistently unacceptable for 90 per cent of the total sample in both States. In particular, the flood capabilities of 50 per cent of the dams in South Australia and of 80 per cent of dams in Victoria do not even satisfy the required criteria for low hazard dams.

For the five dams investigated 10 years ago in South Australia, Table 2 demonstrates that not much has changed in a positive way. Only two of the five dams have slightly improved (possibly due to the spillways becoming slightly larger as a result of being cleaned out by the owner or from erosion), but the improvement is far from being enough to satisfy the ANCOLD guidelines. For the other three dams, the situation has deteriorated. This comes about either from the spillway mouth "silting up", the dam owner allowing large debris to pile up and block the spillway, or the dam owner reducing the spillway depth in order to gain extra storage capacity (such a practice was noted often by Pisaniello, 1997).

These disturbing results reinforce the fact that owners are not taking action in terms of analysis and upgrading of their structures, and that the need for some form of private dam safety assurance policy in South Australia is urgent. One of the problems is that the typical probabilities required for design floods are beyond the average farmer's comprehension, and so some form of regulation is needed to reduce the risk to downstream communities to generally acceptable levels. Pisaniello (1998b) can provide government with the necessary policy guidance in this area. For Victoria, the results demonstrate that while their recent policy and law reform is a step in the right direction, efficient and effective administration of the policy is just as important.

Conclusion

There is a clear need in States where hazardous private dams exist to ensure that owners review and maintain their dams in line with current acceptable practice and take appropriate remedial action where necessary. This was demonstrated 10 years ago and has been re-affirmed. Giving more time, awareness and encouragement to farmers addresses the problem

Table 2. Comparison of flood capability results for South Australia with ANCOLD Guidelines and results for five of the dam reviews from 10 years ago

Dam No.	Minimum Hazard Rating (High/Sig.)	IFF if 100% FULL 1/AEP (years)	IFF if 33% FULL 1/AEP (years)	ANCOLD Guidelines IFF Range 1/AEP (years)	Acceptable under ANCOLD Guidelines? (Yes/No)	100% FULL IFF Results for 5 dams as reviewed 10 years ago (years)	Any improvement for the 5 dams of 10 years ago? (Yes/No)
1	High	110	1050	PMF–10,000	No	320	No, become worse
2	High	280	1700	PMF–10,000	No	80	Slight, but far from meeting ANCOLD guidelines
3	Sig.	90	2600	10,000–1000	No	1400	No, become much worse
4	High	310	1992	PMF–10,000	No	150	Slight, but far from meeting ANCOLD guidelines
5	High	210	1500	PMF–10,000	No	2750	No, become much worse
6	High	20	860	PMF–10,000	No	n/a	n/a
7	Sig.	90	2000	10,000–1000	No	n/a	n/a
8	Sig.	5,500	50,000	10,000–1000	Yes	n/a	n/a
9	Sig.	25	790	10,000–1000	No	n/a	n/a
10	Sig.	20	585	10,000–1000	No	n/a	n/a

Table 3. Comparison of flood capability results with ANCOLD Guidelines: Victoria

Dam No.	Minimum Hazard Rating (High/Sig.)	IFF if 100% FULL 1/AEP (years)	IFF if 33% FULL 1/AEP (years)	ANCOLD Guidelines IFF Range 1/AEP (years)	Acceptable under ANCOLD Guidelines? (Yes/No)
1	Sig.	10	100	10,000–1000	No
2	Sig.	20	250	10,000–1000	No
3	Sig.	10	150	10,000–1000	No
4	Sig.	20	290	10,000–1000	No
5	High	20	330	PMF–10,000	No
6	Sig.	2,247	7,644	10,000–1000	Yes
7	Sig.	10	130	10,000–1000	No
8	High	10	150	PMF–10,000	No
9	Sig.	25	400	10,000–1000	No
10	Sig.	420	1600	10,000–1000	No

An under-designed spillway; its size is clearly too small for this 100 ML impoundment. The spillway is also badly maintained as the owner allows physical obstructions, including a walkway bridge and sandbags, to be present across the spillway restricting its potential capacity.

to a minimal extent. Adequate assurance can only be provided through the implementation of appropriate policy which requires the backing of law-makers. The results of the case studies reported here should encourage such backing in South Australia and other policy-absent jurisdictions. The policy and laws implemented in Victoria serve as a good example for others to follow. However, effective and efficient administration of laws is also vital as evidenced by the Victorian case study.

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