The British Dam Society

Risk Assessments for Reservoir Safety – The Value of a Risk-Based Approach

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SYNOPSIS The Institution of Civil Engineers 'Floods and Reservoir Safety', 4th edition (ICE, 2015) states: *'The risk-based approach using appropriate tools and methods seeks to provide an approach that allows an owner and their advisors to better understand and evaluate reservoir safety risks in a structured way. This then allows for risk-based decisions to be made to reduce risks to people, the environment and the economy but still maintain an important reference to accepted best practice.'*

There is an increasing use in the industry of a risk-based approach to assess reservoir safety. This paper considers four case studies with Undertakers each faced with different threats to their reservoirs, looking at why and how the approach has been applied, aiming for pragmatism in each case whilst maintaining best practice.

An initial screening assessment allows an early view on whether or not the outcome of a risk-based approach is likely to be different to the outcome of a standards-based approach, and therefore whether or not the risk assessment would be of value. Close involvement with the reservoir owner in each case helps to ensure a pragmatic approach to identifying and assessing specific threats, associated probabilities of failure and realistic viable options for improvement works. This involvement has also been found to be critical to ensuring 'buy-in' from the reservoir owner in terms of the assessment outcomes and next steps once options for improvement works have been identified.

INTRODUCTION

There have been and continue to be significant changes that impact how reservoirs are assessed in terms of safety, not least with an increasing awareness of climate change and the prevailing changes in legislation. At the same time the UK has a stock of aging dams and an increasing number of large raised reservoirs as the 10,000m^3 threshold is introduced. A great number of these reservoirs are on private estates as ornamental lakes. Many others, built to serve as water supplies or for industrial use have long since outlived their original purpose and are being sold on or handed over to private owners or local authorities as amenity and fishing lakes. The true cost of owning and maintaining these reservoirs often only becomes apparent following an inspection under Section 10 of the Reservoirs Act 1975. Many owners of these reservoirs are finding that what was once a welcome amenity and an asset becomes a costly liability when the inspection identifies shortfalls in spillway capacity or freeboard, or serious structural or stability issues with the dam.

The application of the relevant standards can be unnecessarily demanding and costly for reservoir owners, in particular where a well constructed and well maintained dam poses little risk to those downstream. When considering the true risk posed by reservoirs the industry has had the benefit of a risk-based approach for many years with well developed and accepted guidance in place. The application of this approach was reinforced with the publication of the fourth edition of 'Floods and Reservoir Safety' (FRS4) (ICE, 2015). Whilst some owners are able to pass on the costs of reservoir maintenance and improvement works to their customers, this is not the case for most private owners or indeed for local authorities where budgets are becoming ever more stretched. The appropriate application of a risk-based approach can offer reservoir owners a more cost-effective and affordable solution for ensuring the right level of reservoir safety to protect people and property downstream whilst still reflecting best practice.

This paper summarises four recent examples of reservoirs which have been found to fall short of the relevant reservoir safety standards and where the risk-based approach has been applied. In each case an appropriate level of pre-screening has been carried out to help the owner decide whether or not a risk-based approach is worth considering. The examples illustrate different outcomes to help understand the extent to which a risk-based approach can be of value. Reflecting on these examples this paper seeks to further raise the awareness of reservoir engineers and those responsible for overseeing and enforcing reservoir safety, and even reservoir owners themselves, of when and how this approach can be applied. In doing so we should hope to maintain and improve the attitudes of the many responsible reservoir owners as they endeavour to fulfil their obligations in respect of reservoir safety.

SUMMARY OF THE RISK-BASED APPROACH

The risk-based approach aims to reduce risk 'as low as reasonably practicable' (ALARP) and is referred to here as an ALARP approach. The approach generally accepted by the industry is based on guidance published by the Environment Agency in the 'Guide to risk assessment for reservoir safety management' (RARS) (EA, 2013). This guidance sets out a rigorous and logical methodology with the aim of identifying options for improvement works that would reduce the risk of failure of a dam to an acceptable level at a cost that is proportionate to the reduction in risk achieved. According to Health and Safety Executive guidance (HSE, 2001), and with reference to RARS, the risk has been reduced to an acceptable level where the 'cost to save a life' (CSL) is less than the 'value of preventing a fatality' (VPF).

The Department for Transport's assessed VPF for road and rail for 2010 was £1.7 million. However, for dams, where the risk to those in the potential inundation area is involuntary, in that the public are not generally aware of the risk posed by reservoirs, it is generally accepted within the industry that the assessed VPF for dams should be approximately five times more than that for roads and railways. Thus, for dams, where the CSL is less than 5 x £1.7M = £8.5M it is considered proportionate to carry out the necessary improvement works.

CASE STUDY 1: EAST MIDLANDS INTERNATIONAL AIRPORT EAST AREA BALANCING POND

The East Area Balancing Pond is a non-impounding reservoir providing temporary storage for water from the airport runways and aprons. As well as the gravity drainage inflows from the airport the reservoir can also receive diffuse overland flows from a direct catchment of some

$1.37km^2$. A Section 10 Inspection in 2020 concluded that the balancing pond is a Category A reservoir. The report also identified that the balancing pond overflow, a 3m long lowered section of the embankment, provided insufficient capacity to safely convey excess inflows from the airport and overland flood flows from the direct catchment. Accordingly, the report made mandatory recommendations in the interests of safety for an updated flood study and implementation of any necessary improvement works.

The subsequent flood study confirmed a significant shortfall in overflow capacity and concluded that either improvement works should be implemented to satisfy the standard defined in FRS4 for a Category A dam, or to carry out a risk-based assessment to determine whether or not the costs of capital works to increase spillway capacity would be proportionate to the reduction in risk achieved. The cost to carry out improvement works to the required standard was estimated at this stage to be in the order of £300,000.

To help inform a decision on which approach to take it was agreed with the Undertaker to carry out an initial screening assessment

Screening Assessment

For the screening assessment high level information and assumptions were used, as follows:

- Existing probability of failure of 1 in 10,000, i.e. the Design Flood which the flood study showed would overflow the dam crest by approximately 150mm.
- Probability of failure must be reduced to at least 1 in 400,000, notionally the probability of the Safety Check Flood (SCF), the Probable Maximum Flood (PMF)event.
- Perform sensitivity analyses, using a 'back calculation' to determine the limiting cost of 'proportionate' improvement, as follows:
  - Assume a Likely Loss of Life of 1 and vary the downstream economic damage resulting from reservoir failure;
  - Assume the economic damage at £1 million and vary the Likely Loss of Life (LLoL).

Varying the downstream economic damage between £100k up to the maximum assessed value of £5M indicated a range of maximum capital costs for improvement works between £25k and £40k, i.e. that the ALARP calculation would not be sensitive to changes in downstream economic damages. On the other hand, varying the LLoL value was found to be a significant factor which would influence the ALARP calculation. However, in this case, even considering a high LLoL value of five the calculation indicated that the maximum value of improvement works that could be considered to be proportionate would be £127k. A greater cost than this would be disproportionate and the justification for carrying out the works would be low. This value was significantly less than the high level estimate of £300k for improvement works to satisfy standards.

The conclusion from this screening assessment therefore was that a risk-based approach would be appropriate to consider options for improvement works involving a reduced scope rather than the full scope of works required to satisfy the standards-based approach. A full scale ALARP assessment was therefore recommended to confirm the appropriate scope of works, if any, to satisfy the risk-based approach.

Risk Based Assessment

With a reasonable level of detail already available to inform the study a Tier 2 risk assessment was adopted, as set out in Section 8.2.2 of RARS, to determine the current probability of failure of the reservoir due to overflowing of the embankment crest. The methodology used the outputs of the flood study to develop rating curves and applied the assessed flow durations and velocities to CIRIA 116 performance curves (CIRIA, 1987) for plain grass to determine the critical velocity that would be likely to lead to dam failure. The critical velocity was then used to estimate the corresponding depth of flow over the embankment crest, i.e., the depth of flow over the embankment crest that can reasonably be assumed to cause onset of significant erosion leading to the failure of the dam. The flood routing results from the flood study were used to develop a graph plotting total reservoir outflow against annual probability, from which the estimated annual probability of the total outflow at the point of failure can then be read. This value was taken to represent a reasonable estimate of the current annual probability of failure of the reservoir due to overflowing of the crest. For the East Area Balancing Pond the annual probability of failure due to overflowing of the crest was determined to be 8.3×10^{-6}, or 1 in 120,000.

Downstream consequences

An assessment of downstream consequences was made with reference to the available Environment Agency reservoir flood mapping. This assessment indicated the following incremental damages:

Table 1. Wet-day failure of East Area Balancing Pond: estimated damages

Consideration	Incremental impact of reservoir failure
Maximum population at risk	269
Time averaged population at risk	110
Likely Loss of Life (LLoL)	0.11
Cost of third party damages	£8M

Table 2. Wet-day failure of East Area Balancing Pond: Pre-scheme risk to life

Consideration	Probability	Comment	Tolerability
Probability of failure of the dam	8.3×10^{-6} (1 in 120,000)	-	-
Individual risk of death per year	2.9×10^{-8} (1 in 34M)	This is less likely than 1 in 1M prescribed by the HSE (2001) as the boundary between the broadly acceptable and tolerable regions.	The individual risk of death per year lies in the broadly acceptable zone.
Societal life loss per year	9.2×10^{-7} (1 in 1M)	Lives per year: product of probability of dam failure and likely loss of life. (see F-N chart, Figure 1)	Broadly acceptable

An F-N chart relates the probability of dam failure (F) to likely loss of life (N) resulting from that failure, as described in RARS. Such curves may be used to express societal risk criteria and to describe the safety levels of particular facilities, in this case reservoirs. An F-N chart was produced for East Area Balancing Pond to show the current societal risk (Figure 1).

The F-N chart shows that East Area Balancing Pond plots in the 'broadly acceptable zone' in relation to the probability of failure during floods and the resulting consequences.

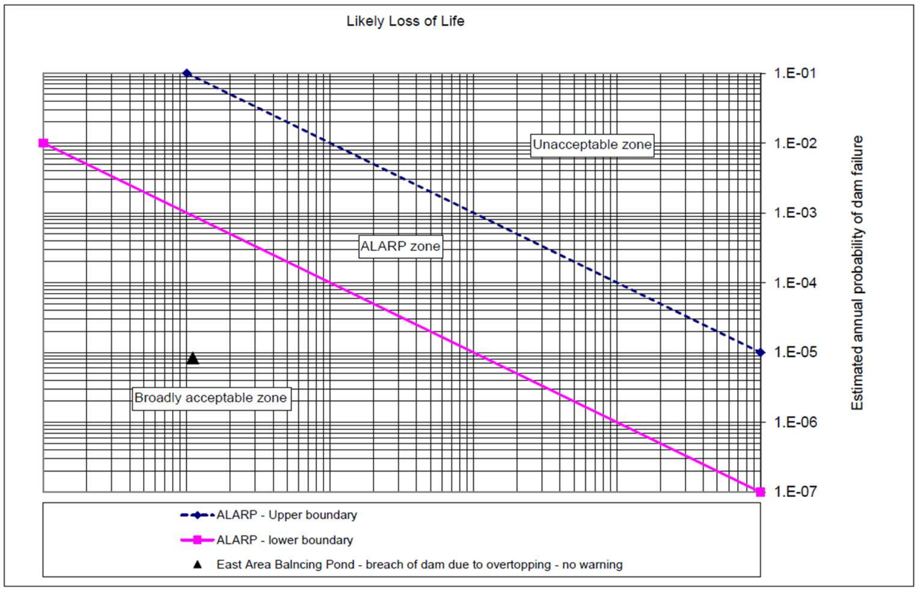

Figure 1. F-N chart: wet-day scenario for East Area Balancing Pond

ALARP Assessment

The HSE (2001) states that when a risk falls within the 'broadly acceptable' region, then further works to further reduce the risk would not usually be required unless reasonably practicable measures are available. RARS argues that this statement by the HSE implies that the ALARP principle still applies to risks that fall within the 'broadly acceptable' region. Therefore, although the risk imposed by East Area Balancing Pond in its current form is within the 'broadly acceptable' region, to strictly satisfy current reservoir safety guidance there is a further requirement to demonstrate that the expenditure related to reservoir safety improvement works would be disproportionate to the reduction in risk achieved.

An initial approach can be followed where an ALARP 'back calculation' is used to determine the cost of works that would be proportionate to the reduction in risk that would match the standards-based approach for a Category A reservoir, in accordance with the FRS4 guidance. This cost can then be compared against a realistic estimate of the actual cost of works that would be required to achieve the standards-based approach for a Category A reservoir. If the actual costs are anticipated to be significantly more than the cost to achieve proportionality, then sufficient proof exists to conclude that any further works to the dam would be disproportionate. The following steps were followed:

- Assume that the probability of failure would need to be reduced to 1 in 400,000; i.e. notionally the probability of the Safety Check Flood for a Category A reservoir.
- Select an appropriate proportionality factor (PF) and discounting factor (DF) using RARS guidance (Appendix B).

- Use the ALARP calculation to determine the maximum cost of proportionate works.
- Compare this cost with a realistic estimate of the actual works required to achieve the reduction in risk required for a Category A reservoir.

The results are summarised in the Table 3.

Table 3. Estimated limit of cost of improvement works proportionate to reduction in risk achieved

Consideration	Value	Comment
Estimated existing probability of failure	1 in 120,000	Reservoir critical outflow: overflows embankment and results in dam breach.
Probability of failure for Category A reservoir following works	1 in 400,000	Assumed return period of the Safety Check Flood for a Category A reservoir.
Estimated economic damage downstream due to reservoir failure	£8M	-
Proportionality factor (PF)	5	Ref RARS
Limit of capital cost of works to ensure proportionality	£1,600	Any expenditure exceeding this amount would be disproportionate in respect of the reduction in risk achieved.

The assessment included a sensitivity analysis, reflecting the uncertainty around both the incremental loss of life and downstream economic damages. This check varied the Average Societal Loss of Life (ASLL) value and the downstream economic damages value to determine the corresponding maximum capital cost of works that could be considered proportionate to the reduction in risk achieved. In both cases a wide range of values had little impact on the ALARP calculation indicating little sensitivity to changes in the ASLL and downstream economic damages. Even a worst case with values significantly higher than those assessed indicated that the maximum cost of works that could be justified would be less than £10k. Indeed, with this cost threshold it is apparent that any works offering even a small reduction in risk could not be justified.

The overall outcome of this assessment was to demonstrate that improvement works could not be justified in this instance. The probability of dam failure in relation to the potential downstream impacts was shown to be already as low as reasonably practicable.

CASE STUDY 2: TAYLOR PARK BIG DAM

Big Dam reservoir is a Category A impounding reservoir located a short distance upstream of a densely populated residential area of St Helens in the north-west of England. A large school is located directly within the reservoir inundation flood area, as is the town centre further downstream. Big Dam reservoir is owned and operated by the local borough council as an amenity feature within Taylor Park. The reservoir is a historic feature and the ageing dam exhibits notable settlement in places. The Section 10 inspection carried out in 2022 determined that there was inadequate wave freeboard across the majority of the dam length and that a short section of the dam had settled to a level where it might be subject to overflowing during extreme flood events. The inspection report also noted poor protection to the downstream face, with significant overshading from trees preventing grass growth.

Standards vs Risk-Based Approach

In discussion with the Council it was agreed that a first step was to properly understand the scale of the issue with a detailed flood assessment and modelling of the performance of the spillway and dam, with a view that this would help to inform a decision on the approach to be taken for determining the necessary improvement works. Accordingly, the flood assessment was carried out which demonstrated that the stillwater flood level would be marginally at the lowest crest level during the Safety Check Flood, with excessive wave overtopping expected during the Design Flood. This outcome suggested that a low wave wall would be sufficient to address these shortcomings and satisfy the standards-based approach for a Category A dam.

Screening Assessment

As with the East Midlands example, a similar screening approach was taken to help decide whether a full risk-based assessment would be of value. In this case the consequences were assessed as being significantly higher. The wet day impacts immediately downstream of the reservoir, unaffected by a concurrent fluvial flood, include a large secondary school, a Fire and Rescue Service station and at least 100 residential properties. Additionally, large incremental damages to both people and property could be expected over a significant area of the valley downstream which includes St Helens town centre and many more residential areas.

For the screening a reduction in the probability of dam failure was assumed to be from 1 in 10,000 (current) to 1 in 400,000 (target for standards). In this instance, a simple sensitivity check confirmed that the threshold cost of capital works was sensitive to both a change in downstream economic damages and a change in LLoL, as demonstrated in the initial screening results summarised in Tables 4 and 5. The results also indicated that the threshold cost was high, with a cost of capital works in the order of £300k shown to be proportionate to the reduction in risk achieved.

Table 4. Screening sensitivity varying economic damages [assumed LLoL = 10]

Downstream Economic Damages	Maximum capital cost of works proportionate to reduction in risk achieved
£10M	£278k
£25M	£322k
£50M	£394k
£75M	£468k
£100M	£541k

Table 5. Screening sensitivity varying LLoL [assumed economic damage = £50M]

Likely Loss of Life (LoLL)	Maximum capital cost of works proportionate to reduction in risk achieved
1	£171k
5	£271k
10	£395k
15	£519k
20	£644k

Managing Risks for Dams and Reservoirs

The results in Table 4 show that any works costing up to between £171k and £644k, the limiting threshold within this range depending on the combination of the LLoL and economic damages adopted, would be proportionate to the reduction in risk achieved. The construction of a low wavewall to prevent wave overtopping was estimated to cost in the order of £100k, substantially below the threshold cost range. The Council was therefore advised that a full risk-based assessment was not necessary as it would not change the outcome. The estimated cost of £100k for a wave wall to meet the Category A dam standards-based approach would be proportionate to the risk reduction achieved and therefore the works should be implemented.

CASE STUDY 3: FURNACE POND

Furnace Pond is a historic reservoir, believed to have been built in the 17th century to provide a reliable source of water for local iron workings. Records suggest that cannons were produced at an adjacent foundry. There has been no significant iron working in the area for nearly 300 years and over that time Furnace Pond, which has remained in private ownership, has been used as a source of irrigation water and as a local amenity, mainly for fishing.

A Section 10 Inspection in 2023 and a review of the downstream consequences confirmed that Furnace Pond is a Category C 'High Risk' reservoir. Downstream impacts in the event of failure would be limited to a number of public footpaths, minor roads and possible shallow flooding of two residential properties. A subsequent up-to-date flood assessment revealed that the spillway capacity and freeboard were significantly below Category C standards when considering the standards-based approach. Further, a survey of the 100m long crest confirmed the presence of a low area exhibiting strong evidence of historic and probably regular overflowing, with the flood assessment suggesting a potential for spilling over the crest during the 1 in 10year flood event.

In discussion with the owner it was agreed that consideration should be given to taking a risk-based approach, noting the relatively low consequences of failure of the dam compared to the likely considerable costs associated with carrying out improvement works to satisfy a standards-based approach. Additionally, the site has many large and mature trees both on and adjacent to the dam, and the abutment areas at both ends of the dam were outside the owner's property boundary.

A high-level ALARP screening confirmed that, in relation to the relatively low downstream damages associated with either the dry-day or wet-day failure scenarios, but apparent high probability of failure, low cost improvement works would be shown to be proportionate. The likely maximum cost of interventions that could be shown to be proportionate in relation to the reduction in risk achieved was estimated as £50k.

Accordingly, a full risk-based assessment was carried out to determine low-cost options that would reduce the risk of dam failure as low as reasonably practicable. In this case options were considered to address both the wet-day and dry-day failure scenarios. A Tier 2 assessment suggested that the current annual probability of failure due to overflowing of the dam, the wet-day scenario, was as high as 2×10^{-2}, or 1 in 50 years. In the case of the dry-day scenario, with failure associated with internal erosion, the probability of failure was shown to be 1.4×10^{-2}, or 1 in 70 years. These remarkably high probabilities in relation to this historic structure are taken as reflecting ongoing ageing and deterioration of the dam, evidenced on site by apparently significant settlement along part of the dam, and notable erosion of the downstream face likely to be as a result of overflowing of the crest.

The assessment process identified combinations of simple options that would reduce the risk of dam failure as low as reasonably practicable, i.e. from RARS: CSL < VPF. These included, for the wet-day scenario, a modified grille to be installed across the service overflow to reduce the potential for blockage, along with minor raising and regularising the crest to reduce the probability of overflowing or wave overtopping and to reduce the potential for concentrations of flows over the crest. For the dry-day scenario, options included improved vegetation management, including the production and implementation of a formal vegetation management plan, and an increased level of surveillance. Combinations of these options were shown to cost below £50k and would therefore be considered proportionate.

The outcome of this assessment, demonstrating a reduction in the probability of dam failure to as low as reasonably practicable, is illustrated in the F-N chart in Figure 2.

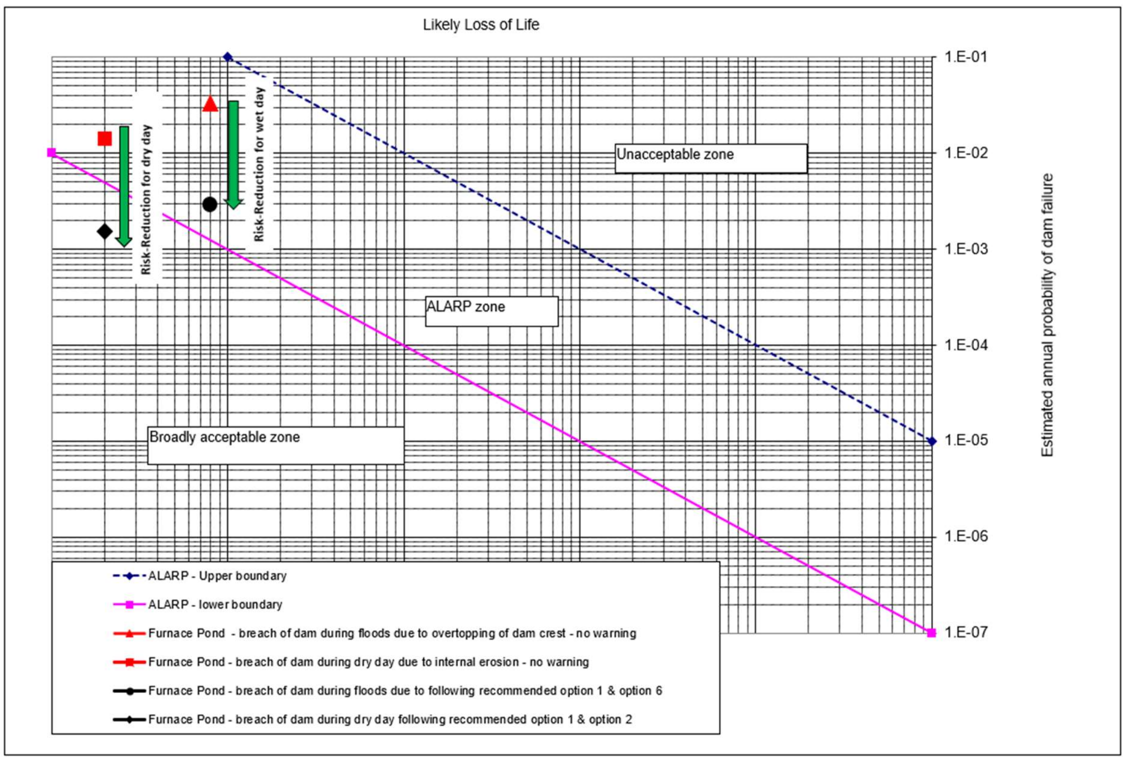

Figure 2. F-N chart: Furnace Pond risk reduction measures

CASE STUDY 4: BUCKSHOLE RESERVOIR

Buckshole Reservoir is a Category A reservoir located a short distance upstream of a densely populated residential area of Hastings in East Sussex. The town centre is also located within the reservoir breach flood inundation area. This 19th century Victorian era reservoir originally formed part of the water supply system for the town and had been operated by the water supply undertaker until the 1970s. At that time the reservoir was taken out of operational service and was passed across to the local borough council as a local amenity and fishing lake.

The Section 10 inspection carried out in 2016 determined that the spillway channel, which follows a sinuous route along the right-hand mitre of the dam, and which also formed part of the original dam works, provided inadequate capacity for extreme flood events and was in a poor condition and in need of either being improved or replaced.

Consequences

To ensure a robust process Stillwater Associates, in collaboration with CC Hydrodynamics, carried out a dambreak assessment of consequences. This assessment revealed significantly lower damages compared to the Environment Agency data available at the time, primarily due to higher damages associated with the wet-day base case yielding a lower incremental impact. For this assessment a range of damages outcomes under different flood events was considered yielding a series of risk curves which were used to determine most likely maximum damages. The relevant flood event was determined as the 1 in 2,000 year event, resulting in an estimated incremental population at risk (PAR) of 828, with a likely loss of life (LLoL) of 1.05 and £11M value of property damage.

Risk-Based Assessment

An initial assessment of the works required to improve or replace the channel concluded that any viable scheme would attract a high construction cost. As a result of the significant damages, and the loss of life and property impacts that could result from failure of the dam, there appeared to be a marginal case for adopting a risk-based approach for determining the necessary improvement works. However, the Council, like many councils, being short of funds was keen to explore options that might reduce the financial burden presented by the measures to be taken in the interests of safety. An options study included the option for discontinuance, but this was ruled out on the basis of cost, environmental impacts and the loss of a well-used public amenity. The logical next step was to carry out a risk-based assessment of viable options with varying levels of risk reduction.

For this assessment, an initial screening identified that failure of the masonry spillway channel presented the critical failure mode. A detailed event tree was prepared to understand the sequence of events that would be expected to lead to dam failure, summarised and illustrated in Figure 3. This process concluded that the failure scenario was a collapse of the spillway channel sidewall leading to erosion of the downstream face of the dam which in turn would destabilise the slope, eventually leading to a slip failure through the crest, initiating a breach.

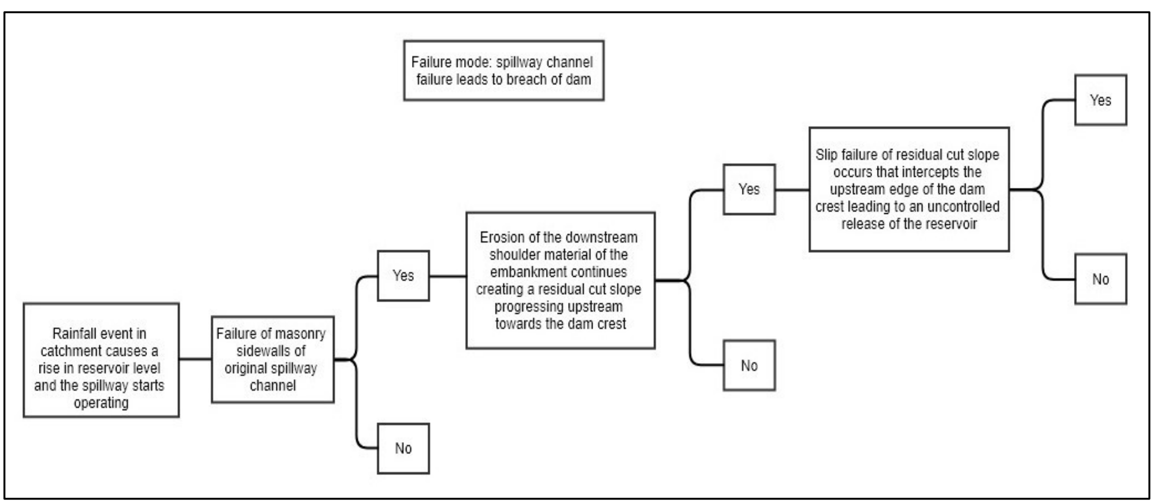

Figure 3. Summary event tree

A fragility curve was developed through a collaborative process involving discussions with the QCE and a study of literature of similar failures that have occurred in the past, such as the Ulley Reservoir incident (Mason, 2010; Hinks et al, 2008). The fragility curve indicated a 10% probability of failure of the masonry channel side wall during flow velocities of around 7m/s, a 50% probability with flow of around 9m/s and a 90% probability with flow of around 11m/s.

Careful consideration was given to the erodibility of the embankment fill materials, drawing on valuable soils information which had been obtained and documented as part of improvement works in the 1970s. Soils were characterised in accordance with an approach developed by Hanson et al (2001).

For the range of flood events considered, the stability of the residual slope was calculated for a critical dam failure slip circle that intercepts the upstream edge of the crest, this taken as initiating a breach. Each factor of safety was then converted to an annual probability of failure in accordance with Figure 8.4 in RARS.

The overall annual probability of failure was determined by summing the products of probabilities associated with each flood event, the corresponding channel sidewall failure and slope failure, for a range of flood events up to the PMF Safety Check Flood. This gave a value of 2.6×10^{-3}, or 1 in 400 chance of dam failure resulting from the loss of the channel sidewall.

The risk-based assessment concluded the following outcomes in terms of risk to life:

Table 6. Buckshole Reservoir: Pre-scheme risk to life

Consideration	Value	Comment	Tolerability
Overall probability of failure of the dam	2.6×10^{-3} (1 in 400)	-	-
Individual risk of death per year	2.8×10^{-4} (1 in 3,600)	Annual probability: product of the probability of failure and probability of loss of life given the dam fails. This is more likely than 1 in 10,000 prescribed by the HSE (2001).	Unacceptable Indicates that spillway channel must be improved to reduce risk of dam failure to an acceptable level.
Societal life loss per year	2.7×10^{-3} (1 in 370)	Lives per year: product of probability of dam failure and likely loss of life. (see F-N chart, Figure 4 below)	ALARP Indicates that spillway channel must be improved to reduce risk of dam failure to an acceptable level and that a risk-based approach can be used.

The risk-based assessment concluded that the level of risk to society was in the ALARP zone and should therefore be reduced as low as reasonably practicable. A series of options was considered for achieving this in discussion with the Council, with a short list reduced to four alternative approaches to replacing the existing spillway channel. These options were assessed in detail against a number of considerations, including ecology, heritage, landscape, operational constraints and safety, as well as cost. The preferred option was then further refined through physical modelling to optimise the design to maximise the benefits and minimise the scheme cost.

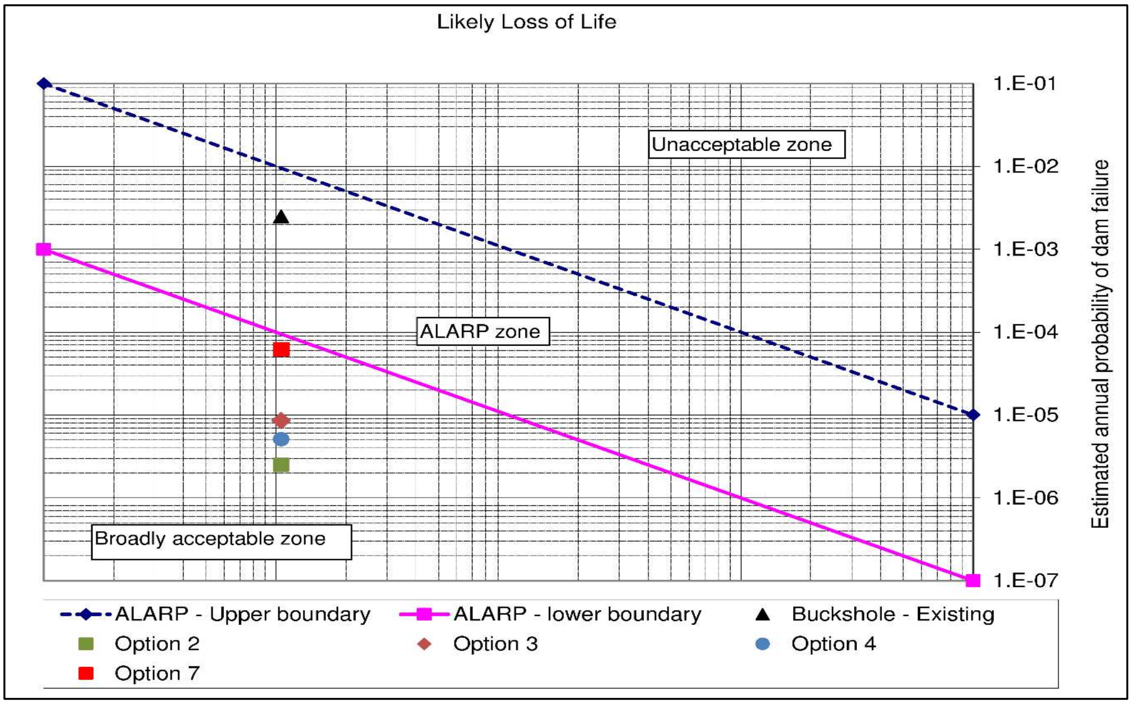

Figure 4. F-N chart: Buckshole Reservoir risk reduction options

Figure 5. Original spillway channel

Figure 6. New spillway channel

This example demonstrates the application of a robust risk-based approach. The high-level screening suggested at best a marginal case to support taking this approach, rather than simply adopting a standards-based approach. In discussion with the Undertaker it was agreed that the risk-based approach should be adopted in an attempt to minimise the cost burden to the taxpayer. The risk-based assessment confirmed the need for the scale of works required and that this outcome, further optimised through physical modelling, was the most cost-effective

CONCLUSIONS

The risk-based approach is increasingly being used in the industry to guide reservoir owners and their advisers in decision making to reduce risks to people, the environment and the economy. A standards-based approach is prescriptive: achieving the standard may unnecessarily burden the owner of a well constructed and well maintained dam that poses little risk to those downstream. As demonstrated with the four case studies presented in this paper a risk-based approach allows wider analysis which may give an optimum solution even meeting future standards in some cases and reducing cases where an owner has to upgrade every time a standard changes.

Pre-screening provides a valuable tool to help Undertakers faced with the potential need for and cost of improvements to decide whether or not a risk-based approach will be of value, or whether the risk is already sufficiently great that a standards-based approach should be followed.

The risk-based approach can justify to the Undertaker that best value is being achieved, which may be particularly relevant to public bodies needing to demonstrate the most appropriate use of available budgets. Further, this approach may prove to be increasingly valuable to the industry and to owners as the stock of ageing and smaller reservoirs increases.

It is to be noted that even when the risk posed by a reservoir has been assessed as acceptable, a residual risk still remains, as is the case for most structures. Given this, it is important that Undertakers understand that the risk can change, either as a result of a change in condition of the dam or due to external factors such as new housing developments downstream.

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