The British Dam Society

Risk Informed Decision Making for Dinas Dam

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SYNOPSIS Dinas dam is located on the Afon Rheidol and forms part of the Rheidol Hydro Scheme owned and operated by Statkraft Energy Ltd (hereby known as the undertaker). It is a 27m-high concrete arch gravity dam that went into operation in 1962. The dam has several well documented historical issues, mainly associated with development of alkali-aggregate reaction (AAR) within sections of the dam, that was first identified during the 1980s and continued to develop for the next 30 years. The identification, monitoring and evaluation of the AAR was largely overseen by an All Reservoirs Panel Engineer (ARPE).

The aim of this paper is to provide a brief background on how the historic issues at Dinas dam have been managed to date from a risk perspective and to describe the methods and techniques used during a Quantitative Risk Assessment (QRA) workshop. The paper will also provide details of how the learnings from the workshop will assist with making risk-based decisions regarding Dinas dam, that will enable effective planning for future management / works to ensure the longevity of the dam. Lastly, the paper will discuss how this type of workshop can be used as a tool for information sharing and knowledge transfer.

INTRODUCTION

Risk informed decision making is fundamental to the undertaker's core principle of being 'Safe and Prepared.' To ensure optimal operation and maintenance of its assets and to capitalise on opportunities, the undertaker must ensure that risks are identified, analysed, and evaluated sufficiently early to establish mitigating actions. This is achieved by conducting risk assessments for all disciplines in all operating units and larger projects. The criticality of assets is evaluated and measures to address uncertainties are established. The use of cost-benefit analysis tools is well established in the organisation and together with the risk assessment, the organisation action plans, maintenance plans, and reinvestment plans are developed. When actions are completed, the residual uncertainty is evaluated, and assessments are updated.

The undertaker's processes for assessing dam safety risks have proved more challenging. This is largely because the statistical probability of a dam failing is so low and yet the consequences could be so significant that it is has proved difficult to quantify these risks and to establish measures to address the uncertainty. The undertaker has looked to address this issue in recent years by updating its governance documents and ensuring that all dams have an updated qualitative risk assessment of the major risks in the catchments where the dams are located. This includes an assessment of design and spillway capacity of each dam and the ability of the dam to endure overtopping. This approach has allowed the undertaker to assess their full global dam portfolio of 363 dams in 11 countries, in a consistent manner and has highlighted which dams have the highest risks associated with them, and which dams may need additional measures or further investigation to properly manage these risks. Based on this screening exercise, dams have been identified that require a quantitative risk assessment to better manage their risks. Dinas dam, which is part of the Rheidol Hydropower Scheme located in the Ceredigion area in Mid-Wales, was one of the dams pre-screened during the qualitative risk assessment that would benefit from a full Quantitative Risk Assessment (QRA) study.

ALKALI AGGREGATE REACTION

Alkali-aggregate reaction (AAR) is the broader term describing the chemical reaction between certain specific mineralogical types of aggregates and alkali of cement in the presence of moisture. AAR of the type evidenced at Dinas is often also referred to as alkali-silica reaction or slow-late reaction, during which the alkalis in the cement react with certain reactive silica-containing aggregates (Charlwood, 2009: 4). Alkalis may also come from other constituents in the concrete mix, such as water or adjuvant (admixtures or additives), and they may also penetrate the concrete from the environment. The alkalis are dissolved in the mixing water during the mixing of concrete and in the pore water. The resultant alkaline solution reacts chemically with the reactive silica-containing aggregates (Saouma & Perotti, 2006: 194). The silica minerals (especially the poorly crystallised ones) are transformed into an alkali-silica gel which is hygroscopic in nature. This causes a swelling action on the microscopic level which causes the aggregate to develop cracks, leading to the expansion and cracking of the surrounding cement paste (Charlwood *et al.*, 2013. It usually takes some time for the reaction to progress to a stage where it is evident on a macroscopic level and therefore evidence of the reaction is typically noticed about 10 years after initial construction (Mason, 2011).

HISTORY OF DINAS

Dinas dam is located on the Afon Rheidol and forms part of the Rheidol Hydro Scheme which is a 56MW scheme consisting of three dams (Nant-y-Moch, Dinas and Cwm Rheidol) and is the largest hydropower scheme in England and Wales. Dinas dam is a 27m-high central arch gravity concrete dam, flanked on either side by gravity dam blocks, impounding a 850,000m^3 reservoir. The dam was constructed between 1957 to 1962 with commissioning and operation starting in 1962. During the first decade there were no significant issues identified and in the 1972 Inspection Report the condition of the dam was recorded as being in a broadly good condition. In the early 1980s the condition of the dam started to deteriorate with cracks and calcite staining forming on the concrete surface; this drew the first suspicions that alkali-aggregate reaction (AAR) was developing. By the mid-1980s a major horizontal crack had developed on the downstream face of the central arched section of the dam at elevation +245.56mOD. Between 1987 and 1988 cores were taken from the dam and tested and this confirmed AAR.

In the 1992 Inspection report it was noted that water was no longer flowing uniformly over the full length of the overflow weir but concentrated over a small section at the centre of the spillway. This indicated that the geometric properties of the dam had altered and from 1993 a network of survey points was established to monitor vertical, radial and lateral movements of the overflow and dam crest. The hypothesis was that concrete expansion had caused the principal linear dimensions of the dam to increase; however, since the dam was restrained both by the foundation and abutments, the expansion had resulted in the dam effectively bowing in the upstream direction with an upstream tilt and rising crest levels. Reinforcement in the upper part of the dam had helped restrain some of the stresses in the downstream face, which resulted in reduced cracking. At the elevation +245.56mOD, the reinforcement stops, and this is where the large crack first appeared in the mid-1980s. Finite element analyses for Dinas dam were carried out by Gibb Ltd. in 1997. The results for the AAR case showed considerably increased compressive stresses throughout the dam and principal compressive stress directions along the central downstream base of the dam having changed to dominantly horizontal, arch action. The results appeared to support the visual observations and survey results.

Based on this developing situation in 1998 and on the recommendation of the Inspecting Engineer, a system of cables was installed around the upstream face of Dinas dam crest to reduce the risk of the upper dam toppling upstream during a seismic event.

For the next ten years the dam was under close supervision from a Supervising and Inspecting Engineer with quarterly surveys taken and shape surveys developed every three years. Although the dam was frequently inspected, no further testing was undertaken. In 2009 ownership of the Rheidol Hydro Scheme, including Dinas dam, changed and this prompted the next phase in how the dam was to be managed going forward. In 2011 the Inspecting Engineer, who had overseen the installation of the restraining cables, was reappointed. With this reappointment, recommendations were given to investigate the extent of AAR development in the preceding years. A summary of the further investigations since 2011 has been provided below:

- Further concrete testing was carried out in 2012 to establish the state of the concrete and the degree of deterioration since the last set of tests in the 1980s.
- A new survey system was established in 2013. New base stations were established and correlated with the previous survey, and new prism-based survey stations established along the dam crest. The results of the new surveys appeared to largely support the 2012 concrete testing results in that there is now little residual capacity in the concrete for AAR, and that the potential for future expansion has, for all intents and purposes, stopped.
- In situ stress tests were carried out prior to the 2017 Section 10 inspection, which confirmed that stresses within the dam remain within acceptable levels.

In the 2017 Inspection Report, an in-depth review of the previous years' testing, as summarised above, was given with the conclusion that concrete expansion from AAR had either ceased or was now negligible, and stresses within the dam were within acceptable limits. Options were provided to the undertaker on how best to manage the dam going forward, including the installation of stress measurement sensors. The Inspecting Engineer also discussed the potential to increase the longevity of the dam by waterproofing the upstream face.

DEVELOPMENT OF QRA IN THE UNDERTAKER'S ORGANISATION

In 2021, the undertaker commissioned the Norwegian Geotechnical Institute (NGI) to develop an international version of the handbook 'Risk Assessment and Management for Dams' (Lacasse, 2022). The handbook was to provide the personnel who are responsible for managing dam safety in the undertaker's organisation with a guide that presented various established risk assessment methods, and detailed how they can be utilised to complete an in-depth risk assessment (qualitative or quantitative analyses) to assist in making risk-informed decisions. The undertaker has used the assessment methods introduced in the handbook to deliver several QRAs on the most high-risk dams in their global portfolio. The assessment method that the undertaker has used for the majority of these QRAs is Event Tree Analysis (ETA). This method has proved useful when working with a large group of workshop participants to best utilise the diverse expertise of the people within the team.

ETA is a method used to evaluate the probability of a failure mode based on a triggering event/mechanism i.e. extreme flood, landslide, earthquake etc. The triggering event/ mechanism should have a time element e.g. a flood with a 1000-year return period. The event tree then describes in graphical format the logical sequence of events that could lead to a dam failure. Since each step (node) in the sequence could have more than one outcome, branches are then formed which should be continued through to either a dam failure or no dam failure. Probabilities can then be assigned to each node and the risk of failure for the triggering event/mechanism can be calculated.

The event tree analysis uses a nine-step procedure (Lacasse, 2022).

1. Site visit and inspection of the dam including geology, siting, and site conditions.
2. Overview of observations, earlier events, and other observations.
3. Brainstorming and screening of triggers and failure modes and prioritisation of plausible scenarios. This step is called 'failure mode screening'.
4. Discussion and agreement on scales to describe uncertainties and probability estimates.
5. Construction of event trees and estimates of probabilities at each node, and continuation of each sequence of events until failure (or non-failure).
6. Calculation of probabilities for each scenario (tree branch) leading to a failure.
7. Iteration of some or all of the event trees.
8. Calculation of total failure probability for the dam (or system of dams).
9. Evaluation of failure probabilities obtained and consequences.

DINAS DAM RISK WORKSHOP

The Dinas dam safety risk assessment workshop took place at the Rheidol Hydro Scheme in October 2023. The timing of the workshop took place between the Inspecting Engineer's periodic safety inspection and the issuing of the Section 10(3) report. This scheduling meant the results of the QRA could inform the recommendations in the Inspecting Engineer's report. This collaborative approach helped the undertaker to achieve one of its governing principles of using risk to inform their decision-making process and is a good example of how a reservoir undertaker can meet their own internal goals while satisfying the local statutory requirements.

Workshop Participants

The following participants took part in the workshop.

- Rheidol O&M team (Site Manager, HSSE Manager, Civil and Mechanical Technician, Production and Maintenance Planner and the Team Leader of the Control Centre).
- Those working in dam safety within the undertaker's organisation, including representatives from Albania, Brazil, Germany, Norway and Sweden.
- Preceding Inspecting Engineer from 1996 to 1998 and 2012 to 2021.
- Current All Reservoirs Panel Engineer (since 2021) (also Inspecting Engineer at the time).
- Current Supervising Engineer (since 2023).

Participants were chosen based on their familiarity with Dinas dam and Rheidol Hydro Scheme, local knowledge, expertise in concrete dams, and familiarity with the undertaker's QRA process. The undertaker also uses these workshops for knowledge sharing for those working within dam safety in the undertaker's organisation. The undertaker's Dam Safety Officer (DSO) for the UK facilitated the workshop and the Supervising Engineer acted as meeting secretary.

Pre-Workshop Meetings, Site Visit, and Introductory Presentation

The QRA process started pre-workshop through online meetings between the DSO, the Inspecting Engineers, and the Supervising Engineer. The primary purpose of these meetings was to identify the main failure modes that were to be assessed during the workshop and to highlight the main issues associated with the dam, with the aim to streamline the physical workshop and ensure the participants were supplied with the relevant information.

The actual workshop started with the participants visiting the Dinas dam site and reservoir. This gave those unfamiliar to the site the opportunity to question the O&M team and the Inspecting and Supervising Engineers. Following the site visit, the participants reconvened at the conference room at Rheidol Hydro Scheme main office. The room was set up with a conference table, a large whiteboard, and a projector. The meeting started with a short presentation from the facilitator about the agenda for the workshop, an introduction to the process of failure mode identification and screening, and how event tree analysis (ETA) would be used to apply annual probabilities for the failure modes identified. The use of F-N charts to plot the results from the QRA was also introduced as a means of evaluating if the risk associated with the failure mode would be acceptable to society.

Background Presentation by the Inspecting Engineer

Following this, a presentation was given by the preceding Inspection Engineer who had been involved on and off with Dinas dam for nearly three decades. This presentation provided a concise overview of the development of AAR within the dam and the issues that the expansion of the concrete has caused related to the safety and security of the dam. Explanation was given on how these issues have been managed and the risks mitigated through testing, monitoring and close supervision. Commentary was also provided on the status of the AAR development and the continuing impact on the dam.

Brainstorming Session for Trigger Events and Potential Failure Modes

The next phase of the workshop was the potential failure mode screening; this involved identifying potential ways the dam could fail and what would trigger these events. The failure modes were not to be considered in great detail at this stage, as the purpose of this activity was to determine if the failure mode was plausible and therefore required further assessment. The team represented a diverse group of disciplines with varying experience, and this added value to this type of exercise, as the aim was to be creative with potential failure modes and promote a 'blue-sky' thought process. Visiting the dam site assisted with this activity, as seeing the dam in-situ helped the team gain a greater understanding of the challenges faced in operating and maintaining the site.

In the pre-workshop meeting between the DSO and the Inspecting and Supervising Engineers, a similar failure mode exercise had taken place. These results were now shared with all participants and compared with the workshop failure mode screening exercise. The combined results were assessed in terms of credibility and perceived ranking (Table 1), and a plan was then formed on how the workshop would proceed with the ETA.

Table 1. Trigger Events and Viable Failure Modes

Ranking	Trigger Event	Failure Mode(s)
1	Earthquake	Toppling of upper (reinforced) part of spillway (dam) into the reservoir. Toppling of upper (reinforced) part of spillway (dam) downstream (into the spilling basin). General dam stability (e.g. abutment failures).
2	Flooding	Toppling of upper (reinforced) part of spillway (dam) downstream (into the spilling basin). Erosion of central rock stilling basin. Erosion of downstream abutments and foundation (overtopping of training walls). Breaking up of concrete steps.
3	Concrete Deterioration	Expansive concrete causing lifting of arch, with load shedding into abutments. Increased cracking / seepages leading to decreased concrete strength. Reduced concrete mass due to spalling concrete in RC section.
4	Cascade Failure (failure at upstream Nant-y-Moch dam)	Nant-y-Moch failure. Note: although this is considered a viable failure mode, a separate workshop for Nant-y-Moch will take place in the future and the cascade failure will be considered then.
5	Impact from plane	The Dinas reservoir is part of the training route for the Royal Air Force, with flybys at low altitude a common practice. In the 1980s a plane crashed into the Nant-y-Moch reservoir.
6	Destructive Investigation	Deliberate or accidental sabotage. Note: Over-tensioning of the spillway cables could potentially cause the top section of the spillway to topple. Further discussion deemed this improbable, and the group decided to discount this failure mode.

Assessment of Downstream Consequences

The 2009 Reservoir Inundation Map (RIM) for Dinas Reservoir was used when assessing the downstream consequence of a Dinas dam breach. The local knowledge of the operations team also assisted in defining potential at risk properties. Due to the limited quality of information available, only a high-level assessment was possible, with the area most at risk identified as a small village downstream of the dam site. Further downstream, flatter floodplains and the potential ability to provide sufficient warning reduced the number estimated to be at risk. It was concluded that a range of 10 to 100 people would be used in the F-N charts but accepted that further work was required to refine this estimate.

Event Tree Analyses

The following event trees were developed with the trigger event shown in brackets:

- *Spillway crest toppling upstream (earthquake)*
- *Spillway crest toppling downstream (flood)*
- Overtopping of spillway training walls (flood)
- Erosion of spillway stilling basin (flood)
- Break-up of left flank spillway steps (flood)
- *Deterioration of concrete from increased seepage through the dam, also considering the effect of Alkali Silica Reaction (seepage)*
- Direct hit on dam by low flying plane (impact)

This paper will only consider the event trees which are directly impacted by the historic issues associated with AAR which are shown in *italics* above.

Event Trees Sensitivity Analysis

Verbal descriptors were used to assign probabilities (p) to nodes on the event trees. The verbal descriptors used with their associated probabilities were as follows (probability range shown in brackets):

- Virtually impossible, p = 0.001 (0 – 0.005)
- Very unlikely, p = 0.01 (0.005 – 0.02)
- Unlikely, p = 0.10 (0.02 – 0.33)
- As likely as not, p = 0.50 (0.33 – 0.66)
- Likely, p = 0.9 (0.66 – 0.98)
- Very likely, p = 0.99 (0.98 – 0.995)
- Virtually certain, p = 0.999 (0.995 – 1.0)

When compiling the event trees during the workshop, a single value within the given ranges was allocated for each of the relevant nodes. Post-workshop, a Monte Carlo analysis was completed for each event tree, which would randomly select a number within the range of the verbal descriptor at each node, the process was completed 10,000 times. These Monte Carlo analyses were then used to calculate the maximum, minimum and average probabilities associated with each failure mode. This range was plotted on the risk diagram. Occasionally the workshop participants could not agree on a single verbal descriptor – for these situations it was agreed that the Monte Carlo analysis would be run using a range decided during the workshop.

ETA - Spillway Crest Toppling Upstream (Earthquake)

The annual probability of failure of the upper part of the dam during an earthquake event (i.e. upper section of the dam toppling upstream), was calculated to be 2.35 x 10^{-5} /yr (see Figure 1 for ETA). The sensitivity analysis based on the ranges of the verbal descriptors was calculated to be between 1.3 x 10^{-5} /yr to 2.1 x 10^{-7} /yr with a mean of 2.8 x 10^{-6} /yr (plotted on F-N risk diagram - see Figure 2). Fundamental to controlling this risk is the capacity of the restraint cables that have been installed on the upstream face. The cables were installed as mitigation for this failure mode in 1998 with a design life of 25 years. Although visual inspection appears to suggest the cables are in relatively good condition, the workshop concluded that their structural capacity should be confirmed through further investigation.

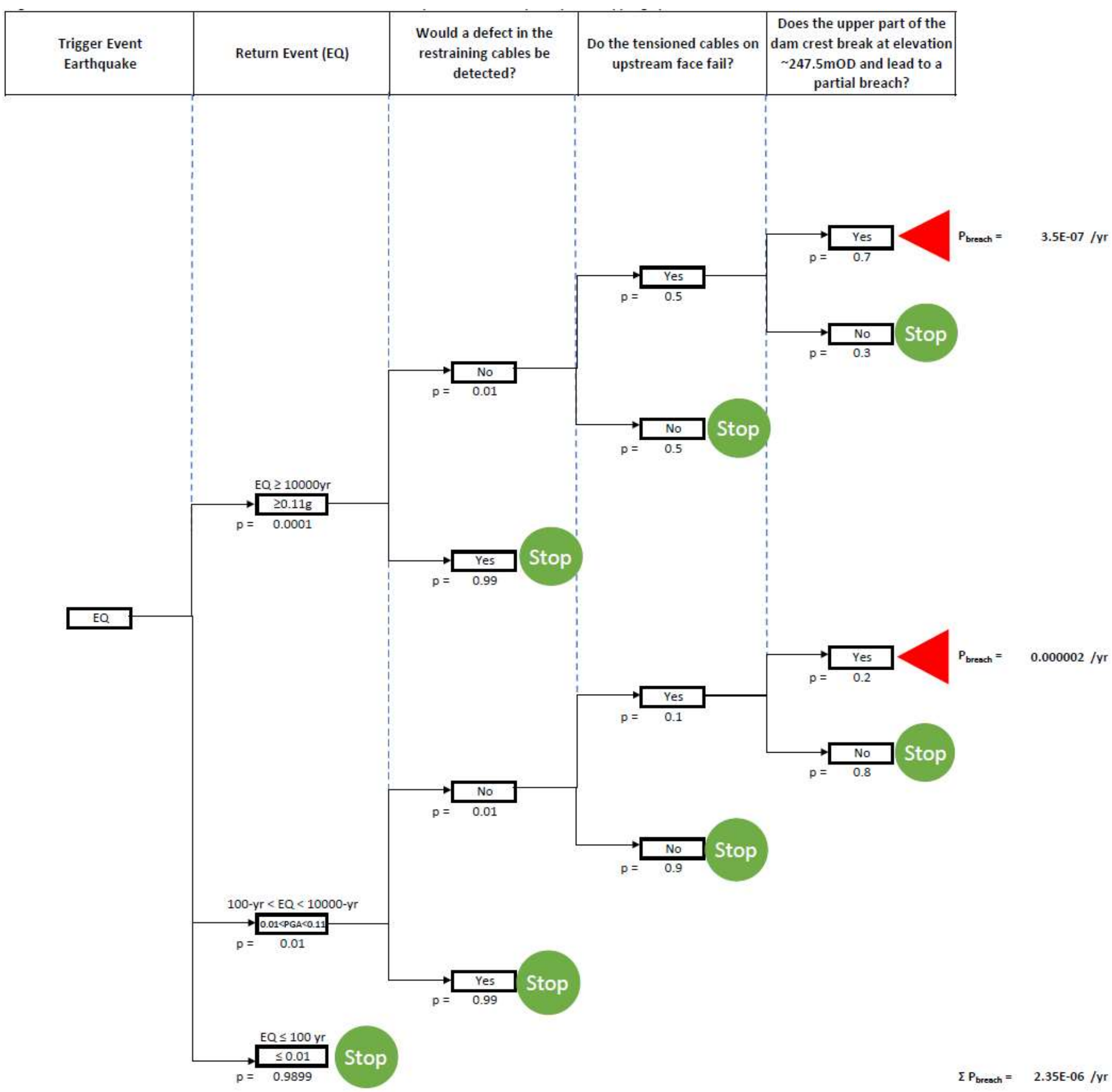

Figure 1. ETA - Spillway Crest Toppling Upstream (Earthquake)

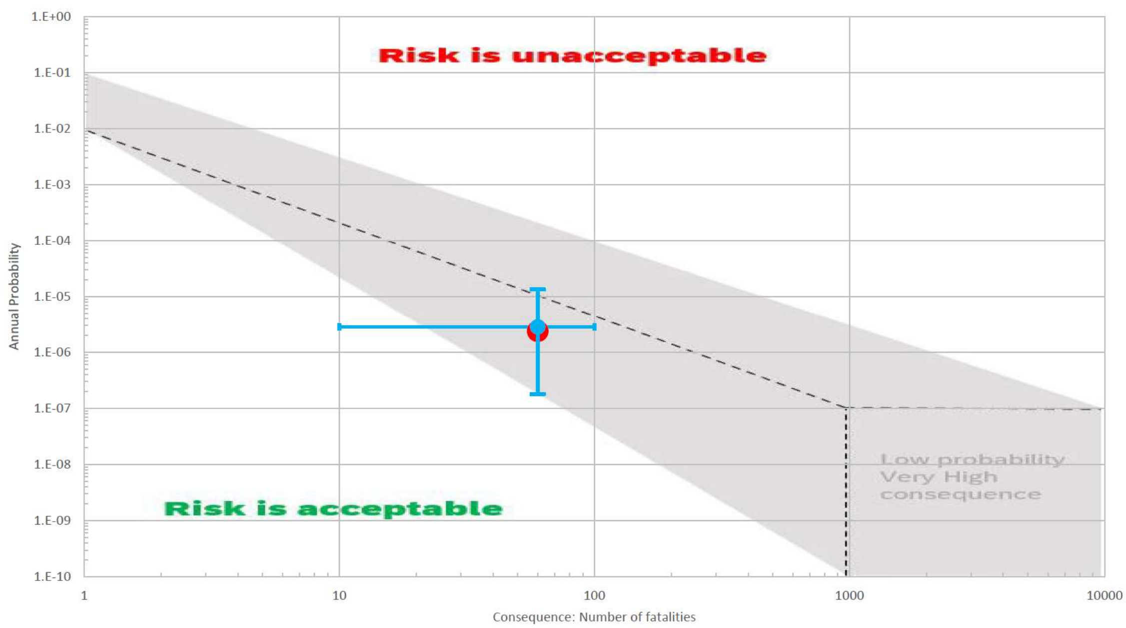

Figure 2. F-N Risk Diagram - Spillway Crest Toppling Upstream (Earthquake)

ETA - Spillway Crest Toppling Downstream (Flood)

The annual probability of failure of the upper part of the dam during a flood event (i.e. upper section of the dam toppling downstream), was calculated to be 2.65 x 10^{-5} /yr (Figure 3). The sensitivity analysis based on the ranges of the verbal descriptors was calculated to be between 1.1 x 10^{-4} /yr to 2.5 x 10^{-5} /yr with a mean of 6.6 x 10^{-5} /yr (plotted on F-N risk diagram - Figure 4). This relatively high probability of annual failure did not really correspond to the general feeling within the room, which felt this mode of failure was unlikely. The event tree developed was potentially over-simplified as the single question 'Does the construction joint fail in shear?' largely governed the end result. Although consideration was given to the impact that detection and monitoring may have on this failure mode, it was not included in the event tree.

This failure mode requires further evaluation. Finite Element modelling of the dam was discussed as an option to better understand the dam's current and possible future behavioural patterns. Due to issues with AAR in the dam, there is further information to be collected from in-situ testing, alongside with ongoing survey monitoring data, both of which should then be incorporated into the model.

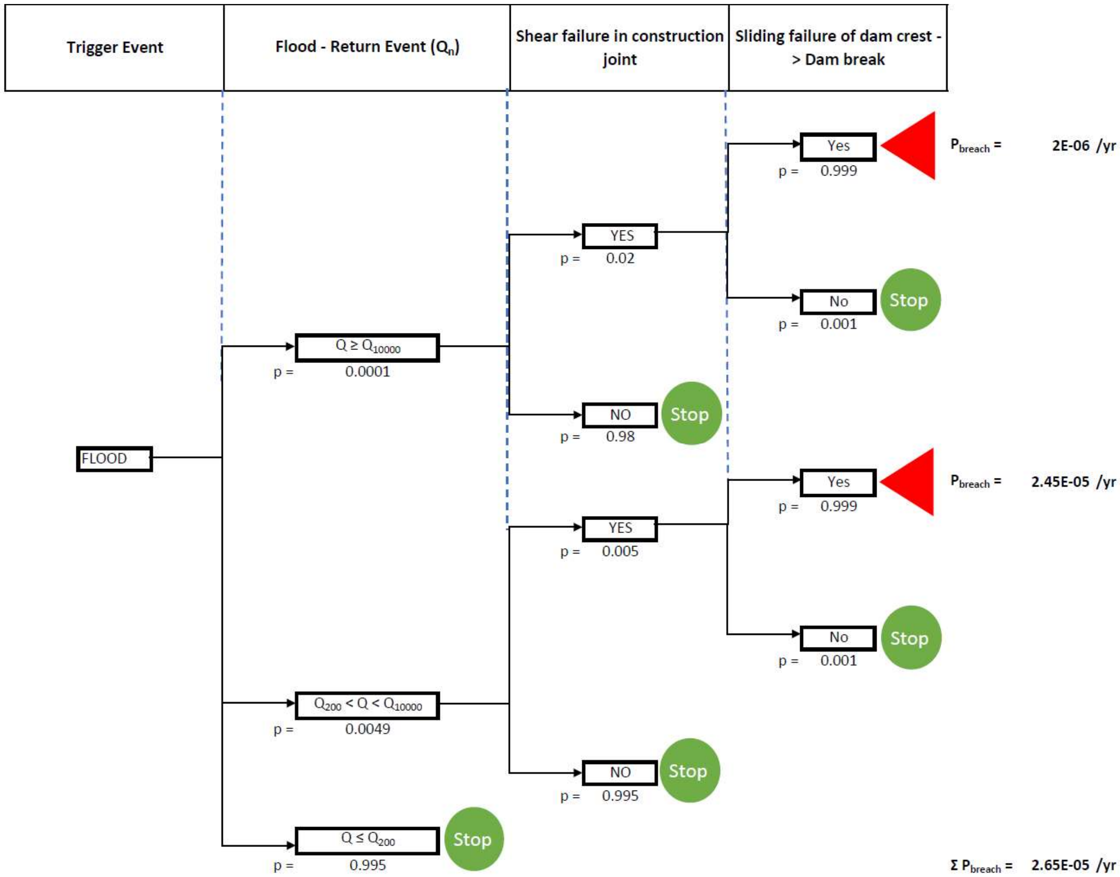

Figure 3. ETA - Spillway Crest Toppling Downstream (Flood)

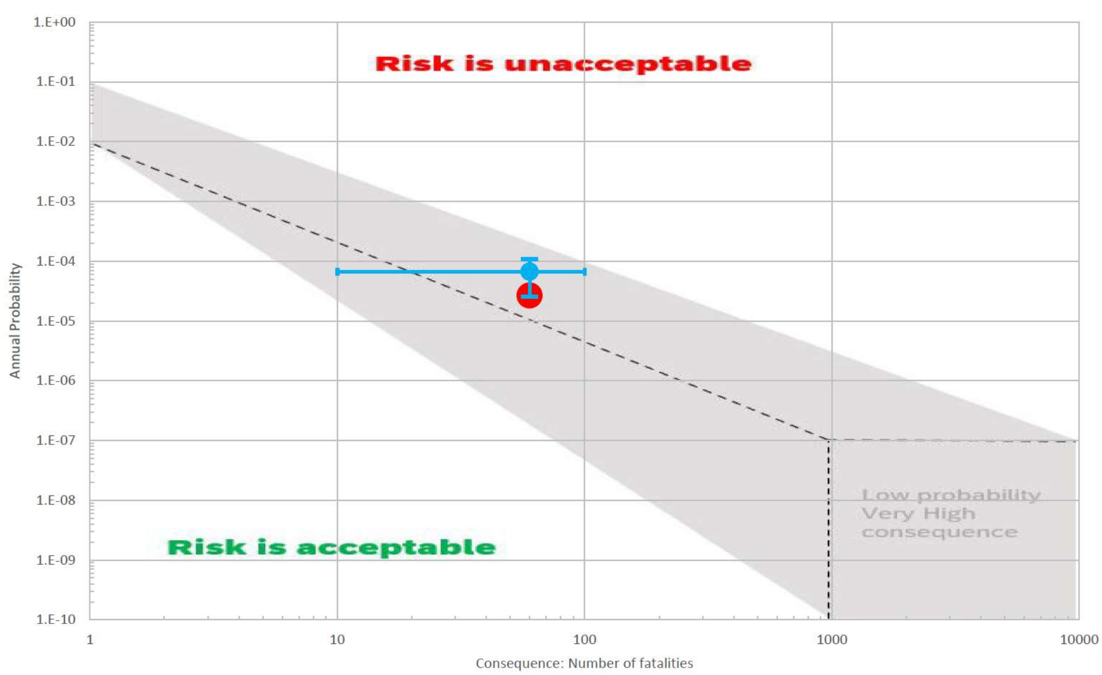

Figure 4. F-N Risk Diagram - Spillway Crest Toppling Downstream (Flood)

ETA - Deterioration of Concrete from Increased Seepage through the Dam, also considering the effect of Alkali Silica Reaction (Seepage)

Based on the current condition of the dam and the reduced impact of the AAR, it was determined that seepage through the concrete dam was not a current day risk; however, if left unabated continued leaching of the concrete paste could cause degradation to an extent that internal stresses will exceed the capacity of the concrete. To assess this risk the condition of the concrete assuming continued leaching was considered over a mid to long-term timeframe (20, 50 and 100 years). The risk assessment demonstrated that in between 20 and 50 years the probability of failure of the dam becomes unacceptable and control measures would likely need to be implemented (see Figure 5 for the ETA developed for predicted condition of the dam in 20 years).

If measures are applied, i.e. sealing the upstream face, this failure mode is no longer considered viable. The same exercise was repeated assuming re-activation of the AAR, but assuming shorter time-frames to account for the further degradation of the concrete caused by the resulting expansion (15, 40 and 80 years). It was assessed that in between 15 and 40 years it was likely that the probability of failure would be unacceptable. The risk diagram for this failure mode is shown in Figure 6 (note: Monte Carlo sensitivity analysis was not included for this assessment, since the main purpose was to demonstrate that the probability of this failure occurring increases with time).

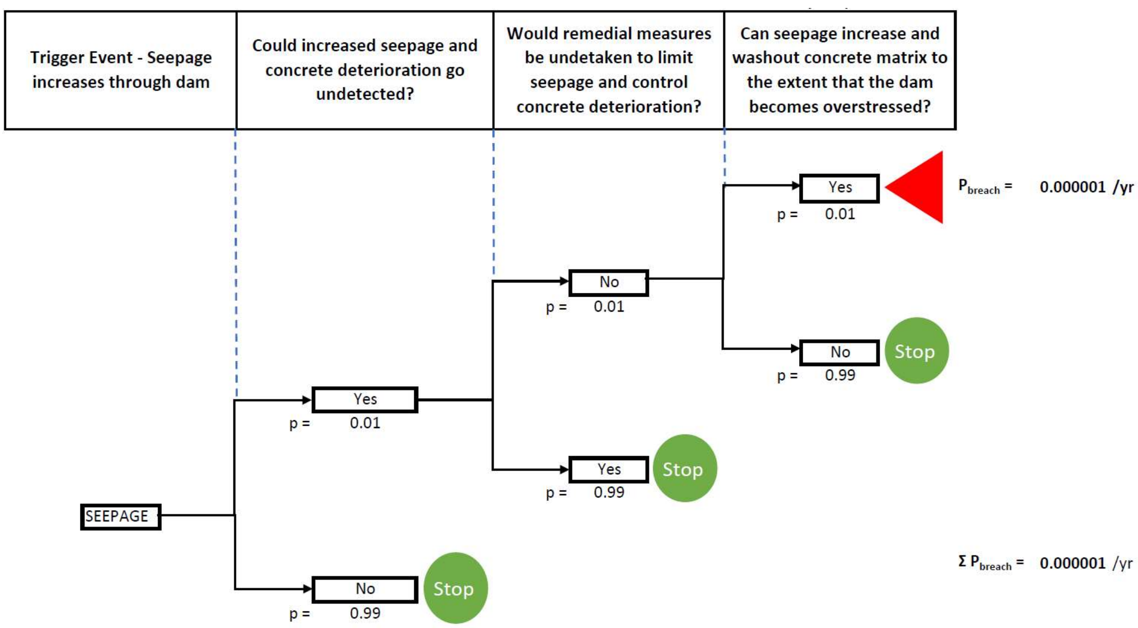

Figure 5. ETA - Deterioration of Concrete from Increased Seepage through the Dam After 20 Years

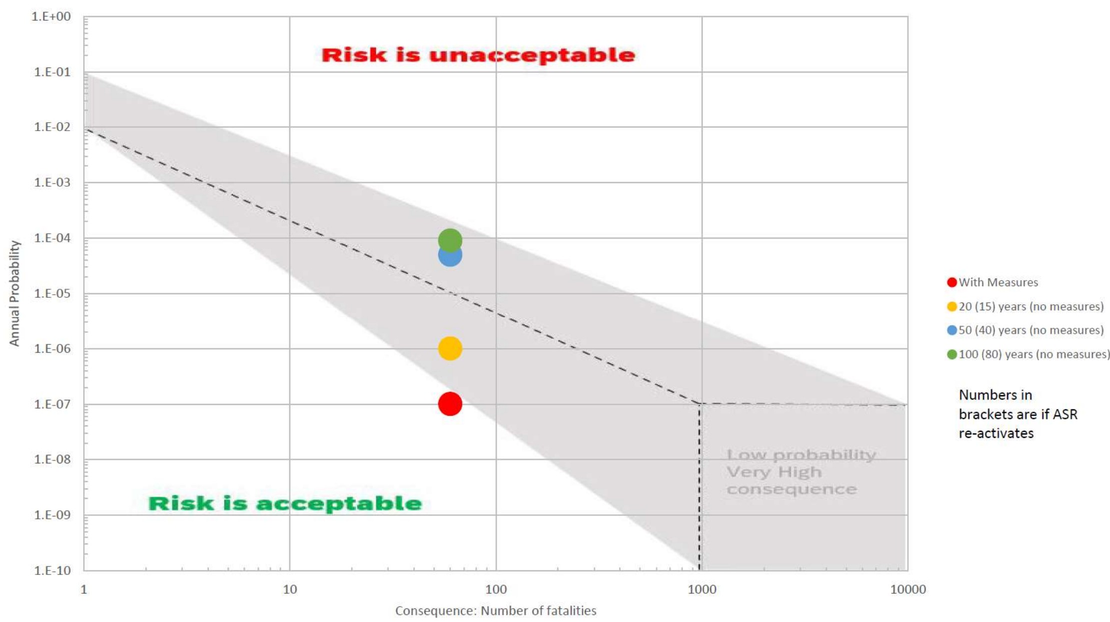

Figure 6. F-N Risk Diagram - Deterioration of Concrete from Increased Seepage through the Dam

QRA Results and Recommendations

The ETAs produced during the QRA workshop are based on a simple method of assigning annual probabilities of failure for the different failure modes identified. It is recognised that these probabilities are subjective and rely on having quality data to inform the decisions. For the different failure modes, it is not a simple case of evaluating whether the risk is acceptable or not, as many risks will fall in a 'grey' area which indicates that not enough information is known to comprehensively evaluate the risk. Inadequate assessment of consequence (as was the case for this study) also promotes indecision in the process as judgements will tend to err on the side of caution, reflected in less certainty applied to verbal descriptors. However, this method of QRA is useful at highlighting where there is potential information lacking. Therefore, the main recommendations that came from the Dinas QRA are associated with the need to obtain better information to inform future decisions.

The main recommendations are as follows:

- Detailed dam break analysis should be completed to better assess the number of receptors at risk in the downstream catchment. Since Dinas reservoir and dam are part of a cascade scheme it would be prudent to assess the Rheidol Hydro Scheme reservoirs as a whole, with assessments for both the individual failure of Dinas, Nant-Y-Moch and Cwm Rheidol, as well as a cascade failure associated with Nant-Y-Moch.
- A new finite element model should be developed which better represents the current condition of the dam.
- The current condition/capacity of the restraining cables on the upstream face of the dam should be investigated.

Alongside the above recommendations, further testing and monitoring of the dam was recommended as follows:

- Carbonation depth tests to determine what remaining pH protection cover is available to the embedded rebar.
- Laser scanning and point cloud surveys to better track deformation changes in the dam.
- Crack mapping with AI to define and track changes to the surface of the dam.
- Ultrasonic Pulse Velocities (UPV) survey to indicate localised concrete strength and soundness. This can be routinely repeated to indicate changes in the concrete.
- PPM tests of seepage flows through cracks in dam to indicate level of concrete leaching.
- New cores to be taken in future years for strength comparison with earlier results.
- In situ stress tests and the installation of stress cells to measure the stress changes in the concrete over time.

Ultimately through the information collected from the studies/monitoring activities detailed above, a strategic plan can be developed for prolonging the longevity of Dinas dam. The majority of the above recommendations have been captured in the recent Section 10 report that was finalised and issued following the workshop.

INFORMATION SHARING AND KNOWLEDGE TRANSFER

A major benefit of running a QRA workshop is that it provides an excellent opportunity to share information about the dam, the QRA process and promote knowledge transfer. Those appointed to the roles of Inspecting and Supervising Engineers have changed in recent years and with reappointment of these vital roles, there is always a danger that important knowledge of the dam gets lost. By inviting the previous Inspecting Engineer to participate in the workshop a wealth of knowledge gained over three decades of involvement with Dinas dam helped drive discussions and added real value to the process.

Although many of the local O&M personnel who took part in the workshop, are not necessarily directly involved in the dam safety programme for Dinas dam, they have knowledge that pre-dates the current undertaker's ownership. Their insights into the local area and events over the past decades helped to inform the process and at times provided eye-witness accounts. Post-workshop feedback from the O&M team also suggested they had gained a greater understanding of the dam, which will inform their own future O&M activities.

The undertaker's own dam safety team used this opportunity to improve processes that have been in development for nearly 5 years. The undertaker is delivering a global dam safety program and providing opportunities for the dam safety personnel to interact and discuss dam safety issues, helps promote a unified approach to dam safety. Selecting participants with a range of experience and knowledge helps promote the process of continuing improvement which can then be refined in future workshops.

CONCLUSION

The main goal for the undertaker in running a QRA type of risk assessment workshop is to gain a greater understanding about the dams that they own and operate and their residual risk. By better understanding the viable failure modes and how these are triggered, and can develop, means mitigation measures can be identified early, planned, and executed. This allows a proactive approach to the management of the dam and with decisions based on risk, resources can be used with greater efficiency.

Managing Risks for Dams and Reservoirs

The timing of the QRA workshop was also critical as it preceded the issuing of the newly appointed Inspecting Engineer's first Inspection Report for Dinas Reservoir. The recommendations outlined in the workshop were largely included in the proceeding Inspection Report and therefore the owner, Inspecting Engineer and Supervising Engineer were all in agreement with regard to the future strategy for the dam.

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