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TOLERABILITY OF RISK AND ALARP: ORIGINS, INTENT AND IMPLICATIONS FOR DAM SAFETY ASSESSMENT

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ABSTRACT

Tolerability of Risk approach and the ALARP principle are often quoted as cornerstones of risk-informed dam safety practice in those common law countries that implement the practice to some degree. This position is frequently supported with reference to the practices of the United Kingdom Health and Safety Executive (UKHSE) which developed the approach over time initially to meet its statutory duties with respect to regulation of nuclear power plants and subsequently adapting the approach for its regulation of health and safety in the workplace. The majority of the dam safety practices that utilise Tolerability of Risk and the ALARP Principle typically rely on the UKHSE explanation as to how it utilises the approach in regulation of health and safety in the workplace. This situation is not limited to dams; several other hazardous industries also refer to UKHSE guidance on Tolerability of Risk and ALARP. Often, these entities present and use adaptations of the UKHSE risk guidance, with reference to the UKHSE as a source of authoritative good practice on risk assessment. However, what is meant by Tolerability of Risk and the ALARP principle and how they might be interpreted in the context of dams are not as straightforward as they might seem nor are the related implications for dam safety decision-making. The difference in context between the application of Tolerability of Risk and ALARP by the UKHSE in discharging its duties in terms of the UK Health and Safety at Work Act, and its application to dams is typically not addressed by those organisations that follow the approach of Tolerability of Risk and ALARP to some degree. This paper sets out the origins of Tolerability of Risk and ALARP, the originally intended interpretation and the originally intended application as an instrument of risk regulation. The paper reveals important assumptions that underlie the Tolerability of Risk and ALARP approach. It then contrasts the situation of the industry for which Tolerability of Risk and ALARP approach were devised with that of dams and other fixed infrastructures, and explains the implications of the differences for risk-informed dam safety decision-making that relies on them. The paper concludes with advice concerning the re-interpretation of the concepts of Tolerability of Risk from dams and the role of the ALARP principle.

1. INTRODUCTION

Framing the safety of dams in terms of the Tolerability of Risk approach was first introduced by BC Hydro (BC Hydro, 1993). The approach proposed by BC Hydro drew heavily on the formative works of the UK Health and Safety Executive's Tolerability of Risk from Nuclear Power Stations (Rimington, 1987, UKHSE, 1988/1992). Subsequently in 2001, the UK Health and Safety Executive published Reducing Risk, Protecting People (UKHSE, 2001), an account of the approach that the Executive adopts in regulatory decision-making in terms of the Health and Safety at Work Act. Reducing Risks, Protecting People subsequently became one of the most quoted policy sources used to support the selection of risk acceptance criteria for dam safety by various entities such as ANCOLD (2003), the US Army Corps of Engineers (2014), and FERC (2016). Reducing Risk, Protecting People in its Framework for Tolerability of Risk, indicates a "Tolerable Region" between the Unacceptable Region and the "Broadly Acceptable Region". In recent years, it has become evident that the Tolerability of Risk and ALARP framework has been interpreted and implemented in dam safety decision-making in subtly different ways. This paper, prepared with the benefit of and heavily reliant on the advice I received from Mr. J.D. Rimington, the former Director General of the UK Health and Safety Executive and the principal architect of the Tolerability of Risk framework, is intended to set out the underpinning assumptions, the context for its development, essential elements of the framework and how it should be applied to dams.

1.1 Historical development

The Tolerability of Risk framework was developed by a small team led by Mr. Rimington. This was in response to criticisms of the ALARP principle that arose during the Sizewell B Public Inquiry (Layfield, 1987). One of those criticisms was that there was an absence of clear definition or widely understood meaning of ALARP, a principle that

was pervasive in the CEGB's and NII's safety criteria. Further, it was noted that the determination of what constitutes 'reasonably practicable' is not straightforward – a conclusion that was also arrived at with respect 'gross disproportion'. Thus, as of 1987, although ALARP was well-established in safety regulation in the UK, and is effectively embodied in the Health and Safety at Work Act 1974, the inquiry concluded that "the serious shortcomings in the way ALARP is interpreted and applied require much further thought". A further conclusion was that: *"as a first step in formulating guidance on tolerable levels of risk and ALARP, the HSE should publish a consultative document to enable public, expert and Parliamentary opinions to be expressed; the preparation and publication of this document should receive high priority"*. It was clear from the demand of the Sizewell Inspector (Layfield) that the explanation as to why the public should accept the residual risks as "tolerable" (the word used in his report) would need to include both the technical and the political (Rimington 2014). The concept of "Tolerability of Risk" (TOR) emerged from this demand.

1.2 Regulatory context

According to Mr. Rimington; *"The key to understanding the TOR approach, and perhaps the reason why it is difficult for some experts to do so, is to bear in mind that the UK safety regulatory tradition to which it belongs has always involved the regulator negotiating a safe situation with the duty-holder against the background of compulsory powers if the negotiation breaks down. This contrasts with other important approaches, notably the German approach, which (to simplify) places critical reliance on fixed non-negotiable standards, conformity with which is held to be "safe".* Thus, Tolerability of Risk has been formulated to reside within and contribute to the workings of the regulatory traditions of the United Kingdom. This means that it is not necessarily directly transferable to other regulatory regimes.

As noted above, safety has political dimensions and even cultural dimensions. As is the case with regulatory regimes, these matters differ between and even within countries. According to Mr. Rimington, "the British tradition is encapsulated in the idea of 'doing what is reasonably practicable' to achieve safety. This is often referred to (below) as, 'SFAIRP', meaning the situation is safe 'so far as is reasonably practicable". In essence, this idea implies that nothing is ever wholly "safe", but there has to be a process whereby duty-holders must show that they are doing whatever they reasonably can to reduce risk, taking into account what is technically possible, what is good practice, and what is the cost in money and difficulty of doing better. The SFAIRP approach implies the existence of a powerful, well-informed and challenging regulator. "Good practice" is regarded as the minimum requirement, so that, for example, an accepted and published standard will be regarded automatically as reasonably practicable and will be enforced by the regulator. However, the approach recognises that in the real world there are a large number of situations that are not covered or are only partly covered by published or accepted standards. Also, changing technologies bring new and cheaper opportunities of converting existing good practice into what becomes "best practice", while on the other hand wholly new risk situations emerge from the decay of existing arrangements. The notion that duty-holders must show that they are doing whatever they reasonably can to reduce risk is central to the notion of a regulatory regime where there is a continual downward thrust on the risk.

The above implies from the start that some degree of risk is always present in any human activity and must be tolerated; and even adherence to good practice will not alter that situation. If this view is not accepted in a particular society, then there is no basis for proceeding with the implementation of the approach. This is a political issue, not an engineering issue or a matter that can be unilaterally decided by dam owners – unless the dam owner has the political authority to make such a decision.

Further, according to Mr. Rimington:

(i) A deterministic view that adherence to engineering standards and judgement can be accepted as sufficient in itself, is implicitly rejected in terms of SFAIRP.

(ii) Also implicitly rejected is the view, often associated with the deterministic approach, that where a standard includes a numerical goal (as for example with exposure limits for chemicals) the number must be as low as is technically achievable.

According to Mr. Rimington, in the negotiation of exposure limits, the typical approach in the UK has been that it is best to recognise risk and commercial realities and to favour a higher number while relying on strict but flexible regulation to achieve the best available solution (within whatever number is agreed) in particular circumstances. Of course, this does not exclude decisions that a particular substance should be banned altogether, as was e.g. the case with crocidolite."

Thus, if an entity (Government or Owner) adopts an adaptation of the UK HSE's Tolerability of Risk approach, it should explicitly address how it deals with the above policy considerations in a political context.

1.3 Malleable risk situation

While not stated in the literature, Mr. Rimington advised that the TOR approach assumes a "malleable" risk situation, and that most situations in industry are malleable. Those that are less malleable, for example in the case of fixed structures with a long life expectancy, and which can only be reinforced at great expense, are in principle less suited to the TOR approach. An intermediate category is that of complex, large scale operating plant, as in the nuclear industry in relation to which the TOR idea originated. Here the British and international approach has been to fasten on the

initial design process and also to secure the establishment and satisfactory maintenance of a "safety case", in reference to which modifications can take place with regulatory concurrence during the plant's lifetime. Such an approach is incorporated in the European Union's Control of Major Accident Hazards (COMAH) arrangements for non-nuclear high hazard plant, which were originally based on emerging British practice. Given that dams are anything but malleable, this underlying ex-pectation has major implications for how Tolerability of Risk and ALARP might be applied to dams. This matter of malleability is particularly relevant in relation to the downward thrust on the risk noted above.

2. TOLERABILITY OF RISK FROM NUCLEAR POWER STATIONS

The publication of Tolerability of Risk from Nuclear Power Stations by the UK Health and Safety Executive in 1988 represents a notable milestone in regulatory decision-making and communication of technological risk.

2.1 Key criticisms of ALARP during the Sizewell B Inquiry

The Sizewell B Inspector, Sir Frank Layfield noted that the matter of what constitutes 'reasonably practicable' is not straightforward, noting that the nuclear regulator, the Nuclear Installations Inspectorate (NII), considered that 'reasonably practicable' implied that "the responsible person should go out of his way to reduce risk until there is 'gross disproportion' between the expenditure and the corresponding reduction of risk. The Inspector noted that in order to assess whether the costs and benefits are grossly disproportionate, they must be expressed in the same units, i.e. in monetary terms. However, the inspector also noted that as the risk from nuclear power includes a wide range of consequences, such a measure is far from straightforward. It was also noted that in practice, the application of ALARP rarely involved explicit cost-benefit analysis in the design and safety assessment of Sizewell B. Rather, a weighing of costs and benefits was implied by the NII"s pressure to improve safety where it was apparent that this might be done at reasonable cost.

2.2 Response to the Report of the Sizewell B Inquiry

In response to the Report of the Sizewell B Inquiry, Mr. Rimington chaired the Group that was convened to address the demands of the Inspector concerning why the public should accept the residual risk from nuclear power stations as tolerable. The resulting report The Tolerability of Risk from Nuclear Power Stations, which was largely written by Mr. Rimington relying on contributions and help from distinguished experts and on much discussion was published in 1988. The report was revised and republished in 1992. The report of the Royal Society study Group on Risk Assessment (Royal Society, 1983) significantly influenced the conclusions concerning the matter of the level of risk that the public might accept as being tolerable.

The Tolerability Of Risk Group's starting point was to ask what levels of risk the public actually accept (even if unknowingly) both from specific high hazard plants and from natural occurrences. Based on these "accepted" risk levels, levels of risk tolerability for nuclear plant were proposed, taking into account certain specific characteristics of the nuclear risk amounting to an "aversion factor" in any comparison with other risks. It was also pointed out that no risks are ever undertaken except in consideration of a benefit, (in that case, a secure electricity supply) and that this was a factor in any judgement the Government (not the regulator) would need to take into account. The regulator's business was simply to ensure that the risks were reduced to the point where the cost of achieving further reduction would begin to outweigh the benefit in risk terms: comparison and consideration of the resulting overall cost and the overall expected benefit were matters for the Government.

2.3 Numerical estimates of risk in context

The development of Tolerability of Risk recognised that during the 1970s the "science" of risk estimation for complex plant developed strongly, and with it, the idea of defining numerical risk goals for the totality of the plant. According to Mr. Rimington, it was always understood that such risk figures were:

(i) approximations with large error margins

(ii) no substitute for detailed examination and challenge to the various engineering and scientific possibilities emerging during design.

Thus, the Tolerability of Risk approach takes as a premise that estimates of risk are highly uncertain and that this uncertainty must be taken into account in decision-making. However, uncertainty in the risk estimates does not invalidate the approach.

2.4 Tolerability of Risk - Summary

All aspects of Tolerability of Risk was already implicit in the British regulatory. To be more explicit, the basic concept involves accepting that:

(i) nothing is risk-free,

(ii) no engineered structure will ever be completely safe

(iii) there is a limit to the extent of any one set of risks that the public can be expected to tolerate;

(iv) that that limit needs to be defined, and the risks in question driven as far below it as is "reasonably practicable".

Tolerability of Risk recognises that this type of judgement is much easier at the design stage of a complex plant, where each increment in the safety system can be valued by reference e.g., to the cost of the safety barriers that it incorporates. If the estimated residual risk remains above the specified limit then of course the project must be abandoned. It is assumed throughout that best engineering practice will be applied, bearing in mind however that new and complex designs are not simply an assembly of well-engineered items. What is, in effect, rejected by the TOR approach is the idea – however subliminal it may often be –that it is enough to go on pouring concrete or adding steel and stopping when judgement suggests that enough has been done.

3. TOLERABILITY OF RISK AND ALARP IN IMPLEMENTATION

3.1 Limit of Tolerability

That there is an upper limit to the risk that can be accepted (i.e. is tolerable) from a plant or family of plants is fundamental to the Tolerability of Risk concept. Further, the TOR Group proposed, if the upper limit of what is tolerable is specified as a number, that number should be:

(i) Roughly derived from other risk numbers applicable to hazards already accepted by the public, and

(ii) That in calculating the risk, a considerable margin of error needs to be allowed for.

On this basis, it was concluded that it was reasonable to adopt a risk of death of 1 in 1000 per annum, being about the worst that is ordinarily accepted under modern conditons for workers in the UK as the dividing line between what is just tolerable and what is intolerable. The Group also expressed the view that the annual risk of plant failure leading to an uncontrolled release at a modern (nuclear power) station is 1 in a million. When accounting for 'unquantifiable' sources of risk, they judged the chance overall to be between 1 in 100 000 and 1 in 1 million per annum.

According to Mr. Rimington, from that onward the process to be applied is the standard British procedure for bringing about risk reduction based on "SFAIRP" or its parallel "ALARP", (meaning "as low as reasonably practicable").

3.2 Dynamic downward thrust in the ALARP region

Mr. Rimington emphasized that when applied to complex plant, both SFAIRP and ALARP incorporate a dynamic downward thrust which seeks to ensure that avenues for risk reduction are identified at the design stage and during plant lifetime, and are undertaken if any increment of risk reduction is both technically feasible and its cost can be justified in terms of the expected reduction in risk.

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Mr. Rimington explained this dynamic downward thrust as follows: "This downward thrust implicit in SFAIRP and ALARP is expressed in the TOR diagram (Figure 1). The diagram incorporates an "ALARP area" below the limit of tolerability and above the area where the risk level is negligible or generally acceptable. The process of risk reduction operates in the "ALARP" area. The diagram also takes account of a secondary idea borrowed from the legal meaning of "SFAIRP", namely that it is not enough to accept a risk on the basis simply that the cost of further improvement is likely to exceed the associated gain in safety; there should be an element of "disproportion" in favour of risk reduction. This idea is incorporated in the TOR concept as applying (only) where the residual risk is thought to be in the upper part of the ALARP spectrum. It takes account of the fact that risk estimates are always approximate – implying that the real level of risk could exceed the limit of tolerability even if the available calculations suggest that this is not the case. This concept of "disproportion" means in effect that greater efforts have to be made and perhaps more expense incurred to get risk levels down so long as they remain high, i.e., not far below the limit of tolerability.

3.3 Valuing a safety gain

The 1988 report on Tolerability of Risk noted that the attempt to assess costs and benefits of a given proposal can usually achieve an acceptable indication of costs. It can also generate some estimate of the reduction in detriment due to the proposal, subject to all the uncertainties in expert assessment. To convert these reductions in detriment into valued benefits involves a further series of uncertainties in valuing life, and in weighing the future against the present. Nevertheless the general approach is helpful, if for no other reason than it provides yardsticks and a degree of comparability to risk reduction measures. The process of deciding whether a benefit is sufficient to justify a cost therefore involves a judgement in which the above factors inform but do not determine the outcome, and indeed must be combined with further judgements as to what represents the 'gross disproportion' within the meaning of the law. It was recognised that the pragmatic approach to valuing costs and benefits as put forward may not produce the optimal level of safety. However, the ultimate aim should always be to inform and clarify how a final judgment on any safety measure should be made as addition factors will usually be involved in the eventual decisions.

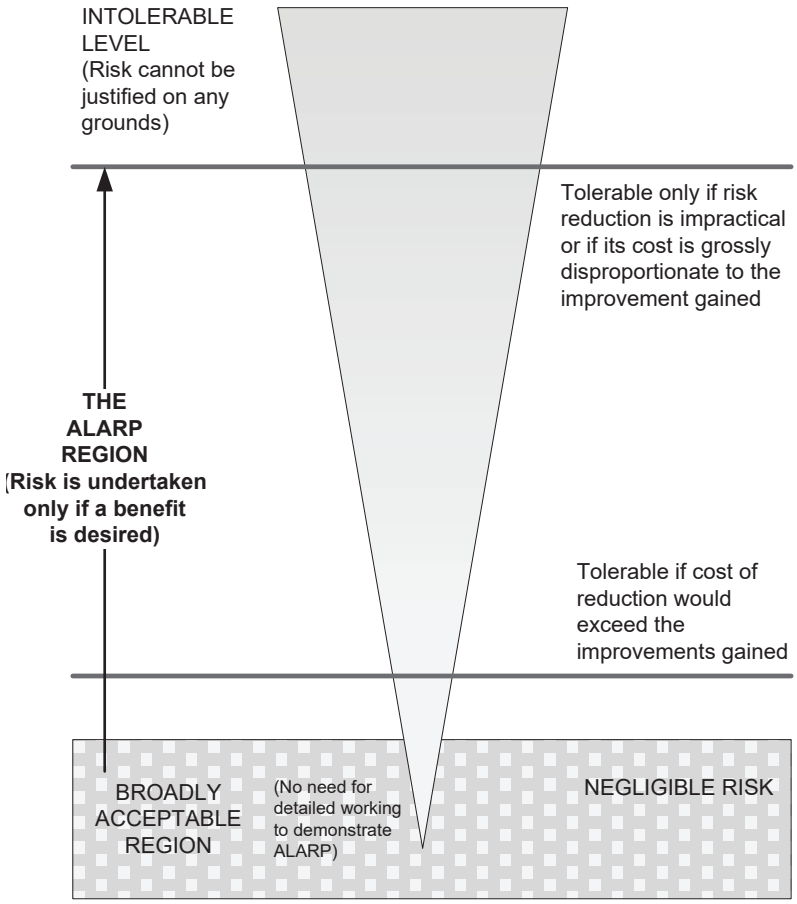

Figure 1 : Levels of risk and ALARP (1988)

3.4 Grounds for objections to Tolerability of Risk

Mr. Rimington addressed the various possible objections to Tolerability of Risk along the following lines. "It may, for example, be objected that what matters is not the risk itself but the perception that the public have of it, which is likely to be influenced more by the possible consequences of an accident than by the probability – or improbability - of its occurrence. This however, if true, is a matter for political judgement and action, not a regulatory issue, and it needs to be remembered that it can cut both ways;- the public may not be at all worried by hazards that – if they understood them better, would scare them stiff. It can also be objected that there is no such thing as a "balance" between cost and risk, and that the idea of such an equivalence is purely theoretical. Finally, it may be objected that risk calculation is such an inexact science that notions of "risk limits" and "risk goals" are not sustainable. We should however note that not only are such calculations made and acted on – and must be made in the era of computer- driven design, -and that the TOR approach simply give structure and method to the kind of calculation we all make whenever we cross a road. Whatever way we may seek to estimate them, risks and costs are both realities of importance. Whatever hesitations there may be about its validity, TOR stands up as a way of looking at critical realities of life in an industrial society where cost and risks have to be accepted and, so far as possible, shared. It is not an exact science, but a way of explaining and justifying a sensible approach to the regulation of high hazards and to the design of the relevant installations".

3.5 Revisions to the Tolerability of Risk Framework

The 1988 version of Tolerability of Risk from Nuclear Power Stations was revised in 1992 following a period of widespread public consultation. While the essence of the 1988 approach was retained, some of the changes were quite subtle. A further statement of Tolerability of Risk was made by HSE in its publication "Reducing Risk, Protecting People (HSE, 2001). The differences in the illustrative diagrams of the Tolerability of Risk framework (Figures 2 and 3).

With respect to nuclear power stations, the numerical values of the 1992 revised report were the same as the 1988 report. It is important to note that where a risk is determined to be in the 'broadly acceptable region', it does not mean that no action whatsoever is required. Rather, the risk is accepted with the provision that normal precautions apply. This was illustrated in both reports with reference to taking normal precautions to avoid the risk of death from lightning.

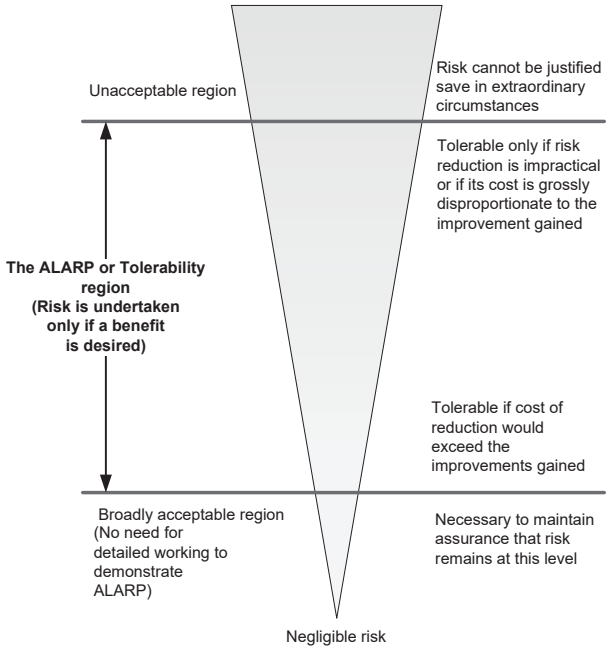

Figure 2 : Levels of risk and ALARP (HSE, 1992)

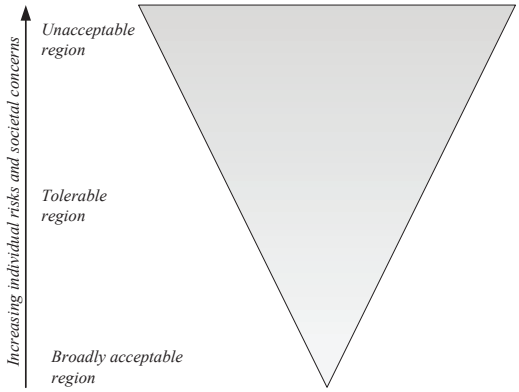

Figure 3 : Conceptual model of HSE framework for tolerability of risk (HSE, 2001)

While the overall framework has remained essentially unchanged since 1998, there have been some subtle changes as noted above and then some quite striking changes between 1992 and 2001. However, an individual risk of death of one in a million per annum for both workers and the public corresponds to a very low level of risk and should be used as a guideline for the boundary between the broadly acceptable and tolerable regions. Of these more striking changes were:

(i) the abandonment of boundary lines between the regions, and

(ii) a more flexible interpretation of the boundary between the 'unacceptable' and 'tolerable' regions

Importantly while noting that the framework is conceptual, the HSE advice is that in practice, risks are controlled to such a degree that the residual risk is driven down the tolerable range so that it falls either in the broadly acceptable region or is near the bottom of the tolerable region, in keeping with the duty to ensure health, safety and welfare so far as is reasonable practicable. At the same time, the HSE did not withdraw its advice concerning the upper limit of tolerability from nuclear power stations. This reflects the broad application of Reducing Risk, Protecting People in the diverse domain of industrial health and safety in comparison to the specific context of nuclear power plants.

4. IMPLICATIONS FOR TOLERABILITY OF RISK FROM DAMS

Although dams were not considered in the development of the Tolerability of Risk framework, Mr. Rimington specifically addressed the matter of the use of Tolerability of Risk in dam safety decision-making with reference to the underlying assumption of a "malleable" risk situation: "In the case of large fixed installations such as bridges or dams, the "TOR" approach has less applicability (though it is not invalid). As noted previously, dams are of the type of fixed structures with a long life expectancy, and which can typically only be reinforced at great expense. In these latter cases the engineering is usually considerably less complex than in an operating plant, and it is perfectly sensible to define an overall risk goal in numerical terms and design to it, while of course maintaining a careful watch to ensure that the risk situation does not deteriorate."

Thus, for large fixed structures such as dams, the idea of a dynamic downward thrust in the ALARP region is impracticable. The process of risk reduction that is intended to operate in the ALARP area referred to in 3.2 above), imposes the strongest thrust higher up the ALARP region, reducing as the lower end of the ALARP region is reached. At the boundary between Tolerable and Broadly Acceptable, measures are required to ensure that the risk stays at that level (Figure 2.). Thus, in principle, the application of Tolerability or Risk and ALARP to dams places the target to be achieved in design at the broadly acceptable level, with operation and maintenance measures designed to prevent the risk from increasing. This view accords with the expectation in the HSE's Reducing Risks, Protecting People that the residual risk is driven down the tolerable range so that it falls either in the broadly acceptable region or is near the bottom of the tolerable region.

4.1 Avoiding a deterioration in the risk situation

As noted in 1.3 above, for complex plants that are amenable to continuing improvement in their safety, the approach has been to fasten on the initial design process and also to secure the establishment and satisfactory maintenance of a "safety case", in reference to which modifications can take place with regulatory concurrence during the plant's lifetime. Dams are not typically not well-suited to this approach. Instead, the approach to dealing with dams must be focused to not only identify the avenues for risk control at the design stage, but to incorporate them to the maximum extent at the design stage when such actions will be either economical or not disproportionately expensive. With reference to Figure 1, the aim at the design stage should be to achieve a level of risk towards the bottom of the risk triangle. After that, it is a matter of a sufficiently high level of maintenance to ensure that there is no deterioration in the risk position over time.

Thus, rather than a dynamic trust to reduce risk as intended when Tolerability of Risk and ALARP for complex, 'malleable' plant, the emphasis for dams is on a dynamic thrust to prevent an already low level or risk from increasing.

4.2 Technological advances and reasonable practicability

While typically dams do not fall into the category of 'malleable', application of the Tolerability of Risk concept to dams does involve keeping a watch for advances in technology and construction methods. This is with the view to determining if newer technologies provide a means of risk reduction that was not available or reasonably practicable at the time that it was previously determined that a particular level of risk was tolerable.

4.3 Societal concerns

Although the importance of the public perception of risk as a consideration in risk assessment emerged in the 1970's and 1980's, risk assessment remained largely a technocratic exercise where public risk acceptance was considered to be represented by accident statistics and societal risk metrics (FN curves) where the accidents did not generally provoke widespread public demands for more stringent regulation. The numerical values of tolerable individual and societal risk used for dams date from the same era as Tolerability of Risk from Nuclear Power Stations or shortly thereafter. Public attitudes have changed dramatically since that time, yet the sciences of societal risk, be they the physical sciences or the social sciences has changed little if at all over the years.

5. CONCLUSIONS

The expectation that the UK Health and Safety Executive's Tolerability of Risk and ALARP approach to demonstrating the safety of hazardous installations could be readily adapted and applied to existing dams is not as realisable as portrayed in the dam safety literature. This is because dams do not conform to the underlying premise of the Tolerability of Risk approach that the industrial situation be 'malleable' meaning that the hazardous installation is amenable to cost-effective improvement in its safety over its life. This, in principle makes structures such as dams with a long life expectancy, and which can only be reinforced at great expense, less suited to the TOR approach.

While the Tolerability of Risk approach has less applicability to dams, it is not invalid. In the case of fixed, long life infrastructures such as bridges and dams, Mr. Rimington considers that: "it is perfectly sensible to define an overall risk goal in numerical terms and design to it, while of course maintaining a careful watch to ensure that the risk situation does not deteriorate."

Thus the application of the UK Health and Safety Executive's Tolerability of Risk and ALARP approach to dams would involve designing dams to achieve a very low level of risk, essentially at the broadly acceptable level, and then maintaining this risk at this low level over the life of the dam through Surveillance and Maintenance. Philosophically and practically, this mirrors long established dam design and safety management practice as set out in ICOLD Bulletin's 61 (Design) and 59 (Dam Safety).

Therefore, the application of Tolerability of Risk and ALARP to dams that are not already very safe is problematic. This is because in terms of the Tolerability of Risk and ALARP approach, risks are only tolerable if they are continually under review (surveillance and maintenance), and the risks are being reduced over the life of the installation (the dynamic downward thrust of the ALARP principle) as and when the opportunity arises and where there propensity to err on the side of safety.

In terms of the Tolerability of Risk Approach to safety management in general, demonstrating that risks from hazardous installations that conform to the premises and principles that underpin the Tolerability or Risk approach are Tolerable and have been reduced As Low As Reasonably Practicable is not a straightforward matter. There is no algorithmic or formulaic method whereby the Consultant can make the safety demonstration on behalf of those with the duty to keep the installation safe in so far as reasonably practicable. In the context of the legal and regulatory regime for which the Tolerability of Risk framework was developed, the matter of Tolerability of Risk and ALARP is a matter between the Regulator and the Duty Holder (owner/operator). Further, the process of reducing risk ALARP is not singular and universally applicable to all industries. The under-lying premise is that the industrial installation is "malleable" and amenable to risk reduction over its life as technologies change, components are replaced and ways of operating improve.

This underlying premise does not apply to dams, as any process of risk reduction over the economic evaluation life of the dam (the time over which the dam becomes fully depreciated in accounting terms) will rarely be at reasonable cost. However, since the physical life of a dam usually exceeds its economic evaluation life Dam owners who are considering declaring their dams to be safe because the "risks and tolerable and ALARP" have good reason to reconsider their positions as the conventional ALARP test for 'malleable' industrial operations is not fit for purpose for long-life, fixed infrastructures.

ACKNOWLDEGMENTS

This paper is based largely on a documented account of the essential underpinnings and elements of the Tolerability of Risk approach entitled "THE TOLERABILITY OF RISK (TOR) APPROACH - A brief description", dated 11 December 2014 as received from Mr. John D Rimington CB, who was the principal architect of the approach. This account of the Tolerability of Risk approach from discussions between the Author, Mr. Rimington and Dr. James McQuaid CB, former Chief Scientist and Director of Science and Technology at the UK Health and Safety Executive concerning the applicability of the approach to dams. This paper also reflects numerous subsequent discussions and e-mail correspondence with Mr. Rimington and Dr. McQuaid that have been ongoing since the early 2000's. The paper also relies on various discussions with the late Dr. Jean Le Guen, OBE, former head of the Risk Assessment Policy Unit at the UK Health and Safety, and principal author of "Reducing Risks, Protecting People".

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