

RECLAMATION

Managing Water in the West

Interim

Rationale Used to Develop Reclamation's Dam Safety Public Protection Guidelines



U.S. Department of the Interior
Bureau of Reclamation
Dam Safety Office
Denver, Colorado

August 2011

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Purpose and Nature of the Guidelines

Reclamation initiated use of quantitative risk analysis to support decision making for dam safety in the mid-1990s. This was based on the belief that quantitative risk analysis, applied in a consistent and comprehensive manner, would facilitate risk identification, improve the quality of decisions and help prioritize dam safety actions resulting in the greatest reduction in public risk for the money expended. Improved decisions through risk analysis, risk assessment, and risk management are believed to come about in two ways:

1. Improved understanding of the problems and vulnerabilities of a facility is achieved through failure mode identification and systematic evaluation of entire dam systems, leading dam safety teams to develop and propose better risk reduction alternatives or recommend more appropriate courses of action to address issues that have been raised relative to dam safety.
2. Improved capability to prioritize and plan dam safety risk reduction actions is achieved through the use of quantitative risk evaluations relative to risk assessment guidelines and consideration of site specific factors.

Although the use of quantitative risk analysis with a consistent established process was the driving force behind the development of Public Protection Guidelines, Reclamation also recognized that risk analysis procedures, although quantitative, do not provide precise numerical results. Thus, Reclamation wanted the nature of the risk analysis to be advisory, not prescriptive, such that site-specific considerations, good logic, and all relevant external factors could be applied in decision-making, rather than reliance on a “cookbook”, numeric criteria approach. *Toward that end, the term “criteria” is not used in Reclamation’s Public Protection Guidelines. Reclamation has also chosen not to use the term “tolerable risk.” This is in recognition that the risk numbers are only approximate, are produced by a variety of methods (often including expert judgment) and by a variety of individuals and teams. A hard line separating tolerable risk from risks that cannot be tolerated would be difficult to define under these conditions. In addition, it is recognized that risk is just one input to the decision process and that other factors go into deciding what can be tolerated by the organization. Therefore, Reclamation’s terminology takes the form of “increasing justification to reduce or better understand the risks” or “decreasing justification to reduce or better understand the risks.” However, that does not suggest that the risk guidelines should be taken lightly. Indeed, every effort should be made to meet them.*

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The Public Protection Guidelines require consideration of two aspects of dam safety risk, which will be described further in this document.

1. The annualized failure probability
2. The consequences in terms of fatalities resulting from failure

Purpose of this Rationale Document

In 1999, a document entitled *Background on Philosophy and Technical Rationale for Reclamation's Dam Safety Public Protection Guideline* [1] was drafted and presented to Reclamation dam safety management. The document provided information on the following key concepts:

1. Purpose and nature of the guidelines;
2. Summary of the guidelines and guideline rationale; and
3. Issues considered in developing the guidelines.

Two key concepts of dam safety risk were described: the “likelihood of failure” and “likelihood of life loss resulting from failure”, and specific quantitative background data was provided for these two concepts. Although the document was never published, it provided valuable information. Therefore, the decision was made to complete a similar report for the 2011 Public Protection Guidelines revision in support of Reclamation’s procedures and to document the reasoning behind the guidelines. Where applicable, information from the 1999 document is included as part of this rationale document. The purpose of this report is to: (1) document the philosophy and rationale that was used to develop the Public Protection Guidelines, (2) briefly describe how Reclamation’s Public Protection Guidelines have evolved over time; and (3) present information that supports the rationale used for the Public Protection Guidelines.

Evolution of the Public Protection Guidelines

Reclamation first instituted interim guidelines by means of a document dated April 4, 1997. Minor updates were made for the June 15, 2003 version of the guidelines. These updates included revisions to risk terminology, changing from “Tier 1” to “Annualized Loss of Life” and from “Tier 2” to “Annual Probability of Failure”. Importantly, the guidelines reflected the actual practice of Reclamation from 1997 through 2003 in applying dam safety risk management principles. Since all dams represent some level of risk to the public, the title, “Guidelines for Achieving Public Protection in Dam Safety Decisionmaking,”

was chosen for these documents to convey the fundamental purpose of the Dam Safety Program and related decisions. This “results oriented” title was chosen in lieu of something like “tolerable risk criteria” to put the focus on managing risk, not tolerating risk. Since they were routinely referred to as the “Public Protection Guidelines,” that shortened title was retained for the 2011 update described in this rationale document. It should be noted that “risk assessment guidelines” are part of and contained within the Public Protection Guidelines, but that the Public Protection Guidelines go further in providing some guidance for risk reduction actions and prioritization of activities.

Supporting Information used for Guideline Revisions

This supporting document is a companion to the 2011 Public Protection Guidelines. To supplement the original rationale, Reclamation has accumulated information from two additional general sources:

- Documents produced in the last 10 years relating to risk management practices
- Experience using the previous versions of the Public Protection Guidelines

Documents Relating to Risk Guidelines

The 2011 revision to the Public Protection Guidelines involved examining documents produced by other agencies and organizations related to risk guidelines. It was evident that there is a general trend toward using risk as a basis for making decisions regarding dam safety. Organizations such as the Australian National Committee on Large Dams (ANCOLD) [2], the Canadian Dam Association (CDA) [3], and the Australian State of New South Wales Dam Safety Committee (NSW DSC) [4] have published risk guidelines for dam safety. In general, these guidelines are more similar than they are different. Portions of these reports influenced the revision of Reclamation’s guidelines as discussed later in this document.

Reclamation Experience

Reclamation has learned much from the years of experience using its Public Protection Guidelines, and many of the lessons learned have been incorporated into the revised guidelines document. After more than 15 years of applying risk guidelines to decisions regarding the need to take dam safety risk reduction actions, as well as prioritizing those actions, it was recognized that a few areas required improvement, as follows:

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1. Reclamation's previous guidelines had a threshold for annualized life loss risk above which there was justification to take "expedited" action. In several cases the risk estimates would be in this area, only to come down significantly when examined in more detail. The risk numbers are only approximate and are developed by different people in different ways with different information and confidence levels. Therefore, using the numbers to establish the urgency of actions (i.e. justification to take expedited action) and as the primary basis for prioritizing dam safety activities was not considered to be the best approach, and the expedited category was deleted in the 2011 revision to the guidelines.
2. This led to the adoption of a Dam Safety Priority Rating (DSPR) system to assist with establishing the urgency and priority of actions, as discussed later.
3. Dams with an estimated low probability of failure but large associated consequences represent cases that are difficult to evaluate in a risk-informed manner. It takes extraordinary effort to obtain loadings and estimate failure probabilities to the remote probabilities needed to evaluate annualized life loss at the levels required by Reclamation's previous guidelines. Even when this effort was expended, the results had a high degree of uncertainty. Therefore, these dams are now treated somewhat differently, as discussed later.
4. Reclamation's previous annualized life loss guidelines were based on comparisons by load class (static, hydrologic, and seismic). This made it difficult to compare dams and was inconsistent with the way in which other organizations approach this issue. Therefore, total risk is used to compare to the revised guidelines.

Terminology

Risk, Risk Management, Risk Assessment, and Risk Analysis

Considerable confusion exists with these terms. OMB uses different terminology in their *Updated Principles for Risk Analysis* memorandum [5], and other organizations have slightly different definitions. Reclamation has used these terms since risk was explored in the 1980s and has chosen not to change at this point. The terms are defined in the Public Protection Guidelines and are not repeated here. Figure 1 shows how the various aspects of risk management fit together in Reclamation's terminology, which is generally consistent with other infrastructure agencies.

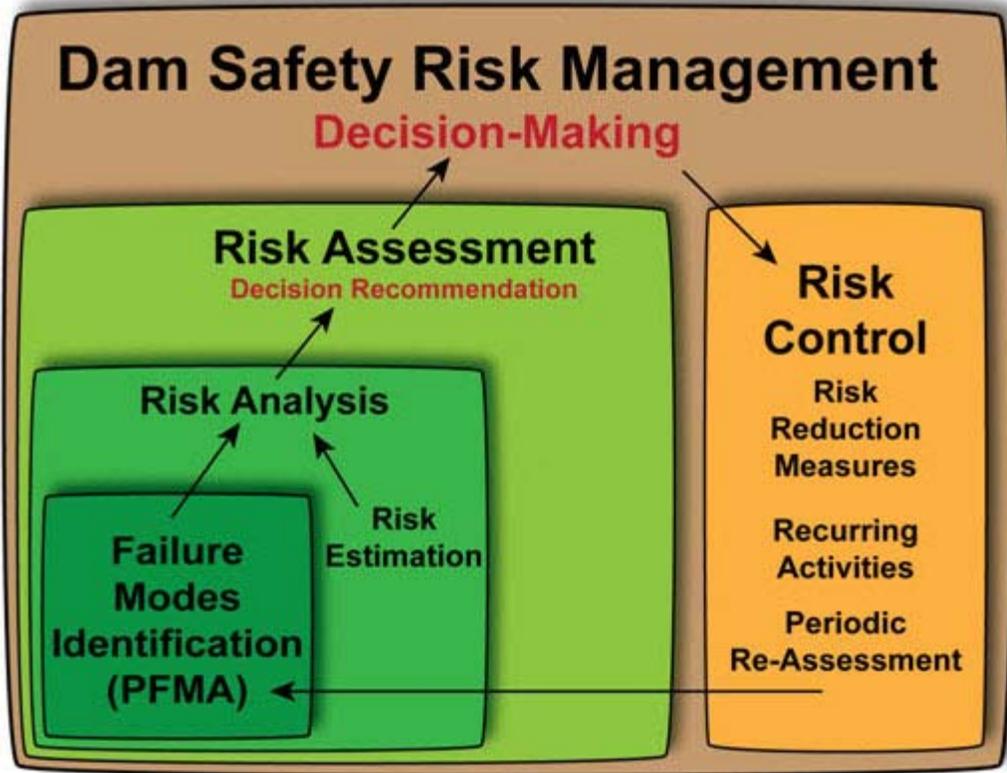


Figure 1. Risk Management Framework for Reclamation

Individual and Societal Risk

The terms individual and societal risk are definitions used by other water resource organizations. Reclamation recognizes these definitions, but instead uses Annualized Failure Probability to cover individual risk considerations and Annualized Life Loss to represent societal risk. This allows the guidelines to be combined into a single f-N chart. The 2011 revised Public Protection Guidelines make no changes in this regard, as Reclamation management is comfortable with this portrayal of the guidelines, and no compelling reason could be found to break these into two separate plots. It should be noted that previous versions of the Public Protection Guidelines used the term “Annual” Failure Probability instead of “Annualized” Failure Probability. The change was made to convey the idea that the failure probabilities are typically “annualized” by multiplying conditional failure probabilities by the annual load probability.

ALARP

“As Low as Reasonably Practicable” is a concept that relates to looking at what can be reasonably done without spending an inordinate amount of time, money, and/or resources relative to the risk reduction benefits, and deciding if that is good enough. Is the agency comfortable with and can it justify continuing to operate the facility under the current residual risk? This concept has not been fully

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utilized in Reclamation prior to the 2011 revision to the Public Protection Guidelines. However, it is expected to play a greater role as dams with no apparent deficiencies but with large consequences are evaluated in the future.

Annualized Failure Probability

Reclamation's guideline uses the term annualized failure probability as opposed to individual risk, since an exposed individual may not perish in the event of dam failure (particularly if dam breach flooding is not particularly severe). In Reclamation's dam safety portfolio, high and significant hazard dams are not distinguished. Both are capable of releasing life-threatening flows with the potential to flood some population, although in the case of significant hazard dams the exposed population may be transient. However, nearly all of the structures managed by the Dam Safety Program are high hazard, so Reclamation's annualized failure probability will generally approximate other groups' "individual risk."

The annualized failure probability guideline was selected to be 1 in 10,000 per year. In the international water resources industry, this threshold is consistent with individual risk guidelines established by the UK Health and Safety Executive (HSE), Australian National Committee on Large Dams, New South Wales Dam Safety Committee, and the Canadian Dam Association. Reclamation originally selected this guideline considering that:

- The guideline should promote a condition better than the historical rate of dam failures prior to the late 1970s, which mark the implementation of Federal and state dam safety programs and the passage of Federal Dam Safety Legislation, and;
- A risk estimate that exceeded the historic failure rate prior to the implementation of dam safety programs would imply that there would be strong justification to evaluate or implement risk reduction actions.

This guideline also roughly matches the thresholds of failure used by other industries including commercial aviation, environmental protection, food and drug, and nuclear power, although actual documentation of thresholds is extremely difficult to find. The first infrastructure-related document that refers to this limit can be found in the original HSE efforts to use risk to manage the UK oil and gas industry in the 1990s following the Piper Alpha oil spill accident of 1988.

This threshold has apparently proven useful and rational for a number of organizations and applications, as the limits remain the same today. Reclamation examined this limit in relation to its entire inventory of high and significant hazard structures, and determined that it was comfortable with the overall inventory risk if failure probabilities could be kept below an estimated 1/10,000 per year for every dam.

Background Risk

It's important to place the 1 in 10,000 annualized failure probability threshold in the context of the background mortality probability to individuals from all causes. The goal of the annualized failure probability guideline is to keep hazards posed by Reclamation facilities from increasing the probability of death for an individual in the inundation areas significantly above the background levels the individual would already be exposed to. Driving the threshold lower would reduce this contribution, but it would come at a cost. Costs to Reclamation, and thus the American taxpayer and water-users, increase dramatically for each order of magnitude the threshold is lowered, and at some point the incremental reduction in risk contribution is inconsequential. Wise use of taxpayer and water-user resources requires avoiding expenditures of excessive amounts to reduce risks to "near zero." Therefore, a reasonable and balanced threshold must be selected. A threshold limit of no more than 1 chance in 10,000 of failure per year reasonably balances the competing requirements of wise stewardship of the taxpayer resources and maintaining structural reliability of the facilities in which the nation has invested.

Figure 2 shows quantitatively the fatality rate as a function of age for all U.S. citizens from all causes. It can be seen that the threshold value of 1 in 10,000 is

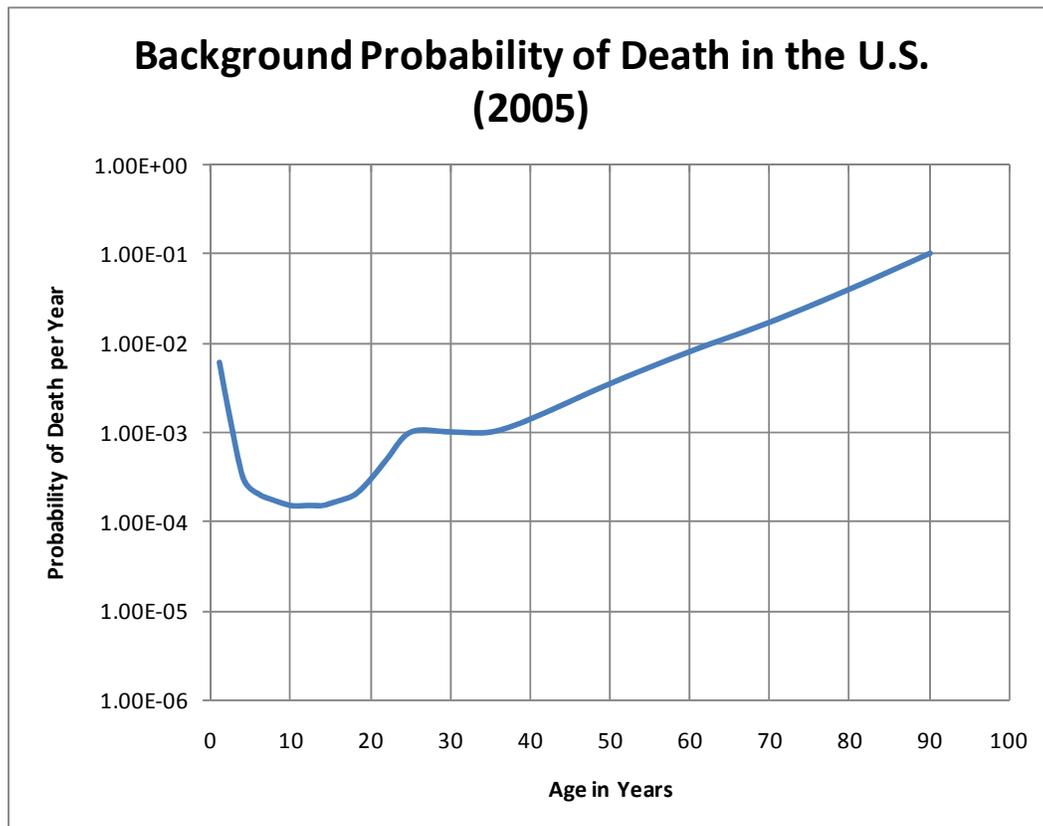


Figure 2. Background Probability of Death (from the CDC, 2005)

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below the total for all age groups, and over the course of an average lifetime, is well below the total. This suggests that on the average, dam failure would contribute a small portion of the risk to even the most exposed individual living below a dam in the U.S. if the annualized failure probability is 1/10,000 or less. In general, the number of fatalities compared to the number of people in an inundation zone has been small (typically a few percent), and therefore the background chance of dying from dam failure for all those living in any dam break inundation zone in the U.S. is actually very small.

Health and Safety Executive (UK)

HSE [6] lists “tolerable limits” for individual risk across all industries as follows: *“In our document on the tolerability of risks in nuclear power stations, we suggested that an individual risk of death of one in a thousand per annum should on its own represent the dividing line between what would be just tolerable for any substantial category of workers for any large part of a working life, and what is unacceptable for any but fairly exceptional groups. For members of the public who have a risk imposed on them ‘in the wider interest of society’ this limit is judged to be an order of magnitude lower – at 1 in 10,000 per annum.”*

Australian National Committee on Large Dams (ANCOLD)

The 2003 ANCOLD guidelines set the limit for individual risk as follows: *“For existing dams, an individual risk to the person or group, which is most at risk, that is higher than 10^{-4} per annum is unacceptable, except in exceptional circumstances. For new dams or major augmentations of existing dams, an individual risk to the person or group, which is most at risk, that is higher than 10^{-5} per annum is unacceptable, except in exceptional circumstances.”* The document goes on to say: *“Life safety risks should be reduced below the limit of tolerability to the extent that is dictated by the ALARP principle.”*

New South Wales Dam Safety Committee (NSW DSC)

The New South Wales Dam Safety Committee states the following for individual risk in their 2006 guidelines; *“For existing dams, the DSC’s limit of tolerability is 1 in 10,000 per annum, which is the same as that of ANCOLD and of the Health and Safety Executive, United Kingdom (HSE). For proposed dams and major augmentations, the DSC’s limit of tolerability is 1 in 100,000 per annum, which is the same as that of ANCOLD.”*

Canadian Dam Association (CDA)

The 2007 Canadian Dam Association guidelines consider the following with respect to individual risk: *“The individual risk should be considered in terms of the ‘maximally exposed individual’ that is permanently resident downstream of the dam. Typically the maximally exposed individual is exposed to the hazard*

significantly more than 50% of the time. The maximum level of individual risk should generally be less than 10^{-4} /year.”

Reclamation's Record

Reclamation's historical record through the time of the Teton Dam failure was 1 failure out of 365 dams and dikes in 1976. This equals about 1×10^{-4} failure probability per dam year of operation (with about 10,300 dam years of operation at the time). The objective of the threshold, then, would be to strive to have Reclamation structures be better than the failure rate at the time of the Teton disaster (prior to modern dam safety legislation and programs). Public confidence in dams and Reclamation's stewardship in protecting the public are reasonably balanced with taxpayer expenditures needed to maintain each dam in the inventory at some minimum safety level by specifying that the likelihood of failure of any dam capable of releasing life-threatening flows be less than 1 in 10,000 annually.

U.S. Dams

Statistical data compiled in the mid-1980s on dam failures and accidents (Von Thun [7] and Hatem [8]) indicate an overall dam failure rate somewhat greater than 1/10,000 per dam year of operation. This is not surprising since the statistics would be somewhat more influenced by the time period prior to the implementation of modern dam safety programs. These evaluations considered all types, ages and heights of dams. The database includes dams which were constructed without a design provided by an engineer. Von Thun's evaluation compared failure and accident rates on the basis of type of dam; type of failure; Eastern vs. Western United States; dams built before 1930, 1930-1960, and after 1960; and dams less than 50 feet high, 50-100 feet, 100-300 feet, and >300 feet. The annual failure rate range for any category (e.g. Western U.S. embankment dams less than 50 feet high built after 1960 that failed by piping) was typically from 1×10^{-3} to 1×10^{-4} per dam year of operation where a reasonable number of dams were in the data base. The overall failure rate was about 1.4×10^{-4} per dam year of operation. This rate was strongly controlled by earth dams less than 50 feet in the Eastern U.S. due to the large number of dams in this category. Hatem also considered failure rates for numerous categories, including a break out for failure rates after 5 years of successful operation. His overall failure rate was estimated to be 2.6×10^{-4} per dam year of operation and his estimate for dams that survived at least 5 years of successful operation was 1.1×10^{-4} per dam year of operation.

More recent evaluations by Foster et al [9] and Douglas et al [10] in 1998 indicate failure rates for dams that survived their first 5 years have reduced somewhat, to about 0.8×10^{-4} per annum for both concrete and embankment dams, indicating that the number of dam failures is decreasing as the number of successful dam years of operation is increasing. Continuing to strive to reduce dam failure rates as far below 10^{-4} as reasonably practicable will help ensure this will continue to be the case.

Reclamation's Selection

Reclamation selected a “gradational break” at 1 in 10,000 per year as the threshold for total annualized failure probability (which can be considered similar to individual risk). This is primarily based on:

- The adoption of the 1 in 10,000 limit per year by other organizations dealing with similar hazards in modern societies.
- Comparison to the background probability of death for the U.S. and keeping dam failure to a small part of this probability.
- Comparison to the average failure rate for dams in the U.S. prior to the implementation of modern dam safety legislation and programs and ensuring that Reclamation's future rate would be lower.

Additional considerations included:

- Balancing safety and structural reliability with the need for responsible stewardship of the Nation's resources.
- Eliminating the need for the potentially complex and unsettling task of trying to identify the specific most threatened individuals and assessing their personal risk contributors.
- Emphasizing that any failure of a Reclamation dam, even if no life loss occurs, would erode public confidence.

Annualized Life Loss

Reclamation's annualized life loss is generally equivalent to the term “societal risk” that is used by some other groups involved in risk assessment.

Ball and Floyd [11] provide a thorough examination of societal risk guideline development in the U.K., Hong Kong, and the Netherlands through 1998. Originally developed by Ball and Floyd, Figure 3 has been updated for this document to include some key incidents in the U.S.

Conceptually, societal risks are thresholds used to reflect the notion that society is increasingly averse to single high consequence events. For example, on any given day more than 100 people may die on U.S. highways in individual car accidents. Most people will not hear about any of these. On the other hand, if an airliner went down and more than 100 people were to perish in this single event, it would be national and international news. To reflect this concept, the threshold for societal risk is usually plotted as a line with a negative slope on an f-N or F-N chart. That is, as the consequences increase for any single event, the probability

of that event must decrease. Following is a review of societal risk guidelines of other organizations.

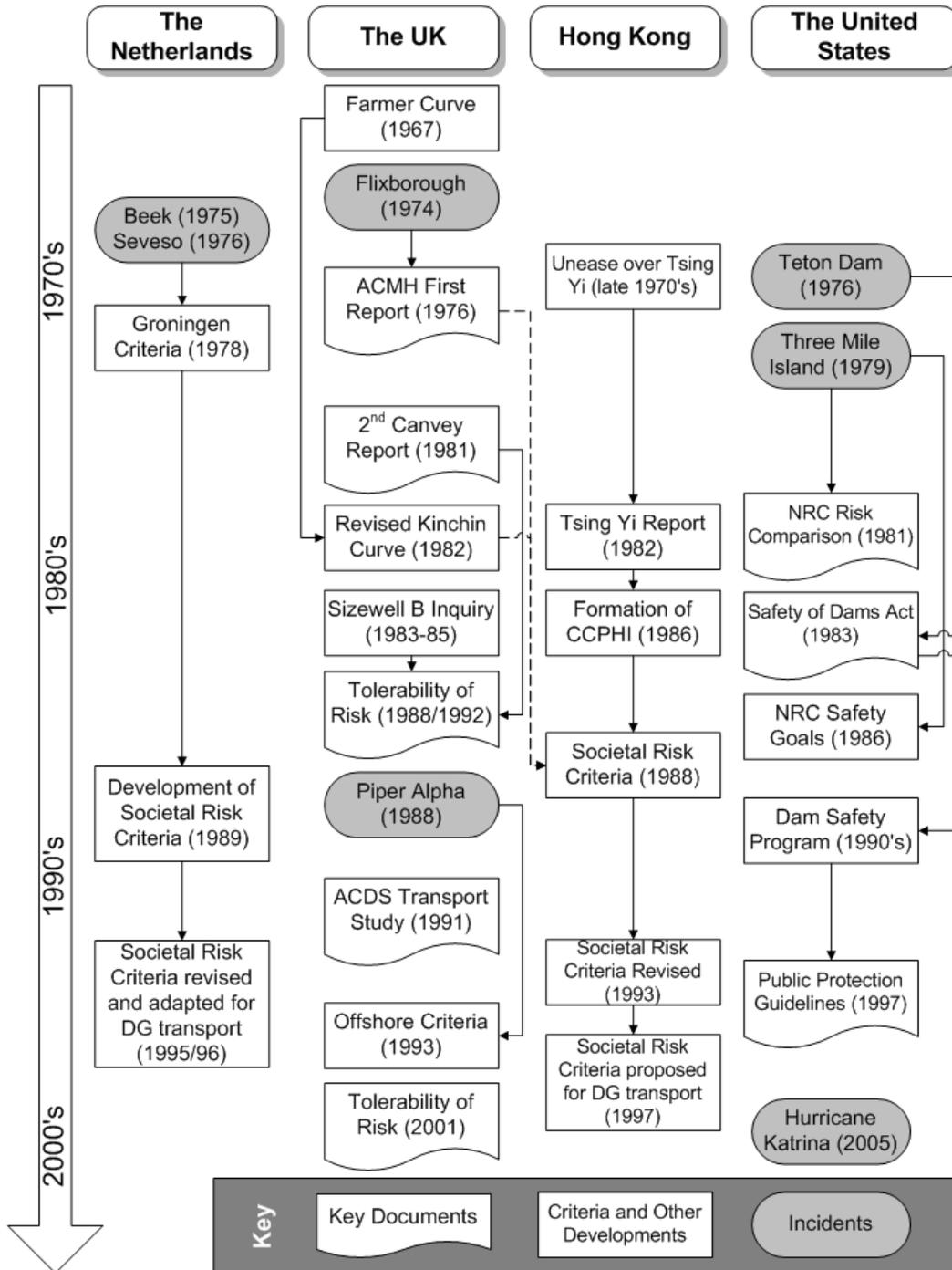


Figure 3. Milestones in the Development of Societal Risk Guidelines (Adapted from Ball and Floyd 1998; note dates are approximate)

Health and Safety Executive (UK)

In the U.K., the development of societal risk can be traced as far back as 1960s from work done by the U.K. Atomic Energy Authority and the eventual development of the “Farmer Curve” that regulated the frequency of Iodine-131 releases. Progress continued in many sectors, in some cases spurred by large accidents such as the Piper Alpha oil spill disaster in 1988. In 1995 HSE defined societal risk as:

“The risk of widespread or large scale detriment from the realization of a defined hazard, the implication being that the consequence would be on such a scale as to provoke a socio/political response, and/or that the risk (ie the chance combined with the consequence) provokes public discussion and is effectively regulated by society as a whole through political processes and regulatory mechanisms.”

ANCOLD

In 1994, ANCOLD published its societal risk curve that corresponded to an annualized life loss of 0.001 lives per year, but included a horizontal truncation at an annualized failure probability of 10^{-6} on the F-N diagram. This truncation was elevated to 10^{-5} in their 2003 revision. They note in their 2003 guidelines that:

“The horizontal truncations . . . are without precedent, but represent ANCOLD’s present judgment of the lowest risks that can be realistically assured in light of:

- *Present knowledge and dams technology; and*
- *Methods available to estimate the risks.*

In the case of existing dams, many were built long ago using very poor technology. Whilst some aspects of safety can be improved, it is simply impracticable to bring such dams full up to the safety levels of a well designed and constructed modern dam. The choice is to either accept the horizontal truncation or to abandon the dam. Since dams are of significant benefit to society, it is considered that the horizontal truncation is justified.”

New South Wales Dam Safety Committee

The New South Wales Dam Safety Committee (DSC) established societal risk guidelines as follows:

“Where safety is judged by reference to the DSC public safety risk guidelines, the DSC requirement for the long-term is that societal risk be below the limit of tolerability [0.001 lives per year for existing dams and 0.0001 lives per year

for new dams] *to the extent dictated by the ALARP principle. . . The DSC is aware of two key considerations:*

- *The potential for loss of many lives is of great concern and loss of over 1,000 lives would be seen by society as catastrophic at the international scale. In addition, the economic costs of such large tragedies are so great that it may be that the Federal Government would have to intervene; and*
- *It is increasingly difficult to reliably estimate probability of failure as it reduces and little confidence could be attached to estimates of probability lower than 1 in 100,000 per annum.*

In judging whether the risks of an existing dam with potential for loss of more than 1,000 lives could be accepted, the DSC will weigh these facts very carefully.”

The last two considerations and associated commentary led to the establishment of a special case for existing dams where the annualized failure probability was estimated to be less than 10^{-6} , and the life loss was estimated to be greater than 1,000. If risks are estimated to fall in this area, the need for action is determined by a critical review of the risks, and costs and benefits of alternative actions.

Canadian Dam Association

The Canadian Dam Association published societal risk guidelines, as follows:

“[The guideline with -1 slope is] based on the understanding that the maximum level of societal risk for life safety should be less than 10^{-3} /year for loss of one life that was not explicitly foreseen and identified in advance of the failure; a higher risk is considered ‘unacceptable’.”

The Netherlands

The Netherlands has adopted a slope of -2 for its societal risk guidelines associated with the chemical industry; although, no formal guidelines exist for the dam and levee safety industry. This means that as the consequences increase, the annualized failure probability must decrease by twice that amount. This indicates that the Dutch are more averse to large consequences events than most other societies.

Reclamation’s Selection

Reclamation has selected a “gradational break” with an anchor point at 10^{-3} annualized failure probability and 1 life lost, sloping at -1 towards the x-axis (representing a total annualized life loss of 0.001 lives per year, which is generally consistent with the guidelines of other dam safety organizations) until it

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reaches 10^{-6} probability of failure and 1,000 lives lost. Below and to the right of this point is an area that has special requirements as discussed below.

Low Probabilities and High Consequences

Decisions related to structures for low failure probabilities combined with high consequences have been difficult to address for both decision-makers and risk estimators. The fact that the 2003 annualized life loss guideline of 0.001 lives per year was extended to very low annualized failure probabilities and high consequences has led to extrapolation of seismic and hydrologic hazards into areas where the basis for the results becomes unreliable. Predicting events with annual exceedance probabilities more remote than about 1 in a million results in extreme uncertainty that must be factored into the decision process.

Structures that have the potential to cause more than about 1,000 deaths are generally large in size and highly visible; are important to Reclamation, the local community, the region, and the economy; and the public is generally aware of their proximity to the reservoir. Because of this, these structures generally receive added attention during all parts of the risk management process by both decision-makers and technical staff. The existence of structures that have the potential to cause severe catastrophes indicates that the trade-off between the hazards posed by the structure and the benefits secured by it should not be taken lightly. It will not always be possible to quantify numerical estimates to the point where estimators will be able to adequately defend the precision and robustness of the risk estimates. There will also always be uncertainties with respect to the conditions of the structures. This does not mean that structures which fall into this category should be ignored or that an attempt should not be made to obtain the best information possible. The opposite is true, although the costs of obtaining the information should be carefully weighed against the potential to gain useful insights that could be used to support a decision. ALARP principles should be considered and actions weighed according to their costs and the residual risks posed by the structure.

Reclamation's revised Public Protection Guidelines include an area bounded by 1×10^{-6} on the top and 1,000 lives lost on the left, similar to those of the New South Wales Dam Safety Committee. If risks are judged to fall in this region, a careful evaluation of the tradeoffs in costs and effort to reduce risks should be undertaken, and ALARP principles applied to the decision making. In these cases, the decisions could involve stakeholders, with public involvement if risk and cost tradeoffs are significant. The importance and visibility of the structure may necessitate modifications that include redundant defensive measures which would improve the performance of the structure. In some cases, this may not be cost-effective. In any case, the manner and approach to reach a decision will require substantial coordination between risk estimators and decision-makers.

There is a lower bound of the likelihood of events beyond which results become unreliable. There is also a threshold beyond which the magnitude of the consequences necessitates extraordinary measures to control risks. However, setting a horizontal threshold below which risk reduction measures need not be evaluated was not considered appropriate. Likewise, setting a vertical threshold to the right of which risks are unacceptable irrespective of the likelihood of the event could necessitate decommissioning projects whose societal benefits are extremely valuable. Therefore, it is appropriate to treat low probability and high consequence situations with care and ensure everything reasonable has been done to reduce risks. Decisions should be made in those cases considering all relevant information rather than using uncertain risk calculations to avoid a potentially difficult decision.

Other Limits

Reclamation's guidelines suggest that the target for risk reduction actions related to major rehabilitation be an order of magnitude below the annualized failure probability and annualized life loss guidelines to ensure that uncertainty, hazard creep, and robustness are considered in the decision process. Although the cost-effectiveness of reaching this level of risk reduction must be considered before deciding to pursue such an alternative, it is typically achieved.

These Dam Safety Public Protection Guidelines are for use in evaluating high or significant hazard dams and are not applicable to the evaluation of risks for low hazard dams or other features, such as canal embankments or levees.

Building the Case and Prioritization

The developers of Reclamation's original Public Protection Guidelines indicated that, *"It should be clear that risk estimates plotting just below this gradational break line have almost as strong justification for action as those just above. . . Reclamation readily recognized that diligence in efforts to prevent the 'gradational break' from becoming 'rigid criteria' need to be made and sustained."* Despite this warning, as time passed and those enforcing the guidelines were different than those involved in their development, the organization gradually transitioned to a practice where the risk estimates and the guidelines were treated as nearly absolute criteria. If the mean point plotted above the line then there was a recommendation to take action, whereas if the point plotted below the line there was not. Further, the priorities were established by sorting the risk estimates in a spreadsheet and giving top priority to the highest numbers. This might have been reasonable if all the risk estimates were consistently generated by the same people, but this was not the case. During the process of revising Reclamation's Public Protection Guidelines, it was decided that measures should be taken to reduce the tendency to rely strictly on the risk estimates as a criteria for decision-making.

Building the Case

The first step in getting away from strict reliance on the risk numbers is requiring what has been termed as “building the case” for all dam safety decision documents. Going through the process of developing the risk estimates, if done thoroughly and rigorously, will result in the “learning” needed to build the case. A well-constructed case should be capable of convincing the decision-makers that (1) the interpretation of the condition of the structures and their ability to withstand future loading, (2) the risk estimates, and (3) the recommended actions are all coherent and make sense. As part of the case, three elements must be addressed: (1) whether the estimated risk justifies action, (2) if so, the urgency of taking action, and (3) the confidence in the estimates and whether additional information is likely to change perception of the need and/or urgency to take risk action. All three components of the risk estimates must also be addressed: (1) the loadings, (2) the response of the structures to the loadings, and (3) the consequences. The case is built from arguments, or claims, and the evidence to support them. These claims and evidence are used to support the risk estimates, not the other way around. Thus, reliance on the risk estimates can be tempered by decision-makers with how well the case has been built.

Prioritizing Actions

As a general rule, as the annualized failure probability and annualized life loss increase, the justification and urgency to take action also increase. Similarly, as the annualized failure probability and annualized life loss decrease, the justification and urgency to take action also decrease. It is important to strive to develop consistent risk estimates through established methodology and review. However, it must be recognized that risk estimates are likely to come from a variety of sources. Complete consistency in the estimates cannot be expected.

In order to avoid prioritization strictly based on the risk numbers, a Dam Safety Priority Rating (DSPR) system has been introduced into Reclamation’s dam safety Public Protection Guidelines. Although where the risk estimates lie relative to the threshold limits established by the guidelines help establish the DSPR classification, the relative classifications assigned to various dams may not be totally consistent with their relative risk estimates. For example, a dam with very high risk estimates could be classified in a lower DSPR category than a dam with lower risk estimates, depending on the confidence in the estimates, cases that are built and the relative sense they provide on how the dams compare.

It is expected that there will be a significant number of dams in DSPR Categories 2, 3, and 4 (particularly in the last two). Therefore, other factors, such as those listed below, have been brought into the DSPR system for use in prioritizing activities. Within any given DSPR category:

- A case where both the annualized failure probability and the annualized life loss are high (exceeding risk assessment guidelines) would generally be more critical than a case where only one or the other is high. Equal weight would be given to cases where one or the other (annualized life loss or failure probability) exceed the guidelines.
- A case where the high annualized life loss or failure probability is driven by a single potential failure mode would generally be more critical than a case where several potential failure modes must be accumulated to arrive at high risk.
- A case where the risk is driven by potential failure modes manifesting during normal operating conditions would typically take priority over cases where the risks stem primarily from large flood or earthquake loadings.
- A case where the uncertainty band is relatively tight and the mean and median estimates are close to each other would take priority over a case where there is significant scatter in the data and the mean and median are far apart.
- A case where it is relatively easy and inexpensive to mitigate or confirm the risk may take priority over a case that is difficult and expensive to mitigate or confirm.

Note that a case where there is direct evidence that failure is in progress and/or the dam is very likely to fail if action is not taken quickly would be considered the highest priority, and would be DSPR 1.

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