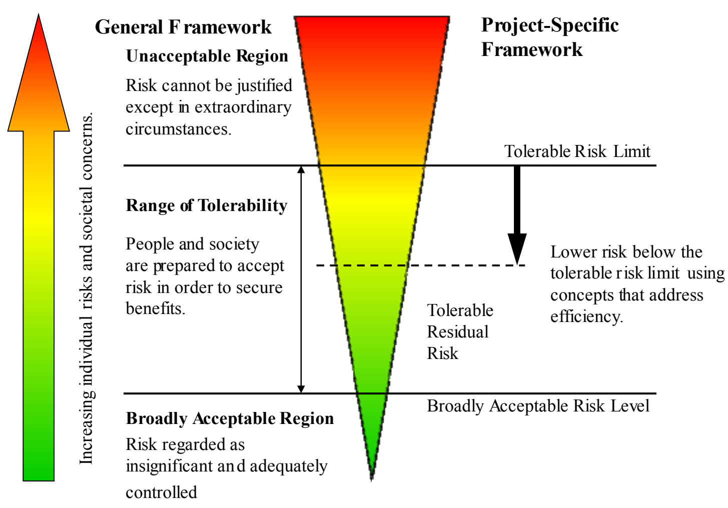
US Army Corps
of Engineers®

INSTITUTE FOR WATER RESOURCES

Proceedings of the Workshop

Exploration of Tolerable Risk Guidelines for the USACE Levee Safety Program

17 – 18 March 2010
Washington, DC



October 2010 IWR Report 10-R-8

Institute for Water Resources

The Institute for Water Resources (IWR) is a U.S. Army Corps of Engineers Field Operating Activity. Its main office is located within the Washington DC region, in Alexandria, Virginia, and includes several satellite centers across the U.S. IWR was created in 1969 to analyze and anticipate changing water resources management conditions, and to develop planning methods and analytical tools to address economic, social, engineering, institutional, and environmental needs in water resources planning and policy.

IWR strives to improve the performance of the Corps water resources program by examining water resource problems and offering practical solutions through a wide variety of technical and policy forums and the promulgation of white papers, reports, training courses, guidance and manuals of practice; the development of new planning, socio-economic, and risk-based decision-support methodologies; improved hydrologic engineering methods and software tools; and the management of national waterborne commerce statistics and a broad range of other Civil Works program performance information. IWR serves as the Corps expertise center for integrated water resources planning and management; hydrologic engineering; risk analysis; collaborative planning; conflict resolution; and international water resources.

The International Center for Integrated Water Resource Management (ICIWaRM) is a distributed, intergovernmental center established at the Institute under the auspices of the United Nations Educational, Scientific, and Cultural Organization (UNESCO). As a UNESCO Category 2 Center -separate from, but "affiliated" with UNESCO – ICIWaRM exists to help implement the objectives of UNESCO's International Hydrological Program (IHP), while concurrently advancing the U.S. goals for international water resources. ICIWaRM's mission focuses on advancing science and practice of IWRM and improving water security around the globe, initially with a focus on developing/emerging nations in Latin America, the Caribbean, and Africa.

The Hydrologic Engineering Center (HEC) in Davis, California specializes in the development, documentation, training, and application of hydrologic engineering and hydrologic models, while the Risk Management Center (RMC) provides a focused, risk-informed analytical capability for the Corps Dam and Levee Safety programs. The Navigation Data Center (NDC) and its Waterborne Commerce Statistics Center (WCSC) in New Orleans, Louisiana comprise the Corps data collection organization for waterborne commerce, vessel movements, port facilities, dredging data, and navigation locks. The Conflict Resolution & Public Participation Center (CPC) focuses on alternative dispute resolution processes (ADR) and the integration of contemporary public participation techniques with decision support and visualization modeling – such as through the technique known as Shared Vision Planning (SVP).

For further information on ICIWaRM, please contact Dr. Will Logan, ICIWaRM's Deputy Director at 703-428-6054, or at: *will.logan@usace.army.mil* , or Dr. Eugene Z. Stakhiv, ICIWaRM's Technical Director at 703-428-8077, or at: *eugene.z.stakhiv@usace.army.mil*.

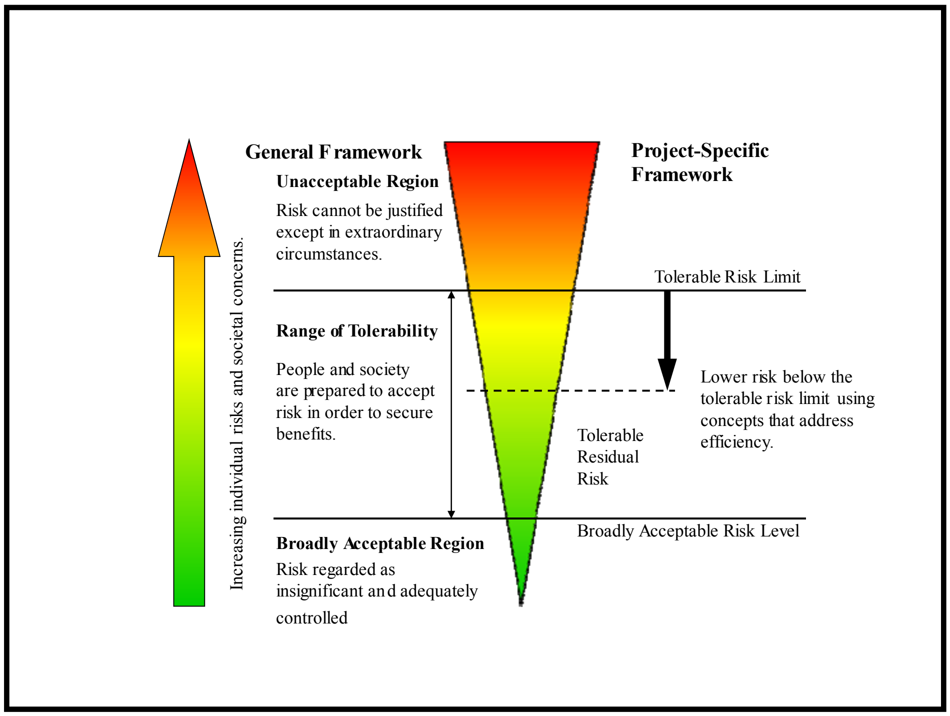
The Director of IWR is Mr. Robert A. Pietrowsky, who can be contacted at 703-428-8015, or via e-mail at: *robert.a.pietrowsky@usace.army.mil*. Additional information on IWR and ICIWaRM can be found at: http://www.iwr.usace.army.mil/index.htm. Our mailing address is:

U.S. Army Corps of Engineers
Institute for Water Resources
7701 Telegraph Road, 2nd Floor Casey Building
Alexandria, VA 22315-3868

Proceedings of the Workshop

Exploration of Tolerable Risk Guidelines for the USACE Levee Safety Program

17 – 18 March 2010
Washington, DC



Sponsored By:
US Army Corps of Engineers
441 G. Street, NW
Washington, DC

Compiled and Published By:
US Army Corps of Engineers
Institute for Water Resources
Casey Building
7701 Telegraph Road
Alexandria, Virginia 22315

October 2010 IWR Report 10-R-8

Table of Contents

Executive Summary

Risk assessment methodologies have been used around the world to provide decision makers with information on the likelihood of adverse outcomes and resulting consequences. Governments are recently moving to broader flood risk management approaches that encompass structural measures and manage floodplain development while recognizing climate change, environmental functions and social factors. Such flood risk approaches consider the probability of a flood hazard occurring; the vulnerability of flood mitigation measures implemented to lessen flood consequences through preparation, response, recovery and mitigation; and the consequences that result from the mitigated flood event. Within that overarching flood risk management context, the U.S. Army Corps of Engineers (USACE) is considering risk management approaches for dams and levee systems in order to make better decisions, better prioritize and justify risk reduction measures, better communicate risks to decision makers and the public, and better understand and evaluate public safety risks in an environment of shared flood risk management responsibilities. USACE consideration of risk management approaches includes the potential use of a Tolerability of Risk (TOR) framework, originally developed in the United Kingdom and adapted elsewhere, as well as Tolerable Risk Guidelines (TRG). Tolerability of Risk was developed as a framework for reaching decisions with stakeholders that focuses on the most serious risks consistently, efficiently, and transparently. Tolerable Risk Guidelines categorize the nature of risks in ways that can assist in assessing their acceptability or non-acceptability, and in prioritizing actions for reducing risks. (Further information regarding TOR and TRG is available in the summary of Dr. Jean LeGuen's presentation, in Section 3 of this report, and in his paper, included in Appendix D.)

In March 2008, three Federal agencies - US Army Corps of Engineers (USACE), Department of Interior, Bureau of Reclamation (Reclamation), and Federal Energy Regulatory Commission (FERC) convened a workshop entitled "Workshop on Tolerable Risk Evaluation – A step towards developing tolerable risk guidelines for dams and levees". With the formation of the USACE Levee Safety Program (USACE 2007), attention began to be directed toward adapting the newly developed risk-informed dam safety policies and methods for application to levee systems. The National Committee on Levee Safety (NCLS) authorized by the Levee Safety Act of 2007 published its draft recommendations in January 2009 (NCLS 2009) including Recommendation #5 that Tolerable Risk Guidelines (TRG) be developed for application in risk-informed, flood risk management (FRM) associated with levees. This March 2010 workshop constitutes one step in USACE engaging the flood risk management community to work collaboratively in developing policies, TRG, and methods to further levee safety for the nation.

The workshop purpose was to examine the concepts and principles of tolerability of risk and tolerable risk guidelines and explore their application to, and use in, managing life, economic, and environmental risk associated with levee systems. The workshop scope encompassed national and international approaches to flood risk management, tolerability of risk, and tolerable risk guidelines as they would apply to the USACE levee safety program. The workshop was comprised of three parts: introductory plenary presentations that set a common base and vocabulary for subsequent discussions; three facilitated break-out sessions that deliberated on questions prepared in advance; and concluding panels and plenary sessions that would capture the sense of the participants in what was learned and how to proceed. Invited participants numbering about sixty were from USACE, FEMA, other Federal agencies, professional societies, NGO's, and from The Netherlands, United Kingdom, Japan, and Spain.

Selected discussion topic summaries include:

Are structures or people safe?: A clear distinction emerged between characterizing the performance of the structure (levee system) and the consequences of unsatisfactory performance of the system. Most agreed that identical levees adjacent to either an uninhabited floodplain, or one highly developed were not equally 'safe'. The integrity of the structure is best described by characterizing its performance as related to its design; whereas the risk to floodplain occupants is best addressed by focusing on the persons affected. Hence, it was suggested that the USACE levee safety program should encompass all elements of the system to include structure performance and consequences of unsatisfactory performance on life-safety, economic, and environmental systems. The idea that someone could suffer harm from unsatisfactory performance of a levee system without knowing they were at risk was characterized as unacceptable. There will always be the inevitable question from the public, elected officials and government officials "Is the levee safe?" As professionals, we need to be prepared to respond in an understandable and transparent way.

Levee System Failure: Considerable discussion ensued about whether the term 'failure' should be parsed into categories when communicating about a system, e.g. design capacity, failure before overtopping, failure after overtopping, overtopping without failure, even whether the term 'failure' was appropriate if the levee performed up to its design but was overtopped. In general, the agreement was to use the terms 'breach' and 'overtopping' as the descriptors of levee performance, and avoid the use of the term 'failure'. It was urged that emphasis be placed on the persons at risk since surely they don't care how or why they would get flooded, just that they are at risk. There was support for the idea that what is more significant was how the breach might occur. For example, whether breach might occur at water levels below the levee crest was recognized to be very relevant in regard to consequences. The 'surprise factor' (the unexpected breaching before flood levels reach the top of the levee) would likely result in substantially higher risk to the floodplain occupants than would be breaching after overtopping or just overtopping without breach.

Shared responsibility: "We want to foster this notion of shared responsibility, but if everyone is responsible, no one is" - a sobering reality eloquently expressed. Closely associated is "we need a way to hold institutions/people accountable." In the United States, there is no one entity authorized to be held accountable for the myriad aspects associated with flood risk management (FRM) and levee safety. For Federal levees constructed, operated and maintained by USACE, USACE can be held accountable for the integrity of these structural systems performance. But land use management and control is not within the authority of the Federal government; instead such control is generally vested at the local government level with some degree of oversight possible at the state level. Therefore, the decisions impacting what is behind levees, the consequence of levee system performance (or more aptly put, exceedance), lies with non-Federal entities with very different considerations affecting their decisions. Further, on the consequence side, emergency management is diffused among at least Federal, state, and local government, and likely special levee districts as well. The European participants expressed that it seemed to them that it would be exceedingly difficult to efficiently orchestrate and hold accountable, the various entities sharing responsibility without a basic enabling law addressing the issue, which does not exist in the US. They pointed out the obvious lack of responsibility for development (and presumably enforcement) of a strategic flood risk management plan; actually no strategic plan exists! There was wide-spread agreement on that view. For non-Federal FRM/levee systems, the picture is even murkier: accountability (liability?) essentially devolves to who wins in court should someone be harmed from some aspect of the flood risk. In the absence of legislation that would affix responsibility, or at least define ‘shared responsibility,’ the emphasis will need to be placed on adapting to each situation, communicating risk (who is at risk and in what way), who will (or should) pay, and the affect on the various stakeholders and officials. Thus the USACE role in a shared responsibility environment is likely to be performing risk assessments and communicating such to the responsible entities, and providing advice and assistance as might be requested.

Use Tolerable risk guidelines for levee systems?: The consensus was yes, as one participant stated it, “TRG are a compact with the citizens reflecting concern for life as well as other risks.” Caveats to the general endorsement and encouragement for USACE to continue to develop, apply, and communicate TRG were raised by participants. For instance it was advised that TRG is applicable for existing infrastructure (prioritization and ranking remediation options) and formulation/evaluation of potentially new projects; but not for ‘design’. Considerable discussion ensued that attempted to pin down a specific definition for ‘design’ so as the better understand the caveat, but the matter was left unsettled for now. Experience is expected to eventually shed light on the utility of application of TRG to these topics that were discussed and likely future applications not yet envisioned. Another caveat was that the TRG should be developed in an open, transparent process that engages the full body of stakeholders, in effect making the guidelines part of the public domain. In furthering the transparency issue, USACE is encouraged to seek independent vetting of proposed guidelines, perhaps including such bodies as the National Academies National Research Council. An appeal was made to engage social scientists since a significant aspect of perceiving and tolerating risk involves social sciences considerations and not purely technical factors. A question was posed along the line “Is the US ready for national policy on the topic of tolerable risk?” The predominant answer was ‘yes’ but it was acknowledged that there are likely to be some entities that would be ‘horrified’ at the prospect, and some entities that would push back energetically; the land development and building communities were mentioned several times as being in this latter group. It was noted that, while TRG might be new to the US, they have been applied in other regions of the world for more than 20 years with mostly general acceptance and endorsement. It was further noted that significant sectors of the engineering community have migrated toward a TRG approach in areas other than levee systems, and it is timely for USACE to step out smartly now to further the exposure of TRG and its potential application in the US.

Tolerable risk guidelines – some more: As defined by the Office of Management and Budget and adapted by USACE, risk analysis is comprised of risk assessment, risk communications and risk management. TRG is implemented as part of all three - risk assessment, risk management, and risk communications. TRG is not a single bright line implying a binary distinction between unacceptable and acceptable risk. TRG is also not a fixed probability and consequence. TRG is a tool that can to be used to explain and characterize (risk communication) the significance of risk estimates, and it may be used to prioritize among options and to evaluate their urgency for action (risk management). Tolerability of risk is a relatively new concept which needs to be explained and understood to forestall objections and push-back due to misunderstanding. Some will believe that the use of TRG are being put forth to justify (on a life safety basis) bigger and more levee projects; this needs to be clearly refuted. The objective for application of TRG is better informed and thus improved decision making. USACE must not develop TRG with a narrow focus of application to its levee safety program. USACE must think, work, and interact in the larger context of using TRG for FRM and how they can serve all users/stakeholders. It was noted that what USACE does will set a pattern for others. Estimating life risk is exceedingly difficult and any estimate includes large uncertainty. Additionally there are some who object to making such estimates on ethical and moral grounds. Reclamation struggled to estimate loss of life for dam failures. They chose to fall back on a generalized study that estimated loss of life based on warning time and warning effectiveness and flood severity categories on a spatially lumped basis – ignoring particular details about the local setting, demographics of populace and evacuation effectiveness. Recently simulation approaches using GIS data bases have been developed to overcome many of these limitations and in one case to include estimates of uncertainty. Just because it is difficult and the estimates uncertain are not valid arguments for not putting life risk forward as a decision metric, making estimates (using standardized models in a transparent way), and communicating the estimates and associated uncertainties to inform stakeholders of risk.

Valuing human life: In parts of Europe and perhaps elsewhere, a monetary value is placed on human life so that potential for life loss may be included in economic analysis. USACE policy does not include placing a value on life and incorporating this value into the economic analysis. Several US agencies have established and periodically update a decision guidance parameter termed ‘value of a statistical life” (VSL, others use the term "willingness-to-pay-to-prevent-a-statistical-fatality" (WTP) for the same idea, and use that parameter in decision making that affects life safety. EPA and the US Department of Transportation were mentioned as examples, with VSL values ranging from $5M to $10M. An element of application of TRG includes the concept of ‘disproportionality’, bringing into the decision framework the notion that the cost to save a statistical (CSSL) for a specific risk reduction measure should exceed the VSL to meet the legal obligations of the hazard owner. It was noted that US Federal agency practice in general has focused on the CSSL for a specific risk reduction measure not significantly exceeding the monetized value of saving a statistical life, although private industry in the US commonly practices the principle of disproportionality to avoid product liability. The resulting proportion, CSSL/VSL, may be different for each option for reducing risk, and such information should play a role in the decision process.

Levee safety standards: The draft report of the National Committee on Levee Safety advocates development of national standards for levee safety. The precise scope and make-up of such standards has not yet been formed. Concepts discussed in this session included improved structural design guidance for such topics as seepage and foundation stability to include resilience and robustness; and the idea that since levees will eventually be overtopped, there should be developed and promulgated guidance that requires ‘design for exceedance’. The latter item is a key factor in the life-safety issue related to levees since it would lessen the likelihood of the ‘surprise factor’ – breaching before overtopping - coming into play. The notion that ‘failure modes analysis’ – identifying and examining significant potential modes of failure for a levee system – and not just characterizing levee systems with a somewhat generic lumped fragility function (probability of failure conditioned on exterior water stage) will provide richer and better information with which to communicate levee safety risk to the populous.

USACE role in TRG (levee safety): In addition to executing its currently-identified mission for levee safety (within existing authorities), USACE should use its ‘Bully Pulpit’ to advance the nation’s levee safety; referred to many times in the workshop as ‘telling the story’. The ‘story’ is informing the populous of their risk associated with levees and other flood risk management measures as well. USACE should develop its risk assessment methods in a transparent way and make the tools available for others to use, move the ‘art of communications’ forward in ‘telling the story’, and primarily lead by example in execution of its levee system life-safety program. USACE is embracing tolerable risk in a risk-informed decision framework, and working within the concept of shared responsibility and accountability. These are concepts worthy of national implementation and USACE has an obligation to assist in making this happen.

Selected Observations about What Was Heard:

‘Tolerable Risk Guidelines’ (TRG) is viewed by some in the USACE as a criticism of the way USACE has formulated projects. The TRG concept seems to challenge the fundamental assumption of the National Economic Development (NED) project formulation policy now in place. TRG should not and would not support implementing a facility or project that would put people at greater risk than they would be without the project. Thought needs to be given to how this relates to other aspects of Federal policy, including the Principles and Guidelines (P&G) and the National Flood Insurance Program (NFIP). USACE leaders need to figure out how TRG and risk estimates will be applied to the USACE civil works program and how it will affect engineering design and judgment. A concern expressed is that the USACE will not be able to communicate the estimated risk and TRG concepts effectively within its own agency let alone to stakeholders

For the most part, stakeholders are unaware of residual risks that levees pose to residents and the transformed risks that levees create. Additionally, stakeholders are unaware of their roles and responsibilities for ensuring that such levee systems are adequately safe and function as planned. Communication plans need to acknowledge these facts and incorporate material to inform unaware stakeholders of their exposure and their responsibilities. USACE should inform stakeholders what is being done ahead of time – no surprises. Prepare and encourage the use of media articles that provide communities with important information ahead of time. Leadership at all levels of government, NGO's, and professionals must engage in the communications.

Selected abbreviated Follow-on Actions/task Tabulation

The following is a list of follow-on actions recommended by the workshop participants:

- Develop USACE levee safety program policies and associated guidance and regulations.
- Develop policies and guidelines in a transparent manner with stakeholder involvement.
- Let the idea that policies and guidance may have utility beyond the USACE levee safety program guide the development of this policy. Include a plan on how TRG will be applied and implemented.
- Assign tasks (TRG working group to lead) and develop a plan and schedule for guidance documents.

Concurrently: develop a stakeholder involvement plan to include a schedule of activities (such as pilot test, examples, briefing materials, interagency collaboration, etc.) associated with the development and implementation of the USACE levee safety program policy.

1. Introduction and Background

Risk assessment methodologies have been used around the world to provide decision makers with information on the likelihood of adverse outcomes and resulting consequences. Governments are recently moving to broader flood risk management approaches that encompass structural measures and manage floodplain development while recognizing climate change, environmental functions and social factors. Such flood risk approaches consider the probability of a flood hazard occurring; the vulnerability of flood mitigation measures implemented to lessen flood consequences through preparation, response, recovery and mitigation; and the consequences that result from the mitigated flood event. Within that overarching flood risk management context, the U.S. Army Corps of Engineers (USACE) is considering risk management approaches for dams and levee systems in order to make better decisions, better prioritize and justify risk reduction measures, better communicate risks to decision makers and the public, and better understand and evaluate public safety risks in an environment of shared flood risk management responsibilities. USACE consideration of risk management approaches includes the potential use of a Tolerability of Risk (TOR) framework, originally developed in the United Kingdom and adapted elsewhere, and as well as Tolerable Risk Guidelines (TRG). Tolerability of Risk was developed as a framework for reaching decisions with stakeholders that focuses on the most serious risks consistently, efficiently, and transparently. Tolerable Risk Guidelines categorize the nature of risks in ways that can assist in assessing their acceptability or non-acceptability, and in prioritizing actions for reducing risks. (Further information regarding TOR and TRG is available in the summary of Dr. Jean LeGuen's presentation, in Section 3 of this report, and in his paper, included in Appendix D.)

In March 2008, three Federal agencies - US Army Corps of Engineers (USACE), Department of Interior, Bureau of Reclamation (Reclamation), and Federal Energy Regulatory Commission (FERC) convened a workshop entitled "Workshop on Tolerable Risk Evaluation – A step towards developing tolerable risk guidelines for dams and levees". USACE was beginning a major initiative to migrate its engineering standards-based dam safety program to that of a risk-informed portfolio management safety program. Reclamation had utilized a risk-informed decision process in its dam safety program for about a decade. FERC was looking to extend the benefits realized from its 'Potential Failure Modes Analysis' program to a more fully risk-informed framework for its regulatory dam safety program. In order for the three agencies to move forward in a consistent manner, a common understanding of tolerable risk as it applies to dams and levees was necessary. The 2008 workshop evolved to focus primarily on tolerable risk and dam safety. Its findings and conclusions are documented in "Workshop on Tolerable Risk Evaluation – A step towards developing tolerable risk guidelines for dams and levees, Summary White Paper" dated April 2009 and contained in Appendix D.
Since the workshop, USACE made great progress in developing and implementing its risk-informed, portfolio management process for the dam safety program. USACE revised and published new policies (USACE 2010) and developed, tested, and applied risk screening and risk assessment methodologies to its portfolio of some 600 plus dams. Included in the new policies are two tolerable risk guidelines (TRG): guidelines adapted

from ‘Public Safety Guidelines’ of Reclamation (Reclamation 2003); and 2) guidelines adapted from the ‘Guidelines on Risk Assessment’ by the Australian Committee on Large Dams, Inc. (ANCOLD 2003) and the New South Wales Government Dam Safety Committee (NSW DSC 2006), supplemented by principles developed by the International Committee on Large Dams (ICOLD 2005).

With the formation of the USACE Levee Safety Program (USACE 2007), attention began to be directed toward adapting the newly developed risk-informed dam safety policies and methods for application to levee systems. The National Committee on Levee Safety (NCLS) was formed by Congressional mandate and published its draft recommendations in January 2009 (NCLS 2009) including Recommendation #5, which is that Tolerable Risk Guidelines be developed for application in risk-informed, flood risk management.

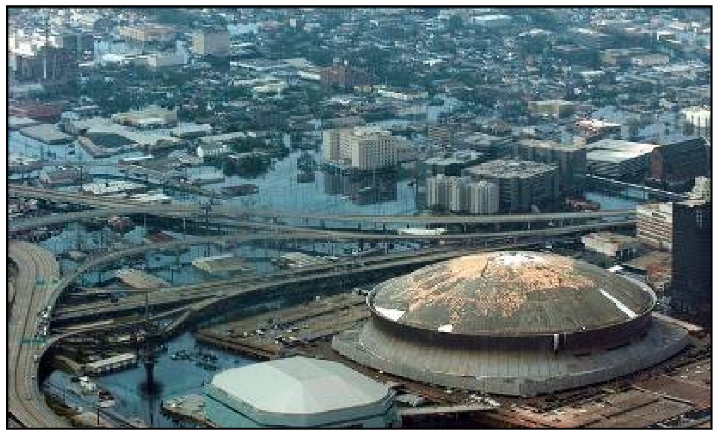
A screening level risk assessment of the USACE levee inventory (14,000 miles of levees within 2000 ‘systems’) had begun in 2009. Thus it was timely to convene a follow-on to the 2008 TRG workshop that would be devoted specifically to TRG for levee systems. USACE concluded it would be helpful to both itself and the community of institutions and professionals with interests in levee safety, to present its ideas and tentative plans for open discussion and debate. This workshop was convened 17-18 March 2010 and constituted one step in USACE engaging the flood risk management community to work collaboratively in developing policies, TRG guidelines, and methods to further levee safety for the nation.

2. Purpose, Scope, Structure, and Participants for Workshop

The workshop purpose was to examine the concepts and principles of tolerability of risk and tolerable risk guidelines and to explore their application to, and use in, managing life-safety, economic, and environmental risk associated with levee systems. The workshop scope encompassed national and international approaches flood risk management, tolerable risk, and tolerable risk guidelines as they could apply to the USACE levee safety program. The thought was to assemble a national/international group of professionals with interests, experience, and ideas to collaborate on what should be the role of tolerable risk guidelines and what should be considered in the formulation of tolerable risk guidelines for use in a levee safety program. The workshop was intended to gather a broad and informed variety of views that would inform USACE efforts, not to achieve consensus on any particular view. This report therefore necessarily reflects diverse, and occasionally conflicting, views. The workshop was comprised of three parts: introductory plenary presentations that set a common base and vocabulary for subsequent discussions; three facilitated break-out sessions that deliberated on questions prepared in advance; and concluding panels and plenary sessions that would capture from the participants a sense of what was learned and how to proceed. The workshop agenda is located in Appendix A, and a listing of participants and their affiliations is located in Appendix B. Participants were from USACE, Federal Emergency Management Agency (FEMA), Reclamation, other Federal agencies, professional societies, non-governmental organizations, and from The Netherlands, United Kingdom, Japan, and Spain. Background reading was provided prior to the workshop so that participants could become familiar with basic concepts and be better prepared to engage in fruitful discussions. The background material was comprised of: 1) a discussion paper summarizing concepts of levee performance, safety, and consequences, a brief tutorial on tolerability of risk concepts and tolerable risk guidelines, including a straw man or draft TRG for USACE levee safety application; 2) a questions/context paper in which the specific questions to be addressed in the workshop are presented and discussed; and 3) a recommended reading list including a few of the referenced documents. Workshop read-ahead materials are located in Appendix C.

3. Overview of Introductory Presentations

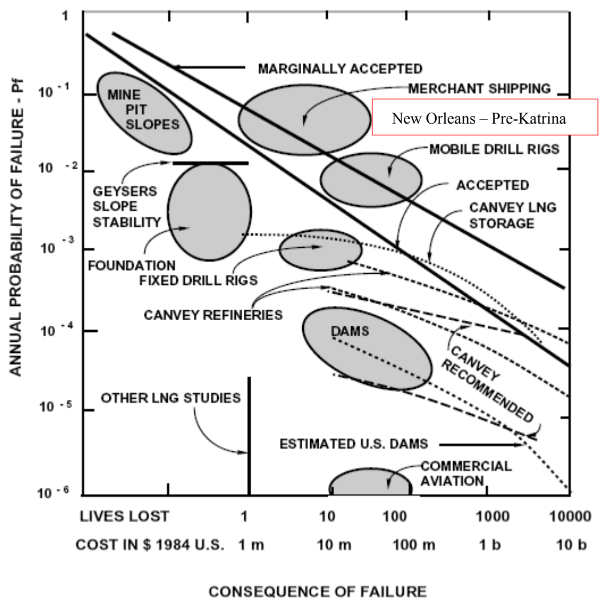
Introductory presentations were made to orient participants to the issues of levees and levee safety, tolerability of risk and associated tolerable risk guidelines, and to provide information on activities underway in the US and internationally. Speakers were, in order of their presentations: Eric Halpin, USACE Special Assistant for Dam and Levee Safety and co-chair, National Commission on Levee Safety (NCLS); Dr. David Moser, USACE Chief Economist; Karin Jacoby and Dr. Les Harder, members of the NCLS; Dr. Jean Le Guen, retired UK Health and Safety Executive Office; and Alex Roos and Durk Riedstra, Rijkswaterstaat, The Netherlands. Copies of slides and papers that accompanied the presenters' talks are located in Appendix D. Brief synopses of their remarks follow.



Eric Halpin, Opening Remarks: Katrina was a wakeup call for USACE. Then USACE Chief of Engineers, General Strock, was quoted as saying " - - we will do everything within our authorities to make sure this doesn't happen again." In response Congress in the Water Resources Development Act of 2007, established the National Committee on Levee Safety (NCLS) and charged it with developing recommendations for a National Levee Safety Program, including a strategic plan for implementation of the program. The committee published a draft report in 2009 (NCLS 2009) and continues its work. While USACE is often thought of as the face of the nation's levee systems, 100,000 miles of levees are outside the USACE program. The NCLS is addressing both the levees in the USACE system as well as the remainder of the nation's levees. USACE is responsible for about 10% of all levees in the United States. In furtherance of its responsibilities, USACE established a levee safety program and has been shaping the program and inventorying its portfolio of levee systems. At this critical juncture in program and policy development, USACE wants to share what is known and where we think we should be going; USACE is here to listen to "you" (the participants), the experts. The focus topic of this workshop is a critical issue for levee safety. USACE held a similar workshop in 2008 focused on tolerable risk concepts for dams. The workshop discussions are to be documented in "Proceedings" (non-attribution) and will contribute to development of policy products.

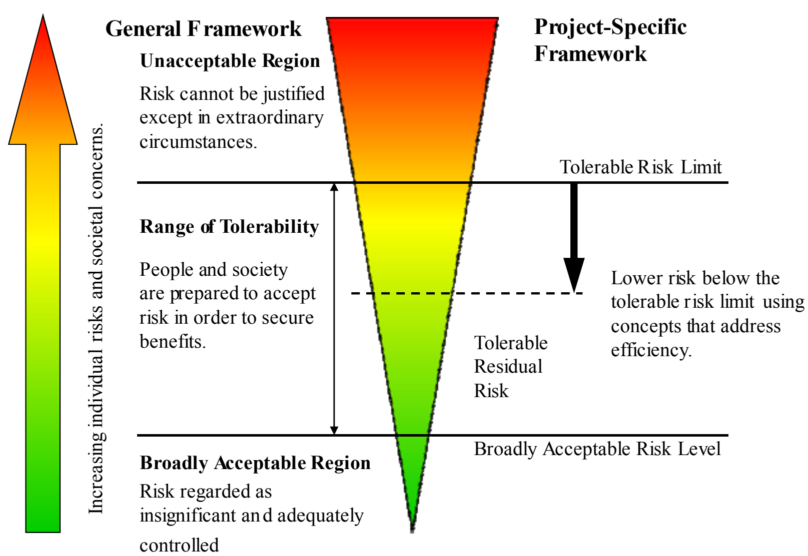
Dr. David Moser, Summary of 2008 Workshop on Tolerable Risk Evaluation: Workshop participants in 2008 included a broad array of US Federal agencies with safety interests and many professional and non-governmental organizations also representing safety interests. Several participants were from other countries and agencies. A white paper summarizing the workshop discussions and findings is located in Appendix D.

The 2008 workshop helped inform dam safety policies as reflected in new and emerging dam safety regulations. Key topics were: How is tolerable risk defined? How is it being used to evaluate risks? What are implementation problems and how are they addressed? The bottom line is to make better decisions; since USACE owns the dams, it is akin to a regulatory policy. Levee safety is a shared responsibility. We learned that there were similarities across agencies; differences were a function of the organizations' purpose. Also learned was that there is a difference between acceptable risk and tolerable risk, and that the difference is subtle but very important. The principles and concepts supporting tolerable risk - equity, efficiency, shared responsibility for risk management, and ALARP (as low as reasonably practicable) - were defined and discussed. The conceptual 'Risk Triangle' [see summary for Dr. Leguen's talk on page 15 below] was presented, explained, and discussed pertaining to its applicability to dams ***and now levee systems***. The following rhetorical question was posed to the participants of this tolerable risk for levee safety workshop: "Is the tolerable risk limit a fixed or static threshold once established for a specific program, e.g. dam or levee safety, and if a community locates downstream, are they choosing to accept risk? **NOTE:** Because Dr. Le Guen's talk that follows later is 'Tolerable Risk Concepts and Principles', definitions and concepts for such are not repeated here from Dr. Moser's presentation.



Karin Jacoby and Dr. Les Harder, Overview of National Committee on Levee Safety Recommendations Pertaining to Tolerable Risk Guidelines: Extreme floods have occurred distressingly frequently: Great Flood of 1993 (upper Mississippi); California Central Valley 1997; New Orleans flooding in 2005 (Katrina); Mid-west floods of 2008; 2008 Hurricane season. The National Committee on Levee Safety (NCLS) was formed by the Levee Safety Act of 2007 (WRDA Title IX, Section 9000) in response to New Orleans flooding from Hurricane Katrina. Committee charge: *"The committee shall develop recommendations for a National Levee Safety Program including a strategic plan for implementation"*. There is estimated to be more than 100,000 miles of levees in the US, with about 15,000 miles in the USACE program. The NCLS is interdisciplinary, supported by USACE and FEMA, and comprised primarily of representatives from non-Federal agencies. Major recommendations include: the formation of a National Levee Safety Commission; strong levee safety programs in all states; and alignment of Federal agency programs. Selected other key recommendations included development of a national levee database, levee safety standards, a hazard classifications system, ***development of tolerable risk guidelines***, and addressing the emerging liability issues. The 20 recommendations are put forward by the NCLS as a suite of items that together are part of an overall program to achieve "an involved public and reliable levee systems working as part of an integrated approach to protect people and property from floods." Implementing the recommendations is not just an expense – it is an investment in protecting lives and the US economy.

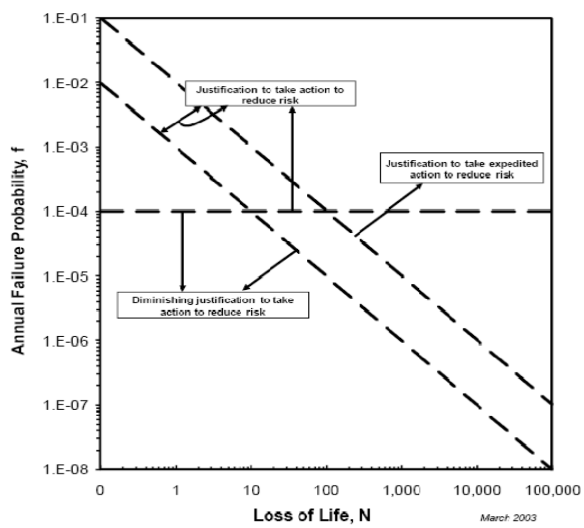
Dr. Jean Le Guen, Tolerable Risk Concepts and Principles: Dr. Le Guen prepared a paper that is included with his presentation in Appendix D. The tolerability of risk framework evolved from the recognition that absolute safety in work and public life was not practical; that in their everyday lives people live very happily with different levels of risk, depending on circumstances; and if they did not they would not leave their houses and industry would collapse. The TRG system was first developed in the UK some 35 years ago in relation to health and safety at work, but has now been adapted as a useful framework in other spheres and other parts of the world (for example in The Netherlands for coastal and riverine flood defences and for dam safety in Australia). Several studies have shown that a person's tolerance of risk is not always rational. People are more inclined to tolerate exposure to certain risks if the exposure is voluntary. At the same time people tend to deal with the perception of risk rather the 'true' risks as established, for example, by experts. Risk is the probability that someone, or a thing that is valued, will be adversely affected by the hazard in a stipulated way. Tolerability of risk is essentially a process for reaching decisions that reaches out for and involves stakeholders in its operation. Embedded in the process are criteria for deciding what risks are unacceptable, tolerable or broadly acceptable that mimics the way that people make decisions in their everyday life. Tolerable risks are: risks that society is willing to live with so as to secure certain benefits; risks that society does not regard as negligible (broadly acceptable) or something it might ignore; risks that society is confident are being properly managed by the owner; and risks that the owner keeps under review and reduces still further if and as practicable. "Broadly acceptable risk" is contrasted with tolerable risk in that risks falling into the broadly acceptable region are generally regarded as insignificant and adequately controlled or trivial in their daily lives. The left side of the following figure (Risk Triangle) shows in general how that tolerable risk is a range between unacceptable, where the risk cannot be justified except in extraordinary circumstance, and broadly acceptable, where the risk is regarded as negligible.



Equity and efficiency also play key roles in TRG. "Equity" is the right of individuals and society to be protected, and the right that the interests of all are treated with fairness. "Efficiency" is the need for society to distribute and use available resources so as to achieve the greatest benefit. There can be conflict in achieving equity and efficiency. Achieving equity justifies the establishment of maximum tolerable risk limits for individual and societal risk. Efficiency is defined by the risk level where marginal benefits equal or exceed the marginal cost. In general, society is more averse to risks if multiple fatalities were to occur from a single event and hence impact on society as a whole, creating a socio-political response. In contrast, society tends to be less averse to

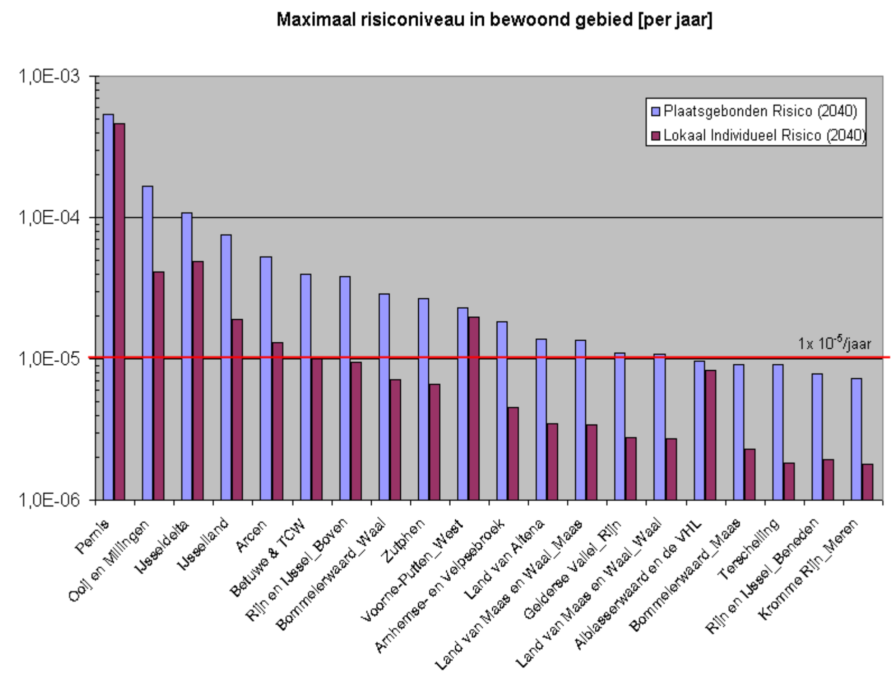
risks that result from many individual small loss accidents involving only one or two fatalities, even if the total loss from the sum of all of the small loss accidents is larger than that from the single large loss accident. Risks lower than the tolerable risk limit is considered as tolerable only if further risk reduction is impracticable. The tolerability of the remaining risk is conditional on the application of the ALARP criteria – i.e. that the level of risk has been brought down 'as low as reasonably practicable'. What is 'reasonably practicable' when determining ALARP is a matter for judgment where the risks (individual and societal) fall within the tolerable/ALARP region on the Tolerability of Risk (TOR) diagram, have been found useful for informing such judgments.
TRG are commonly presented as a diagram displaying probability of failure (or of occurrence) vs. the parameter of interest, in our case, fatalities. Either of these representations are alternatives for presenting histograms of statistical data configured with a specific objective in mind. An example of a TRG (Reclamation's Public Safety Guidelines) is depicted in Mr. Halpin's summary below.

Eric Halpin, Overview and Update on Flood Risk Management, Levee Safety, TRG and Portfolio Risk Management for Levee Systems: The focus here is all about decisions and communications. Decisions are informed by risk, not simple numerical calculations. Decisions require engineering judgment and stakeholder input; risk-informed decisions do not replace engineering standards. Risk assessment is a credible way to deal with uncertainty; it is integral to the profession. Risk assessment facilitates prioritization, but a tolerable risk guideline identifies what is unacceptable, tolerable, and acceptable. The USACE levee safety program consists of routine activities and non-routine activities. The routine activities are inventory, inspections, and risk based screening to identify problems. The non-routine activities deal with identified problems and consist of interim risk reduction measures, problem assessment, and development and implementation of permanent risk reduction measures. A new element to USACE programs, 'potential failure modes analysis', formally determines how failure might occur and the follow-on risk assessment systematically estimates the likelihood. The range of appropriate actions for risk assessment findings varies from primarily those that would be undertaken by USACE, to shared responsibility with local stakeholders, to primarily those of local stakeholders. It is anticipated that a large share of the USACE levee system portfolio may fall in an unacceptable region regarding life safety; this is in contrast to dams where the proportion that is unacceptable



is smaller. For example, a levee system that plots above TRG may be structurally improved to bring it below the line; or, it may be raised and this may not actually reduce risks below the line; or raise the levee coupled with land use restriction; or implement building code improvements; or all of the above. It should be noted that USACE does not have the authority to set TRG for the nation; that is why NCLS, state and other Federal agencies and professional associations were invited to the workshop.

Alex Roos and Durk Riedstra, Rijkswaterstaat, Overview and Update on Development of Tolerable Risk Guidelines for The Netherlands' Coastal and Riverine Defences:



Context: The Netherlands is roughly 16,000 sq. miles with a population of 16 million; about twice the size and population of New Jersey. Twenty percent of the land area lies below sea level, as does 20% of the population, with 50% of the land area less than one meter above sea level. The country is largely the floodplains and estuaries of three important European rivers. About 60% of the country is prone to flooding. The flood disaster in 1953, which took 1,800 lives, resulted in major government interest in, and response to, flooding that continue to today. Protection levels are reported to be on the order 1 in 10,000 per year for coastal areas to about 1 in 1,250 per year for inland river floodplains. Legislation in the mid-1990's authorized systematic examination of the state of the protection works, targeting assessments at five-year intervals and evaluation of standards at ten-year intervals; 30% of levees were found to be in unsure condition due to lack of information. New safety standards evolved and subsequent to 2008, loss of life and TRG began to be incorporated in assessments. Individual and societal risks are considered; the final proposal for TRG is scheduled for May 2010. In the matter of choice between being 'risk averse' and 'risk neutral' in forming the TRG, the Dutch have tentatively chosen to be 'risk neutral' for flood risk management, (e.g. the probability – fatality diagram slopes downward at a 45 degree angle) (1 to 1 slope). A research project termed 'Flood Risks and Safety in the Netherlands' (FLORIS) explored application of Probable Failure Mode Analysis (PFMA) for a pilot area as an improved method for assessment of levee system integrity. Efforts are now underway to implement the PFMA analysis concepts for more extensive levee systems than represented by the pilot areas.   Safety assessments with the new standards are programmed to begin in 2017. Plots were presented comparing proposed flood risk in The Netherlands, to industrial safety standards in The Netherlands, and proposed USACE TRG. Flood risks in the Netherlands are approximately one to several orders of magnitude higher (because of more fatalities) than the proposed USACE TRG. The role of potential evacuation of flood threatened areas in relation to protection by structural means only was extensively discussed. The above diagram illustrates an example of analyzing the potential role of evacuation in meeting an individual risk TRG for selected dike areas in the Netherlands – blue without evacuation, and purple with evacuation.

4. Questions for the Break-out Sessions

Six questions were posed as one of the workshop vehicles to obtain input on what should be the role of tolerable risk guidelines and what should be considered in their formulation and application in the USACE levee safety program. There were three separate break-out sessions. Workshop attendees were divided into assigned groups for the break-out sessions. Each group addressed the same questions in facilitated working sessions and reported-out their findings to the larger group. Notes were taken and used to prepare the summaries that follow.

4a. Session 1

What are the measures and metrics that can help guide determination of 'adequately safe levee systems' in the development and application of tolerable risk guidelines (TRG)?

For levee safety considerations is the difference between life safety and structure safety (structural integrity) for levee systems important and how might each contribute to achieving TRG for levee systems?

Summary Session 1: There were substantial similarities among the discussions of the three break-out groups and a few notable differences. One commonality is that each group's discussion was much broader than addressing the specific questions posed. Since the questions were complementary and the discussions were broad, the summary of key points does not distinguish between the two questions. The discussion summaries are grouped into themes as noted below. Both supporting and dissenting views are captured within the theme summaries.

Use of the terms 'Safe/Unsafe': There was near unanimous agreement that the terms 'safe' and 'unsafe' were not good terms to use primarily because they communicate the notion of a binary dividing line of safe/unsafe. On the one hand, most attendees agreed that there are degrees of safety that need to be communicated and therein lays a potential role for 'tolerable risk guidelines'. On the other hand, the groups acknowledged that in general, the public is 'risk ignorant' and that a label of 'unsafe' is more likely to get attention and stimulate action than some qualified alternative labeling while a label of 'safe' may generate undue complacency. Regulations and decisions are more facilitated by binary distinctions than by shades and qualified distinctions. It was further noted that it seems that defining what is unsafe is OK, but it is generally up to the individual to conclude what is safe to them. A phrase often mentioned in this regard was 'Do you see what I see?' Another take was that people behind levees believe that they are 'safe'; there is an obligation to inform them that there is risk remaining and to tell people what they can do to reduce the risk. There was considerable agreement that to communicate effectively, the terms used and their definitions needed to be as simple as possible. There was an interesting discussion about how EPA addressed the same issue when needing to communicate about water quality standards: words like 'fishable', 'swimmable' and 'drinkable' ended up as the favored terms. A similar set of terms communicating floodplain risk was suggested ('visit-able', 'workable', 'livable').

Are structures or are people safe?: A clear distinction emerged between characterizing the performance of the structure (levee system) and the consequences of unsatisfactory performance of the system. Most agreed that identical levees adjacent to either an uninhabited floodplain, or one highly developed were not equally 'safe'. The integrity of the structure is best described by characterizing its performance as related to its design; while the risk to floodplain occupants is best addressed by focusing on the persons affected. Hence, it was suggested that the levee safety program should encompass all elements of the system: not only structure performance but consequences of unsatisfactory performance on life-safety, economic, and environmental systems. The idea that someone could suffer harm from unsatisfactory performance of a levee system without knowing they were at risk was characterized as unacceptable. There will always be the inevitable question from the public and government officials "Is the levee safe?" As professionals, we need to be prepared to respond in an understandable and transparent way.

Tolerability: 'Tolerably safe' was favored for labeling the upper end of the range of tolerability (Unacceptable to Broadly acceptable) in the general framework and further, it was agreed that no levee systems would be considered as 'broadly acceptable'. A brief poll taken indicated that there are no objections to development of TRG, at least conceptually. Concerns were expressed that such guidelines could be taken too rigidly and thus hinder consideration of the broader flood risk management concept. It was also noted that the same guidelines may not apply for all entities of interest, such as Federal agencies, tribes, state government, local government, and private sector. This led to the idea that a set of national guidelines developed with full stakeholder involvement was the way to proceed. Near consensus was reached on the notion that tolerability should be a goal in a flood risk management plan; levees without a risk management plan constitutes an unsafe situation. A contrary perspective expressed was that the term 'tolerable' is an affront to the public's sense of equity and is inherently inflammatory.

Levee System Failure:

Considerable discussion ensued about whether the term 'failure' should be parsed into categories when communicating about a system, e.g. design capacity, failure before overtopping, failure after overtopping, overtopping without failure, even whether the term 'failure' was appropriate if the levee performed up to its design but was overtopped. In general, the agreement was to use the terms 'breach' and 'overtopping' as the descriptors of levee performance, and avoid the use of the term 'failure'. It was urged that emphasis be placed on the persons at risk since surely they don't care how or why they would get flooded, just that they are at risk. There was support for the idea that what is more significant was how the breach might occur. For example, whether breach might occur at water levels below the levee crest was recognized to be very relevant in regard to consequences. The 'surprise factor' (the unexpected breaching before flood levels reach the top of the levee) would likely result in substantially higher risk to the floodplain occupants than would be breaching after overtopping or just overtopping without breach.

Framework for Flood Risk Management: Those of us in the business of flood risk management should refer to all systems and measures as 'flood risk management actions' instead of referring individually to levee systems, flood control reservoirs, bypass systems, and the variety of non-structural measures. One view expressed was that we should think in terms of 'structures/responsibilities/consequences'; and following with the notion that government can reduce probabilities [of inundation] but local communities that make land use and associated management decisions should be held accountable for consequences (a counter to 'build it and they will come'). Another way of expressing this perspective was stated as ". . articulate that floodplain practices/development decisions are also critical to determining risk levels behind levees, so education of developers, local planning and local zoning management is key to determining these risk level outcomes". Several comments expressed the need for responsible and knowledgeable entities to 'manage expectations' with regard to the risk reduction that is provided by levee systems for each specific floodplain.

Liability: Concern with the issue of liability was expressed in several ways. At present, who is ultimately held responsible for damage that might result from unsatisfactory performance of a levee system, is unclear. The Federal government has 'hold harmless' clauses in its agreements with sponsors; albeit USACE is being sued for losses in New Orleans resulting from Hurricane Katrina flooding. The ultimate outcome of this suit is yet to be decided. In a well know and documented case, a state agency that has a maintenance function for a Federal levee system has been successfully sued for losses that resulted from a levee breach. Some private sector firms are refusing to perform 'certification' studies for the FEMA national flood insurance program, citing liability concerns. While changes in terminology are suggested, it is unlikely that wordsmithing under existing laws will resolve the present uncertainties in regards to liability.

Tolerable risk metrics: Synthesizing 'metrics' with which to measure risk from the disparate comments and views expressed from all three groups during the first break-out session lead to the following list of metrics: annual probability of failure (APF), probability of overtopping, individual and societal life-risk, annualized life loss (ALL), economic risk, environmental risk, life-line infrastructure risk, and short and long-term cultural impacts. A suggestion was to shorten and simplify these to APF, ALL and annual property damage but the implications of such simplifications need to be fully explored and weighed. It was observed that natural resource and environmental values generally have not been a consideration in flood risk management but that these need to be included in risk calculations and the results communicated to the public. Several expressed the view that 'level-of-protection' is a poor metric and should be dropped along with such terminology as the '100-year flood' because in general, these terms are poorly understood. There was a unanimous call for 'transparency' in assessing flood risk, communicating flood risk, and any actions taken towards development and application of tolerable risk guidelines.

4b. Session 2

What is the responsibility of each stakeholder for achieving and maintaining levee safety?

Considering the number and variety of stakeholders, how could tolerable risk guidelines be used to assist in life safety risk assessments and levee systems risk management decisions?

Summary Session 2: Similar to session 1, each group diverged significantly from the questions posed, inventing some of their own along the way. Following report-outs by the groups, there was a sense that a bit more open plenary discussion would be helpful to further expand on the session 2 topics and prepare for the last session (session 3). This spawned an ad-hoc luncheon presentation by Eric Halpin with substantial follow-on discussions and questions and answers. The issues raised and discussed in this ad-hoc session are also included in this summary. In addition to the questions posed, several additional themes (or sub-themes) emerged and are included in the discussion that follows. Please note that on issues where significantly different views were express, both supporting and dissenting views are captured within the themes.

Who are the stakeholders for levee safety?: Stakeholders were identified from several perspectives ranging from the view that stakeholders are primarily those who want the levee as their option (conversely, those who do not), to be inclusive of almost all levels of government, private developers, insurance industry, and the public that either will reside behind the levee or will likely be expected to pick up the tab either for levee construction, maintenance, or rehabilitation. It was pointed out that USACE is responsible for perhaps 15% of the nation's levees, and that the stakeholders that USACE would engage for their authorities (Federal government funds 65% of costs for these levee systems) might be different than for the non-Federal levee systems. The discussion eventually evolved to the view that 'who pays' is a major determiner of stakeholder group make-up and their views. It was suggested that it would better serve the larger community for this discussion to be expanded from just those focused on levee safety to the larger community concerned with flood risk management (FRM). With the focus on FRM, a basic listing of stakeholders includes: owner (operate and maintain); local government (zoning and permits); emergency management (warnings and evacuation); state regulators (power to adopt/enforce FRM plans); USACE, FEMA, other Federal agencies (depending on role); Congress (major funder of many deverse programs that impact the flood plain); tribes; industry; interest groups; and the public (especially those choosing to accept risk and those that are not aware they are at risk). As an aside, it was pointed out that there are many entities that are not aware that they are, or should be, stakeholders.

Shared responsibility: "We want to foster this notion of shared responsibility, but if everyone is responsible, no one is" - a sobering reality eloquently expressed. Closely associated is "we need a way to hold institutions/people accountable." In the United States, there is no one entity authorized to be held accountable for the myriad aspects associated with flood risk management (FRM) and levee safety. For Federal levees constructed, operated and maintained by USACE, USACE can be held accountable for the integrity of or performance of these structural systems. But land use management and control is not within the authority of the Federal government; instead such control is generally vested at the local government level with some degree of oversight possible at the state level. Therefore, the decisions impacting what is behind levees, the consequence of levee system performance (or more aptly put, exceedance), lies with non-Federal entities with very different considerations affecting their decisions. Further, on the consequence side, emergency management is diffused among at least Federal, state, and local government, and likely special levee districts as well. The European participants expressed that it seemed to them that it would be exceedingly difficult to efficiently orchestrate and hold accountable, the various entities sharing responsibility without a basic enabling law addressing the issue, which does not exist in the US. They pointed out the obvious lack of responsibility for development (and presumably enforcement) of a strategic flood risk management plan; actually no strategic plan exists! There was wide-spread agreement on that view. For non-Federal FRM/levee systems, the picture is even murkier: accountability (liability?) essentially devolves to who wins in court should someone be harmed from some aspect of the flood risk. In the absence of legislation that would affix responsibility, or at least define 'shared responsibility,' the emphasis will need to be placed on adapting to each situation, communicating risk (who is at risk and in what way), who will (or should) pay, and the affect on the various stakeholders and officials. Thus the USACE role in a shared responsibility environment is likely to be performing risk assessments and communicating such to the responsible entities, and providing advice and assistance as might be requested.

Shared responsibility functions: The array of functions associated with levee safety is pretty straight forward albeit no less murky than the picture for 'shared responsibilities'. However, in the case of Federally-authorized levee systems operated and maintained by a Federal agency, the situation is less murky. The functions discussed in the workshop include: design and construction; risk assessment; risk communications; operations and maintenance; repair and rehabilitation; emergency response/evacuation; recovery (subsequent to flooding or a capacity exceedance); strategic risk reduction planning; interim risk reduction measures; enforcement/ regulation; FRM program management and integration. An attempt was made to form a matrix of stakeholders and responsibilities. What evolved was a tabulation of the 'four R's' – risk, reward, responsibilities, resources - and an abbreviated stakeholder tabulation: owner/operator, local government' Federal' and state. History has shown that, typically, various functions are performed by different entities, but responsibilities (functions and accountability) are not shared.

Tolerable risk guidelines – some more: Further discussions continued to surface on TRG. Key points raised in addition to those in Session 1 are as follows. As defined by USACE, risk analysis includes risk assessment; risk communications; and risk management. TRG is implemented as part of risk assessment. TRG is not a single bright line implying a binary distinction between "at risk" and "not at risk" or unacceptable and acceptable risk. TRG is also not a fixed probability and consequence. TRG is a tool that can be used to explain and characterize the significance of risk estimates, and it may be used to prioritize among options, and to evaluate their urgency for action. Tolerable risk is a relatively new concept which needs to be explained and understood to forestall objections and push-back due to misunderstanding. Some will believe that TRG are being put forth to justify (on a life safety basis) bigger and more levee projects; this needs to be clearly refuted. The objective for application of TRG is better informed and thus, improved decisions. USACE must not develop TRG with a narrow focus of application by USACE to its levee safety program. USACE must think, work, and interact in the larger context of using TRG for FRM and recognize that the concept can serve all users/stakeholders. It was noted that what USACE does will set the pattern for others. Estimating life risk is exceedingly difficult and any estimate includes large uncertainty. Additionally there are some who object to making such estimates. Reclamation struggled to estimate loss of life for dam failures. They chose to fall back on a generalized study that estimated loss of life based on warning time and warning effectiveness and flood severity categories on a spatially lumped basis – ignoring particular details about the local setting, demographics of the populace and evacuation effectiveness. Recently simulation approaches using GIS data bases have been developed to overcome many of these limitations and in one case to include estimates of uncertainty. Just because it is difficult and the resulting estimates are uncertain are not valid arguments for not putting life risk forward as a decision metric, making estimates of potential life loss (using standardized models in a transparent way), and communicating the estimates and associated uncertainties to inform stakeholders of risk.

4c. Session 3

What are the issues to be addressed to develop tolerable risk guidelines for levee systems and what would the tolerable risk guidelines look like?

How do we proceed?

Summary Session 3: The last session of the workshop reflected information gathered over the previous sessions, improved understanding and interest in TRG for levees, and was more focused on the specific questions posed. Some re-cycling of issues discussed and points made previously did occur, and where those provide new information or insights, they are recorded in the summary. As a consequence, in addition to the questions posed, several additional topics are included in the discussion that follows. Please note that on issues where significantly different views were expressed, both supporting and dissenting views are captured within the themes.

Tolerable risk guidelines for levee systems?: The consensus was yes, as one participant stated it, “TRG are a compact with the citizens reflecting concern for life as well as other risks.” Caveats to the general endorsement and encouragement for USACE to continue to develop, apply, and communicate TRG were raised by participants. For instance it was advised that TRG is OK for existing infrastructure (prioritization and ranking remediation options) and formulation/evaluation of potentially new projects but not for ‘design’. Considerable discussion ensued that attempted to pin down a specific definition for ‘design’ so as to better understand the caveat, but the matter was left unsettled. Concern was expressed with uncertainty in what to do should a newly designed and built levee system not being able to meet the TRG. Experience is expected

to eventually shed light on the utility of application of TRG to these topics that were discussed and likely future applications not yet envisioned.
Another caveat was that the TRG should be developed in an open, transparent process that engages the full body of stakeholders, in effect making the guidelines part of the public domain. In furthering the transparency issue, USACE was encouraged to seek independent vetting of proposed TRG guidelines, perhaps including such bodies as the National Academies National Research Council. An appeal was made to engage social scientists since a significant aspect of perceiving and tolerating risk involves social sciences considerations and not purely technical factors. Communications will be a key, and social scientists should be able to help in this arena. A question was posed along the lines of; “Is the US ready for a national policy on the topic of tolerable risk?” The predominant answer was ‘yes’ but it was acknowledged that there are likely to be some entities that would be ‘horrified’ at the prospect, and some entities that would push-back energetically. The land development and building communities were mentioned several times as being potential members of this latter group. It was noted that, while TRG might be new to the US, they have been applied in other regions of the world for more than 20 years with mostly general acceptance and endorsement. It was further noted that significant sectors of the engineering community have migrated toward a TRG approach in areas other than levee systems, and it is timely for USACE to step out smartly now to further the exposure of TRG and their potential application in the US with levee systems.

Key drivers: Key drivers were restated to be life-loss, economic, and environmental issues. Some advocated monetizing the value of all key drivers to enable summing for comparison. Others strongly argued that each key driver should be represented by its own metrics (e.g. potential life-loss, dollars for economic losses, and habitat/species impacted) and should be individually weighed in the decision process. (See subsequent paragraph about valuing human life). Most participants agreed that no one driver should always dominate but rather each circumstance should be treated case-by-case. It was acknowledged that life risk would more often be the likely key driver (some disputed this would be the case except for a small number of systems with large population behind the levee system), but that it should not be used alone in developing and deciding among risk reduction options. Instead, other factors should be considered as well. It was also emphasized that TRG is being viewed as supporting and complementary to existing USACE policy and programs, rather than replacing or substantially altering these policies and programs. Sustainability was put forth as an important commitment in present society that should in some manner be embodied in tolerable risk considerations.

Valuing human life: In parts of Europe and perhaps elsewhere, a monetary value is placed on human life so that potential for life loss may be included in economic analysis. USACE policy does not include placing a value on life and incorporating this value into the economic analysis. Several US agencies have established and do periodically update a decision guidance parameter termed ‘value of a statistical life (VSL)’, others use the term "willingness-to-pay-to-prevent-a-statistical-fatality" (WTP), and use that parameter in decision making that affects life safety. The Environmental Protection Agency and the US Department of Transportation were mentioned as examples, with VSL values ranging from $5M to $10M. An element of application of TRG includes the concept of 'disproportionality', bringing into the decision framework the notion that it may be appropriate that the cost to save a statistical life (CSSL) for a specific risk reduction measure should exceed the VSL or WTP to meet the legal obligations of the hazard owner. It was noted that US Federal agency practice in general has focused on the CSSL for a specific risk reduction measure not significantly exceeding the VSL or WTP, although private industry in the US commonly practices the principle of disproportionality to avoid product liability. The resulting proportion, CSSL/VSL, may be different for each option for reducing risk, and such information may appropriately play a role in the decision process.

Relationship to proposed revised Principles and Guidelines: The President's Council on Environmental Quality (CEQ) has drafted and proposed new Principles and Guidelines (P&G) that expands beyond the current National Economic Development (NED) principle for Federal water resources-related decisions. To some extent, the proposal is a return to the 'four accounts' of some decades past; NED, regional economic development, environmental quality, and social well being. A key addition to the proposed new P&G is inserting a Public Safety Subcategory into a Non-Monetary Effects Category. The guidelines are in the vetting process, but are expected to eventually be adopted and to include some reference to life safety. Hence, USACE proposed application of TRG is - and should continue to be - consistent with emerging thinking for national decision criteria for water resources-related decisions.

Automobile (or fire, or . .) safety as a model/example?) Significant time was consumed to try to make analogies with other 'safety' programs in the US. Fire safety and automobile safety among others were mentioned. An analogy was made that the automobile industry, which was at first reluctant, later embraced safety features such as seat belts and made them an element of their marketing. This begged the question "Is this model applicable for levees – somehow cast levee safety as a marketing advantage (for local communities)?" An example was cited wherein a location decision for a big box store included safety from flooding as a key factor. It was further noted that ideally, developers would be advocates; make them want invest in locations that meet TRG and provide information on "un-safe" situations. None-the-less, the preponderant view was that it is not wise to go down the path of using such analogies at this time. It was pointed out that the driver for automobile safety was not the auto industry, but instead an energetic and zealous safety concerned group that pressured the government into adopting and enforcing safety standards. The discussion concluded by harkening back to Dr. Le Guen's discussion of a gas pipeline safety issue in the U.K. In this case, an agreement between the safety regulator and the gas industry to replace old unsafe gas mains over an extended period of time incorporated tolerable risk concepts. The tolerable risk concepts formed the central feature of a successful defence in a legal action in an unfortunate explosion resulting in deaths (see Le Guen's paper in appendix D).

Levee safety standards: The draft report of the National Committee on Levee Safety advocates development of national standards for levee safety. The precise scope and make-up of such standards has not yet been formulated. Concepts discussed in this session included improved structural design guidance for such topics as seepage and foundation stability; resilience and robustness; and the idea that since levees will eventually be overtopped, guidance should be developed and promulgated that requires 'design for exceedance'. The latter item is a key factor in the life-safety issue related to levees since it would lessen the likelihood of the 'surprise factor' – breaching before overtopping - coming into play because the levee system would be designed to handle water flood levels over the top of the levee system. Incorporating the use of 'potential failure mode analysis' (PFMA) as part of the levee safety standards was discussed. It was suggested that PFMA, which identifies and examines a complete set of potential modes of failure for a levee system, rather than just characterizing levee systems with a somewhat generic lumped fragility function (probability of failure conditioned on exterior water stage), will provide richer and better information with which to communicate levee safety risk.

USACE role in TRG (levee safety): Besides executing its currently-identified mission for levee safety (within existing authorities), USACE should use its 'Bully Pulpit' to advance the nation's levee safety; referred to many times in the workshop as 'telling the story'. The 'story' is informing the population of their risk associated with levees and other flood risk management measures. USACE should develop its risk assessment methods in a transparent way and make the tools available for others to use, move the 'art of communications' forward in 'telling the story', and most generally lead by example in executing its levee system safety program using life safety as significant parameter in the program. USACE is embracing tolerable risk in a risk-informed decision framework and working within the concept of shared responsibility. These are concepts worthy of national implementation and USACE has an obligation to assist in making this happen.

5. Wrap up - concluding plenary panel and closing observations

The concluding plenary panel included a selection of principals from among the participants (Larry Roth, American Society of Civil Engineers; Don Basham, NCLS; Dr. Jean Le Guen, UK Health and Safety Executive (Retired); and Eric Halpin, USACE). Dr. Moser moderated the panel, providing each panelist with an opportunity to summarize their observations. Following the panelist's summaries, Eric Halpin presented a wrap-up statement. The following bullet points capture the statements made by each panelist.

Larry Roth

- Surprised that life-safety has not been paramount in decision-making for the Corps.
- USACE should not let someone else take the moral high ground with regard to levee systems and life safety.
- ASCE advocates four guiding principles for critical infrastructure (The Vision for Civil Engineering in 2025 report available on ASCE website) at: http://www.asce.org/uploadedFiles/Infrastructure_-_New/GuidingPrinciplesFinalReport.pdf.
- The four guiding principles, developed to protect public safety, health, and welfare, are:

    1. Quantify, communicate, and manage risk.
    2. Employ an integrated systems approach.
    3. Exercise sound leadership, management, and stewardship in decision-making processes.
    4. Adapt critical infrastructure in response to dynamic conditions and practice.

These guiding principles are fully interrelated. No one principle is more important than the others and all are required to protect the public's safety, health, and welfare.

Don Basham

- The National Committee on Levee Safety supports USACE work on TRG and believes this should set the stage for implementation nationally.
- Involve others in development of TRG and criteria.
- Use the 'Bully Pulpit' to push the life-safety agenda to a national stage.
- Life loss is important and should be included with economic and environmental considerations – it has been considered in the past, but some assumptions were faulty.
- Need to figure out how this will work with new Principles and Standards. Needs to be worked into new guidance.
- Workshop might have been better served talking about more than guidelines, e.g. focus should be on larger context of the FRM process.
- Strongly encourage continued work on assessing and plotting levee systems on a risk chart – get the portfolio plotted.

- BUT – need to tackle specifically what might be the guidelines and put them in a policy context.

Dr. Jean Le Guen

- Impressed by progress since 2008 workshop.
- No reason TRG shouldn't work, but need to put the system for managing risk in the public domain.
- What is needed is a wider FRM plan that goes broader than the Corps.
- The decision about acceptable/tolerable is a political decision.
- Took 20 years to develop and implement Tolerability of Risk (TOR) and TRG in the UK.
- Lines are not rigid – not controlling; decisions require judgment.
- Corps will need to invest more resources into describing shared responsibilities – letting others know what is required of them.

Eric Halpin – comments he heard in the workshop:

- "Do you see what I see?" – Communication issue (internal and external) may be most important issue – we need professional help with the communications and outreach.
- "TRG much richer than a line or number" – this is a critical takeaway. See full definition of TRG components. This full definition brings a lot to the table for risk managers to consider. Important to communicate effectiveness and urgency of risk reduction.
- "Dams have spillways, levees don't" – both will pass unregulated flow, but one is considered a failure when it occurs - that is overtopping of a levee, the other – full spillway discharge at a dam - is not.
- "Not very good at estimating risk and uncertainty" – but getting better.
- While working to implement the levee safety program:

  - Still have to be able to communicate;

  - Still have to make decisions;

  - Still have to get out there and do it.
- USACE will give all feedback serious consideration in how it moves forward.
- USACE will share workshop proceedings.
- USACE will undertake drafting, vetting, and testing policies and products in support of the USACE levee safety program. This is not solely about USACE, and will use public processes, which will mean complying with the Federal Advisory Committee Act (FACA) if required.

Eric Halpin – key takeaways:

- TRG is a framework or guide – for decision making and for communication.
    - Need to be Transparent; use multi-criteria; may need to address individual and societal risk; understand risk and sources; TRG not a simple number, not a bright line; not without uncertainty; can potentially replace binary discussion; and bring life safety to the fore front.

- Should TRG be used? Yes. Should life safety be included? Yes. Should it be the only criterion? No.
- How we advise and communicate with stakeholders is critical.
- TRG environment is: tough; complex; people are risk ignorant; there will be compelling detractors; and the need to communicate risk it is a part of the bigger FRM issue.
- 'Solutioneering' – cooperatively developing and implementing solutions - is a key concept in FRM.
- Concepts in levee safety will mature and policy governance will evolve.
- Need a national flood risk management policy. This is a new role for Federal government and it may be awkward; the way to address it is to involve stakeholders.
- USACE role in TOR/TRG: must engage others; consider a parallel group that is independent, external for peer review of TOR/TRG;
- For levee safety, or USACE, have primary role in assessment, advisory role with partners in communication, and advisory role in management (although primary if Federal investment); pilot tests; policy group; advisory role; partnering with stakeholders; communicate the risk story; and putting concepts into practice.
- Issues that linger: Is risk a choice? How to apply to new projects? Who plans FRM strategic activities? Who has the lead role? USACE needs to tell the story and support solutions. Collaboration is the only way this can move forward.
    - Can no longer say it is a matrix approach with shared leadership.
    - Communications need to portray risk in a visual way.

6. Way Forward

The workshop steering committee members (USACE staff and lead facilitator), USACE levee safety leadership, and other select workshop principals gathered for a half-day following the workshop to review and discuss the outcomes. The summary of these discussions and conclusions is presented below in two parts: observations about what was heard; and abbreviated follow-on actions/task tabulation.

6a. Observations about What Was Heard

TRG is viewed by some in the USACE as a criticism of the way it has have formulated projects. The concept seems to challenge the fundamental assumption of the National Economic Development (NED) project formulation policy now in place. TRG should not and would not support implementing a facility or project that would put people at greater risk than they would be without the project. Thought needs to be given to how this relates to other aspects of Federal policy, including the Principles and Guidelines (P&G) and the National Flood Insurance Program (NFIP). USACE leaders concerned about how TRG and risk analysis will be applied to the USACE civil works program and how it will affect engineering design and judgment. A concern expressed is that the USACE will not be able to communicate the estimated risk and TRG concepts effectively internally and to stakeholders.

Implementation will be helped significantly if the TRG and Tolerability of Risk (TOR) framework gets introduced into the larger professional community and among stakeholders. The meaning of TRG is difficult to grasp and can be easily misunderstood. TRG is not just a number but a tool to be used in combination with other mechanisms and techniques in furthering levee system safety. Risk assessment tools need to be straightforward to use, particularly if it is desired to have non-USACE entities to use them. Advocates should look at introducing TOR first and ensure that it is understood, and then TRG as a means of implementing TOR.

Caution needs to be observed in that TOR and TRG might be considered and used as a repudiation of the Federal Emergency Management Agency (FEMA) and the National Flood Insurance Program (NFIP). Although established in the broader risk literature internationally, “tolerable” is a word that makes some people have a negative reaction. For implementation success, it is essential that FEMA participate positively (or at least neutrally) so that the Federal government is speaking with the same voice. For stakeholders and the general public, it is difficult to understand how levees may fail. Therefore, there is a tendency to only want to look at overtopping risk, which is a very simplistic and misleading approach to assessing the safety of levee systems. It is worth considering developing a relationship with Architect-Engineer firms to introduce TOR and TRG concepts into their thinking and practice.

Common definitions and concepts related to safety, risk, reliability, robustness, and redundancy are needed to assist in the forthcoming and significant communications challenge. There needs to be a simple way to explain TOR and TRG. USACE needs to develop corporate messages on TOR and TRG for both internal as well as external communications. It should think about the utility of aligning these concepts with the changes proposed in the evolving, new Principles and Guidelines. USACE might want to consider preparing and presenting on TOR and TRG to other organizations (Federal and local), non-governmental organizations, professional engineering and urban planning conferences and workshops, and other gatherings that might be attended by the full range of stakeholders associated with levee safety.

Some felt that for the most part, stakeholders are unaware of risks that levees impose and are unaware of their roles and responsibilities for ensuring that levee systems are adequately safe. USACE communication plans need to acknowledge those obstacles and incorporate material to inform unaware stakeholders. USACE should inform all stakeholders what is being done ahead of time – no surprises. USACE should prepare media articles with important information ahead of time and encourage their dissemination to communities. Leadership at all levels of government, non-governmental organizations, and professionals must engage in the communications.

Environmental risk has thus far not been part of the discussions; it needs to be included.

Are we expecting levees to operate as dams? Dams have spillways designed to pass excess flow without failing; levees overtop and breach from floods exceeding design – a critical difference. We need to get that message out to the stakeholders.

It was suggested by more than one participant that better use of floodplain management plans required in association with a Federal project would be a possible tool to begin implementation of various flood risk management practices such as TRG.

6b. Summary of Follow-on Actions/task Tabulation

- Accepted draft outline, made assignments, and adopted schedule for preparing and publishing workshop proceedings. Rough schedule includes: draft for USACE team review by end of May – comments due first of July; final draft available for review by others early July; final document to undergo technical editing with publication mid-September.

- In the interim prior to publication of the workshop proceedings, prepare a public website with links to workshop materials (agenda, read-ahead documents, presentations) by early-April; include links in thank-you letters to participants**.** Completed.

- Develop briefing material on TRG workshop and overall USACE levee safety program. Include an example of how TOR and TRG are to be used. Consider adapting UK gas main replacement case example for use as a similar case to levee safety. Also consider comparing with house fires, wild fires, bridges, structure safety, etc. Underway.

- Develop in a transparent manner with stakeholder involvement, draft USACE levee safety program policies and associated guidance and regulations. Develop these policies and guidance with the idea that they may have utility beyond the USACE levee safety program. Include a plan on how TOR and TRG will be applied and implemented. Assign tasks (TRG working group to lead) and develop plan and schedule for guidance documents. Underway.
- Concurrently, develop a stakeholder involvement plan to include activities (pilot test, examples, briefing materials, interagency collaboration) and schedule associated with USACE levee safety program policies, guidance, and implementation. Underway.

7. References

ANCOLD (2003), Australian National Committee on Large Dams, "Guidelines on Risk Assessment," October 2003.

ICOLD (2005), "Risk Assessment in Dam Safety Management: A Reconnaissance of Benefits, Methods and Current Applications," International Commission on Large Dams (ICOLD) Bulletin 130, 2005.

NLCS (2009), National Committee on Levee Safety, “Recommendations for a National Levee Safety Program, A Report to Congress from the National Committee on Levee Safety,” Draft, January 15, 2009.

Reclamation (2003), United States Department of the Interior, Bureau of Reclamation, "Guidelines For Achieving Public Protection In Dam Safety Decision-making”, 15 June 2003.

USACE (2007), US Army Corps of Engineers, “Levee Safety Program Implementation,” Memorandum for Major Subordinate Commands and Districts, MG Don T. Riley, 16 November 2007.

USACE (2010), US Army Corps of Engineers, “Safety of Dams – Policy and Procedure, ER 1110-2-1156, Draft, 30 April 2010.

Appendices

Contents Page

Appendix A: Agenda **Page**

Workshop Agenda
"Exploration of Tolerable Risk Guidelines for Levee Systems"
March 17-18, 2010

Crowne Plaza Old Town Alexandria
901 North Fairfax Street
Alexandria, Virginia

Workshop Objectives:

- Examine the concepts and principles of tolerable risk for different hazards and explore their application to and use in managing risk (life, economic, and environmental) associated with levee systems;
- Obtain input on role of tolerable risk guidelines (TRG) and what should be considered in the formulation of TRG for use in the USACE levee safety program;
- Review the status of the use of TRG in the United States and other countries to determine applicability to levee systems; and
- Poll participants regarding issues and concepts that should be considered in developing TRG for levee systems, and identify next steps in their development.

Day One: March, 17, 2010

08:00 Welcome and Charge of the Workshop
Eric Halpin, U.S. Army Corps of Engineers
Mr. Halpin will welcome participants and review the objectives of the workshop.

08:10 Agenda Review and Introductions
Linda Manning, The Council Oak (facilitator)
Ms. Manning will review how the workshop is to function and introduce facilitators.

08:15 Summary of March 2008 Workshop on Tolerable Risk Evaluation
David Moser, U.S. Army Corps of Engineers
Dr. Moser will present a summary of the 2008 Workshop on Tolerable Risk Evaluation for background information.

08:30 Overview of National Committee on Levee Safety Recommendations Pertaining to Tolerable Risk Guidelines
Karin Jacoby & Les Harder, National Committee on Levee Safety
Ms. Jacoby and Dr. Harder will briefly present the work of the National Committee on Levee Safety (NCLS) and the specific recommendation related to the development and adoption of national Tolerable Risk Guidelines in the United States.

09:00. Tolerable Risk Concepts and Principles
Jean Le Guen, Private Consultant (retired from the UK Health and Safety Executive office)
Dr. Le Guen will introduce foundational principles and concepts of tolerable risk and provide his observations on how these principles can be applied to levee systems.

10:00 Break

10:30 **Overview and Update on Flood Risk Management, Levee Safety, TRG and Portfolio Risk Management for Levee Systems**
Eric Halpin, U.S. Army Corps of Engineers
Mr. Halpin will provide an overview of the U.S. Army Corps of Engineers activities most related to levee safety in order that participants can understand the programmatic, legislative and organizational contexts for levee safety in the United States.

11:15 **Overview and Update on Development of Tolerable Risk Guidelines for The Netherlands' Coastal and Riverine Defences**
Alex Roos & Durk Riedstra, Rijkswaterstaat
Mr. Roos and Mr. Riedstra will provide information regarding Rijkswaterstaat efforts to date to develop TRG for coastal and riverine defences in the Netherlands.

12:00 **Roadmap for the Rest of the Workshop**
David Moser, U.S. Army Corps of Engineers & Linda Manning, facilitator
Dr. Moser will discuss with participants the objectives for the rest of the workshop. Ms. Manning will discuss instructions for the breakout sessions, ground rules, and participant assignment to breakout groups.

12:15 **Working Lunch (provided)**

13:15 **Breakout Session #1**
Questions to address:

- *What are the measures and metrics that can help guide determination of 'adequately safe levee systems' in the development and application of tolerable risk guidelines (TRG)?*
- *For levee safety considerations is the difference between life safety and structure safety (structural integrity) for levee systems important and how might each contribute to achieving TRG for levee systems?*

15:15 Break

15:30 **Plenary Panel Discussion: Report from Breakout Groups**
Moderator: David Moser, U.S. Army Corps of Engineers
A representative from each breakout group will report the answers to the questions as well as any other relevant observations. Q &A to follow panel presentations.

16:25 **Day One Summary**
David Moser, U.S. Army Corps of Engineers

17:00 Adjourn

Day Two: March, 18, 2010

08:00 Recap of Day One/Day Two Agenda Review
David Moser, U.S. Army Corps of Engineers & Linda Manning (facilitator)

08:10. Breakout Session #2
Questions to address:

- *What is the responsibility of each stakeholder for achieving and maintaining levee safety?*
- *Considering the number and variety of stakeholders, how could tolerable risk guidelines be used to assist in life safety risk assessments and levee systems risk management decisions?*

10:10 Break

10:25 Plenary Panel Discussion: Report from Breakout Groups
Moderator: David Moser, U.S. Army Corps of Engineers
A representative from each breakout group will report the answers to the questions as well as any other relevant observations. Q &A to follow panel presentations.

11:30 Working Lunch

12:30 Breakout Session #3
Questions to address:

- *What are the issues to be addressed to develop tolerable risk guidelines for levee systems and what would the tolerable risk guidelines look like?*
- *How do we proceed?*

14:30 Break

14:45 Plenary Panel Discussion: Report from Breakout Groups
Moderator: David Moser, U.S. Army Corps of Engineers
A representative from each breakout group will report the answers to the questions as well as any other relevant observations. Q &A to follow panel presentations.

15:45 Closing Plenary Panel Discussion: Panelists' Perspectives
Moderator: David Moser, U.S. Army Corps of Engineers
Panel will present their observations and perspective on the applicability of tolerable risk concepts and guidelines to levee safety. This will be followed by a question and answer session.
Panelists:

- Eric Halpin, U.S. Army Corps of Engineers
- Don Basham, National Committee on Levee Safety
- Dr. Larry Roth, American Society of Civil Engineers
- Dr. Jean Le Guen, Private Consultant (UKHSE, retired)

16:45 Closing Remarks, Summary and Path Forward
Eric Halpin, U.S. Army Corps of Engineers

17:00. Adjourn

Appendix B: Attendees **Page**

Participating Organizations
Tolerable Risk Guidelines for Levees Workshop
March 17-28, 2010

Country	Organization
United States	American Society of Civil Engineers
United States	Association of State Dam Safety Officials
United States	Association of State Floodplain Managers, Inc.
United States	Bureau of Reclamation
United States	California Department of Water Resources
United States	Chair, United States Society on Dams Levee Committee
United States	Council Oak
United Kingdom	Environment Agency, United Kingdom
United States	Federal Emergency Management Agency (FEMA)
United States	Federal Energy Regulatory Commission
United States	FM Global
United States	Galveston District, United States Army Corps of Engineers
United States	HDR
United States	HR Wallingford Ltd
United States	Louisville District, United States Army Corps of Engineers
United States	Mid-America Regional Council
United States	Mississippi River Commission
United States	National Association of Flood & Stormwater Management Agencies (Miami Conservancy District)
United States	National Committee on Levee Safety
United States	New England District, United States Army Corps of Engineers
United States	Office of Infrastructure Protection, United States Department of Homeland Security
United States	Office of the Assistant Secretary of the Army – Civil Works
Japan	Public Works Research Institute, JAPAN
United States	Resources for the Future
The Netherlands	Rijkswaterstaat - Centre for Water Management, The Netherlands
United Kingdom	Risk Policy Unit of the Health and Safety, Executive, United Kingdom
Japan	River Department, National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Tourism ,
United States	St. Louis District, United States Army Corps of Engineers
United States	St. Paul District, United States Army Corps of Engineers
United States	United States Army Corps of Engineers, HQ
United States	United States Section, International Boundary & Water Commission
United States	University of Maryland
Spain	Universidad Politecnica de Valencia (Spain)
United States	United States Army Corps of Engineers Institute for Water Resources
United States	United States Army Corps of Engineers Risk Management Center
United States	Utah State University
United States	World Bank

List of Participants
Tolerable Risk Guidelines for Levees Workshop
March 17-28, 2010

22-Mar-10

Name	Title	Position	Organization	email	telephone	Address
Richard A. Allwes, P. E.	Mr.	Structural Engineer	USACE Risk Management Center	richard.a.allwes@usace.army.mil	412-804-8867	U.S. Army Corps of Engineers, Risk Management Center, 2200 William S. Moorhead Federal Building, 21st FL, 1000 Liberty Avenue, Pittsburgh, PA 15222-4186
Tony Andryszewski	Mr.	Technical Manager, Asset Management, Flood Risk Management	Environment Agency, UK	tony.a@environment-agency.gov.uk	0113 231 2447	Rivers House, 21 Park Square South, Leeds, LS1 2QG, UK
Beto Arenas	Mr.	Civil Engineer	U.S. Section, International Boundary & Water Commission	harenas@ibwc.gov	915- 832-4797	4171 North Mesa, Suite C-100, El Paso, TX 79902-1441
Gregory B. Baecher	Dr.	Professor of Civil Engineering	University of Maryland	gbaecher@umd.edu	202-285-3902	College Park, MD 20742
Bob Bank, P. E.	Mr.	Chief, Civil Works Branch	U. S. Army Corps of Engineers, HQ	Robert.Bank@usace.army.mil	202-761-5532	441 G St NW, Wash DC 20314-1000
Michael J. Bart, P.E.	Mr.	Chief, Engineering & Construction Division; Team Lead, USACE Levee Safety Policy & Procedures Team	St. Paul District, USACE	Michael.J.Bart@usace.army.mil	651-290-5303	Sibley Square at Mears Park, 190 5th Street East, Suite 401, St. Paul, MN 55101-1638
Don Basham, P. E.	Mr.	Member	National Committee on Leve Safety	dlbasham@bellsouth.net	502-243-4010	8215 Chapel Drive, Crestwood, KY 40014
Doug Bellomo	Mr.	Division Director, Risk Analysis Division, Mitigation Directorate	Federal Emergency Management Agency (FEMA)	Doug.Bellomo@dhs.gov	202-646-2903	1800 South Bell Street, Arlington VA, 20598-3030
Janet Bly	Ms.	Flood Management Committee Co-Chair (General Manager)	National Association of Flood & Stormwater Management Agencies (Miami Conservancy District)	jbly@miamiconservancy.org	937-223-1271	38 E. Monument Ave, Dayton, OH 45402
Lisa Bourget, P.E.	Ms.	Engineer	USACE Institute for Water Resources	Elizabeth.C.Bourget@usace.army.mil	715-386-0124	Casey Building, 7701 Telegraph Road, Alexandria, Virginia, 22315
David Bowles, P. E., D.WRE	Dr.	Professor, Civil and Environmental Engineering; Director, Institute for Dam Safety Risk Management; and Managing Principal, RAC Engineer & Economists	Utah State University	bowles@cache.net	435-770-8709	Utah Water Research Laboratory, Utah State University, Logan, Utah 84322-8200
Theodore (Tab) A. Brown	Mr.	Chief, Planning and Policy Division, Directorate of Civil Works	U. S. Army Corps of Engineers, HQ	Theodore.A.Brown@usace.army.mil	202-761-0115	441 G St NW, Wash DC 20314-1000
David Capka, P.E.	Mr.	Supervisor, Dam Safety Engineering, HQ	Federal Energy Regulatory Commission	David.Capka@ferc.gov	202-502-6314	Federal Energy Regulatory Commission, 888 First, NE Washington, DC 20426

List of Participants
Tolerable Risk Guidelines for Levees Workshop
March 17-28, 2010

Rita Cestti	Ms.	Sr. Rural Development Specialist	World Bank	Rcestti@worldbank.org	202-473-3473	1818 H Street, NW, Washington, DC 20433, USA
Tammy Conforti, P. E.	Ms.	Levee Safety Program Manager	U. S. Army Corps of Engineers, HQ	Tammy.Conforti@usace.army.mil	202-761-4649	441 G St NW, Wash DC 20314-1000
James C Dalton, P.E.	Mr.	Chief, Engineering and Construction, Dam and Levee Safety Officer, USACE	U. S. Army Corps of Engineers, HQ	James.c.dalton@usace.army.mil	202-761-8826	441 G St NW, Wash DC 20314-1000
Darryl W. Davis, P.E., D.WRE	Mr.	Senior Advisor, Water Resources Engineering	USACE Institute for Water Resources	darryl.w.davis@usace.army.mil	530-756-1104	609 Second Street, Davis, CA 95616
James E. Demby, Jr., P.E.	Mr.	Senior Technical and Policy Advisor, National Dam Safety Program	Federal Emergency Management Agency (FEMA)	james.demby@dhs.gov	202-646-3435	1800 South Bell Street, Arlington VA, 20598-3030
Susan Durden	Ms.	Economist	USACE Institute for Water Resources	Susan.E.Durden@usace.army.mil	703-428-9089	115 Turkey Trail, Statesboro, GA 30458
Stephen G. Durrett, P. E.	Mr.	Chief Engineering Division	Louisville District, USACE	Stephen.g.durrett@usace.army.mil	502-315-6220	ATTN: LRL-ED, P.O. Box 59, Louisville, KY 40201-0059
Ignacio Escuder	Dr.	Professor	Universidad Politecnica de Valencia (Spain)	iescuder@hma.upv.es	+34963879893	Camino de Vera S/N. 46022 VALENCIA. SPAIN.
Gerry Galloway, P. E., PhD, D.WRE	Dr.	Professor of Engineering	Univeristy of Maryland	gegallo@umd.edu	571-334-2103	College Park, MD 20742
Clive Goodwin	Mr.	Manager, Flood and Wind Underwriting	FM Global	clive.goodwin@fmglobal.com	401-415-1952	FM Global, 270 Central Avenue, P.O. Box 7500 Johnston, RI 02919-4949 USA
Eric Halpin, P. E.	Mr.	Special Assistant for Dam and Levee Safety	U. S. Army Corps of Engineers, HQ	Eric.C.Halpin@usace.army.mil	202-761-7662	441 G St NW, Wash DC 20314-1000
Brian Harper	Mr.	Economist	Galveston District, USACE	Brian.K.Harper@usace.army.mil	409-766-3886	
Leslie F. Harder, Jr. P. E., G. E.	Dr.	Senior Water Resources Technical Advisor	HDR	les.harder@hdrinc.com	916-768-1585	Senior Water Resources Technical Advisor HDR - ONE COMPANY | Many Solutions 2365 Iron Point Road, Suite 300, Folsom, CA 95630-8709
Atsushi Hattori	Dr.	Head, River Division	River Department, National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Tourism	hattori-a92f4@nilim.go.jp	+81-029-855-2539	Ministry of Land, Infrastructure, Transport and Tourism, Asahi 1, Tsukuba-Shi, Ibaraki-Ken, 305-0804, JAPAN

Perry Hensley	Mr.	Senior Advisor Design , Estimating and Construction and Dam Safety Officer	Bureau of Reclamation	PHensley@usbr.gov	303-445-2986	Senior Advisor, DEC/Dam Safety Officer, Denver Federal Center, Bldg. 67, Rm 25007 (86-62000), Denver CO 80225-0007
Peter J. Hradilek, P. E., G. E., D.WRE	Dr.	Technical Advisor for Dams & Hydraulic Structures, HDR Engineers	Chair, United States Society on Dams Levee Committee	peter.hradilek@hdrinc.com	916.817.4912	HDR - ONE COMPANY | Many Solutions 2365 Iron Point Road, Suite 300, Folsom, CA 95630-8709 y
Karin M. Jacoby, PE, Esq.	Ms.	Waterways Coordinator	Mid-America Regional Council	kjacoby@marc.org	816-701-8295	600 Broadway, Suite 200, Kansas City, MO 64105,
Jeffrey Jensen	Mr.	Deputy Director, Flood Risk Management Program	USACE Institute for Water Resources	Jeffrey.D.Jensen@usace.army.mil	703-428-9068	7701 Telegraph Road, Casey Building, Alexandria, VA 22315-3868
Joseph P. Koester, P. E.	Dr.	Geotechnical and Materials Community of Practice Lead	U. S. Army Corps of Engineers, HQ	Joseph.P.Koester@usace.army.mil	(202) 761-4828 office; (202) 406-0589 BB	420 Lake Forest Drive, Vicksburg, MS 39183 (Telework)
Larry Larson	Mr.	Executive Director	Association of State Floodplain Managers, Inc.	larry@floods.org	608-274-0123	2809 Fish Hatchery Rd., Ste. 204, Madison, WI 53713
Jean Marie Le Guen, O. B. E.	Dr.	Private Consultant	Ex Head of the Risk Policy Unit of the Health and Safety, Executive, United Kingdom	jeanmarie.leguen@btinternet.com	0044 (0)20 8852 8669	1 Lock Chase, Blackheath, London, SE3 9HB, United Kingdom
Mark Locke	Mr.	National Design Engineer, Conservation Engineering Division	USDA, Natural Resources Conservation Service	mark.locke@wdc.usda.gov.	202-720-5858	USDA, NRCS, Conservation Engineering Division, 14th and Indepence Ave, SW, Room 6136-S, Washington, DC 20250
Dave Margo, P.E.	Mr.	Risk Assessment Methodology Lead	USACE Risk Management Center	David.A.Margo@usace.army.mil	412-395-7353	1000 Liberty Avenue, Pittsburgh, PA 15222
Enrique E. Matheu	Dr.	Chief, Dams Sector Branch	Office of Infrastructure Protection, U.S. Department of Homeland Security	enrique.matheu@dhs.gov	703-603-5110	DHS, NPPD/IP/SSA EMO, 245 Murray Lane, Mail Stop 0608, Washington, DC 20528-1002
Louis Mauney	Mr.	Civil Works Fiscal Program Manager	Office of the Assistant Secretary of the Army – Civil Works	louis.a.mauney@us.army.mil	202-761-0017	441 G St NW, Wash DC 20314-1000
Rod Mayer, P. E., G. E.	Mr.	Assistant Deputy Director for FloodSafe California	California Department of Water Resources	rmayer@water.ca.gov	(916) 574-0653	3310 El Camino Avenue, Sacramento, California 95821
Hirotoshi Mori	Mr.	Senior Researcher, Soil Mechanics and Dynamics Research Team, Material and Geotechnical Engineering Research Group	Public Works Research Institute, JAPAN	hi-mori@pwri.go.jp	81-29-879-6771	1-6 Minamihara, Tsukuba, Ibaraki 305-8516, JAPAN
David A. Moser	Dr.	Chief Economist, USACE	U. S. Army Corps of Engineers	David.A.Moser@usace.army.mil	703-428-6289	7701 Telegraph Rd, Alexandria, VA 22315

List of Participants
Tolerable Risk Guidelines for Levees Workshop
March 17-28, 2010

Dale F. Munger, P. E.	Mr.	Member, Levee Safety Policy and Procedures Team	USACE	dale.f.munger@usace.army.mil	503-970-3437	2430 SW Wonderview Drive, Gresham, OR 97080
Michael Navin	Dr.	Civil Engineer	St. Louis District, USACE	Michael.P.Navin@usace.army.mil	314-331-8441	1222 Spruce Street, St. Louis, MO 63103
Jason Needham	Mr.	Consequence Specialist	USACE Risk Management Center	Jason.T.Needham@usace.army.mil	530-756-1104	609 Second Street, Davis, CA 95616
Scott Nicholson	Mr.	Policy and Planning	U. S. Army Corps of Engineers, HQ	scott.r.nicholson@usace.army.mil	202-761-7770	441 G St NW, Wash DC 20314-1000
Mark Ogden	Mr.	Levee Committee Chair	Association of State Dam Safety Officials	mogden@damsafety.org	859-333-3650	3594 Rochfort Bridge Drive, Columbus, OH 43221
Bob Patev	Dr.	Risk Assessment Specialist	New England District, USACE	Robert.C.Patev@usace.army.mil	978-318-8394	696 Virginia Road, Concord, MA 01742
Dave Pezza, P.E.	Mr.	Deputy Chief, Engineering and Construction	U. S. Army Corps of Engineers, HQ	David.a.pezza@usace.army.mil	202-761-5347	441 G St NW, Wash DC 20314-1000
Pete Pierce	Mr.	PAO	U. S. Army Corps of Engineers, HQ	Walter.E.Pierce@usace.army.mil	202-761-1809	441 G St NW, Wash DC 20314-1000
Durk Riedstra	Mr.	Senior Advisor	Rijkswaterstaat - Centre for Water Management	durk.riedstra@rws.nl	+31.6 1011 7755	PO Box 17, 8200 AA Lelystad, The Netherlends
Rick Robertson	Mr.	Civil Engineer	Mississippi River Commission	rick.robertson@usace.army.mil	601-634-5067	1400 Walnut St CEMVD-PD-WM, Vicksburg, MS 39180
Alex Roos	Mr.	Senior Advisor	Rijkswaterstaat Centre for Water Management	alex.roos@rws.nl	+31.620249192	PO Box 17, 8200 AA Lelystad, The Netherlends
Lawrence H. Roth, PE, GE	Mr.	Executive Vice President	American Society of Civil Engineers	lroth@asce.org	703-295-6102	1801 Alexander Bell Drive, Reston, VA 20191-4400
Paul Sayers	Mr.	Director Flood & Water Management	HR Wallingford Ltd	p.sayers@hrwallingford.co.uk	+44 (0) 1491 822344	Howbery Park, Wallingford, Oxfordshire, OX10 8BA, United Kingdom
David A. Schulenberg	Mr.	Planning	USACE	david.a.schulenberg@usace.army.mil	716-879-4263	

List of Participants
Tolerable Risk Guidelines for Levees Workshop
March 17-28, 2010

Leonard Shabman	Dr.	Resident Scholar	Resources for the Future	shabman@rff.org	202 328 5139	1616 P street NW, Washington DC
Nate Snorteland, P. E.	Mr.	Director, Risk Management Center	USACE Risk Management Center	Nathan.J.Snorteland@usace.army.mil	571-232-9189	
Doug Wade	Mr.	USACE contractor	Council Oak	douglas.j.wade@usace.army.mil	202-761-4668	441 G. Street NW, CECW-CE, Washington, DC 20314-1000
Jerry W. Webb, P.E., D.WRE	Mr.	Principal Hydrologic & Hydraulic Engineer	U. S. Army Corps of Engineers, HQ	Jerry.W.Webb@usace.army.mil	202-761-0673	441 G. Street NW, CECW-CE, Washington, DC 20314-1000
Laura Zepp	Ms.	Economist	USACE Institute for Water Resources	Laura.J.Zepp@usace.army.mil	703-428-7760	7701 Telegraph Rd, Alexandria, VA 22315
FACILITATORS:						
Gail Bingham	Ms.	Facilitator	RESOLVE	gbingham@resolv.org	202-965-6200	1255 23rd Street, NW, Suite 875, Washington, DC 20037
Linda Manning	Ms.	Facilitator	The Council Oak	lmanning@thecounciloak.com	703-395-3570	3828 Pickett Court, Annandale, VA 22003
Maria Placht	Ms.	Facilitator	USACE Institute for Water Resources	Maria.T.Placht@usace.army.mil	703-428-6242	7701 Telegraph Rd, Alexandria, VA 22315

Appendix C: Read-ahead documents **Page**

USACE Levee Safety Program and Tolerable Risk Guidelines - A Discussion Paper for the Exploration of Tolerable Risk[1] Guidelines for Levee Systems Workshop

Introduction

Background, USACE Levee Safety Program - In the past, there was no USACE 'Levee Safety Program' as such. USACE monitored the status of levees within its jurisdiction via annual inspections, or review of inspections performed by local sponsors. Depending on the findings of the inspections, action may have been initiated to repair deficiencies, restore the levee system to its authorized condition, or study the need for expanding the scope of the system. The actions taken were not formally coordinated from a national perspective and varied greatly across the country depending on USACE district past experience, status of new restudies of the levee system, varied interpretation of authorities, and local sponsor capabilities, such as funding their cost share of studies and remediation. With the formation of the USACE Levee Safety Program (USACE 2007), the inspection program is being modified from an inspection program primarily focused on owner maintenance to an inspection program that now has a significant safety component. Annual inspections will continue, periodic inspections to include a review of design criteria used for the levee system will occur but less frequently than annually, and levee risk screenings are underway. A portfolio risk management process is under development that addresses each system in order of its national priority for reducing safety risk. The USACE portfolio of levees will be centrally managed for safety taking a national perspective while levee safety corrective actions will be locally executed. The portfolio management process includes: inspections, screening, levee safety action classification, interim risk reduction measures, issue evaluation and risk reduction studies, and permanent risk reduction measure implementation. These actions are consistent with recent recommendations by the National Committee on Levee Safety (NLCS draft 2009).

Tolerable Risk Guidelines, Partners, and Stakeholders - The concept of tolerable risk is fundamental to risk-informed decision making. Tolerable risk guidelines are essential for successful assessment, management, and communication of the risk involved with levee systems in the USACE inventory. The tolerable risk guideline concepts presented in this paper were developed as a starting point for further refinement of tolerable risk guidelines for the USACE levee safety program. Further development and testing of the utility of these proposed guidelines, with adjustments to improve them, will take place over the next several years. It is fully expected and welcomed that the USACE levee safety partners and stakeholders will be engaged with USACE in further development and refinement of the tolerable risk guidelines for levee safety.

Tolerable risk guidelines for levees present an interesting puzzle and opportunity. At the present, the interest in tolerable risk guidelines for life risk is not likely to be viewed as a sole justification criterion, which would in all cases override economic justification, especially for proposed new levee projects. The thought is that for the near-term such tolerable risk guidelines would be a tool primarily for application to deficient existing levees. The application results would be used for

---

[1] The definition of 'risk' adopted by USACE and used in this paper is: "Measure of the probability and severity of undesirable consequences."

prioritizing and ranking existing levees with deficiencies, formulating the structural and non-structural measures to lower life risk, and as a general guide for assessing and reporting vulnerability of floodplain occupants to life threat.

Life Safety as a Decision Metric - By adopting TRG for levees and integrating their application in levee remediation and planning studies, life safety becomes elevated from not being directly considered to now being a visible decision metric. This is a quantum departure from the past and a very big step indeed! Elevating life risk in this manner may tend to promote moving away from level-of-protection as an indirect criterion for considering life safety to assessing life risk along with economic justification, environmental restoration, and sustainability of floodplain values in project decision making. Let it be noted that higher levels-of-protection for a project do not necessarily lower floodplain life-risk; rather, in some situations, a higher level-of-protection may result in higher residual life-risk to floodplain occupants. This is due to the fact that while there is expected to be lower likelihood of levee failure for higher levels-of-protection, there is often more floodplain development that is induced, subjecting more people to flood threat, ergo higher life-risk. As a bit of a footnote, the USACE levee safety program is using the term 'risk reduction' rather than 'protection' for communications purposes; ‘protection’ implying a binary concept of one being threatened or not.

Shared Responsibility - For fixing or repair of an existing levee that is estimated not to meet TRG, under existing levee safety program authorities USACE is unlikely to raise, extend, or in someway expand the scope of the levee beyond its original authorization. If an increase or major change in scope appeared appropriate, then a Section 216 restudy (ER 1165-2-119 - a new feasibility study) would be the logical path to developing a solution. The speculation here is that USACE would consider repair of the levee to its original authorization intent of no failure breach prior to overtopping, but that in many cases this would still not meet TRG. To close the remaining gap between performance of the levee and meeting TRG, USACE would work with partners and stakeholders in a ‘shared responsibility’ context to devise an acceptable solution.

USACE Levee Safety Vision, Mission Statement, and Objectives - The vision statement, mission statement, and objectives of the risk-informed USACE levee safety program are:

Vision - A safe public and reduced economic losses by means of adequately safe levees - a vital element of flood risk management.

Mission statement – To assess the structural integrity and viability of levees and to recommend actions to assure that levee systems do not present unacceptable risks to the public, property and the environment.

Objectives

- To Hold Public Safety Paramount;
- To Reduce Economic and Environmental Consequences associated with levee failure;
- To Maximize the Cost Effectiveness of risk reduction measures;
- To Develop Reliable and Accurate Information about the risks posed by levees; and

- To Build Public Trust, Acceptance, and a Shared Responsibility for flood risk reduction initiatives.

Levee System Safety in Context

The principal function of levee systems is to exclude flood waters from a portion of the floodplain for the purpose of reducing flood losses. Embankments that behave as levees also exist in water conveyance systems, navigation channels, recreation areas and habitat restoration projects. Levees systems are generally of low height in comparison to dams, and do not store water nor regulate flow. They can be expected to be overtopped during a future event that is sufficiently large to exceed the top of the levee. In contrast, dams managed by USACE are relatively high, and are designed to store and/or regulate the flow of water for various purposes, which may include flood damage reduction. Because of the potentially catastrophic consequences that would result from the uncontrolled release of the reservoir pool caused by a dam failure, safety actions are taken to make dam failure highly unlikely. Therefore dam safety has its focus on avoiding overtopping and maintaining a structure that will safely withstand all types of loadings ranging from normal operations to very extreme events. Thus for dams, the focus in on integrity of the structure and the universe of possible failure modes, and the associated consequences should there be a failure that results in uncontrolled release of the reservoir pool. Another key metric includes the chance of the dam not failing and the consequences thereof.

Levee system safety is concerned with structural integrity of the levee system for flood loadings up to the top of levee, and also with structural integrity during overtopping. As a result, the chance of a levee system breaching, and leading to an uncontrolled flow through one or more breaches for loadings that do not overtop the levee, is but one key levee safety metric. Other key metrics include the chance of the levee system becoming overtopped but not breaching and the consequences thereof, and the chance of the levee system becoming overtopped and subsequently breaching and the consequences thereof. Thus, a levee safety program must include a management process and a method of risk characterization that give attention to levee failure breaching for loadings that are less than the top of levee elevation and for loadings that exceed the top of levee elevation. To capture these important concepts, the following definitions are adopted for the USACE levee safety program:

> **Breach** – the formation of a gap in the levee system through which water may flow uncontrolled onto the adjacent floodplain. ‘Breach’ is used herein as a general term applying to both failure breach prior to overtopping, and to an overtopping breach.
>
> **Failure breach** – a term restricted to the breach of the levee, prior to overtopping.

The overtopping, and possible breaching of a levee due to overtopping, is not considered to be an engineering or design failure. The levee system, by design, is expected to prevent flooding up to a given flood elevation, but it is expected to be overtopped by less frequent but higher flood elevations.

Risks associated with a levee system are to be estimated and reported for following three scenarios:

1) A failure breach below or at the top of levee elevation,
2) Overtopping without breach, and
3) Overtopping with breach.

USACE Levee Safety Portfolio Risk Management Process

Figure 1 is a generalized flowchart that illustrates the major features of the USACE levee safety portfolio risk management process. The overall portfolio risk management process comprises logical and hierarchical activities that are used to assess and manage the risks associated with the USACE inventory of levees. The outer loop of activities comprises normal operations, maintenance and levee risk screening, which are routinely performed on all levees in the USACE inventory. The activities inside the outer loop deal with the assessment and management of levee safety issues, including the planning, design and implementation of risk reduction measures.

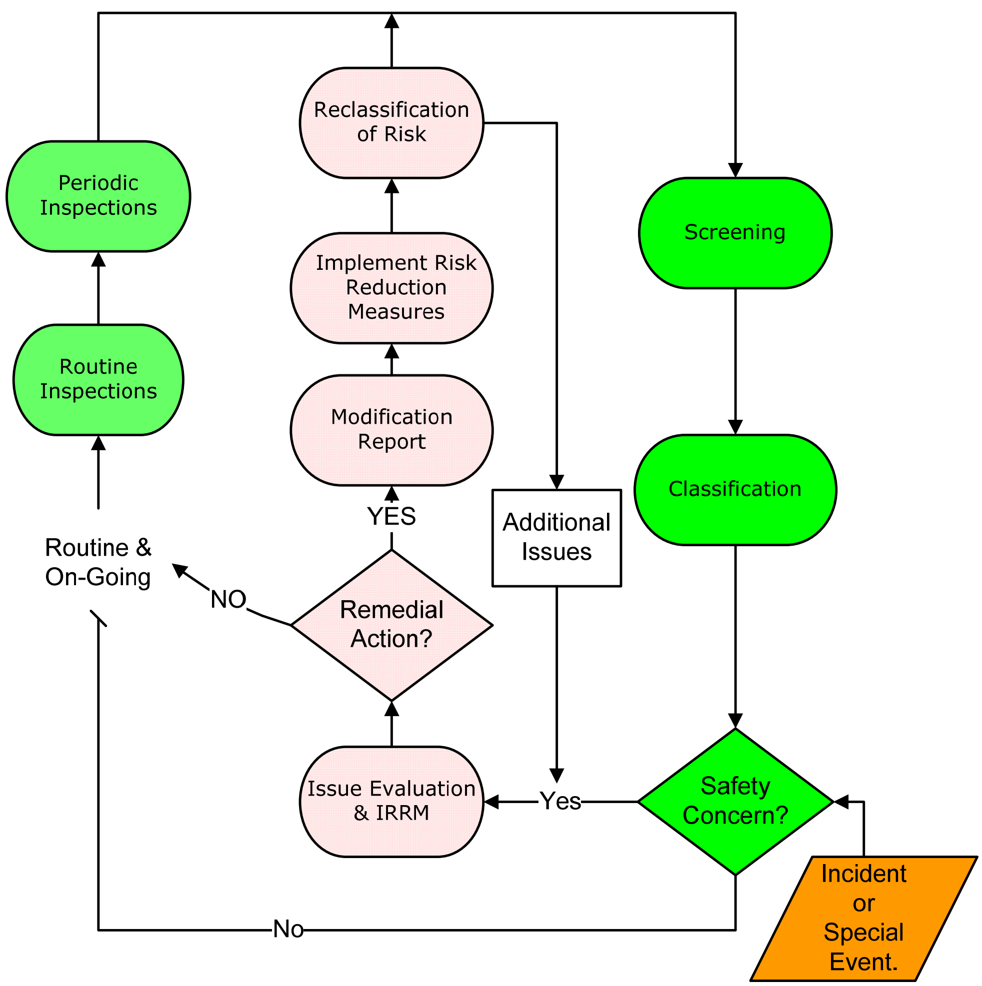


Figure 1 - Generalized USACE Portfolio Risk Management Process for Levees

Levee Safety Action Classification

Table 1 displays the draft USACE Levee Safety Action Classification (LSAC) system, which is intended to provide consistent and systematic guidelines for appropriate actions to address the levee safety issues in the USACE levee safety program. Levees are placed into an LSAC class based on the risk estimate for the levee system that they belong to. The action classification of levee systems is dynamic over time. The assigned LSAC changes as projects are modified or more refined information becomes available affecting the loading, and the probability and the associated consequences of a failure breach, overtopping without a breach, or overtopping with a breach.

The structure and make-up of the LSAC table resulted from the concept of formally recognizing different levels and urgencies of actions that are commensurate with the safety status of levee systems in the USACE inventory of levee systems. These actions range from immediate recognition of an urgent and compelling situation (LSAC Class I) requiring extraordinary action, through to normal operations and levee safety activities for levee systems considered adequately safe (LSAC V). Note that the actions described appropriate for each LSAC class in the last column of Table 1 are subdivided to reflect categories of levee systems for which USACE has varying authorities. The USACE inventory of levee systems includes: Levees that are USACE operated and maintained – full responsibility and authority; USACE constructed levees transferred to a local sponsor – limited responsibility, authority to inspect, perform assessments, advise local sponsor; and non-federally owned and operated levees participating in and meeting the requirements of Public Law (PL) 84-99 – very limited responsibility, authority to perform screening-level evaluation and share information with owner.

There are two measures of the residual risks considered in assigning an LSAC class:

1) Failure breach risk at flood loads up to the top of the levee, expressed as a combination of life, economic, or environmental consequences with the probability of failure breach;

2) Overtopping risk is a combination of life, economic, or environmental consequences with the probabilities of overtopping without a breach and overtopping with breach.

Residual risk is the remaining level of risk at any time before, during or after a program of risk reduction measures has been taken.

Levee Screening and LSAC Classification - A screening level risk assessment of the portfolio of levees in the USACE inspection program is being performed to provide a relative risk ranking as a means to make the initial assignment of LSAC classes. The screening level risk assessment will provide key information for the following uses in support of risk-informed decision making:

- Estimation of the relative risk and an initial characterization of the portfolio of levees.
- As a guide for setting national priorities for levee safety activities.
- Identification of performance concerns as well as potential consequences of levee failure.
- Communication of levee deficiencies and levee failure consequences with local sponsors.
- Identification of issues to assist in the development of Interim Risk Reduction Measures.
- Initial assignment of a LSAC class for each levee system.

Table 1 - USACE Levee Safety Action Classification Table* 4 February 2010

Levee Safety Action Class	Characteristics of this class	Actions for levees in this class ***Additional actions apply for 1) USACE Operated, and Maintained Levee Systems; and 2) Other Levee Systems in USACE Program***
I **Urgent and Compelling** (Unsafe)	**FAILURE BREACH LIKELY AT LESS THAN TOP OF LEVEE** Probability of failure breach in combination with loss of life, economic, or environmental consequences results in extremely high risk **OR EXTREMELY HIGH RISK FROM OVERTOPPING** Combination of life, economic, or environmental consequences with the probability of overtopping with or without subsequent breach, is extremely high.	Immediately perform levee system inspection; expedite confirmation of LSAC classification; communicate risk findings to sponsor, state, Federal, Tribe, local officials, and public; stress improved floodplain management to include: immediate verification that warning, evacuation and emergency action plans are viable; purchase of flood insurance; and vigilant levee monitoring program. **1)** Take urgent action to reduce the likelihood of a failure breach and mitigate failure breach consequences through implementation of interim risk reduction measures. Support portfolio priorities for remediation. **2)** Advise owner to take urgent action to develop and implement interim risk reduction and remediation plans. Support portfolio priorities for remediation.
II **Urgent** (Unsafe or Potentially Unsafe)	**FAILURE BREACH LIKELY AT TOP OF LEVEE** Probability of failure breach in combination with loss of life, economic, or environmental consequences results in very high risk. **OR VERY HIGH RISK FROM OVERTOPPING** Combination of life, economic, or environmental consequences with the probability of overtopping with or without subsequent breach, is very high.	Perform levee system interim inspection; verify classification; communicate risk findings to sponsor, state, Federal, Tribe, local officials, and public; stress improved floodplain management to include: verification that warning, evacuation and emergency action plan are viable; purchase of flood insurance; and vigilant levee monitoring program. **1)** Take immediate action to implement interim risk reduction measures; develop and implement remediation plan. Support portfolio priorities for remediation. **2)** Advise owner to take immediate action to develop and implement interim risk reduction and remediation plans. Support portfolio priorities for remediation.
III **High Priority** (Potentially Unsafe)	**FAILURE BREACH MAY OCCUR AT TOP OF LEVEE** Probability of failure breach in combination with loss of life, economic, or environmental consequences results in moderate to high risk. **OR RISK FROM OVERTOPPING IS HIGH** Combination of life, economic, or environmental consequences with the probability of overtopping with or without subsequent breach, is high.	Verify inspection is current; confirm classification; communicate risk findings to sponsor, state, Federal, Tribe, local officials, and public; stress improved floodplain management to include: verify that warning, evacuation, and emergency action plan are viable; purchase of flood insurance; develop and execute levee monitoring program. **1)** Implement interim risk reduction measures; schedule development of remediation plan and support portfolio priorities. **2)** Advise owner on development of interim risk reduction and remediation plans. Support portfolio priorities.
IV **Priority** (Marginally Safe)	**FAILURE BREACH NOT LIKELY AT TOP OF LEVEE** Probability of failure breach in combination with loss of life, economic, or environmental consequences results in low risk. **OR RISK FROM OVERTOPPING IS MODERATE TO LOW** Combination of life, economic, or environmental consequences with the probability of overtopping with or without subsequent breach, is low to moderate. The levee system does not meet all essential USACE guidelines.	Continue routine levee safety activities, stress improved floodplain management to include: verify that warning, evacuation, and emergency action plan are viable; purchase of flood insurance; develop and execute levee monitoring program.**1)** Support portfolio priorities. **2)** Support portfolio priorities.
V **Normal** (Adequately Safe)	**BREACH HIGHLY UNLIKELY AT TOP OF LEVEE** There is a very low probability of failure breach. Levee system is considered adequately safe, meeting all essential USACE guidelines. **AND RESIDUAL RISK IS CONSIDERED TOLERABLE**.	Continue routine levee safety activities, normal inspections, stress improved floodplain management to include: operation and maintenance; annually ensure that warning, evacuation, and emergency action plan are functionally tested; purchase of flood insurance; maintain levee monitoring program.

* At any time, a levee from any action class can become an emergency requiring activation of the emergency action plan.

Tolerable Risk Guidelines for Levee Safety – Concepts

Introduction - The tolerable risk guidelines (TRG) concepts and subsequent straw-man presented in this paper were developed as a starting point for the USACE levee safety program. Further development and testing of the utility of these proposed guidelines, with adjustments to improve them, will take place over the next several years. USACE invites its levee safety partners and stakeholders to become engaged with USACE in further development and refinement of the TRG for levee safety.

TRG are used in risk management to guide the process of examining and judging the significance of estimated risks obtained using risk assessment. The outcomes of risk assessment are inputs, along with other considerations, to the risk management decision process. TRG should not be used alone to prescribe decisions on "How safe is safe enough?" Meeting or achieving the TRG is the public safety goal for all risk reduction measures. The loss of project benefits should not override the need to reduce life risk.

This document presents concepts similar to those adopted by the USACE dam safety program, but there are some differences. The USACE guidelines for a risk-informed dam safety program, EC 1110-2-1156 (in final draft being processed for publication) provided the initial starting point for thinking and discussion of TRG for levee safety. The Bureau of Reclamation (Reclamation) dam safety program for some time has been using "Guidelines for Achieving Public Protection in Dam Safety Decision making" http://www.usbr.gov/ssle/damsafety/Risk/ppg2003.pdf . The Reclamation, ANCOLD and NSW DSC guidelines were used as a basis for preparing the TRG for USACE dam safety program.

USACE will use the concept that a levee system is considered adequately safe (LSAC Class V) when:

1) The levee system is "HIGHLY UNLIKELY TO BREACH AT TOP OF LEVEE;" "There is a very low probability of failure breach…" at any flood level prior to overtopping;
2) The levee system meets "… all essential USACE guidelines;" AND
3) The "RESIDUAL RISK IS CONSIDERED TOLERABLE." This is the combined residual risk from failure breach and overtopping by floods that exceed the top of the levee.

Key Concepts for Tolerable Risk Guidelines

Definition of Tolerable Risk: Tolerable risks are:

- Risks that society is willing to live with so as to secure certain benefits;
- Risks that society does not regard as negligible (broadly acceptable) or something it might ignore;
- Risks that society is confident are being properly managed by the owner; and
- Risks that the owner keeps under review and reduces still further if and as practicable. [Adapted from HSE (2001)]

Definition of Broadly Acceptable Risk: "Broadly acceptable risk" is contrasted with tolerable risk in that risks falling into the broadly acceptable region are generally regarded as insignificant and adequately controlled. The levels of risk characterising this region are comparable to those that people regard as insignificant or trivial in their daily lives. By the nature of the hazard that levee systems pose it is inappropriate to attempt to manage them as a broadly acceptable risk and therefore the concept of the broadly acceptable risk level or limit does not apply to levee systems.

Definition of Tolerable Risk Range: The left side of Figure 2 shows in general how that tolerable risk is a range between unacceptable, where the risk cannot be justified except in extraordinary circumstance, and broadly acceptable, where the risk is regarded as negligible. The right side of Figure 2 illustrates the point at which the residual risk for a specific levee system is tolerable within the general range of tolerability shown on the left side.

Equity and Efficiency: Two fundamental principles, from which tolerability of risk guidelines are derived include "Equity"- the right of individuals and society to be protected, and the right that the interests of all are treated with fairness; and "Efficiency" - the need for society to distribute and use available resources so as to achieve the greatest benefit.

Conflict between Equity and Efficiency: There can be conflict in achieving equity and efficiency. Achieving equity justifies the establishment of maximum tolerable risk limits for individual and societal risk. Efficiency is defined by the risk level where marginal benefits equal or exceed the marginal cost. Equity requires that a tolerable risk limit should be met regardless of the lack of economic justification or the magnitude of the cost. Equity implies the need for this limit even if efficiency does not support reducing risks to meet the maximum tolerable risk limit. There is, therefore, a need to obtain an appropriate balance between equity and efficiency in the development of tolerable risk guidelines.

The need for this balance is further illustrated in depicting the effectiveness of structural and non-structural risk reduction measures for failure breach residual risk and overtopping residual risk. Figure 3 shows how for dams structural risk reduction measures are usually expected to lower the residual risk to the tolerable risk limit (although there are exceptions in situations where the consequences are very high and non-structural solutions are necessary). For most levee systems, non-structural risk reduction measures are likely required, in addition to structural risk reduction measures, to lower the residual risk to or below the tolerable risk limit.

Societal and Individual Risks: In general, society is more averse to risks if multiple fatalities were to occur from a single event and hence impact on society as a whole, creating a socio-political response. In contrast, society tends to be less averse to risks that result from many individual small loss accidents involving only one or two fatalities, even if the total loss from the sum of all of the small loss accidents is larger than that from the single large loss accident. This leads to the notions that tolerable risk should consider both societal and individual risks as an integral part of the framework for managing risks and that tolerable risk limits should be lower for large loss events than for small loss events.

Efficiency Considerations: Finding systematic and defensible concepts that address efficiency aspects in both individual and societal tolerable risk guidelines for levee safety is as yet, an unmet need. These considerations would be applied below the tolerable risk limit shown in Figure 2. That is, risks lower than the tolerable risk limit are considered as tolerable only if further risk reduction is impracticable or is not economically justified. Determining if the risk is tolerable is ultimately a matter of judgment.

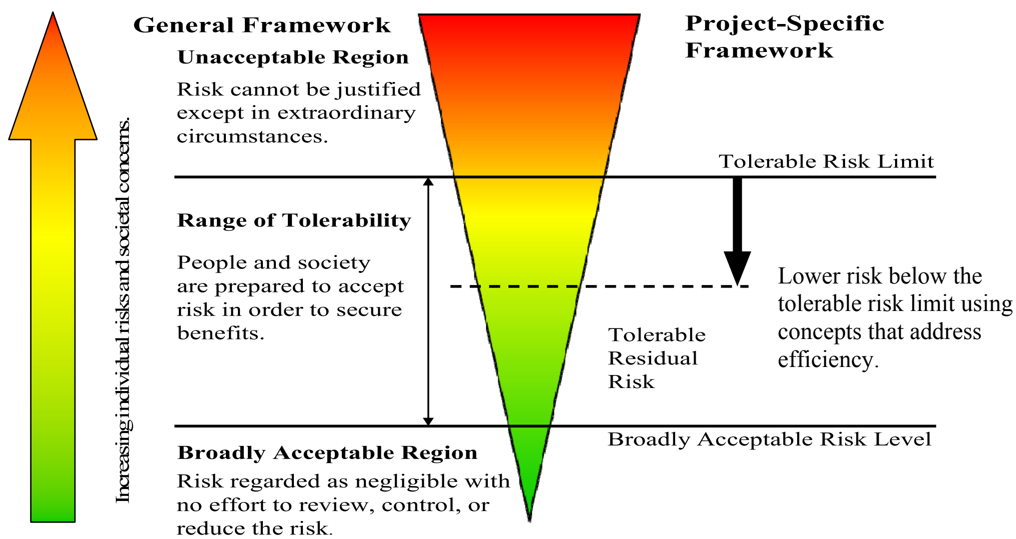


Figure 2- Generalized and Project Specific Tolerability of Risk Framework [Adapted from HSE (2001)]

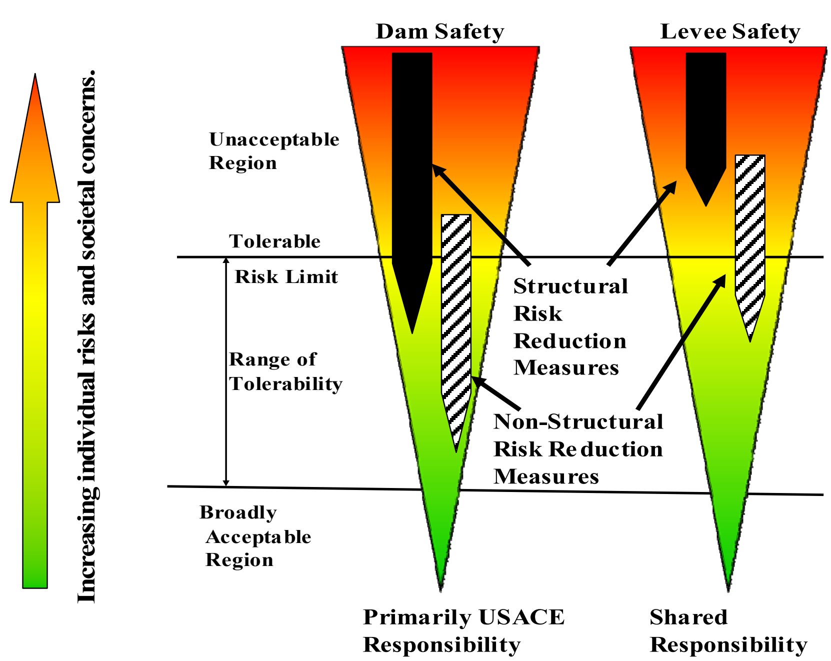


Figure 3 - Tolerable Risk - Dams vs. Levees [Adapted from Bowles (2008)]

Consequences: In applying tolerable risk guidelines for levee safety, the total consequences will be considered. This concept, when applied to failure breach, overtopping without a breach and overtopping with a breach, is illustrated in Figure 4 for life-loss for consequences and Figure 5 property damages. This concept distinguishes between the following:

- Property damage and life-loss consequences generated due to failure breach of the levee system prior to overtopping.
- Property damage and life-loss consequences generated due to overtopping with a breach.
- Property damage and life-loss consequences generated due to overtopping without a breach.

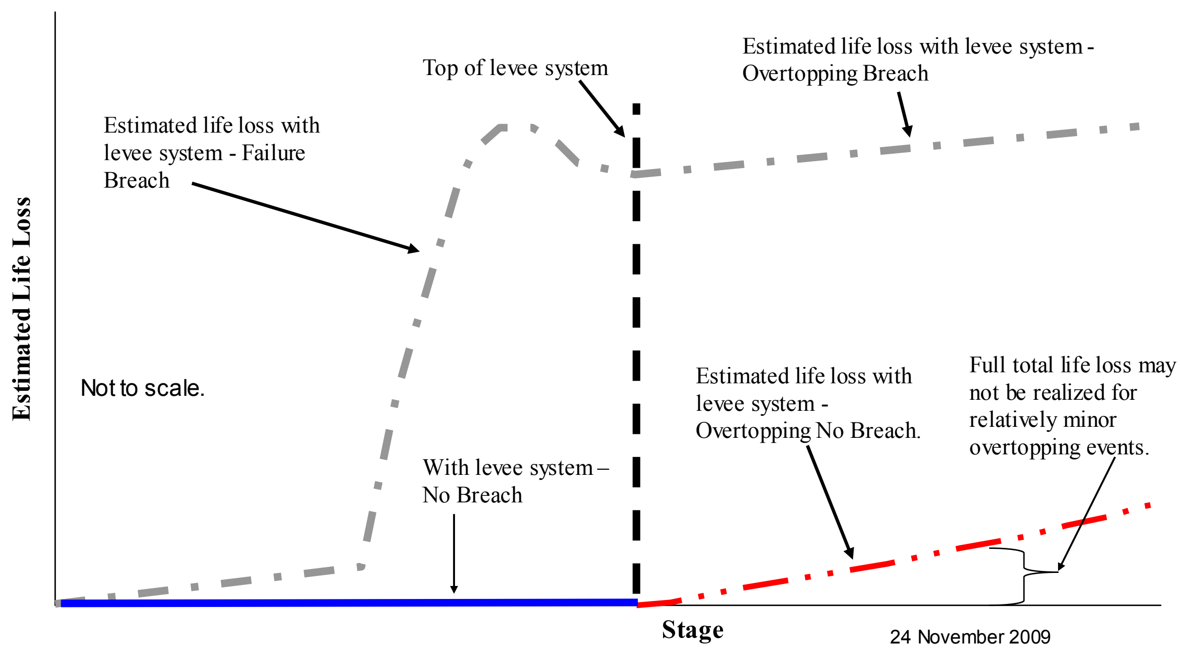


Figure 4 - Conceptual Illustration of Estimated Life Loss versus Flood Stage for Levee Failure Breach, Overtopping without a Breach, and Overtopping with a Breach

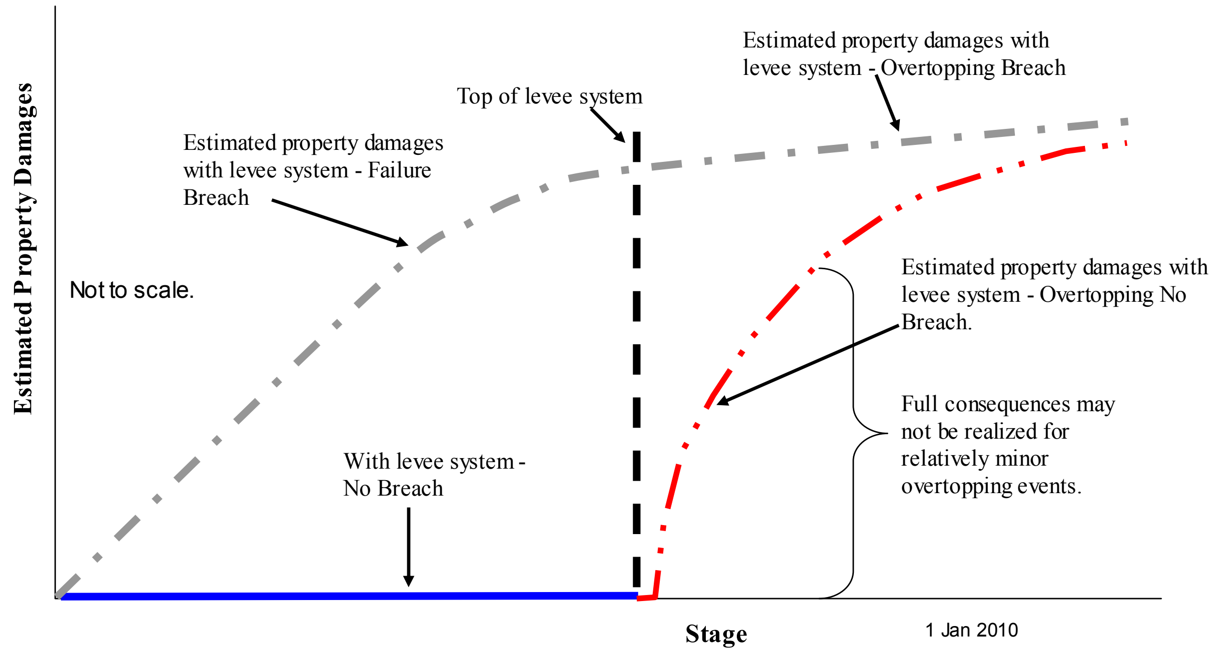


Figure 5 - Conceptual Illustration of Estimated Property Damages versus Flood Stage for Levee Failure Breach, Overtopping without a Breach, and Overtopping with a Breach

A Straw-man or Beginning Point for Discussion of Tolerable Risk Guidelines for Levees

Risk measures

The following types of risk measures for levee failure breach and overtopping with and without breach will be evaluated under the USACE levee safety TRG:

- Life-loss risk,
- Economic risk (Note: Application of economic analysis in concert with life loss considerations is addressed in the later section on economic consequences), and
- Environment and other non-monetary risks.

Equity and Efficiency Balance

A basic concept in TRG is that one seeks to achieve the tolerable risk limit guidelines to satisfy equity considerations without consideration to cost or efficiency but such accomplishment is not the stopping point. Further life safety risk reduction measures should be pursued, following the 'As Low As Reasonably Practicable' (ALARP) considerations, as long as the solution is 'reasonably practicable' and does not require a disproportionate investment for the risk reduction. The concept underpinning ALARP has merit for consideration for levees, but its application must be reconciled with Federal economic justification policies that are reflected in the present and the proposed "National Objectives, Principles and Standards for Water and Related Resources Implementation Studies" (CEQ 2009).

In addition to the above three risk measures, ALARP considerations will be applied to determine when the residual risk is considered to be tolerable. In making a judgment on whether residual risks are tolerable, USACE shall take the following considerations into account:

- The level of risk in relation to the tolerable risk limit;
- The possible disproportion between the sacrifice (money, time, trouble and effort) in implementing the risk reduction measures (structural and non-structural) and the subsequent risk reduction achieved;
- The cost-effectiveness of the risk reduction measures;
- Compliance with essential USACE guidelines; and
- Societal concerns as revealed by consultation with the community and other stakeholders.

Life safety risk will be given preference, with economic and environmental impact being given due consideration. For those projects where there is very low or no life safety risk, economic consequences will be the primary consideration used along with environmental benefits and impacts in making risk management decisions.

Life Safety (Life Loss) Tolerable Risk Guidelines

The following types of life safety risk guidelines are proposed for use under the USACE tolerable risk guidelines for levees:

- Individual life safety risk using probability of life loss (illustrated in Figure 6a),

- Societal life safety risk expressed in two different ways:
    - Probability distribution of potential life loss (F-N chart as discussed in the section on *Probability Distribution of Potential Life Loss* and illustrated in Figure 6b), and
    - Annualized Life Loss (ALL) [f-N chart is discussed in the section on *Annualized Life Loss (ALL) Guideline* and illustrated in Figure 7].

The total life safety risk is to be evaluated against the life safety guidelines. Note that the contributions to the total from all performance modes (with and without breach), loading types, loading ranges, exposure conditions, subpopulations at risk, etc, are to be analyzed. This analysis can lead to an improved understanding of the failure modes and the exposure conditions that affect the total life safety risk. It can also provide insights that can lead to the identification of both structural and non-structural risk reduction measures, including interim measures.

<u>Individual Life Safety Tolerable Risk Guideline</u>: The individual risk is represented by the probability of life loss for the identifiable person or group by location that is most at risk. This is combined over all performance modes (including combinations of failure locations and overtopping without a breach) with due regard for non-mutually exclusive failure modes, for the purpose of tolerable risk evaluation.

The straw-man proposal for individual risk to the identifiable person or group by location that is most at risk should be less than a limit value of 1 in 10,000 per year, except in exceptional circumstances (Figure 6a). The value of 1 in 10,000 per year is used as an individual risk limit guideline in dam safety and other life risk situations such as chemical contamination and exposure, and some land use planning guidelines. This value was derived from background fatality rate studies and then adjusted to what is deemed reasonable as an 'imposed risk' on modern society. It has achieved some consensus among government and private sectors institutions engaged in safety management. It should be noted that some have advocated consideration of a higher limit for individual and societal life risk (accept more risk) using the logic that occupants of floodplain lands behind levees fall into the category of 'informed consent'. Another argument for accepting more risk for levees is that those exposed to the risk of project "failure" are also beneficiaries of the project that is posing the risk and therefore they should be willing to live with a higher risk than situations in which the project puts non-beneficiaries at risk. This topic is likely to be debated for some time but herein, the perspective taken is that floodplain occupants for all practical purposes do not make 'informed consent' location decisions, nor should they be subjected to higher risk because of where they live.

<u>Probability Distribution of Potential Life Loss:</u> The societal risk is represented by a distribution of the estimated annual probability of potential life loss from a levee system for all loading types and conditions and all performance modes (including combinations of failure locations and overtopping without a breach) and all population exposure scenarios. This is displayed as an F-N chart (Figure 6b).

The F-N chart is a plot of the annual probability of exceedance (greater than or equal to[2]) of potential life loss (F) vs. potential loss of life (N). Thus, the F-N chart displays the estimated probability distribution of life loss for a levee system encompassing all performance modes and all population exposure scenarios.

Levee systems with risks that plot above a tolerable risk limit on an Individual Risk chart or on the F-N chart are considered to have an unacceptable level of risk. As with the individual tolerable risk limit, in principle risks should be reduced to the tolerable risk limit regardless of cost considerations and then further until ALARP is satisfied, except in exceptional circumstances.

In some instances, this tolerable risk limit may be difficult to reach, particularly when applied to existing levee systems, and thus the tolerability of risk would be based on an HQUSACE 'official review' of the benefits and risks as described in the *Except in Exceptional Circumstances* section below.

If life loss is estimated to exceed some threshold of potential losses 'special review' by HQUSACE would be required. For dams, the life loss threshold is 1,000 for a failure event. No life loss threshold for a failure event has been vetted for levees. The 'special review' of the tolerability of risk shall be based on an HQUSACE 'Official Review' of the benefits and risks as described in the *Except in Exceptional Circumstances* section below.

[2] Note: In probability textbooks a cumulative (probability) distribution function (CDF) is defined to have probability "less than or equal to" on the vertical axis and a complementary cumulative (probability) distribution function (CCDF) is defined to have probability "greater than" on the vertical axis. Although similar to a CCDF, an F-N chart is subtly, but in some cases importantly, different because it has probability "greater than or equal to" on the vertical axis rather than "greater than" as in the CCDF.

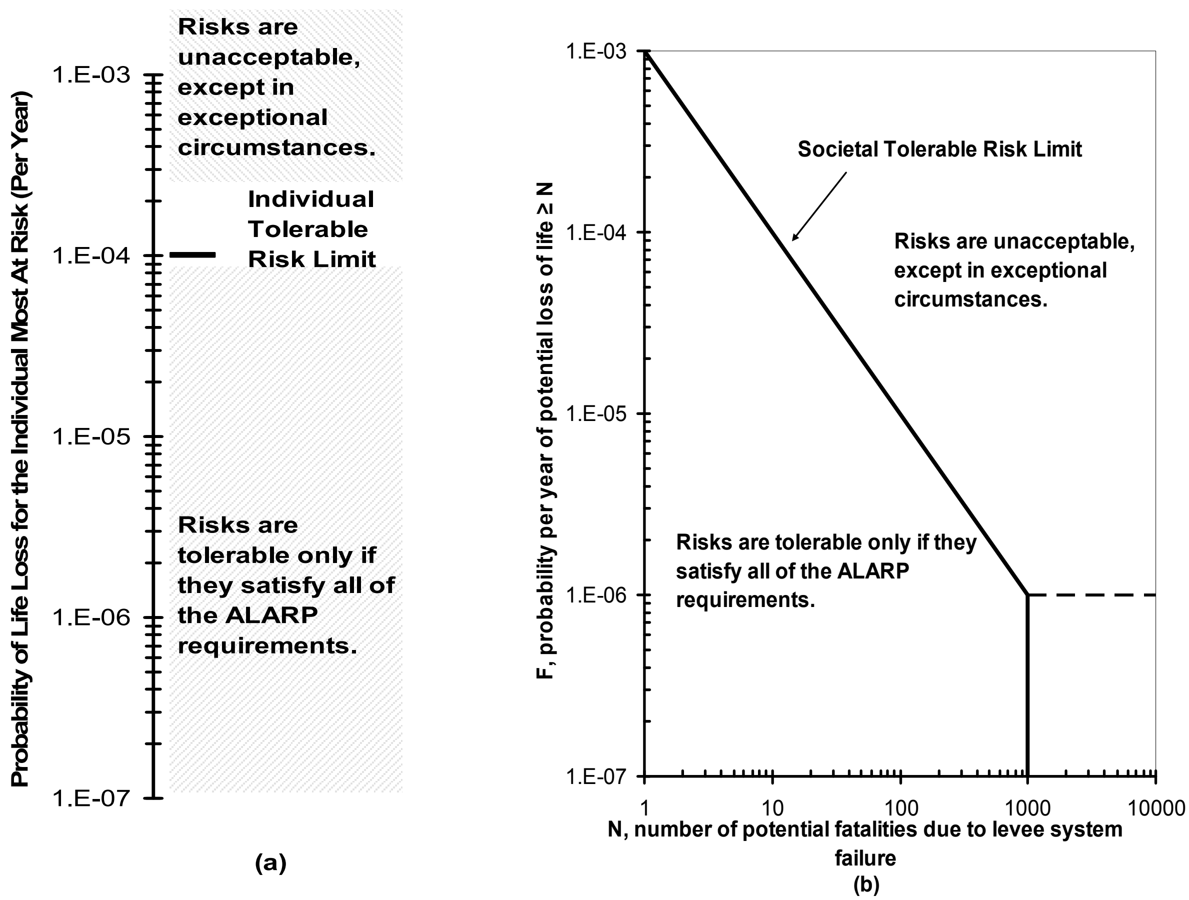


Figure 6(a) Individual Risk and Figure 6(b) Societal (F-N) Risk Guideline for Levee Systems.

Annualized Life Loss (ALL) Guideline: The US Department of Interior, Bureau of Reclamation (Reclamation) makes use of the Annualized Life Loss (ALL) as a guideline in its dam safety program. It is presented here to be inclusive of potential candidates that exist for dams for consideration as tolerable risk guidelines for levees. The ALL guideline is the expected value (average annual) of potential life loss resulting from levee system failure and is shown as the f-N[3] chart in Figure 7.

Annualized societal life loss will be evaluated based on the limit values as shown in the ALL guideline. This should be applied to the total estimated annualized life loss from all failure modes (including combinations of failure locations and overtopping without a breach) associated with all loading or initiating event types and considering all exposure conditions associated with life loss.

The policy for the estimated ALL under the Reclamation tolerable risk guidelines and the recently developed USACE ALL guideline for dam safety is:

ALL < 0.001 lives/year: ALL risk in this range may be considered tolerable provided the other tolerable risk guidelines are met.

ALL > 0.01 lives/year: ALL risk in this range is unacceptable except in exceptional circumstances and is reason for urgent actions to reduce risk**. ALL between 0.01 and 0.001 lives/year**: ALL risk in this range is unacceptable except in exceptional circumstances and is reason for actions taken to reduce risk.

Levees with risks that plot above a tolerable risk limit on an f-N chart are considered to have an unacceptable level of risk. In principle risks should be reduced to the tolerable risk limit regardless of cost considerations and then further until ALARP is satisfied, except in exceptional circumstances.

In some instances, this tolerable risk limit may be difficult to reach, particularly when applied to existing levee systems, and thus the tolerability of risk would be based on an HQUSACE 'official review' of the benefits and risks as described in the *Except in Exceptional Circumstances* section below.

If life loss is estimated to exceed some threshold of potential losses 'special review' by HQUSACE would be required. For dams, the life loss threshold is 1,000 for a failure event. Although one is shown, no life loss threshold has been vetted for levees. The 'special review' of the tolerability of risk shall be based on an HQUSACE 'Official Review' of the benefits and risks as described in the *Except in Exceptional Circumstances* section below.

Except in Exceptional Circumstances: "Except in Exceptional Circumstances" is a concept that exists for dam safety that is generally part of TRG in countries with common law legal systems. The qualifier "except in exceptional circumstances" refers to a situation in which government,

[3] For dams the f-N chart is used to evaluate dam safety risks by plotting the total annual probability of failure vs. the estimated life loss as a weighted average across all failure and exposure scenarios. In addition, points are plotted for individual failure modes to provide insights into their contributions to the overall risk but it is the total point that is the focus of the risk evaluation itself. This procedure may or may not be used for levee systems.

acting on behalf of society, may determine that risks exceeding the tolerable risk limits may be tolerated based on special benefits that the levee system brings to society at large. This is an example of the conflict between the fundamental principles of equity and efficiency in which no practical options may exist to achieve tolerable risk limits or they may be prohibitively costly. Thus equity consideration might be relaxed because of special benefits that are deemed to outweigh the increased residual risk. For dams this exception might be made where the residual potential life loss and economic consequences are large, but where the probability of their occurrence is very low and state-of-the practice risk reduction measures have been implemented. USACE and the stakeholders will look critically at the confidence in the estimate of the risk. Full compliance with essential guidelines will be expected. The adequacy of potential failure modes analysis and risk assessment will be carefully examined. HQUSACE would reach a decision based on the merits of the case. Guidance will need to be developed for what circumstances would appropriately justify exceptions to tolerable risk limits for levee systems.

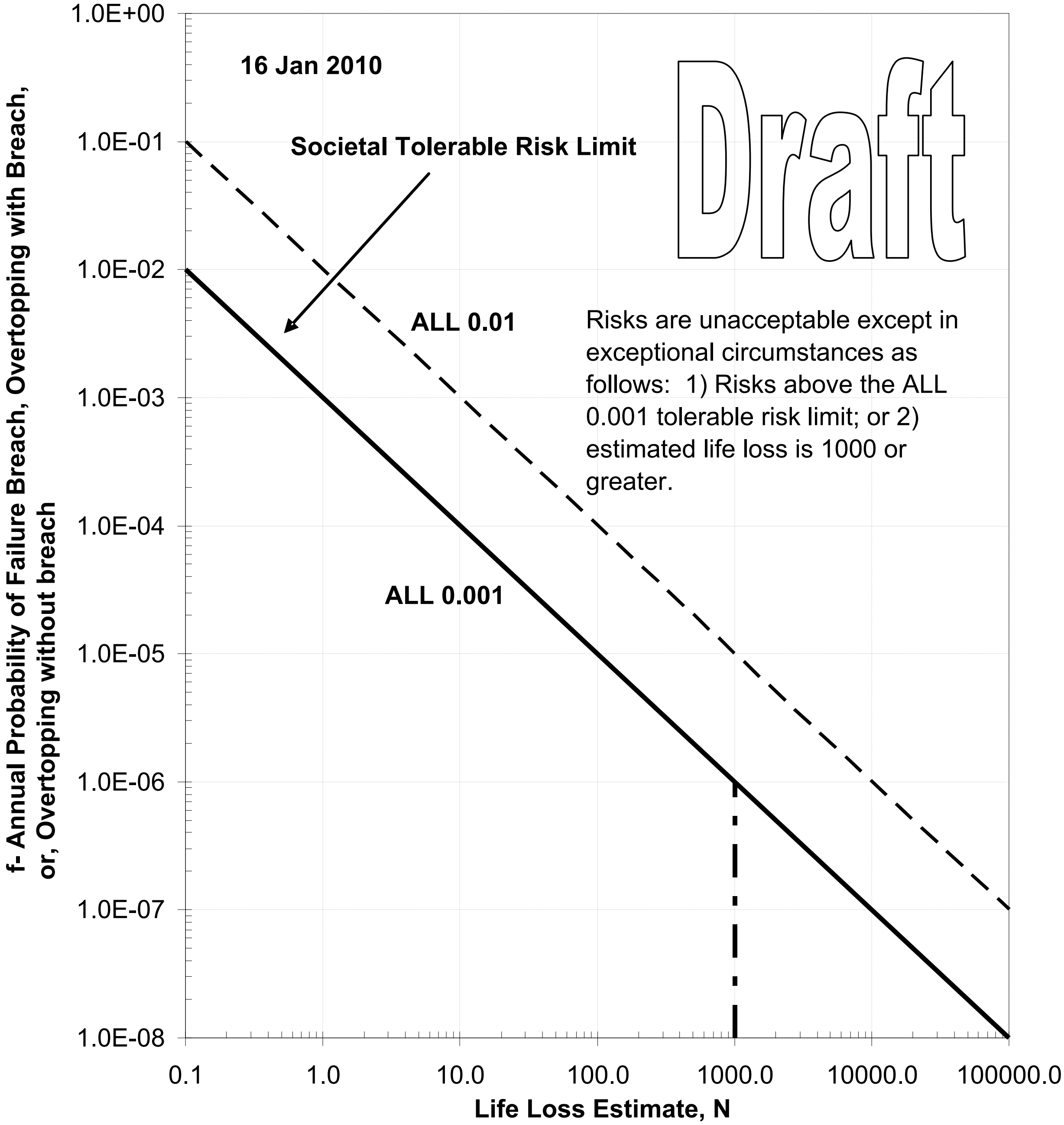


Figure 7- Annualized Life Loss (ALL) Guideline

Economic Consequences

Economic considerations to help inform risk management decisions include both the direct losses of the failure breach or overtopping of a levee system with or without subsequent breach and other economic impacts on the regional or national economy. Part of the direct losses is the damage to property located behind the levee system. Items in this category include those commonly computed for the National Economic Development (NED) account in any USACE flood risk management study (USACE 2000). These include damage to private and public buildings, contents of buildings, vehicles, public infrastructure such as roads and bridges, public utility infrastructure, agricultural crops, agricultural capital, and erosion losses to land. Direct losses also include the value from the loss in services provided by the levee system such as flood damage reduction and navigation (incremental cost for alternate transportation - if available). Another category of NED values is the emergency response for evacuation and rescue and the additional travel costs associated with closures of roads and bridges. The NED value of these losses should be included in computing direct economic loss due to levee system failure breach or overtopping. (NOTE: one potential direct loss is the cost of repairing the damage to the levee system. This is a complicated issue and to some degree depends on the extent of damage to the levee system. If the levee system can be repaired, these repair costs could be counted as an economic cost. In the case of catastrophic failure, these rebuilding costs should not be included in the direct costs, as the decision to rebuild the levee system depends on the post-failure benefits which would be a separate analysis.)

These direct economic losses can be compared to costs of any levee system modification to display a measure of the economic efficiency of the modification. Additionally, these direct economic losses are used to net against the cost of remediation measures to evaluate cost-effectiveness measures in the evaluation of ALARP to meet the tolerable risk guideline for life loss.

After adjustment for meeting the tolerable risk guideline for life loss the remaining benefits will be used to determine if additional modification can be justified using standard economical analysis.

Indirect economic impacts are those associated with the destruction of property and the displacement of people due to the failure breach or overtopping with or without subsequent breach. The destruction due to the failure breach or overtopping with or without subsequent breach can have significant impacts on the local and regional economy as businesses at least temporarily close resulting in loss of employment and income. All these indirect losses then have ripple or multiplier effects in the rest of the regional and national economy due to the resulting reduction in spending on goods and services in the region. In this way, a levee system failure breach or overtopping with or without subsequent breach can have widespread economic losses throughout the region.

Environment and Other Non-Monetary Consequences

A levee system failure breach or overtopping with or without subsequent breach has both direct and indirect consequences that cannot be measured in monetary terms. These stem from the impacts of the inundation for levee system failure breach or overtopping with or without subsequent breach on environmental, cultural, and historic resources. In most cases, the assessment of the impacts of levee system failure breach or overtopping will be the reporting of area and type of habitat impacted, habitat of threatened and endangered species impacted, number and type of historic sites impacted, and the number and type of culturally significance areas impacted so that these can be considered in the decision process.

An additional indirect non-monetary consequence could be the exposure of people and the ecosystem to hazardous and toxic material released from landfills, warehouses, and other facilities. An estimate of the locations and quantities should be compiled identifying where significant quantities are concentrated. Identifying and enumerating these indirect hazards could be important enough to require additional risk assessments including estimating additional fatalities due to exposure to theses hazards. Although these non-monetary consequences may not provide the sole basis for risk reduction, they can provide additional risk information for decision making. They can also be used to identify risks to be managed separately from levee system modifications.

Intangible consequences are those that have no directly observable physical dimensions but exist in the minds, individually and collectively, of those affected. Such consequences are real and can support decisions. Intangible consequences identified include such things as:

- The grief and loss suffered by relatives and friends of those who die;
- The impact of multiple deaths on the psyche of the community in which they lived;
- The stress involved in arranging alternative accommodations and income;
- The sense of loss by those who enjoyed the natural landscape destroyed;
- The grief and loss of identity associated with the damage or destruction of a community or culture; and
- The fear of lost status and reputation of the levee system owning organization and its technical staff.

REFERENCES

Bowles, D.S. (2008), Invited presentation (PowerPoint) for the Panel on "Should Levees be treated like Dams?" GeoCongress 2008: The Challenge of Sustainability in the Geoenvironment, Annual Congress of the Geo-Institute of ASCE. New Orleans, Louisiana. March, 2008.

HSE (2001), Health and Safety Executive, "Reducing Risks, Protecting People: HSE's Decision-making Process," Risk Assessment Policy Unit, HSE Books, Her Majesty's Stationery Office, London, England, 2001. (http://www.hse.gov.uk/risk/theory/r2p2.pdf).

National Committee on Levee Safety (NLCS draft 2009), "Recommendations for a National Levee Safety Program - A Report to Congress from the National Committee on Levee Safety," January 15, 2009. http://www.iwr.usace.army.mil/ncls/docs/NCLS-Recommendation-Report_012009_DRAFT.pdf

President's Council on Environmental Quality (CEQ), "Proposed National Objectives, Principles and Standards for Water and Related Resources Implementation Studies", December 3, 2009. http://www.whitehouse.gov/sites/default/files/microsites/091203-ceq-revised-principles-guidelines-water-resources.pdf

Reclamation (2003), United States Department of the Interior, Bureau of Reclamation, "Guidelines For Achieving Public Protection In Dam Safety Decisionmaking," 15 June 2003. http://www.usbr.gov/ssle/damsafety/Risk/ppg2003.pdf

USACE Engineer Regulation ER 1165-2-119, "Modification to Completed Projects", 20 September 1982. http://140.194.76.129/publications/eng-regs/er1165-2-119/toc.htm

USACE (2000), United States Army Corps of Engineers, ER 1105-2-100. "Planning Guidance Notebook." http://140.194.76.129/publications/eng-regs/er1105-2-100/toc.htm

USACE (2007), CECW-HS Memorandum, Subject: Levee Safety Program Implementation, Nov 16, 2007.

Workshop: Exploration of Tolerable Risk Guidelines for Levee Systems
Questions and Context for each Question for the Break-out Sessions
(Draft 9 Feb 2010)

The following questions are posed as one of the workshop vehicles to obtain input on what should be the role of tolerable risk guidelines and what should be considered in their formulation and application in the USACE levee safety program. Planned are three separate break-out sessions. Workshop attendees will be divided into assigned groups for the break-out sessions. Each group will address the same questions in facilitated working sessions and report out their findings to the larger group. A brief context description is included for each question to assist in focusing discussions on the key issues.

Break-out Session 1 (questions 1 and 2).

1. What are the measures and metrics that can help guide determination of 'adequately safe levee systems' in the development and application of tolerable risk guidelines (TRG)?

2. For levee safety considerations is the difference between life safety and structure safety (structural integrity) for levee systems important and how might each contribute to achieving TRG for levee systems?

These two questions are complimentary. USACE has chosen to make use of tolerable risk guidelines as one key element in accomplishing its levee safety program. The implications of development and application of TRGs, wherein life safety is put forth as a metric for assessing levee system performance related to safety, is to be contemplated and discussed. The concept of 'levee safety' has only recently become a focus of discussion and action, often in the context of an extension or adaptation of 'dam safety' principles and perhaps application of their associated guidelines. Dam safety is a mature ethic institutionalized in government agencies and in the professional community and is accomplished with fairly well established processes by the regulatory agency, dam ownership, and emergency management community. Whereas major dams are not expected to 'fail', such that there is uncontrolled release of the reservoir pool, levees by their nature will be overtopped (and perhaps breach) and in most cases this will result in uncontrolled release of floodwaters onto the floodplain. Much of dam safety attention is focused on the structure and its performance under various loadings. For levees, while a focus still needs to be on the levee system structural performance, there is strong logic to add a focus on the threatened populous and infrastructure occupying the floodplain. The difference between the performance of dams and levees, the threats that each pose, what might constitute 'tolerable risk', risk management solutions available specifically for levee systems is worthy of thoughtful discussion.

Another issue worthy of discussion in this session includes the potential role (or not) that traditional performance metrics such as 'level-of-protection' might play in levee system safety assessments and management.

Lastly, contemplate the following: Two identical levees systems in every respect; one adjacent to a densely developed urban floodplain, and another adjacent to a floodplain with essentially no urban development. Are they both equally safe because their structures perform identically, or should they somehow be characterized differently given the substantial difference in the public/life safety threat?

Break-out Session 2 (questions 3 and 4).

3. What is the responsibility of each stakeholder for achieving and maintaining levee safety?

In recent years, accelerated in the aftermath of the Hurricane Katrina caused disaster in New Orleans, the concept of 'shared responsibility for flood risk management' has emerged. The concept is currently in the evolving phase as it matures, but it is clear that no one level of government, NGO or private institution, or individual floodplain occupant completely 'owns', and thus is completely responsible for managing, the residual risk. The concept of 'shared responsibility' is thus applicable to levee safety, which is but one sub-component of flood risk management.

This question is intended to stimulate discussion of what are the various functions that need to be accomplished (e.g. adequate design and construction, risk assessment and risk information dissemination, operation and maintenance, repair and rehabilitation, emergency response and repair, etc.) to support a robust levee system safety program. Additionally, and in a general way, who should be taking on the respective functions and how should the responsibility and accountability for ensuring each is achieved be accomplished?

4. Considering the number and variety of stakeholders, how could tolerable risk guidelines be used to assist in life safety risk assessments and levee systems risk management decisions?

Given that USACE is committed to developing and using TRGs in the management of its levee safety program, how might these guidelines, or perhaps some variation of them, be of value in accomplishing the various functions (by other stakeholders) that are appropriate to achieving levee safety program goals? Note here that the TRGs will likely reflect public/life-safety goals and engineering standards. Also note that there are various roles that the stakeholders play in accomplishing several of the functions needed to achieve levee safety goals.

Another hoped-for discussion stimulated by this question is the issue of potentially developing a framework for a national set of TRGs for levee systems, or developing national guidelines with the necessary flexibility to adapt to specific settings and situations that might be appropriate.

Break-out Session 3 (questions 5 and 6).

5. What are the issues to be addressed to develop tolerable risk guidelines for levee systems and what would the tolerable risk guidelines look like?

The first part is an open question intended to stimulate thought and discussion on the range of issues that should be considered in developing guidelines – the range is purposely left open to foster full exploration of the subject. The second part of the question is intended to rein in the issues to those that are amenable to shaping guidelines development, and present an opportunity for speculation on what more specifically might be the product that depicts the guidelines, e.g. tables, text, f-N or F-N diagrams, action bands, applicability of ALARP, etc.

Other issues that could also be considered under this question include the following: 1) the relationship between the Federal Principles and Guidelines National Economic Development account and TRG; 2) and should TRG for levees be the same as for dams and other hazardous industry or is there a justification for different TRG?

6. How do we proceed?

This is another open question. For this one, the full range of actions and participants are fair game; their drafting, vetting, testing, adoption (by USACE and possibly others), involvement of professions, and other nations and international agencies and societies. The hoped for report out would be a very preliminary time-line of actions, participants, and products. Also, it would be helpful to make a rough assessment of the likelihood of accomplishing each action and explore as well the likely support for and impediments to TRG development and use.

Workshop Reading List

This list of selected readings on the subject of risk assessment, tolerable risk concepts, and associated guidelines, is provided as an introduction to the topics to be addressed at the workshop. Items 1, 2, and 3 will take about sixty minutes or so to read. For those with a desire to gain more background on the general concepts of tolerability of risk we recommend reading items 4 and 5. There is an extended bibliography starting on the second page provided by Dr. David S. Bowles.

1. Read-a-head paper for the workshop

USACE Levee Safety and Procedures Team, "USACE Levee Safety Program and Tolerable Risk Guidelines - A Discussion Paper for the Exploration of Tolerable Risk Guidelines for Levee Systems Workshop" - Draft, 16 Jan 2009 A pdf file accompanying this document.

2. Two page summary or primer on tolerable risk guidelines and their application.

Pages 37 and 38, National Committee on Levee Safety (2009), "Recommendations for a National Levee Safety Program - A Report to Congress from the National Committee on Levee Safety," January 15, 2009. http://www.iwr.usace.army.mil/ncls/docs/NCLS-Recommendation-Report_012009_DRAFT.pdf

3. Summary paper on the workshop that is the fore-runner to this current workshop.

Workshop on Tolerable Risk Evaluation, Summary White Paper for the Workshop Sponsored by USACE, Reclamation, and FERC, March 18-19, 2008.
http://www.usbr.gov/ssle/damsafety/jointventures/tolerablerisk/TRWorkshopdraft-080429.pdf

4. Introductory article with a good summary of the concepts dealing with tolerable risk and suggested guidelines for dams. A pdf file accompanying this document.

Munger, D. F., Bowles, D.S, Boyer, D.D., Davis, D.W., Margo, D.A., Moser ,D.A., Regan, P. J. and Snorteland, N., "Interim Tolerable Risk Guidelines for US Army Corps of Engineers Dams." *Proceedings of the 29th USSD Annual Meeting and Conference*, Nashville, Tennessee. April 2009.

5. Document on how risk assessment is used in the UK by regulatory agencies. A major purpose of the document was to set out an overall framework for decision taking by the Health and Safety Executive which would ensure consistency and coherence across the full range of risks falling within the scope of the Health and Safety at Work Act.

HSE (2001), Health and Safety Executive, "Reducing Risks, Protecting People: HSE's Decision-making Process," Risk Assessment Policy Unit, HSE Books, Her Majesty's Stationery Office, London, England, 2001. http://www.hse.gov.uk/risk/theory/r2p2.pdf

Some Additional Readings on Tolerable Risk Guidelines

(Prepared by Dr. David S. Bowles for the USSD 2009 Workshop on "The Future of Dam Safety Decision Making: Combining Standards and Risk" and used with his permission)

Ale, B. (2005). "Tolerable or acceptable: A comparison of risk regulation in the United Kingdom and in the Netherlands." Risk Analysis, 25(2), 231-241.

ANCOLD (2003), Australian National Committee on Large Dams, "Guidelines on Risk Assessment," October 2003. http://www.ancold.org.au/publications.asp

Ball, D. J., and Floyd, P. J. (1998). "Societal risks." Health & Safety Executive, Risk Assessment Policy Unit, London.

Bowles, D.S. (2007) Tolerable Risk for Dams: How Safe is Safe Enough? Proceedings of the 2007 USSD Annual Lecture, Philadelphia, Pennsylvania. March.

Bowles, D.S. (2004) ALARP Evaluation: Using Cost Effectiveness and Disproportionality to Justify Risk Reduction. ANCOLD Bulletin 127:89-106. August 2004. (D.S. Bowles).

Bowles, D.S., L.R. Anderson, T.F. Glover, and S.S. Chauhan. (2003) Dam Safety Decision-Making: Combining Engineering Assessments with Risk Information. In Proceedings of the *2003 USSD Annual Lecture,* Charleston, SC, April.

Bowles, D.S., L.R. Anderson, and T.F. Glover. (1995) Comparison of Hazard Criteria with Acceptable Risk Criteria. *Dam Safety '95*. Proceedings of the 1995 Annual Conference of the Association of State Dam Safety Officials, Inc. Atlanta, GA, September.

HSE. (1992). "The tolerability of risk from nuclear power stations." UK Health and Safety Executive, HSE Books, Her Majesty's Stationery Office, London, England..

HSE (Health and Safety Executive). (2002a) The Health and Safety System in Great Britain. HSE Books, Her Majesty's Stationery Office, London, England.

HSE (Health and Safety Executive). (2002b) Principles and Guidelines to Assist HSE in its Judgments that Duty-Holders Have Risk as Low as Reasonable Practicable.

HSE (Health and Safety Executive). (2002c) Assessing Compliance with the Law in Individual Cases and the Use of Good Practice.

HSE (Health and Safety Executive). (2002d) Policy and Guidance on Reducing Risks as Low as Reasonably in Design.

IAEA (International Atomic Energy Agency). (1992) The Role of Probabilistic Safety Assessment and Probabilistic Safety Criteria in Nuclear Power Plant Safety. Safety Series No. 106. IAEA, Vienna, Austria. 27pp.

ICOLD (2005), "Risk Assessment in Dam Safety Management: A Reconnaissance of Benefits, Methods and Current Applications," International Commission on Large Dams (ICOLD) Bulletin 130, 2005.

Kniesner, T.J. (1997) Evaluating risk reduction programs. Risk in Perspective 5(12), Harvard Center for Risk Analysis. December.

Lowrance, W.W. 1976. Of Acceptable Risk: Science and the Determination of Safety, William Kaufmann, Inc., Los Altos, California.

Marsden, J., L. McDonald, D.S. Bowles, R. Davidson and R. Nathan. (2007) Dam safety, economic regulation and society's need to prioritise health and safety expenditures. . In Proceedings of the NZSOLD/ANCOLD Workshop on "Promoting and Ensuring the Culture of Dam Safety", Queenstown, New Zealand. November.

Morgan, M. Granger and M. Henrion. (1990) Uncertainty: A Guide to Dealing with Risk and Uncertainty in Quantitative Risk and Policy Analysis, Cambridge University Press.

Netherlands Ministry of Housing, Physical Planning and Environment. (1989) Dutch National Environmental Policy Plan – Premises for Risk Management, Second Chamber of the States General, Session 1988-1989, 21 137, No. 5.

NSW DSC (2006), "Risk Management Policy Framework for Dam Safety," New South Wales Government, Dam Safety Committee, 22 August 2006. http://www.damsafety.nsw.gov.au/DSC/Download/Reports_PDF/PolicyFramework.pdf

OMB (Office of Management and Budget). (1992) The Budget for Fiscal Year 1992, Part Two, IX.C. Reforming Regulation and Managing Risk-Reduction Sensibly. U.S. Government. pp8.

OMB (2003), United States Office of Management and Budget, "Circular A-4, Subject: Regulatory Analysis," 17 September 2003. http://www.whitehouse.gov/OMB/circulars/a004/a-4.pdf

Planning NSW. (2002) Risk Criteria for Land Use Safety Planning, Hazardous Industry Planning Advisory Paper No. 4, Reprint of Second Edition, March.

Planning NSW 2008. Risk Criteria for Land Use Safety Planning, Hazardous Industry Planning Advisory Paper No. 4, Consultation Draft, July 2008.)

Reclamation (U.S. Bureau of Reclamation). (1997) Guidelines for achieving public protection in dam safety decisionmaking. Dam Safety Office, Department of the Interior, Denver, Colorado. 19 p.

Reclamation (2003), United States Department of the Interior, Bureau of Reclamation, "Guidelines For Achieving Public Protection In Dam Safety Decisionmaking," 15 June. http://www.usbr.gov/ssle/damsafety/Risk/ppg2003.pdf

Slovic, P. (1987). "Perception of risk." Science, 236(4799), 280-285.

Starr, C. (1969) Social Benefit versus Technological Risk, Science, Vol. 165, September.

TAW (Centre for Civil Engineering Research and Codes/ Technical Advisory Committee on Water Defences). (1990) Probabilistic Design of Flood Defences, the Netherlands.

USACE (2000) United States Army Corps of Engineers, ER 1105-2-100. "Planning Guidance Notebook. http://140.194.76.129/publications/eng-regs/er1105-2-101/toc.htm

USDOT (U.S. Department of Transportation). 2009. Treatment of economic value of a statistical life in departmental analysis. Memorandum to Secretarial Officers and Modal Administrators from J. Szabat, Assistant Secretary for Transportation Policy, and L. Knapp, Acting General Counsel. March 18. http://regs.dot.gov/docs/VSL Guidance 2008 and 2009rev.pdf

USSD. (2003) Dam Safety Risk Assessment: What is it? Who's using it and why? Where should we be going with it? USSD Emerging Issues White Paper.

Viscusi, V.K. (1998), "Rational Risk Policy," Oxford University Press Inc., Oxford, New York. 138 p.

Vrijling, J.K., (2001) Probabilistic Design of Water Defense Systems in the Netherlands, Reliability Engineering and System Safety, 74, pp. 337-344.

Appendix D: Presentation slides and accompanying papers **Page**

Exploration of Tolerable Risk Guidelines for Levee Systems

A Workshop Sponsored by the US Army Corps of Engineers

Opening Remarks
Eric C. Halpin, PE
Special Assistant for Dam and Levee Safety

March 2010

US Army Corps of Engineers
BUILDING STRONG®

US Army Corps of Engineers

Wake-Up Call We Couldn't Ignore: Katrina

BUILDING STRONG℠

11/14

US Army Corps of Engineers

Workshop Objectives

- Examine Concepts of TRG
- Obtain Input on Role of TRG in Levee Safety Programs
- Review Status of Use of TRG
- Poll Participants on Issues of Implementation

BUILDING STRONG℠

Summary of March 2008 Workshop on Tolerable Risk Evaluation

The Role of Tolerable Risk Guidelines in Risk Management

- **Tolerable risk guidelines are used in risk management to guide the process of examining and judging the significance of estimated risks obtained using risk assessment. The outcomes of risk assessment are inputs to the risk management decision process along with other considerations.**

Purpose of the Workshop

- **Reasons for Interest in Tolerable Risk**
  - **Better Determine, Prioritize, and Justify Risk Reduction Actions**
  - **Better Communicate Risks**
  - **Better Understand and Evaluate Public Safety Risks in an**
  - **Environment of Shared Flood Risk Management Responsibilities**
  - **Make better decisions**

Questions Addressed By Speakers

- **How tolerable risk is defined**
- **How it is being used to evaluate risks and to justify risk reduction measures**
- **What implementation problems have been encountered and how they have been addressed.**

Presenters / Attendees

What We Learned

- **The various industries, agencies, and nations are more similar than they are different and that the differences are largely a function of the particular organization’s focus**
- **The origin of many of the risk guidelines was not clearly defined**
- **Many of the guidelines had borrowed from each other**

Acceptable vs Tolerable

- **Acceptable Risk** - A risk whose probability of occurrence is so small or whose consequences are so slight that individuals or groups in society are willing to take or be subjected to the risk. Actions to further reduce such a risk is usually not required.
- **Tolerable Risk** - A tolerable risk is a non-negligible risk that has not yet been reduced to an acceptable level but where society is willing to live with in order to secure the benefits associated with the risky activity. These risks need to keep under review for further reduction.

“ Building Strong ”

Key Principles

Equity and Efficiency

- Equity justifies the establishment of maximum tolerable risk limits for individual and societal tolerable risk. Equity implies the need for this limit even if efficiency, defined by marginal benefit equal to or greater than the marginal cost, does not support reducing risks to meet these maximum limits.

“ Building Strong ”

Risk Limit Measures

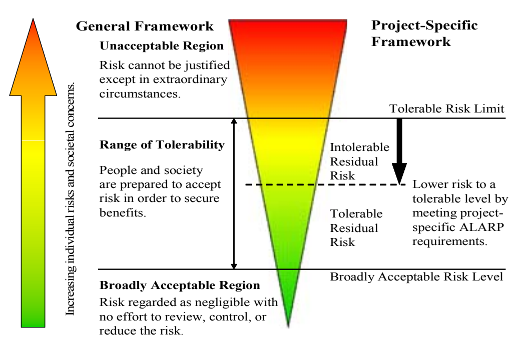
- **Annual probability of failure**
- **Life safety risk**
- **Economic consequences**
- **Environmental and other non-monetary consequences.**

“ Building Strong ”

ALARP Considerations

- **“As-Low-As-Reasonably-Practicable**
- **Determining that ALARP is satisfied is a matter of judgment**
- **When is ALARP satisfied?**
  - **the disproportion between the sacrifice (money, time, trouble and effort) in implementing the risk reduction measures and the subsequent risk reduction achieved;**
  - **the cost-effectiveness of the risk reduction measures;**
  - **any relevant recognized good practice; and**
  - **societal concerns as revealed by consultation with the community and other stakeholders**

“ Building Strong ”

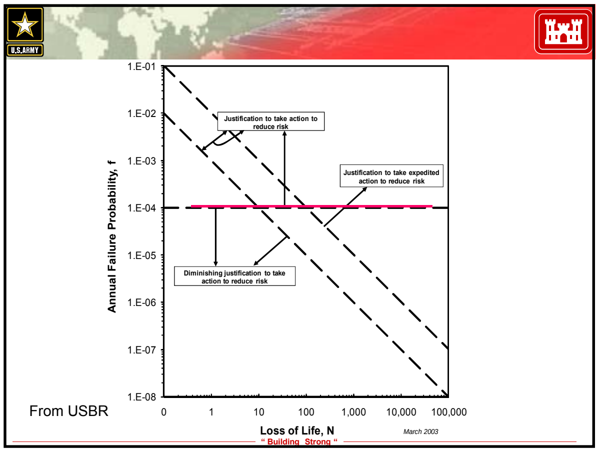


“ Building Strong ”

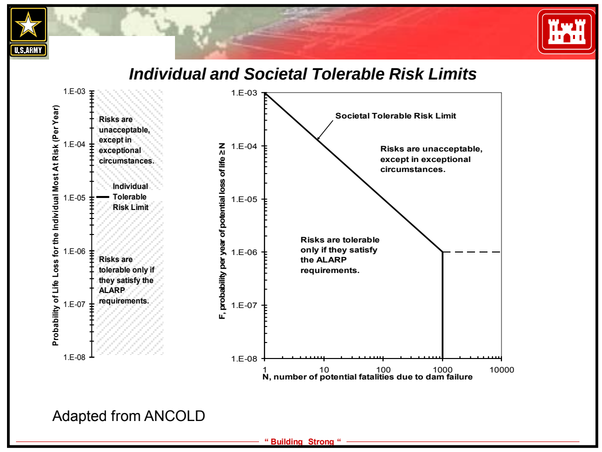
USACE Interim Guidance on Tolerable Risk For Dams

- **Adapted from both USBR and**
- **Australian National Committee on Large Dams (ANCOLD)**

“ Building Strong ”



Annual Failure Probability, f
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
Justification to take action to reduce risk
Justification to take expedited action to reduce risk
Diminishing justification to take action to reduce risk
0
1
10
100
1,000
10,000
100,000
Loss of Life, N
March 2003
From USBR
" Building Strong "



Individual and Societal Tolerable Risk Limits
Probability of Life Loss for the Individual Most At Risk (Per Year)
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
Risks are unacceptable, except in exceptional circumstances.
Individual Tolerable Risk Limit
Risks are tolerable only if they satisfy the ALARP requirements.
F, probability per year of potential loss of life ≥ N
Societal Tolerable Risk Limit
Risks are unacceptable, except in exceptional circumstances.
Risks are tolerable only if they satisfy the ALARP requirements.
1
10
100
1000
10000
N, number of potential fatalities due to dam failure
Adapted from ANCOLD
" Building Strong "

Workshop on Tolerable Risk Evaluation

A step towards developing tolerable risk guidelines for dams and levees

Summary White Paper
on
Workshop Co-Sponsored by USACE, Reclamation and FERC
March 18-19, 2008

Purpose of Workshop

Risk assessment methodologies have been used in various industries around the world to provide decision makers information on the likelihood of an adverse outcome and the resulting consequences. This information is then used by each organization to support life safety decisions. Of particular interest to the management of risks for dams and levees is risk assessment's ability to assess potential failure modes that are not amenable to deterministic analytical solutions and to capture the affects of uncertainty in the analysis parameters on the results of the analysis.

Reclamation has utilized a risk informed decision process in its dam safety program for many years. Reclamation's purpose for participating is to take advantage of advances in risk management strategies to more thoroughly understand and more consistently implement tolerable risk concepts. In cooperation with Reclamation, USACE and FERC are working to develop guidance for incorporating risk informed decision making into their dam and levee safety programs. USACE's Actions for Change initiative is an over-arching program designed to manage the Corps' portfolio of dams and the nation's portfolio of levees in a risk informed framework. The FERC is looking to extend the benefits realized from their Potential Failure Modes Analysis program so that the probability of failure and the resulting consequence are captured in a more consistent and credible manner and so that decisions are made in a risk informed framework.

In order for the three agencies to move forward in a consistent manner, a common understanding of tolerable risk as it applies to dams and levees is necessary.

As part of this effort the three agencies co-sponsored this workshop on tolerable risk. The agencies' interest in tolerable risk was driven by a common desire to:

- Make better decisions
- Better determine, prioritize, and justify risk reduction actions
- Better communicate risks to decision makers and the public
- Better understand and evaluate public safety risks in an environment of shared flood risk management responsibilities

The workshop was developed in order for the agencies to learn:

- How tolerable risk is defined by other federal agencies and selected international organizations (see attached list of presenting and participating agencies and organizations).

- How tolerable risk is being used to evaluate risks and to justify risk reduction measures
- What problems have been encountered in implementing a tolerable risk policy and how the problems have been addressed
- How the invited agencies and organizations assess their success in achieving the intended purposes of using tolerable risk.

Workshop Insights on Tolerable Risk
Speakers were asked to address three specific areas:

- How tolerable risk is defined by other Federal agencies and some international organizations,
- How it is being used to evaluate risks and to justify risk reduction measures
- What implementation problems have been encountered and how they have been addressed.

Overall summary and synthesis
In general, the workshop indicated that the various industries, agencies, and nations are more similar than they are different and that the differences are largely a function of the particular organization's focus.

The workshop speakers developed two additional principle themes:

- Governance; and
- Communication

A summary of the discussions on these five topics is provided below.

Tolerable Risk Approaches
Speakers noted that tolerable risk can be defined in different ways including a cooperative approach by stakeholders, the courts, or both. Cooperative approaches that bring together technical and political/ societal interests have the ability to bring synergy to the process.

The way in which tolerable risk guidance, criteria, or thresholds was originally developed by each of the speakers was generally not clearly defined. In many cases it appeared that one group borrowed concepts from another who had borrowed their guidance from a third party.

The purpose of tolerable risk guidance is to facilitate understanding, consistency, credibility, decision-making, communication, equity, and efficiency (population risk and cost effectiveness).

Tolerability was often described as an inverted triangle with a broad unacceptable base, a generally acceptable region near the point and an uncertain middle. Somewhere within the uncertain region is the limit of tolerability. The concept of As Low As Reasonably Practicable (ALARP) can help define where the tolerable risk region lies.

Embedded in this concept is that understanding and considering uncertainty is critical.

Standards based decisions still have value in cases where there is a well understood problem and a well understood solution. For new problems, with no agreed upon standards, or those problems with significant uncertainty, standards are not appropriate.

Tolerable risk means different things to different people and organizations. Some focus on economic risks to their company or organization (insurance, chemical, offshore oil and gas, etc.) while others focus on loss of life. Loss of life is treated in various ways including Value of Life Saved (VLS), Cost Statistical Life Saved (CSLS), and Loss of Life (LOL) Risk. LOL is often plotted on a F-N or f-N Chart. Tolerable risk on a F-N plot can be defined by lines (not hard, bright lines but fuzzy lines) that are analogous to the regions of the inverted triangle. Key considerations are the slope, y-intercept, and truncations of the lines and whether the F-N chart should present annualized risks or lifetime risks and cumulative risks or individual risks. As noted below in communication, it is important for clear and consistent communications that a common methodology is developed among the U.S. dam and levee safety community.

Governance

A common theme was that good decisions came from good governance. Governance approaches varied from prescriptive, in particular New Zealand, to notional or delegated. In some instances risk based decision making is legislated and in other industries use may be voluntary or due to a common state of practice.

Tolerability of risk was often cited as having political and values components. The role of the stakeholder; owner, regulator, decision maker, contributor, legal advisor, etc. has a significant impact on the perception of tolerable risk. Use of risk assessment methodologies was often used in general communication and decision making with stakeholder groups.

Non-infrastructure industries often have a broad use and acceptance of risk methods and tolerability. In most of these cases risk methods are industry based and are utilized more to make operating decisions and to assure the long-term health of the company. Since these decisions are often internal to a particular company and the results may not be made public, there is in general less resistance to monetization of life safety as opposed to a tolerable loss of life guideline. In most instances a level of equity across the general population in the range of 10^{-4} to 10^{-6} annualized loss of lives was used by non-infrastructure industries. Some of the numerical thresholds were difficult to compare because some of the limits were referring to cumulative effects of the life of the individual while others were referring to instantaneous effects.

Infrastructure industries had used of risk methods less broadly and in many cases use of risk is in its infancy. Where tolerable risk guidelines had been developed, they were within the same range as that used by non-infrastructure industries.

Communication

Communication was described as a key component of risk management. Risk assessment methodologies were often cited as making the communication process open and transparent, robust, and defendable. It was noted by several speakers that communications had to include appropriate simplification for the public. Starting with consequences and then, if necessary, the probability of the event can be introduced.

Risk methods can be used in communications to enhance the concepts of shared responsibility among the various stakeholders.

A common concern was the lack of a consistent terminology which inevitably can lead to confusion. The common term "safe" in risk based decision making has a certain amount of uncertainty since it can not mean a zero chance of an adverse event occurring. A common terminology, at least among the federal dam and levee safety community, was recognized as a key need.

Decision Making

Making sound defendable decisions should be the focus of the risk-informed process, not the numerical risk estimate or a tolerable risk guideline. Decisions are about options, there are no simple numerical solutions or distinct lines on a graph separating acceptable from unacceptable.

Risk informed decision making may be complicated since risk management is often a shared responsibility and the varied interests of the stakeholders can lead to different and conflicting and different options.

Risk informed decision making includes traditional/deterministic analyses complemented by risk assessment methodologies.

Decision making over a large portfolio is different than decisions made for a single dam or levee especially when resources are a limiting factor (nearly always the case). Greater risk reduction may be achieved by work at multiple dams with lower levels of risk rather than committing vast resources to a single project leaving little to no resources to reduce other risks. This trade-off needs to have a level of rigor in order to achieve the goals of openness and defensibility and should be risk informed rather than risk based as other societal and organizational values will need to be considered.

In a regulatory framework, it was apparent from several speakers that it is not the business of the owner of a facility to consider whether more risk reduction would be achieved by spending the same amount of money in some other sector than making his dam safer to comply with the law. This conclusion indicates that it would be the responsibility of the regulator or groups of regulators to come to common method for enforcing this equity. Large expenditures spent disproportionately in one industry could actually lead to an increased overall fatality rate.

Tolerability of risk is formed by the choices available. The ALARP principle brings this concept to the decision making process.

This will require a larger role or engagement in the communications process for the engineers than traditionally seen coming from the engineering community. Engineers must consider both the technical issues and the values of society and their organization.

Implementation challenges

This area was covered in less depth than the other areas of interest. Implementation was not well covered as a holistic system (New Orleans, LA example). There was an obvious difference in perspective to implementation between the regulator, owner, or industry association. There was a definite difference between regulators depending on the industry that was being regulated.

Where implementation challenges were covered, the focus was on externalities, those factors outside of the organization over which the organization has little to no control, and how the values of these external stakeholders were often at odds with those of the organization that was responsible for paying the bill. Risk management was valued as a means of telling the story of shared responsibilities.

In some cases the speakers addressed organizational resistance to change, especially among technical staff. Risk was seen as a fuzzy logic as opposed to the crisp decisions of a standards based method. With experience, this resistance generally faded.

Future Steps

The day after the workshop, the steering committee and session recorders met to map out the steps necessary to move forward on developing guidance on tolerable risk for dams and levees. Nine action items were identified with assigned responsibilities and due dates. This draft white paper is the first item; the overall goal is to develop tolerable risk guidelines for water resources facilities that are consistent between the federal agencies.

More information and workshop presentations can be found at:

http://www.usbr.gov/ssle/dam_safety/jointventures/tolerablerisk

National Levee Safety Program

Presented at the Tolerable Risk Guidelines Workshop
Alexandria, VA, March 17, 2010
by Karin Jacoby & Les Harder

A Report to Congress from the National Committee on Levee Safety

Presentation Overview

- Stating the Problem
- Levee Safety Act of 2007 and formation of the National Committee on Levee Safety
- NCLS Recommendations
  - Leadership via a National Commission on Levee Safety
  - Strong Safety Programs in All States
  - Aligned Federal Programs
- Technical Considerations
- Tolerable Risk Guidelines
- Questions

Levees – Early construction methods

- *Varied methods*
- *No common standards*
- *Not good levee records*
- *Buried their technology within them*

Complacency Regarding Levees

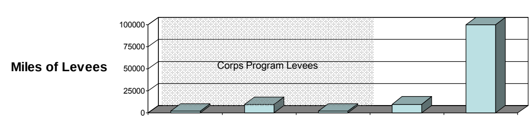
Unheeded wake-up calls:
-1993 Midwest Floods
-1997 Central California Valley

Wake-up call we cannot ignore:
-2005 Katrina

Extreme Events that Keep Happening

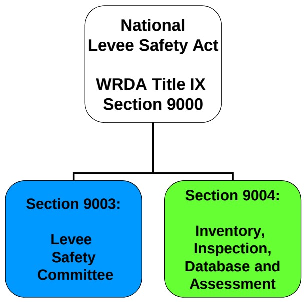
- **Great Flood of 1993**
  - Covered 400,000 square miles
  - 200 counties declared disaster areas
  - 72,000 homes destroyed
  - Losses and Costs exceeded $20B
  - 47 Lives Lost
  - Lasted 200 days
- **Hurricane Katrina**
  - >$200B in direct and indirect damages
  - 1,810 Lives Lost
- **2008 Midwest Flood**:
  - 40,000 evacuated
  - 24 lives lost
  - $2.7B federal relief
- **2008 Hurricanes**
  - >3M evacuated

Our Current Situation



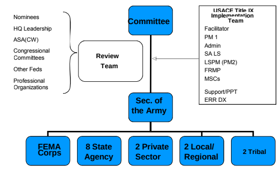
- ✓ **Levees are Abundant and Integral to Communities:**
  - ***Critical for the Protection of People, Property, and other Infrastructure***
  - ***Estimated that tens of millions of people live and work in leveed areas***
- ✓ **No National Standards, nor Approaches**
  - ***Designed for one purpose now serving another***
  - ***Systems based approaches were most often not used, but are needed***
- ✓ **Risk: A Dynamic that We Can Keep Up With?**
  - ***Average age of 50 years, Climate Change, Infrastructure Degradation, & Increasing Population Growth***

National Levee Safety Act



- **Complements Existing Activities & Authorities**
- **Two Major Components:**
  - Recommendations
  - Safety Data Collection
- **"One Time" Nature**
- **Levees Include:**
  Hurricane, Storm & Flood Structures:
  - Earthen embankments
  - Floodwalls
  - Structures along canals

National Committee on Levee Safety Section 9003



Mission Statement –

from Title IX of WRDA 2007

*"The committee shall develop **recommendations** for a National Levee Safety Program, including a **strategic plan** for implementation of the program."*

- Committee - Multidiscipline in nature: Engineering, Law, Public Administration, Business, etc.
- Supported by USACE and FEMA, but primarily non-federal composition
- Review Group – Multidiscipline in nature, including above and Budget, Environmental, Tribal, etc.

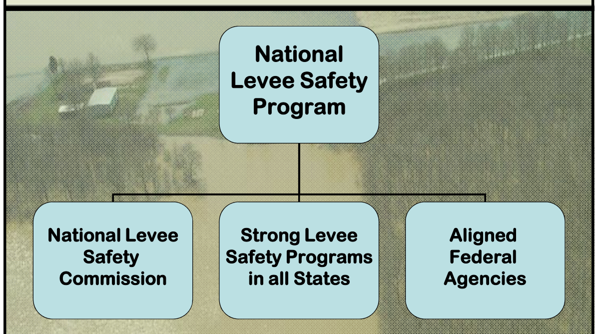
Vision and Approach

"An involved public and reliable levee systems working as part of an integrated approach to protect people and property from floods"

Approach – Focus on foundational elements in the Act supporting the vision, while distinguishing from broader issues of flood risk management

- Use of sound technical practices in levee design, construction, operation, inspection, assessment, security and maintenance
- Ensure effective public education and awareness of risks involving levees
- Establish and maintain competent levee safety programs and procedures that emphasize the protection of human life
- Implement feasible governance solutions and incentives that encourage and sustain strong levee safety programs at all levels of government, including hazard reductions and mitigation measures related to levees

Major Recommendations



Comprehensive and Consistent National Leadership

1. Establish a National Levee Safety Commission
2. Expand and Maintain the National Levee Database
3. Adopt a Hazard Potential Classification System
4. Develop & Adopt National Levee Safety Standards
5. **Develop Tolerable Risk Guidelines**
6. Change "Certification" to "Compliance Determination"
7. Require Peer Review of Levee Compliance Determinations
8. Swiftly Address Emerging Levee Liability Issues
9. Develop/Implement PI and Education/Awareness Campaign
10. Provide Technical Materials and Technical Assistance
11. Develop a National Levee Safety Training Program
12. Harmonize Safety and Environmental Concerns
13. Conduct a Research & Development Program

Building and Sustaining Levee Safety Program in All States

14. Design and Delegate Program Responsibilities to States
15. Establish a Levee Safety Grant Program
16. Establish the National Levee Rehabilitation, Improvement, and Flood Mitigation Fund

Aligning Existing Federal Programs

17. Explore potential incentives and disincentives for good levee behavior
18. Risk-Based Flood Insurance Mandated in Leveed Areas
19. Augment FEMA's Mapping Program
20. Align FEMA's Community Rating System to Reward Safety Programs that Exceed Requirements

Engineering Perspectives for a National Levee Safety Program

Engineering & Technical Issues

3. **Adopt a hazard potential classification system**
4. Develop & adopt national levee safety standards
5. Develop tolerable risk guidelines
6. Change "Certification" to "Compliance Determination"
7. Subject Levee Certifications ("Compliance Determinations") to Peer Review
8. Swiftly address emerging levee liability issues
10. Provide comprehensive technical materials and direct technical assistance

Engineering & Technical Issues

Adopt a Hazard Potential Classification System

Proposed Classification System Based on:

Consequences of Levee Failure in an area protected by a levee:

- **Population and property at risk**
- **Depth of flooding**
- **Area and facilities within protected area**
- **Height of Levee**

Engineering & Technical Issues

Adopt a Hazard Potential Classification System

Hazard Potential Classification	Number of People Potentially Inundated	Number of People Potentially Inundated to Depths $\geq$ 3 feet
High	$\geq$ 10,000*	$\geq$ 10,000*
Significant	> 1,000**	< 10,000**
Low	< 1,000	0

* *Also includes areas of consequence where critical life safety infrastructure is at risk (e.g. major hospitals, regional water treatment plants, and major power plants)*

** *Also includes areas of consequence where the number of people potentially inundated is low, but there may be significant potential for large economic impacts or losses*

Engineering & Technical Issues

Adopt a Hazard Potential Classification System

Hazard Potential Classification	Number of People Potentially Inundated	Number of People Potentially Inundated to Depths $\geq$ 3 feet
High	$\geq$ 10,000*	$\geq$ 10,000*
Significant	> 1,000**	< 10,000**
Low	< 1,000	0

* *Also includes areas of consequence where critical life safety infrastructure is at risk (e.g. major hospitals, regional water treatment plants, and major power plants)*

** *Also includes areas of consequence where the number of people potentially inundated is low, but there may be significant potential for large economic impacts or losses*

Engineering & Technical Issues

Adopt a Hazard Potential Classification System

Hazard Potential Classification	Number of People Potentially Inundated	Number of People Potentially Inundated to Depths $\geq$ 3 feet
High	$\geq$ 10,000*	$\geq$ 10,000*
Significant	> 1,000**	< 10,000**
Low	< 1,000	0

* *Also includes areas of consequence where critical life safety infrastructure is at risk (e.g. major hospitals, regional water treatment plants, and major power plants)*

** *Also includes areas of consequence where the number of people potentially inundated is low, but there may be significant potential for large economic impacts or losses*

Engineering & Technical Issues

Adopt a Hazard Potential Classification System

Hazard Potential Classification	Number of People Potentially Inundated	Number of People Potentially Inundated to Depths ≥ 3 feet
High	≥ 10,000*	≥ 10,000*
Significant	> 1,000**	< 10,000**
Low	< 1,000	0

* *Also includes areas of consequence where critical life safety infrastructure is at risk (e.g. major hospitals, regional water treatment plants, and major power plants)*

** *Also includes areas of consequence where the number of people potentially inundated is low, but there may be significant potential for large economic impacts or losses*

Engineering & Technical Issues

Adopt a Hazard Potential Classification System

Hazard Potential Classification	Number of People Potentially Inundated	Number of People Potentially Inundated to Depths ≥ 3 feet
High	≥ 10,000*	≥ 10,000*
Significant	> 1,000**	< 10,000**
Low	< 1,000	0

* *Also includes areas of consequence where critical life safety infrastructure is at risk (e.g. major hospitals, regional water treatment plants, and major power plants)*

** *Also includes areas of consequence where the number of people potentially inundated is low, but there may be significant potential for large economic impacts or losses*

Engineering & Technical Issues

Adopt a Hazard Potential Classification System

Hazard Potential Classification	Number of People Potentially Inundated	Number of People Potentially Inundated to Depths ≥ 3 feet
High	≥ 10,000*	≥ 10,000*
Significant	> 1,000**	< 10,000**
Low	< 1,000	0

* *Also includes areas of consequence where critical life safety infrastructure is at risk (e.g. major hospitals, regional water treatment plants, and major power plants)*

** *Also includes areas of consequence where the number of people potentially inundated is low, but there may be significant potential for large economic impacts or losses*

Engineering & Technical Issues

Adopt a Hazard Potential Classification System

Classification System Proposed for *Interim Use*:

- Proposed for Initial Inventory and Screenings
- Anticipated for use over initial 5 years
- Revised Classification system anticipated after inventories are analyzed and risks better understood

Engineering & Technical Issues

3. Adopt a hazard potential classification system
4. **Develop & adopt national levee safety standards**
5. Develop tolerable risk guidelines
6. Change "Certification" to "Compliance Determination"
7. Subject Levee Certifications ("Compliance Determinations") to Peer Review
8. Swiftly address emerging levee liability issues
10. Provide comprehensive technical materials and direct technical assistance

Engineering & Technical Issues

Develop & Adopt National Levee Safety Standards

Applies to levees, floodwalls, canal structures, and related facilities and features

- ✓ Develop *Interim National Levee Engineering Guidelines* within one year – based on revisions to existing federal criteria
- ✓ Develop a *National Levee Safety Code* within 5 years
- ✓ Enact federal legislation to require that all federal agencies, and later state levee safety programs, adopt the National Levee Safety Code once it becomes available

Engineering & Technical Issues

3. Adopt a hazard potential classification system
4. Develop & adopt national levee safety standards
5. Develop tolerable risk guidelines
6. **Change "Certification" to "Compliance Determination"**
7. Subject Levee Certifications ("Compliance Determinations") to Peer Review
8. Swiftly address emerging levee liability issues
10. Provide comprehensive technical materials and direct technical assistance

Engineering & Technical Issues

Replace Levee "Certification" Term

Use *"Compliance Determination"* or another term in lieu of *"Certification"* for use with FEMA's National Flood Insurance Program

[Corps uses *"Levee Evaluations for NFIP"*]

Purpose:

- *"Certification"* implies that there may be a warranty. This has misled the public and policy makers. It has also led liability insurers to impose constraints and higher insurance rates on AE firms
- *"Compliance Determination"* or another term would more accurately reflect the nature of the levee evaluations and decisions made to allow the community to participate in the National Flood Insurance Program
- Reduces misunderstandings by the public related to their level of risk

Engineering & Technical Issues

3. Adopt a hazard potential classification system
4. Develop & adopt national levee safety standards
5. Develop tolerable risk guidelines
6. Change "Certification" to "Compliance Determination"
7. **Subject Levee Certifications ("Compliance Determinations") to Peer Review**
8. Swiftly address emerging levee liability issues
10. Provide comprehensive technical materials and direct technical assistance

Engineering & Technical Issues

Subject Levee Certifications ("Compliance Determinations") to Peer Review

Purpose:

- **Increase confidence and reliability in technical determinations of levee integrity**

✓ **FEMA to contract for peer or independent technical review of submitted Levee Certifications and associated supporting data**

✓ **Done prior to accreditation**

Engineering & Technical Issues

3. Adopt a hazard potential classification system
4. Develop & adopt national levee safety standards
5. Develop tolerable risk guidelines
6. Change "Certification" to "Compliance Determination"
7. Subject Levee Certifications ("Compliance Determinations") to Peer Review
8. **Swiftly address emerging levee liability issues**
10. Provide comprehensive technical materials and direct technical assistance

Engineering & Technical Issues

Swiftly Address Emerging Liability Issues

✓ Issue: Parties potentially subject to liability:
- Engineering service providers, both private sector and public entities
- State and local governments that are sponsors of a federal flood control project
- New liability could be acquired by states and local agencies from implementing Levee Safety Programs

✓ Effects:
- Private firms and public sector engineering organizations refusing to provide engineering services
- States and local agencies reluctant to sponsor new flood projects and programs for fear of acquiring new liability

Recommended Action:
Congress should swiftly address growing concerns regarding liability through a range of measures aimed at reducing potential liability for those providing levee related services.

Engineering & Technical Issues

3. Adopt a hazard potential classification system
4. Develop & adopt national levee safety standards
5. Develop tolerable risk guidelines
6. Change "Certification" to "Compliance Determination"
7. Subject Levee Certifications ("Compliance Determinations") to Peer Review
8. Swiftly address emerging levee liability issues
10. **Provide comprehensive technical materials and direct technical assistance**

An Involved Public and Reliable Levee Systems 31/48

Provide Comprehensive Technical Materials and Direct Technical Assistance

✓ **Technical Materials that support adoption of a National Levee Safety Code:**

- **Federal Agency Led (Corps and USBR)**
- **Publications on design, construction, operations, maintenance, and safety processes**

An Involved Public and Reliable Levee Systems 32/48

Provide Comprehensive Technical Materials and Direct Technical Assistance

✓ **Technical Assistance to Federal, State, Local and Regional Agencies from the National Commission on Levee Safety:**

- **Understanding and implementing safety programs**
- **Implementing standards and codes**
- **Using technical assistance materials**

An Involved Public and Reliable Levee Systems 33/48

Engineering & Technical Issues

3. Adopt a hazard potential classification system
4. Develop & adopt national levee safety standards
5. **Develop tolerable risk guidelines**
6. Change "Certification" to "Compliance Determination"
7. Subject Levee Certifications ("Compliance Determinations") to Peer Review
8. Swiftly address emerging levee liability issues
10. Provide comprehensive technical materials and direct technical assistance

An Involved Public and Reliable Levee Systems 34/48

Engineering & Technical Issues

Develop Tolerable Risk Guidelines

Tolerable Risk:

Risks society is willing to live with so as to secure certain benefits

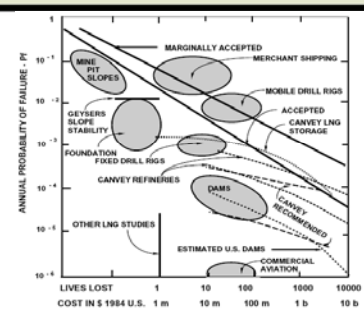
Tolerable Risk Guidelines:

- An improved methodology for decision making
- Enables investors to understand how the infrastructure-related risks compare to what society and engineering practice deem to be tolerable.
- Does not replace engineering standards, but complements and informs them
- Based on judgment rather than simple numerical solutions
- Inform decisions on both structural and non-structural alternatives.

An Involved Public and Reliable Levee Systems 35/48

Engineering & Technical Issues

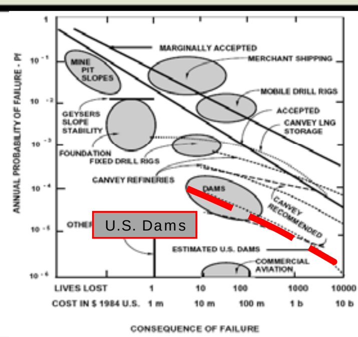
Develop Tolerable Risk Guidelines



An Involved Public and Reliable Levee Systems 36/48

Engineering & Technical Issues

Develop Tolerable Risk Guidelines



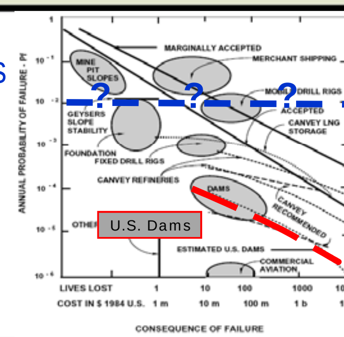
Engineering & Technical Issues

Develop Tolerable Risk Guidelines

LEVEES

FEMA

NFIP



Engineering & Technical Issues

Develop Tolerable Risk Guidelines

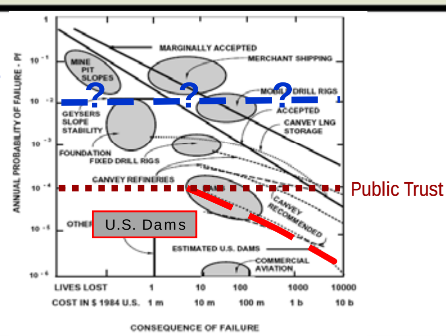
LEVEES

FEMA

NFIP

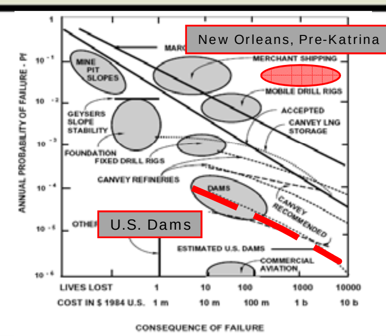
USBR

Tier 2



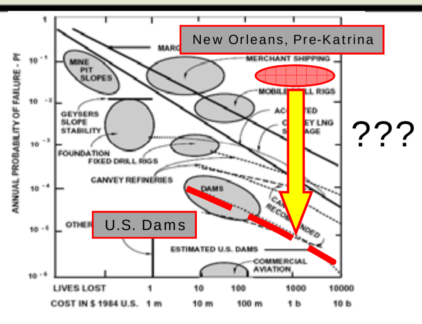
Engineering & Technical Issues

Develop Tolerable Risk Guidelines



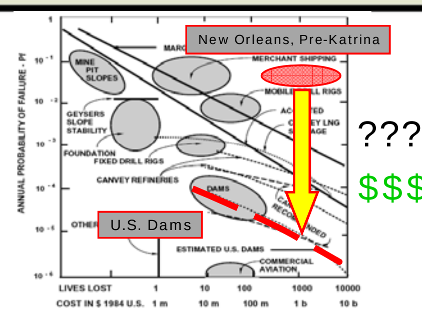
Engineering & Technical Issues

Develop Tolerable Risk Guidelines



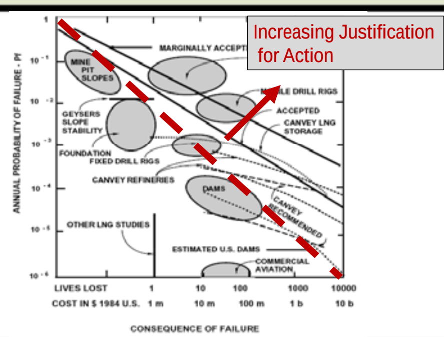
Engineering & Technical Issues

Develop Tolerable Risk Guidelines



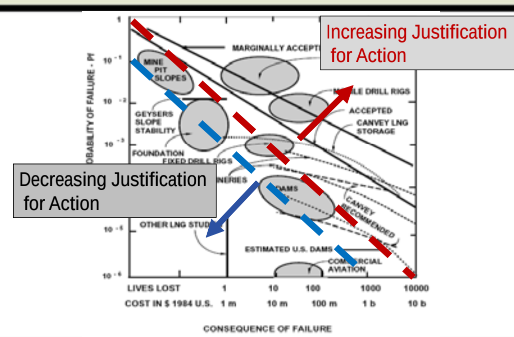
Engineering & Technical Issues

Develop Tolerable Risk Guidelines



Engineering & Technical Issues

Develop Tolerable Risk Guidelines



Engineering & Technical Issues

Develop Tolerable Risk Guidelines

Why are Tolerable Risk Guidelines Needed for Levees?:

- **Most levees over 50 years old**
- **Most levees do not meet modern standards**
- **Increasing development and consequences**
- **Limited resources**
- **Need to prioritize and *buy down the highest risks first***

Tolerable Risk Guidelines will help us balance the desire to reduce risks with the availability of resources

Engineering & Technical Issues

Develop Tolerable Risk Guidelines

Purpose:

- **Better prioritize public investment**
- **Improved evaluation of alternatives to reduce risk**
- **Better understanding of uncertainties**
- **Better communication of Risk**

✓ **Assemble a panel of internationally renowned experts in risk management to develop *National Tolerable Risk Guidelines***

✓ **Conduct a expert peer review of the *Guidelines***

✓ **Enact federal legislation to require use of the *Guidelines***

Closing

✓ **Recommendations Intended to Address all Facets of Risk:**

- ***Recommendations outlined are the bare minimum to properly manage our critical life safety infrastructure***
- ***Not just an expense – it is an investment in protecting lives and our economy***

✓ **If we don't act**

- ***A worsening disaster relief environment***
- ***Pay more later***

✓ **Securing a Better Future:**

→ ***A National Levee Safety Program***

QUESTIONS???

Exploration of Tolerable Risk Guidelines for Levee Systems
Workshop 17 - 18 March 2010

The Tolerability of Risk Framework

Dr Jean Marie Le Guen O.B.E.
Private Consultant

"Set down all the reasons,
pro and cons, in opposite columns,"

Benjamin Franklin to nephew John Priestley

Theme

- Describe the Tolerability of Risk Framework (TOR)
- Inform the discussions of the Tolerable Risk Guidelines proposed by USACE

Presenting my own views and **not** those of USACE

Agenda

- Explore how we view risks
- Explain rationale for TOR Framework
- Look at the TOR framework in detail
- Highlight issues arising in applying TOR to levees

Language and concepts

- Hazard: Potential for undesirable consequences to occur

  Risk: Probability that harm will occur and the severity of its consequences

Innate Senses

Deep in the human psyche lie a pre-disposition for

- Fairness
- Revenge & Punishment
- Dealing with risks

$10 notes are to be divided between 2 players A and B subject to the following rules

A decides how the $10s are to be divided

B must accept the deal otherwise neither player gets anything

Most people will not accept a deal if A gives only 50c

How we view risks : Innate senses

Deep in the human psyche lies a pre-disposition for

- Fairness
- Revenge & Punishment — Banker's bonuses- Enough said
- Dealing with risks

Dealing with risks

We are at times irrational : Hardwiring?

- Bandwagon effect — We do things because others do them
- Inbuilt risk aversion — We prefer avoiding the risk of making a loss rather than taking the chance of making a gain
- Framing effects — We reach conclusions depending on the way the data is presented
- Confirmation bias — We search for or interpret information in a way that confirms our preconceptions
- Halo effect — We attach less risks to objects with a favourable impression and vice versa

How people view risks : Effects on Behaviour

Governed by two types of concerns

Individual concerns

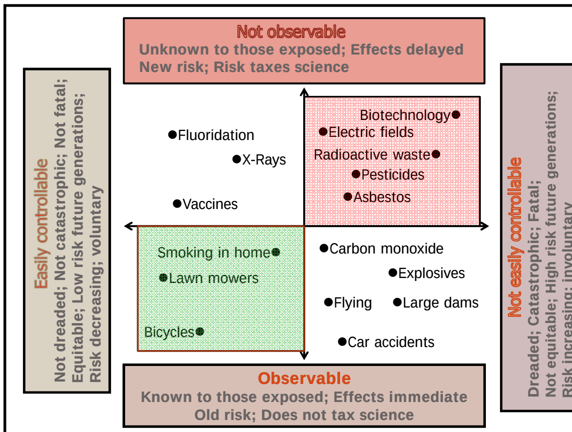
- How the risks affect them personally – Individual risk

Societal concerns

- Risks that impact upon society
  - When due to multiple fatalities in single event known as societal risk

Attributes of hazards giving rise to societal concerns

- Dreaded
- Severity not controllable
- Catastrophic
- Certain to be fatal
- Risks and benefits inequitable
- Threatens future generations
- New (unfamiliar)
- Taxes science to the limit
- Many people exposed
- Many people killed in single event
- Affects me personally
- Involuntary
- Risk increasing



Rationale for TOR Framework

Decision making system similar to what people use in their every day life for dealing with risks

Need for a system that was:

- Focussed
- Efficient
- Consistent
- Transparent
- Clear on accountability

Decision-making system

Stage 1: Defining the Issue

Framing questions to be tackled

- Requires investigation:
  - Causes of the problem
  - Who and what affected
- Need to take on board views of all stakeholders

Stage 2: Risk assessment

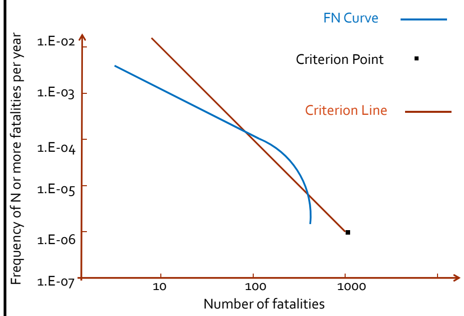
- Identify hazards
- Assess likelihood that hazards will be realised and
  - Who and what affected
  - Consequences
- Identify possible measures to control risks
- Done by looking both at:
  - Individual risks
  - Societal risks

Assessing Individual Risks

- Individual risks assessed :
  - Usually in relation to hypothetical persons
  - Rarely in relation to actual persons
- Important that:
  - all risks covered
  - People at risk have confidence in choice of hypothetical persons

Persons constructed to be representative of main groups of people affected

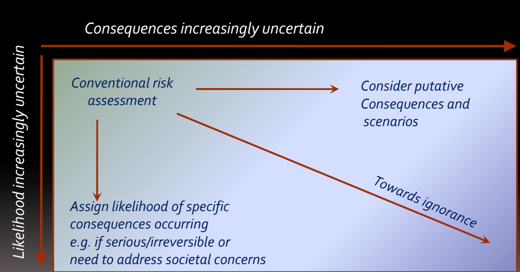
Assessing societal risks



Uncertainty

- Permeates all risk assessments
- addressed by making assumptions
- Transparency essential

Uncertainty : Precautionary Approach



Stage 3: Options and Their Merits

- How effective
- Compliance with hierarchy of control
- Adverse consequences
- Constraints
- Cost benefit analysis

Cost-benefit Analysis

- Done according to protocols
- CBA Protocol used in UK for informing TOR takes account of benefits of lives saved
- Value for preventing a fatality currently $2.6 million
- If benefits of saving lives not included, cost of a measure will appear higher
- Other detriment rated relative to risk of death

Cost-benefit Analysis

- Cost and benefits discounted
- Real rate of return of 6% used to discount costs and benefits
- Benefits uprated by 4% to take into account increased value that people place on safety benefit as living standards improve
- Discounting not applied when costs and benefits accrue very far in the future (30 years or more)

Stage 4 : Adopting Decisions

Raises three questions

- What level of risk is tolerable?
- What to do when it is not?
- Who decides?

Stage 4 : Adopting Decisions

What Level of risk is tolerable?

Three categories identified

- Broadly acceptable
- Tolerable
- Unacceptable

Stage 4 : Adopting Decisions

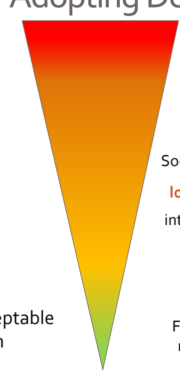
What criteria to use?

TOR criteria accommodate three approaches

- Equity-based
- Utility-based
- Technology-based

Criteria for Adopting Decisions

Increasing Individual risks and societal concerns



Unacceptable Region — Risk cannot be justified save in extraordinary circumstances

Annual risk of death (workers) 1 in 1,000 (Public) 1 in 10,000

Tolerable Region — Society prepared to tolerate risks for benefits. Control measures must be introduced to drive risks towards the broadly acceptable region

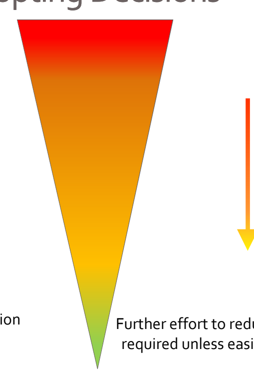
Risks must be reduced as low as reasonably practicable

Broadly Acceptable Region — Risk regarded as insignificant. Further effort to reduce risk not required unless easily achieved

Annual risk of death of 1 in 1,000,000 (workers and public)

Criteria for Adopting Decisions

Increasing Individual risks and societal concerns



Unacceptable Region — Risk cannot be justified save in extraordinary circumstances

Tolerable Region — Society prepared to tolerate risks for benefits

Broadly Acceptable Region

Further effort to reduce risk not required unless easily achieved

What is ALARP?

- ALARP stands for As Low as Reasonably Practicable
- ALARP is a qualification to a duty
- Duty discharged when there is gross disproportion between the sacrifice involved in introducing a measure and the subsequent benefits

In terms of money, time and trouble

Reduction in harmful consequences, eg. fatalities, injuries etc

ALARP CONSIDERATIONS

- ALARP met by adopting (authoritative) good practice
- Good practice must be relevant and up to date
- If good practice not available use 6 step management process to determine ALARP
- May not be reasonably practicable to apply enhanced measures
- Whether to retrofit will depend whether measure is grossly disproportionate or not

ALARP considerations

Relation between costs and benefits

- Costs' to 'benefit' ratio be disproportionate
- Affordability not a legitimate consideration

Ratio Depends on the baseline of individual risks + Where relevant on the baseline of societal risks

- Low baseline of individual risks, no societal risks — Ratio 1-2
- Low baseline of individual risks, societal risks present — Ratio 3
- High baseline of individual risks, — Ratio 3-10

ALARP considerations

Optioneering

Occurs when there are options for risk reduction in tolerable region

Number of options exist → Differences in the time that options can be implemented?

- No → Choose option that reduces risk to greatest extent (not necessarily cheapest)
- Yes → Cheaper option may be acceptable if can be implemented in shorter time

ALARP considerations

Transfer of risks

- Occurs when a control measure results in a transfer of risk for the same hazard to other people
- Additional risk to people affected offset against the benefits of the measure
- Where transfer results in exposure to a new hazard, risk from new hazard considered as a new hazard to be reduced ALARP

: ALARP considerations

Removal of existing control measure or replacement by a less stringent one

- The following criteria apply

Allowed

Where circumstances have changed, e.g.
- Changes in technology
- New knowledge about risks etc
- Sacrifice can be shown to be grossly disproportionate to benefits (does not apply to good practice)

Disallowed

Where established good practice remains valid, even if it can be shown that sacrifice for introducing measure disproportionate to benefits

Stage 4 : Adopting Decisions

Who has the final say?

- Body necessary to give guidance on what is ALARP in a particular case
- In UK for example this performed by HSE a multipartite body with legal responsibilities and legal powers

Stage 5: Implementing decisions

Approach is to get implementers to:

- Have a plan
- Enlist the cooperation of those involved
- Foster an appropriate culture
- Essential where responsibility is shared

Helped when this is backed by law

Stage 5: Implementing decisions

Staged implementation:

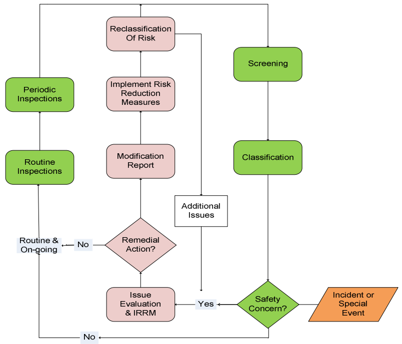
- May be necessary when existing risks are in the unacceptable region
- Banning - an incomplete solution
- Scale of action needed such that remedial measures will take time to introduce

Stage 6: Evaluating effectiveness

Examination of :

- Whether action taken resulted in what was intended
- Whether decisions need to be modified

Generalised USACE Portfolio Management Process



Case Study: Gas Mains Replacement

- Parallels
- Wally Gas as a case study
  - Interesting parallels
  - Legacy of deteriorating iron pipelines (91,000) km
  - Demonstrates one way of tackling levee problems
  - Review showed that large percentage of pipes in unacceptable region
  - Shared responsibility between body responsible for the pipes, body signing off their safety and the body footing the bill
  - Public expectation that the system would be safe
  - Recognition that there would be some accidents

Case Study: Gas Mains replacement

How programme implemented

- In 2001 replacement programme agreed with main players using the TOR framework in reaching decision
- Implementation staged over a 30 year period
- Selection of pipes prioritised according to individual risks and societal risks using TOR framework
- Threshold for incident and fatality rate adopted
- Gas operator obliged to submit rolling replacement plan for approval
- Plan approved by safety regulator if suitable and sufficient

Case Study: Gas Mains replacement

How programme implemented

- In 2003 programme accelerated
- Costs currently about £760 million ($1.1 billion per year)
- Costs met by consumers through a levy on gas bills (currently about $150 a year on average)
- Programme about one third through

Case Study : Shared Responsibility

Gas mains pipeline explosion

- On 22 December 1999, huge gas leak discovered in residential area in Glasgow
- HSE decided not to cut supply because risk of people dying of hypothermia greater than that of risk explosion
- In subsequent explosion, a family of 4 were killed
- Gas distributor did not implement staged plan
- Gas distributor found guilty and fined £15 million
- Accelerated pipe replacement programme put in place

Case Study : Shared Responsibility

Gas **mains** pipeline explosion

- On 30th November 2005 gas explosion at Buckstone Grove, Edinburgh – Occupant badly burnt
- Cause - Fracture of 4 inch cast iron main that:
  - was part of an established prioritised mains replacement programme.
  - had no history of problems associated with this section of main
  - had a low risk rating and therefore was not scheduled for replacement for a number of years.
- HSE did not take any enforcement action . No evidence that a breach of relevant safety legislation had occurred

Would Benjamin Franklin have approved the TOR framework and the TRG Guidelines?

Probably, Yes

The Tolerability of Risk Framework

Paper for the Exploration of Tolerable Risk Guidelines for Levee Systems Workshop - March 2010

Dr Jean Le Guen O.B.E.
Private Consultant
Former head of the Risk Policy Unit
Health and Safety Executive, United Kingdom

Introduction

This paper describes The Tolerability of Risk Framework[1] (known as TOR) that was originally published by the Health and Safety Executive (HSE) in the United Kingdom (UK) to make transparent its approach to the management of risk to people arising from work activities. The main purpose of the paper is to inform the discussion of the Tolerable Risk Guidelines (TRG) that the United States Army Corps of Engineers (USACE) is developing for the successful assessment, management, and the communication of risk involved with levees in its inventory. **This paper presents the author's views and not those of the Corps of Engineers.**

The paper summarises the rationale for the TOR framework, especially the thinking about how people behave towards risk; then describes the steps envisaged in the management system and the issues raised in applying it to levees.

Background

Rationale for TOR framework

The tolerability of risk framework evolved from the recognition that absolute safety in work and public life was not practical; that in their everyday lives people live very happily with different levels of risk, depending on circumstances, and if they did not they would not leave their houses and industry would collapse. It was felt that the system of controlling risk therefore needed to reflect more explicitly how people and society view risks in general and how people at an individual level deal with the risks they are exposed to. At the same time it was essential that the system had the confidence of the people affected; and for this it was deemed necessary to make the system as transparent as possible, and to involve the stakeholders in its operation.

The system was first developed in the UK some 35 years ago in relation to health and safety at work, but has now been adapted as a useful framework in other spheres (for example the environment and planning) and in countries in Continental Europe and other parts of the world (for example in the Netherlands for coastal and riverine flood defences and for dam safety in Australia and New Zealand).

The context in the UK is a legal framework where there is a duty on those who create risks to take appropriate measures to protect people and the environment. For many major hazards this legal duty

[1] HSE (2001), Health and Safety Executive, "Reducing Risks, Protecting People: HSE's Decision-making Process," Risk Assessment Policy Unit, HSE Books, Her Majesty's Stationery Office, London, England, 2001. (www.hse.gov.uk/risk/theory/r2p2.htm)

extends to the submission of a safety case to the regulator setting out how they propose to control hazards and risks in accordance with TOR criteria and their plan for implementing the safety case. If the regulator approves the safety case and duty holders adhere to it, the latter are unlikely to be found negligent in a court of law should an accident subsequently happen. The legal requirement for a safety case for major hazards also applies to countries in the European Community.

However the approach can and does operate without these specific legal requirements. What is necessary, however, is a clear understanding of who is responsible for what, and the mechanisms for cooperation between the different bodies involved.

How people view risks

Analyses of how people behave towards risk in their everyday lives were crucial to the development of the TOR framework, as providing indicators of the sort of control regime that would command public confidence.

That people are prepared to take more or fewer risks in different circumstances can in many instances of course be explained rationally. They are more likely for instance to accept higher levels of risk if there is some benefit to them – whether financial or in their quality of life.

However, several studies have shown that our tolerance of risk is not always rational[2,3,4]. Though rationality may play a part, our decisions on the risk issues are influenced to a considerable extent by in-built mechanisms in the human psyche. So for example, people are more inclined to tolerate exposure to certain risks if the exposure is voluntary – hence willingness to partake in sports that entail an element of danger, or acceptance, when given a choice, of “dangerous” work (especially if it brings a higher salary or other rewards).

At the same time people tend to deal with the perception of risk rather the ‘true’ risks as established, for example, by experts. This has been examined extensively and it is now well established that this phenomenon is often linked to attributes of certain hazards. People want a higher degree of regulation to apply to hazards that give rise to risks that are dreaded (e.g. cancer); to risks the severity of which are not controllable (e.g. untreatable cancers such as mesotholemia); to those risks over which they have no personal control (hence the desire to see higher standards of safety for public as opposed to personal transport; to hazards which have the potential to cause catastrophes on a global scale (e.g. depletion of the ozone layer); and those which threaten future generations (e.g. global warming).

Psychologists go so far as to affirm that the concept of risk is strongly shaped by human minds including language and the terminology used for describing it. Accordingly TOR makes a distinction between ‘hazard’ and ‘risk’ (in every day parlance these words are used interchangeably). We consider a hazard as something which has the potential for causing harm arising from an intrinsic property or disposition of something to cause detriment. Risk, on the other hand, is the probability that someone, or a thing that is valued, will be adversely affected by the hazard in a stipulated way. For example, a

---

[2] Fischoff B, Slovic P, Lichtenstein S et al ‘How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits.’ *Policy Sciences* 1978 **9** 127-152

[3] Funtowicz SO and Ravetz JR ‘Three Types of Risk Assessment and the Emergence of Post normal Science’ in *Social Theories of Risk* Praeger Westport Connecticut 1992 251-274

[4] Pidgeon NC Hood C Jones D et al *Risk: Analysis, Perception and Management*. The Royal Society London 1992 89-134

levee provides flood risk reduction by excluding flood water from leveed areas but also poses a hazard because it has the potential to breach and cause dangerous flooding. The risk is the probability of the flood occurring and its consequences.

Studies[5,6,7] have identified other heuristics, i.e. influences on how we regard risk:

- **An innate** sense of fairness. We do not like activities where the risks and benefits are unevenly distributed in society (as bankers have found recently);
- **A desire** for punishment or revenge when we perceive that we have been wrongly exposed to risk and suffered some kind of detriment;
- **A bandwagon effect**. We often engage in risky activities because others do them;
- **An inbuilt aversion to losses**. We prefer avoiding the risk of making a loss rather than taking a chance of making a gain;
- **A predisposition** to be influenced by the way the data is presented. This is not confined to risk issues but it can affect, for example, how we perceive the harm and benefits attached to a particular activity. This is known as the 'framing effect';
- **An inclination** to search for or interpret data in a way that confirms our preconceptions (confirmation bias);
- **A predilection** to attach less risk to hazards that confirm a favourable impression and vice versa ('halo effect').

So far, these observations have related to **Individual concerns:** this is how individuals see the risk from a particular hazard affecting them and things that affect them personally.

However risks may also raise **societal concerns,** which may or may not impact directly on the individuals who have such concerns. Thus people are wary of risks that impact on society as a whole because they are seen as posing a threat to the society's fabric and its social and cultural values. This type of concern is often associated with hazards that give rise to risks that were they to materialise, would provoke a socio-political response, creating uneasiness and undermining not only the institutions responsible for ensuring that society operates smoothly but also the long established processes that they use towards that end.

Hazards giving rise to societal concerns share a number of common features. They often give rise to risks which could cause multiple fatalities, or risks that may not be obvious to the general public, and require expert opinion to understand their nature and to predict their possible consequences; they may involve exposure to vulnerable groups, e.g. children; and the risks and benefits tend to be unevenly distributed – for example between groups of people with the result that some people bear more of the risks and others less, or through time so that less risk may be borne now and more by some future generation. Typical examples relate to nuclear power generation, railway travel, or the genetic modification of organisms.

---

[5] Malcolm Gladwell (2005); Blink "The Power of Thinking Without Thinking", Penguin Books.

ISBN 978-0-14-101459-3

[6] R H Thaler and C R Sunstein (2009); Nudge "Improving Decisions about Health, Wealth and Happiness", Penguin Books. ISBN 978-0-141-04001-1

[7] P Lunn (2008); "Basic Instinct – Human Nature and the New Economics", Marshall Cavendish.

ISBN 978-0-462-09920-0

Societal concerns due to the occurrence of multiple fatalities in a single event are known as **societal risk**. Societal risk is therefore a subset of societal concerns. Societal risk is the only societal concern for which techniques have been developed for incorporating a societal concern in decision making on the control of risk (see stage 4 on the TOR framework below).

What are the implications for developing a control system for managing risks for levees?

The first is that the level of safety that people expect will vary in the different interest groups. Thus those for whom the levees bring obvious benefits may be prepared for a higher residual risk in return for the benefits, whilst still wanting risks to be kept low and clearly controlled. These benefits may be to individuals (for example work and salary mentioned above); or to groups, such as farmers and consumers of farm products, when levees permit irrigation on land otherwise less productive.

However, regardless of this, expectations of safety levels may be higher than is justified by a straightforward inspection of the risks posed by the state of maintenance and repair of a particular structure. Amongst other reasons, this is because individuals personally have little control over the measures; because in some cases (e.g. of dams and levees being breached) the consequence of failure falls into the category of events people dread; and because in some cases such consequences are the subject of societal concerns – threatening for example an entire community, or indeed the socio-political system, whether in fact or perceived. The latter was demonstrated clearly following the cyclone Katrina, when the public reacted not only to the harm done to the individuals, but also to the reputation of the administration and even to the reputation of the US abroad.

Both individual perception of risks, and societal concerns over levee and dam safety are aggravated by media coverage. The dramatic pictures of the distress of individuals and the apparent disarray of the emergency response after Katrina mean that a great deal of work is necessary to restore confidence in the system of protection.

Such a sophisticated risk analysis can be useful in prioritising within a programme of repair and improvement. Such considerations as the number of people affected, the extent to which they have choices, the repartition of benefits between groups, as well as an assessment of the material state of the dams and levees can help in deciding the order in which work might be undertaken.

I now turn to the Tolerability of Risk framework itself.

The Tolerability of Risk Framework

TOR was developed as a framework for reaching decisions on the degree and form of regulatory control for occupational hazards. In developing it, the Health and Safety Executive were working to criteria that were considered to make for good regulation. These required:

- A focus on the most serious risk or those hazards in need of greater control;
- Efficiency, meaning action commensurate with the risk;
- Consistency by adopting a similar approach in similar circumstances to achieve similar ends;
- Transparency over how decisions are arrived at and what their implications are;
- Clarity on who is accountable when things go wrong.

TOR is essentially a process for reaching decisions that reaches out for and involves stakeholders in its operation. Embedded in the process are criteria for deciding what risks are unacceptable, tolerable or broadly acceptable that mimic the way that people take decisions in their every day life.

For ease of presentation, the process is described under six stages. In practice the boundaries between them are not clear-cut, and the process becomes an iterative exercise as information is accumulated. Each stage is described briefly then followed by observations on how it might apply to dams and levees

Stage 1: Defining the issue

The first stage is the framing of the questions to be tackled. It requires investigation into the causes of the problem, and identifying who and what are affected.

In articulating the problems, whether with dams and levees or in any other sphere, it is important to take on board the viewpoints of all stakeholders, not just those who may be responsible for their effective operation. The body in charge may consider that ensuring the integrity of a levee system is essentially about preventing it from breaching prior to overtopping thereby avoiding a flood. However, people living in the shadow of the levee may see other factors as equally important, such as fair treatment between them and those living on higher ground. Environmentalists might advocate the need to protect nearby eco-systems. It may well not be possible to meet everyone's objectives; but failure to find out what matters most to different stakeholders runs the danger that any action decided will be seen as an imposition rather than a solution.

Stage 2: Characterising the issue - Risk assessment

This stage is essentially about gathering information to assess how great the risk is, how serious, how it impacts on those affected, and any wider implications. The stages are: identifying the hazards, i.e. what could cause harm or damage; assessing how likely the harm will actually be experienced; identifying the population that might be affected; and assessing what might be the consequences. It is at this stage that societal concerns, in particular societal risks, need to be identified. The rigour of the risk assessment will vary, depending on how great the potential for harm.

Actual and hypothetical persons

Though a risk assessment can be done (and is sometimes done) to assess the risk to an actual person – i.e. the risk to an individual taking full account of the nature, extent and circumstances in which the exposure arises – there are problems which limit the usefulness of such an approach for managing risks generally. First, the approach could be very resource intensive. Exposure to most hazards is seldom confined to one person; and individuals are affected by risk differently depending, amongst other things, on their physical make up, abilities, age, and the circumstances giving rise to their exposure. Assessing risks for each of these variables would take time. Moreover, it would be very difficult to extract and distil useful information from all the individual assessments, so much time would be wasted. In practice therefore, assessment of the risks to an actual person has rather limited uses such as checking whether a generic measure introduced is suitable for a particular person (e.g. one with disabilities).

Under TOR, what is done instead is to perform the assessment in relation to a hypothetical person whose circumstances and exposure to risk are representative of those of the main groups of people affected. To ensure that all significant risks for a particular hazard are adequately covered, there will usually have to be a number of hypothetical persons constructed. What is important is that all risks are covered; and that the real people at risk have confidence that their situation is being taken into account.

In the context of dams and levees, we might hypothesise: a person who lives in the shadow of a dam or levee, who is there 24 hours of the day all year round, whose family and whose home are in close proximity to the dam; an employee of the dam or levee, who does shift work, but whose work takes them onto the structures; a member of the emergency services who might be involved in directing operations in the event of a crisis; a person who lives further away from the dam or levee, but who might be affected if measures were taken to divert water to avoid overtopping; a shopper in a development near the dam or levee who in the hypothesis is there throughout opening hours, though would be representing the reality of a series of shoppers visiting in sequence. In practice, measures to protect the most exposed of these hypothetical people in many cases will protect others – most of the hypothetical persons mentioned above would be protected by the one living permanently at the bottom of the levee, including the shopper – so not all persons will require special consideration.

Uncertainty

The process of assessing risks will very often have to deal with uncertainty, for example:

- **Epistemic uncertainty:** that arises when knowledge is represented by data based on sparse statistics or subject to random errors in experiments. Techniques for representing this kind of uncertainty include confidence limits, and sensitivity analysis, which provides information relating to the importance of different sources of uncertainty which can then be used to prioritise further research and action;
- **Modelling uncertainty** ; which occurs because any model is a proxy for real life situations based on a number of assumptions;
- **Aleatory uncertainty:** There are limits to the predictability of phenomena (e.g. the weather) when the possible outcomes are very sensitive to inaccuracies in the assumed initial conditions (as any weather forecaster will confirm).

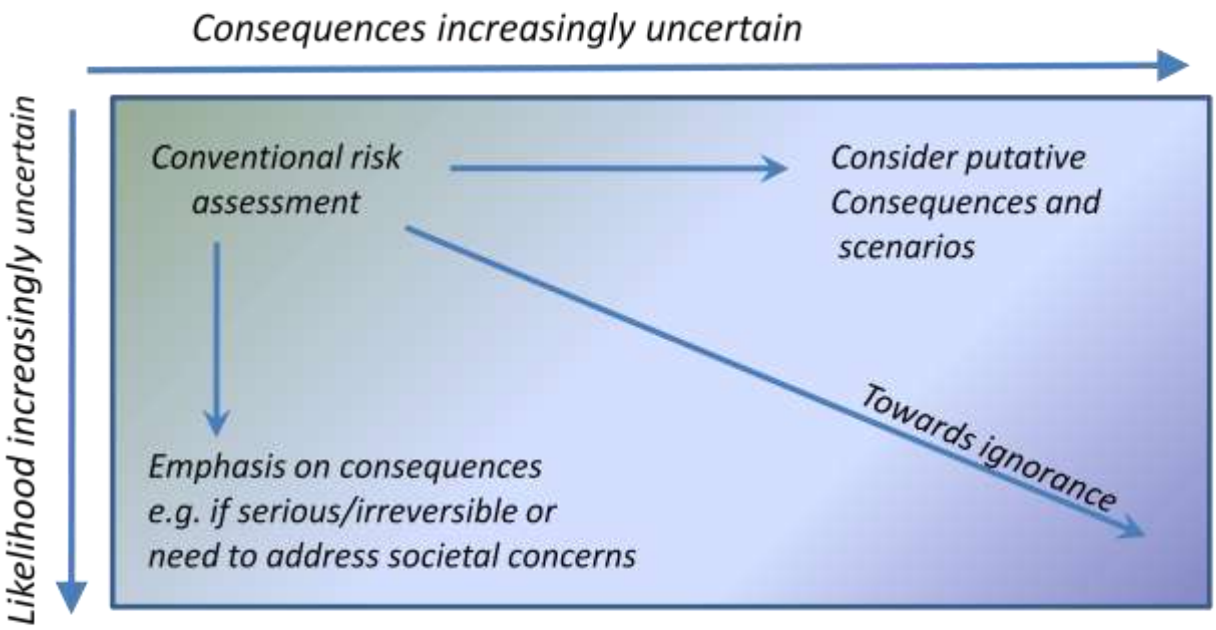


Figure 1: Procedures for tackling uncertainty when assessing risks

Uncertainty in risk assessments is tackled by making judicious assumptions. There are techniques in for testing (within limits) the validity of these assumptions. Figure 1 illustrates some of the procedures used when likelihoods and consequences become increasingly uncertain.

Up at the top left hand corner, we have enough information to predict with confidence the chance of a hazard being realized and the consequences if it does, using conventional risk assessment methods. However, as we move along the axes, uncertainty increases, but we are still able to use conventional risk assessment techniques to predict the chance of a hazard being realised and its consequences by making assumptions to fill our gaps in knowledge. One condition must be met though. The assumptions must pass tests to ensure their validity, e.g. by checking, whether small changes in the assumptions cause large differences in the results of the risk assessment, say, in the likelihood and the consequences of a levee failing.

As we continue to move along the axes, a stage is reached where any assumption made fails the validity test. At this point, conventional risk assessment is no longer adequate. We then posit one or more scenarios - for example that a levee will definitely fail –and work backwards from that to calculate what would happen to people at risk. Flawed though this approach is, it can help inform the decision on what action is necessary. For example, if the levee failing will result in a very large number of deaths, and widespread societal concern, then however uncertain the chance of that happening, it might be decided appropriate to take remedial action immediately.

The inspection of levees will of course already have had to deal with the issue of how to factor in uncertainty when judging the integrity of safety measures, and indeed may have in future to cope with a new area of uncertainty – the direction of climate change. In the UK this is already bringing in further uncertainty: its impact on rainfall, the likelihood or otherwise of an increase in heavy rainfall causing flooding; and where the rain will fall. Many models which were set up to predict calamities were based on historical data, which is now deemed by many to be little guide to the future. Others take a broad-based precautionary approach, on an assumption that rainfall will increase everywhere; but this may be of no help in predicting the major disasters, and could result in resources being diverted to places where they are not needed. More sophisticated models which take account of mini-climates, local topography and geology take time to develop and test. In the meantime, risk assessments have to be made, and in situations where societal concerns, and societal risk, is potentially very great.

The TOR approach does not duck the potential for wide margins of error. However its insistence on transparency means that the bold assumptions that have had to be made are in the public domain. This should help demonstrate that decisions were made on the best information available at the time and that they were made in good faith. It also facilitates debate with experts over the development of new models as more information becomes available.

Risk assessment is not a new activity for those in charge of dams and levees. However the risk assessment envisaged under TOR goes beyond the standard-based approach traditionally used: were well established rules followed, is the levee or dam operating within its design specifications -especially those relating to loads and structural capacity, and are factors such as safety coefficients and defensive measures still valid? Under TOR, a risk assessment will include other factors such as the risks to the community, and the critical role of human factors in failures; and it will need to involve in some way the different interest groups the safety regime is designed to protect.

Stage 3: Examining options available and their merits

This stage identifies the options available for managing the risks and evaluates their potential. The identification of options available is usually done by looking at existing control regimes for managing the risks that represent best or good practice. On those occasions when specific good practice for the issue under consideration is not available, promising options can also be found by examining whether good practice in other contexts are directly transferable or whether they can be modified in some way to provide a suitable control measure for addressing the risk.

The relative merits of the options found can then be determined by examining:

- **how effective** they are in controlling the risks;
- **how well they comply with well-established general principles on the hierarchy of controls** for the prevention of risks. These are: eliminating the risk, combating the risk at source, applying sound engineering practice such as inherently safer design and adopting collective protective measures rather than individual protective measures.
- **possible constraints attached to a particular option;** for example whether the option is technically feasible; or whether there are legal constraints on its adoption.
- **any adverse consequences associated with a particular option**. Very often adopting an option for reducing one particular risk of concern may create or increase another type of risk.
- **the costs and benefits** attached to each option which allows for a comparison to be made between the cost of implementing the option and the degree of risk reduction that it is likely to achieve.

Application to levees

In general, the options available for managing the risk of levees are well known. For example, those often used for preventing breach failure or overtopping include: providing a more resistant structure; increasing the height of the levee; increasing the flow of water by widening it; improving the management of the flow of water through it; bettering the management of floodplains etc.; while those for mitigating the risk should a disaster happen, include warning systems, emergency plans and evacuations plans etc.

Levees being a shared responsibility, there will also be constraints at community, state and federal level. For example, there will be a need to reconcile possible options with the Federal economic justification policies that are reflected in the present and the proposed **"**National Objectives, Principles and Standards for Water and Related Resources Implementation Studies" (CEQ 2009).

The criteria described above should therefore prove useful in sifting the options that should be put forward for the next stage. However, the need to take economic justification and the cost and benefit of a possible measure in the evaluation of options raises an important question. How can this be achieved in practice?

Economic justification and the assessment of cost and benefits are usually carried out by undertaking a cost and benefit analysis (CBA). This is a useful tool for judging the balance between the benefits of an option and the costs incurred in implementing it. However, for a CBA to be meaningful it has to observe certain agreed protocols. For example, those used generally by the UK Government have been published in guidance[8] from Her Majesty's Treasury and the latter has been further supplemented by the HSE for assessing the relationship between cost and benefits of occupational health and safety measures.

USACE already has well-tested protocols for cost-benefit analyses. In considering their use under TOR, a number of issues arise.

[8] HM Treasury (1997) Appraisal and Evaluation in Central Government *The Green Book*, HMSO London

The first is how the CBA can be used – along with other tools – for informing decisions over measures to save lives. The rationale for doing so is that the TOR framework is specifically about reducing the risks to people – individuals and groups (societal risks). To be meaningful therefore the benefits in any cost benefit analysis therefore will inevitably include an assessment of how many lives will be saved. A comparison of the numbers saved using a range of different measures and in different places – along with other benefits as well as the costs – has been a useful tool in the UK for helping select the most effective protective measure and for prioritising. From this experience it has been possible to extrapolate a hypothetical monetary value of life saved - without of course implying any ethical judgement of what a life is worth. Its use in informing decisions about priorities has the advantage of transparency. It must be stressed that using a CBA that takes account of the benefits of lives saved is not essential for the operation of TOR. However, if lives saved are excluded then the cost of a particular measure will appear higher.

The current value for preventing a fatality (known (VPF)) used in the UK for that purpose is just over $2.6 million. VPF is a generic figure obtained by undertaking research on what people would be willing to pay for a small reduction in risks and subsequently extrapolating the results to derive a figure for the prevention of death. Where potential benefits are not concerned with a reduction in the risk of death, for example, avoiding a major injury, the value placed for preventing such detriments is obtained by comparing how society rates these detriments relative to the risk of death. For example, in the UK the value for preventing a major injury has a value of about $500k. VPF was derived from 'willingness to pay' studies for the prevention of road accidents and strictly speaking should be used for conducting CBAs in the transport industry. However, in the UK the transport-derived VPF is now used for CBAs in many other contexts.

Two other issues that arise with cost benefit analysis under TOR are:

- **the costs and benefits that should be included**: For example, should the costs be limited to those that are unavoidably incurred for maintaining and repairing the levees or should it include other costs such as emergency and evacuation procedures or softer measures such as providing education and giving guidance on changes to land management. Or again, should the costs be offset by the monetary gains accrued from the introduction of the measure such as the costs that would have incurred without the improvement such as evacuations, the payment of compensation following flooding etc. Finally, should the benefits include other intangibles such as a greater sense of well being or security.
- **discounting of cost and benefits**: When preparing formal CBAs, it is customary to discount future costs and benefits to reflect the fact that people, on balance, prefer to have benefits now and pay for them later. A benefit in the present is valued more highly than the same benefit received some time in the future. Similarly, a health and safety measure paid for in the present is considered more costly than if it is paid for at some future date. Conventional economic theory is that such preferences are reflected in the rate of interest paid by borrowers or to savers for capital.

  In the UK, for most public policy applications, a real rate of return of 6% a year is used currently to discount costs and benefits. This assumes that all monetary costs and benefits are expressed in real terms (constant prices). The value that individuals place on safety benefits tends to increase as living standards improve, so the future values applied to such benefits should be uprated to allow for the impact on well-being of expected growth in average real income.

Treasury guidance regards an uprating factor of 4% a year as appropriate on the benefits side of the comparison.

However, when costs and benefits accrue far into the future (30 years or more), these discounting conventions do not apply.

Before leaving the topic of CBA it is worth mentioning that when an option is finally chosen (the next stage) it is possible to calculate the cost of a measure for avoiding a fatality (CPF) for that option by dividing the net cost of implementing the option by the number of lives that it is expected to save. Options for levees and dams are known to command often high CPFs.

Stage 4: Adopting decisions

We now come to the crucial stage: deciding what level of risk is tolerable, and what to do when it is not.

Classifying risks

Under TOR, three categories have been identified for classifying activities:

- **Broadly acceptable** because the risks are not worth worrying about;
- **Tolerable** because the risks can reasonably be reduced through the introduction of control measures to a level worth taking to obtain specific benefits;
- **Unacceptable** because society believes that the risks are not worth the benefits whatever the circumstances.

What criteria to apply for classifying activities? In the past, a number of approaches have been used.

One is **equity-based**. This starts with the premise that all individuals have unconditional rights to certain levels of protection. This leads to standards, applicable to all, held to be usually acceptable in normal life, or which refer to some other already accepted level of protection. In practice, this often converts into fixing a limit to represent the maximum level of risk above which no individual can be exposed. If the risk estimate derived from the risk assessment is above the limit and further control measures cannot be introduced to reduce the risk, the risk is held to be unacceptable whatever the benefits.

The strong demand for equity surfaced in the coverage of the effects of the Katrina cyclone. Media reports drew attention to the particular vulnerability of some communities: the very poor, often black, and often with not much voice in the governance of the area.

However an equity-based approach used on its own can be too rigid. In practice there are many circumstances, as we have discussed, where some groups accept a higher level of risk: for work purposes for example, for which they are remunerated; for sporting activities which they elect to undertake; for other quality of life benefits. Ignoring these differences can result in disproportionate costs, or indeed the removal of a benefit that people want.

Another approach is **utility-based.** This involves a comparison between the incremental benefits of the measures to prevent the risk of injury or detriment, and the cost of the measures. In other words, the utility-based criterion compares in monetary terms the relevant benefits (e.g. lives saved, life-years extended) obtained by the adoption of a particular risk prevention measure with the net cost of introducing it, and requires that a particular balance be struck between the two.

This approach has the advantage of some objectivity; but has limitations. For some major projects, the long-term uncertainties mean it might be difficult if not impossible to make a convincing case at the time for value for money, especially when the sums are large. An example in the UK of such a project is the Thames barrier built to prevent the flooding of London. At the time it was criticised for siphoning off too many public funds when the likelihood of flooding seemed unproven. Yet the possibility of disaster, however remote, was deemed to override any narrow cost/benefit calculations. Similarly with levees, small differences in water flows give rise to wide differences in cost/benefit comparisons; and ultimately other factors may be decisive.

Another approach is **technology-based**. This supposes that a satisfactory level of risk prevention is attained when 'state of the art' control measures (technological, managerial, organisational) are employed to control risks whatever the circumstances.

Again, used by itself, this approach has shortcomings. It does not take into account the balance between costs and benefits. On dams and levees for example, it would require the safety measures appropriate for the Hoover Dam to be applied to the tiniest little levee – not realistic.

However, all these approaches are useful, and are not mutually exclusive. The Tolerability of Risk criteria accommodate all three.

The TOR framework for classifying risks is illustrated in Figure 2.

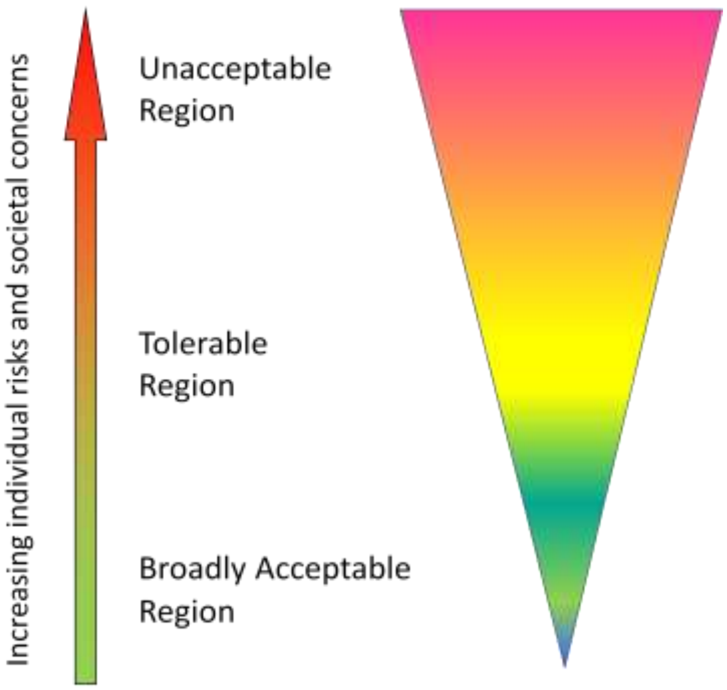


Figure 2: Tolerability of Risk Framework

The triangle represents increasing level of 'risk' for a particular hazardous activity (measured by the individual risk and societal concerns it engenders) as we move from the bottom of the triangle towards the top. The dark zone at the top represents an **unacceptable region**. For practical purposes, a particular risk falling into that region is regarded as unacceptable whatever the level of benefits associated with the activity. Any activity or practice giving rise to risks falling in that region would, as a matter of principle, be ruled out unless the activity or practice can be modified to reduce the degree of risk so that it falls in one of the regions below, or there are exceptional reasons for the activity or practice to be retained.

The light zone at the bottom, on the other hand, represents a **broadly acceptable region**. Risks falling into this region are generally regarded as insignificant and adequately controlled. The levels of risk characterising this region are comparable to those that people regard as insignificant or trivial in their daily lives. They are typical of the risk from activities that are inherently not very hazardous or from hazardous activities that can be, and are, readily controlled to produce very low risks. Further effort to reduce the risks further would be a waste of limited resources.

The zone between the unacceptable and broadly acceptable regions is the **tolerable region**. Risks in that region are typical of the risks from activities that people are prepared to tolerate in order to secure benefits, in the expectation that:

- the nature and level of the risks are properly assessed and the results used properly to determine control measures. The assessment of the risks needs to be based on the best available scientific evidence and, where evidence is lacking, on the best available scientific advice;
- the residual risks are not unduly high and kept as low as reasonably practicable. This is considered to be the case when there is a gross disproportion between the costs (money, time, trouble etc) of taking a measure and the residual risks; and
- the risks are periodically reviewed to ensure that they are as low as reasonably practicable, for example, by ascertaining whether further or new control measures need to be introduced to take into account changes over time, such as new knowledge about the risk or the availability of new techniques for reducing or eliminating risks.

The criterion of as low as reasonably practicable is often shortened to **ALARP**, and the classification of the areas between acceptable and unacceptable as the ALARP region.

The TOR criteria can be seen as essentially applying an equity-based criterion for risks falling in the upper region and lower regions, while a utility-based criterion predominates for risks falling in the middle region with technology-based criteria complementing the other criteria in all three regions.

Figure 2 is a conceptual model that in principle can be applied to all hazards. However, the factors and processes that ultimately decide whether a risk is unacceptable, tolerable or broadly acceptable are dynamic in nature. Standards change, public expectations change with time, what is unacceptable in one society may be tolerable in another, and what is tolerable may differ in peace or war.

In the diagram the gradient correctly represents the reality of a continuum of activities posing risks, with no clear line between what is acceptable and what is not. Decision-makers have to draw clear lines however. In most cases this will involve the exercise of professional judgement. Whilst there will always be a need for such judgements, some rules of thumb have been developed to assist consistency.

Boundary between the 'broadly acceptable' and 'tolerable' regions for risk entailing fatalities

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 is now widely used by many regulators and industry worldwide for the boundary between the broadly acceptable and tolerable regions. In other words a residual risk of one in a million per year is considered to be broadly acceptable to society at large. Such a residual risk is extremely small when compared to the background level of risk to which everybody is exposed. Indeed many activities which people are prepared to accept in their daily lives for the benefits they bring, for example, using gas and electricity, or engaging in air travel, entail or exceed such levels of residual risk.

Moreover, many of the activities entailing such a low level of residual risk also bring benefits that contribute to lowering the background level of risks. For example, though electricity kills a number of people every year and entails an individual risk of death in the region of one in a million per annum, it also saves many more lives, e.g. by providing homes with light and heat, operating elevators, life support machines and through a myriad of other uses. The same can be said of levees because by reducing the risk of flooding they protect people and their property. Indeed, it is the combined effect of many activities involving such low levels of residual risks that contributes to the wealth of any nation and leads to improvements in health and longevity.

Boundary between the 'unacceptable' and 'tolerable' regions for risk entailing fatalities

Three decades ago the UK published their figure for assessing what society might tolerate in terms of risks of fatalities from nuclear power stations. It was accepted then, and since has been applied to risks in other contexts. An individual risk of death of one in a thousand per annum was proposed as the dividing line between what could be just tolerable for any substantial category of workers for any large part of a working life, and what would normally be unacceptable. For members of the public who have a risk imposed on them 'in the wider interest of society' this limit is an order of magnitude lower – at 1 in 10,000 per annum.

Risks giving rise to societal concerns

No generally accepted yardstick is yet available for measuring the tolerability of risk for hazards giving rise to societal concerns. This is not surprising: society is made up of groups of people with different values, which are anyway impossible to rank objectively. How to attribute more or less importance to the death of a child for example as opposed to an elderly person dying from a dreaded cause, e.g. cancer; or the potential of affecting future generations? How to rate costs and benefits to people relative to those to the environment?

Nevertheless, attempts have been made to develop criteria for addressing societal risks, i.e. societal concerns arising when there is a risk of multiple fatalities occurring in one single event. One figure used in the UK relates to the risk of an accident causing the death of 50 people or more in a single event. It is regarded as intolerable if the frequency is estimated to be more than one in five thousand per annum. In the US, it is being proposed that the risk of a failure of a dam or levee system causing the death of 1000 people or more should be less than 1 in a million per year. Techniques are available for extrapolating from this criterion other numbers for casualties and their frequency through the use of so-called F-N-curves and making certain assumptions about how averse society is to events causing multiple fatalities (See Annex 1). The technique provides a useful means of comparing the impact profiles of man-made accidents with the equivalent profiles for natural disasters with which society has to live. The technique is imperfect, but in the absence of much else the method has proved a helpful tool, when applied with common sense, for reaching a decision.[9,10,11.]

---

[9] Ball DJ and Floyd PJ *Societal risks* 1998 Report available from the Risk Assessment Policy Unit, HSE.

[10] ICOLD (2005), "Risk Assessment in Dam Safety Management: A Reconnaissance of Benefits, Methods and Current Applications," International Commission on Large Dams (ICOLD) Bulletin 130, 2005.

[11] Bowles, D. S. and L. R. Anderson (2003), "Risk-informed Dam Safety Decision-making," ANCOLD Bulletin 123:91-103, April 2003.

Deciding on action

Where the risk falls within the TOR triangle is of course only the first part of the decision making process. What action is then needed?

Tolerable region

In practice most risks encountered in everyday life will fall in the tolerable region. However as we have seen "tolerable" does not mean that those in charge have no more responsibility; in the definition (see above) the tolerability of the remaining risk is conditional on the application of the ALARP criteria – i.e. that the level of risk has been brought down as low as is reasonably practicable.

This is usually achieved through the adoption of authoritative good practice, irrespective of specific risk estimates.

One consequence of linking the required control regime to relevant good practice (or measures affording similar levels of protection) is that the control measures so derived apply regardless of the length of exposure. In other words the control measures are expected to be in place at all times.

There will be some cases where no existing good practice can be identified or is enough to address the combined levels of individual and societal risks. This might be, for example, because the hazard is new or not well studied, or people interface with the hazard in ways that are untypical or exceptional or societal concerns are untypically high. If there is no good practice the risk managers will have to look at the measures identified at Stage 3 and adopt one that reduce the risk ALARP.

What is gross disproportion when determining ALARP is a matter for judgement. However, certain disproportion factors and where the risks (individual and societal) fall within the Tolerable/ALARP region on the TOR diagram, have been found useful for informing such judgements. The factors are used as follows:

- the ratio between the cost of the measure for preventing a fatality (CPF) and the value for preventing a fatality as derived from 'willingness to pay' studies (VPF) for risks which are close to the broadly acceptable risk region within the TOR diagram, the disproportion factor should be at least 1 (and possibly at least 2)
- the ratio between the cost of the measure for preventing a fatality (CPF) and the value for preventing a fatality as derived from 'willingness to pay' studies (VPF) for risks which are close to the unacceptable risk region the disproportion factor should be at least 10; and
- for risk between these levels the disproportion factor is somewhere between these two.

Other issues that have arisen over ALARP, and the line taken under UK practice, are listed below:

- **Affordability:** Whether a duty holder can afford the costs of introducing a measure is not a legitimate argument in any ALARP argument.
- **Risk transfer:** Where the adoption of a measure results in a transfer of risk to other people, the added risk to those people should be taken into consideration in the ALARP considerations. For example, this guideline would be appropriate in situations where raising the height of a levee at one location causes flooding at another. However, there will be instances where it would be more appropriate to treat the transferred risks as a new situation that must be examined on its own merits; i.e. requiring a new examination for deciding the measures that need to be adopted for reducing the risks ALARP. For example, the latter would be more appropriate if in the previous example, flooding occurred at a remote location.

- **New versus old good practice.** It may not be reasonably practicable to apply an enhanced control measure retrospectively to an existing operation, for example to raise the standard of protection of an old levee or dam to that afforded by modern construction techniques short of rebuilding those structures completely. This may be the case even if the enhanced measure had become in effect good practice for all new operations. However, there will become a point where what was good practice at one time becomes so obsolete that it can no longer be regarded as providing an adequate level of safety. In those cases the risk would be deemed to be unacceptable and it will be necessary to make a fresh judgement on the measures that should be taken to reduce the risks so that they fall in the ALARP region. This could be achieved, for example, by introducing a programme of progressive improvements for reducing the risks.
- **Selection of options:** Meeting the ALARP criteria requires that when a number of options for risk reduction exist, the option (or combination of options) that could reduce the risk to the greatest extent is the one that should be implemented and not the cheapest option. However, this is not cast in tablet of stone. For example, there might be significant differences in the time needed to implement the various options available and this could be a legitimate factor in the choice of options.

Broadly tolerable and unacceptable regions

If the risk assessment puts the hazard in the broadly acceptable region, no further action to reduce the risk is required.

However, where the decision on the risk assessment places an activity or a facility in the unacceptable region, then drastic action may be required – for example to close it down. More likely however consideration of the control methods will identify means of bringing down the risks to a level to the “tolerable” level. Advances in technology mean that most risks can now be controlled.

Practical application to dams and levees

Inevitably this section of the paper has been very theoretical. Its practical application to dams and levees is well illustrated however in the programme set out in the USACE levee safety programme.

Some general observations may also be useful arising from the experience of the operation of TOR in relation to major works, whether public or private, and certainly comparable with large dams and levees.

The first is that in deciding where a particular facility might fall within the TOR diagram following the risk assessment. Because of the high profile of such installations and the catastrophic consequences of failure however remote, societal concern tends to place them higher up the triangle than would be justified by an assessment of individual risks.

The second is the desirability where possible for sharing responsibility for any decisions reached. The safety case regime for major hazards in Europe mentioned earlier formalises agreement both to the risk assessment and the action plan both by the body in charge of the facility, and the law enforcer. This offers some defence against any legal challenge to the assumptions made – though of course not to a failure to carry out the action plan.

Finally, once risks from hazard have been assessed as above the lowest level – i.e. above the “acceptable region” - the system does not allow expense *per se* to justify failure to act. What might be negotiable if a review has identified a wide programme of renovation is a phased programme in accordance with agreed priorities. Again this is illustrated in the proposed levee safety programme.

Stage 5: Implementing decisions

The implementation of TOR requires those who create risks to:

- have a plan for taking action;
- look ahead and set priorities for ensuring that risks requiring most attention, as identified by going through the stages, are tackled first;
- set up a system for monitoring and evaluating progress, e.g. by identifying potential indicators for evaluating how far the control measures introduced have been successful in addressing the problem.

In a situation where responsibilities are shared such a programme needs to make clear who is responsible for what and to whom.

Stage 6: Evaluating the effectiveness of action taken

This stage requires a review after a suitable interval of the decisions taken to establish:

- whether the actions taken to ensure that the risks are adequately controlled resulted in what was intended;
- whether decisions previously reached need to be modified and, if so, how; for example, because levels of protection that were considered at the time to be good practice.

The review offers a good opportunity to assess whether 'established standards of good practice' are out of date.

How these stages are taken into account for levees is described in the 'Generalised USACE Portfolio Risk Management Process for Levees'.

Evaluation of TOR

The TOR framework has been emulated by many other organisations and regulators both at home and abroad. Its evaluation in the UK has shown that by far and large it has met its objectives. The main reservation that have been expressed by industry relate on how societal risks should be incorporated in the decision making process. It was suggested that this should be explained more explicitly than described in the TOR framework, for example, when reaching decisions on the control regime that should apply in producing safety cases for major hazards sites; and for informing decisions on the use of land around such sites, for instance, to deal with the problem of encroachment, i.e. allowing developments in the vicinity of a major hazard. This criticism is being addressed (see Annex 1).

March 2010

Annex 1

F-N Curves

What is an F-N Curve

We are used to using graphs, bar charts and histograms for presenting data visually on paper. F-N curves are an alternative to these. Indeed F-N curves can be used to present the same information as histograms but in a different visual form. They are for many reasons the preferred way for presenting information about the frequency of fatal accidents in a particular system (e.g. failure of levees) and the distribution of the numbers of fatalities in such accidents.

How to draw F-N curve drawn to represent accident data

The first step is to obtain the required data, i.e. information about the frequency (F(N)) of fatal accidents and the distribution of the numbers of fatalities for the system under consideration. There are two ways of obtaining this. The first is to calculate the F-N-curve directly from empirical frequency data on past accidents by pooling data from similar systems. This is quite demanding because no systems are exactly similar. Moreover, we need to know exactly how many fatalities there were in every accident in a specified period of time. Furthermore, because we may require detail at the low-frequency high-consequence end of the fatality distribution, we may need to consider long periods of time in order to assemble enough data for sensible analysis.

The second method is to develop and use a probability model to estimate the frequencies. It is usually used for generating an F-N curve for a single system. The method is very resource intensive and may be subject to many uncertainties. However, it may be the only method available if historical data is patchy or unavailable.

The next stage is to plot the frequency $F(N)$ of accidents (on the y-axis) against N **or more** fatalities, where N ranges upward from 1 to the maximum possible number of fatalities in the system. Because the values of both $F(N)$ and N sometimes range across several orders of magnitude, F-N-graphs are usually drawn with logarithmic scales.

Properties

The plot draw has several interesting properties. For example:

- F-N-curves never rise from left to right, but are always falling or flat. This is very apparent from a study of the data. The difference between the frequency of accidents with N or more fatalities, $F(N)$, and that with $N+1$ or more, $F(N+1)$, is the frequency of accidents with exactly N fatalities. , usually denoted by $f(N)$, with lower-case f. Because $f(N)$ must be non-negative, it follows that $F(N)$ is greater or equal to $F(N+1)$ for all N.
- The lower an F-N-curve is located on the F-N-graph, the safer is the system it represents. This is because the lower F-N-curves represent lower frequencies of fatal accidents than higher curves.
- The value $F(1)$ is the frequency of accidents with 1 or more fatalities, or in other words the overall frequency of fatal accidents. This is the left-hand point on F-N-curves, where the curve meets the vertical axis (usually located at $N = 1$ with logarithmic scales). Parallel F-N-curves with different

intercepts on the vertical axis represent the same distribution of fatalities in accidents, but with different overall accident frequencies *F*(1).

- It is possible from the data to calculate the overall accident frequency, the probability distribution of fatalities in accidents, the mean and standard deviation of number of fatalities per accident, and the mean number of fatalities.

Using F-N curves for estimating societal risks

It is possible to draw a general criterion line on an F-N curve that plots the cumulative frequency of various accident scenarios against the number of fatalities to help determine what societal risks are tolerable or unacceptable. For example, it could be surmised that if a system's F-N-curve lies wholly below the criterion line, the system should be regarded as tolerable, but if any part of the F-N curve crosses the criterion line, the system should be regarded as unacceptable.

F-N-criterion lines have been used in various contexts in several countries. They were reviewed for the HSE by Ball and Floyd (1998). As mentioned in the body of this paper, HSE has recommended an F-N-criterion point (not a line) for estimating the societal risk of major hazardous industrial sites in the UK. Namely, that accidents causing 50 or more fatalities should not have a frequency greater in 1 in 5,000 per year. However, it has become fashionable for industry to extend this point criterion to a criterion line by drawing a line with a slope of -1 passing through the criterion point. This is illustrated in the figure 3 below.

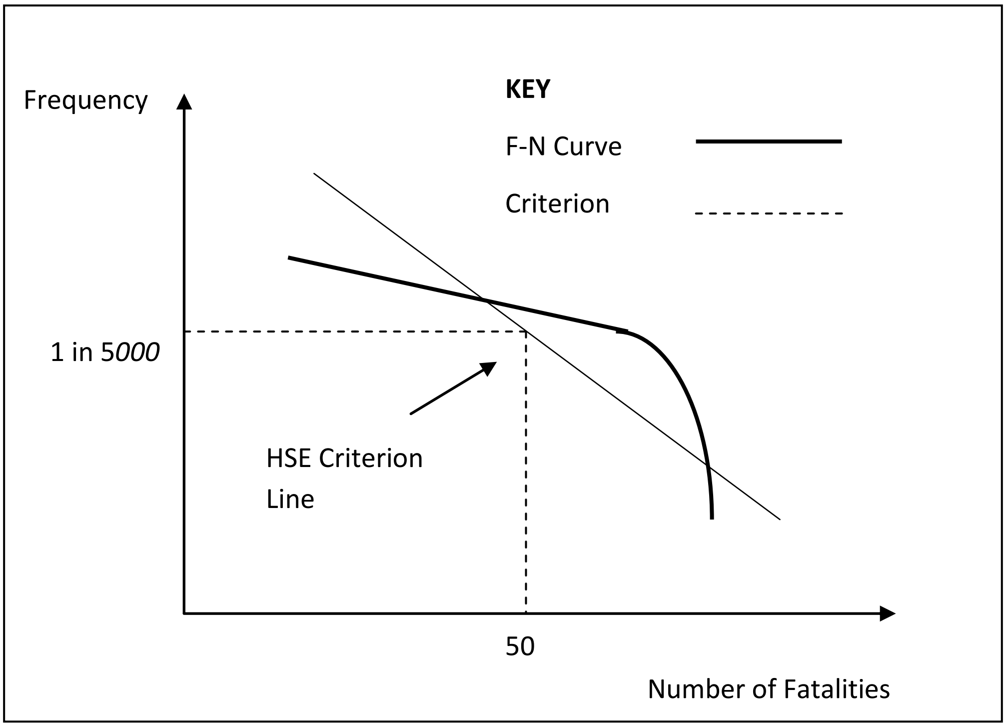


Figure 3: Example of an idealised F-N Curve showing HSE criterion point extended to a line.

F-N curves in real situations often cross the criterion line. Accordingly, it is not applied rigidly. Professional judgement is often used to decide whether an excursion above the line is unacceptable.

In 2005, the Interdepartmental Task Group on Societal Risk in the UK requested an independent review of HSE's methodology for assessing societal risk. The Institute of Chemical Engineers was commissioned to carry out the review[12] which they completed in January 2006. Since then, a public consultation[13] has been carried out and in 2008 ministers agreed for HSE to work with others to include the assessment of societal risk in both the regulation of on-shore major hazard installations and in decisions on planning for development near such installations. A first report in the form of an initial briefing[14] was produced in March 2009. A preliminary position report[15] was published on 26 February 2010.

[12] HSE (2006) An independent review of HSE methodology for assessing societal risk. http://www.hse.gov.uk/societalrisk/review.pdf

[13] HSE (2007), CD212, Consultative document on proposals for revised policies to address societal risk around onshore non-nuclear major hazard installations. http://consultations.hse.gov.uk/inovem/gf2.ti/f/4610/130181.1/pdf/-/cd212.pdf

[14] HSE (2009), RR703 - Societal Risk: Initial briefing to Societal Risk Technical Advisory Group. http://www.hse.gov.uk/research/rrpdf/rr703.pdf

[15] http://www.hse.gov.uk/societalrisk/technical-policy-issues.pdf

Tolerable Risk Guidelines for Levee Safety

"Better Decisions, Better Communicated"

Eric Halpin, PE
Special Assistant for Dam and Levee Safety
Headquarters, U.S. Army Corps of Engineers
United States

March 2010

US Army Corps of Engineers
BUILDING STRONG®

US Army Corps of Engineers

Principles of Risk Informed Approaches

- No simple numerical solutions – decisions are informed, not based, on risk
- Risk compliments, does not replace, traditional engineering standards or experience
- Credible way to treat uncertainty
- Periodic and Continuing
- Risk is integral, not "bolt on", to our profession

BUILDING STRONG℠

US Army Corps of Engineers

Bottom Line Up Front

- Risk justifies *Priorities*, but better decisions must *also* be driven from:
  - ***Understanding of what is Unacceptable, Tolerable, and Acceptable*** (tolerability limits & essential standards)
  - ***What is achievable,*** (As Low As Reasonably Practicable Considerations)
  - and the ***Urgency of Action*** (proximity to tolerability)
- …which is why ***Tolerable Risk Guidelines*** are needed***!***

BUILDING STRONG℠

Definition of Tolerable Risk (and examples)

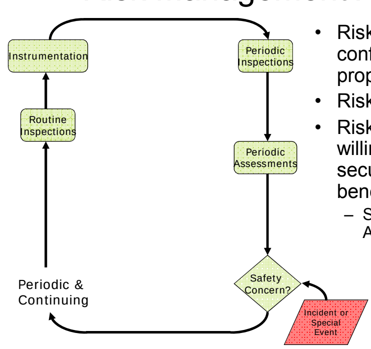
1. Risks society is willing to live with so as to secure certain benefits,
2. Risks society does not regard as negligible or something it might ignore,
3. Risks that society is confident that are being properly controlled by the owner, and
4. Risks the owner keeps under review and reduces still further if and as practicable.

Levee Safety	Auto Safety

ANCOLD Oct 2003

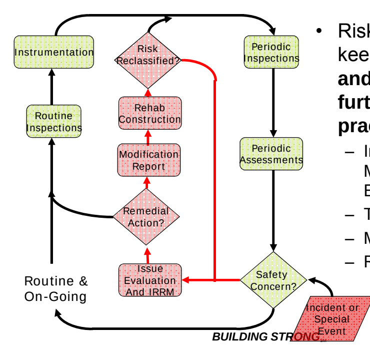
BUILDING STRONG℠

Part 1: Routine Levee Safety Risk Management Activities



- Risks that society is confident are being properly controlled
- Risks under review
- Risks Society is willing to live with to secure certain benefits:
  - Safety Concerns Addressed Thru:
    - Routine Processes:
    - Special Events
    - Incidents

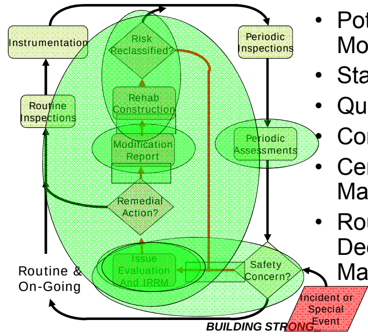
Part 2: Non-Routine Levee Safety Risk Management Activities



- Risks that the owner keeps under review **and reduces still further if and as practicable**
  - Interim Risk Reduction Measures & Issue Evaluation
  - Tolerable Risk?
  - Modification
  - Risk Characterization

BUILDING STRONG℠

Other Considerations: Levee Safety Risk Management Activities

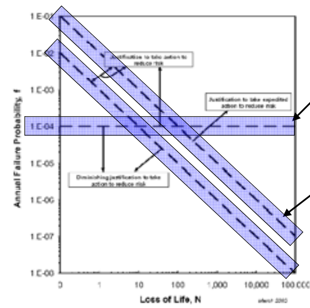


- Potential Failure Modes Analysis
- Staging
- Queues
- Communications
- Centrally Managed
- Routine is Decentrally Managed

BUILDING STRONG℠

US Army Corps of Engineers

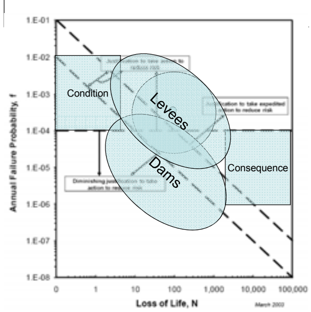
Tolerable Risk Guidelines



BUILDING STRONG℠

US Army Corps of Engineers

Challenging Decisions

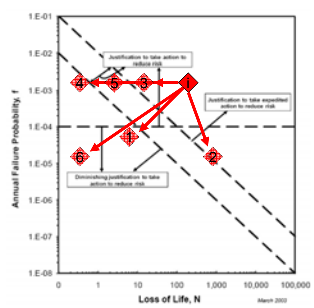


- Making decisions with large uncertainties
  - Methodology
  - Data
- Prioritizing between condition driven and consequence driven risks
- Dams vice levees

BUILDING STRONG℠

US Army Corps of Engineers

Challenging Decisions



- Risk Reduction Alternatives:
  - (1) Structural Rehabilitation
  - (2) Structural Improvements
  - (3) Land Development
  - (4) Evacuation
  - (5) Building Codes
  - (6) Combinations!
  - Better Project Formulation?

BUILDING STRONG℠

US Army Corps of Engineers

Why Tolerable Risk? …Begin with the End in Mind

- Identify levees that pose greatest risk
- To what extent do risk need to be reduced? (tolerability)
- Understanding shared responsibilities
- Which levees should be modified/mitigated first? (priority/sequence)
- How do we balance the desire to reduce risk with the availability of resources? (urgency)
- Improve Risk Communication
- ….**BETTER DECISION MAKING**

BUILDING STRONG℠

US Army Corps of Engineers

Why Risk Management?

- " That ***engineers have moral and legal obligations beyond those of the ordinary citizen*** is well accepted. This is because trained engineers can perceive and evaluate hazardous conditions that ordinary persons are not aware of. This is especially true for man-made hazards, because engineers are often involved in making them … In more basic ethical terms, the moral obligation of the engineer arises from the general philosophy that it is part of a natural relationship between human beings to warn and protect one another from hazards as far as they can be known. ***Because of his knowledge, therefore, an engineer has a higher moral obligation than one who is not knowledgeable in the field***."

  » Unattributed

BUILDING STRONG℠

Questions?

BUILDING STRONG[SM]

US Army Corps of Engineers
Best Practices in Levee Safety

Eric Halpin, PE
Special Assistant for Dam and Levee Safety
Headquarters, U.S. Army Corps of Engineers

March 18, 2010

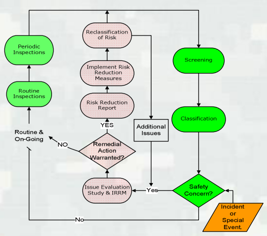
US Army Corps of Engineers
BUILDING STRONG®

Topics

- Levee Portfolio Management
- Levee Inventory and Database
- Levee Inspection Tool
- Levee Screening Tool
- Risk Classification

BUILDING STRONG®

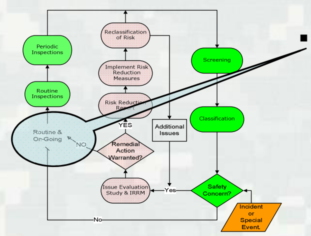
Levee Safety Portfolio Management Process



- Routine Processes (the outer loop):
  - Decentrally Executed
  - Continuing and Periodic
- Non-Routine Processes (the inner loop):
  - Centrally Led and Executed

BUILDING STRONG®

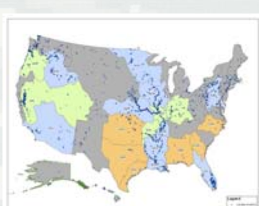
Levee Safety Portfolio Management Process



- National Levee Database
  - Established in Law
  - Repository of All Levee Data
    - Routine
    - Non-Routine
  - Geospatial
  - Foundation for Decision Making

BUILDING STRONG®

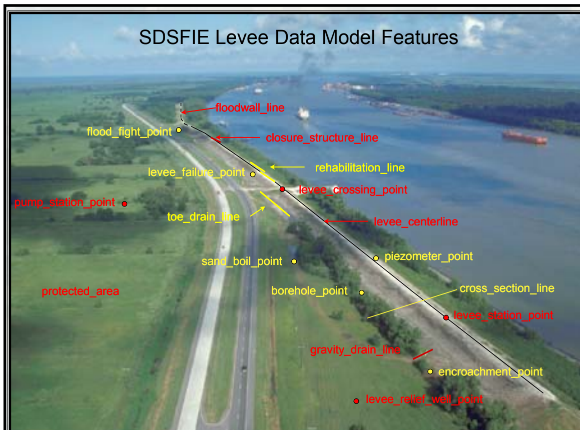
Status: National Levee Database (NLD)

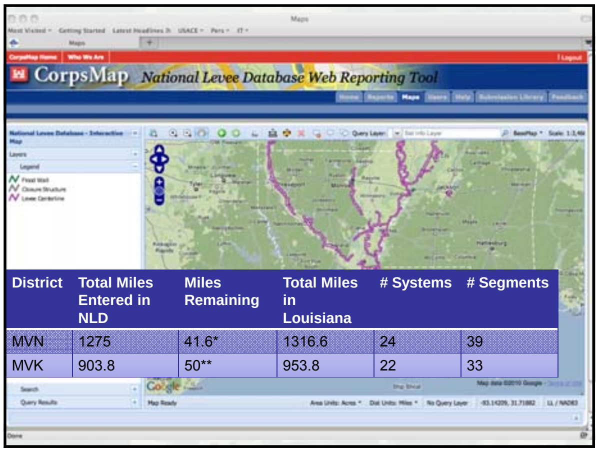


2,000 Levee Systems
In Corps Authorities

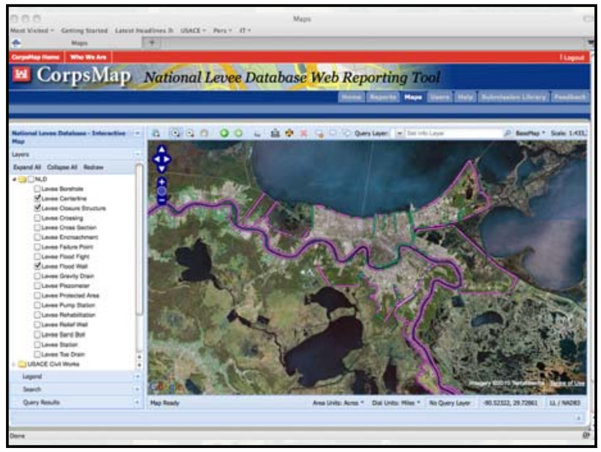
- Fiscal Year 2010
  - NLD available to project stakeholders through a web accessible application
  - Complete survey of USACE Program Levees
  - Integration of FEMA Mid-Term Levee Inventory
- American Recovery and Reinvestment Act – On Going
  - Questionnaire for other Federal Agencies & States
  - Initial Technology Transfer & Training
  - Support Periodic Inspection of USACE Program Levees

BUILDING STRONG®





District	Total Miles Entered in NLD	Miles Remaining	Total Miles in Louisiana	# Systems	# Segments
MVN	1275	41.6*	1316.6	24	39
MVK	903.8	50**	953.8	22	33



Objectives of NLD Path Forward Activities

- Coordinate/Collaborate with Federal and Non-federal Levee Owners on Path Forward
- Transfer Technology of NLD
  - GIS Model and Database
  - Guidance and Operating Manuals
  - Training to Levee Owners
  - Technical Assistance in Populating Data
- Transfer of Non-Corps Data to the NLD
- Provide Access to and Awareness of NLD to the Nation
- NLD Management…

BUILDING STRONG®

Levee Inspection System

A Set of Automated Tools that Assist Inspectors and Managers by Providing Greater Efficiency and Standardization to the Processes of:

Inspection

Data Collection

Reporting

BUILDING STRONG®

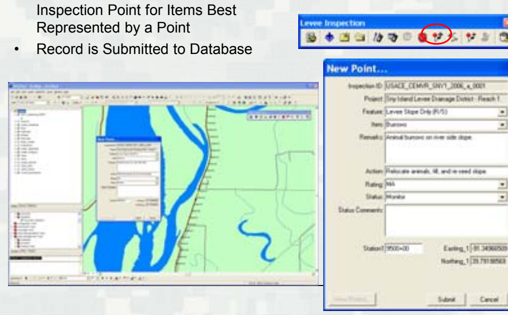
Application Components

- **Levee Inspection Tool**
  - Field Inspection Data Collection and Database Updates
- **Photo Management Tool**
  - Organizing and Assigning Digital Photos to Field Observations
- **Data Management Tool**
  - Managing Data Within the Organization
- **Reporting Tools – Basic and Advanced**
  - Provide Organizational Standardization to Reporting Requirements

BUILDING STRONG®

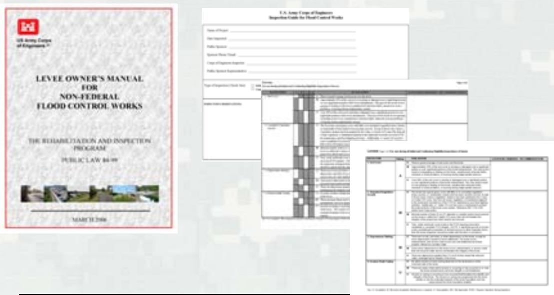
Inspection Data Collection - Points

- Levee Inspector Selects Create Inspection Point for Items Best Represented by a Point
- Record is Submitted to Database



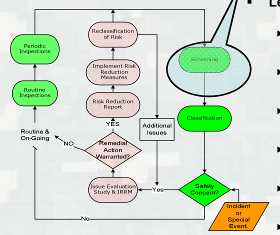
BUILDING STRONG®

USACE Standard Inspection Report



BUILDING STRONG®

Levee Safety Portfolio Management Process



- Levee Screening Tool Outcomes (2010):
  - Identify relative risk and initially characterize the portfolio.
  - Guide setting priorities for national levee safety activities.
  - Identify performance concerns as well as potential consequences of a levee failure.
  - Communicate levee deficiencies, qualitative conditional performance, and consequences.
  - Identify issues to assist in the development of Interim Risk Reduction Measures.
  - Assist in the assignment of the Levee Safety Action Classification (LSAC) for each levee system.

BUILDING STRONG®

Simplified Risk Informed Framework

$$Risk\ Index = \left[\left(AEP_T - AEP_{OT}\right) \cdot PI \cdot C\right] + \left[AEP_{OT} \cdot C'\right]$$

Risk Index for Failure Prior to Overtopping

Risk Index for Overtopping

BUILDING STRONG®

Flood Loading

- Variety of data sources and methods
- Example
  - Levee designed based on historic flood discharge of 45,000 cfs with three feet of freeboard
  - Available data includes stage versus discharge information at a local gage
    - Original design report
    - National weather service gage
    - Flood insurance study
  - Frequency discharge information also available at the gage location
    - Original design report
    - Analytical frequency analysis
    - Flood insurance study

BUILDING STRONG®

Performance Index
Value of Information

- Absent any information, our best estimate of conditional performance would initially be based on the average rate of failure for all levees
- As we gain information, our estimate of conditional performance improves
  - Can implement using Bayes' Theorem

BUILDING STRONG®

Our Additional Information
Inspection Assessment Ratings

- Each performance indicator within a performance mode is rated as
  - A: Acceptable
  - M: Minimally Acceptable
  - U: Unacceptable
- Assessment ratings are made in the context of whether the observation for a specific item is an indication of distress and/or failure initiation considering actual and/or expected performance under flood loading

BUILDING STRONG®

Levee Screening Approach - Consequences

- Initial distribution of people and damageable properties
  - Protected area (NLD)
  - HAZUS
    - Population at risk and economics
- Redistribution of people
  - Evacuation effectiveness = f( )
    - Evacuation planning
    - Community awareness
    - Flood warning effectiveness
    - Population density
    - Overtopping vs. breach (warning)
- Fatality rates from Jonkman research

BUILDING STRONG®

Population at Risk (PAR)

- Protected area polygon
- Census data
- Verify and update

Population Redistribution Parameters

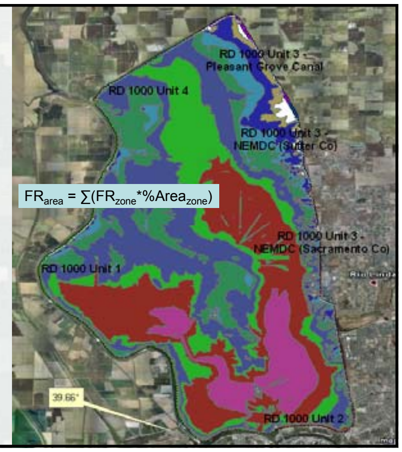
- Evacuation effectiveness =

  ep * ca * fwe * pd * $F_{scenario}$
  - ep = evacuation planning
  - ca = community awareness
  - fwe = flood warning effectiveness
  - pd = population density
  - $F_{scenario}$ = warning time parameter

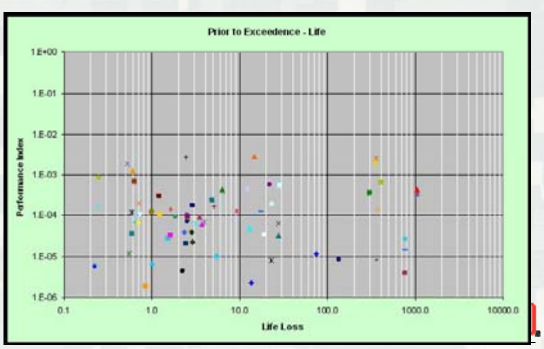
BUILDING STRONG®

Consequence Estimates

- Protected area polygon
- DEM
- Minimum elevation of levee segment
- Depth
- Area-weighted depth and fatality rate

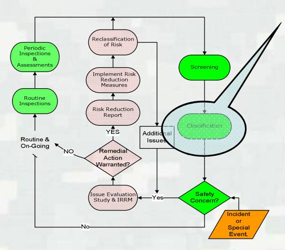


$$Risk\ Index = [(AEP_T - AEP_{OT}) \cdot PI \cdot C] + [AEP_{OT} \cdot C']$$



BUILDING STRONG®

Levee Safety Portfolio Management Process



- **Levee Safety Action Classification:**
  - LSAC Similar to DSAC
  - Used to Consistently Inform:
    - Characterization
    - Communication
    - Risk Reduction Action

BUILDING STRONG®

Table 1 - USACE Levee Safety Action Classification Table* 29 July 09

General Description | Urgency & Risk Description | Actions Required Description

Levee Safety Action Class	Characteristics of this class	Actions for levees in this class *1) USACE Operated, and Maintained Levee Systems; 2) Other Levee Systems in USACE Program; 3) All Levee Systems.*
I **Urgent and Compelling** (Unsafe)	**LIKELY FAILURE BREACH AT LESS THAN TOP OF LEVEE** Combination of life, economic, or environmental consequences with probability of failure breach is extremely high. **OR EXTREMELY HIGH OVERTOPPING RISK** Combination of life, economic, or environmental consequences with probability of overtopping with or without subsequent breach, is extremely high.	1) Take urgent action to prevent/mitigate failure breach and implement interim risk reduction measures. Support portfolio priorities for remediation. 2) Advise owner to take urgent action to develop and implement interim risk reduction and remediation plans. Support portfolio priorities for remediation. 3) Immediately perform levee system inspection; expedite confirmation of classification; communicate risk findings to sponsor, state, Federal, Tribe, local officials, and public; stress improved floodplain management to include: immediately verify that warning, evacuation, and emergency action plans are viable; purchase of flood insurance; vigilant levee monitoring program.
II **Urgent** (Unsafe or Potentially Unsafe)	**FAILURE BREACH LIKELY AT TOP OF LEVEE** Combination of life, economic, or environmental consequences with the probability of failure breach is very high. **OR VERY HIGH OVERTOPPING RISK** Combination of life, economic, or environmental consequences with probability of overtopping with or without subsequent breach, is very high.	1) Take immediate action to implement interim risk reduction measures; develop and implement remediation plan. Support portfolio priorities for remediation. 2) Advise owner to take immediate action to develop and implement interim risk reduction and remediation plans. Support portfolio priorities for remediation. 3) Perform levee system interim inspection; verify classification; communicate risk findings to sponsor, state, Federal, Tribe, local officials, and public; stress improved floodplain management to include: verify that warning, evacuation and emergency action plan are viable; purchase of flood insurance; vigilant levee monitoring program.
III **High Priority** (Potentially Unsafe)	**FAILURE BREACH MAY OCCUR AT TOP OF LEVEE** Combination of life, economic, or environmental consequences with probability of failure breach is moderate to high. **OR HIGH OVERTOPPING RISK** Combination of life, economic, or environmental consequences with probability of overtopping with or without subsequent breach, is high.	1) Implement interim risk reduction measures; schedule development of remediation plan and support portfolio priorities. 2) Advise owner on development of interim risk reduction and remediation plans. Support portfolio priorities. 3) Verify inspection is current; confirm classification; communicate risk findings to sponsor, state, Federal, Tribe, local officials, and public; stress improved floodplain management to include: verify that warning, evacuation, and emergency action plan are viable; purchase of flood insurance; develop and execute levee monitoring program.
IV **Priority** (Marginally Safe)	**FAILURE BREACH AT TOP OF LEVEE NOT LIKELY** Combination of life, economic, or environmental consequences with probability of failure breach is low. The levee system does not meet all essential USACE guidelines. **OR MODERATE TO LOW OVERTOPPING RISK** Combination of life, economic, or environmental consequences with probability of overtopping with or without subsequent breach, is low to moderate.	1) Support portfolio priorities. 2) Support portfolio priorities. 3) Continue routine levee safety activities, stress improved floodplain management to include: verify that warning, evacuation, and emergency action plan are viable; purchase of flood insurance; develop and execute levee monitoring program.
V **Normal** (Adequately Safe)	**HIGHLY LIKELY NOT TO BREACH AT TOP OF LEVEE** Levee system is considered adequately safe, meeting all essential USACE guidelines. There is a very low probability of failure breach. **AND RESIDUAL RISK IS CONSIDERED TOLERABLE.**	**All Levee Systems** Continue routine levee safety activities, normal inspections, stress improved floodplain management to include: operation and maintenance; annually ensure that warning, evacuation, and emergency action plan are functionally tested; purchase of flood insurance; maintain levee monitoring program.

Comments – Questions?

Eric Halpin, P.E.
US Army Corps of Engineers
eric.c.halpin@usace.army.mil

BUILDING STRONG®

Rijkswaterstaat
Ministerie van Verkeer en Waterstaat

Safety Standards in the Netherlands

Towards Tolerable Risk

Rijkswaterstaat Centre for Water Management
Alex Roos & Durk Riedstra

17 maart 2010

Outline

- Introduction to the Netherlands
- Current Safety Standards and legal basis
- Developments in Policy
- Dealing with Tolerable Risk, results and discussion

Characteristics of the Netherlands

- 400 km of Rhine river
- International catchment
- 350 km coastline
- 9 million inhabitants below flood level
- 59% flood prone
- Invested value 1800 10^9 euro, 65% of GNP
- 3500 km of flood defenses, hundreds of locks, sluices, pumping stations
- Safety level: 1:10.000 – 1:1250

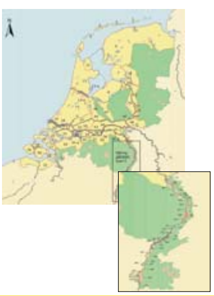
Brief overview of the (recent) history of Flood Management

- 1953: major flooding / disaster in the southwest of the Netherlands
- "Deltacommission": "how can we prevent this"?
- 1958: Delta Law
- 1960: Dike reinforcements and building of dams and storm surge barriers ("Deltaworks")
- 1986: the barrier in the eastern Scheldt
- 1997: the "Maeslantkering"
- 1993 / 1995 Flooding in rivers
  => "Delta Act for Rivers"

Fundament: Flood Defense Act

- Flood Defense Act (1996, updated 2005):
  – Purpose: maintain protection levels
  – Specify safety standards (based on economical optimization)
  – Responsibilities of public parties
  – Assessment in a five-year cycle
  – Evaluation of standards in a ten-year cycle (since 2005)
  – Definition of an investment program

Dike ring areas and safety standards



1. Every dike ring area has a safety standard
2. West Netherlands 1:10.000
3. The Delta, North-Netherlands, de Flevopolders 1:4000
4. River area 1:1250

Results of the safety assessment

- First round (1996 – 2001)

- 3,558 km
- 808 structures

Second round (2001 – 2006)

3,599 km
1,171 structures

Results of the safety assessment: investment programs

- General investment program
- Special programs:
  - River program ("Space for the river")
  - Program for the river Meuse
  - "Weak spots in the coastal zone"

Developments in Policy

Two track approach:
- VNK/FLORIS
- Water Safety in the 21s Century: Discussion about safety standards

- Since 2006 discussion about new safety standards
  – Due to climate change and risk awareness
  – Reconsider heigth of safety standards
  – Change towards probability of flooding
  – Development of techniques through project VNK/FLORIS VNK project (still continuing..)

- After previous TRG session 2008 also attention for casualties !

FLORIS

- Probabilistic calculation of probability of failure
- Several simulations for different breaches & flooding scenario's
- "Picture" of risk (probability * consequences) in the Netherlands

Results used for

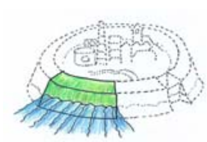
- Economical damage
- Loss of life studies
- Insight in failure mechanisms and failure processes

Water Safety 21st Century versus FLORIS

	FLORIS	Water Safety 21st Century
type of project	research project	policy evaluation
objective	insights in risk determining failure mechanisms & dike ring sections	flood probabilities based on tolerable risk
approach	scientific approach (2006-2012)	simplified approach (2009-2010)
year of reference	current situation	situation 2015 / 2020
failure mechanisms	all mechanisms	only overflowing & wave overtopping
method	fully probabilistic	partly probabilitic

2nd Delta Committee (2008)

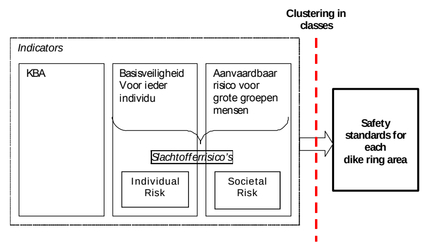
Current approach



New approach

'60s	> 2011(?)
exceedance frequency	risk (probability x consequences)
overflow & wave overtopping	all failure mechanisms
dike ring section	dike ring
cost-benefit analysis	idem + loss of life risk analysis

Role of Tolerable Risk in defining new standards

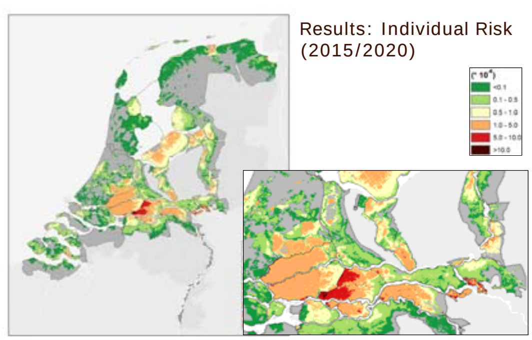


So far for the theory….

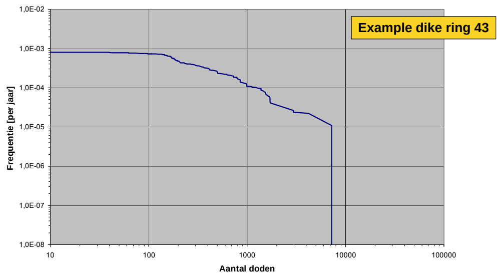
Now the practical implementation

Durk Riedstra

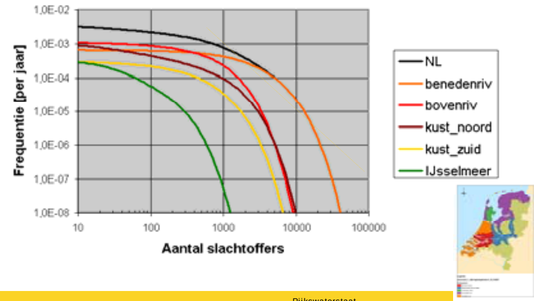
Results: Individual Risk (2015/2020)



1. Societal Risk per dike ring area

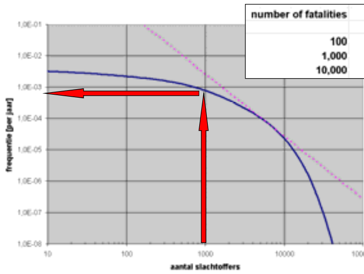


2: Societal Risk for each independent 'water system'

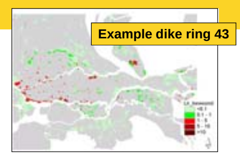


3. Societal Risk on the national scale

number of fatalities	probability [per year]	return period [year]
100	$2{,}2 \times 10^{-3}$	450
1,000	$8{,}0 \times 10^{-4}$	1,250
10,000	$2{,}2 \times 10^{-5}$	45,000



Tolerable Individual Risk?



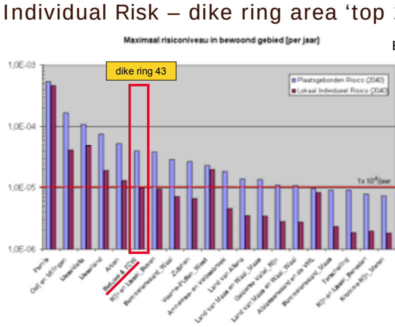
Considerations:

- **maximum** or average value?
- for **populated areas only** or complete dike ring area?
- **with** or without evacuation?

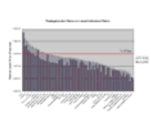
- Tolerable Individual Risk Limit **???**
  - *Tolerable Risk Limit Industrial Safety the Netherlands = 1 × 10^{-6}/year*

Example: maximum value = 1 × 10^{-5}/year for populated areas
→ What should be the flood probability per dike ring area?

Individual Risk – dike ring area 'top 20'



Blue: without evacuation
Purple: with evacuation



Tolerable Societal Risk?

Considerations:

- Should risk limit refer to **national scale** or value per dike ring area?
  → More than 1 dike ring area can be flooded during one event
- Risk neutral or **risk averse**?
  → a flood event with 10× more fatalities should have a 100× less probability (accepted approach industrial safety)
- **with** of without evacuation?

- Tolerable Societal Risk Limit **???**
  → What should be the flood probability per dike ring area to fulfil the national societal risk limit?

Tolerable Societal Risk according the Dutch Expertise Network for Flood Protection (ENW)

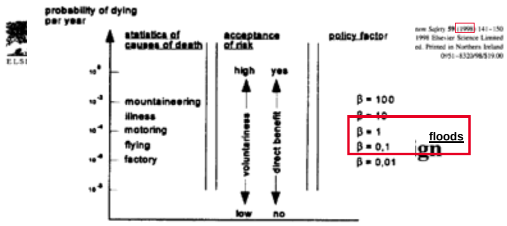
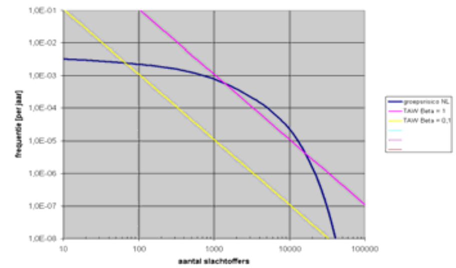
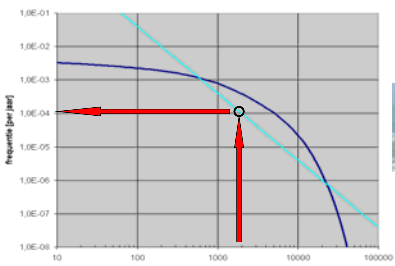


Fig. 2. Personal risks in Western countries, deduced from the statistics of causes of death and the number of participants per activity.

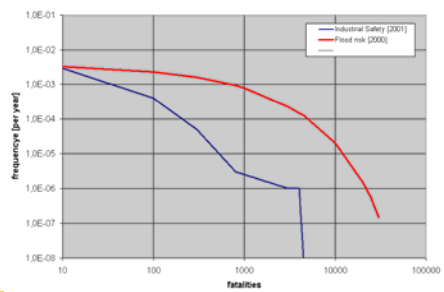
1. Tolerable Societal Risk according ENW (2)



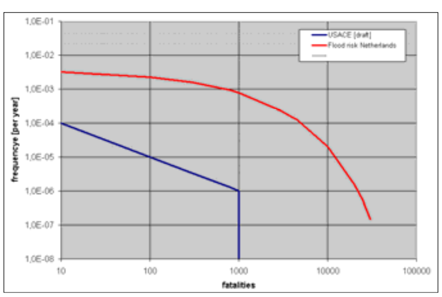
2. Tolerable Societal Risk based on failure frequency of the Dutch flood defense system in relation to the 1953 disaster



Tolerable Societal Risk – comparison with Industrial Safety



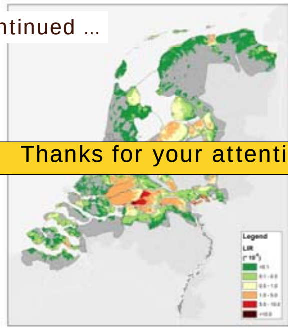
Tolerable Societal Risk – comparison with USACE proposal



The process continues...

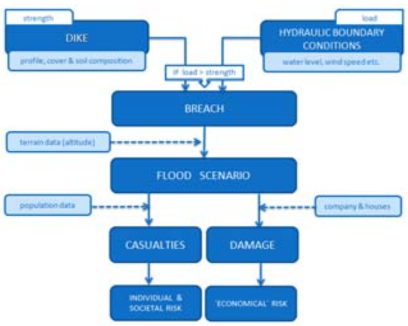
• May 2010	• Policy options for new safety standards, based on CBA, IR and SR
• June-Dec 2010	• Consultation with stakeholders
• 2011	• Proposed new policy for safety standards
• 2011 – 2017	• Safety assessment with new standards, parallel to current safety assessment
• 2012	• FLORIS finished, use insights in final proposal
• 2017	• Formal change to new safety standards, adjustment legal basis
• After 2017	• Safety assessment with new safety standards

To be continued …

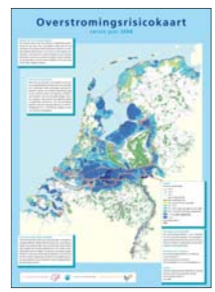


Thanks for your attention

Method

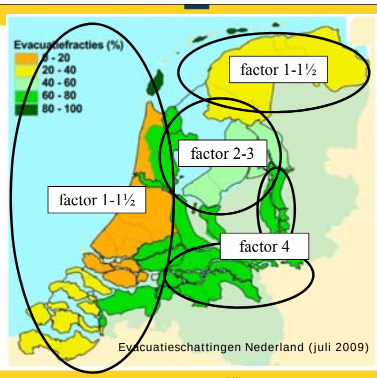


Risk approach



probability × consequences

Evacuation fractions



Evacuatieschattingen Nederland (juli 2009)

Framework expertise network for flood protection

- Tolerable societal risk

$$C_N = \left(\frac{\beta 100}{k}\right)^2$$

acceptable. The acceptable societal risk at a national scale can be limited as follows:

$$1 - F_N(n) < C_N/n^{\alpha} \qquad (3)$$

where $F_N(n)$—cumulative distribution function of the number of fatalities; C_N—constant that determines the vertical position of the FN limit line at a national scale [yr^{-1} $fat^{-\alpha}$]; α—risk aversion coefficient that determines the steepness of the FN curve.

- Policy factor ß → 0,1 - 1
- K-constant → 3

- ß = 0,1 → C_N = 11
- ß = 1 → C_N = 1100

URBAN FLOOD RISK CHARACTERIZATION AS A TOOL FOR PLANNING AND MANAGING

Workshop Alexandria March 2010
Exploration of Tolerable Risk Guidelines for Levee Systems

Dr. Ignacio Escuder-Bueno[1]

Eng. Adrián Morales-Torres[2]

Eng. Sara Perales-Momparler[3]

ABSTRACT

Understanding and quantifying urban flood risk can be a very useful tool for planning measures in advance and managing flood events.

This article starts by defining and identifying the different sources of flood risk. Subsequently, the role of structural and non-structural measures is analyzed, existing tools for risk estimation are summarized and available tolerability criteria reviewed.

In addition, some preliminary ideas on how risk characterization can be a tool for planning and managing, are provided.

These ideas are part of the works that are currently being developed by the authors for the European Commission (ERA-Net CRUE initiative 2009-2011) within the SUFRI (Sustainable Strategies of Urban Flood Risk Management with Non-structural Measures to Cope with Residual Risk) Project.

Finally, some closing remarks on the risk informed "process" beyond any risk characterization "methodologies" or risk tolerable "guidelines" are summarized.

ACKNOWLEDGEMENTS

It is important to remark that this paper presents the authors' views and not that of the Corps of Engineers.

The authors want to acknowledge the US Army Corps of Engineers for the invitation to participate in the "Exploration of Tolerable Risk Guidelines for Levee Systems" workshop, hold in Alexandria (Virginia), in March 2010.

1: Professor. Department of Hydraulic Engineering and Environment. Polytechnic University of Valencia. Camino de Vera S/N. 46022 Valencia, Spain. Contact: iescuder@hma.upv.es

2: Researcher. Department of Hydraulic Engineering and Environment. Polytechnic University of Valencia. Camino de Vera S/N. 46022 Valencia, Spain. Contact: admotor@cam.upv.es

3: President. PMEnginyeria. Av. Aragón, 18, 1º 1º 46021 Valencia, Spain. Contact: sperales@pmenginyeria.com

1 Introduction

Directive 2007/60/EC of the European Union [5] defines a flood as a temporary covering by water of land not normally covered by water. As this directive explains, this shall include floods from rivers, mountain torrents, Mediterranean ephemeral water courses, and floods from the sea in coastal areas, and may exclude floods from sewerage systems.

During the period 2000 to 2006, water-related disasters killed more than 290,000 people, affecting more than 1.5 billion, and inflicting more than US$ 422 billion of damage [16]. In general, flood consequences will be especially important in urban areas.

Flood risk can be defined as the combination of the probability of a flood event, called hazard, and the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event [5], called vulnerability. Consequently flood risk has two main components, hazard and vulnerability.

Hazard is a potentially damaging physical event, phenomenon or human activity that may cause loss of life or injury, property damage, social and economic disruption, or environmental degradation. Hazard is often characterized by the individual risk, which is the probability that an average unprotected person, permanently present at a certain location, is killed due to an accident resulting from a hazardous activity [8].

On the other hand, vulnerability can be defined as the conditions determined by physical, social, economic and environmental factors or processes which cause the susceptibility of a community to the impact of hazards.

Risk is commonly expressed by the notation Risk = Hazards x Vulnerability. Its units are the ones used for measuring the vulnerability divided per time. When risk consequences are computed in number of victims (typically by year), resulting risk is usually called societal risk.

Flood risk analysis is a methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend.

Flood can be caused by a complex interaction of a range of sources, especially in urban areas. The main sources are rainfall, river flood, maritime flood and also structural collapse, issue that will be discussed later in the paper. Phenomena such as climate change may indeed increase the flooding risk. Other important hazard to be considered is terrorism, sabotage and vandalism which can aim to destruction of structures such as dams and dikes [7].

2 The role of structural and non-structural measures in reducing risk

There are many kinds of measures to reduce flood risk. Generally, they are divided into two groups: structural and non-structural measures.

Structural measures refer to any physical construction to reduce or avoid possible impact of floods, which include engineering measures and construction of hazard-resistant and protective structures and infrastructures, such as levees or dams.

As introduced before, despite the fact that structural measures are key actors in reducing flood risk, their existence can also add potentially more adverse consequences (typically associated to very low probabilities of occurrence). Some examples are:

- If the structure is in a poor state, measures must be taken to control the incremental risk linked to its failure.
- If due to the decrease of flood risk perception new settlements are planned in hazardous areas, proper policies should be implemented to avoid the increment of risk linked to such urban developments.
- If some areas can only be physically flooded by a structural collapse, particularly low tolerability criteria should apply.

Non-structural measures are the policies, awareness, knowledge development, public commitment, and methods and operating practices, including participatory mechanisms and the provision of information, which can reduce risk and related impacts [16].

As discussed before, structural measures provide protection up to a certain severity of the event, typically called design event. Beyond, there is always a residual risk. Non-structural measures will help to reduce this residual risk, which cannot be completely eliminated.

3 Existing tools for risk characterization

Tools for risk estimation can be divided in partial, if they only evaluate either hazard or vulnerability, and complete, it they evaluate both components. Additionally, they can be divided in quantitative or qualitative, depending on whether they provide or not a numerical value for the risk.

A general description of existing tools for risk estimation is provided bellow. They have been broadly classified as qualitative, quantitative, partial and complete, consistently with the definitions previously provided.

Partial and qualitative

This kind of tools can be divided in two groups, depending on the part of the risk equation that they characterize. Tools for the estimation of hazard probability are usually based on historical flood events, defining the flood occurrence in terms of the number and magnitude of past flood events (Figure 1). They can also be based on simplified hydrologic and hydraulic calculations, without making a detailed computation on probability of exceedance.

When the tool is focussed on consequence estimation, defining areas where there might be a significant loss of life plays an important role. Similar methodologies are currently used to estimate the direct economic consequences of flooding, identifying different qualitative levels of potential consequences depending on the land use.

Qualitative tools for measuring flood consequences can be the only option to make a proper description of environmental and cultural losses, which are not easily quantifiable [1]. Qualitative tools for estimating consequences are also widely used to describe social trauma and indirect economical effects of floods.

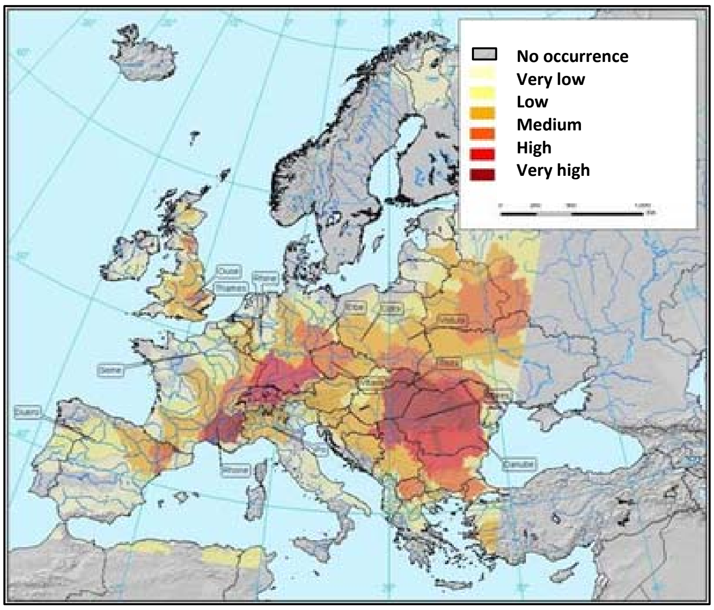


Figure1. European map of the levels of flood occurrence in the river catchments, based on historical flood events in the period 1998-2005 [4]

Complete and qualitative

One of the most common complete and qualitative tools are risk maps, which are obtained by combination of a quantitative estimation of flood occurrence, using hydrologic and hydraulic models, and a qualitative consequence estimation (Figure 2). These consequences are usually divided in levels depending on the estimated flood depth.

This type of qualitative tools can be very useful for planning and managing as they identify the areas where measures for flood risk reduction may be applied in first place. However, their lack of accuracy, especially due to the way consequences are estimated, may result in not properly informed decision making.

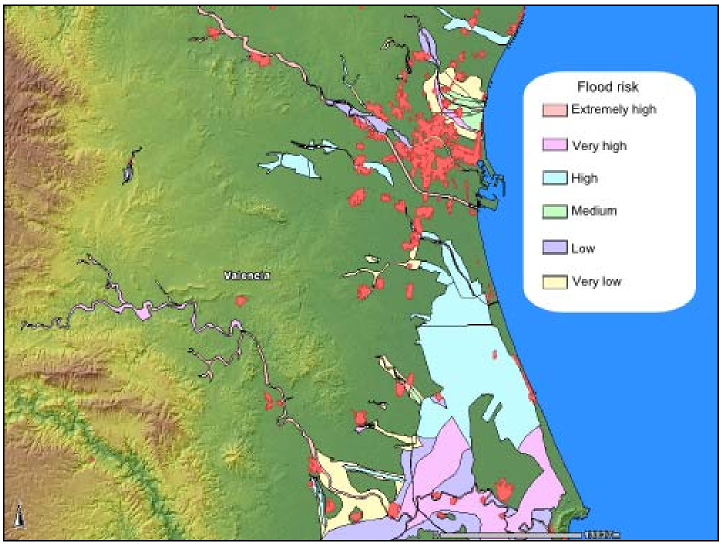


Figure 2. Flood risk map in the area of Valencia, Spain [3]

Partial and quantitative

One of the most common partial and quantitative tools are flood hazard maps (Figure 3). These maps define the inundation area for different flood events, each one associated to an annual probability of exceedance.

The general process that must be followed to develop flood hazard maps is [15]:

a) Historical analysis: Historical floods and variations of the river morphology must be studied using old aerial photos and registers.

b) Geomorphologic analysis: A proper study of the morphology and geology of the potential inundated area is crucial to analyze flood behaviour.

c) Hydrological studies: Frequency and magnitude of floods are analyzed statistically to estimate the magnitude of the flood associated to each probability of occurrence that is computed.

d) Hydraulic modelling: When the geomorphologic analysis and magnitude of the flood are known, a correct hydraulic model provides the inundated area.

e) Calibration and comparison: The hydraulic model must be calibrated and its results must be compared, using the historical flood data.

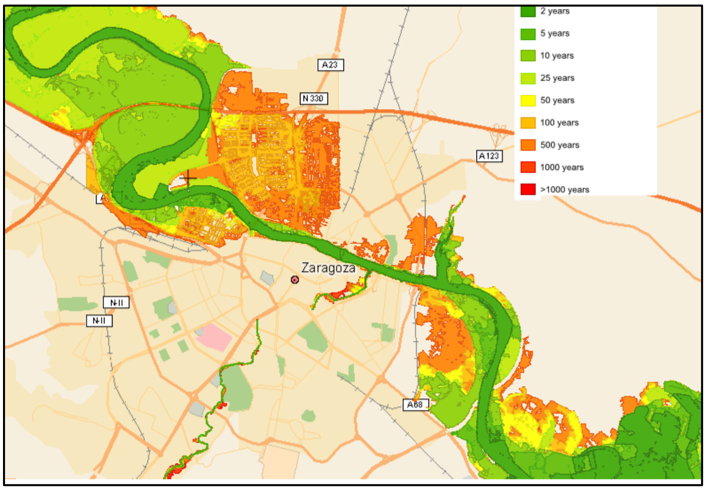


Figure 3. Hazard map for different floods defined by its return period in Zaragoza, Spain [11]

On the other hand, the comparison of data about the expected loss of life for different historical flood events shows that the average event mortality rates are quite constant for each kind of flood, mainly depending on the severity of the effects and the possibilities for warning and evacuation [9]. As a result of this, most of the methodologies rely on the application of constant mortality rates to the population at risk depending on the warning time and severity of the floods. Currently, other more sophisticated methodologies have been developed that require more data and simulate the different processes during floods, like warning and evacuation procedures and shelters resistance, as are the methodology proposed by Jonkman [8], the methodology proposed by Reiter [14] and the model developed in GIS LifeSIM [2].

Regarding to the estimation of economic losses, most of the existing methodologies are based on original works of Kates [10]. These methodologies use the depth of water as a basic parameter and depth-damage curves to estimate the direct economical consequences depending on the value of the land use [3]. More recent methods are supported by GIS and use depth-damage calibrated curves, discriminated to different sectors (industry, services, sales, single family homes, multifamily housing and vehicles). In general the indirect costs are calculated as a fraction of the direct costs, although it can produce significant errors.

Complete and quantitative

A tool for computing total flooding risk in urban areas could be based on flood risk maps, dividing the area under study in small cells. However, flood risk maps are nowadays usually a combination of hazard maps with a list of the points where the higher damages are produced and the quantifications of these consequences for each flood [3]. Although these maps and lists can also be considered a complete and quantitative tool, they do not provide a numerical value for flood risk, which is needed to compare numerically different situations.

Another type of quantitative and complete tools for estimating flood risk in a certain area are the F-N curves (Figure 4). These curves represent the relation between the probability of occurrence of a hazard and the number of victims produced by it. They show the societal flood risk in an easily understandable way.

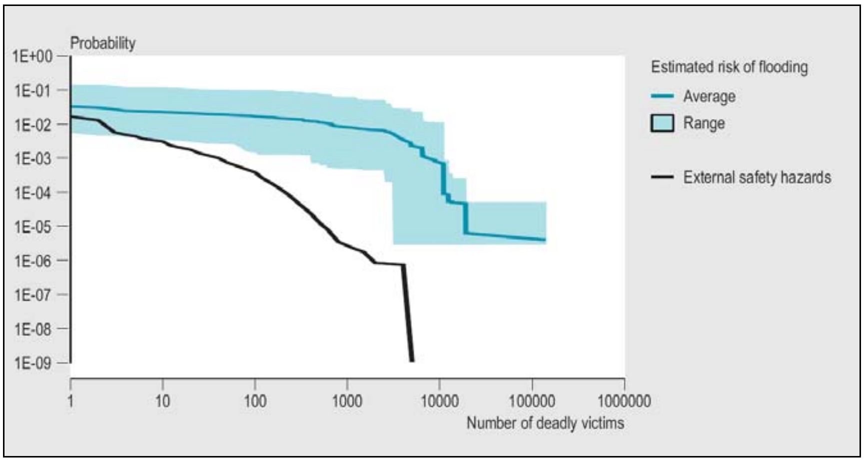


Figure 4. Societal risks of flooding in the Netherlands compared to the sum of external safety risks [13]

This kind of curve can also be built for economical consequences.

4 Existing tolerability criteria for flood risk

Tolerability criteria for flood risk are the basis for a proper risk management. In fact, the concept of tolerable risk is fundamental to risk-informed decision making [12].

Figure 5 shows the three general ranges of risk tolerability. The first range is the unacceptable region, where risk can only be justified in extraordinary circumstances. The second region is the range of tolerability, where the risk is under the tolerability risk limit. In this region the analysis of risk is crucial because this risk is accepted by the society if it cannot be lowered in an economically efficient way. The third region is the broadly acceptable region, where risk can be defined as insignificant and can be controlled adequately.

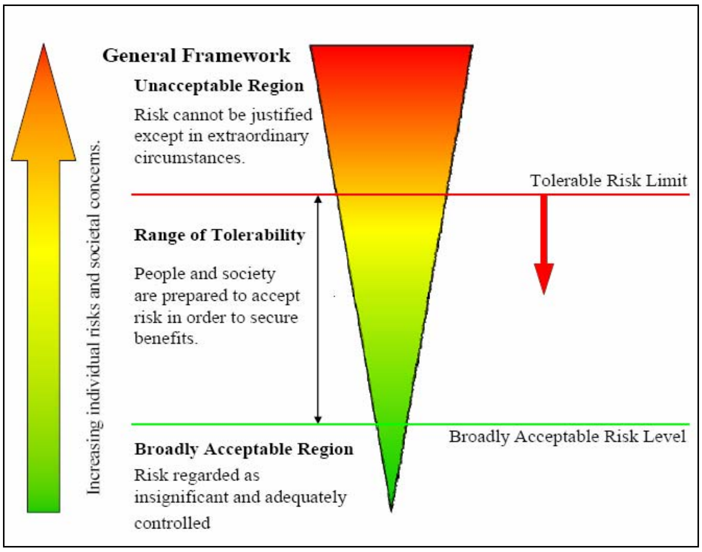


Figure 5 Generalized tolerability of risk framework [6]

In general, in the range of tolerability, the ALARP principle (As Low As Reasonably Practicable) must be followed. This concept considers that risks lower than the tolerable risk limit are only tolerable if further risk reduction is impracticable or if the costs is grossly disproportional to the risk reduction.

Despite the fact that in most countries flood risk tolerability criteria have not been developed, some examples of these criteria are provided next in the text, classified in two groups: tolerability guidelines for individual risk and for societal risk.

Tolerability criteria for individual risk

Dutch Ministry of Housing, Urban Planning and Environment (VROM) limits individual risk in urban areas to 10^{-6}. In addition, limitation of individual risk proposed by the Dutch Technical Committee for Advising in Defence Constructions (TAW) is [17]:

$$IR < \beta \cdot 10^{-4}$$

Where β is the policy factor, which varies accordingly to the degree to which participation in the activity is voluntary and with the perceived benefit. Proposed values for this factor are between 0.01 for involuntary activities and 100 for voluntary activities for personal benefit. Typical values of this factor are shown in Figure 6. In the case of dikes that protect from flooding urban areas, the β factor usually used is between 1 and 0.1.

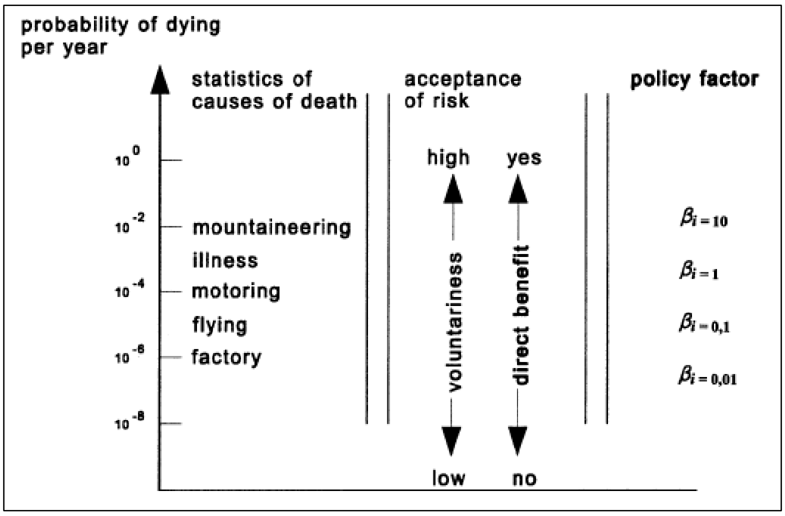


Figure 6. Personal risks in western countries, deduced from the statistics of causes of death and the number of participants per activity [17]

Tolerability criteria for societal risk

It is generally accepted that individual risk criteria must be accompanied with societal risk limits [8].

The best known criterion for evaluating societal risk has been formulated in terms of F-N curves by Vrijling [17], establishing the tolerable risk by means of the following equation:

$$1 - F_N < \frac{C_i}{n^\alpha}$$

Where F_N is the flood probability of occurrence, C_i is a constant that determine the vertical position of the F-N limit line, n is the number of fatalities and α is the risk aversion coefficient that determines the steepness of the F-N limit curve (more usual value is 2).

The value of C_i depends on the political factor, β, used for the limit of the individual risk and the population at risk. The results of the application of these limits for the societal flood risk in the province of South Holland with different values of C_i are shown in Figure 7.

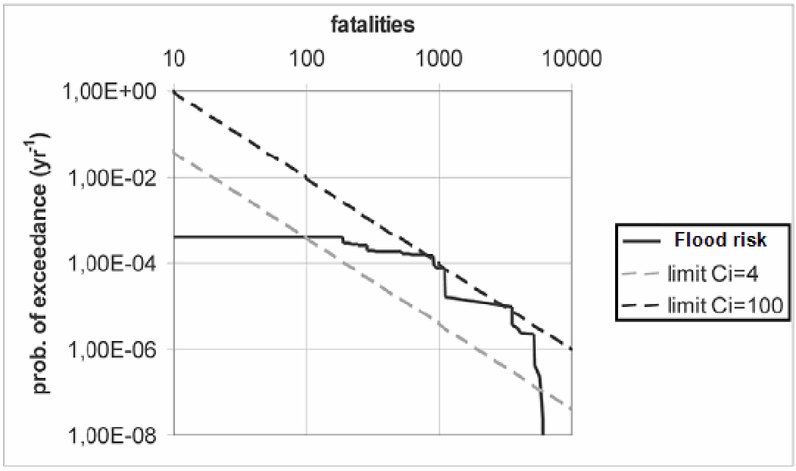


Figure 7. FN curve for dike ring South Holland and two limit lines for different values of C_i [8]

Furthermore, some tolerability criteria of flood risk have been developed for incremental societal flood risk produced by the existence of large dams. These criteria are also usually drawn in F-N curves, as the criteria proposed by ANCOLD [1]. These criteria have been developed for incremental risk, so they cannot be used to evaluate the total societal flood risk as the criterion proposed by Vrijling [17].

5 SUFRI: Towards a tool for planning and managing

SUFRI (Sustainable Strategies of Urban Flood Risk Management with non-structural measures to cope with the residual risk) is a European project whose main objective is improving flood risk management in case of disaster floods by means of non-structural measures. The project aims to define sustainable flood risk management strategies, including advanced warning systems, vulnerability analysis, and risk communication to optimize the disaster control management. Six project partners from four European countries (Austria, Germany, Italy and Spain) are working within the ERA-Net CRUE initiative for the period of 2009 - 2011.

The authors of the present paper are responsible for a work package entitled "residual risk and vulnerability analysis", being involved in providing a tool to characterize residual flood risk in urban areas that can be used to inform strategies to reduce flooding risk.

After reviewing all the issues summarized in the previous sections of this article, a preliminary proposal on how a complete and quantitative way to characterize urban flood risk as a tool for planning and managing could be implemented is presented. The following graphs have been drafted for encouraging discussion.

The first one, Figure 8, shows the effect of structural and non-structural measures on flooding risk, using typical values in both axes (annual exceedance probability and estimated loss of life) that have to be properly studied for each particular case.

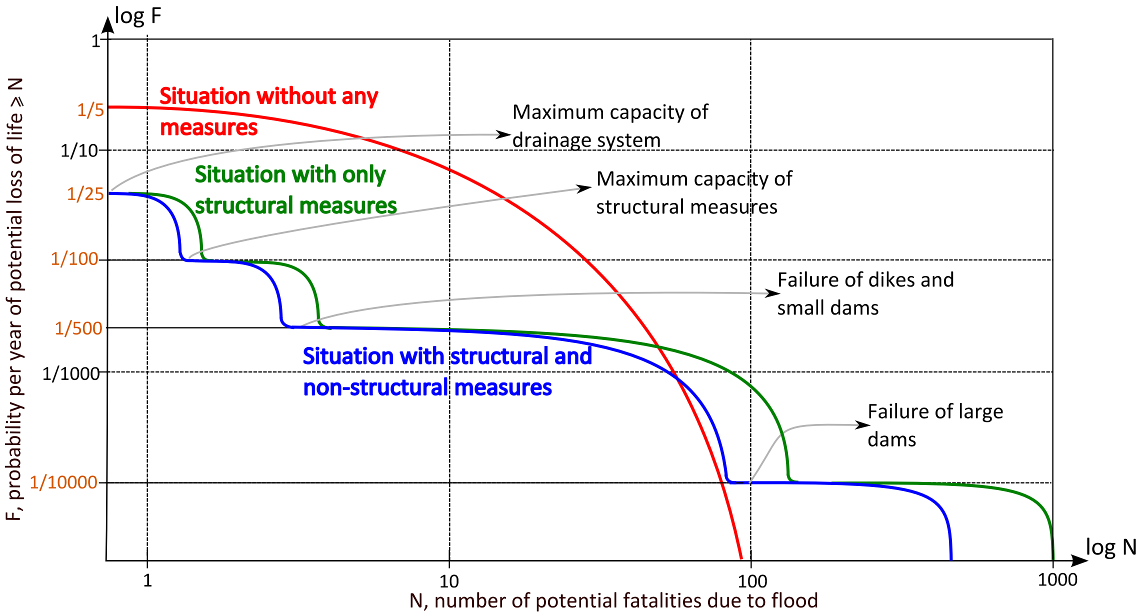


Figure 8. Effect of structural and non-structural measures on the F-N curve for societal flood risk

The equivalent graph in terms of economical losses is provided in Figure 9:

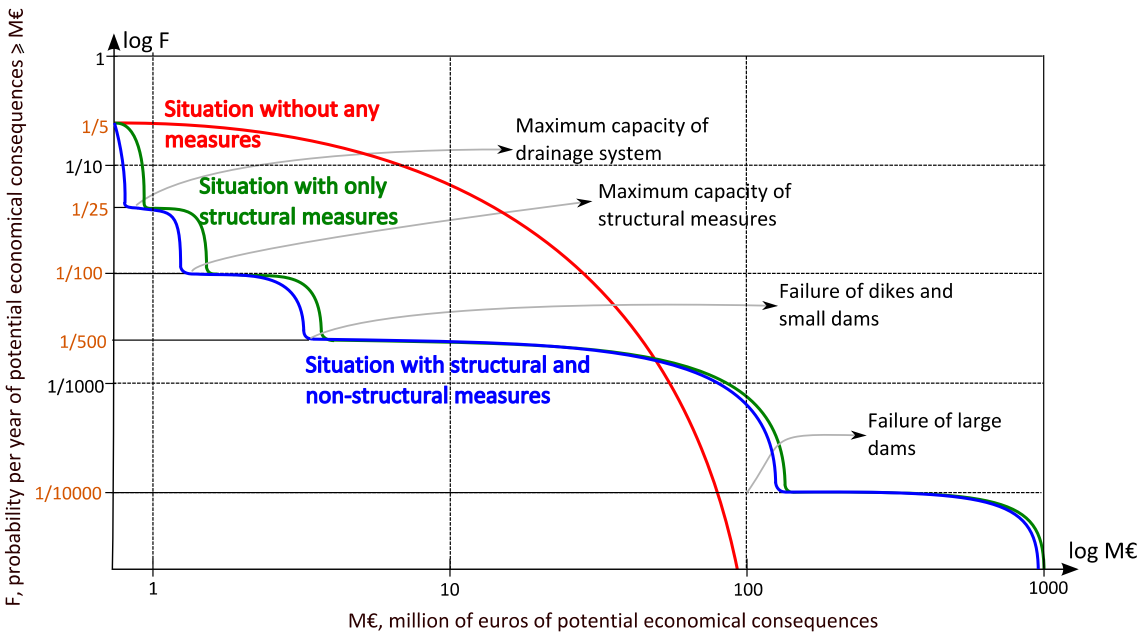


Figure 9. Effect of structural and non-structural measures on the F-M€ curve for flood risk

The isolated effect of the structural measures is then shown in Figure 10:

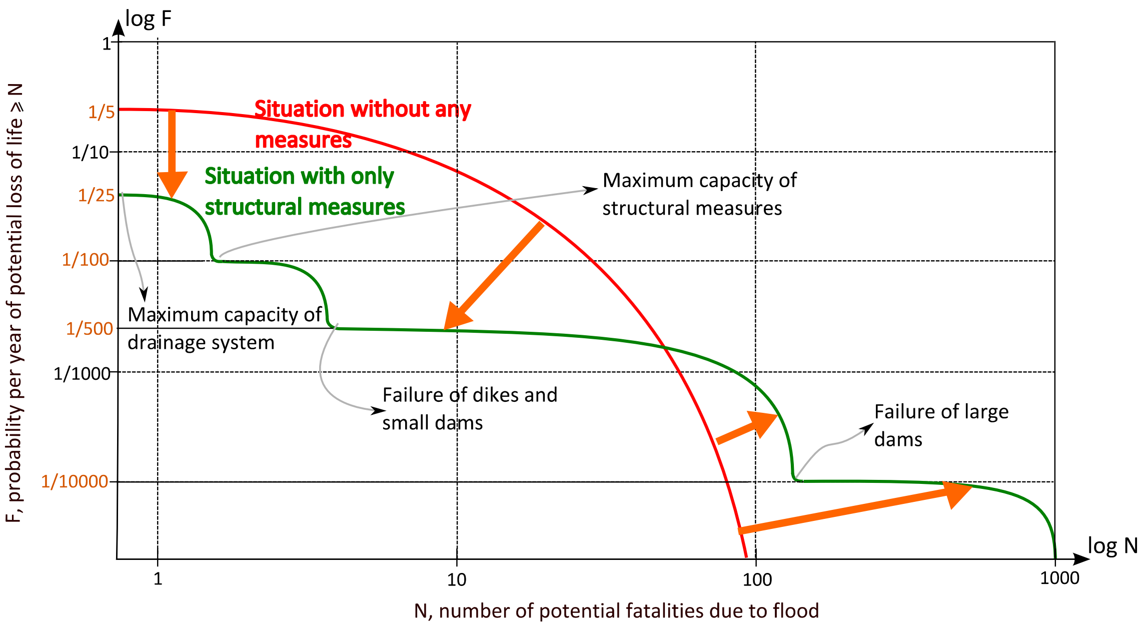


Figure 10. Effect of structural measures on the F-N curve for societal flood risk

And finally, the isolated effect of non structural measures is provided in Figure 11.

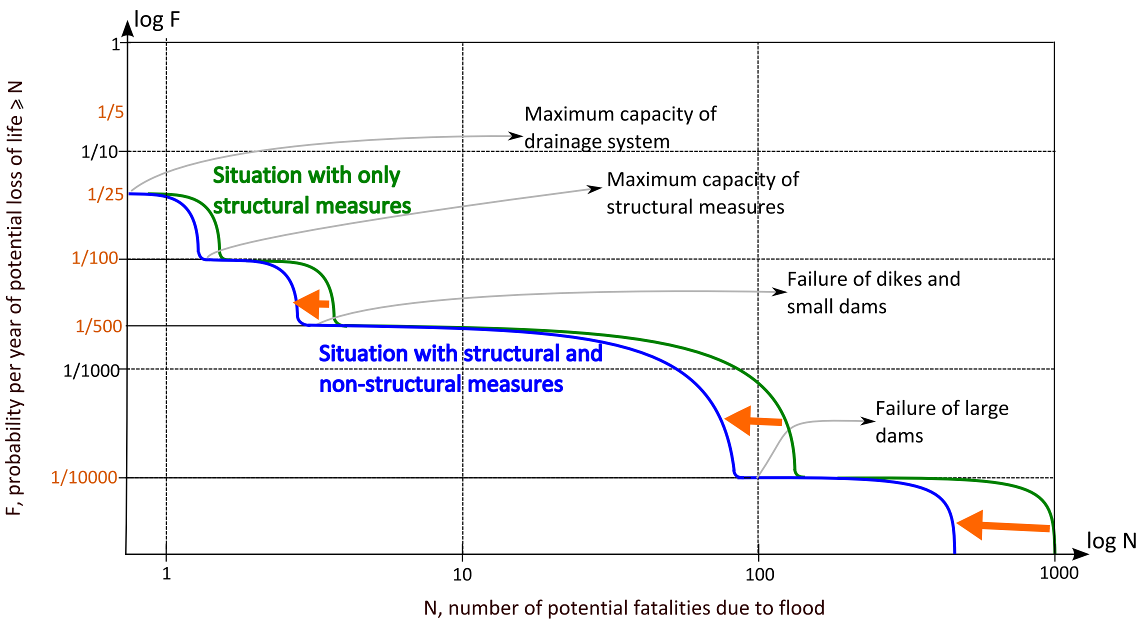


Figure 11. Effect of structural measures on the F-N curve for societal flood risk

It is expected that these curves may be the basis of a helping tool to quantify the effect of different measures on flood risk reduction, thus providing a guide for planning and managing.

Still a lot of discussion and work is required and the figures may be modified in the near future.

However, the approach has been adopted by all SUFRI partners in March 2010, and will be applied to the cities of Graz (Austria), Lodi (Italy) and Valencia and Benaguasil (Spain) before September 2011.

6 FINAL REMARKS ON THE RISK INFORMED "PROCESS" BEYOND THE RISK CHARACTERIZATION "METHODOLOGIES" AND THE RISK TOLERABLE "GUIDELINES"

Any risk assessment "METHODOLOGY" should be a tool for making the communication process open and transparent, robust and defendable in a shared responsibility environment. It replaces binary decisions and balances equity and efficiency when tolerable "GUIDELINES" are properly defined and applied. In any case, the "PROCESS" itself of estimating risk and applying tolerability criteria is beyond any "METHODOLOGY" or "GUIDELINE".

Starting by the "METHODOLOGY", all sources (hazards) of flooding risk should be captured or there may be some significant misunderstanding of such risk (i.e. the threshold beyond which the drainage system reaches ineffectiveness, the role of levee integrity, small dam performance or large dam operation should all be included). From the consequences (vulnerability) part of the risk equation, these have to be estimated preferably in cooperation with local and state agencies or stakeholders.

In fact, Federal Government (in the USA) or Central Governments (in many European countries) have clear responsibilities on the "structural" measures, either linked to new constructions or to secure the integrity of the existing ones. But also in general, "non-structural" responsibilities such as warning, evacuation, or urban planning are in hands of more that one local or regional agency. In any case, the methodology has to be sensitive and capture the effect of both "structural" and "non-structural" measures on risk. Also, any methodology should be easily scaled to the appropriate level of effort needed, meaning that the level of detail and adequacy required must be appropriate to support the decision being made within a reasonable level of confidence.

Coming to developing tolerable risk "GUIDELINES", they have to be thus consistent with the risk estimation methodology and useful in terms of how they both are related. There is a need of getting people involved, vetting and testing before adoption.

Consequently, by encouraging and performing a "flood protection system assessment", a learning "PROCESS" beyond any guideline or methodology should take place. Also, it should "give value" to the work typically done by federal and non-federal agencies, thus better risk mitigation measures should be commonly identified to achieve risk tolerability and, at the same time, a degree of commitment among stakeholders (including urban developers) should be reached.

Ideally, the learning and cooperative "PROCESS" described before should involve the following steps:

- Risk assessment tools and, if possible, tolerability guidelines, are given/recommended by the leading organization.
- Stakeholders are involved by helping to properly estimate the consequences and in some cases the hazards (when they operate their own structures or have relevant information with this regard).
- Responsibilities and current work is better clarified and valued by all participants.
- Better risk mitigation measures are planned.
- Towards meeting any Risk Tolerability Guideline there has been and there will be lots of benefits in the "PROCESS".

In summary, by performing flooding risk assessments (according to any methodology with the identified characteristics) and providing and applying risk tolerability criteria (according to guidelines consistent with such methodology), a significant change in the role of the leading organization (i.e. the USACE) will take place.

REFERENCES

[1] ANCOLD (Australian National Committee On Large Dams Inc.). *Guidelines on Risk Assesment*. Australian National Committee on Large Dams, October 2003.

[2] David S. Bowles and Maged Aboelata. Evacuation and life-loss estimation model for natural and dam break floods. *Extreme Hydrological Events: New Concepts for Security*, pages 363–383, 2007.

[3] COPUT (Conselleria D'Obres Públiques Urbanisme i Transports Generalitat Valenciana). *Plan de Acción Territorial de Carácter Sectorial sobre Prevención de Riesgo de Inundación en la Comunidad Valenciana (PATRICOVA)*, 2002.

[4] EEA (European Environment Agency). Catastrophic floods cause human tragedy, endanger lives and bring heavy economic losses. 2006.

[5] European Parliament. Directive 2007/60/EC on the assessment and management of flood risks. Official Journal of the European Union, October 2007.

[6] HSE (Health and Safety Executive). *Reducing risks, protecting people - HSE's decision-making process*. 2001.

[7] Institution of Civil Engineers. *The State of the Nation: Defending Critical Infrastructure*. Institution of Civil Engineers, 2008.

[8] Sebastiaan Nicolaas Jonkman. *Loss of life estimation in flood risk assessment. Theory and applications*. PhD thesis, Civil Engineering Faculty, Technical University of Delft, 2007.

[9] S.N. Jonkman and J.K. Vrijling. Loss of life due to floods. *Flood Risk Maangement*, 1:43–56, 2008.

[10] R. Kates. Industrial flood losses: Damages estimation in the Lehigh Valley. *Department of Geography Res. University of Chicago*, 98:37, 1965.
[11] MMA (Ministerio de Medio Ambiente y Medio Rural y Marino). Sistema nacional de cartografía de zonas inundables, 2010.
[12] Dale F. Munger, David S. Bowles, Douglas D. Boyer, Darryl W. Davis, David A. Margo, David A. Moser, and Patrick J. Regan. Interim tolerable risk guidelines for US Army Corps of Engineers Dams. *USSD Conference*, 2009.
[13] NEAA (Netherlands Environmental Assessment Agency). Dutch dikes and risk hikes, a thematic policy evaluation of risks of flooding in the Netherlands. *National Institute for Public Health and the Environment (RIVM)*, May 2004.
[14] Peter Reiter. RESCDAM loss of life caused by dam failure, the RESCDAM LOL method and its application to Kyrkosjarvi dam in Seinajoki. *Water Consulting Ltd.*, 2001.
[15] Javier Sánchez. Guía para la aplicación del sistema nacional de cartografía de zonas inundables. In Agència Catalana de l'Aigua, editor, *Jornada Retos y Oportunidades sobre evaluación y gestión de los riesgos de inundación*. Dirección General del Agua. Ministerio de Medio Ambiente y Medio Rural y Marino, 2010.
[16] United Nations World Water Assessment Programme. *Global Trends in Water-Related Disasters an insight for policymakers*. United Nations, 2009.
[17] J. K. Vrijling. Probabilistic design of water defense systems in The Netherlands. *Reliability engineering and system safety*, 74:337–344, 2001.