

Using Risk to Make Decisions, Prioritise Resources, and Measure Performance for Water Resources Facilities at the U.S. Bureau of Reclamation

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Reclamation has been using risk to evaluate its structures since 1997. In the last 10 years, the way Reclamation uses risk information to manage dam safety across its inventory has developed gradually and steadily. Today, risk is used at the failure mode level to determine a course of action and at the facility level to determine the risk exposure. Risk is also used at the program level to assign resources, budget for studies and modifications, and justify potential structural modifications to Congress. Recently, Reclamation also began using risk to assess its own performance for the Office of Management and Budget. This paper will examine the various levels of detail and levels of effort used to accomplish Reclamation's objective of efficiently managing its inventory of dams and its resources. At each step, the available information, strategies, and decision-making processes will be explained.

Keywords: dams, dam safety, risk, risk management, tolerable risk, prioritisation

Introduction

The U.S. Bureau of Reclamation is responsible for managing an inventory of 375 high and significant hazard dams and dikes at 249 project facilities in the Western 17 United States as shown in Figure 1. Following the Teton Dam failure in 1977, Reclamation was forced to re-evaluate its dam safety and decision making processes. In the late 1990's, Reclamation adopted a risk informed decision making process to manage its infrastructure of dams. Reclamation is committed to providing the public and the environment with adequate protection from the risks which are inherent to collecting and storing large volumes of water for later distribution and/or release.

Reclamation has two official documents related to risk management; one that defines the tolerable risk guidelines and basis for decision making, and one that describes the methods used to calculate risks. Reclamation published the first document related to risk management "Guidelines for Achieving Public Protection in Dam Safety Decisionmaking" (USBR 2003). The second document, "Dam Safety Risk Analysis Methodology" (USBR 2003), was originally published in 1997 and revised in 2003. These documents, although vital to the execution of a dam safety program, do not fully describe the risk management and risk-informed decision making that occurs.

Using these two documents as broad guides, Reclamation uses many methods to manage risks, prioritise resources, and measure performance. Over the years, the methods have been refined, the prioritisation has become more detailed, and the decision documentation has become more thorough. This paper will attempt to "fill in the gaps" between the broad published guides and the actual practice.



Figure 1 - Reclamation Regions and Dams in the Western United States

Definitions

Many definitions have been used to describe the thresholds that in this paper are titled "guidelines", but they are generally described one of two ways – as tolerable risk guidelines or acceptable risk guidelines.

In the context of risk management, risk tolerability implies that the risks are identified, understood, and tolerated in some cases – understanding that no matter the level of risk, effort will be taken to minimize it. Risk acceptance implies that the risks are accepted and not evaluated further. As described by the United Kingdom's Health and Safety Executive:

'Tolerability' does not mean 'acceptability'. It refers to a willingness to live with a risk so as to secure certain benefits and in the confidence that it is being properly controlled. To tolerate a risk means that we do not

regard it as negligible or something we might ignore, but rather as something we need to keep under review and reduce still further if and as we can. For a risk to be 'acceptable' on the other hand means that for purposes of life or work, we are prepared to take it pretty well as it is. (HSE 1992)

As Reclamation strives to continually refine risk estimates and minimize risks, the term “tolerable risks” will be used in this paper to describe the thresholds and in Reclamation’s public protection guidelines.

Reclamation uses a process referred to as “*expert elicitation*” for its detailed risk analyses. The traditional definition of this term refers to a panel of prominent experts synthesizing their opinions on a particular topic.

Reclamation has extended this and defines *expert elicitation* as:

A multi-disciplinary team of engineers and scientists who generate dam safety risk estimates for a particular facility. The team assessment of risk is facilitated by a certified senior member of Reclamation’s staff and contains several members experienced with risk. The team generates probabilities subjectively using an event tree approach.

Risk Tolerance and Risk Management

The focus of this paper is the risk management aspect of dam safety. Although the tolerable risk guidelines will be mentioned in the context of managing risks, they will not be discussed in great detail. The primary purpose here is to describe how the tolerable risk guidelines are interpreted and applied.

Types of Decisions

Within the dam safety program, Reclamation makes many types of decisions regarding its structures. These decisions will be further described later, but they are introduced here as part of the decision framework. The types of decisions which require formal documentation and signatures can be defined as:

- Safety Decisions – Decisions that relate directly to the safety of the structure and its continued operation.
- Priority Decisions – Decisions that are made to relatively rank structures and schedule more detailed evaluations or modifications.
- Modification Decisions – Safety decisions that are made to reduce identified risks at an individual structure in the most efficient manner possible.

Organizational Framework

History

It is useful to briefly describe the process that led Reclamation to use risk to inform decisions, as the need that led Reclamation to choose this path have not changed.

As part of Reclamation’s transition from a construction agency to a water resource management agency, some of the processes that were valuable to specification-driven and contract-driven management were not well adapted to managing limited dam safety resources. Many times, “deficiencies” would be addressed on a “first come – first served” basis. These deficiencies were also compared to applicable standards such as the Probable Maximum Flood (PMF) or the Maximum Credible Earthquake (MCE) with little regard to the relative frequency of such events. The result of this was that funds were expended for low risk remote events and not on reducing higher risk from more immediate threats or threats with higher consequences.

It was finally the desire of the agency to incorporate three concepts into the decision process that led Reclamation to choose risk as a management tool.

- The concept of relative frequency.
- An examination of a large database of historical failures led to the conclusion that engineering efforts were not always focused on events that were aligned with the likelihood of those events happening.
- The desire to incorporate failure modes into engineering analysis and decision making.

Organization and Management

The particular manner in which Reclamation is organized contributes to the manner in which decisions are made. Decisions are made by groups rather than individuals. There are multiple internal organizations that participate in the decision process as shown below.

Technical Services Centre

Reclamation’s Technical Services Centre provides the technical resources to analyse risks for Reclamation facilities. They also develop Reclamation’s risk methodology.

Dam Safety Office

The Dam Safety Office is part of the Security, Safety, and Law Enforcement Division of Reclamation. The dam safety program is responsible for funding and managing dam safety activities in Reclamation.

Regional Office

There are 5 regions in Reclamation. The Regional Director for each region is responsible for safety and security at each facility.

Area Office

There are several area offices in each region. The Area Manager is responsible for the safe operation of the facilities in each area.

Decision Makers

In general terms, the Chief of Dam Safety is responsible for ensuring program consistency and achievement, the

Regional Director is responsible for the safety of each facility within that region, and the Area Manager is responsible for safe operation of each facility within that area. This is a gross generalization, but it is the easiest way to explain the roles of the decision makers. Depending on the region and area office, these roles can be quite different. Together, the Chief of the Dam Safety Office, the Regional Director, and the Area Manager form what's referred to as "the dam safety decision makers". Each decision document has the concurrence of each decision maker or their official delegate.

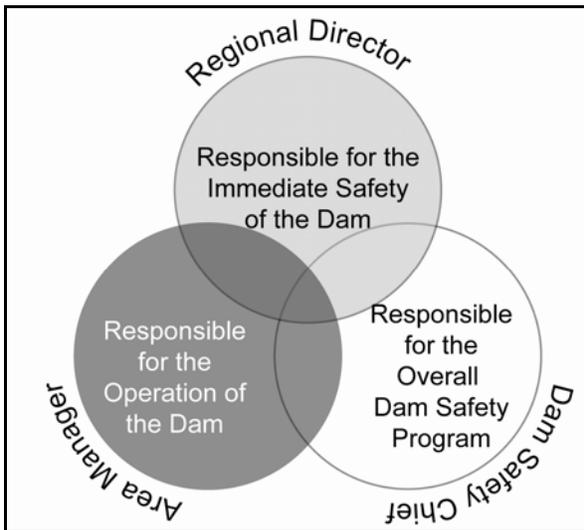


Figure 2 – Dam Safety Decision Makers

Objectives and Constraints

“One key aspect of water resources decision making is that the process almost always requires the evaluation of multiple objectives such as national economic development benefits which can be derived from additional capital investment, public safety, resource protection, and consideration of social concerns.” – USBR Public Protection Guidelines

“The concept is to focus on identified, targeted areas of potentially-serious and more-likely dam safety deficiencies so that limited financial resources can be used most effectively in ensuring dam safety and public safety.” – Federal Energy Regulatory Commission Potential Failure Modes Analysis Guidelines

One of the most important benefits of making risk informed decisions is the ability to weigh the benefits and costs of potential action or inaction. This can be more easily explained by understanding that every decision made is done while considering objectives and constraints that affect each project. Whether explicit or implicit, each decision is made by balancing the potential benefits and the limiting factors.

Rarely, a single decision will optimize all the objectives. Sometimes, it is difficult to make decisions that meet all the constraints. The goal is to achieve an appropriate balance among the objectives while meeting all the constraints.

Primary Objectives

The primary objectives listed below are the objectives that are critical to the decision making process.

Accomplish the Agency Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American Public. The critical interpretation of this mission with regard to dam safety is that Reclamation is responsible for reliably delivering water and power to its stakeholders. This objective is a paramount concern, as water delivery for municipal, industrial, agricultural, and power production is the primary purpose for Reclamation's existence.

Achieve Public Safety Goals

The mission of Reclamation's Dam Safety Program is "To ensure that Reclamation facilities do not present unreasonable risks to the public, public safety, property, and/or the environment." Reclamation has developed guidelines to describe thresholds of tolerable risks. The primary goal of the dam safety program is to minimize risks to downstream population using the guidelines and other risk management practices.

Responsible Government

As a government agency, Reclamation is responsible for ensuring that the government spends funds in a responsible fashion.

Secondary Objectives

The objectives listed below are considered during the decision process, but do not always significantly affect the final outcome.

Minimize Environmental Impacts

Reclamation strives to minimize the impacts to the environment due to its structures. However, as with most water resources facilities and with heavy civil construction, this cannot always be attained. Because of the nature of water resources facilities, they tend to become integral parts of the ecosystem after many years of operation.

Maintain Program Consistency

One of the goals of the dam safety program is to ensure a consistent level of safety for downstream residents without regard to their location. This is a difficult objective to achieve. Inherent uncertainties make the absolute achievement of this goal impossible, but it is nonetheless a critical component of risk management.

Constraints

Applicable Laws and Guidelines

Reclamation is required to follow the applicable laws and abide by or request official waivers to internal policies and guidelines.

Maintaining Project Benefits

The water resources projects managed by Reclamation were originally authorized by the Congress. As such, Reclamation is required by law to maintain the authorized benefits of the project. This becomes important when considering actions such as reservoir restrictions.

Economic Constraints

Reclamation has limited funds to manage dam safety activities.

Design Standards

Reclamation has many design and analysis standards used by engineers to evaluate the safety of a structure and to design modifications to that structure.

Life Safety Decisions

With the objectives and constraints as background information, one can begin to understand the decision process. Reclamation uses risk as the primary factor for life safety decisions. The levels of evaluation determine the nature of the potential decision to be made. Reclamation has 4 levels of risk assessment.

Levels of Risk Assessment

For any level of risk assessment, risk is defined using the following equation:

$$P(\text{load}) * P(\text{structural response}) * \text{Consequences} = \text{Risk}$$

For every level of evaluation except screening, a quantitative assessment is made of risk for each likely failure mode using this as the basic equation.

Screening

Although Reclamation no longer uses screening evaluations for its facilities, it does do some screening for other agencies. The original screening was done using the Risk Based Profiling System, which classified structures on a point scale using some general risk factors. Reclamation is currently evaluating a screening tool developed for the Federal Emergency Management Agency by URS Corporation.

Comprehensive Facility Review

Every 6 years, each high and significant hazard Reclamation facility is examined during a Comprehensive Facility Review. A multi-disciplinary team of engineers, geologists, hydrologists, and seismologists develops a list of potential failure modes. An inspection team visits the facility to examine the structure, its appurtenant structures, and its mechanical equipment. A senior engineer develops an assessment of risks from the failure modes and the assessment is peer reviewed. This assessment is included in a Report of Findings, which describes the comprehensive risk setting of the facility, and a Decision Document, which recommends action or inaction based on the findings.

Each Comprehensive Facility Review report is then reviewed for quality and consistency by an internal advisory panel of rotating experts. If actions are required to further identify, assess, or reduce risk, an official recommendation is generated and tracked until its completion. An *Issue Evaluation* phase is initiated to further identify and assess specific issues in detail in a risk context. A consistency review is performed and the Decision Document is signed by the Regional Director, Area Manager, and the Chief of Dam Safety or their official delegates.

Other Examinations

Reclamation has two other types of scheduled examinations of each facility, Periodic Facility Reviews and Annual Inspections. Periodic Facility reviews occur 3 years following the Comprehensive Facility Review. Unlike Comprehensive Facility Reviews, neither of these examinations includes a quantitative evaluation of risks unless something significant is observed.

Other special exams such as outlet works inspections or underwater exams are scheduled when necessary. These also do not contain a quantitative evaluation of risk unless something significant is observed.

Issue Evaluation

When specific issues have been identified at a facility, it enters the Issue Evaluation phase. Many activities can take place during this phase. Loads, structural responses, or consequences and all studies needed to refine these may be evaluated. Investigations and explorations may be performed.

The final part of the issue evaluation is a team level evaluation of risk – expert elicitation as defined by Reclamation above. Occasionally, this evaluation of risk requires further investigation or analyses. The purpose of an Issue Evaluation is to thoroughly examine the risk at a facility to determine if action is required to reduce risk. If the risks are minimal, the facility returns to the facility review process. If the decision-makers determine that action is required to reduce risks, the facility enters the Corrective Action Study phase.

Corrective Action Study

Depending on the size of the facility, downstream consequences, and magnitude of the risk, further evaluations of risks may be required. The level of detail required to evaluate risk reduction alternatives is high and becomes higher as the cost of potential actions increases. Once Reclamation is comfortable with the risk picture, preferred alternative, and cost estimate, a Modification Report is submitted to the Office of Management and Budget for clearance and then to Congress for approval. The Modification Report includes information about the costs, benefits, and a simplified explanation of the risks and risk reduction. Currently 24 Reclamation facilities are being evaluated for potential risk reduction actions. Of these 24, 12 have been approved by Congress for structural modifications to reduce risk.

Basis for Decision Making

Decisions regarding the safety of the facility are made using two pieces of information; the actual risk estimate and the case made to justify the risk estimate. Reclamation has many levels of detail for the risk estimates it generates relative to the significance of the corresponding decision. Some evaluations are simplified and scripted, some are determined after several team evaluations and consultant reviews, some have significant uncertainty and some have minimal uncertainty.

For any level of risk estimate, a technical report of findings is developed to justify the numbers that are generated. It also includes the primary factors that led to the risk estimate, a description of the uncertainties, and the strengths and weaknesses behind the numbers. These pieces of information are used to “make the case” to the advisory panel and the decision makers. This is a critical component that is intended to give the decision makers enough information to make an informed decision.

Risk Estimates Related to Tolerable Risks

Reclamation uses the tolerable risk guidelines as goals for achieving public protection, as shown in Figure 3. They are also thresholds used to justify expending funds to reduce risks. They are not the sole piece of information used to judge the absolute safety of a structure, but they are the primary means to judge the relative safety of a structure. When considering these guidelines, Reclamation generally uses the *mean estimate of risk for an individual failure mode* in comparison to the threshold values. The graphical depiction of this is shown in the f-N diagram in Figure 4. Each point on the plot represents the mean risk estimate for an individual failure mode. The lines near the two axes represent the uncertainty associated with each estimate. Uncertainty is also considered in the decision process, and will be discussed in a later section.

The primary focus of the dam safety program is life safety. As such, the thresholds are listed below in order of importance.

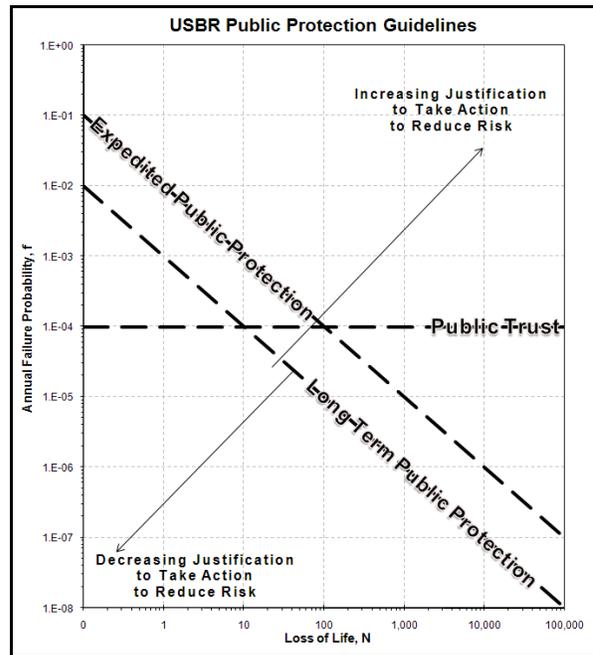


Figure 3 - Reclamation's Public Protection Guidelines

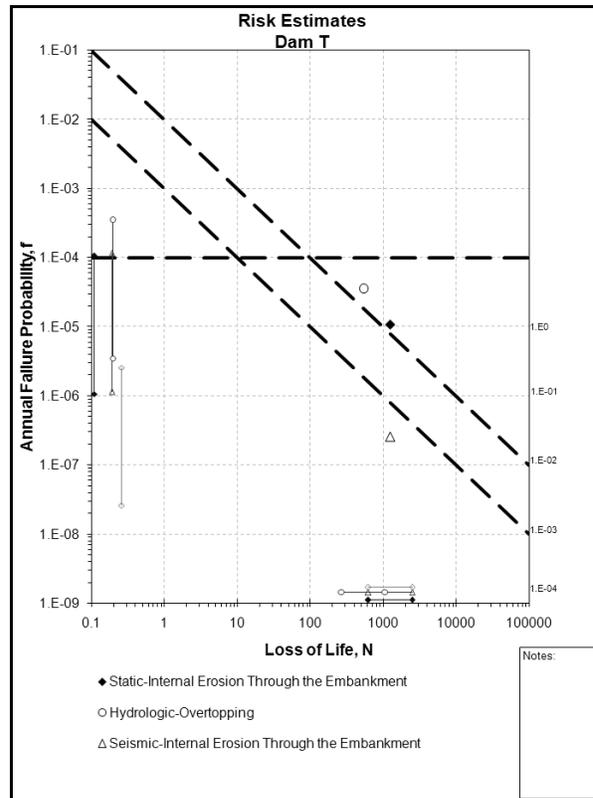


Figure 4 - Example of an f-N Diagram for a Facility

Expedited Public Protection

Reclamation considers that there is justification for taking expedited action to reduce risk when the mean estimate of the annualized life loss exceeds 1 in 100. While there is a full range of possible risk reduction actions that can be taken, Reclamation focuses on those that can quickly reduce risk or improve understanding of the uncertainties associated with the risk. As confidence increases that the

risk is in this range, actions concentrate more on reducing the risk than reducing the uncertainties. Every effort is made to take actions to reduce risks and complete any reassessment within 90 days of determining the need for expedited risk reduction action.

The purpose of the “expedited guideline” is to reinforce the importance of addressing significant risks in an expedited fashion. In general, *identified risks* are addressed more rapidly the higher they plot in relation to the guidelines. In many occasions, expedited risks are a result of an incident or observed change in structural behaviour. In these cases, every effort is made to reduce risks on an interim basis while the magnitude of the problem is evaluated.

Long Term Public Protection

Reclamation considers that there is increasing justification for taking action to reduce risk when the mean estimate of the annualized life loss exceeds 1 in 1,000. When the range of risk estimates falls in this range, there are a wide variety of possible actions which may be appropriate. However, the actions are scheduled into the dam safety program and coordinated with other needs at the facility and at other facilities. Actions to reduce risks are implemented on a schedule that is consistent with budgeting and appropriations processes. Typically, risk reduction should be accomplished within 7 years of a decision that identifies a need to reduce risk.

The purpose of the “long term” guidelines is to identify a threshold where actions are important, but not necessarily urgent. In this area, risks are managed in a more detailed and conscious manner while awaiting further evaluation or structural modifications. Interim actions are considered but not required. Decisions related to interim actions are constantly re-evaluated acknowledging that structures change over time and new information may influence the original decision.

Public Trust

The justification to implement risk reduction actions increases as the mean estimate of the probability of failure becomes greater than 1 in 10,000. Actions considered reasonable and prudent should be considered for implementation when the annual probability of failure estimate exceeds this value. A variety of possible actions may be appropriate.

The purpose of the public trust guidelines is to reinforce the idea that safety is important even for facilities with low consequences. Some might argue that the primary focus should be on the likelihood of failure, but Reclamation has chosen to focus primarily on the likelihood of adverse consequences. Regardless of the focus, Reclamation recognizes that this is an important factor to consider.

Uncertainty

There are three components of risk. As consequences increase, risk increases. As the likelihood of failure

increases, risk increases. As the uncertainty increases, risk borne by the agency also increases. Conceptually, a facility with no information is more risky than one with volumes of information. Intuitively, the uncertainty decreases as the detail of related studies and evaluations increase.

Reclamation evaluates uncertainty in its Comprehensive Facility Review and Issue Evaluation processes, but it is not a primary decision criteria. Every attempt is made to reduce uncertainty in risk estimates, but we recognize that this is not always possible or even cost-effective.

Reclamation is in the process of evaluating alternatives for explicitly considering uncertainty in its public protection guidelines. Alternatives include developing tolerable thresholds for Probability of Exceedance or Reliability Indices or some other measure of uncertainty.

High Life Safety Consequences

The public protection guidelines use uniform levels of risk to delineate tolerable and intolerable life safety risks. These risk levels are based on a fairly small sample set for Population At Risk (PAR) under 60,000 and actual loss of life between 1 and 500. In most of those cases, life loss was less than 10. Facilities that have high consequences present difficult decisions. It is difficult for engineers and managers to comprehend events leading to flooding that affect hundreds of thousands of people. Events such as these are difficult to grasp or envision.

Low probability events combined with high consequences present challenges to the intuition that accompanies risk informed decisions. Reclamation’s position is that low probability events with relatively high consequences should be treated with equal consideration as high probability events and relatively low consequences of equivalent risk. The Tsunami in Indonesia in 2004 is an example of an unlikely event combined with high consequences. A magnitude 9.1 earthquake is an extremely low probability event, yet the public perception of the consequences overshadowed the perception of the unlikely nature of the precipitating event.

Although it becomes increasingly difficult to evaluate risks as the probability of failure decreases, Reclamation has decided that increasing consequences should be equivalent to increasing likelihood of failure, when decisions are made to pursue more detailed evaluations and/or structural modifications. That being said, there are situations with high potential consequences where little can be done to reduce risks in a cost-effective manner. When these situations arise, Reclamation prefers to consciously accept the risks as they are stated and identify the underlying reasons in a decision document. However, this has not proven to be a common situation.

ALARP

Reclamation does not use a defined guideline or threshold to measure risks that are determined to be “As Low As Reasonably Practical” – ALARP. The organization prefers to make the best effort to quantify the risks

associated with a facility. However, Reclamation does consider the concept in its decision process.

As mentioned earlier, each facility is reviewed by an internal panel of experts. During this review, the panel and the senior engineer must answer the question of whether or not it is appropriate to operate the facility until the next review or inspection.

The underlying question that is posed by asking this question is “*have risks been reduced as low as they reasonably can to ensure the continued operation of the facility until its next review?*”

Safety Decisions

No Action

On many facilities, Reclamation makes a decision to operate the facility as it is currently being operated until the next facility review.

Prudent Actions

Even with low risk, some actions are considered reasonable and prudent to ensure the continued safe operation of the facility. These may include examining drains or cleaning or installing instrumentation.

More Information

If there is an indication that risks are in the range where there is increasing justification to take actions to reduce risks, further analysis or investigations may be required to develop a clear picture of the risk profile.

Interim Actions to Reduce Risk

If risks are high enough to cause concern about the immediate safety of a facility, actions may be required to reduce risks before risks can be evaluated in further detailed or actions to reduce risks can be evaluated. This may consist of restricting the reservoir or increasing monitoring, but in some cases has included emergency construction.

Structural Modifications to Reduce Risk

When risks have been identified as presenting an unacceptable risk to the public, Reclamation makes a decision to take action to reduce risks. This is not undertaken lightly, as stakeholders are required to pay a percentage of the design and construction costs. This is often done in conjunction with interim actions to reduce risks. The objective of the modification is to reduce the risks to a *tolerable level*. The most common risk reduction target is an annual life loss less than 1 in 100,000, but this varies greatly and is not always possible.

The ALARP principle is also used when determining risk reduction options. Ideally, the goal for reducing risks is to reduce the mean annualized life loss below the long term public protection guidelines. However, it may be cost-effective to reduce risks even further while modifying the structure or operations. It may also be beneficial to reduce the probability of failure to a level

low enough to ensure future development does not increase the risk into a range where further risk reduction actions are warranted.

Figure 5 illustrates the Reclamation facilities that have been modified or are scheduled to be modified. It also shows the residual risk estimates.

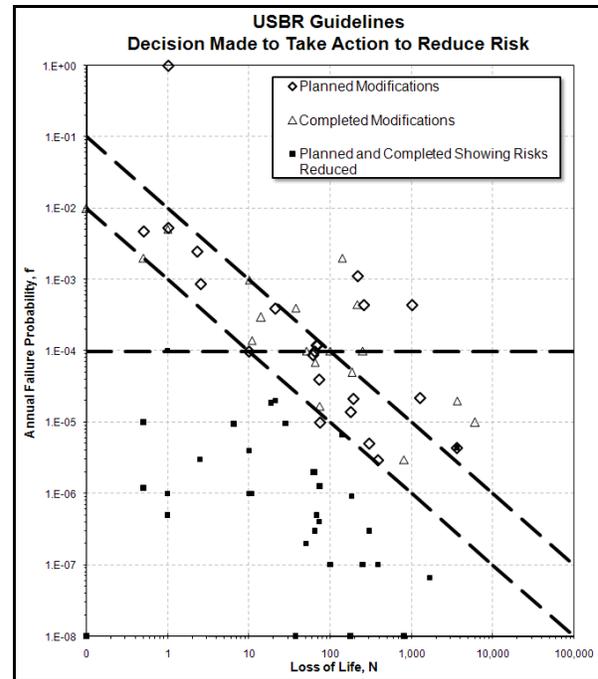


Figure 5 - f-N Chart of Facilities to be Modified

Prioritisation

Issue Evaluation

Issue Evaluation studies are initially prioritised based almost solely on total risk. Twice each year, the workload is re-prioritised and updated based on information learned in the prior 6 months. As higher risks are identified, some projects are delayed to accommodate them. There are other considerations; scheduling work at nearby facilities may provide a cost advantage, some products may be significantly easier to produce, etc. Prudent actions may also be pursued when appropriate or when an opportunity arises.

Corrective action studies and structural modifications are prioritised based on each failure mode, as modifications are generally constructed to address a single mode of failure. However, due to environmental clearances, the level of effort involved planning construction projects, and other factors, structural modifications are not always completed in the order of the highest risk.

Total Risk

Figure 6 illustrates the risk profile for one of Reclamation’s five regions. Each point represents the total risk for an individual facility. In Reclamation, decisions are made using the *mean estimate of risk for an individual failure mode*, whereas studies are prioritised

based on the *mean estimate of total risk for an individual facility*.

Occasionally facilities with lower risk are worked on due to stakeholder requests or project requirements. Occasionally facilities with higher risk or probability of failure are delayed either intentionally or by circumstance. As Figure 6 illustrates, most of the high risk facilities in this particular region are currently being studied or modified. There are five exceptions. At one facility, Reclamation has identified risks, but because the consequences are so low, it has agreed to temporarily tolerate the risks. At two of the facilities, risks have been evaluated during recent Comprehensive Facility Reviews, have not been documented yet, but the risks are lower than are portrayed here. And at one of the facilities, a failure mode was identified during a Comprehensive Facility Review as having high risks. However, specific areas of needed refinement to this risk analysis have been identified that need to be incorporated before the estimate is used. This procedure is done for the entire Reclamation inventory, but only one Region is shown here to reduce the data to a manageable group.

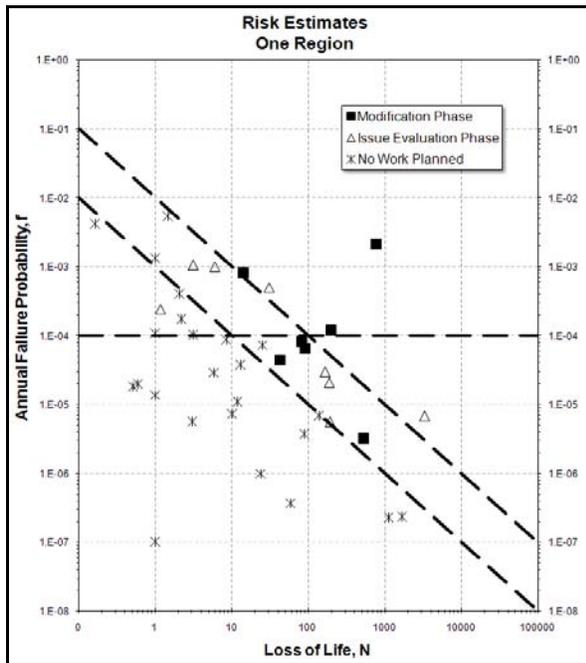


Figure 6 - The Risk Profile for One Region in Reclamation

Program Performance

Effectiveness of Risk Reduction Actions

Several measures of the effectiveness of risk reduction are considered by Reclamation. Reclamation has evaluated tools like Cost per Statistical Life Saved (CSLS), Risk Reduction Indices (RRI), Benefit/Cost Ratio (b/c), and recently the Disproportionality Ratio. However, most of the statistical or economic formulas used to calculate effectiveness generally illustrate what is intuitively apparent. Projects that are critical and cost effective are obvious, and projects that have little risk reduction per dollar spent are also quite obvious. Those that are in

between are challenging. Much effort is spent attempting to prioritise projects with identified risk estimates between the expedited and long term guidelines and with cost estimates between \$20 Million (U.S.) and \$80 Million (U.S.).

Internal Evaluations

The Dam Safety Program evaluates its performance using several measures:

- Its performance accomplishing facility reviews
- The annual report from Reclamation's Dam Safety Officer
- The performance measures developed for the Office of Management and Budget as part of the Program Assessment Rating

One of the goals of the program is to accomplish all the Comprehensive Facility Reviews and Periodic Facility Reviews scheduled for that year. These are tracked very closely, as those examinations are a key part of ensuring the safety of each facility.

It would be important to note that if risk is used to make decisions and prioritise resources, evaluating the program performance is fairly straightforward. The true measure of program performance is how efficiently risk is reduced. Because of the nature of calculating efficiency, addressing the high risk items first leads one down the path of doing just that.

Dam Safety Officer

Reclamation has an independent Dam Safety Officer who also oversees the dam safety programs in the entire Department of the Interior. The Dam Safety Officer receives copies of all products produced by the dam safety office prior to publication. He also convenes the Independent Review Panel, which will be discussed below. The Dam Safety Officer writes a report each year to Reclamation's Commissioner detailing his assessment of the performance of the dam safety program in meeting the objectives of the Federal Dam Safety Guidelines.

PART

Reclamation has five performance measures for its Dam Safety Program. These performance measures, scores, and detailed information can be found at <http://www.whitehouse.gov/omb/expectmore/summary/10003702.2005.html>.

1. **Complete Comprehensive Facility Reviews of every high and significant hazard dam once every six years.** On average, 42 Comprehensive Facility Review examinations and reports should be completed annually to meet Reclamation's Comprehensive Facility Review goal. This performance measure is intended to evaluate Reclamation's ability to accomplish routine dam safety activities.

Reclamation maintains a set schedule of exams for its facilities and work tasks associated with

completing each exam. These tasks are tracked on a monthly basis.

2. **Percent of the Facility Reliability Rating (FRR) related to dam safety.** The FRR is a numerical rating from 0 to 100 which reflects the overall reliability of the facility; 35 of these points are related to dam safety. For each high and significant hazard dam, the possible score of 35 is reduced based on dam safety operational restrictions and risks that exceed Reclamation guidelines for public protection. The score will also be affected if dam safety recommendations and decisions are not addressed, including a structural modification, in a timely manner. The overall score (maximum of 345) is divided by 35 to determine the percentage of the dam safety-related FRR score. The objective is to maximize the percentage achieved each year which indicate reduced risk to the public and to impacts on water management. Tracking this measure will also identify program effectiveness in identifying and resolving dam safety issues.

3. **Total Annualized Life Loss per dam.** This represents the total risk posed by all high and significant hazard dams divided by the number of dams with risk data. This measure is an indicator of the program effectiveness in reducing risk to the public. The numerator is the total risk as presented in Safety of Dams total risk portfolio. The denominator is the total number of dams in Reclamation's inventory.

Reclamation's goal is to reduce overall life safety risk 5% per year. The total risk for the portfolio is significantly affected by the facilities that exceed annualised life loss of 1 in 1,000. As such, this performance measure is in effect a measure of how efficiently we are reducing risks for facilities where high risks have been identified.

4. **Percent of Decision Documents related to dam safety issues at high and significant hazard dams, completed within 60 days of source document completion.** All decisions with regard to Safety of Dams recommendations and issues are formally documented in decision documents. Reclamation guidance requires that all decision documents be completed within 60 days of the completion of the source document (Comprehensive Facility Review, Periodic Facility Review, Annual Inspection, Issue Evaluation), i.e., the document which identifies the basis for a dam safety concern. In order to reduce risk to the public it is critical that decisions related to dam safety issues are completed in a timely manner. Tracking this measure provides insight into the effectiveness of the program with regards to timely decision making to reduce risk.

This performance measure is an indicator of Reclamation's ability to make decisions at high risk facilities. Although there are many factors that would lead to a delay making a decision at any facility, those with controversial issues generally take longer.

5. **Percent of Safety of Dams recommendations that have been completed.** Safety of Dams recommendations result from facility reviews or observed performance abnormalities. Dam Safety recommendations are made to further evaluate or to correct dam safety deficiencies. This measure indicates the long term effectiveness of the program in addressing dam safety deficiencies. The number of dam safety deficiencies is an indicator of dam safety risk. Tracking this measure also indicates the long-term reduction of risks to the public, public safety, property and/or the environment. Tracking this measure helps to better manage the program by indicating if Program resources are adequately directed to identify and address Safety of Dams recommendations. The numerator is the number of recommendations completed as of that particular year. The denominator is the total number of recommendations made up to that particular year, including recommendations that carried over from prior years.

Reclamation uses those 5 performance measures to evaluate the performance of the program. Measures 1, 2, and 5 relate to the ability of the program to ensure the safety of the entire portfolio of facilities. Measures 3 and 4 are targeted more towards higher risk facilities.

External Evaluations

Several external entities also evaluate Reclamation's performance on a periodic basis.

Independent Review Panel

Each year, an Independent Review Panel, composed of a 3 person panel of rotating members examines the dam safety program. They report their findings and make recommendations. Each year Reclamation is responsible for accomplishing those recommendations and reporting the results to the next review panel and the Dam Safety Officer.

Office of Management and Budget

The Office of Management and Budget reviews Reclamation's Program Assessment Rating Tool self-assessment and completes its own assessment.

National Academy of Science

The National Academy of Science reviewed the Dam Safety Program in 2006 as part of their review of all of Reclamation (NAS 2006).

Conclusions and Remarks

Reclamation's Risk Management Process is Mature

Reclamation has been using risk information to make decisions and prioritise resources long enough that it is becoming routine. For the first few years (1996-2000), consistency was difficult to achieve and continual development made it difficult to compare risks between facilities. Many decisions that were made are now being re-visited. Since approximately 2000, the methods used to calculate risks have been fairly consistent. The risk management has also become more consistent; decisions have followed and also become more consistent. Reclamation has developed its internal processes and philosophies enough to be comfortable judging relative risks and is confident that it is currently making sound risk informed decisions. Over the last two years, risk-based prioritization of Reclamation's workload has dramatically improved. Due to budget constraints, risk is now the primary justification for pursuing work activities.

Risk Information Generates More Defendable Decisions and More Informed Decision Makers

In many cases, decisions regarding dam safety are apparent. There are challenges, especially when considering the differences between Operations and Maintenance and Dam Safety. When these types of challenges arise, risk information makes it easier to make sound decisions and defend them. Risk estimates focused on identified failure modes are easier to explain and simpler to understand for decision makers, senior management, and the public.

Risk Information Makes Prioritisation and Decision Making Consistent

The most challenging part of risk management at Reclamation has been allocating resources to match the magnitude of the decisions. There are parts of Reclamation that are less risk averse than others. These influences remain. But slowly, those biases are being overcome through consistent application of risk management. Although difficult, each year the prioritisation process has evened the risk exposure across the program. There are still areas of Reclamation that are carrying more risk than others, but the difference is not as dramatic.

Risk Assessment Does Not Necessarily Make Difficult Decisions Easier

Although risk is useful to make and justify decisions, it does not always make a difficult decision easier. Decisions where risks hover near guidelines, where high consequences are involved, and risk estimates that have large uncertainties are still difficult. This is perhaps because those decisions should be difficult, and no analytical tool can absolve decision makers from making those tough decisions.

Senior Managers Embrace the Risk Management Concept

Risk is an excellent tool to explain expenditure of funds. Both internally to explain why the dam safety program takes actions, and externally to explain to the Office of Management and Budget and Congress why funds are

being expended, risk is a convincing way to convey the dam safety message. Because of this, it is easy for managers without a technical background to understand risk concepts as they relate to spending money. The Dam Safety Program enjoys a measure of respect and credibility for its ability to make sound and consistent decisions.

Risk is Here to Stay

The most difficult aspect of risk management and risk analysis is the transition from standards-based and analysis-oriented philosophies to risk-based thought processes. However, as time has passed, the technical staffs have become more comfortable with the risk processes. This is in part because the processes have led to reasonable conclusions. Because of the support of both the technical staff and senior managers, the risk management concept is certain to remain a fixture of the dam safety program at Reclamation.

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