THE USE OF RISK ASSESSMENT METHODOLOGIES TO PROTECT RESOURCES & ASSETS

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INTRODUCTION

The use of risk assessment methodologies is being used more frequently by organisations for a number of reasons.

Risk assessment can be used to assist asset owners in a number of ways including identification of risks, identification of risk impacts, intervention strategies and the management of safety, but can also be used to demonstrate to regulators/investors a defensible, logical approach to asset management and risk integration.

This paper will describe a number of initiatives being utilised by KBR to assist its clients in protecting and maintaining resource assets for the future.

An important issue is to identify to whom or what the risk impacts; whether the customer, the business supplying the water or to some third party such as those living downstream of a large dam. This dictates the potential impact of concern, whether of dam failure (release of water) or operational failure (inability to supply water to the customer via the treatment works); these having very different probabilities of occurrence and consequences.

RISK CRITERIA

Society does not have a logical view on acceptable levels of risk: it is reasonable to assume that accidents killing the same number of people are equally as acceptable or unacceptable. There is, however, a tendency to be more concerned about accidents involving a high number of fatalities such as air crashes, when in fact statistically air travel is far safer than road travel. The perception of risk is also influenced by factors such as whether the risk is undertaken voluntarily (eg rock climbing) or is imposed by others (eg construction of a nuclear power station). It is therefore difficult to set rigid risk criteria for all industries or situations.

IMPACT OF LEGISLATION

In some areas of water resources legislation may have an important impact in directing management of the resource. This is particularly true with elements of water resources which include high hazard installations such as dams and also chemical installations.

In the UK the Health & Safety Executive has recently published a discussion document which is relevant. “Regulating Higher hazard Industries” (HSE, 2000) compares the regulations in place for four industries – nuclear sites, onshore chemical plants (COMAH), offshore and railways. It also sets out the four principles underlying the approach by HSE to the regulation of higher hazard industries, the first three being reproduced in Table 1 (the fourth relates to the role of the regulator, and is not directly relevant to systems to assess dam safety).

This document is important to the strategy for management of water resources, as it sets out the need for active management by the owner, rather than relying on satisfying prescriptive standards. One of the tools identified by HSE is quantitative risk assessment (QRA), which can assist in analysing, assessing and managing risks.

Table 1 Principles of "permissioning" regimes (as HSE, 2000)

1. Through the political process, the regulator and the regulated are subject to society's views about the tolerability of risk:
   - *"Permissioning" regimes are applied to high hazard industries, about which society has particular concerns.*
2. The legal duty to manage risks lies with the organisations that create the risks – "permissioning" regimes require them to describe how, but a description is not sufficient without the active commitment of the duty holder in practice:
   - *Duty holders must identify the hazards, assess the risks, develop effective control measures and keep a current documentary record of all this;*
   - *The control measures must cover design and hardware, systems and procedures and human factors in a coherent whole;*
   - *Duty holders must implement control measures and keep them up to date;*
   - *Duty holders must make and test arrangements for managing emergencies and mitigating their consequences.*
3. A goal-setting framework is preferable to a prescriptive one because it makes duty-holders think for themselves.
   - *The flexibility of goal-setting is more likely to lead to arrangements for controlling risk which are tailored to the particular circumstances, and which through safety case maintenance and re-submission will remain so;*
   - *Within a goal-setting context, "permissioning" regimes define elements of the management arrangements required.*

INITIATIVE 1 - INTEGRATED SYSTEM FOR DAM SAFETY

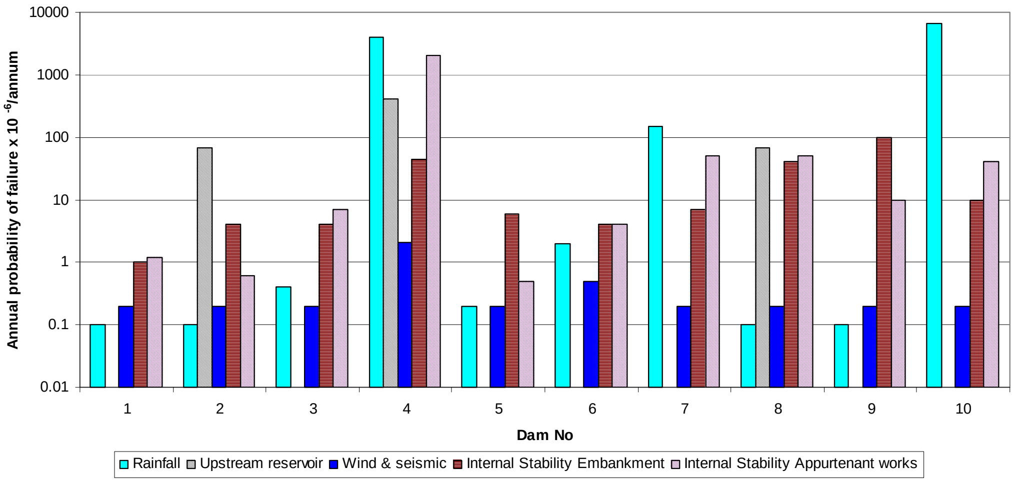
One of the issues that has recently received increased prominence in the UK is the method of estimating floods, the new Flood Estimation handbook (2000) in some cases providing the estimated magnitude of a 10,000 year flood in excess of the Probable Maximum Flood estimated using the older Flood Studies Report (1974) (MacDONALD D E and SCOTT C W, 2000).

This led to the UK Government, through the Department of Environment, Food and Rural Affairs (DEFRA), awarding a research contract to KBR for which the terms of reference include consideration of whether "an Integrated System of assessing possible threats to dam integrity could be devised in which standards for reservoir spillway capacity are determined in association with other features of dam design, condition and operation". The results of this research contract concluded that it is possible to devise such a system, with preliminary results being reported in Brown & Gosden (2002). It is anticipated that it will be developed into a Preliminary System for Risk Assessment of Dams in the near future. Although there is insufficient space here to report the system some of the key concepts relevant to sustainable water resources management are described.

A difficulty that is inevitable in any form of periodic review of adequacy of an asset is that when this review is carried out in isolation of the review of similar assets it is difficult to ensure consistency in the standard against which the asset is measured. The objective of the Integrated System is to use QRA to allow consistent evaluation of a single asset, for example a periodic safety inspection of a dam.

One of the decisions in management of a resource is to determine which are the most important issues. Development of an Integrated System which can estimate the probabilities of failure due to individual threats and then aggregate these to provide an overall probability of failure is one example of how QRA may be used to rank the various threats. An example of this in a pilot study of the Integrated System on 10 dams is given in Figure 1. It can be seen that for Dams 4, 7 and 10 the greatest threat comes from rainfall, whilst for Dams 2 and 8 the greatest threat comes from another dam further upstream.

Figure 1 Histogram of annual probability of failure due to individual threats



A further decision is the level of detail of risk assessment which is appropriate. For some elements of a water resource system a relatively simple level of assessment may be appropriate, whilst for other elements a more sophisticated analysis may be warranted. It must be recognised that different levels of analysis exist and one of the first steps in any Risk Assessment is the level of detail of input data which is available, and the level of detail warranted by the issue under consideration. Related to this is how failure is defined, for a dam it may be catastrophic release of water or it may be some form of operational inadequacy.

Related to this is the methodology used to estimate probabilities of failure. One of the techniques that has found to be useful is databases of failures and "near misses", which if covering a sufficiently large population can be used to estimate the likely future rates of incidents and failures. Although in some industries, such as aviation and offshore petrochemical these databases are well established and provide useful information they are less well established in regard to dams and water resources. Nevertheless the data available on UK dams from the database held by the Building Research Establishment has found to be of some use in estimating probabilities of failure and incidents relating to dam safety; and work is currently underway as to ways in which the value of such a database can be increased.

An issue which is receiving increasing attention is the realisation that our understanding of physical processes has improved with time, and will continue to change in the future. One example is prediction of floods, where in UK in 1933 best practice was based on safety factors on maximum observed floods (ICE, 1933), being overtaken in 1974 by a methodology to estimate a nominal Probable Maximum Flood (NERC, 1974). It is likely that our estimates of floods will change further in the future, both because of improved accuracy of flood estimating and possibly also because of realising the effect of climate change. QRA is of value in this respect, as it allows sensitivity studies.

Benefits that were identified in trialling the pilot Integrated System on ten dams included

- The ability to quantitatively rank the different threats to dam safety, rather than relaying on a judgement as to relative importance
- The implicit use of a sliding scale of acceptability, rather than a simple pass/fail system; this is consistent with the advocacy of use of ALARP to define tolerability of risk
- Providing a quantitative measure of probability of failure would allow comparison between different elements of a water resources system, as well as with other industries

INITIATIVE 2

A Portfolio Risk Assessment has been undertaken for one of the major utilities in the UK. The initial study involved consideration of the owners portfolio of dams, but it is likely that the process will be extended in the future to the assets.

The overall purpose of the Portfolio Risk Assessment (PRA) was as follows:

'To facilitate management of dam safety in the context of the owner's business.'

PRA outcomes can be grouped into the following types:

1) A current risk profile for existing dams including an evaluation against engineering standards/current practice.
2) A basis for improving recurrent dam safety activities (e.g. monitoring and surveillance, inspections, and community emergency preparedness and business contingency planning).
3) An identification of the need to consider urgent short-term risk reduction measures.
4) A basis for formulating a Dam Safety Improvement Program comprising a phased programme of investigations and risk reduction measures, with business justifications, and leading to a more rapid rate of risk reduction than other prioritisation approaches.
5) Inputs to business processes, such as the following:

    a. Insurance and loss financing
    b. Capital budgeting
    c. Business contingency planning and incident management
    d. Benchmarking and due diligence assessments
    e. Community consultation and public relations

PROJECT SCOPE

The PRA was conducted at a 'reconnaissance' level of detail. The dam safety risk model was a generalised and simplified structure, but sufficient to represent all important identified failure modes at UU's dams, probably estimates were based on standard UK practice for floods and earthquakes.

In the case of some failure modes, such as piping, historical performance statistics, modified for attributes of each study dam were used.

Risk reduction measures were identified during the PRA process, only the most likely solution obtaining a representative estimate of risk reduction and the cost effectiveness of risk reduction measures.

Implementation of the PRA process for the dams was accomplished through a team comprising the following:

- Reservoir Safety staff
- Representatives from all business areas
- Inspecting Engineer and support staff
- Engineers & Economists – PRA Team Leader, PRA Engineering Facilitator, Consequences Assessor, and Risk Analyst.

The demands on the clients staff were minimised through efficient PRA input elicitation processes. An Inspecting Engineer from KBR who has extensive experience with dams participated in the PRA input elicitation process together with the Supervising Engineer who was familiar with each dam.

Representatives from business areas were places in determining target outcomes through a detailed PRA design process and through interpretation on the PRA results as part of the development of PRA findings. A Dam Safety Committee was formed to coordinate and inform all business areas on dam safety related issues, including providing oversight to the PRA process (desired outcomes, availability of inputs, use and interpretation of outcomes, review of and strengthening the process, maintaining and updating the PRA). Its membership included management from each business area that relates to dam safety.

WORK PLAN

The PRA work plan was divided into eight tasks.

Detailed PRA design

A key to maximising the value from a PRA is to tailor the PRA process to meet the clients information needs for managing dam safety. We refer to this process as ‘outcome targeting’.

Develop PRA inputs

- Conduct a briefing on risk assessment process and typical format of outcomes
- Review available information on study dams
- Perform engineering assessment based on UK engineering standards/current practice
- Review estimates of loading probabilities (flood, earthquake, normal operating)
- Identify failure modes
- Represent each dam using generic event tree risk model
- Select potential structural or non-structural risk reduction measures and breach parameters for structural measures
- Estimate system response probabilities for existing dam and risk reduction measures
- Estimate warning time inputs
- Identify necessary and possible supporting analyses
- Decide which supporting analyses will be conducted

Flood and earthquake loading

Develop reservoir peak stage – annual exceedance probability (AEP) and peak ground acceleration – AEP relationships for each dam.

Reservoir flood routing

Where not already available, reservoir routing was performed to estimate peak reservoir stages for various design floods and for spillway blocking cases where this was considered to be a possibility.

Dam beak analyses

Where dam break analyses have been performed in the PRA to the maximum extent possible, The results were utilised, otherwise simple dam break analysis was carried out.

Consequences

- Collect inputs for population at risk, evacuation, potential life loss and economic damage estimates
- Conduct population at risk, evacuation, and potential life loss estimates
- Conduct economic damage estimates
- Assemble engineering and consequences inputs for risk analyses

Cost estimates

The most likely risk migration scheme was selected for use in the PRA for obtaining representative estimates of risk reduction and the cost effectiveness of risk reduction.

PRA processing

Risk analysis and risk evaluation calculations were performed for existing dams and risk reduction measures. Initial prioritisations for risk reduction measures and investigations were performed.

Development of findings

A presentation review of review study results with client and management was undertaken to develop the study findings.

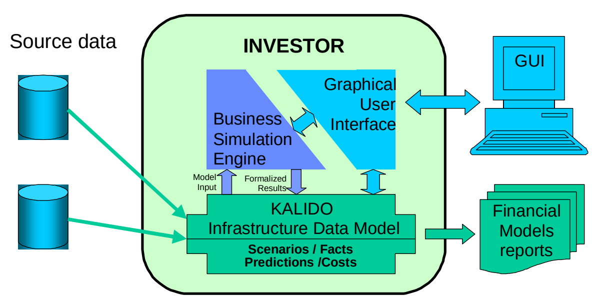
Task 7 report

A final PRA report was prepared. The report documented the risk assessment study process, the inputs, the outcomes, and the limitations. It also discussed the significance of risk assessment results and make recommendations for any additional engineering or risk-based evaluations. It also included a recommended phased approach to further investigations and implementation of risk reduction measures.

INITIATIVE 3

INVESTOR is a UK Department of Trade & Industry sponsored project with the key aim of transferring best practice asset management techniques from the Oil & Gas Industry combined with the latest mathematical modelling, interactive software and data management technologies to other industry sectors.
A proof of concept for INVESTOR technology has been successfully completed in the water industry, with a rail pilot about to commence.

Fig 2 – INVESTOR Architecture



Features

The programme requires the development of a tool set that includes:

- A Model of the relationship between Service Delivery and Asset Condition to determine Whole Life Costing, Including Business Interruption Cost
- ‘What If?” Scenarios for Different Maintenance, Renewal & Engineering Procurement and Construction (EPC) Strategies

- Long-Term Investment Plans with KPI's for Business Improvement
- Business Learning & an Interactive Training Environment for Engineers
- Seamless access through a Data Store to the Asset Catalogue, Legacy and Replacement Information Systems, and Capture of Model Scenarios with Feedback Loops

Description

INVESTOR is being developed to enable whole life cycle-based optimisation of maintenance and renewal interventions for interacting elements within an asset system. It will offer user configurable time frames and is designed to be a decision-support tool.

The model is configured with the predicted investment profiles for a user-defined planning horizon. This allows monitoring of actual physical asset condition, performance and investment, against an asset management plan, providing a key tool for managing performance-based contracts. The Simulation Engine is designed to minimise the data needed to provide acceptable predictions so that the model can be applied at an acceptable cost.

INVESTOR will satisfy the requirement for the Infrastructure Owners and Regulators to monitor not only asset expenditure but also the resultant asset condition and performance.

And provide a strategic vehicle for Infrastructure Owners and Manufacturers to share information in order to improve the performance of their products and enhance their competitiveness.

General description

A prototype version of the Graphical User Interface and business simulation model has been created and is being employed on pilot studies in the Water and Rail sectors. The data store represents mature technology from the Oil & Gas sector. It is used to hold a copy of the asset catalogue, access legacy systems, handle data manipulation, scenario outputs, feedback loops and repository aspects.

The data store is designed to work with asset data models that can change through time. This enables an evolutionary data collection process that is incremental rather than "big bang".

Proof of concept linking condition to serviceability over a 30 years planning horizon

A proof of concept has been undertaken on a large and complex Water Treatment Plant with the objective of demonstrating the feasibility of relating asset condition to serviceability at the tap. The Asset Owner needs were to demonstrate:

- UK Water Industry Research (UKWIR) process compliant & considers condition/deterioration
- Availability of Capex/Opex optimisation process
- A rigorous Investment Verification methodology
- Initial focus on high risk areas
- Linkage to other modelling systems and information systems employed by the asset owner
- Incremental implementation

Asset catalogue and RAM studies

The model design enabled the clients Asset Catalogue to be imported to the data warehouse and used to build the business simulation model. The business model is configurable and operable through the GUI. The GUI also interacts directly with the asset catalogue in the data store.

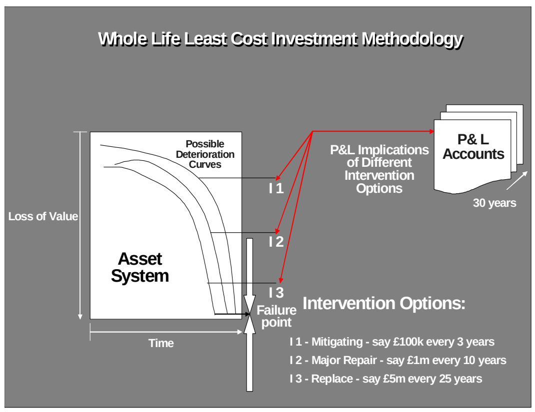
The team carried out an Availability, Reliability and Maintainability (ARM/RAM) study and produced deterioration and failure profiles for each of the processes and asset systems. Information was drawn from a number of sources; Company Systems, Local Systems, Ad-hoc plant data, Personnel, In formats that included; Mainframe, Access, Excel and Hard Copy.

<u>Whole life costing</u>

A “systems” deterioration and failure approach with interactions between components was adopted for the model design. This was necessary to enable optimisation of whole life decisions between maintenance, renewal and enhancement in a “what if?” context that supported learning and use of feedback loops.

The relationships between asset systems deterioration and failure based life cycle interventions and the P&L are illustrated below.

Figure .3 – Whole Life Costing (WLC) Investment Methodology



If we apply an NPV rate to the three intervention strategies set out above, the whole life least cost strategy can be determined.

A number of these major expenditures coming together within a short time frame outside the usual planning period of five to ten years will either seriously undermine the ability of a business to meet its financial targets or result in insidious decline in the assets. Hence the need for both current accounting and NPV methods of measurement within a whole life cycle approach based on an understanding of the rate of deterioration. This is critical to fully understanding the impact of investment decisions for long-lived assets.

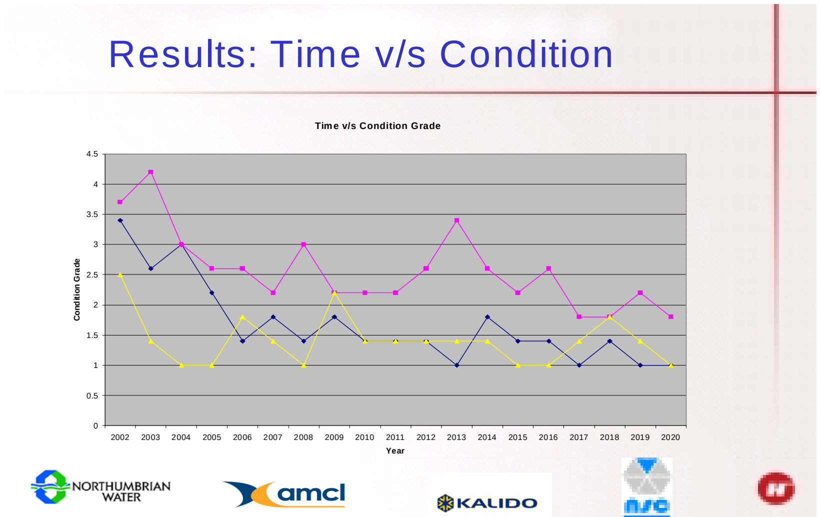
<u>Model outcomes</u>

Outputs from the modelling process include:

- Identified relationships between condition, performance and serviceability
- Management of condition through interventions
- Different through life cost scenarios
- Enabled “What if?” process – optimisation next stage
- Basis for investment verification over time
- Evidenced that it is economic to collect the necessary deterioration and failure data
- Evidence that it could be integrated with other client models if required

Figure 4 below illustrates a typical output from INVESTOR showing the different expected condition grades for three different maintenance policies. INVESTOR has been accepted as compliant with the "common framework" and is being included in the water industry's "Best Practice" forum for delivering CAPEX/OPEX efficiencies.

Fig 4 – Example Output – Time Vs Condition for 3 Maintenance Regimes



The asset owner involved in the proof of concept is planning to use INVESTOR early next year. A number of other water companies have also expressed interest in linking INVESTOR into their risk based modelling techniques and methodologies.

<u>Conclusion</u>

QRA is seen as a valuable additional tool in the management of dam safety, which is likely to play an increasingly important role in the management of all elements of water resources. KBR believes it is at the forefront of the development of a number of tools to help owners, regulators, and others in using risk assessment methodologies in a number of ways.

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