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Environmental risk assessment: An Australian perspective

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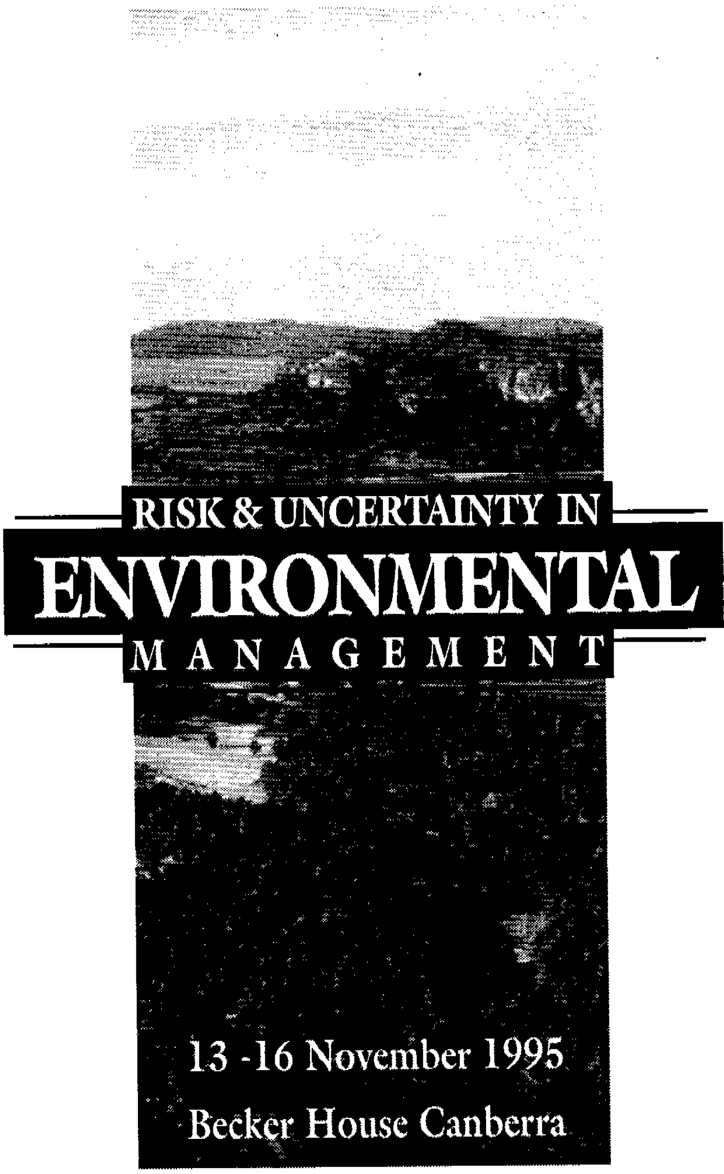

1995 Australian Academy of Science Fenner Conference on the Environment

This report has been prepared to assist with workshop discussions at the 1995 Fenner Conference *supervising scientist report* **102**

Environmental risk assessment: An Australian perspective

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ISSN 1325-1554

ISBN 0 642 24301 8

Printed in Darwin by Image Offset.

Foreword

During 1994 the Department of Environment, Sport & Territories advertised a need for policy advice on a risk assessment review of national environment priorities. Two people undertook this task. Dr Tom Beer was appointed to a six months term as Science Adviser to the Environment Protection Agency (EPA), an agency of the Federal Environment Department and Dr Frank Ziolkowski, an officer of the EPA who was designated as an EPA Fellow during this period.

Our initial response to the assignment was that the brief is akin to being asked to use agricultural science to improve farm productivity. The topic is extraordinarily wide, its method of implementation will differ from area to area and there is a myriad of tools that could be used.

Further, there are three observations that need to be made:

The topic of risk can be likened to an onion. It is composed of many layers, each subsuming the underneath layers. It is fascinating, however, to find that it is a topic in which each single layer of the onion believes itself to be the whole onion.

In American English, the word pavement refers to the roadway. In Australian English, pavement refers to the footpath. In a similar manner, American English and Australian English reverse the meanings of the words risk assessment and risk analysis. In the United States, risk assessment refers to the component of the overall process that is devoted to the calculations, whereas risk analysis is the overall process which includes risk assessment, risk management, risk perception and risk communication. In Australia, risk analysis is widely used to describe the component that is devoted to calculations, whereas risk assessment is understood to be the overall process. The remainder of this document will follow Australian usage, except in direct quotes from US sources.

Risk assessment is a tool to facilitate informed decision making. The decision facing Australian environmental agencies is whether to introduce a process of formalised risk assessment; and if so, how should it be done, and what should be its scope. This document is the first step in this process. The next step will be a conference on risk and uncertainty in environmental management.

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Acknowledgments

Mr Barry Carbon, Executive Director, EPA provided his guidance on the topic in general. Mr Stewart Needham and Mr John Whitelaw provided the requisite administrative support to the science adviser and EPA fellow respectively. In addition, we would like to acknowledge our many colleagues, too numerous to mention, who assisted with advice and information.

Preface

Dr Tom Beer, on secondment from CSIRO's Division of Atmospheric Research, was appointed from December 1994 to June 1995 as Science Adviser to the Environment Protection Agency (EPA) of the Department of the Environment, Sport and Territories (DEST) to investigate and recommend on a risk assessment review of national environmental priorities. Dr Frank Ziolkowski, an EPA Fellow, assisted him during this period.

Environmental risk assessment can be used as a strategic tool to set environmental priorities and as a tactical tool to set environmental standards.

This report is designed to inform Australian environmental managers about the techniques and applications of environmental risk assessment and to familiarise risk analysts with some of the issues that are of concern to environmental managers.

The use of risk assessment is illustrated by applying its techniques to five case studies. Then, by considering Australian and overseas practice, a generic framework is presented within which environmental risk assessment in Australia can be undertaken, and possible methods of implementation are discussed.

A companion document to this report will be prepared in early 1996 which will canvass the options for applying risk assessment to the activities of the DEST portfolio.

Environmental Risk Assessment

An Australian Perspective

Executive Summary

Environmental risk

Environmental risk deals with the probability of an event causing a potentially undesirable effect. Quantitative risk assessment thus deals with statistics, because probability is the mathematical measure of risk, and with hazard assessment which determines the nature of the undesirable effect. The terms have different meanings and different definitions in different areas of study.

Over the past two decades, risk assessment has attained maturity as an engineering discipline assisted by seminal reports by the United States National Research Council and by the Royal Society in Britain. Environmental agencies, principally the US EPA, have embraced it as an objective tool to enable them to set standards, set priorities and provide assistance in decision making. It has long been applied in this way to evaluate the risks to human health arising from radionuclides and chemicals in the environment. Hazard assessment has been used to study natural hazards and assist in preparing for them. The recent application of risk assessment techniques to flora and fauna is being called ecological risk analysis.

The US has a major program using risk assessment to determine environmental priorities at national, state, regional, community and tribal level. Its use in this form is called comparative risk assessment. It involves ranking issues on the basis of their likelihood of occurrence and the magnitude of the actual or perceived consequences.

The means by which risk is managed, the means by which risk is communicated to the public and the consequences of failing to undertake adequate risk assessment or undertaking incorrect risk assessments need to be known and appreciated by environmental practitioners. These issues are seen as an integral part of a quality assured environmental management system.

Methods and results

The approach adopted to the study was based on the following elements:

I. Reviewing the literature, plus extensive consultation to determine Australian practice, and international best practice, in the application of quantitative risk assessment.

II. Identifying areas that are of current concern to environmental protection and choosing appropriate case studies for each area.

Each case study deals with an apparently contentious topic and the discussion of the case study seeks to determine whether the contentious aspects of the topic could have been minimised through application of quantitative risk assessment. The areas, identified by the Executive Director of the EPA, and case studies are:

Risk from chemicals and from contaminated sites: Case study — atrazine.

Field trials on their own fail to provide definitive answers to the behaviour of chemicals. They must be integrated with computer modelling, with the results of the field trials being used to calibrate and validate the model. The model provides a predictive tool in situations other than those of the field trial. There is a reluctance to undertake such integrated studies because no model has received official accreditation. This should be done.

Risk to people from development: Case study — Sydney 3rd runway.

This case study identified deficiencies in the standard methods of measuring the impacts of noise.

Risk to the natural environment from development: Case study — setting priorities to investigate uranium mining.

The techniques of comparative risk assessment were used to propose topics for the next four environmental performance reviews to be conducted by the Office of the Supervising Scientist.

Risks of the uncertainty of nature: Case study — climate change.

Present work on climate change is driven by the implicit risk assessment expressed in the precautionary principle. This envisages large adverse consequences as a result of inaction in the face of a possible hazard.

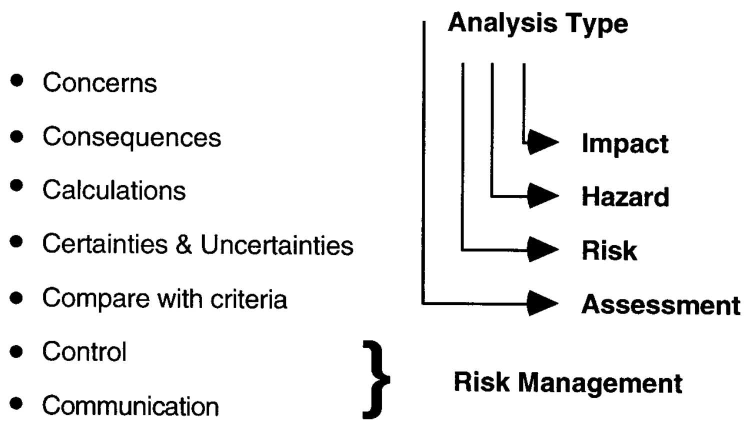
Risk associated with political decision-making: Case study — Coronation Hill.

The Coronation Hill saga highlights the importance of timing. The combination of environmental issues, Aboriginal issues, the timing of elections and leadership disputes led to the failure of the proposal to mine and concern about sovereign risk as an issue in Australian environmental concerns. Time heals. Sovereign risk is no longer perceived to be a risk for miners in Australia.

III The search for a generic framework that can be used for quantitative risk assessment in Australia.

The final choice of generic framework is shown in Figure 1. When the formal methodology of the framework was applied to the question of release of water from the restricted release zone of the Ranger Uranium Mine, the result confirmed that long term land disposal has a 90% probability of exceeding recommended radiation dosages for Aboriginal people living traditional life-styles in the area of land disposal. More significantly, the methodology highlighted that previous research and this analysis all assumed perfect knowledge of the future behaviour of the traditional owners. The fact that this is not known indicates that the Environmental Research Institute of the Supervising Scientist (ERISS) should widen its research to include Aboriginal lifestyles and culture.

Figure 1 Risk Assessment Framework



Implementation

Risk assessment is a tool for informed decision making. The decision facing Australian environmental agencies is whether to introduce a process of formalised risk assessment; and if so, how should it be done and what should be its scope. Any agency that deals with risk assessment needs to be able to deal not only with matters referred to it, but also to have the freedom to identify issues that may pose future risks. This document is the first step in this process.

The next step will be a conference on risk and uncertainty in environmental management. This conference, designated a Fenner Conference by the Academy of Science, will be held 13-16 November 1995. The final day of the conference will consist of a workshop at which it is intended to undertake a risk-benefit analysis of introducing risk assessment. It is anticipated that the costs are quantifiable, once the scope of the process has been determined.

The important benefits are expected to be:

- transparency of process;
- informed decision making; and
- input to priority setting.

Thus, one purpose of a conference such as this is to decide whether the value of these benefits are likely to exceed the costs of implementation.

The generic framework provides a model for accomplishing the technical aspects of risk assessment.

Application of a quantitative risk assessment requires capabilities in four primary areas:

(i) a systems analysis capability that can be used for scenario development;

(ii) technical expertise that can be used to quantify hazards;

(iii) statistical skills, possibly in conjunction with computer modelling expertise, that can be applied to uncertainty analysis as, for example, in probabilistic modelling; and

(iv) expertise that can be used to quantify the costs or benefits associated with assessing priorities.

In most cases, quantitative risk assessment will involve the use of computers and the need to obtain or develop appropriate software. There is probably not enough work within one section of the Department to keep risk analysts employed but there should be enough work across the whole of DEST to do so. Examples from within the EPA include chemicals, contaminated sites, EIA reviews, cumulative impacts, urban air quality and Northern Territory concerns.

Overview

1. Environmental risk assessment

The draft Australian/New Zealand Standard on Risk Management (DR 94351) of October 1994 defines risk as follows:

> *" ... risk arises out of uncertainty. It is the exposure to the possibility of such things as economic or financial loss or gain, physical damage, injury or delay, as a consequence of pursuing a particular course of action."*

The concept of risk has two elements, i.e. the likelihood of something happening and the consequences if it happens.

Hazard is an intrinsic property of a substance, which is activated upon an event. To be more specific, consider the risks associated with diving into shallow water. The shallow water itself constitutes a hazard. The act of diving is the event that precipitates the risk. The consequences can range from severe, such as death by drowning to mild, such as cuts and scratches.

Hazard becomes a risk only when there is a finite probability of a manifestation of the hazard. Within this framework, toxicologists define risk as the product of a hazard and its likelihood of occurrence. To make it easy to remember, Environment Canada uses a definition based on the letter E, in which likelihood of occurrence is replaced by entry into the environment so that

RISK = HAZARD x ENTRY = EXPOSURE x EFFECTS x ENTRY

1.1 Risk analysis and risk assessment

Environmental risk analysis considers the risks to human health, welfare and ecosystems that result from adverse developmental impacts on the natural environment. When the risk analysis is built into a framework that allows one to identify and characterise potential adverse effects of exposure to environmental hazards then the term risk assessment is used. Because so much has been done, especially in the United States, on risks to human health from hazardous chemicals, the concepts from this area have driven much of the thinking about environmental risk assessment.

American English and Australian English reverse the meanings of the words risk assessment and risk analysis. In the United States, risk assessment refers to the component of the overall process that is devoted to the calculations, whereas risk analysis is the overall process which includes risk assessment, risk management, risk perception and risk communication. In Australia, risk analysis is widely used to describe the component that is devoted to calculations, whereas risk assessment is understood to be the overall process.

The environmental impact assessment (EIA) process as undertaken in Australia is itself a form of environmental risk assessment, albeit in general, a qualitative rather than a quantitative risk assessment. An Australian EIA starts with a scoping study that determines the issues and concerns that will need to be addressed by consultation and further studies. The environmental impact statement that is produced should address the consequences arising from the identified issues and concerns. This type of scoping is also an essential part of the risk analysis process. A hazard analysis would then quantify these consequences. The essential extra step involved in converting a hazard analysis to a risk analysis is the introduction of the probabilistic element by finding an answer to the question: what is the likelihood of this hazard causing an effect? The answer to such a question involves some form of uncertainty analysis.

Figure 1 summarises the above generic framework. The left hand side lists the steps involved in undertaking the analysis or assessment shown on the right hand side. Risk assessment requires some determination of the acceptability, or otherwise, of the numbers produced by the risk analysis. Finally, in practice, one wishes to introduce actions to control risks and to communicate these actions as part of .risk management

Risk analysis and risk assessment involve judgements of probability. There are at least three ways in which this is done:

- judgements of *a priori* probability e.g. the chance of throwing double-six with a pair of true dice is one in 36;
- estimates of actual frequency e.g. there is a slightly better than even chance that any given unborn infant will be a boy;
- judgements of credibility e.g. there is now very little chance that France will cancel its atomic tests.

The first two of these methods of determining probability produce a value, when applied to hazards, that is called the actual risk or the objective risk. Risk estimates determined from judgements of credibility are known as the perceived risk, or the subjective risk. In an area as complex as the environment, there is, nowadays, a view that it is impossible to provide a truly objective measure of risk because, for example, there is subjective judgement involved in choosing the data set of historical statistics to be used to determine the objective risk.

1.2 Perceived risk versus actual risk

There is little doubt that the opinions of the public should underlie the evaluation of risk. There is no agreement on how to ascertain the opinions of the public in such a way that they can be reliably used as the basis for risk evaluation. Layfield (1987) states that:

> *"As in other complex aspects of public policy where there are benefits and detriments to different groups, Parliament is best placed to represent the public's attitude to risk."*

People do not perceive risk solely as the expected number of deaths or injuries per unit time. People also rank risks based on how well the process is understood, how equitably the danger is distributed, how well individuals can control their exposure and whether risk is voluntarily assumed. These items can be combined into three major factors. The first is an event's degree of dreadfulness, as determined by features such as the scale of its effects and the degree to which it affects innocent bystanders; the second is a measure of how well the risk is understood; and the third is the number of people exposed. (Morgan, 1993; Slovic, 1994).

The Aboriginal attitude towards uranium mining in the Northern Territory illustrates this. The risk, as perceived by the Aboriginal community, is so great as to preclude risk management options based on technically determined actual risks. McLaughlin(1991) asks: "...Will the assurances of regulators today become regrettable errors in 20 years time?" The water management issue is one that best illustrates the wide discrepancy between the actual risk, as assessed using the tools of ecological risk assessment as they presently stand, and the perceived risk. Extreme rainfalls during the first two months of 1995 meant that the Federal authorities gave approval for the release into Magela Creek of water from the restricted release zone. On 9 March 1995 the Northern Land Council sought an injunction against ERA (who control the Ranger Uranium Mine) to prevent release. ERA offered to hold the release for a week. During that week the heavy rains ceased and the flow rate in Magela Creek dropped below a level sufficient to ensure adequate dilution. Thus no release took place.

2. The benefits in applying environmental risk assessment

Risk analysis comprises a formal set of tools that enables one to deal with uncertainty. Given that societies have long made decisions with less than complete attention to the associated uncertainties, one needs to consider explicitly the reasons for using it, and the benefits to be gained by its use.

An important point to note is that there are two separate uses for environmental risk assessment: strategic risk assessment; and tactical risk assessment. The two will be considered separately.

2.1 Strategic Risk Assessment

Strategic risk assessment refers to the use of risk assessment methods to determine corporate activities such as setting environmental priorities, allocating resources or making informed decisions.

Forecasting

A central purpose of policy analysis and policy research is to help identify the important factors and the sources of disagreement in a problem, and to help anticipate the unexpected through, for example, the development of worst-case scenarios. An explicit treatment of risk and uncertainty forces careful thought, helps identify important and unimportant factors, and assists in contingency planning.

Setting priorities

The use of risk assessment methods to set environmental priorities is encapsulated by the slogan that seeks to undertake actions on worst things first. Examples of such use comprise the setting of topics for company environmental performances reviews — especially when these are of widespread public interest as in the case of uranium mining.

Informed decision-making

The tools of decision analysis and risk assessment require systematic treatment of the possibilities and, if possible, an assignment of probabilities to each of the possibilities. The discipline required to do this informs decision-making. The tools, themselves, will not provide a unique basis from which the answer flows because the evaluation of consequences is filtered through the risk-bias of the decision maker. The debate concerning the Tailings Dam at the Ranger Uranium Mine illustrates this.

Reconciling viewpoints

It is hard to make decisions when experts differ in their judgement. If one insists that the experts divulge the uncertainties of their judgement, then it is easier to determine how much they think they know and whether they really disagree.

Cumulative impact assessment

The present Commonwealth environmental impact assessment process is constrained to deal only with the proposal under consideration. Regulatory authorities who wish to undertake planning studies on the impact of a number of similar activities would need to use risk analysis to do so.

2.2 Tactical risk assessment

Quantitative risk assessment is taken by many toxicologists as being synonymous with assessments of the adverse effects of chemicals. Tactical risk assessment includes this use of the term as well as the use of risk assessment methods to determine the risk to people from planned or existing development. This may arise, for example, from an industrial accident.

Objectivity

The use of quantitative risk assessment to determine environmental standards provides an objective method of setting such standards. To ensure that there is widespread community acceptance and awareness of the process it is vital that appropriate consultation should take place. When dealing with the technical details the consultation needs to be with the technical experts. When translating the technical details to regulatory standards then the consultation needs to be with the wider community.

Transparency of process
Choosing, and implementing, a risk assessment framework provides a transparent process for decision making. This applies both to tactical risk assessment when the process is used to determine regulations, and to strategic risk assessment.

Documentation
Problems are rarely solved permanently. If one wishes to use, or adapt, policy analyses that have been done in the past to help with present problems, then the task is made easier when the uncertainties of the past work have been carefully described. One can then have confidence that the earlier work is being used in an appropriate way.

Reduce Costs
The institution of standard methods of risk analysis provides guidance for environmental practitioners. By training a corps of people able to use such standard methods, analysis costs can be reduced because there is no need to devise individual and unique methods or models for each investigation. This aspect of risk analysis has, to date, made computer modelling particularly attractive in fields such as air quality assessment.

3. International Best Practice in Environmental Risk Assessment

Government
Quantitative risk assessment has been incorporated into the procedures and workings of many environmental agencies around the world. This use of risk assessment in the analysis of chemicals is practised world-wide though the techniques themselves differ. The European Communities favour laboratory tests, the Canadians favour field tests, whereas the United States favours computer modelling. Nevertheless, all their practitioners would agree that, depending on the circumstances, a judicious mix of these techniques may be needed.

There is a growing tendency to use comparative risk assessment as a means of setting environmental priorities. Comparative risk assessment uses the methods of risk analysis, but applies them to problems in which the actual probabilities and consequences cannot be determined from actual historic data. Instead, the probabilities and consequences need to be determined on the basis of community polling in which the various risks are compared.

Industry
Risk assessment is an integral part of quality management systems. It is needed to ensure that objectives are appropriately identified and that activities and resources applied to the achievement of the specified objectives are appropriate. Risk analysis is also useful in addressing the cost-benefit considerations of setting and achieving objectives in light of residual risk tolerances.

Risk analysis has not been explicitly included in the Australian and International standards for environmental management systems. However, risk assessment is seen as a useful component of such a system wherein it can be used to set priorities, to identify environmental problem areas and to implement procedures for risk management and reduction.

Environmental Protection
International best practice in the use of risk assessment for environmental protection manifests itself as ecological risk assessment. This generalises the concept of human exposure to an effect and deals with the response of an ecosystem when exposed to a stressor. Its use in the United States requires a combination of field tests and computer modelling.

Setting environmental standards

Risk management involves evaluating alternative policy options and selecting among them. The United States risk assessment framework separates risk management from risk analysis. Once risk assessment moves out of the toxicological area, it is difficult to maintain such a neat distinction. Cox et al. (1994) point out that:

> *"The separation of science (risk analysis) and economic and social welfare policy (risk management) on the basis that science deals with facts while economics deals with values is unrealistic and illusory. A clean separation is not possible. The recognition and acknowledgment that facts and values are often inseparable gives a human perspective to the technical nature of risk assessment."*

We agree.

Standards comprise one of the major frameworks used to regulate, and hopefully to avoid, risk. They are a centralised process of setting permissible levels of an environmental hazard with the incentive for compliance being liability or a fine. Their advantage is that technological decisions are used to construct a uniform threshold of acceptable risk. The major drawback is that usually no attention is paid to the costs of implementation.

Other possible means of regulating risk are:

(i) taxes and charges;

(ii) using cost effectiveness studies to find the least costly method of achieving a pre-determined risk reduction target — the target may be set on some other basis, usually through the political process;

(iii) cost-benefit analysis; or

(iv) information programs through hazard warnings, labelling and risk communication.

4. Australian (Commonwealth) environmental practice

The Environment Protection Agency (EPA) is part of the Federal Department of the Environment, Sport and Territories. Its objective is to protect and enhance the environment of Australia through national leadership and cooperation.

The EPA:

- provides timely and reliable advice to Government and other decision makers about the environmental impact of proposals;
- works with others to reduce the generation of waste and to ameliorate the impacts of wastes and contaminants;
- works with others to set clear rules for protection against pollution and unacceptable environmental impacts;
- works with others to encourage better protection of the environment;
- provides independent and informed advice on the environmental acceptability of the management of specific developments nominated by Government (for example, uranium mining in the Alligator Rivers Region); and
- conducts environmental research and provides environmental advice to further the management capability for sensitive areas nominated by Government (for example, the impacts of uranium mining in the Alligator Rivers Region, the wetlands and estuaries of the Alligator Rivers Region).

The EPA is currently responsible for the assessment of the environmental effects of industrial, agricultural and veterinary chemicals, and has provided a coordinating mechanism for State authorities in relation to contaminated sites, and in relation to the siting of hazardous facilities. Overseas approaches to these issues focus on computer-based models developed in recent years. For example, the Uniform System for the Evaluation of Substances (USES 1.0) was launched in 1994 in support of the

Netherlands National Environmental Policy Plan. It is a decision support instrument for use by relevant authorities which enables them to make rapid and efficient assessments of the risks posed by substances, including new and existing substances, agricultural pesticides and biocides.

Government agencies responsible for protecting the environment face difficult decisions due to two problems that must be resolved:

- identification and quantification of a particular environmental problem;
- determination of acceptable levels of risk for society.

In making regulatory decisions, these agencies have turned to, or are considering using, risk assessment to identify substances to be regulated, to set budget and resource priorities and to select final control levels. Simulation models that can integrate both the chemical-response profile and exposure are useful in obtaining probabilistic estimates of risk.

The Environment Protection Agency (EPA) conducts a simplified form of risk assessment as part of its assessment of the environmental effects of industrial chemicals, as well as agricultural and veterinary chemicals. Despite the overseas use of risk assessment in dealing with contaminated sites, there has been little such activity by Australian regulatory authorities.

The Office of the Supervising Scientist assesses the adequacy of environmental protection relating to uranium mining in the Alligator Rivers Region and by advising on best practice in environmental protection. There has been considerable ecological, chemical and hydrological research conducted at the Environmental Research Institute of the Supervising Scientist that could form the basis for ecological risk assessment of mining activities.

Another area of present Australian practice which could benefit from the use of risk analysis is in the assessment of the impact of proposals. Many proposals incorporate risk assessments and there is no in-house capability for the EPA to determine the soundness of such analyses. Neither is there an ability to conduct cumulative impact assessment, should there be a requirement for such.

In addition to the requirement for risk assessment within the operational activities of the EPA there is scope for its use as a tool within management decision making. It has previously been mentioned that risk assessment — and risk management — is considered to be an integral part of quality management systems.

5. An Australian environmental risk assessment model

Because risk assessment is used in a large variety of different situations, a generic environmental risk assessment framework — such as that of Figure 1 — provides a conceptual picture, but cannot provide the detailed guidance for the actual steps that need to be implemented to carry out a risk assessment task. The case studies given in the report provide some guidance along these lines and indicate situations in which risk assessment is useful.

The Management Advisory Board of the Australian Public Service (MAB, 1995) identifies a five step generic process for managing risk which, they claim, can be applied at any stage in the life of a policy, program, project, activity or asset. It can also be applied to all levels of an organisation — strategic, tactical and operational. Their five steps — analogous to the generic framework of Figure 1 are in Table 1.

The context establishes the form of hazard analysis and the form of uncertainty analysis that is required. The various chapters in the attached report provide examples of the use of risk assessment to set priorities, to examine the impacts of uranium mining, and to examine chemicals. Table 2 shows how these specific examples fit into the generic framework.

Table 1 Comparison of the generic risk management process and the generic environmental risk assessment framework

	MAB PROCESS	GENERIC FRAMEWORK
Step 1	Establish the context	(Environmental)
Step 2	Identify the risks	Concerns, Consequences
Step 3	Analyse the risks	Calculations/Certainty and Uncertainty
Step 4	Assess and prioritise risks	Compare with criteria
Step 5	Treat the risks	Control, communication

Table 2 Examples of the application of the generic framework

Generic Framework	Risk Assessment Type		
	Comparative	Ecological	Chemical
Concerns	Consultation to identify issues	Stressors to ecosystems	Exposure to chemicals
Consequences	Resources at risk	Ecological Effects	Effects to humans & biota
Calculations	Quantify community concerns	Quantify hazards	Evaluate expected concentrations
Certainty and Uncertainty	Quantify likelihood of manifestation of items of concern	Pathway analysis Monte-carlo modelling	Worst-case analysis
Compare with Criteria	Prioritise	Ecosystem integrity	Q-method
Control	Act on high priority items	Restrict hazardous activities	Restrictions on use or labelling
Communication	Feedback to participants	Document publish and advise	Notify

In practice, many of the variations amongst different forms of risk assessment, such as comparative risk assessment and ecological risk assessment, arise from the way in which the analysis of certainties and uncertainties is carried out. For example, probabilistic modelling based on a Monte-carlo analysis involves four steps:

1. Develop flow charts of the system, likely emissions, pathways and fate of materials.
2. Quantify the hazards associated with each step of the process.
3. Determine probability distributions for key steps in the process and run the Monte-carlo simulations to determine the expected probabilities.
4. Rank the probabilities on the basis of some criterion.

Such an approach highlights the value of, and the need for, computer modelling. A full probabilistic assessment based on Monte-carlo modelling provides comprehensive statistical information on likely outcomes but can only be implemented using computer models.

Application of risk assessment requires capabilities in:

- systems analysis for scenario development;
- technical expertise to quantify hazards;
- statistical and computer modelling skills; and
- expertise to quantify the costs or benefits.

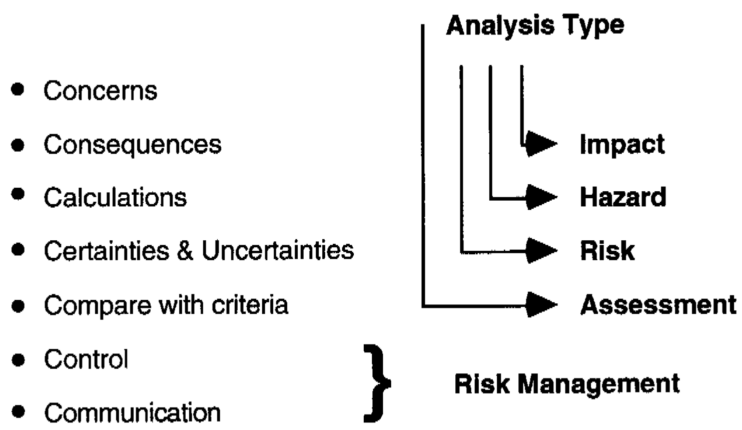
This means that any risk assessment unit needs to consist of at least four people — one in each of the above areas. In practice, more than one person would be needed to handle all the areas of technical expertise that are of relevance to the EPA which embrace chemicals, contaminated sites and issues related to mining.

Any risk assessment unit would be reliant on information technology (IT) support. The need to maintain specialised hardware and software would involve an extra person.

The case study dealing with atrazine indicates the need for a systematic examination of software to be used to assess the environmental effects of chemicals. If a suitable model is then chosen for Australian applications, it will focus data collection on the requirements of the model. At the moment, the lack of suitable databases is being used to argue against running particular models — yet there is a reluctance to collect such databases in case the wrong variables are measured. This need is one of high priority.

The issue of software is then related to the choice of computing platform. Though the IT strategy of the EPA calls for the use of Macintosh systems, most (if not all) of the software developed by the US EPA has been developed for IBM systems. An issue that needs to be determined is, then, whether a risk assessment unit should have access to both platforms — or whether there should be adherence to a single platform, with a program of software translation.

Figure 1 Risk Assessment Framework



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Chapter 1

Why are we Here ?

The Executive Director of the Environment Protection Agency also holds the position of Supervising Scientist, a position which was originally established in 1978 to supervise, coordinate and undertake research related to the protection of the environment from the effects of uranium mining operations. The Executive Director has identified items of risk that are of current concern to environmental protection. These are:

1. **Risk from individual chemicals and risk from contaminated sites**

   The issue here is whether quantitative risk methods or qualitative risk methods are most appropriate to assess the risk of new, and sometimes of old, chemicals in Australia.

   There are two issues related to contaminated sites. The first is the component of risk and consequence associated with determining priorities for clean-up, containment or do-nothing approaches for that contamination. There is also a major risk component in determining the degree of clean-up and the level of clean-up that is satisfactory. Risk in this sense is risk of physical or biological contamination, but is equally risk in terms of financial liability for acceptability of any of the above alternatives.

2. **Risk to people from development**

   The possible occurrence of a large industrial accident such as Bhopal in India, the LPG explosion in Mexico City, Seveso in Italy, Chernobyl in the Ukraine and Piper Alfa in the North Sea needs to be considered as part of an assessment of risk related developments. It is now accepted that quantitative risk assessment is a proper part of such an assessment. A Commonwealth position is needed in relation to quantitative risk, consequences analysis, hazard reduction and other such matters.

3. **Risk to the natural environment from development**

   It would be advantageous for the EPA and the Office of the Supervising Scientist to do a quantitative analysis of the risks of potential impacts from major development and their consequences for environmental protection. The need is for a quantitative assessment of the risks associated with activities and the consequences associated with those risks. This is to allow a consideration of hazard reduction activities, a better basis for priorities for research and a better basis for priorities for environmental management.

4. **Risks of the uncertainty of nature**

   Does Australia understand the risks of changing climate? What are the consequences of nature conservation and for production?

5. **The risk associated with political decision-making**

   The term sovereign risk is used for a part of this. The aim is to systematise, if not quantify, those factors that lead to the risk of a new project not being allowed or being severely constrained.

Approach

The approach adopted to the study of these six issues revolves around the following elements:

1. A literature review followed by extensive consultation to determine present Australian practice and international practice in the application of quantitative risk assessment.

2. The choice of appropriate case studies. Each case study deals with an apparently contentious topic and the discussion of the case study seeks to determine whether the contentious aspects of the topic could have been minimised through application of quantitative risk assessment.
3. The search for a generic framework that can be used for quantitative risk assessment in Australia.

History

Environmental risk deals with the probability of an event causing an undesirable effect. Quantitative risk assessment thus deals with statistics, because probability is the mathematical measure of risk, and with hazard assessment; which ties together the effects of a pollutant with the exposure to the pollutant. Over the past two decades, risk assessment has attained a certain maturity as an engineering discipline assisted by seminal reports from the United States National Research Council (NRC, 1983) and by the Royal Society (Warner, 1983).

The subject recently received renewed interest. The Royal Society considered it timely to update their original report (Royal Society Study Group, 1992). In the United States there has been an almost continuous process of studying and refining risk assessment. The National Research Council has produced at least three recent books dealing with various aspects of the topic (National Research Council, 1989, 1993, 1994) namely: risk communication; toxicological and ecological risk assessment; and risk assessment of hazardous air pollutants respectively.

There are certain areas in which risk assessment has long been applied by environmental protection agencies, principally, the risks to human health arising from chemicals in the environment. Examples of this are to be found in the legal limits on chemical pollutants in air and water. In the United States, the Environmental Protection Agency (US EPA) moved quickly to implement the National Research Council (1983) recommendations and in 1986 adopted a set of guidelines for carcinogen risk assessment. The agency also extended the uses of risk assessment to decisions regarding pesticide residues in food, industrial chemicals, carcinogenic contaminants of drinking water supplies and industrial emissions of carcinogens to surface waters. Particularly important was US EPA's adoption of risk assessment as a guide to decisions at hazardous waste sites.

More recently, there has been a realisation that existing tools of systems analysis can be applied to environmental problems in a manner which is being called ecological risk analysis (Suter, 1993). There has also been a realisation that risk assessment can be used to determine environmental priorities. The US EPA initiated a program, nowadays called comparative risk assessment, that compared the relative residual risks posed by a range of different environmental problems. This was done by systematically generating informed judgements from US EPA managers and technical experts. This resulted in two reports: *Unfinished Business* (US EPA, 1987) and its sequel *Reducing Risk* (US EPA, 1990); and a *Guidebook to Comparing Risks and Setting Environmental Priorities* (US EPA, 1993).

All of these documents emphasise that risk assessment is an overall process of which risk analysis is only a part. The means by which risk is managed, the means by which risk is communicated to the public and the consequences of failing to undertake adequate risk assessment, or undertaking incorrect risk assessments, need to be known and appreciated by environmental practitioners.

Setting Environmental Priorities

There has been a number of recent environmental issues in Australia that led to vigorous public debate. Toyne (1994) recounts a number of the most virulent including Coronation Hill, and the Wesley Vale pulp mill. Coleman (1994), writing from an industry perspective in a recent article, pointed out that the lack of a consistent government environmental policy has led to community uncertainty and identified three associated risks:

- risk of permanent environmental damage if the most pressing issues are not tackled;
- business risk of industry allocating scarce funds to environmental improvements which turn out to be too far ahead of compliance; and
- risk of losing international competitiveness if Australia adopts (or fails to adopt) new environmental policies.

So, what are the most pressing issues and how can they be determined? The US EPA (1987) did this by using its managers and technical experts as risk analysts. The universe of environmental problems was divided into 31 problem areas (eg. air pollutants, hazardous waste sites, pesticide residue in food etc.) with the problem areas corresponding generally to existing US programs or statutes. Four different types of risk were considered for each problem area: cancer risk, non-cancer health risks, ecological effects and welfare effects, but the risks were treated separately and not aggregated. Economic aspects, or technical controllability of the risk, were not considered and neither were the voluntary or involuntary nature of the risk.

Harwell et al. (1992) and Morgenstern & Sessions (1988), in reviewing the project, point out that it involved more judgement and less objective analysis than was expected. They also make much of the difference between the rankings of the experts and the rankings of the public. For example, the public at the time ranked the risks from active and inactive hazardous waste sites as most serious, whereas the EPA experts ranked the risks from these sites as medium/low. At the other end of the scale, the public ranked the seriousness of indoor air pollution and global warming as relatively low, while the EPA experts ranked them as high. In a number of other areas there was agreement between public and experts.

The views of the Australian public on environmental issues have been determined by a number of different groups on a number of occasions (Lothian, 1994). The most recent of these was the 1993 survey conducted by ANOP (1993), a firm that had previously conducted a similar poll in 1991. The respondents' ranking of the priorities that they believe that the Federal Government should have are given in Table 1.1

Table 1.1 Desired Federal Government priorities for the most important environmental issues

Rank	December 1991	September 1993
1	Disposal of chemicals and industrial waste	Disposal of chemicals and industrial waste
2	Water pollution	Water pollution
3	Land degradation	Air pollution
4	Recycling	Recycling
5	Air pollution	Protection of native forests
6	Depletion of ozone layer	Depletion of ozone layer
7	Greenhouse effect	Land degradation
8	Endangered plants and animals	Endangered plants and animals
9	Energy conservation	Protection of coastlines
10	National parks and heritage areas	Greenhouse effect
11	Schemes for environmentally friendly products	Land clearance controls
12	Urban sprawl	Protection of grazing lands
13	Preservation of Antarctica	Urban sprawl

The rankings in Table 1.1 are determined on the basis of responses to pre-determined questions. When respondents were asked spontaneously to nominate the main issues of concern in Australia, then industrial waste was ranked fifth (in 1993), being mentioned by only 12% of those surveyed.

There is little doubt that the opinions of the public should underlie the evaluation of risk. There is, however, no agreement on how to ascertain the opinions of the public in such a way that they can be used reliably as the basis for risk evaluation. Layfield (1987) (quoted in Royal Society Study Group, 1992, p. 93) states that: "As in other complex aspects of public policy where there are benefits and detriments to different groups, Parliament is best placed to represent the public's attitude to risk."

Perceived risk versus actual risk

The historical antecedents of risk assessment are in operations research. The field thus has a long history of quantifying industrial operations to determine the probability of an untoward consequence. For example, the working paper on hazard analysis and risk assessment for the Sydney Third Runway Proposal (ACARRE, 1990) cites accident rates for airline operations that were deduced from data obtained from the Bureau of Air Safety Investigation and the Civil Aviation Authority. These are given in Table 1.2

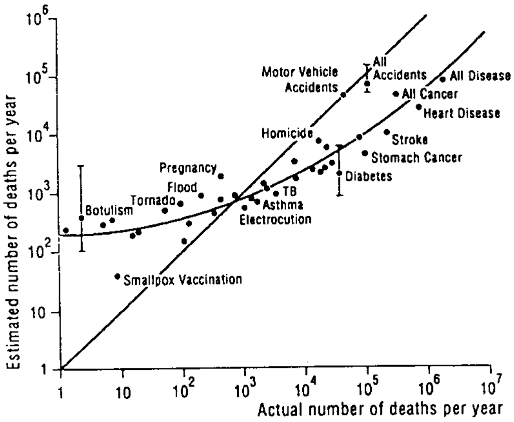
Table 1.2 Accident rates for Australian airline operations, 1978-87

	International	Domestic	Total
per 100 000 hours flown	0.230	0.188	0.198
per 100 000 landings	1.126	0.229	0.297
per 100 million km flown	0.391	0.452	0.429
per 100 million passenger km	0.0012	0.005	0.0026

Provided that information on the flying habits of people are known, then it is possible to use the data in Table 1.2 to calculate the risk of an accident to an individual. Because the calculation is based on objective data, such a risk is called the actual risk. The perceived risk, or subjective risk, is the risk estimate obtained by surveying the public either for their estimate of the hazard involved (very safe, safe, marginal, dangerous, very dangerous) or for their estimate of the number of airline accidents.

To a certain extent it is impossible to provide a truly objective measure of risk. Choosing numbers from one of the four rows of Table 1.2, rather from another row, involves a subjective decision. There is also an impression that the public does reasonably well at estimating risk. Figure 1.1 depicts the scatter plot when educated lay subjects' estimates of the annual frequency of death in the US from 40 hazards are plotted against the best available US public health statistics. Respondents tend to overestimate the deaths from infrequent causes such as botulism and tornadoes, but to underestimate the deaths from frequent causes such as cancer and diabetes.

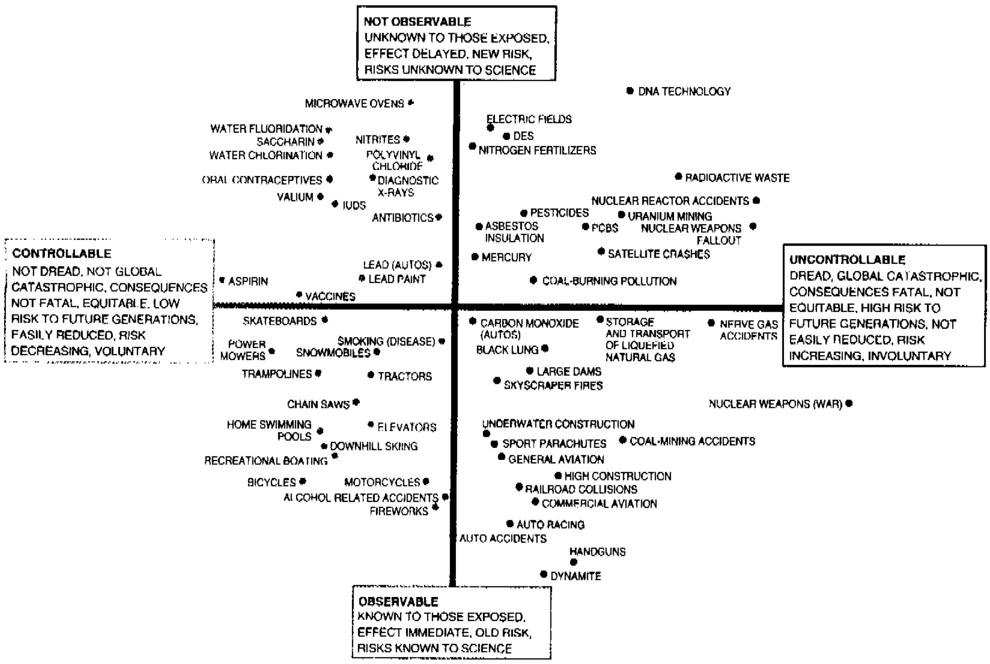
Figure 1.1 Relationship between judged frequency and statistical estimates of the number of deaths per year (US) for 40 causes of death. (From Fischhoff et al, 1981)



People do not perceive risk solely as the expected number of deaths or injuries per unit time. People also rank risks based on how well the process is understood, how equitably the danger is distributed, how well individuals can control their exposure and whether risk is voluntarily assumed. These items can be combined into three major factors. The first is an event's degree of dreadfulness, as determined by features such as the scale of its effects and the degree to which it affects innocent bystanders; the second is a measure of how well the risk is understood; and the third is the number of people exposed. (Morgan, 1993; Slovic, 1994).

The three factors can be used to define a risk space. The location of a hazard within this space indicates how people are likely to respond to it. Risks carrying a high level of dread, for example, provoke more calls for government intervention than do some more workaday risks that actually cause more deaths or injuries (Figure 1.2).

Figure 1.2 Two dimensions of a three-dimensional risk space link a hazard's controllability (dreadfulness) and observability (understanding). *(From G Morgan, July 1993).*



Risk and uncertainty in policy analysis

Subsequent parts of this document will make it clear that we envisage risk analysis as a formal set of tools that enable one to deal with uncertainty. Morgan & Henrion (1990) point out that societies have long made decisions with less than complete attention to the associated uncertainties, and then ask the rhetorical question: why does technical uncertainty in risk assessment and other forms of policy research and analysis really matter? Their answer is three-fold:

1. A central purpose of policy research and policy analysis is to help in identifying the important factors and the sources of disagreement in a problem, and to help in anticipating the otherwise unexpected. An explicit treatment of uncertainty forces careful thought, helps identify important and unimportant factors, and assists in contingency planning.
2. It is hard to make decisions when experts differ in their judgement. If one insists that the experts divulge the uncertainties of their judgement, then it is easier to determine how much they think they know and whether they really disagree.
3. Problems are rarely solved permanently. To use, or adapt, past policy analyses to help with present problems, then the task is made easier when the uncertainties of the past work have been carefully described. One can then have confidence that the earlier work is being used appropriately.

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Chapter 2

What Is Risk?

Introduction

The antecedents of what has become risk analysis and risk assessment are intertwined in many different areas of science, engineering and technology. Because of this, important and helpful papers have appeared in a wide assortment of journals not easily accessible to all interested parties. Glickman & Gough (1990) produced a collection of readings that provides a useful overview of the topic.

The hazards of ionising radiation have been appreciated since early this century and it is therefore fitting that one of the earliest large-scale risk assessments was the Reactor Safety Study which used a team of about sixty people to undertake a quantitative study of the safety of light-water reactors (US Nuclear Regulatory Commission, 1975, Rasmussen, 1981). The health issues involved in the radiation area, where large doses of radiation lead to serious health problems, and the methods used to study them, helped to shape the tools involved in health risk assessment. Work on natural hazards, and the use of applied statistics in engineering design has come together in risk assessment methods to examine issues such as oil spills, accidental chemical releases and climate change.

The use of risk analysis by regulatory agencies in the United States was an outcome of the US prohibition on the use of food additives found to be carcinogenic. As recounted in the influential report of the National Research Council (1983), widely known as the red book because of the colour of its cover, the law was also interpreted as prohibiting approval of any drug, for use in animals produced for human food, that had been shown to cause cancer. In 1962 this requirement was relaxed so that a carcinogenic animal drug could be approved if the Food and Drug Agency (FDA) was convinced that, by using approved analytical methods, no residue of a drug would be found in edible tissues of treated animals. This proved unworkable for two reasons: firstly, progress in analytical chemistry was so rapid that approved methods of analysis quickly became obsolete and, secondly, improved detection methods showed that no drug administered to animals is ever entirely absent from animal tissues.

In an attempt to provide a consistent and predictable procedure for approving methods to search for drug residues, the FDA decided that, rather than gear criteria to an analytical technique, the standards would be defined in terms of risk, and they specified a 10^{-6} lifetime risk of cancer as a quantitative criterion of insignificance.

Risk and Hazard

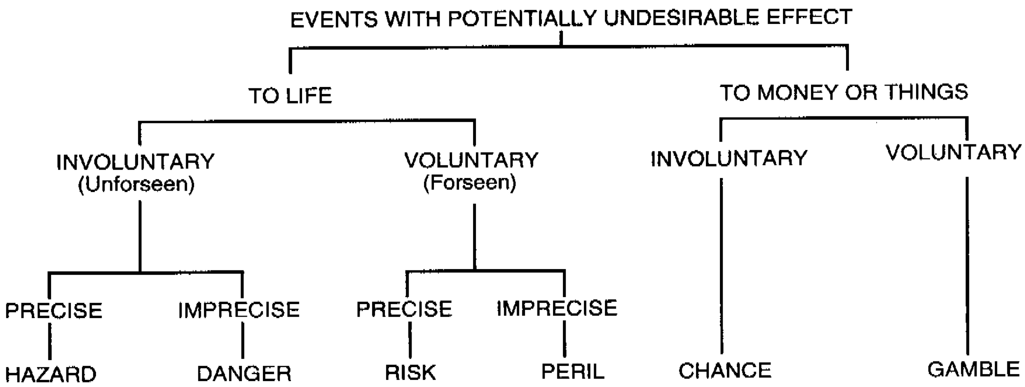
There is a distinction between risk and hazard, but the nature of the distinction between the two varies depending on the discipline. Ingles (1991) considers the term hazard to refer to a precisely defined involuntary (i.e. unforseen) event with potentially undesirable effects on life, whereas risk refers to a voluntary event (i.e. foreseen). This is summarised in Fig. 2.1.

This is **not** the way that hazard and risk tend to be used in the literature related to technological risk. In these disciplines it is more usual to consider hazard to be an intrinsic property of a substance, which is activated upon an event. The term risk then tends to have a dual usage. It is sometimes used to refer to the probability of the event occurring; and it is sometimes used to refer to the combination of the probability and its consequences.

To be more specific. Consider the risks associated with diving into shallow water. The shallow water itself constitutes a hazard. The act of diving is the event that precipitates the risk. The consequences can range from severe, such as death by drowning to mild, such as cuts and scratches.

The concept of risk, and the idea of risk management, are used in many diverse fields. Sometimes, however, even though the words used are the same, their meaning differs in different disciplines. This section discusses the way in which different disciplines use the term risk.

Figure 2.1 Modern English Usage for "Events with potentially undesirable effects." (From Ingles, 1991)



Risk in Financial Management

Imagine the situation where you wish to purchase 1000 shares of a company at $1 each. What is your risk?

When phrased like this, it begins to look as if the question is not adequately defined. One response is, risk of what? Risk of being run over by a car on the way to the stockbroker's office? Risk of financial loss? Risk of financial liability? Risk of legal liability? Or all of these?

Some of the possible answers that one could envisage are:

a) You are risking $1000. This perfectly legitimate answer concentrates on the upper bound of financial loss. If you really believed that you were risking this money, with no possible compensating benefit, then you would not go ahead with the purchase. Many who never purchase shares must feel like this. But the many who do own shares must believe that the possible future benefits outweigh this particular definition of risk. Thus, a more sophisticated definition should capture this complexity.

b) A statistically proficient stockbroker could prove to you that there is no risk. Consider that the shares move in $1 price increments. And let us assume that over the course of a year the probability of a $1 decrease is 0.1, the probability of no change in price is 0.6, the probability of a $1 gain is 0.2 and the probability of a $2 gain is 0.1. These are summarised in Table 2.1

Table 2.1 Hypothetical likelihood table for a share purchase

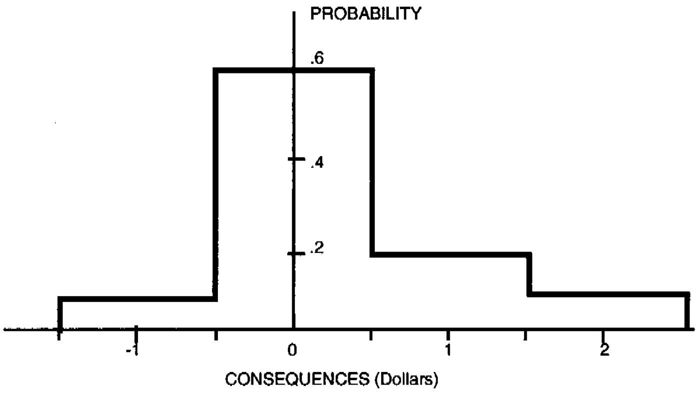
Expected price movement	Probability
$2	0.1
$1	0.2
$0	0.6
-$1	0.1

The expected mean value of the purchase is then obtained by adding together the product of each price movement with its associated probability. The answer is then $0.30 per share. The expected return on the purchase is a gain, hence, one could argue, there is no risk.

Alternatively, one could argue that the risk is 0.1, namely the probability of a loss, or that the risk is $0.10 per share, the expected mean value of the loss.

c) The applied statisticians approach to the discussion so far would be to note that all of the information given in Table 2.1 could be expressed in a single function, the probability distribution function, that plots the probability on one axis and the consequences on the other axis. The dollar values such as the $1000 ($1 per share) given in section (a), or the $0.30 and $0.10 mentioned in section (b), are then particular estimates obtained from this distribution. This is depicted in Fig. 2.2

Figure 2.2 The probability distribution function for an assumed share purchase links the consequences (measured in terms of price movements) with their probability of occurrence.



d) The original question posed in this section failed to specify the nature of the company in which one wished to purchase shares. Surely the purchase of $1000 worth of shares in a large, well-established company is less risky than the purchase of $1000 worth of shares in a speculative venture. This is true, and can be accommodated in Fig. 2.2 and Table 2.1 by changing the probabilities according to the type of company under consideration.

e) The term risk, when used in financial management, attempts to quantify the probability of loss as contrasted to the probability of gain. When used in connection with the stock market, risk is equated with volatility, which is defined as the standard deviation of the share price (Brearley, 1969). Thus, a share whose price fluctuates little is considered to be of lower risk than a share whose price fluctuates a lot.

The financial management definition of risk emphasises the statistical nature of risk categorisation. Though it is easy to criticise the process as being one in which a future, unknown standard deviation (the future risk) is estimated from historical data, it is also true that the definition is simple and allows an analyst to compute the risk of a particular share rapidly, and also the relative risk between them.

The problems of allocating financial priorities (i.e. investment decisions) solely on the basis of financial risk should be evident. It is a valid technique only if the past continues to be a guide to the future, and this cannot, in general, be guaranteed. An investment decision based solely on risk minimisation will give first priority for investment to a stock whose price has remained steady for as long as possible. Conversely, a risk-based strategy designed to offer the greatest probability of profit (but also the same probability of loss) would give first priority for investment to a stock with the most volatile share price. Yet in both cases the strategy could be flawed because of future changes. The apparently risk-free strategy (based on risk defined as the standard deviation of the share price) has a real risk attached to it that a change in circumstances (e.g. death of a key executive) will alter the hitherto unalterable share price. And the high risk strategy designed to offer the maximum potential for profit can come adrift not just because the profit could turn into a loss, but also because a previously volatile stock could suddenly become quiescent.

Earthquake risk and insurance

Brillinger (1993) deals with the statistical issues involved in using financial insurance to protect against natural catastrophes such as an earthquake. The problem of risk within the insurance industry focuses on two crucial components:

- calculation of a premium commensurate with the risk;
- estimation of the size of the probable maximum loss resulting from a potential catastrophe.

To be specific, consider a time period of one year and suppose that the yearly possible loss is a random amount U. The pure risk premium for a year's insurance is given by the expectation value of U. Other premium formulas have been suggested that take note of random fluctuations by incorporating the standard deviation or the variance of the random distribution of U.

Yet another procedure for determining premiums is to select some acceptable probability of financial ruin and determine premiums such that the probability of financial ruin is less than the probability that the total of claims paid out exceeds the income plus reserves of the insurance company.

Application of the above concepts combined with probabilistic modelling of the spatial and temporal aspects of earthquakes may be found in Brillinger (1993).

Bushfire management

Australian fire-fighting authorities have long made a distinction between fire danger, fire hazard and fire risk. Of these, fire danger is the one most commonly used and disseminated to the community through boards in country areas warning people that the fire danger is low, medium, high, very high or extreme. These five categories are actually based on a complicated formula that combines meteorological information (wind, relative humidity, temperature) with information on the fuel dryness to produce a number between 0 and 100, known as the Macarthur Fire Danger Index. This is then divided into five categories such that 50-100 is extreme, 25-50 is high, 12-25 is high, 6-12 is medium and less than 6 is low fire danger.

Fire hazard is normally considered to be measured by the intensity of a fire once it is alight. This can be calculated as a function of the fire danger and the quantity of fuel. Fire risk, by contrast, needs to incorporate some measure of the probability of ignition actually taking place. In practice, this is correlated with the fire danger. Days of extreme fire danger have a higher probability of ignitions taking place than days of lower fire danger. But it is also true that days of extreme fire danger can exist with no fires during the day.

Defining risk

The above discussion illustrates the many problems facing a definition of risk. One particular problem, mentioned by White (1995), is that a perfectly sensible definition of risk within a specialised area may be ludicrous when applied to another area. His example is, that if risk is defined solely in terms of uncertainty, then playing Russian Roulette with six bullets in the chamber has a zero risk associated with it, because there is no uncertainty about the outcome.

The US Society of Risk Analysts set up a definitions committee in 1985 to consider the issue. After two years of work they produced the following list of thirteen possible definitions:

1. Possibility of loss, injury, disadvantage or destruction; to expose to hazard or danger; to incur risk of danger.

2. An expression of possible loss over a specific period of time or number of operational cycles.
3. Consequence per unit time = Frequency (Events per unit time) x Magnitude (Consequences per event)
4. Measure of the probability and severity of adverse effects.
5. Conditional probability of an adverse effect (given that the necessary causative events have occurred).
6. Potential for unwanted negative consequences of an event or activity.
7. Probability that a substance will produce harm under specified conditions.
8. Probability of loss or injury to people and property.
9. Potential for realisation of unwanted, negative consequences to human life, health or the environment.
10. Product for a probability of an adverse event times the consequences of that event were it to occur.
11. Function of two major factors: (a) probability that an event, or series of events of various magnitudes, will occur, and (b) the consequences of the event(s).
12. Probability distribution over all possible consequences of a specific cause which can have an adverse effect on human health, property or the environment.
13. Measure of the occurrence and severity of an adverse effect to health, property or the environment.

The unifying thread is that the definition of risk involves one or more of three essential elements:

- a time frame over which the risk or risks are being considered;
- a probability of the occurrence of one or more events; and
- a measure of the consequence of those events.

As a general definition we would therefore postulate a set theory definition (Kaplan & Garrick, 1981) that treats risk over a given time as the union of the set of possible consequences and their associated probabilities. However, the exact implementation of this definition is going to depend on the particular discipline. Kaplan & Garrick (1981) specifically include the choice of scenarios as one of the sets under consideration, but it seems more sensible to consider the range of scenarios as defining the universe of discourse. They also fail to consider time explicitly within their definition, though it can appear implicitly when the probabilities are determined on the basis of recurrence intervals. As a general definition we therefore suggest that:

RISK DURING A GIVEN TIME = {CONSEQUENCES} **U** {PROBABILITIES}

of the scenarios under consideration

but will use specific definitions appropriate to the sub-fields of interest.

Risk in toxicology

Hazard assessment is the most commonly used methodology for analysing the effects of chemicals on the natural environment. Klöpffer (1994) formalises the definition of hazard with:

HAZARD = EXPOSURE X EFFECTS

The multiplication sign in this case is taken to indicate that there should be no hazard if there is no exposure or if there is no adverse effect. There is some concern, noted by Klöpffer (1994) that the above concept of hazard may not be applicable to extremely toxic and persistent chemicals. For example, polychlorinated dibenzodioxins and dibenzofurans are examples of a rare group of products (xenobiotica) that are both extremely toxic and persistent. This is the worst possible combination of properties. Substances such as these pose a hazard even if their exposure is zero because of the potential for future exposure. Similarly, persistent chemicals do not fit the above definition because even if their effects are believed to be zero, it may subsequently emerge, as in the case of DDT, that this is incorrect. Persistent chemicals that are currently perceived as benign need to be viewed as having potentially hazardous effects.

The distinction that is usually made between risk and hazard is, then, that hazard is an intrinsic property that becomes a risk only when there is a finite probability of a manifestation of the hazard. Within this framework, one would then define risk as the product of a hazard and its likelihood of occurrence

RISK = HAZARD X LIKELIHOOD OF OCCURRENCE

This definition has widespread acceptance within toxicology. To make it easier to remember, Environment Canada use a definition based on the letter 'e', in which likelihood of occurrence is replaced by entry into the environment so that:

RISK = HAZARD x ENTRY = **E**XPOSURE x **E**FFECTS x **E**NTRY

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Chapter 3

What Is Risk Assessment, Anyway?

Introduction

Figure 3.1 shows the basic methodology for hazard and risk assessment used by the New South Wales Department of Planning to assess the risk to a surrounding population from an industrial accident (Department of Planning, 1994). It comprises four elements:

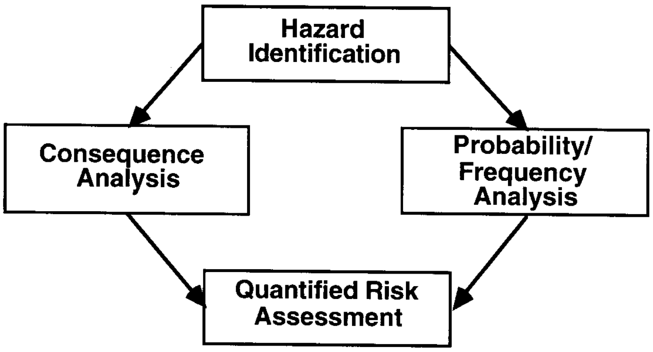
Hazard Identification consists of systematically identifying hazardous events, their potential causes and their consequences — in qualitative terms.

Consequence analysis consists of estimates of the effects of potentially hazardous incidents. This step relies on mathematical models and computerised tools. The outcome of a consequence analysis will be a quantitative estimate of the hazard.

Probability/Frequency Analysis consists of estimates of the likelihood of incidents occurring and the likelihood of particular outcomes (or effects) should those events occur.

Quantified Risk Assessment refers to the combination of the likelihood and the consequences. Risk results are most commonly expressed in terms of human fatality when industrial accidents and chemicals are considered. Other terms can be used such as levels of injury, property damage or environmental damage.

Figure 3.1 Basic Methodology for Hazard Analysis (From Dept of Planning, NSW, 1994)



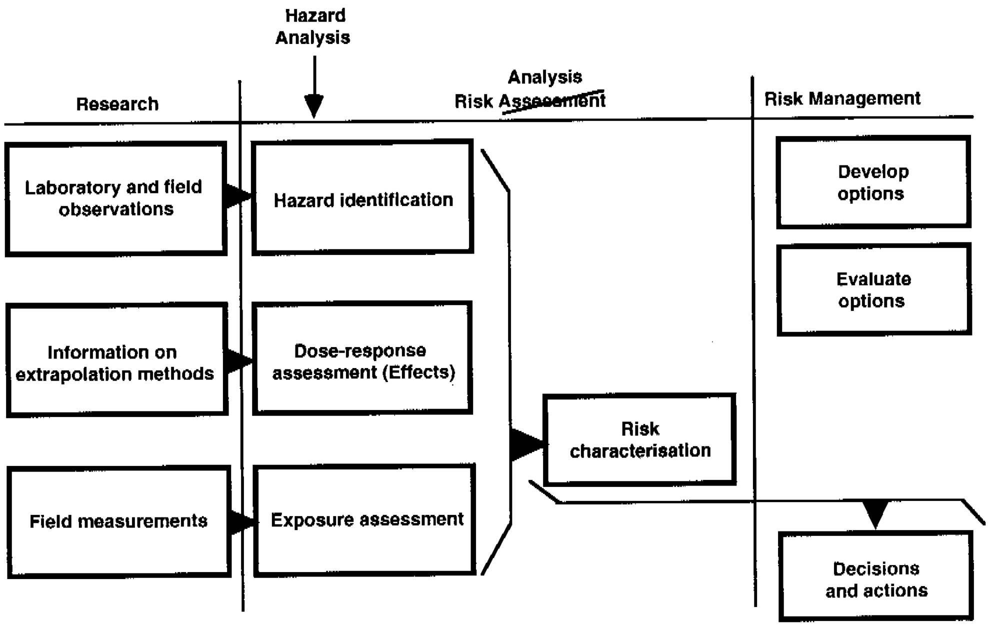
Analysis, assessment and management of risk

Environmental risk analysis considers the risks to human health, welfare and ecosystems that are the result of adverse developmental impacts on the natural environment. When the risk analysis is built into a framework that allows one to identify and characterise potential adverse effects of exposure to environmental hazards then the term risk assessment is used. Because so much has been done, especially in the United States, on risks to human health from hazardous chemicals used or produced in industrial projects the concepts from this area have driven much of the thinking about environmental risk assessment.

American English and Australian English reverse the meanings of the words risk assessment and risk analysis. In the United States, risk assessment refers to the component of the overall process that is devoted to the calculations, whereas risk analysis is the overall process which includes risk assessment, risk management, risk perception and risk communication. In Australia, risk analysis is widely used to describe the component that is devoted to calculations, whereas risk assessment is understood to be the overall process.

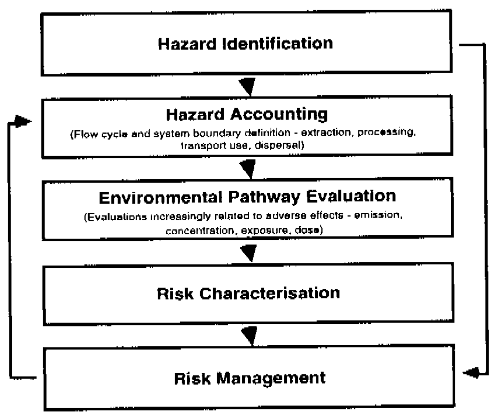
The most frequently cited risk assessment framework (in the US meaning of the term) is that of the National Research Council (1983) which is reproduced in Fig. 3.2. This framework is used by the US EPA for the health effects of chemicals, which they refer to as human-health risk assessment. This framework is based on a belief that most risk assessment problems are similar to those concerning food additives. The framework does not apply equally well to toxics in the environment.

Figure 3.2 Risk Assessment US (1983) Framework (From National Research Council, 1983)



Other criticisms (Office of the Environment, 1991) are that it fails to note the critical importance of carefully and systematically describing the relevant aspects of the project in question, including setting boundaries in space and time. This step is considered necessary to identify the important points where chemical and other hazards may exist. The Asian Development Bank (Office of the Environment, 1991) considers that the National Research Council framework essentially represents the results of such a determination only for a particular set of conditions and management questions. It therefore suggests that the framework of Smith et al. (1988), as shown in Fig. 3.3, is more appropriate. In fact, the US EPA when developing their guidelines for ecological risk assessment (US EPA, 1992) also felt that the framework of Fig. 3.2 was not the most appropriate one and used an alternative (Fig. 7.1) to be discussed in Chapter 7.

Figure 3.3 Recommended risk assessment framework (Smith et al. 1988:23)



It is noteworthy that Fig. 3.2 considers risk management to be separate from risk assessment, whereas Fig. 3.3 integrates risk management into the risk assessment framework. The concept of separation, strongly espoused by ex-US EPA administrator Ruckelshaus (1985), sees regulators (such as the US EPA) who, in striving to support the continued improvement of the science that underpins the risk assessment process, must keep this process separate from risk management, which considers risks in the light of related socio-economic factors. They share a vision of decision making in this process being accomplished at the local level, within broad bounds set at higher government levels.

Paustenbach (1993) also considers the separation of risk assessment from risk management to be the most significant accomplishment of the report of the National Research Council (1983). The purpose of this separation is to ensure that the risk assessment process remains one that is objective. According to Paustenbach (1993), many of the early assessments were so laden with value judgments and the subjective views of the risk assessors that the risk manager was unable to separate the scientific interpretation (the risk analysis, within the terminology that we are using), from the wishes of the risk scientist.

This issue of the separation of management and analysis tasks is related to the ethos of the organisation. If an organisation considers itself to be composed of technicians and regulators, then the US orientation is appropriate. If the organisation sees its role as management and policy analysis, then it is not necessarily appropriate to insist on a clear separation between the analysis and management functions.

Risk communication

Following the favourable reception of the 1983 report of the National Research Council (1983), the emphasis in the United States turned from risk assessment to risk communication (Plough & Krimsky, 1987). A National Research Council (1989) report emphasises that risk communication is more than one-way communication of risk messages from experts to non-experts. Risk communication is an interactive process of exchange of information and opinion among individuals, groups and institutions.

These bland words hide the fact that environmental priorities need to reflect the risks perceived by the community. Experts primarily interested in risk communication have suggested that this can be expressed by using a definition for risk based on community perception as follows:

RISK = HAZARD x OUTRAGE

Health risk assessment , ecological risk assessment, and comparative risk assessment

The literature on environmental risk assessment is divided into three major areas: health risk assessment (Paustenbach, 1995), which deals with the effects of chemicals on the human population, the recent notions of ecological risk assessment (US EPA, 1992; Suter et al., 1993) and, more recently, comparative risk assessment (Davies, 1995).

Much of the development of health risk assessment is the result of work done outside environmental agencies. Ecological risk assessment, by contrast, is a more recent activity that integrates numerous techniques from ecology, environmental systems analysis and traditional engineering risk analysis to use them in a risk assessment framework. This approach has produced some useful advances in that attention is directed to the common elements of the disciplines in the search for a synergistic approach that combines the best elements of both.

The United States EPA was also a major motivating force in the use of risk assessment as a tool with which to determine environmental priorities (Davies, 1995). This has already been mentioned in Chapter 1. The issue of comparative risk analysis rose to the top of the environmental policy agenda in the 1990s because the budgetary squeeze at all levels of government made it obvious that not every environmental problem could be addressed — somehow priorities had to be set. One of the strengths of the comparative risk assessment process is that it encourages people to take a much broader look at the environment than they would if they focused only on a single agency's existing programs, as typically happens in the budget process (Minard, 1995).

The United States experience

An overview of the United States approach to science-based environmental management, and its strong reliance on risk assessment to provide quantitative answers, may be found in a special issue of *Technology: Journal of the Franklin Institute* (Moghissi and Tise, 1994) devoted to this topic.

Health Risk Assessment

The United States experience with risk assessment, primarily health risk assessment, is dealt with by the National Research Council (1983, 1989). The use of risk assessment in regulatory decision-making necessitates a decision on which substance to regulate. This depends in part on the degree of hazard, so risk assessment has been used (either explicitly or implicitly) to set priorities. The United States experience was that risk assessment for priority setting (i.e. choosing from amongst the range of substances to regulate) was more informal, less systematic and less visible than those for establishing regulatory controls.

Agenda setting involves decisions about which substances to select, and in what order, for more intense formal regulatory review. In this phase there must be some assessment, however informal, that indicates reason for concern. Chemicals that are judged to present appreciable risks to health are candidates for regulatory action and an agency will begin to develop options for regulatory exposures. An important point here is that priority setting and regulatory option determination place different requirements on risk assessors. A risk assessment to establish testing priorities may incorporate many worst-case assumptions if there are data gaps because research should be directed at substances with the most critical gaps. But such assumptions may be inappropriate for analysing regulatory controls, particularly if the regulator must try to ensure that controls are acceptable and comprise 'good law' to the extent that they are, by and large, complied with and can be enforced. In establishing regulatory priorities, the same inference options should be chosen for all chemicals, because the main point of the analysis is to make useful risk comparisons so that agency resources will be used rationally.

Ecological risk assessment

The US EPA (1992) published a framework for ecological risk assessment and followed this up with policy guidance for managers that have to deal with ecological risk (Troyer & Brody, 1994). The framework constitutes an interim product to be refined at a later stage with the production of formal risk assessment guidelines. The report (US EPA, 1992) defines ecological risk assessment as 'a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors'. A stressor includes any chemical, physical or biological entity that can induce adverse effects on individuals, populations, communities or ecosystems. The term stressor is a deliberate attempt to replace the term 'dose-response' and steer conventional views in risk assessment to include risks due to elements other than chemicals. The framework for ecological risk is similar in concept to the human health risk guidelines (National Research Council, 1983), but there are three areas of difference:

i) it considers effects beyond individuals of a species and examines populations, communities or ecosystems as appropriate;

ii) there is no single set of ecological values to be protected that can be generally applied; and

iii) non-chemical, as well as chemical, stressors are considered.

The United States attitude towards risk assessment has, in many cases, flowed from legislative initiatives. For example, the 'Delaney clause' of the Food Additive Amendments of 1958 stipulated that no additive that was found to be carcinogenic could be allowed in the food supply, on the grounds that it was not possible to specify a safe human exposure to such an agent. Quantitative risk assessment is seen as attractive because, at least ideally, it allows decision-makers and the public to discriminate between important and trivial threats — thus going beyond qualitative findings that there is some risk, however small. The Clean Air Act, and the 1990 Clean Air Act Amendments, required the EPA to enter into a contract with the National Resarch Council (NRC) to create a committee to report on risk assessment of hazardous air pollutants (National Research Council, 1994).

Comparative risk assessment

During 1995 the Republican party introduced a number of bills in Congress dealing with risk assessment requirements. The first of these, known colloquially as the 'risk bill' (Title III of H.R.9), requires federal agencies to conduct comprehensive risk assessments before issuing any new regulation. It also mandates cost-benefit analyses for any proposed rule for which compliance would cost industry more than $25 million, with the results of such analyses determining whether the rule would be issued. This bill and HR1022, which is the Risk Assessment and Cost/Benefit Act of 1995, have been supported by industry but denounced by environmental groups and the EPA. An official statement by the US EPA administrator, Carol M. Browner, in early February 1995 says:

> *"The risk bill purports to be an application of sound science; in truth, it perverts not just science but also common sense. It mandates a costly, procedural maze that will delay or stop the public-health protections traditionally enjoyed by all Americans. Under the provisions of the bill recently marked up by the House, EPA could not have banned lead from gasoline or dangerous pesticides like DDT. The House Committee actions to date dictate new, costly procedures that would supersede all existing laws. This means 20 years of protections for our children and our air, our land and our water are being rolled back in the dead of night without even a thoughtful debate in Congress. Risk analysis is an important tool that is already used to assure all major rules are scientifically justified. Requiring it for every single action is neither fair, effective nor affordable. We strongly urge Congress to rethink this hastily drafted and potentially detrimental measure."*

A subsequent statement on HR1022 indicated that the EPA would be working with the Senate to oppose these bills.

In discussing this matter during a visit to the United States the view was expressed that the present congressional interest in risk assessment arose from concerns of industry and state governments that they had to spend considerable sums to comply with EPA requirements. Risk assessment was perceived as the only tool with which to fight Federal requirements. Until two years ago no congressman had heard of risk assessment, which was then merely a decision-making tool within the EPA. Environmental groups have strongly opposed risk assessment, most probably because risk assessment expertise lies within industry and they feel correspondingly disadvantaged.

Much of the value in comparative risk assessment is in the process itself. It forces people to think systematically about the issues and determine their priorities. At the moment it appears that the US may require risk assessments and cost-benefit analyses to be done, but there is no enforcement mechanism.

The judicial reviews of regulations that occur in the US as a result of court actions are an important driving force for risk assessment. Courts, in determining truth (as opposed to accepted truth) need to know how to make determinations. These events have led policy makers to see risk as the most probable estimate of the risk, not the upper bound estimate of risk which has, in the past, been advocated on the grounds of environmental conservatism.

The US EPA wants national environmental protection that is informed by risk assessment, but not dictated by risk assessment.

Superfund

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, better known as Superfund) provides the legislative framework (and authorises the funding) for the US Department of Defense clean-ups at its military bases, the Department of Energy's clean-ups at the nuclear weapons plants and for the US EPA to clean up sites that pose serious health and ecological risks.

Superfund provides a mechanism to rank such sites. The most troublesome are placed on the National Priorities List. Towards the end of 1994 there were 1 286 such sites on the list. (Portney & Probst, 1994). The law also established a process for determining the appropriate clean-up approach. It created several new federal taxes to fund a trust fund that is used on an emergency basis to finance clean-ups, or on a long-term basis to finance clean-up at sites where no responsible party can be found and made to clean up the site. Further, the Superfund law created a mechanism to enable the EPA to identify responsible parties and require them to pay for clean-up.

Section 121 of Superfund calls for a clean-up that "utilizes permanent solutions and alternative treatment technologies..to the maximum extent practicable" at each site. This innocuous wording appears to rule out a risk based approach to remediation — in which the extent of the clean-up depends on the seriousness of the current health risks that a site poses. Portney & Probst (1994) give the example of a site near a residential area. The site was once an industrial dump but is now fenced off and currently vacant. The soil at the site is contaminated but is not contributing to the contamination of the groundwater. In view of the low risk presently posed by the site some people claim that it would be appropriate to cap the site to contain the contamination, build a stronger fence and continue to monitor.

Many in the environmental community and Congress do not believe that the above approach would be a permanent remedy, believing that a permanent remedy is one that goes well beyond containment, extending perhaps to the excavation and incineration of contaminated soils or the pumping and treatment of groundwater. They would baulk at a remedy that would reduce exposure to contamination without removing the contamination itself.

The Department of Energy, faced with similar problems in relation to its nuclear weapons complexes, requested the National Academy of Sciences to assess whether a risk based approach to evaluating the consequences of alternative remedial actions is feasible and desirable (National Research Council, 1994b). The conclusion was that it was both feasible and desirable for the Department of Energy to undertake the necessary, credible, scientifically-based risk assessment program to define, on a major site-by-site basis, in a meaningful way, the major long-term product and health and environmental risks at their sites.

Major contractors to the Department of Energy, such as Battelle or Argonne National Laboratory (MacDonnell et al, 1994), already use integrated risk management in their program of managing contaminated sites. Figure 3.4 provides a schematic of the integrated risk management approach used by Battelle to determine risk management strategies.

Canada

Toft & Meek (1993) note that the concept of identifying and evaluating potential risks associated with industrial chemicals before they are manufactured or imported has been incorporated into the new Canadian Environmental Protection Act of 1988. Canada uses a three step process of health risk assessment and risk management:

1. Hazard identification
2. Risk estimation
3. Option evaluation

Figure 3.4 Integrated Risk Management

The first two of these refer to risk assessment whereas the third deals with risk management. The new substances program deals with chemicals, polymers and the products of biotechnology. It aims to ensure that no new substances are introduced that are harmful.

The Canadian Act also deals with existing chemicals by requiring establishment of a priority substances list (PSL). The definition of toxic chemicals is on the basis of either: (a) immediate or long term harmful effect on the environment; (b) danger to the environment on which human health depends; or (c) danger in Canada to human life or health. In this activity, the Canadians use a definition of risk as ENTRY-EXPOSURE-EFFECTS to obtain a risk definition based on the letter 'E'. In determining the priority substance list (PSL) there are flowcharts to assist with evaluation of each of the three components of the risk.

Environment Canada is presently extending PSL from a list based on human health effects to a second list based on ecological effects (e.g. effects of hexachlorobenzene on mink on the St. Claire River).

Canada has recently produced a framework for ecological risk assessment (Gaudet, 1994) as part of the national contaminated sites remediation program. As may be expected, the framework considers receptors and ecological effects to populations rather than to individuals in the species. It also accepts that each site is unique and sets no single level of protection for ecological systems.

The unique feature of the Canadian framework is its three tier approach which allows the ecological risk assessment to be tailored to the level of complexity of the problem. The first tier (level one) is a simple, qualitative comparison based on previous data and literature — often descriptive in form. The second tier (level two) is semi-quantitative with emphasis on standard environmental methods and models. The third tier (level three) uses site-specific data to undertake predictive modelling, using quantitative information on complex ecosystem responses.

There is a separate agency — Pest Management Regulatory Agency — set up on 1 April 1995 that deals with pesticides. This agency favours field trials to test the toxicity of chemicals.

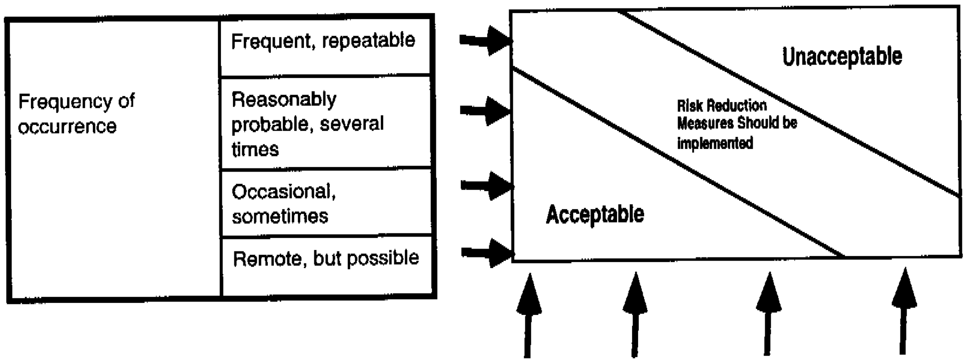
Asian Development Bank

The Asian Development Bank (ADB) has published a lengthy report (Office of Environment, 1991) dealing with environmental risk assessment. The report is divided into three parts:

- Part 1 Review of the state of the art of environmental risk assessment;
- Part 2 Guidelines for environmental risk;
- Part 3 Case examples

The guidelines for Part 2 consist of methods by which one may determine whether a risk analysis needs to be done, rather than guidelines for doing the risk analysis. The guidelines are designed to enable an analyst to categorise a development project on the basis of the frequency of occurrence of risks and the severity of consequences or damage. A full risk assessment is undertaken only when a project falls outside the region marked as acceptable in Fig. 3.5. The case examples of Part 3 then deal with case studies in determining where a proposed project lies on Fig.3.5. The location on the figure indicates whether a full risk assessment needs to take place.

Figure 3.5 Risk Assessment - Asian Development Bank Evaluation Matrix



		Range of Consequences and Damage			
		Negligible	Marginal	Critical	Catastrophic
Industrial and Community Facilities	Disruption	< 1 day	A few days	> 1 month	Widespread destruction
	Monetary damage	< $100,000	$100,000- $1million	$1 -10 million	> $ 10 million
Human Health and Safety		Minor	≥ 2 mo. lost work time	to ≥ 1 person (s)	Death to > 10 severe injury to > 100
Pollution Damage to Ecosystem		Slight	Temporary	Loss of key species	Complete, irreversible

Netherlands

The Dutch National Environment Protection Policy (Directorate General for Environmental Protection, 1988) aims to protect the structure (the species) of an ecosystem and by doing so also protecting the function (the qualitative and quantitative distribution of species) of the ecosystem. The Netherlands has recently published risk limits of chemical substances in soil, air and water (Directorate for Chemicals, External Safety and Radiation Protection, 1994).

Criteria in the form of risk limits are set such that exposure of a listed substance at a concentration below the limit should not result in adverse effects to humans or ecosystems. Three risk limits are considered:

i) Serious contamination risk concentration. This occurs when 50 percent of the species potentially present in an ecosystem experience hazardous effects as a consequence of one or more substances present in concentrations above the no observed effect concentration of these species.

ii) Maximum permissible risk concentration (also known as maximum tolerable risk). This is the concentration above which the risk of adverse effects is unacceptable. It is set to protect 95 percent of the species, and is derived from an extrapolation model. For human health, this is set at 10^{-6} per year for non-carcinogens and non-genotoxic carcinogens, and is set at 10^{-4} per lifetime for genotoxic carcinogens, based on the no observed effect level (NOEL).

iii) The negligible risk concentration. This is set at 100 times below the maximum permissible risk concentration.

Until recently, assessment of substances in The Netherlands differed for the various categories of chemicals using different methods and criteria. The need to harmonise the various hazard and risk assessment systems gradually became evident, resulting in the development of the Uniform System for the Evaluation of Substances (USES 1.0) which was launched in April 1994 in support of the Netherlands National Environment Policy Plan.

USES is a decision-support instrument for use by relevant authorities which enables them to make rapid and efficient assessments of the general risks posed by substances, including new substances, existing substances, agricultural pesticides and biocides. It is not designed for comprehensive assessments, but merely allows initial (screening) and more refined assessments to be made. USES 1.0 is available as a user-friendly computer program and we have acquired a copy.

USES considers the expected emissions of a substance and the effects of those emissions, and establishes the hazard quotient, which is the ratio of the potential exposure to the substance and the level at which no adverse effects are expected. Where possible, USES also quantifies the uncertainties in the hazard quotient so that it constitutes a genuine risk assessment. In this way USES determines hazard quotients for several groups at risk: humans; micro-organisms in sewage treatment plants; aquatic ecosystems; terrestrial ecosystems; and top predators.

The hazard quotient for these groups can be determined on both a local and regional scale based on a standardised environment (i.e. USES has not been developed for the assessment of site specific risks). To keep underestimation and overestimation of the risks to a minimum, USES takes a realistic worst case approach, whereby average values are taken, wherever possible, for parameters and variables while the exposure scenario is a conservative estimate.

USES 1.0 is the first version of this system and further development will focus on its current limitations, the main ones being:

- it currently can be applied only to organic substances and is not yet suitable for the assessment of inorganic chemicals, surfactants or ionised substances;
- the uncertainty analysis is still very limited, both for exposure and effects assessment;
- model analysis, including validation, needs further work; and
- hazards such as global warming, ozone depletion, acidification, eutrophication, calamities etc. are not considered.

Acceptance of USES is being pursued amongst European Community (EC) member states and it is hoped formal adoption will occur towards the end of 1996.

A procedure for the assessment of contaminated sites, comparable to USES, has also been developed.

New Zealand

New Zealand has substantial activity underway involving risk assessment. The Hazardous Substances and New Organisms (HSNO) reform, being undertaken by the Ministry for the Environment, seeks to evaluate the risks from introducing hazardous substances or new organisms (including genetically modified organisms) in the New Zealand environment. There are plans to set up an Environmental and Risk Management Agency in June 1996 to oversee this reform.

The Ministry of Health and Ministry for the Environment (1993) recently proposed draft health and environmental guidelines for selected timber treatment chemicals. The risk assessment part of the guidelines follows the US EPA methods.

United Kingdom

The United Kingdom follows a scheme for the assessment of new chemicals that is based on recent work from the OECD that has been harmonised for use throughout the European Community. New chemicals assessment for eco-toxicity is based very strongly on laboratory work, especially aquatic risk characterisation using daphnia, algae and fish. The OECD classification is given in Table 3.1.

The European Community (Official Journal of the European Community, No L 110A/68, 1993) has a system with a number of classes for substances with eco-toxic properties. These classes are divided into those that affect aquatic environments (R50-53, from very toxic to harmful) shown in Fig. 3.6 and those that affect non-aquatic environments (R54-59), e.g. toxic to flora, fauna, soil organisms or bees.

Figure 3.6 Aquatic Environmental Classification EEC Directive

Classification	Risk Phrase	Criteria
Very Toxic (carries symbol)	R50 & R53	a) L(E) C50 ≤ 1 mg/l *and* not readily biodegradable or log P > 3
	R50	b) L(E) C50 ≤ 1 mg/l
Toxic (carries symbol)	R51 & R53	L(E) C50 1 > & ≤ 10mg/l *and* not readily biodegradable or log P > 3
Harmful	R52 & R53	L(E) C50 >10mg/l ≤ 100mg/l *and* not readily biodegradable Other evidence allowed on degradability and toxicity may lead to non-classification
Safety Clause	R52 &/or R53	Substances not satisfying above may be considered as being hazardous eg. Poor water solubility

The European Community issued a directive in September 1993 (Directive 93/67/EEC) that requires new chemicals to be subject to detailed risk assessment. This directive fits in with the overall EU scheme as illustrated in Fig. 3.7. The risk assessment decision scheme for substances affecting aquatic environments (Fig. 3.8) is based on determining the ratio between the predicted environmental concentration and the predicted no effect concentration (based partly on the laboratory studies mentioned above). If the exposure exceeds the no effect level, then the substance is considered to have the potential to cause adverse effects and requires refined assessment. One possibility for such refined assessment is that of computer modelling, and the Department of Environment is working with the Dutch on USES, a computer model to deal with the air, soil and water compartments.

Figure 3.7 Decision Making for Controls in the EU

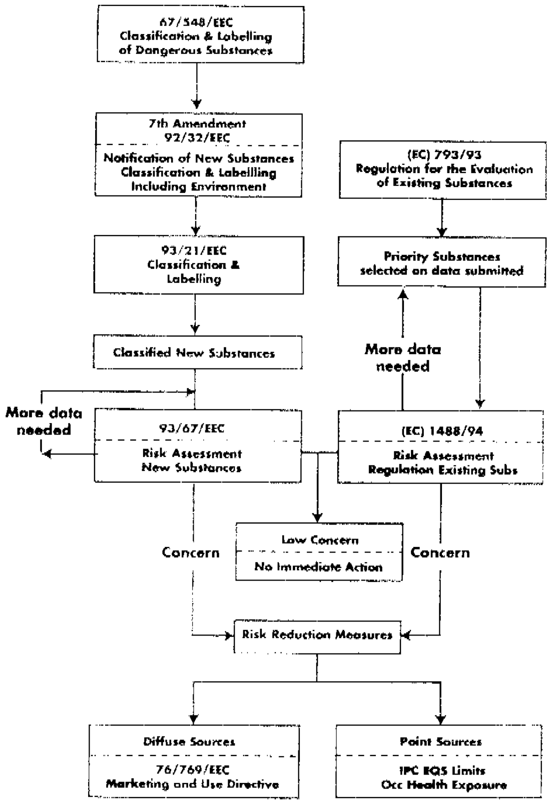


Figure 3.8 Aquatic Risk Characterisation Decision Scheme for Further Testing

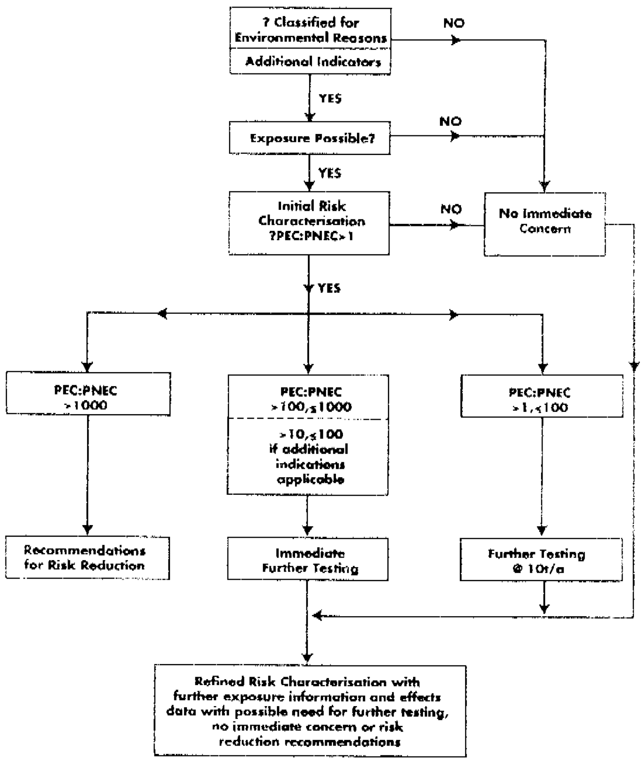


Table 3.1 OECD Threshold Values

Aquatic Acute Toxicity Test			
		Criteria	
	Very Toxic	Toxic	Harmful
96h LC50 fish	≤ 1.0 mg/l	≤10 mg/l	≤ 100 mg/l
or			
48h EC50 Daphnia	≤ 1.0 mg/l	≤10 mg/l	≤ 100 mg/l
or			
72h EC50 algae	≤ 1.0 mg/l	≤10 mg/l	≤100 mg/l

Bioaccumulation

Kow > 1000 unless Biological Concentration Factor is less than 100

Bio-degradability

BOD_5/COD ratio < 0.5

Source: Ministry for the Environment (1994)

Her Majesty's Inspectorate of Pollution (HMIP) in association with the consulting firm Technica-DNV has established CIERA (Centre for Integrated Environmental Risk Assessment) as a joint initiative to focus on four priority areas:

- corporate risk management for setting HMIP national priorities;
- regional risk management for regional priorities;
- site risk management for local site priorities; and
- inspection and monitoring prioritisation using risk technology.

CIERA is in place until the UK establishes a new Environmental Agency which is expected to occur probably in 1996. This will combine HMIP, the River Authorities and the Waste Authority.

CIERA is expected to deal with both top and tail issues.

Top issues: Risk identification, hazard identification setting boundaries and objectives for studies.

Tail issues: Decision making, risk reduction measures and strategies, cost-benefit analysis, risk communication, monitoring and feedback.

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Chapter 4

So What Is Australia Doing?

Safety Risk

The concept of risk is all-pervading, which means that there are numerous organisations and government departments involved in evaluating risk. The Industry Commission (1995) recently produced an information paper giving the results of a survey of Commonwealth Government regulatory agencies that ascertained how they currently develop and implement regulation to reduce safety risk in Australia.

The survey consisted of responses to questions. One of these was:

> *How does your agency calculate the 'risk factor' (or the probability of an accident or other outcome occurring if the safety problem is not addressed)?*

Most of the agencies that were surveyed attempted to account for risk in developing or assessing regulatory proposals, although not necessarily by calculating a risk factor as described in the question. Several agencies were able to use historical data to determine risk factors. For some issues, data were unavailable and guesstimates had to be used.

The Australian Radiation Laboratory calculates the risks of contracting fatal cancers and selected non-fatal ailments associated with different levels of exposure to radiation. These risk factors are based on epidemiological evidence from high exposure groups, extrapolated to lower exposure levels.

Those agencies dealing with chemicals, or other substances which may cause harm to humans exposed to them, take a different approach. Rather than seeking to determine the level of risk that would result from a particular level of exposure to a particular substance, they seek to determine the level of exposure that would result in no appreciable risk. Data are gathered by exposing test animals to different levels of the substance to determine the maximum level of exposure for which there is no observable effect. This is known as the NOEL (no observable effect level) and is used to calculate allowable exposure levels for humans. This is done by applying a safety factor (typically 100) to the NOEL to determine an acceptable daily intake (ADI). The ADI is the amount of the substance, expressed on a body-weight basis, that can be ingested daily, for an entire lifetime, without appreciable risk.

The survey also dealt with the question of whether the agencies base their actions on actual or perceived risk. Only two agencies incorporated perceived risk into their work. The Federal Office of Road Safety undertakes analysis which (indirectly) incorporates consumer's risk perceptions through its 'willingness to pay' studies. Although the National Food Authority bases its risk assessment on actual risk levels, its risk management strategy also takes into account community perceptions of risk. As community perceptions sometimes do not align closely with actual risk levels, this can result in a need for regulation to overcome community concerns that are ill-founded. The case of irradiation is cited as an example, where lack of community confidence has led to a ban being imposed, even though there is a general consensus among the scientific community that food irradiation is safe.

Perceived needs

Before the establishment of the EPA in Australia Cocks (1992) wrote that

> *"Australia does not have a Federal body like the US Environment Protection Agency to set standards for chemical levels in food and in the environment. There is a clear and growing need for such a body, despite the contributions from Health and other departments...*

However, rather than setting up a version of the US Environment Protection Agency, there would appear to be value in establishing something much broader in its interests. A National Risk-management Authority could be given responsibility for studying the whole range of potential disasters (natural, chemical, socio-economic etc.) and recommending relative expenditures on reducing the impact of each."

Cocks (1992) noted that some of the advantages of considering all major risks in a common framework are that it:

(i) allows disparate risk management to be compared meaningfully (a process now called comparative risk assessment);

(ii) allows strategic analysis of the higher-order or ripple effects of risk across the economy and across the community;

(iii) allows interdependent risks to be considered jointly; and

(iv) facilitates identification of priority areas with maximum potential for reducing risk across the board — defined in this case as increasing the life expectancy of Australians.

The EPA

The public acceptance of any risk is more dependent on public confidence in the risk management process than on the results of the risk analysis process. The agency of the Federal Government with responsibility for protection of the environment is the Environment Protection Agency (EPA). It is an agency of the Federal Environment Department and has six branches:

The *Environment Assessment Branch* protects the environment by assessing proposals for development.

The *Environmental Protection Partnership Branch* protects the environment by working with industry, government and the community to adopt cleaner production strategies and to help develop and market environmental technologies.

The *Waste Management Branch* protects the environment by acting to reduce waste created at work, at home, and by industry.

The *Environment Standards Branch* protects the environment by evaluating the environmental impact of a range of chemicals and genetically modified organisms as well as helping to develop national environment protection measures for air and water.

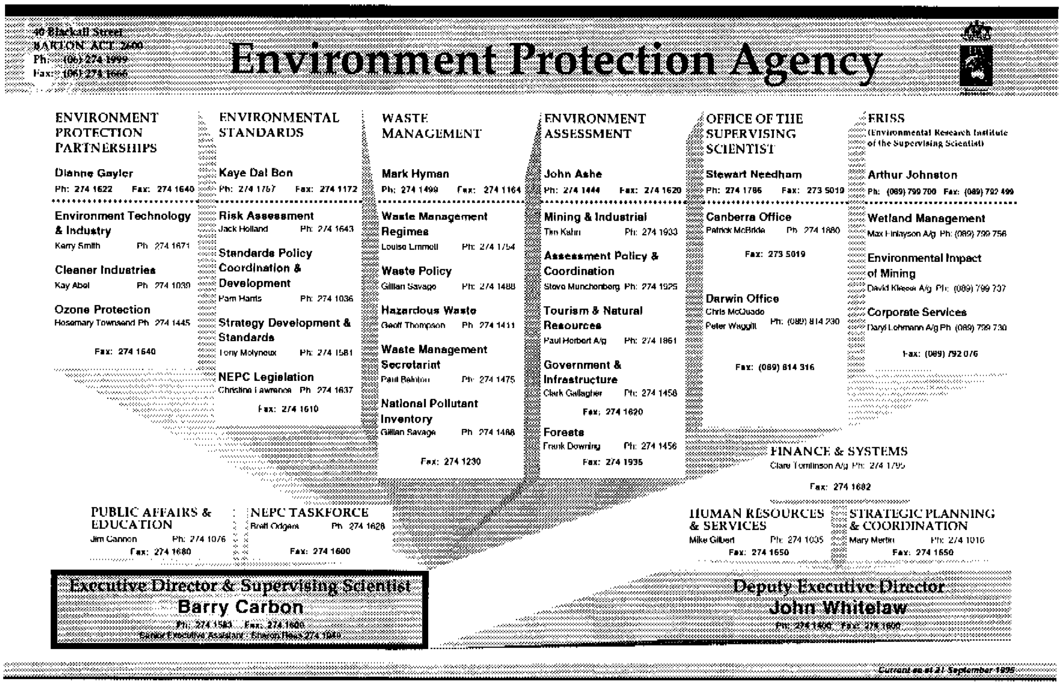
The *Office of the Supervising Scientist* protects the environment by assessing the adequacy of environmental protection relating to uranium mining in the Alligator Rivers Region, and by advising on best practice in environmental protection.

The *Environmental Research Institute of the Supervising Scientist* protects the environment by carrying out scientific research on the environmental impact of mining, particularly uranium mining, and by research on tropical freshwater and estuarine ecosystems with a view to their protection and management.

The structure of the EPA is depicted in Figure 4.1. One of the sections of the Environment Standards Branch is called the Risk Assessment section. Its role is to assess chemicals, because Australia has passed legislation to make mandatory the assessment of both industrial, and agricultural and veterinary chemicals. Holland (1991) describes the approach taken by the section, which undertakes two tasks: exposure and toxicity assessment; and hazard assessment.

The exposure and toxicity assessment varies from chemical to chemical depending on its likely usage patterns and its chemical nature in relation to persistence, accumulation, mobility and possible toxic effects on non-target organisms.

Figure 4.1 The Environment Protection Agency Structure Chart



The hazard assessment conducted by the section is based on an approach called the quotient method (Urban and Cooke, 1986). In this approach (Fig. 4.2) the estimated environmental concentration (EEC) is divided by the most sensitive toxicity concentration relevant to the particular organisms of concern. These calculations are conducted initially on a worst-case scenario where it is assumed that the area has been sprayed with the highest proposed application rate. A quotient, known as the Q value is calculated. If Q is low, then there is little risk of adverse effects. A Q-value greater than 0.1 will lead to further examination of environmental hazard including other pathways of environmental contamination.

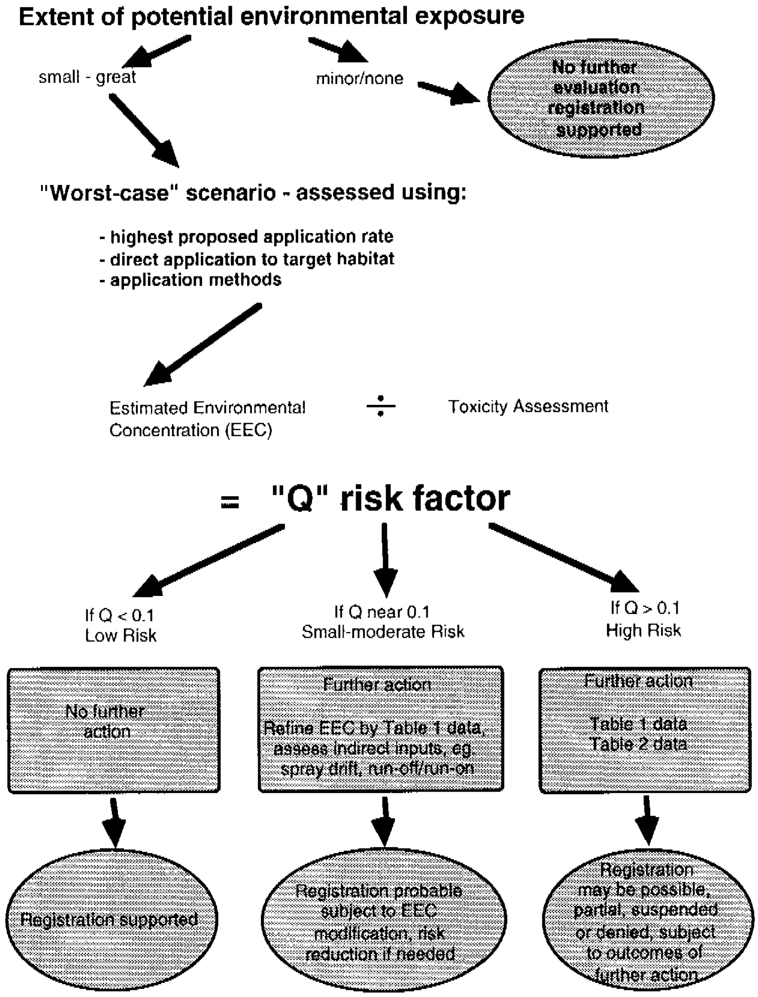
The quotient method was originally designed for aquatic impact assessment. The reason is the assumption that chemicals eventually reach groundwater and aquifers through leaching. However, soils may also act as sinks for pollutants and should be considered in hazard assessments.

Environmental risk and due diligence

Criminal liability for the wilful flouting of environmental legislation is not confined to the actual perpetrators of the environmental offence. It stretches to include management and the directors of companies. Thus, to the legal profession in Australia the term environmental risk now means the possibility of a company or individual facing legal action for a breach of environmental legislation. The issue recently received publicity when, in March 1995, a Perth company director became the first person in Australia gaoled for an environmental offence when he was sentenced to three months prison for the illegal dumping of 22 000 litres of toxic waste.

The legal profession argues that the only way that directors could avoid conviction for illegal actions of their employees would be to show that they had complied with the process of due diligence. This means that directors and managers should show that they had an input into putting together a policy that minimises the risk of an environmental accident for their company. Company directors seeking to prove their innocence need to show that they either had no knowledge of the offence — which begs the question of whether the director was in control of their company in the first place — or that they had in place an adequate due diligence system to minimise the risk of an environmental accident.

Figure 4.2 Hazard Assessment as currently conducted by EPA



A generic environmental risk assessment framework for Australia

The existing literature on environmental risk assessment does not, in general, attempt to pinpoint the difference between a risk analysis and a risk assessment. The United States uses the term risk assessment for the step that involves quantifying and combining the hazards and the probabilities, as shown in Figure 3.2. This terminology has also been used by the New South Wales Department of Planning, as shown in Figure 3.1. The difference between a risk analysis and a risk assessment is currently under consideration in a draft Australian and New Zealand Standard (Standards Australia & Standards New Zealand, 1994) which suggests that the steps shown in Figure 3.1 and Figure 3.2 as risk assessments should be termed risk analysis. Risk assessment consists of comparing the quantified level of risk with criteria for risk acceptability.

A second issue to consider is that the environmental impact assessment (EIA) process as undertaken in Australia (ANZECC, 1991) is itself a form of environmental risk assessment, albeit in general a qualitative rather than a quantitative risk assessment. An Australian EIA starts with a scoping study that determines the issues and concerns that will need to be addressed by consultation and further studies. The environmental impact statement that is produced will then address the consequences arising from the identified issues.

Identifying issues and determining their consequences comprise essential parts of the risk analysis process, as shown in Fig. 3.1. A hazard analysis would then quantify these consequences. The essential extra step involved in converting a hazard analysis to a risk analysis is the introduction of the probabilistic element, by finding an answer to the question: what is the likelihood of this hazard causing an effect? The answer to such a question will involve some form of uncertainty analysis.

Figure 1 summarises the above generic framework. The left hand side lists the steps involved in undertaking the analysis or assessment shown on the right hand side. Impact analysis considers only concerns (i.e. issues) and consequences. A hazard analysis requires a further step, namely undertaking calculations to produce quantitative estimates. Risk analysis requires introducing statistical aspects through uncertainty analysis. Risk assessment then requires some determination of the acceptability, or otherwise, of the numbers produced by the risk analysis. And finally, in practice, one wishes to introduce actions to control risks, and to communicate these actions as part of risk management.

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Chapter 5

Worst Things First

Setting Priorities Using Risk Analysis

Introduction

Risk assessment, or comparative risk assessment to be more precise, is one of a number of tools that can be applied to the process of setting priorities. Comparative risk assessment is the act of evaluating two or more risks simultaneously and juxtaposing the results to examine whether the relative effort devoted to each risk should be changed. Often, in fact, there is a hope that risk assessment can solve complex problems with which the community has long grappled. The hope may be there, but agreement is sometimes lacking, as shown by the existence of an on-going debate in the United States over risk based national environmental priorities (Finkel & Golding, 1994).

Whether risk assessment can solve such problems depends on the nature of the problem and how inclusive one wishes the term risk assessment to be. For example, in the case of uranium mining the two reports of the Ranger Uranium Environmental Inquiry (Fox et al., 1976, 1977) comprise an extensive assessment of uranium mining, with recommendations for overall risk management and risk minimisation. The risk in this case is the risk of environmental degradation and the risk of adverse impact on Aboriginal society. What is missing from the Ranger Uranium Environmental Inquiry is a **quantitative** risk assessment that attempts to place such issues within a statistical framework.

Certain arguments refuse to die because the Ranger Uranium Environmental Inquiry did not couch its recommendations in appropriately quantified risk assessment terms. Page 150 of the second report states:

> *"The Commission recommends that the project be permitted to commence only if there is a firm, legally binding undertaking by Ranger to replace the tailings in the mine pits. We recommend elsewhere the provision of a security or surety to provide finance for this operation even in the event of the failure of the Ranger company or of it ceasing to carry on for any reason. Any stockpiles of low grade ore remaining after milling ceased should be placed with the tailings in one or other of the pits.*
>
> *Many of the long term environmental effects of the project are unpredictable... For this reason we recommend that the supervising authority should not have the ability to relax the requirement that the tailings and unused ore be returned to the pits."*

Despite such unequivocal assertions, the final legislated environmental requirement (ER) for tailings disposal from the Ranger lease was ER29 which requires all tailings to be returned to the worked out pits at the cessation of operations unless the Supervising Scientist is satisfied that, by dealing with the tailings in another manner, the environment is no less well protected.

Barrow et al. (1994) state:

> *"ER29 (Environmental Requirement 29) poses some special problems of interpretation... if the lease is extended, and mining of North Ranger and Ranger 3 occurs, then the comparison implied in ER29 is between moving the tailings from the current tailings dam to pit number 3, versus leaving them in the dam. In order for the tailings to remain in the dam the Supervising Scientist must be satisfied that the environment is no less well protected. However, the kind of risks posed by these two options differ. The pit option might contribute more contaminants to the environment on an annual basis and be more at risk from infrequent events such as a 1:10 flood, but be much less at risk from the very rare event such as a 1:100 cyclone. In contrast the tailings dam might be much more at risk from the 1:100 events and the release very much greater. We suggest that*

there is a need to consider the ground rules in terms of risk/damage for making the comparisons involved in ER29."

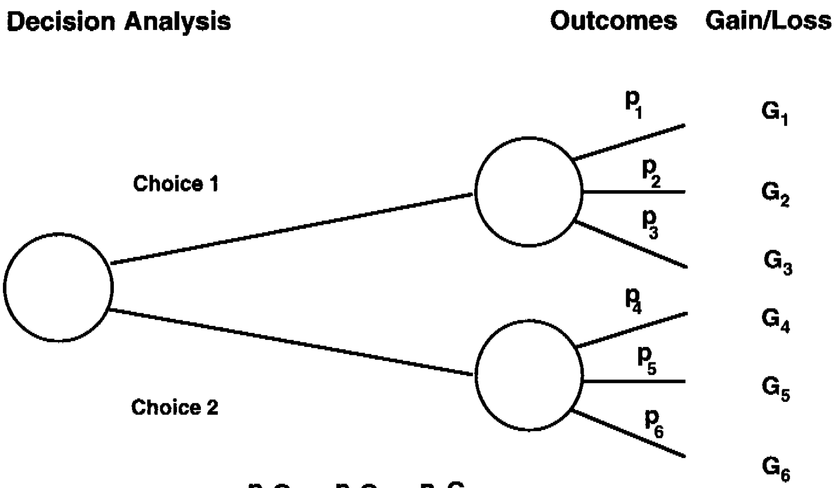
Decision Analysis

Decision analysis consists of a set of mathematical and organisational tools that help a decision maker think systematically about complex problems and improve the quality of the resulting decisions (Clemen, 1991). The essentials of decision analysis consist of the construction of a decision tree, assigning probabilities to the nodes of the tree and determining the outcomes on the basis of the probabilities. Decisions are then made on the basis of the outcomes.

Textbooks on decision analysis deal with decision tree outcomes expressed in monetary terms and deal with the concept of risk in terms of risk profiles. These are graphs which show the probabilities associated with possible outcomes. In statistical terms, one would describe the risk profile as the probability distribution function for the expected outcomes. Thus, in decision theory the concept of risk does not refer just to a single measure of uncertainty, such as standard deviation. Instead, it refers to the whole probability distribution function associated with the potential outcomes.

Decision analysis defines a risk-benefit outcome in terms of the expected monetary value. For example, if the pay-offs in a game when a coin is tossed are $30 for a win and $1 for a loss, then the expected monetary value (EMV) is $14.50. But the extension of decision analysis to deal with risk tackles the issue that people make decisions on criteria other than the EMV. For example, if the amounts in the previous case are altered so as to pay $2000 for a win, but to demand $1900 for a loss then few individuals would choose this second game despite it having an EMV of $50. Fig. 5.1 shows a general decision tree. For the two choices given above, we have

Figure 5.1 Making a Decision



$$\text{EMV Choice 1} = \frac{P_1 G_1 + P_2 G_2 + P_3 G_3}{P_1 + P_2 + P_3}$$

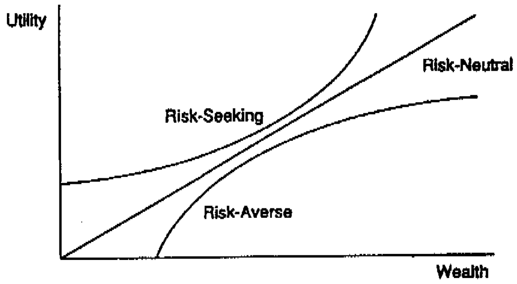
$$\text{EMV Choice 2} = \frac{P_4 G_4 + P_5 G_5 + P_6 G_6}{P_4 + P_5 + P_6}$$

$p_1 = p_2 = p_4 = p_5 = 0.5 \quad p_3 = p_6 = 0$

$G_1 = \$30 \quad G_2 = -\$1 \quad G_4 = \$2000 \quad G_5 = -\$1900 \quad G_3 = G_6 = 0$

The ultimate decision, when faced with a choice such as that of Fig. 5.1, depends on the risk attitude of the individual making the decision and this, in turn, depends on how the monetary amounts are transformed into personal utility. Thus, when risk analysis is used in decision analysis, there needs to be extensive investigation of the utility function that translates dollars to utility. Three shapes of utility functions are normally considered (Fig. 5.2). Concave utility functions indicate risk aversion (e.g. buying insurance), convex utility functions indicate risk seeking (e.g. buying lottery tickets), whereas a straight line indicates a risk neutral individual. For a risk neutral person, maximising EMV is the same as maximising expected utility. Such a person is considered to be one who does not care about risk and ignores the risk aspects of the alternatives that are faced.

Figure 5.2 Three Different Shapes for Utility Functions

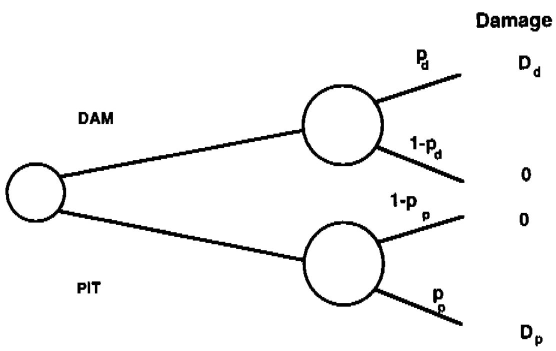


These issues are very relevant when one considers the risk assessment approach to environmental issues. Environmental impact statements that incorporate risk assessments assume that society as a whole is risk neutral, and that decisions can be made solely on the basis of the hazards (which are the environmental equivalents of the monetary outcomes considered in decision theory) and the probabilities. This has led to the situation, much lamented by technical experts (eg National Research Council, 1989, p.52), in which certain activities, such as nuclear power, evoke much more serious public opposition than others, such as motorcycle riding, that cause many more fatalities. As we have previously discussed in Chapter 1, and depicted in Fig. 1.2, the familiarity and controllability of the risk plays an important role in the way it is perceived.

Dam versus pit — a simple decision tree and utility curves

The option between dam and pit, as presented above, can readily be presented in the form of a decision tree. Decision trees are used as a management tool to decide between competing options, as shown in Fig. 5.1. A probability is assigned to each of the outcomes and the likely financial rewards from each outcome is also estimated. The expected mean value (EMV) of each choice is then the sum of the products and probabilities corresponding to each of the outcomes associated with that choice.

Figure 5.3 DAM vs PIT



The decision tree for the dam versus pit option is shown in Fig. 5.3. The probability of environmental damage as a result of a cyclone impinging on the dam is set at P_d whereas the probability of environmental damage as a result of a flood affecting the pit is set at P_p. In doing the quantitative analysis it is important to note that Bayesian statistics need to be used. The probability of release of material as a result of a 1/100 cyclone is not 1/100 but is

$$P_d = P(R|c) \times 1/100$$

where P (R | c) is the probability of release of material in the presence of a 1/100 cyclone. P(c) = 1/100 is the chosen probability for the cyclone.

The damage resulting from the two events is unknown. Thus it has been shown in Fig. 5.3 as being D_d for dam failure and D_p for pit integrity failure. The expected mean value (EMV) of the damage arising from the dam is then P_dD_d and the EMV of the pit is P_pD_p. A choice based solely on an EMV criterion would then advocate the pit option if its EMV is lower than the EMV of the dam. That is, choose the pit if $P_dD_d > P_pD_p$.

The probabilities that are assigned depend on the nature of the engineered constructions that are in place. At present, the tailings dam at Ranger is designed to contain water and prevent the tailings dam from overflowing up to a 1 in 10 000 year storm (McQuade, pers. comm.) implying that P(R | c) is about 1/100. The probability of release of material from the pit to groundwater at some (unknown) time in the future is virtually certain. A first estimate, then, would be to set P(R | f) = 1. Thus, as an extremely simplified example, if we use the values advocated by Barrow et al. (1994) and compare the results of a 1/10 flood and 1/100 cyclone, the probabilities are $P_d = 1/10\ 000$ and $P_p = 0.1$ so that $P_p/P_d = 1000$. If $D_d/D_p > 1000$ then the pit is to be preferred, whereas if $D_d/D_p < 1000$ then the dam is to be preferred.

The analysis of probabilities is too simplistic because it ignores likely engineering considerations, and the more likely pathways of releases to the environment. Waggitt (1994) reviews typical design considerations and their relative advantages and disadvantages. In a detailed study of the above ground tailings containment for mine rehabilitation (Waggitt & Riley, 1994) it is pointed out that the risk of release of tailings is a function of time and that it could fail as the result of the cumulative effects of a number of medium sized events over a long period of time, with a figure of 1 000 years being given as typical for the structural life of the dam.

We now have the situation of a cumulative probability distribution function with two known points. The probability of failure is zero at t= 0 (the dam is still standing) and the probability is one at t=1000. The question of interest is: what is the probability of failure within the next year — at t=1. The answer to this question depends on the shape of the curve that is drawn connecting the two points. The simplest answer is to draw a straight line which implies that the probability of release in any particular year is $P_d = 1/1000$.

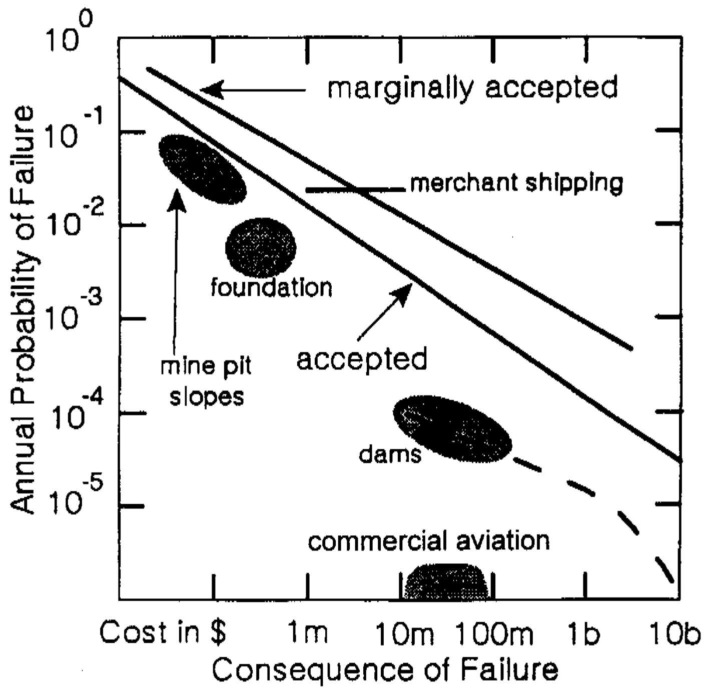
The choice of curve is arbitrary, though professional practice determines the shape in many areas of science and engineering. Much of the technical argument related to risk analysis arises because of this arbitrariness in curve fitting. Paustenbach (1995: Fig. 1) discusses an analogous case in toxicology where scientists must rely on a model or theory to provide the appropriate curves to estimate human responses at doses well below the lowest animal dose tested. In an effort to derive risk estimates that are unlikely to underestimate the risk, the models most frequently used by regulatory agencies assume non-zero values everywhere except the origin. A similar justification could be used to justify the linearisation of the probability.

It may also be argued that the environmental hazard from retention of mine tailings in the pit is not the leaching of contaminants into groundwater, which will occur during every severe storm and flood. The environmental hazard occurs when the contaminated groundwater reaches the nearest flowing water body. The time for this is not known, but some 'back-of-the-envelope' calculations of Dillon (1991) indicate that groundwater movement from Pit 3 could be as high as 5 m per year. Magela

Creek is only about 100m from the northern edge of No. 3 ore body, so that there remains the possibility that there will be environmental release of pit-disposed material within 20 years. Thus, we take the probability of release in any particular year as $P_p = 1/20$.

There remain many problems with the above simple example of a decision tree. Firstly, the EMV criterion given above assumes episodic event-based damage and refers only to the EMV up to the expected time of the first event, or expressed alternatively, it analyses risk in the first year after decommissioning (assuming a linear increase in the cumulative probability of failure). This is accepted decision analysis procedure. Alternative viewpoints can arise because, over a 1000 year period, there is an expectation of a release from the tailings dam, but over this period the probabilities correspond to the occurrence of 50 releases from the pit. If the damage per pit release stays the same then the EMV criterion for choosing the pit becomes: choose the pit if $P_dD_d > 50\ P_pD_p$. Further difficulties arise if one considers that once the contaminated groundwater plume from the pit reaches the receiving waters, then there will be continuous flow into the water system, but release from the dam is likely to be episodic.

Figure 5.4 Risks for Selected Engineering Projects



The values of D_d and D_p are not known and are difficult, if not impossible, to calculate. Further, the values of D_d and D_p are unlikely to be constant values. Whitman (1983) points out that the consequences of failure — expressed either as lives lost or as a cost in dollar terms — generally increase as the probability decreases (Fig. 5.4). This ties in with the accepted view that a tailings dam release would lead to widespread damage (D_d is very large) whereas the damage from release from the pit is much lower. An alternative viewpoint, espoused by mining company representatives, is that at very low probabilities D_d approaches zero, because it would require a catastrophic event to breach the tailings dam. The overall devastation during such an exceptional event (eg. the combination of an earthquake and an intense tropical cyclone) would be so large that the contribution of the tailings dam would be negligible. Support for this viewpoint would also be found from the standard economic concept of discounting future damage to present day dollars. A very large damage occurring in 1000 years time when discounted is generally very much less than a moderate damage occurring in 20 years time.

Figure 5.5 (a, b, c) EMV - PIT/DAM

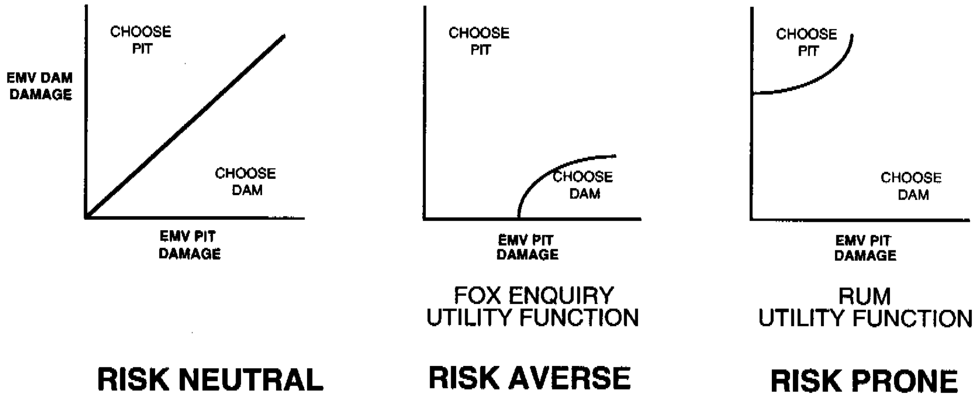


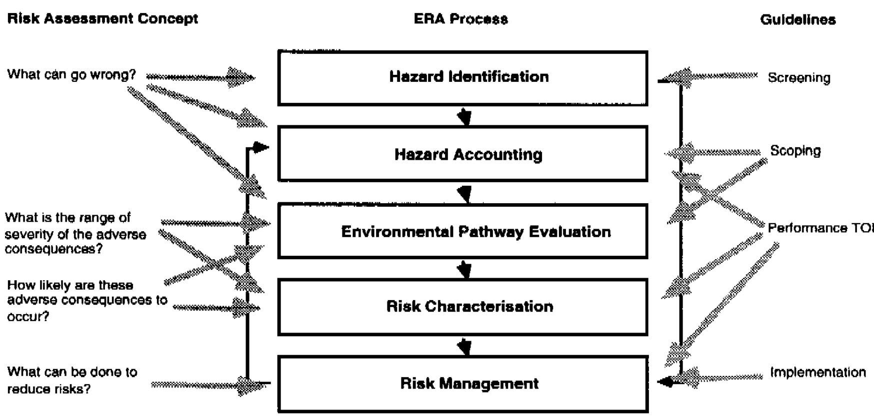
Figure 5.5 illustrates three utility functions. Fig. 5.5a corresponds to the utility function discussed above. The choice of pit or the choice of dam is determined by the lower EMV. The Ranger Uranium Environmental Inquiry used a utility function that could be approximated by the one shown in Fig. 5.5b. A pit was to be preferred, regardless of the possibility of pit failure. The figure, however, allows for the possibility that if the cost of pit failure is shown to be very high, then the dam would be chosen. The mining company, however, appears to have a utility function as shown in Fig. 5.5c. The preferred choice is the dam, unless — presumably — it can be shown that the cost of dam failure is so high that it is an indefensible choice.

It has long been known that utility curves indicate risk attitudes of the individual (Clemen, 1991, Ch. 13). A straight line utility curve, such as Fig. 5.5a is that of a risk neutral individual. The convex boundary of Fig.5.5b is interpreted to be that of a risk averse individual, whereas the concave boundary of Fig. 5.5c is that of a risk seeking individual. The role of investigation, study, consultation and debate is to transform the individual utility functions to risk free utility functions.

Prioritising issues

Figure 5.6 depicts the concept, process and guidelines for environmental risk assessment (ERA) as promulgated by the Asian Development Bank (Office of Environment, 1990). The first step of a risk assessment is to identify and list the hazards associated with the operations performed. This is termed screening in the ADB guidelines. As a case study in the use of comparative risk assessment, the next section considers its use and applicability for setting the nature of the topics to be discussed in future six-monthly environmental performance reviews of the Ranger Uranium mine.

Figure 5.6 Relationship of basic concepts to the ERA process and the Guidelines



The Asian Development Bank concept of using a matrix to determine risk is illustrated in Figure 3.5. The concept is one of evaluating risk on the basis of two variables — likelihood of occurrence, and severity of consequences. One can also set priorities using two variables. Australia's research organisation, CSIRO, sets its research priorities (and hence its funding allocations) on the basis of an attractiveness-feasibility matrix that is intended to determine the return to the nation of particular research areas (CSIRO, 1994). The national research priorities determined in 1994 for the next triennium placed the area of Mineral Resources in the far right of the matrix, being highest in attractiveness to the nation and second highest in feasibility.

Attractiveness considers both the potential economic, social and environmental benefits from successful research and Australia's ability to capture these benefits by converting new knowledge of technical progress into realised gains.

Feasibility considers both the potential for progress in the relevant areas of science and technology and Australia's capacity to undertake the necessary research in a timely manner.

The lowest area on the attractiveness-feasibility scale was social development and community service. This reflects the fact that this is not an area of core competence for CSIRO but needs to be undertaken as an ancillary to research conducted for other purposes.

Case Study: Environmental Performance Reviews (EPR)

Under new supervisory arrangements documented in the 1993-94 annual report of the Supervising Scientist (Supervising Scientist, 1994) routine site inspections of the Ranger Uranium mining operations were replaced with twice-yearly reviews of the environmental performance of each uranium mining operation. This arrangement was implemented to avoid unnecessary duplication by the Office of the Supervising Scientist (OSS) of some of the regulatory and monitoring responsibilities of the Northern Territory regulators in respect of uranium mining. The reviews are designed to address both the environmental impacts of the mines and the environmental management, research and planning activities of the mining companies with a view to determining the likely future environmental performance of the mines. Particular attention is given to identifying any mining practices, procedures and measures that threaten the Alligator Rivers Region environment.

The reviews are undertaken jointly by a review team comprising officers of the OSS and the Northern Territory Department of Mines and Energy. The review process involves construction of an extensive questionnaire on environmental performance, meetings with companies to gather responses to the questionnaire, examination of documentary evidence to verify the responses given, a site inspection and an evaluation of the adequacy of the responses given to each question. To date, two environmental performance reviews have been conducted. The first was from 11-14 July 1994 and the second was from 2-8 December 1994. The first review, EPR1, emphasised the outcomes of environmental management practice at the mine sites and included more detailed questions that examined operational aspects relevant to achieving the environmental outcomes. The second review, EPR2 , concentrated on the mine's water management system.

The areas covered in EPR1 and EPR2, and the number of questions in each area, are:

EPR1

1. Environmental Management	
overview	6
environmental preparedness	3
legislation and general	7
2. Environmental and public health monitoring and reporting	
overall impact	9
monitoring regimes	8
general monitoring	17
3. Water management	
overview	6
water storage and disposal	7
4. Mine and mill operation	
mine and stockpiles	5
metallurgical plant	5
tailings retention system	7
support services	5
5. Environmental research	2

EPR2

1. General	
matters arising from EPR1	7
impacts during review period	13
Best Practicable Technology	5
2. Water management system overview	
management plans	11
implementation of water management	17
3. Water storage system	
RP1	3
RP2	4
RP3	2
RP4	7
tailings system	6
4. Water disposal system	
land application area	10
Georgetown Creek	1
5. Groundwater	
groundwater management	5

Discussion

Within the context of a risk assessment framework, the EPR process is a risk-screening process. Only those issues that fail to meet an acceptable criterion need to go through the further stages of the process shown in Fig. 5.6 — including management. Yet, in determining the questions, their topics, their nature and their number, some form of pre-screening must have been established. For example, the inclusion of one question on Georgetown Creek in EPR2 is an indicator that there was a perception that this issue should be raised. No questions were included on other creeks.

The question on Georgetown Creek was included because water quality in Georgetown Creek catchment was given only minor coverage in the Annual Environmental Report of the mining company, although the occurrence in July of the second highest sulfate concentration (11 mg/L) recorded for Georgetown Billabong was described. The NT Supervising Authorities (1994) attribute the occurrence to dumping of waste rock in the Georgetown (Corridor) Creek catchment. The OSS considered that the 1994 sulfate concentrations did not pose an environmental threat, but the high rate of increase could possibly impact on Magela Creek in the future (Office of the Supervising Scientist, 1994). The question was there because it was perceived that a future environmental risk may flow from that source.

To try to determine perceptions of future risk, and perceived sources of future environmental risk, it was necessary to interview those concerned with these issues. A program of discussions was arranged during a visit to Darwin and Jabiru. Issues of concern raised either directly or indirectly during discussions were noted and a list compiled, as given in Appendix 1.

The Asian Development Bank (Office of the Environment, 1990) uses a matrix to categorise risk. The two axes are: frequency of occurrence; and severity of consequences and damage. Each axis has four possible values and the acceptability or unacceptability of the risk is determined graphically on the matrix in a procedure that is equivalent to the sum of the two values. The categories given in the ADB matrix are not appropriate ones to use to determine priorities for future EPRs. The reason is that the ADB matrix has to be able to evaluate a project *ab initio*. Thus, the range of consequences and damage to the ecosystem run from: a minimum of slight, quickly reversible damage to few species; to a maximum of complete, irreversible and immediate destruction of all life. The risk management procedures implemented as part of the procedures governing uranium mining ensure that such a risk is a very remote possibility. Accordingly, it seems to be more relevant to use a criterion of perceived risk as determined by community concern. This concept of comparing risk (i.e. likelihood of occurrence) to other factors such as community concern, or to the EPA budget was an independent re-discovery of ideas produced by the US EPA (1990). Ranking of the issues, on the basis of the discussions, has thus been done on the basis of the scoring given in Table 5.1

Table 5.1 Ranking for risk prioritisation of EPR topics

Score	Likelihood of occurrence	Community concern
1	Remote, but possible	negligible
2	Occasional, sometime occurs	marginal
3	Reasonably probable, several times	critical
4	Frequent, repeatable	unanimous

High priority items

The two items that scored highest were: (i) the release of mine site water; and (ii) the problems associated with decommissioning and rehabilitation. There was little doubt that the water management system was the single topic about which there was the most community concern and it was appropriate for it to be tackled soon after the EPR process was initiated. The assessment below indicates that it remains a high priority item which will need to be examined at frequent intervals.

Other high priority topics are:

- risk of possible impacts on surface waters;

- the water management system;
- coping with public concerns over uranium;
- maintenance of the Kakadu ecosystem; and
- the responsibilities of the mining company after decommissioning.

Topics that are relevant but of lower priority are:

- tailings dam — its management, risk of collapse and eventual rehabilitation;
- major industrial accident;
- societal disturbance from exploration activity;
- sacred sites;
- ecosystem preservation; and
- consultation with all key groups.

On the basis of the above list the following major topics need to be addressed in future EPR:

1 Plans for decommissioning and rehabilitation
2 Coping with public concerns
3 Plans for coping with industrial accidents
4 Ecosystem maintenance

The need for adaptive assessment

The above list of four topics provides a risk assessment framework to identify the themes for four future EPRs. It would be inappropriate to produce more than four topics, and one may argue that even four is too many, because it implies a planning horizon of two years. It is unlikely that a risk assessment based on the community concerns of January 1995 will still be valid in January 1997. One would expect new, possibly even unforseen, problems to arise and become concerns. Thus, the process of setting topics for EPRs needs to be an adaptive process that is capable of responding in case of a sudden, new development. Such an adaptive assessment regime would also be capable of dealing with the likelihood that after two years it would probably be appropriate to look again at the high profile issue of the environmental performance of the water management system.

An organisation such as the Office of the Supervising Scientist needs sufficient flexibility in the EPR process to be able to ask questions related to important issues that have arisen since the previous EPR. At the same time there is a need to avoid the appearance of entrapment by springing unexpected questions. One way of resolving this dilemma may be to have sections of every EPR that do not follow the main theme of the EPR but are regularly devoted to issues such as: (i) operational aspects of the mine's environmental performance; and (ii) significant recent issues.

This document has, to date, outlined a risk assessment approach to prioritisation. However, the quantitative risk analysis — which consisted of the assignment of values for likelihood and community concern — were allocated by a single risk analyst. Though these should approximate community concerns, as voiced during discussions in the Northern Territory, any final determination of EPR themes should be based on a list of questions, along the lines of those in the appendix, being distributed to the relevant persons (mining company, traditional owners, supervising authorities, politicians etc.) who are asked to assign the values 1 to 4 to both the likelihood and to the community concern. The final ranking would then be based on the sum of the mean scores.

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Chapter 6

Risk To People From Development

Introduction

The Australian approach to the risks to people from development, especially hazardous industrial development, is handled through the Hazardous Industries Planning Task Force, which is a joint State Governments' technical body intended to share skills and information on managing the risks from hazardous facilities. Most of the States have produced guidelines, with those of Western Australia and New South Wales being the most detailed.

Western Australia

In May 1987 the Environmental Protection Authority published details of its requirements for the evaluation of risks and hazards (EPA, 1987). These were subsequently reviewed and extended (EPA, 1992a, b) to produce risk criteria as guidelines for assessing the acceptability of risks imposed upon surrounding land uses by new hazardous industry. These criteria were:

(a) A fatality risk level in residential zones of less than one in a million per year is so small as to be acceptable to the EPA.

(b) A fatality risk level for 'sensitive developments' such as hospitals, schools, child care facilities and aged care housing developments of between one half and one in a million per year is so small as to be acceptable to the EPA.

(c) Fatality risk levels from industrial facilities should not exceed a target of fifty in a million per year at the site boundary for each individual industry, and the cumulative fatality risk level imposed upon an industry should not exceed a target of one hundred in a million per year.

(d) A fatality risk level, for any non-industrial activity located in buffer zones between industrial facilities and residences, lower than ten in a million is so small as to be acceptable.

The fatality risk level of one in a million per year assumes that residents will be outdoors at their homes, exposed to the risk 24 hours a day, continuously day after day for the whole year and do nothing to avoid being harmed. The risk levels calculated under such assumptions are deliberately conservative and a similar spirit of environmental conservatism exists in most of the applications of risk analysis to the environment. Criterion (b) is excessively conservative. An LPG tank used for heating a hospital that is sited on the hospital grounds will have, according to the above definitions, an unacceptable level of risk immediately adjacent to the storage facility itself. Accordingly, a modified criterion for risk generators situated on the grounds of sensitive developments was produced (EPA, 1994).

New South Wales

Within New South Wales there has been a long-standing policy that development proposals for potentially hazardous industry should be subject to a comprehensive assessment of the risks, often as part of an overall impact assessment. The integrated approach to land use safety planning is set out in the Department of Planning's Hazardous Industry Advisory Paper Number 3 (Department of Planning, 1994) which was first issued in 1989 and is presently in its third edition.

The approach considers a development in the context of its siting and its technical and management controls. The assessment process includes a number of studies that need to be carried out at various stages of the development process — from concept, through initial design and examination of environmental impact, to detailed design and operation. Quantitative risk assessment criteria similar (but not identical) to those of Western Australia have also been produced (Department of Planning, 1992). The New South Wales criteria are summarised in Table 6.1

Table 6.1 New South Wales suggested individual fatality risk criteria for various land uses

Land use	Criterion (risk in a million per year)
Hospitals, schools, child-care, nursing homes	0.5
residential, hotels, motels, tourist resorts	1
commercial developments	5
sporting complexes and active open space	10
industrial	50

Department of Planning (1992), in setting the criteria of Table 6.1, took account of the various risks to which people are exposed during various activities. The basis of setting criteria is to determine a risk from a potentially hazardous installation that is below most risks being experienced by the community. Typical risks to individuals in New South Wales (extracted from Department of Planning, 1992, who quote Higson, 1990) are given in Table 6.2. Irrespective of the numerical value of any risk criterion level, certain qualitative principles are also set out:

- all avoidable risks should be avoided;
- the risk from a major hazard should be reduced wherever practicable, irrespective of the cumulative risk level from the whole installation;
- the effects of the more likely hazardous events should be contained within the installation; and
- where there is an existing high risk from a hazardous installation, additional hazardous developments should not be allowed if they add significantly to that existing risk.

Table 6.2 Risks to individuals in New South Wales

Voluntary Risks	Chance of fatality per million persons per year
Smoking (20 per day) — all effects	5000
Swimming	50
Playing rugby football	30
Transport risks	
Travelling by car	145
Travelling by train	30
Travelling by aeroplane (risk of accident)	10
Risks averaged over the whole population	
Cancers from all causes	1800
Accidents in the home	380
Pedestrians being struck by motor vehicle	35
Lightning strikes	0.1

Organisations undertaking risk assessment in New South Wales

There is a number of risk assessment consultants in New South Wales with the experience and capability to undertake risk assessments of hazardous industry. The

Department of Planning has an in-house capacity to evaluate such consultancies through the Major Hazards Policy Unit of the New South Wales Department of Planning. This unit of five people also has the task of preparing and communicating the guidelines contained in the hazardous industry planning advisory papers. The unit has purchased the computer model SAFETI, developed by Technica, which it can use to assess possible hazardous industrial operations. A brief, open-literature description of SAFETI and its incorporation into a decision support system may be found in Fedra & Weigkricht (1995).

The University of Sydney, in conjunction with ANSTO, has established the only centre for risk engineering in Australia: the Australian Centre of Advanced Risk and Reliability Engineering. This centre is headed by an executive director who is also a Professor of Risk Engineering within the Department of Chemical Engineering. The centre thus acts as both a research body and a consultancy organisation.

Risk to the biophysical environment

The above discussion has concentrated on the risk to people. In part this perpetuates the health-risk aspect of traditional risk assessment and in part it is an accurate indication of the fact that the majority of Australians live in cities, so that the primary component of the ecosystem surrounding an urban industrial location consists of people. However, a proper risk assessment that is sufficiently general in scope should certainly consider the risk from accidental releases to the biophysical environment.

In fact, the principles of ecologically sustainable development (Commonwealth of Australia, 1992: page 60) require land use planners and decision makers to place risk-weighted values on goods and services while encouraging decision making that takes full account of all relevant land and natural resource values. The main concern here is with the effects on ecosystems, rather than with effects on individual plants or animals. The topic is complicated. Ecological risk assessment is a topic of active research which will be discussed in the next section.

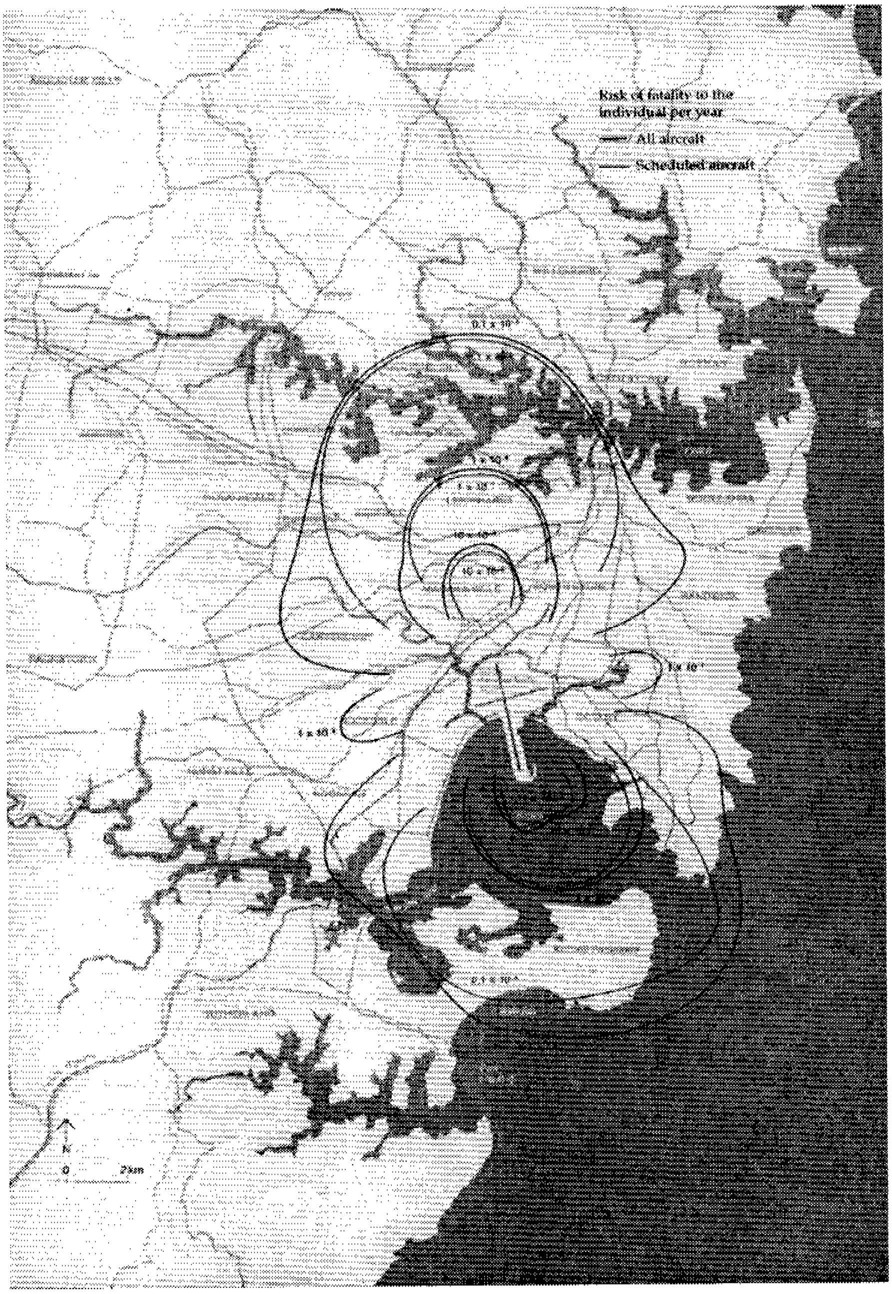
Individual risk and societal risk

Human fatality risk results are expressed in two forms: individual risk and societal risk. Individual risk is the risk of death to a person at a particular point. As an example, Figure 6.1 reproduces the fatality risk contours that formed part of the environmental impact statement for the Sydney Airport Third Runway proposal. The risk contours indicate the expected risk of fatality to an individual in residential areas surrounding the airport when the third runway is in operation.

Societal risk is the risk of a number of fatalities occurring. It combines the consequences and likelihood information with population information. The societal risk concept is based on the premise that society is more concerned with incidents that kill a larger number of people than incidents which kill fewer numbers. The societal risk contours for the Sydney Third Runway proposal are shown in Figure 6.2. This figure is presented as an F-N curve that indicates the cumulative frequency (F) of killing N or more people. Thus, Figure 6.2 indicates that there are, on average, about 1000 people killed in fatal road accidents in NSW (i.e. accidents that kill one or more people), but only about 100 people killed in road accidents that kill two or more people.

As an illustration of the care that is needed in interpreting risk statistics, this figure of 1000 per year differs slightly from the figure that can be obtained from Table 6.2. The chance of a fatal motor vehicle accident in NSW is 145 per million per year. The population of NSW in 1987/88 was 5.7 million people, so multiplying the two numbers indicates that the actual number of motor accidents involving one or more fatalities was 826. This figure represents drivers and passengers. When pedestrians are included (RTA, 1990) then the figure rises to 1029 fatalities in 1986, drops to 959 fatalities in 1987 and increases again to 1037 fatalities in 1988.

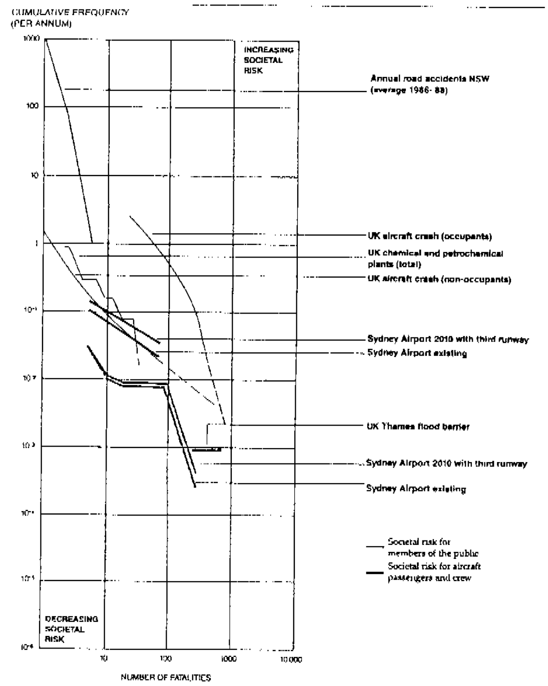
Figure 6.1 Predicted risk to the individual for long-term scenario (From Kinhill Engineers Pty Ltd, 1991)



Societal risk data on major natural and human-made accidents (Fig. 6.3) has been used by some authorities as the basis of deriving a societal risk acceptability criteria F-N curve. The Dutch National Environmental Plan (Directorate-General for Environmental Protection, 1988) sets limits for societal risk (or group risk as they are called in the Dutch document) on the basis of incremental risk, as follows (Fig. 6.4):

An increase in the number of deaths by a factor n in a given situation is only acceptable if the probability of this event occurring is a factor n^2 lower for both types of level. The maximum permissible risk levels for disasters are defined as 10^{-5} per year for n = 10 or more deaths and 10^{-7} per year for n = 100 or more deaths. The corresponding negligible levels are defined as 10^{-7} per year for n = 10 or more deaths and 10^{-9} per year for n = 100 or more deaths.

Figure 6.2 Predicted Societal Risks (From Kinhill Engineers Pty Ltd, 1991)



The NSW Department of Planning (1990, 1992) believes that much more research is needed before societal risk guidelines or criteria can be adopted. The major reason for this is that societal risk acceptability is specific to each society and it is very important that allowance be made to reflect differences between societies and cultures. Thus, judgements on societal risk need to be made on the basis of a qualitative approach on the merit of each case rather than on specifically set numerical values.

Figure 6.3 Societal risk curves for some human-caused events in the USA

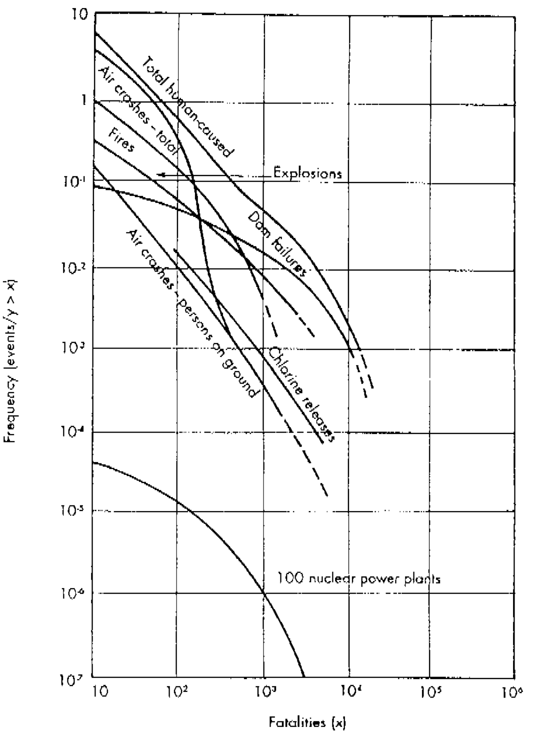
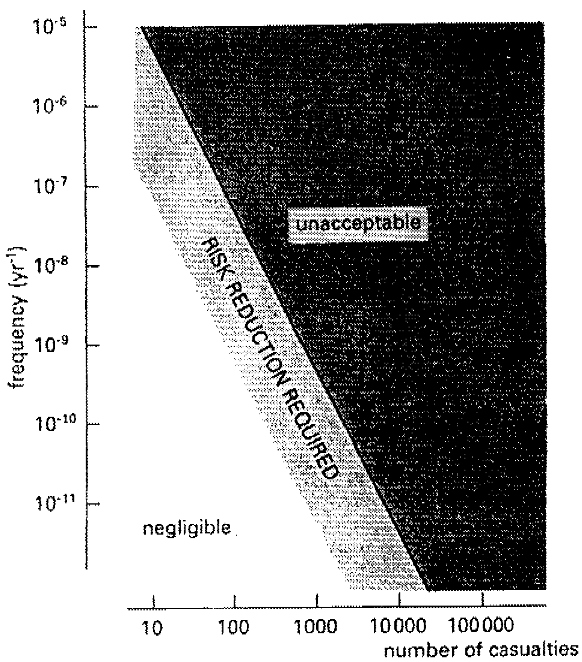


Figure 6.4 Incremental group risk limits for major accidents (From Directorate-General for Environmental Protection 1988: VROM Publication No. 90569/12-89)



Case Study: Sydney Third Runway

Background

On 4 November 1994 a third runway at Sydney Airport was opened for traffic. As a result, airport operations changed to accommodate the new runway by maximising north-south traffic flow and greatly reducing use of the east-west runway.

The increase in noise levels in areas north of the airport that arose as a result of the use of the third runway caused consternation among the local populace and resulted in community protest and demonstrations, including a mass blockade of the airport on 17 December 1994 which consisted of a group variously estimated as being 6 000 to 15 000 strong (Canberra Times, 18 December, 1994). The protest by residents and local councils from the northern areas attracted considerable media coverage, especially the use of loudspeakers, mounted on a truck, that were taken to locations such as Parliament House in Canberra and used to direct amplified aircraft noise at politicians so as to make them aware of the problems faced by the local populace.

The Environmental Impact Statement

The Federal Airports Corporation prepared an environmental impact statement (EIS) for the proposed third runway (Kinhill, 1990, 1991). Environmental agencies in Australia have long adopted an issues-based approach to environmental impact assessment, as opposed to the checklist-based approach that was used in the early days of environmental impact assessment. Thus, any properly constituted EIS should itself constitute a risk assessment of the issue, within the framework established by the United States National Research Council or that of the Asian Development Bank. It is a risk assessment in that the role of an EIS is (amongst others) to identify the hazards associated with the activity and to determine whether these hazards pose a risk to the environment.

The Sydney 3rd runway EIS examined 17 issues which were divided into three parts. These were:

- *issues relating to project layout* — heritage, hydrology (groundwater and surface), terrestrial ecology, aesthetics, interrelated issues;
- *issues relating to project construction* — sources of bulk fill, coastal hydrodynamics of Botany Bay, marine ecology of Botany Bay, effects of extraction on other fill sources, other construction issues; and
- *issues relating to project operation* — aircraft noise, economics and land use, social and demographic environment, hazards of airport operation, air quality, surface transport, other issues.

The section of the EIS that dealt with the hazards of aircraft operation consisted of a quantitative risk assessment using the traditional engineering approach to risk assessment. This was an important issue that had been identified as being of public concern. In addition, there was substantial public concern over the issue of noise.

The effect of noise was the single issue that was of overwhelming concern to people opposed to the proposed third runway. During the consultation phase of the EIS, it was raised as an issue 594 times. The next most contentious issue among opponents was the risk of aircraft crashes, which was raised 321 times. Publication of the EIS did not allay these concerns. The preface to the supplement to the draft EIS (Kinhill, 1991) lists the concerns raised during the public review phase of the draft EIS. Of the above list of issues, social and demographic issues topped the list of concerns, but when these are examined they primarily relate to the social disruption arising from excessive aircraft noise. Aircraft noise, *per se*, was the issue of next-highest concern, followed by hazards.

The aims of this case study are to examine the following questions:

1. Despite the formal process of an EIS, public review and Commonwealth assessment; the ensuing aircraft noise was unacceptable to a large and influential section of the public. Were the needs and concerns of the affected population adequately considered in the original framing of the issues?
2. Was there a technical deficiency in the assumptions made in evaluating aircraft noise contours, the methodology used or in the interpretations of the results?
3. Could the use of a quantitative risk assessment process have predicted such a problem?
4. What guidelines could be implemented that would cover both the traditional engineering risk assessment, as well as the risk assessment of an issue such as the public response to excessive noise?

The engineering risk assessment

Full details of the engineering risk assessment may be found in a working paper (ACARRE, 1990) which is summarised in the draft EIS. Four hazards were identified and quantitatively evaluated: (i) fuel spills, (ii) collisions, (iii) crashes, and (iv) fires and explosions. The predicted risks to individuals were presented as contour plots of probability that overlay a map of the general area. The overall result, which was reproduced in both the draft EIS and the environmental assessment report (DASETT, 1991), estimated that, under airport operations prior to the 3rd runway, the risk of fatality to the individual per year at a near-north location such as Marrickville, was 42 chances in a million (4.2×10^{-5}) (ACARRE, p. 81). These risks increased by about a factor of 2.5, to 103 chances per million, after the third runway was in operation though at the same time, because use of the third runway would reduce use of the east-west runway, the risk of a crash into a residential area in the east-west direction was reduced by a factor of about ten.

There are a number of aspects of this analysis of relevance to a Commonwealth position on quantitative environmental risk assessment. The first is the usefulness of the analysis for determining priorities for the most fruitful areas for risk reduction. Three areas emerged from the formal risk analysis of ACARRE (1990):

- emergency procedures;

- flight paths over hazardous industrial facilities; and
- risk posed to residential areas.

A disturbing aspect of the risk assessment is that the risk to populations immediately to the north of the airport far exceed the levels deemed acceptable for industrial risks imposed on various forms of land use (Department of Planning, 1990). These risks are given in Table 6.1. Three different approaches seem to have been taken to deal with this:

Bell (1990) undertook a study of areas in which risks may have been understated. His review of the data and assumptions implies (but does not actually state) that, if the situation without the third runway already exceeds risk guidelines, then no further development should be allowed. In fact, Fig. 5 of Bell (1990) contains contours indicating areas unsuitable for residential purposes at present and an even larger area considered unsuitable for schools and hospitals. The implication is that present usage of the airport should be reduced.

The Environmental Assessment Report (DASETT, 1991, p. 148) looks at the incremental risk, which is the increase in fatality risk levels. The implication here is that, in a proposal that consists of an upgrade of a facility in which the existing risk level is high, it is acceptable to reduce the risk but not to increase it.

The NSW Department of Planning (DASETT, 1991, Appendix 4) emphasised that risk estimates are themselves uncertain and that the values given in the EIS were 'cautious best estimates'. By thus implicitly reducing the risk estimates it was then possible to argue that the benefits of access to air travel outweigh the risk implications. Though the justification for doing this was not spelt out in the response it seems to hinge on two issues.

Firstly, the NSW Department of Planning quantitative criteria are for industrial development. The implication is that the crtieria apply to a development such as a factory, from which the affected public do not receive immediate benefit (unlike, say, the owners of the factory). In the case of Sydney airport, the people at risk derive direct benefit from its existence because it provides the only means of rapid interstate and international communication.

The second issue is that, by not having set criteria for societal risk, it is possible to argue, as was done by the NSW Department of Planning, that "it is generally accepted that the benefits of access to air travel in major cities outweigh the societal risk implications". It is certainly the case that the societal risk contours presented in the EIS indicate that the societal risk for members of the public that arises from Sydney airport (with or without the third runway) is much less than the societal risk for UK aircraft crashes.

The noise assessment

Full details of the noise study may be found in a two volume working paper (Vipac, 1990) which is summarised in the draft EIS. The noise study used the Australian Noise Exposure Forecast (ANEF) system. This provided an index that has been incorporated into a dose-response relationship by the National Acoustic Laboratories (Fig. 1 in the paper). The EIS measured the social impact of noise in terms of the number of people affected by the noise. It used a complex measure to determine whether people were moderately or seriously affected. As a rough guide, 15 ANEF values approximate moderate disturbance and 25 ANEF values approximate serious disturbance.

Table 6.3 Estimated numbers of people affected by aircraft noise

	1988 Base case		Long-term (2010) scenario	
	Moderate	Serious	Moderate	Serious
South	1 100	300	800	200
West	60 100	19 000	1 000	200
North	61 600	19 800	65 100	20 500
East	47 300	15 600	3 300	600
Total	**170 100**	**54 700**	**70 200**	**21 500**

The figures published in the draft EIS for the number of people affected by noise were revised downward in the supplement to the EIS on the basis of a revised fleet mix using newer, quieter planes. The number of people estimated to be moderately or seriously affected are given in Table 6.3.

Even though there is a sizeable decrease in the total number of people affected, as shown in Table 6.3, the numbers affected to the north increase. Nevertheless, if these figures are taken at face value then one would expect the 1988 base case group to have acclimatised to the present noise regime, so that it would be realistic to expect complaints to come only from the 4 200 people newly exposed to noise. It is unanimously agreed that more than this number protested during the December blockade of Sydney airport. Thus, either the numbers in Table 6.3 misrepresent the short-term situation, or a sizeable number of existing residents were not acclimatised to the noise and were willing to protest.

An internal report of the NSW Environment Protection Authority (Environment Protection Authority, 1995), released to the media in January 1995, states that

> *"There appears to be a general community feeling that the information provided did not adequately inform the community about the magnitude and location of the noise impacts under the interim operation regime."*

The major problem that was identified was a greatly increased frequency of aircraft noise events over that predicted for take-offs to the north. The ANEF contours were based on 13% of daily movements being to the north. However, during summer months, as a result of expected northerly wind conditions, over 25% of all movements, on average, are predicted to take-off to the north during afternoons and evenings.

Over a period of a few days, the variation in the percentage of take-offs to the north can be even higher. This occurred with the opening of the third runway, which coincided with a period of winds from the northerly direction. The average daily ANEF, derived from annual averages, is not well suited to predicting the short term impacts experienced since the new runway was opened. The NSW Environment Protection Authority expects, however, that over a period of time the level of impact will converge to that originally assessed.

Discussion

The case study began by asking a number of questions. In hindsight it appears that the needs and concerns of the affected population were not adequately considered. For example, there was no public hearing on the EIS. In part this probably reflects the fact that the benefits associated with improvement in air services was a major influence in determining the acceptable options for airports in Sydney. The development of the third runway is one of three elements of a strategy announced by the Commonwealth Government in March 1989 to meet the airport needs of the Sydney Basin into the next century. The issue of whether the expression of such benefits in the form of political factors count as risks and, if so, how to deal with them will be discussed in the Chapter on risks of political decision making.

The inadequacy of the process appears to have been a direct result of the environmental impact statement noise contours being based on an annual average, whereas the community has reacted very strongly to the impact over a very much shorter period. In retrospect, the annual average ANEF contours are inappropriate for estimating community reaction. Worst-case contours should have been presented for periods of persistent northerly winds.

Had the noise study been done with risk assessment techniques in mind then such a worst-case scenario would have been expected. Such considerations have been built into accepted practice in air dispersion modelling. The air quality contours (Kinhill, 1990, p. 26-15) give predicted maximum one-hour concentration contours for January, April, July and October. The emphasis is to look at the worst-case and to look at seasonal variability. The lack of a similar level of sophistication in the approach to noise assessment led to some of the ensuing problems.

The issue of guidelines that could be implemented to cover both the traditional engineering risk assessment, as well as the risk assessment of an issue such as the public response to excessive noise, will be considered later. However, this case study has indicated the need for risk assessments within the EIS process to be more wide-ranging than just engineering risk assessments of fatality risk. In fact, a full risk assessment and risk communication process considering public health problems (including noise) and alternative land use plans conducted within a strategic planning context (i.e. considering the options of other airport locations) would have improved both the environmental impact assessment and the basis for eventual decision-making.

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Chapter 7

Risk To The Environment From Development

Introduction

Any consideration of the risk to the environment from development needs initially to confront a number of issues:

1. Does the natural environment include humans?
2. Any general procedures related to risk assessment need to be applicable to the risk to the natural environment from development associated with chemicals (to be dealt with in Chapter 8) as well as other sources of risk to the natural environment from development.
3. In the same vein, the methods adopted to deal with contaminated sites need to be applicable to the risk to the environment from development.

The Executive Director of the Environment Protection Agency is also the Supervising Scientist, responsible for protecting the environment by assessing the adequacy of environmental protection relating to uranium mining in the Alligator Rivers Region and by advising on best practice in environmental protection. The Supervising Scientist controls an Environmental Research Institute situated in Jabiru, Northern Territory, which undertakes research.

The environment and human populations

Section 3 of the Commonwealth *Environment Protection (Impact of Proposals) Act 1974* defines the environment to include all aspects of the surroundings of human beings, whether affecting human beings as individuals or in social groupings. This is generally taken to mean the ecological, economic, social and cultural aspects relevant to whatever matter is under consideration.

There are certain activities conducted by the EPA in which the term environmental risk includes the risk to human populations, and certain activities in which consideration of the risk to humans is the responsibility of another government department. In its consideration of uranium mining in the Northern Territory, the EPA needs to consider risks to the flora, the fauna, and to both present and future generations of humans who may occupy the area. When dealing with the potential risks of agricultural or industrial chemicals, or the risks associated with contaminated sites, then responsibility for human health risk assessment is with the National Health & Medical Research Council (NHMRC) so that the use within the EPA of the term environmental risk, in relation to these areas, refers to the flora and fauna only.

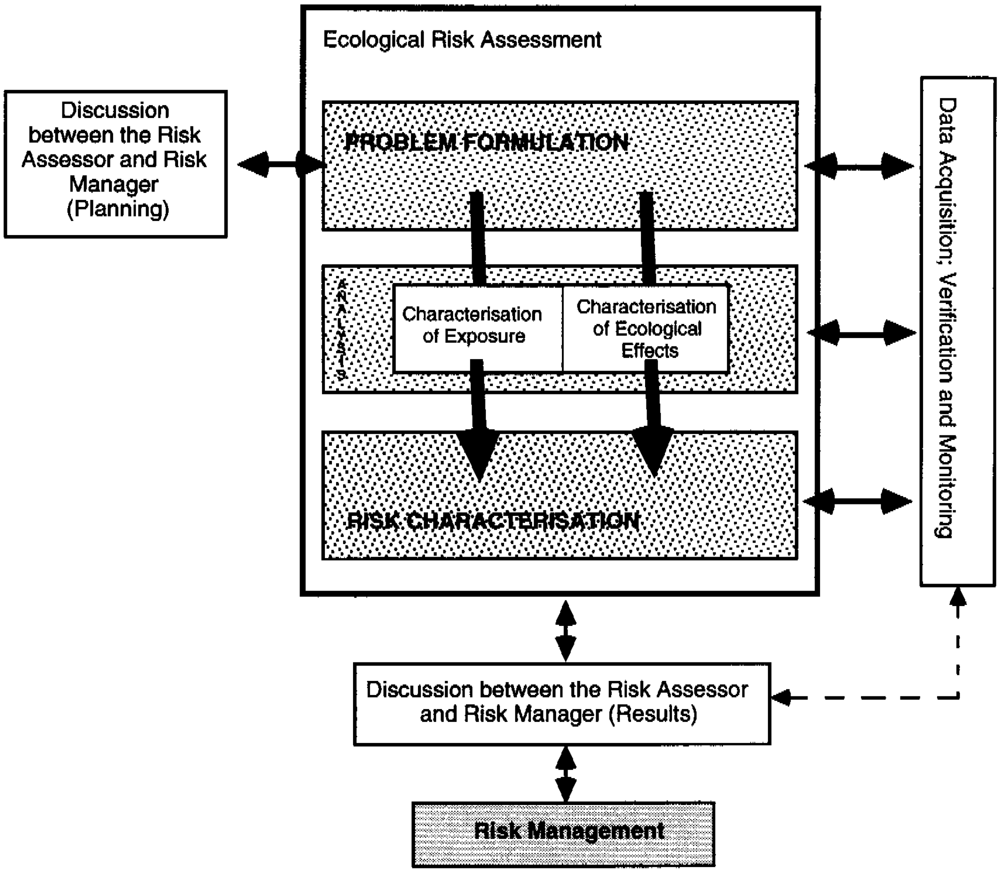
Such conflicts mean that it will be difficult, if not impossible, to find acceptable definitions for terms such as environmental risk assessment and ecological risk assessment. To some the terms are synonymous and include risks to people — after all there is a field of scientific endeavour known as human ecology. To others they are synonymous and exclude risks to people. And to a third group the first term includes people whereas the second term excludes people.

In a consultancy report to the Department of Human Services and Health (Axis Environmental, 1995) environmental health is defined as "the state of human health and well-being related to the environment and environmental factors such as air, water, soil contamination (as distinct from occupational factors, infectious diseases etc.)". Such a definition of environmental health is too narrow as it does not consider the state of the environment — a topic of crucial interest to the EPA. As mentioned in the previous chapter, there is a growing realisation that hazardous industry planning needs to include the biophysical environment

Ecological risk assessment

The US EPA uses the term ecological risk assessment to exclude human health risk assessment and has issued a framework for ecological risk assessment (US EPA, 1992). This framework, shown in Figure 7.1, was based on the principles of human health risk assessment and thus provides an entry to an integrated framework for human and ecological risk assessment. The framework of Figure 3.2 could equally well apply.

Figure 7.1 Framework for Ecological Risk Assessment (US EPA - 1992)



Whatever theoretical framework is chosen, most of the problems in conducting an ecological risk assessment are practical. The problem formulation step (i.e. dealing with concerns and their consequences) is vital because one needs to determine which part of the ecosystem is vulnerable. This is not easy because there is little agreement amongst ecologists on appropriate measures for the health of an ecosystem.

Another recent area of convergence between human health risk assessment and ecological risk assessment is in the use of probabilistic methods, such as Monte-carlo modelling, to accomplish the uncertainty analysis. Monte-carlo models have been used in systems analysis, and specifically ecosystems analysis, for about fifteen years. The method was used, as an initial screening tool, to identify the causes of eutrophication in the Peel Inlet of Western Australia (Hornberger and Spear, 1983) and has recently been advocated for human health risk assessment (Finley & Paustenbach, 1994; Copeland et al., 1994).

The Office of the Supervising Scientist (OSS) and the Environmental Research Institute of the Supervising Scientist (ERISS)

The Office of the Supervising Scientist was set up under the Environment Protection (Alligator Rivers Region) Act of 1978 (as amended in 1993), following the findings of the Ranger Uranium Environmental Inquiry into the environmental aspects of mining newly-discovered uranium mineralisation in the Alligator Rivers Region of the Northern Territory.

The purpose of the Supervising Scientist is to protect the environment in the Alligator Rivers by assessing the adequacy of existing methods of environmental protection, by developing improved ways of environmental protection and by providing expert advice.

The Environmental Research Institute of the Supervising Scientist is situated at Jabiru, in the Northern Territory. ERISS carries out scientific research on the environmental impact of mining and on tropical freshwater and estuarine ecosystems. As at December 1994 this was done within two research programs — Wetland Management and Impact of Mining — which were divided into five research groups: biology, ecosystems, chemistry, radioactivity and geomorphology.

Tasks in prioritising risk

In this section we will conduct an uncertainty analysis by using a probabilistic methodology to apply ecological risk assessment techniques to the operations of the Ranger Uranium Mine so as to prioritise risks. This will be followed by a case study, more limited in scope, that examines some issues associated with radiological pathways. In both cases, the particular probabilistic modelling tool to be used in such an ecological risk assessment is Monte-carlo modelling.

There are three areas of environmental risk that need to be considered:

- failure of engineered constructions;
- chemical contamination; and
- radiological pathways.

The case study, which serves as an example of the use of the methodology, considers only the radiological pathways.

To apply probabilistic modelling involves four steps (Fig. 7.2):

Figure 7.2 Steps in Uncertainty Analysis for Ecological Risk Assessment

- Determine resources at risk
- Flowchart interconnections
- Assign values
- Monte-carlo model

1. Develop flow charts of the systems, likely emissions, pathways and fate of materials.

   This requires discussion and collaboration with experts in each of the three aspects to be studied.

2. Quantify the hazards associated with each step of the process.

   When examining chemical contamination or radiological pathways this step requires collaboration with a health physicist or toxicologist able to assign hazards to particular chemicals and radioactive species.

3. Determine probability distributions for key steps in the process, and run Monte-carlo simulations to determine the expected probabilities.

   This step requires collaboration between the hazards expert and a statistician/Monte-carlo modeller capable of expressing the hazards information in the form of probability distributions to be assigned to each step of the flow pathway and incorporate the distributions into a Monte-carlo model.

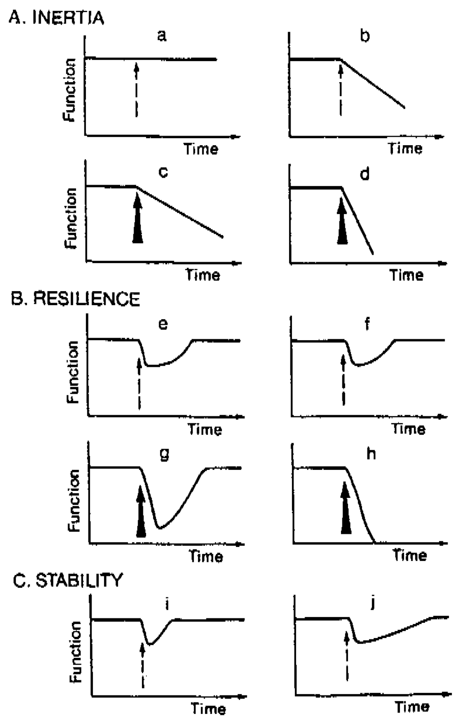
4. Rank the probabilities on the basis of some criterion such as risk/benefit, utility, or other grounds.

   This step, which is the prioritorisation step, requires the skills of an expert, or an expert panel, able to assign priorities (e.g. research priorities) on the basis of technical information. It may be possible to accomplish this by using an environmental economist able to assign utilities or determine risk/benefit curves. But then again, it may not. The discussion in Chapter 5 indicated that assigning numeric values to environmental damage is a difficult, if not impossible, task.

Characterising the health of an ecosystem is a difficult task and there is little agreement on which population variables to use. Ecological response indicators quantify the integrated response of ecological resources to individual or multiple stressors. Examples include measurements of the condition of individuals (e.g. frequency of tumours), populations (eg. abundance, biomass), and communities (species composition, diversity). Much of the work done in assessing the risk to the environment as a result of uranium mining in the Northern Territory has concentrated on studies of key indicator species such as freshwater snails, or the rainbow fish (Melanotaenia negrans).

Research in Australia has cast doubt on the utility of community measures, diversity indices in particular (Campbell, 1990), whereas it is extremely difficult to obtain sufficient monitoring data to characterise population characteristics such as those suggested by Underwood (1990) as shown in Fig. 7. 3.

Figure 7.3 Characteristics of populations relevant to monitoring programs and environmental disturbances (From Underwood, 1990)



Because of this diversity in possible ecological response indicators the methods used to conduct ecological risk assessments will differ. The US EPA has assembled case studies on eleven ecological risk assessments (US EPA, 1993, 1994) to determine whether they addressed generally accepted components of an ecological risk assessment (as defined by the US EPA) or provided an alternative approach to assessing ecological effects.

As an example, in the use of ecological risk assessment techniques to investigate the problem of radiological pathways involved in the operations of the Ranger Uranium Mine, we have re-analysed the work involved in estimating the risk associated with the land application of effluent water, given by Moroney (1992). The framework used to examine this particular problem is given in Figure 7.2.

CASE STUDY: Risk assessment of radionuclide pathwaysinto the environment

1. Introduction

There is considerable literature on the hazards associated with radionuclide release. A scientific summary is given by Vennart (1983), whereas a popular account may be found in Caufield (1990). The absorbed dose(Gray) is defined as the energy deposited per unit mass of material. The SI units are J/kg which are given the special name of Gray (Gy). However, the biological damage produced by radiations depends not only on the absorbed dose but also on the type of radiation that delivered the dose. These differences are roughly measured by a quantity called the quality factor, which has values of 1 for X, gamma and beta radiation, 10 for neutrons, and 20 for alpha particles. To place all radiations on an equal footing with respect to biological damage a quantity known as the dose-equivalent has been introduced, which is the product of the absorbed dose and the quality factor. The unit of the dose-equivalent is the Sievert (Sv). Annual dose-equivalent limits above background, set by the International Commission on Radiological Protection (ICRP) in 1977 for the general public, were 1 mSv per year as a lifetime average, with 5 mSv permitted in any one year.

The particular problem dealt with by Moroney (1992) is the radiation exposure that would be received following the land application of effluent water from the restricted release zone of the Ranger Uranium Mine. The problem has been chosen for analysis because of the conflicting results of Moroney (1992) and Carter et al. (1994). The Ranger Uranium Mine, between 1986 and 1989, applied an average annual load corresponding to 2 kBq/m^2 of radium-226, and 44 kBq/m^{2}of uranium (Moroney, 1992, Table 1). The calculations of Carter et al. (1994) indicate that after 30 years of application to the land this will lead to a dose-equivalent that is above the acceptable limit, whereas the calculations of Moroney (1992) indicate that the resulting dose-equivalent will be below the acceptable limit. Both studies used the same assumptions, but varied the parameters used to model the pathways. In this paper we wish to study the probability distribution of the dose-equivalent by: (i) allowing the model parameters to be treated as random variables; and (ii) examining the sensitivity of the results to the assumptions.

2. Pathways

The pathways for radionuclides are shown in Fig. 7.4. The risk analysis endpoint is the radiation health of local residents who live a traditional lifestyle, after the end of the land application program. Each pathway in Fig. 7.4 is, in practice, determined from a complex model. We follow a traditional systems analysis approach which brings the flow pathways to the simplest possible pathways that still incorporate the essential and relevant features of the system. This decomposition was undertaken by Moroney (1992) and Carter et al. (1994) and simplifies the problem to one of linear relations linking an input, expressed in kBq/m^2 , with an output expressing dose-equivalent in terms of Sv per year. If we express this as

$$D = \sum c_i I_i$$

then c is the linear function linking the input I and the dose-equivalent D for each of the pathways, represented by the subscript i. Altogether ten values need to be considered for the subscript i. Each pathway has a dose-equivalent as a result of radium and a dose-equivalent as a result of uranium.

The function, c, depends on exposure to the particular activity considered under the particular pathway, as well as any physical parameters that are part of the sub-model involved in determining the relationships. Thus

$$c_i = A_i \beta_i C_i$$

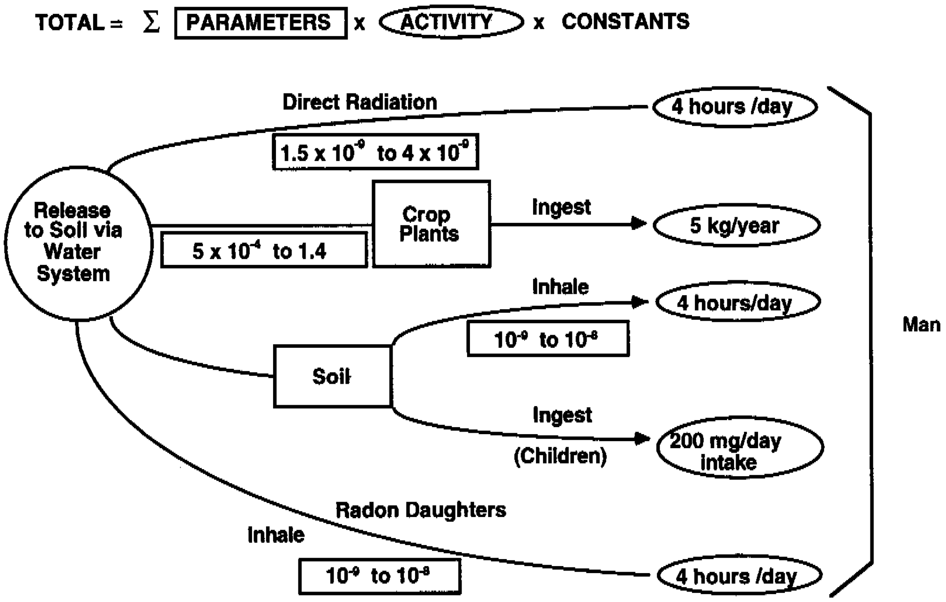
where A is used to represent human activity that determines the dose-equivalent, ß represents a physical parameter whose value can vary over a range, and C is a constant along any particular pathway. The values of C were determined from the estimates for c given in Moroney (1992, Table 9), which are reproduced in Table 7.1.

Table 7.1 Values of A and c used to infer ß and C

	i	A	units of A	c (Moroney)	c (Carter et al)
Direct	1 (Ra)	4	hours per day	3.5×10^{-6}	4×10^{-6}
Food	2 (Ra)	5	kg/year	1.7×10^{-6}	2×10^{-6}
Soil ingest	3 (Ra)	200	mg/day	n/e	2×10^{-7}
Inhale Rn	4 (Ra)	4	hours per day	6.1×10^{-7}	6×10^{-6}
Inhale dust	5 (Ra)	4	hours per day	1.2×10^{-9}	6×10^{-8}
Direct	6 (U)	4	hours per day	4.7×10^{-8}	n/e
Food	7 (U)	5	kg/year	3.7×10^{-8}	2×10^{-8}
Soil ingest	8 (U)	200	mg/day	n/e	1×10^{-7}
Inhale Rn	9 (U)	4	hours per day	n/a	n/a
Inhale dust	10 (U)	4	hours per day	2.0×10^{-8}	6×10^{-7}

n/e - not estimated   n/a - not applicable

Figure 7.4 Uncertainty Analysis



2.1 Direct radiation:

Radium:

The activity is assumed to be the gathering of fruit and vegetables for 4 hours per day. This will be denoted by A_1 and will be used in a number of the other pathways. The major physical parameter uncertainty arises from the value of the effective dose-equivalent rate relating kBq/m^2 to Sv/h. According to Carter et al. (1994) this ranges from 1.5×10^{-9} to 4×10^{-9} Sv/h per kBq/km^2 for Radium (^{226}Ra), with Carter et al. (1994) choosing a value of 3 x 10^{-9}, and Moroney (1992) choosing a value of 2.6×10^{-9}.

Thus

A_1 = 4 hours per day

$\beta_1 = 1.5 \times 10^{-9}$ to 4×10^{-9}

$C_1 = 336$

Uranium:

Moroney (1992) estimates direct radiation from uranium in surface soil. Values used are:

A_1 = 4 hours per day

$\beta_6 = 3.5 \times 10^{-11}$

$C_6 = 336$

With this choice of units, C represents the number of days per year that food collection takes place. Moroney appears to have assumed 336 days which corresponds to 7 days a week for 48 weeks.

2.2 Ingestion from food

Radium

The activity is assumed to be the gathering of 5 kg per year of edible fruit and vegetables. According to IAEA (1992) 1 Bq/g of ^{226}Ra in the soil would result in a concentration factor of 4×10^{-2} Bq/g in edible vegetation. Moroney (1994) lists a large range for the concentration factors with a low value of 5×10^{-4} for vegetables, and a high value of 1.4 for pastures.

A_2 = 5 kg per year

$\beta_2 = 5 \times 10^{-4}$ to 1.4

$C_2 = 1.0 \times 10^{-5}$

where C has been calculated assuming $\beta_2 = 4 \times 10^{-2}$, and $c_2 = 2 \times 10^{-6}$

Uranium

Moroney (1992) lists concentration factors for uranium as ranging from 1.6×10^{-4} for vegetables to 0.14 for pastures, and uses a value of 3.7×10^{-2}. Appropriate factors then appear to be

A_2 = 5 kg per year

$\beta_7 = 1.6 \times 10^{-4}$ to 0.14

$C_7 = 2.0 \times 10^{-7}$

where C has been calculated assuming $\beta_7 = 3.7 \times 10^{-2}$ and $c_7 = 3.7 \times 10^{-8}$

2.3 Direct ingestion of soil

Carter et al. (1994) assume that children ingest about 200 mg per day of soil. Factors are then

A_3 = 200 mg per day

β_3 = 1

C_3 = 10^{-9}

Uranium

A_3 = 200 mg per day

β_8 = 1

C_8 = 5.0×10^{-10}

2.4 Inhalation of radon daughters

Moroney (1992) estimates c to be 6.1×10^{-7} whereas Carter et al. (1994) obtain a value one order of magnitude larger. Both assume that the radon daughters are inhaled during the 4 hours per day that fruit and vegetables are being collected:

A_1 = 4 hours per day

β_4 = 0.1 to 1

C_4 = 1.5×10^{-6}

Uranium does not emit radon daughters. Take $\beta_9 = 0$

2.5 Inhalation of resuspended soil

The inhalation of suspended soil particles occurs during the period that collection of fruit and vegetables takes place. The major parameter uncertainty arises from assumptions concerning the resuspension factor for contamination in the surface layer. Carter et al (1994) assume this to be 10^{-8}/m whereas Moroney (1992) assumes that it is 10^{-9}/m. Using these values gives:

A_1 = 4 hours per day

β_5 = 10^{-9} to 10^{-8} /m

C_5 = 1.5

Uranium

A_1 = 4 hours per day

β_5 = 10^{-9} to 10^{-8} /m

C_{10} = 15.0

2.6 Total

The total effective dose equivalent rate (Sv/y) for all exposure pathways for the deposition of 1 kBq/m^2 of radium and uranium is the sum of the above effective dose-equivalents.

$$\text{Total dose} = T[A_1\{P_R(\beta_1 C_1 + \beta_4 C_4 + \beta_5 C_5) + P_U(\beta_6 C_6 + \beta_5 C_{10})\}$$

$$+ A_2\{P_R \beta_2 C_2 + P_U \beta_7 C_7\} + A_3\{P_R C_3 + P_U C_8\}]$$

where T = effective time period of disposal

P_R = annual load in kBq/m^2 for radium

P_U = annual load in kBq/m^2 for uranium.

This is shown diagramatically in Figure 7.4.

3. Monte-carlo modelling

Results of Carter et al. (1994) gave the total for all pathways as 1.2×10^{-5} for radium and 7.2×10^{-7} for uranium. Moroney (1992) obtains 5.8×10^{-6} for radium and 1.0×10^{-7} for uranium (or 3.2×10^{-7} using a different soil loading model).

There are two sources of parameter uncertainty in the problem. The first is the uncertainty in the physical parameters denoted by beta in the above pathways. The second is the uncertainty in future traditional use of the land. This uncertainty in lifestyle parameters is indicated by the term A in the above pathways. The above description has followed both Moroney (1992) and Carter et al. (1994) in setting fixed values for postulated traditional use of the land following cessation of land application. In practice it is widely acknowledged that these quantities are highly uncertain. The assumption of 4 hours per day spent in gathering fruit and vegetables is likely to be an upper bound and assumes virtually full-time gathering during the daylight hours of the dry season.

The choice of 5kg per year per person of flora to the Aboriginal diet is justified by Akber & Marten (1992). At first sight the figure seems low, both in terms of land productivity of the 35 ha (McQuade, 1992) irrigated site (1/7 kg per ha per year) and in terms of the finding by Beck (1986) who estimated that day trips for hunting provided between 0.2 and 2.0 kg of bush food. However, this bush food is primarily meat, whereas the 5kg per person per year refers only to fruit and vegetables harvested from the land application area.

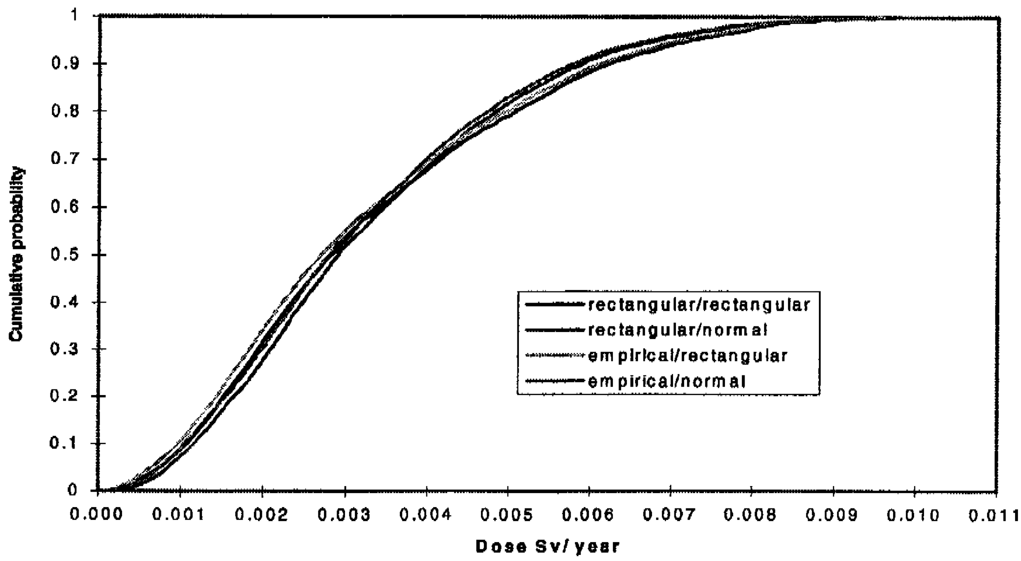
The assumed figure of 200 mg/day soil ingestion by children is also the figure used by the US EPA (US EPA, 1989). Finley et al. (1994) discuss the data on which it is based and provide a cumulative probability density function for soil ingestion rates for children that allows for the observation that most children ingest virtually no soil, but that a small group ingest very large amounts.

4. Results

Macpherson (1995) undertook an uncertainty analysis of the above problem using Monte-carlo modelling. Various probability distributions were assumed for the variation of the beta distribution. The results are based on an assumed 30 year disposal period for an average annual load corresponding to 2 kBq/m^2 of radium-226 and 44 kBq/m^2 of uranium. The results, depicted in Figure 7.5, indicate that there is a 90% probability that a dosage of 1mSv/yr will be exceeded.

Two aspects of this result are noteworthy. The first is that the result is relatively insensitive to the choice of probability distribution. The second is that the result is strongly driven by the high value of 1.4 for beta in the pathway dealing with crops and plants. This pathway dominates the subsequent analysis because of this large value for beta. However, the value of 1.4 refers to pastures. If this is considered unrealistic, and a maximum value of 0.014 is assumed, then the probability of exceeding 1 mSV/yr drops to 57%.

Figure 7.5 Cumulative Probability Results of Radiation Exposure from Land Application of Effluent Water



5. Discussion

Detailed risk analysis of the issue of land application of contaminated water reveals the importance of Aboriginal issues in determining the outcome of any Monte-carlo modelling. This result is, of course, not original. The paper by Robotham & McLaughlin (1992), of the Northern Land Council, identified the occupancy rate as a key variable, deemed the choice of 4 hours per day as appropriate and reached the conclusion that restrictions would have to be placed on the land application area to prevent it becoming a permanent camp site. What is original in our analysis is that the application of a formal ecological risk analysis methodology has led to the identification of the uncertainties associated with Aboriginal lifestyles as being the key environmental uncertainties and thus leads to the question of whether the existing research priorities of ERISS, which concentrate on reducing the uncertainties in the physical, chemical, biological and geomorphological parameters are indeed adequate to meet future issues that arise.

There seems little doubt that the Aboriginal perspective will emerge as a key variable, and a key unknown, in any risk analysis of the radionuclide risk, the chemical risk and probably even of the risk of failure of engineered constructions. The reason is that the risk, as perceived by the Aboriginal community, is so great as to preclude risk management options based on technically determined actual risks. This is exemplified by McLaughlin (1991) who states:

> *The history of technical man in the Alligator Rivers Region in explaining himself to Aboriginal people has not been successful as the field practices, certain field results, debate and acrimonious politics surrounding the release practices of land application and stream releases have created suspicion and cynicism among Aboriginal people as to the efficacy of such practices.*

and

> *... contaminant encapsulation in a single or known limited number of repositories is a far more viable means of managing contaminants over time, as opposed to dispersing them beyond recall in the environment...Aboriginal people also perceive this risk in the dilute and disperse approach and insist that their future should not have to depend on the present scientific assurances of 'dispersers'.*

and also

> *...Will the assurances of regulators today become regrettable errors in 20 years time?*

The water management issue is one that best illustrates the wide discrepancy between the actual risk, as assessed using the tools of ecological risk assessment as they presently stand (Suter, 1993), and the perceived risk as illustrated by the above quotes. Armstrong & McNally (1991) point out that "Ranger has applied for approval to release water directly from the restricted release zone to Magela Creek, if required, every year since 1986....However, such releases have not received final approval from the Federal authorities ...".

In fact, the extreme rainfalls during the first two months of 1995 meant that the Federal authorities gave approval for such a release to take place. On 9 March 1995 the Northern Land Council sought an injunction against ERA (who control the Ranger Uranium Mine) to prevent release. ERA offered to hold the release for a week. During that week the heavy rains ceased and the flow rate in Magela Creek dropped below a level sufficient to ensure adequate dilution. Thus no release took place.

Social trust

There seems little chance of quantitative risk assessment being able to provide answers that reconcile such strongly held divergent views in relation to water release. The situation is one in which the Aboriginal community has a risk averse utility function that treats the possibility of any contamination of the natural water system as unacceptable. The utility function for the mining company is one that would be considered risk neutral (on the basis of the technical risk), or risk prone (on the basis of the Aboriginal communities' perceived risk). We have suggested in the chapter on setting priorities that, in such a situation, the role of research and education is to bring the two utility functions closer to the risk-neutral utility function. In this particular case, it seems that no amount of quantitative, technical work will reassure the Aboriginal community. This suggests that the Aboriginal community does not trust the work of the Supervising Authorities, presumably including the Office of the Supervising Scientist. It seems that, at the moment, the link between the Office of the Supervising Scientist (OSS) and the Aboriginal community is through the Northern Lands Council (NLC). Research work needs to be undertaken that will enable direct face-to-face contact between the Aboriginal community and research workers.

Earle & Cvetkovich (1994) distinguish two types of trust, interpersonal trust and social trust. Social trust, which is a trust in abstract systems and institutions, determines the success or failure of risk communication. The reason for this is that most members of the public lack the means by which to assess risky technologies. They therefore have to assess the institutions which appear to control technology. Questions of public trust, credibility, openness and the past track record in these respects become the key features in framing social attitudes (Wynne, 1980: p.186).

Earle & Cvetkovich (1994) argue that social trust is a risk judgement based on cultural values, rather than on notions of competency. Their ideas are governed by the United States and United Kingdom experience of community groups' opposition to hazardous projects.

The situation in relation to the release of water from the Ranger Uranium Mine appears to be one in which social trust can follow only from interpersonal trust. There has, to date, been a view that relationships between the OSS and the NLC should be conducted on an organisation to organisation basis. Such an approach, presumably designed to increase inter-organisational social trust, has failed in the case of the March 1995 attempt to release water. The traditional owners would not accept the assurances that the release would have no significant environmental impact.

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Chapter 8

Risks Associated With Chemicals And Contaminated Sites

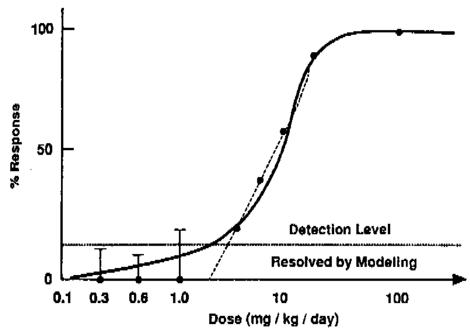
Setting standards

Most Australians are aware that if their blood alcohol level is above a certain value then they are deemed legally to be intoxicated and, should they be foolish enough to be discovered driving a motor vehicle, will have their driving licence confiscated. Further, as a result of an extensive publicity campaign, most Australians will be able to tell you the numeric value of the level. In NSW and Victoria it is .05. Few will be able to tell you the units associated with this value, and fewer still would have any idea of the methods used to arrive at such a value.

The methods used to set the permissible concentrations of chemicals in air or in water are generally based on the applications of risk assessment methodologies. One way of doing this is to take laboratory experiments on animals exposed to high concentrations and extrapolate the results to humans. The permissible concentration is then based on a probabilistic criterion such as a 10^{-4} chance of a response. There are at least two problems with this approach, as may be seen in Figure 8.1 (Paustenbach, 1995).

Figure 8.1 (From Paustenbach, 1995)

A dose-response curve from an exceptionally thorough (8 dose groups) carcinogenicity study. The solid line is a best fit of the eight data points identified in the test. The three lowest points indicate that at these doses, no increased incidence in tumors was observed in the test animals. The error bars on the three lowest doses indicate the statistical uncertainty in the test results since a limited number of animals were tested at each dose (n = 100). In an effort to derive estimates that are unlikely to underestimate the risk, the models most frequently used by regulatory agencies to estimate risk are based on the upper bound of the plausible response, rather than the best estimate.



The first problem is that, in interpreting the data shown in Figure 8.1, a principle of environmental conservatism has been used. In an effort to derive risk estimates that are unlikely to underestimate the risk, the models most frequently used by regulatory agencies to estimate risk are based on the upper bound of the plausible response, rather than on the best estimate.

The second problem is that the choice of model used to derive the curve that best fits the data will greatly affect the result. If, for example, a straight line were used to connect the origin of Fig. 8.1 and the 2 mg/kg/day data point, then the dosage that leads to a 10^{-4} response will be substantially different to the dosage that leads to the same response using the curve shown in the figure.

In one form or another, the problem of the arbitrariness of extrapolations of measurements conducted at high values into estimates at low values, bedevils much of the practice of risk assessment.

Chemicals

The Australian approach to the risks to people and the environment from chemicals is handled under different schemes administered by different agencies depending on the class of chemical:

- the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) is administered by Worksafe Australia within the portfolio of the Minister for Industrial Relations;
- the National Registration Authority operates a national system that evaluates, registers and regulates agricultural and veterinary chemicals and exists within the portfolio responsibilities of the Minister for Primary Industries and Energy; and
- a national coordinated approach to contaminated sites is being developed by the Australian and New Zealand Environment and Conservation Council and the National Health and Medical Research Council.

Industrial Chemicals

The general objective of the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) is to aid in the protection of people at work, the public and the environment from the harmful effects of industrial chemicals. The Scheme complements pre-existing mechanisms for regulation of pharmaceuticals, agricultural and veterinary chemicals.

The *Industrial Chemicals (Notification and Assessment) Act 1989* was passed by Parliament in 1989. NICNAS commenced operation on 17 July 1990. The national scheme for Australia relies heavily in its approach upon concepts and technical methods agreed within the OECD framework. NICNAS is currently being reviewed (Gwynne, 1995) to assess the implications for both industry and the Scheme in implementing the full cost recovery objective set by the Federal Government in the 1994-95 Budget.

This Act requires notification and assessment of new chemicals prior to their introduction by import or manufacture. Selected chemicals in use prior to February 1990, or otherwise not required to be notified, may be declared priority existing chemicals and assessed. However, a systematic screening of all existing chemicals has not been undertaken.

Assessment of hazard addresses effects on human health and on the environment. Each assessment is based on a dossier of information on the use and properties of the chemical which is supplied by the manufacturer or importer of the chemical. Worksafe Australia assesses occupational health and safety aspects of the chemical. The environmental effects are addressed by the Environment Protection Agency and public health considerations by the Department of Human Services and Health. The outcome is a report recommending appropriate controls and precautions relevant to the manufacture, handling, use and disposal of the chemical. Implementation of control recommendations remains largely a State responsibility (i.e. transport, disposal etc.) with Commonwealth responsibility in areas such as import controls.

The scheme applies to all industrial chemicals including cosmetics, but its scope does not include chemicals used solely for agriculture; veterinary drugs; food additives; and human therapeutic substances. Mixtures and formulations are not subject to the Scheme, but ingredients are. Also, NICNAS does not apply to manufactured articles. NICNAS has a wide scope because industrial chemicals are defined by exclusion, ie if a chemical is not a therapeutic agent, food additive or agricultural & veterinary chemical (as defined by the relevant Commonwealth Acts) then it is an industrial chemical.

Where a chemical new to Australia has been notified and assessed under a recognised equivalent scheme of another country, the data submitted with that notification and the report of the assessment will suffice, providing it is available, accessible and relevant to the proposed use of and exposure to the chemical in Australia.

Agricultural & Veterinary Chemicals

In July 1991 the Commonwealth, State and Territory Ministers responsible for agricultural issues decided to establish a National Registration Scheme. Under the arrangements, the Commonwealth is responsible for the registration of agricultural and veterinary chemicals up to the point of retail sale, with State and Territories responsible for control-of-use. The monitoring of products in the marketplace — to ensure that they are supplied and labelled in accordance with the conditions of registration — is undertaken by the States and Territories on behalf of the Commonwealth. Legislation to establish the National Registration Authority (NRA) received Royal Assent on 24 December 1992 and came into effect on 15 June 1993. The NRA has developed from being a small Branch within the Australian Public Service to become a separate statutory authority.

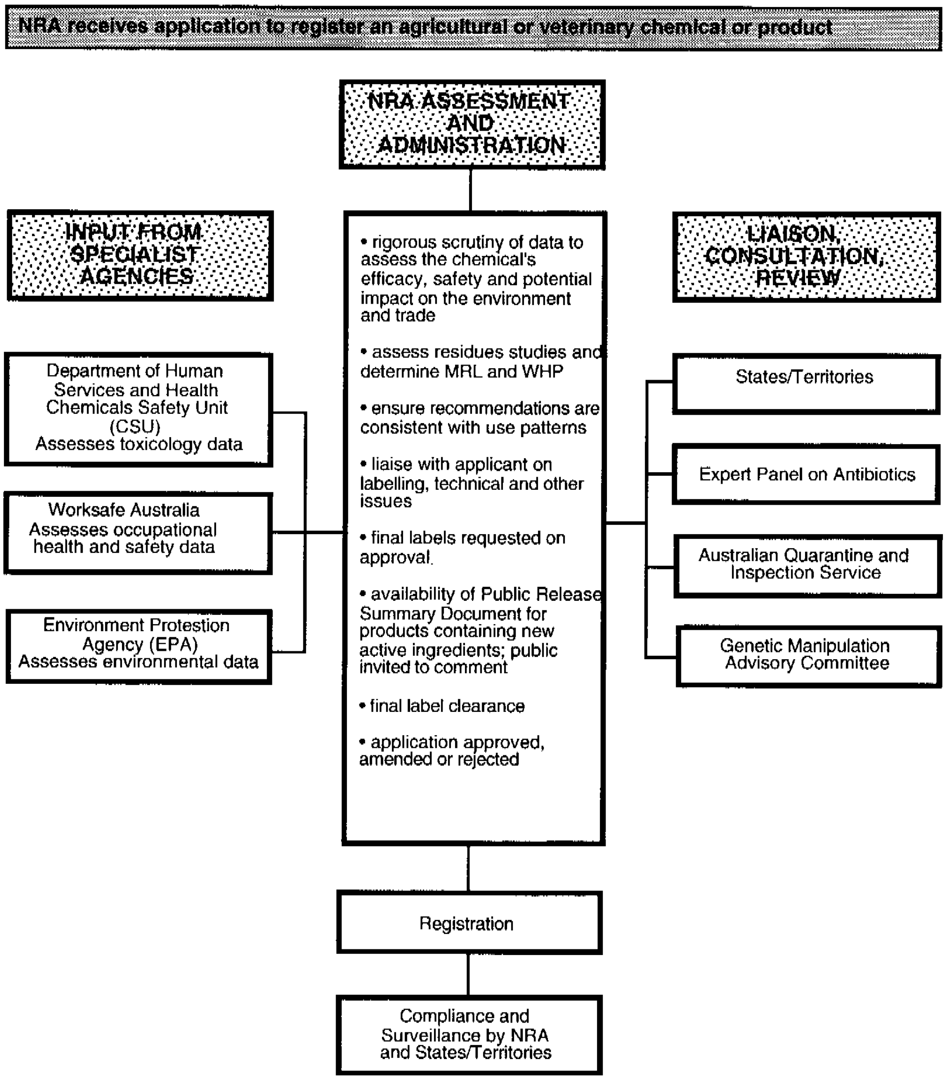
Registration is required for a large range of products that kill pests and control disease. These products include herbicides, fungicides and insecticides used for crop protection and in the home garden, and veterinary medicines and treatments. Before applying to register a new chemical product, companies have usually undertaken extensive product development, testing and field trials to generate data that both justifies commercial decisions to register the product and meet the rigorous standards imposed by the NRA's assessment process.

Following an application to register a product, the role of the NRA is to undertake an assessment of all data on the chemical to ensure that high standards of quality, safety and efficacy are met and that the product will have no unacceptable adverse impact on public health, occupational health and safety, trade or the environment. Residue studies on food crops and animals are assessed in order to establish a Maximum Residue Limit and withholding period. The recommendations for using the product are checked to see that they are consistent with data provided and labelling is examined to ensure it is accurate and meets Commonwealth and State legislative requirements.

During the assessment process, the NRA receives input from: the Chemicals Safety Unit of the Department of Human Services and Health, which undertakes a detailed assessment of toxicological and human health data; the Risk Assessment Section of the Environment Protection Agency, which undertakes a hazard assessment (depicted in Fig. 4.2) to ensure that the chemical will not pose a threat to the environment; and Worksafe Australia, which assesses the data relating to occupational health and safety to ensure that risk to chemical users is avoided. Each year the NRA registers 8 to 10 new active ingredients and approximately 700 to 800 new products based on existing chemicals. This is in addition to some 800 applications to vary existing products, ranging from repacks of registered products through to major changes to formulations. Fig. 8.2 summarises the registration process.

The Existing Chemicals Review Program aims to review registered agricultural and veterinary products systematically to ensure they meet contemporary standards for efficacy and safety, and do not pose any unacceptable risk to the environment or to trade with other nations. Chemicals are prioritised from those nominated by the public and reviews involve a thorough re-assessment of data available since the chemical was first registered. The Adverse Product Experience Program, introduced in January 1995, requires manufacturers to report any adverse effects of a veterinary product. This Program will be expanded in late 1995 to include agricultural chemicals.

Figure 8.2 A summary of the registration process for agricultural and veterinary chemicals



Contaminated Sites

A contaminated site is broadly defined as a site at which hazardous substances occur at concentrations above background levels and where assessment indicates it poses, or is likely to pose, an immediate or long term hazard to human health or the environment. The fundamental goal of contaminated site clean-up should be to render a site acceptable and safe for a long term continuation of its existing use and to maximise, to the extent practicable, the potential future uses of the site. The main concerns associated with site contamination are:

- groundwater contamination;
- residential development of former industrial, commercial or agricultural land;
- abandoned industrial land and waste disposal sites;
- soil contamination by hazardous materials; and
- unexploded ordinance contamination.

The legislative responsibility for the assessment and management of contaminated sites rests with individual State and Territory authorities, excluding sites on Commonwealth controlled territory.

Broadly speaking, there are two basic approaches to dealing with contaminated sites. This has been illustrated in the discussion in Chapter 3 of the US Superfund scheme. The first approach involves adherence to a set of predetermined soil criteria, which serve both to define a condition of contamination and the standard which sites must meet in order to be considered to have been decontaminated. The second approach, which is generally considered to be the risk-based approach, does not advocate any universal standard (or criteria) to which contaminated sites must be cleaned up but relies on careful consideration of site-specific factors to derive criteria which will ensure that public health, local amenity and soil, air and water quality are protected. This approach usually involves the use of modelling techniques (transport models, exposure assessment, risk estimation) in conjunction with physico-chemical, toxicological, demographic and geographic data.

Given the experience of individual States and Territories, and that of other countries, it has been concluded that the most appropriate approach for Australia to adopt is to combine the above two approaches (Australian & New Zealand Guidelines for the Assessment and Management of Contaminated Sites, January 1992). This approach incorporates, at a national level, a general set of management principles and soil quality guidelines which guide site assessment and may guide site clean-up action obviating, where appropriate, the need to develop costly site-specific criteria. However, this approach also recognises that every site is different and that in many cases, site-specific acceptance criteria and clean-up technologies need to be developed. In some cases clean-up may not always be technically achievable and containing contaminants on site or using planning controls to limit site use may be the preferred option. It should be noted that the Guidelines document is currently being revised and the EPA is involved in this process. One of the objectives of the revision is to develop a national environmental risk assessment framework for contaminated sites and national soil quality objectives. Also, proposals are being developed to establish a broad management policy for areas of contaminated land for which the Commonwealth has responsibility and a report on clean-up liabilities.

Commonwealth liabilities

Equity, effectiveness and efficiency considerations should underpin the liability regime for contaminated sites for which the Commonwealth has responsibility. Polluters are responsible for cleaning up contaminated land; land managers are responsible for minimising contamination and for clean-up when polluters are insolvent or cannot be identified. Commonwealth agencies should show due diligence in managing their contaminated land to minimise liabilities.

When Commonwealth agencies dispose of sites they should provide to prospective buyers the best information available at the time on site contamination and its effects. This will help to ensure the smooth transfer of liabilities. However, liabilities for contamination unrecognised at the time of sale are sometimes unclear and this matter requires further consideration. Also, liability for unexploded ordinance (UXO) contamination raises special issues and is being considered separately under the primary carriage of the Department of Defence.

As basically the same general principles and approach apply to determining the environmental risk posed by any chemical, a separate case study was not prepared for each of the above classes of chemicals. In order to demonstrate the utility of using quantitative risk assessment techniques a herbicide, atrazine, has been selected as the case study due to its presence in water bodies at levels which are of concern.

Case Study: Atrazine

Introduction

Atrazine is a triazine herbicide that is used in large volumes for agricultural and non-agricultural weed control. It is available in dry-flowable, liquid and granular formulations. Major uses include residual weed control on firebreaks and railway and road reserves, and pine plantation establishment. Atrazine is typically applied at rates of 0.5-4 $kg.ha^{-1}$ in crop situations. For non-crop use, applications may reach 40 $kg.ha^{-1}$.

Atrazine is a mobile, persistent and somewhat hydrophilic herbicide. A number of States have raised concerns regarding contamination of ground and surface waters. Several media reports concerning the detection of atrazine in Tasmanian streams, following forestry applications, have appeared in recent years.

Health based guidelines proposed by the National Health and Medical Research Council (NHMRC) for levels of atrazine in drinking water are higher than those adopted by the WHO. NHMRC is reluctant to change drinking water guidelines from the current levels of 20 $\mu g\ L^1$ (health guideline) and 0.5 $\mu g\ L^1$ (aesthetic guideline, set at the level of determination) although the latter will be renamed as the action level. The WHO guideline is 2 $\mu g\ L^1$. It is argued that the Australian guideline is already more stringent as it requires action when the aesthetic guideline is breached, whereas the WHO tolerates levels above this but below 2 $\mu g\ L^1$. The Australian health guideline is higher because of different interpretations of carcinogenicity, ie different safety factors were applied: in WHO's case 1000 times the actual known safe maximum and in Australia 100 times.

Ciba-Geigy proposed, in October 1993, to withdraw Atrazine from all non-crop situations, including forestry. This was resisted by State Governments and the forest plantation industry on the grounds that removal of a cheap and effective herbicide would make a marginal industry non-viable. The forest industry proposed restricted use conditions which were agreed on a trial basis. Weeds outcompete the young trees during the initial season or two. Less persistent herbicides, notably glyphosate, may be used instead but their limited persistence requires more frequent applications. The issue with users is one of short-term costs.

To address the problem of finding levels of Atrazine in waterways which have exceeded the standard for potable water of 20 $\mu g\ L^1$, agreement has now been reached on a new strategy that is consistent with that adopted in the US (Chem Reg Reporter, 1992) which requires:

- no mixing, loading or application within 20 metres of any well, sink-hole, intermittent or perennial stream or river;
- no application within 60 metres of natural or impounded lakes or dams
- no use in channels or drains; and
- no use in industrial and non-agricultural situations.

The strategy also calls for a maximum application rate in all crops except forestry of 3.0 kg of active ingredient/ha/yr. In forestry, the maximum rates will be 4.5kg/yr in sandy soils and those defined as 'highly erodable', and 8kg/yr in clay loams and heavier-textured soils. A task force has been set up to monitor water quality, and the overall impact of the new use patterns, and is to complete its work by early 1997. The results of field trials will help in determining long-term use patterns for Atrazine in forestry.

However, if the revised use conditions and monitoring program prove the new strategy to be ineffective, the Commonwealth will be obliged to withdraw Atrazine from forestry. The National Registration Authority for Agricultural and Veterinary Chemicals (NRA) has indicated that continued use of Atrazine in forestry will be reassessed if the new restrictions on use are inadequate to ensure that residues are kept well within levels established by health authorities.

The herbicides most commonly detected in drinking water in the UK are Atrazine and Simazine (Solomon & Powrie, 1994). Atrazine, there, is used almost entirely non-agriculturally, on roadside verges and railways. The UK experience is that when one herbicide is banned or restricted another takes its place. Consequently, Diuron is now contaminating drinking water in the UK.

Aim

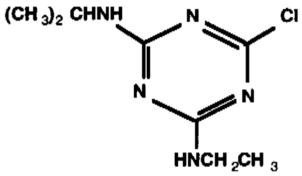
Atrazine is used as a case study to illustrate whether a formalised risk assessment procedure could have predicted concentrations in surface waters that might exceed the current health guidelines for potable water.

Environmental Chemistry and Fate (Kidd and James, 1991 and Howard, 1991)

Physico-chemical properties

Atrazine is hydrophilic, with a water solubility of 30 mg L^{-1} at neutral pH and a partition coefficient (log P) of 2.75. It is hydrolytically stable, with an estimated half-life of 1800 years at neutral pH. Hydrolysis is catalysed by acids, bases and humic materials, and is notably faster when microbially mediated. Its chemical structure is shown in Fig. 8.3.

Figure 8.3 Chemical structure of Atrazine



Degradation

In soils, degradation proceeds via dealkylation and hydrolytic dechlorination, with half-lives typically falling in the range 6-10 weeks. Degradation slows markedly in cold winter soils. Mineralisation of the triazine ring is slow. At deeper horizons, where microbial populations are less active, Atrazine can be highly persistent. For example, Helweg (cited in Klint et al, 1993) observed 20% mineralisation of Atrazine incubated for 90 d with topsoil, but only 1% recovery of $^{14}CO_2$ when subsoil from a depth of 1 m was used as substrate.

Mobility

Atrazine does not sorb strongly to soils (average Koc 163 from 56 soils) or sediment (Koc 216 in Georgia pond sediment) and is mobile in the environment, particularly in sandy soils or exposed sub-soils. Accordingly, a significant proportion of applied Atrazine will remain associated with the aquatic compartment and move within it to contaminate both surface and groundwater. Atrazine can be identified as a probable leacher using the method of Gustafson (1989). It is one of the most widely detected contaminants of ground and surface water in the USA and Europe.

The presence of Atrazine in Australian groundwater has been confirmed in NSW and WA (4th Meeting of Registration Liaison Committee, 1993). Particularly high levels (55 and 300 µg L^{-1}) were detected in groundwater beneath Dianella, WA, where lawns watered from this source had died. Contamination was traced to a local pest control operator, where the wash-down area drained into two sand bottomed sumps. A new code of practice (Health Dept of WA 1993) has recently been prepared in an effort to prevent a recurrence.

Ciba-Geigy has monitored groundwater in three States, in conjunction with State authorities. No detectable residues were found in Queensland during 1987. Positive detections in WA occurred in the Myalup and Esperance areas. In SA, where vulnerable sites were deliberately selected, Atrazine was detected in groundwater in concentrations from 0.3 to 2 µg L^{-1}. Contamination was linked to use of Atrazine in irrigation and drainage channels, and in forest areas.

Atrazine may also enter surface water via runoff, leaching or atmospheric drift, either during or after application. Persistent contamination at levels above 10 µg L^{-1} is generally not observed, although levels may exceed 740 µg L^{-1} for brief periods, particularly after rain (Eisler, 1989). In Tasmania (see below) somewhat higher levels of contamination have been reported.

Atrazine export from pre- and post-emergence applications at 1.7 $kg.ha^{-1}$ to a fine loamy soil planted with maize have been compared (Pantone et al, 1992). Planting times were separated by 28 d in order that simultaneous herbicide management regimes could be practised in each situation. Herbicide exports following the pre-emergence application were consistently higher, being twice as high soon after application (1 d), twenty-fold higher at 7 d and still eight times higher at 30 d. The rate of surface runoff rather than the concentration of herbicide contained was the critical factor contributing to the larger losses following pre-emergence application.

Because of its widespread use, considerable amounts of Atrazine circulate in the environment. For example, it has been estimated that the Mississippi River discharged 160 t of Atrazine to the Gulf of Mexico during 1991 (Pereira & Hostettler, 1993).

Field dissipation

A recent review of Atrazine (Eisler, 1989) cites half-lives of 4, 3, 30 and 35 d in soils, freshwater, seawater and marine sediment respectively, noting that persistence can be much more pronounced (half-life 385 d) in dry, sandy, alkaline soils. Field measurements in Swiss lakes (see below) suggest that similar degrees of persistence may also be encountered in aquatic environments. Studies with groundwater and sediment from an unpolluted sandy aquifer indicate that Atrazine is recalcitrant and may persist for long periods of time in groundwater (Klint et al, 1993). Atrazine has limited bioaccumulation potential.

Monitoring in Switzerland (Buser, 1990) detected Atrazine in all lakes sampled over a 12 month period. Rainwater samples taken during the growing season were also contaminated, with peak levels of 0.6 $\mu g\ L^{-1}$ in May and June. The only consistently clean location was an aquifer that had not been in contact with the atmosphere for several thousand years. In many instances, weed control on roads and railways in the lakes' drainage basins appears the main source of contamination, but in others it would appear that agricultural inputs are substantial. In the more remote mountain lakes, where levels remained below 0.001 $\mu g\ L^{-1}$ and in some instances were undetectable (<0.00005 $\mu g\ L^{-1}$) during winter, atmospheric transport is thought to deliver the largest inputs. Levels were higher (up to 0.46 $\mu g\ L^{-1}$) at lower altitudes. Atrazine proved rather stable in Swiss lakes, with removal occurring mainly by export with outflowing water rather than degradation.

Contamination of Tasmanian waterways by Atrazine used in forestry operations has been documented. Initial peak levels approaching 60 mg L^{-1}, orders of magnitude above levels reported from overseas, were recorded in one stream draining a treated plantation on the day of application, as well as persistent residues in the low ppb range, particularly following rain (Barton & Davies, 1991-92).

Environmental Effects

Atrazine has low toxicity to birds, mammals and bees, but is an unusual herbicide in being moderately to highly toxic to a range of aquatic fauna (Eisler, 1989). The most sensitive species was a marine copepod, with a 96 h LC50 of 94 $\mu g\ L^{-1}$. Indirect effects such as reduced emergence of midge were noted at 20$\mu g\ L^{-1}$ as a result of disruption to habitat and food supply.

As expected of a herbicide, Atrazine is toxic to terrestrial and aquatic vegetation, including algae. Reversible inhibition of photosynthesis can be observed in sensitive aquatic plants exposed to concentrations of 1-5 $\mu g\ L^{-1}$ for several days, although concentrations must remain above 10 $\mu g\ L^{-1}$ for extended periods to cause lasting damage (Eisler, 1989). In the field, permanent changes in algal community structure result from 14 d exposure at 100 $\mu g\ L^{-1}$. Short term exposures of this magnitude can also induce acute effects. The net primary productivity of flowing streams, as measured by oxygen production from periphytic algae, is reduced by exposure to Atrazine concentrations above 100 $\mu g\ L^{-1}$ (Day, 1993). However, at low concentrations (a few ppb) algal photosynthetic activity may be stimulated (Buser, 1990).

Table 8.1 Results of Atrazine toxicity tests

Test	Species	Result
96 h acute	Rainbow trout (*Salmo gairdneri*)	$4.5 < LC50 < 24$ mg L^{-1}
	Bluegill sunfish (*Lepomis macrochirus*)	$8 < LC50 < 42$ mg L^{-1}
48 h acute	*Daphnia magna*	LC50 = 6.9 mg L^{-1}
48 h acute	Midge (*Chironomus tentans*)	LC50 = 0.72 mg L^{-1}
96 h acute	Mysid shrimp (*Mysidopsis bahia*)	LC_{50} = 1 mg L^{-1}
96 h acute	Marine copepod (*Acartia tonsa*)	LC50 = 0.094 mg L^{-1}

Environmental Hazard

Atrazine is a mobile, persistent and somewhat hydrophilic herbicide that is commonly found as a contaminant of surface and groundwater. It is moderately to highly toxic to aquatic flora and fauna. Eisler (1989) has proposed that threshold levels for protection of aquatic flora and fauna from the adverse effects of Atrazine be set at 5 and 11 $\mu g\ L^{-1}$, respectively. In the US the maximum contaminant level for water supplies is set at 3 $\mu g\ L^{-1}$. For potable water the Australian criterion was recently set at 20$\mu g\ L^{-1}$. Limits for surface and groundwater have yet to be established in Australia.

The degree to which Atrazine's toxic hazard is manifested in the field depends to a large degree on application rates. For example, an application rate of 40 kg.ha^{-1} would equate to a concentration of 27 mg L^{-1} if applied to 15 cm of standing water. Accidental overspray at 4 kg.ha^{-1} would result in a concentration of 2.7 mg L^{-1} in such water bodies. Such levels clearly have the potential to affect aquatic vegetation and invertebrates.

While the above represent a theoretical worst case situation of direct application to water, still higher levels have been detected in the field, notably a concentration of 60 mg L^{-1} in a stream draining a treated pine plantation. It is unclear why such high levels of contamination arose. Levels were correlated with distance from the water and the nature of the riparian vegetation.

Environmental Assessment of Chemicals

The EPA undertakes environmental hazard assessments of all new, and some existing, agricultural and veterinary chemicals, and all new industrial chemicals and existing industrial chemicals of particular concern. Assessments are undertaken to determine:

- the degree of environmental exposure;
- the toxicity of the chemical to aquatic organisms(and terrestrial organisms, birds, and desirable vegetation as applicable); and
- the overall environmental hazard of the chemical that takes into account both exposure and toxicity.

Unlike agricultural/veterinary chemicals, industrial chemicals are not intentionally biologically active or purposely released into the environment. However, such release may occur at any stage of an industrial chemical's life cycle: during manufacture, processing, distribution; during or after its use; and on disposal. There is a wide spectrum of exposure profiles for industrial chemicals. At one extreme, a chemical intermediate may be used solely in a closed process, resulting in negligible environmental exposure. At the other extreme, a chemical such as a household detergent will have a high and uncontrolled exposure and its environmental release may approach 100%.

A tiered system is used for assessment of agricultural chemicals, as depicted in Fig. 4.2. Initially, a worst case approach is used and the expected environmental concentration (EEC) is calculated. This assumes a direct spray of the chemical to a shallow water body at the highest proposed application rate. This is divided by the relevant toxicity concentration, usually the most sensitive acute or chronic value. The resulting quotient, Q, then provides a measure of the risk to the organism concerned. If Q is small, the risk of adverse effects is low. While the EPA does not have any fixed threshold ratios, a ratio greater than 0.1 often indicates that the chemical should be given further consideration in view of the large uncertainties necessarily involved in testing and extrapolation.

If the ratio is close to 0.1 the next level or tier needs to be considered. Surface runoff and spray drift are the principal mechanisms for pesticide loss to the aquatic environment. For spray drift the US EPA estimates that approximately 10% of the amount of pesticide applied reaches the aquatic environment. In this way the EEC can be recalculated and a new Q derived.

A similar calculation can be done for runoff. In this case, chemical and site dependent variables (such as drainage basin size, surface area of pond, average depth of pond and percent runoff) need to be selected, in other words, variables for a typical environment where the pesticide is proposed to be used.

If, after the second tier, calculations of the Q value still indicate a possible hazard, an estimate of the aquatic EEC is required. This can be obtained from field tests, a state-of-the-art exposure model or both.

Modelling

A consultancy was let in 1990 to the Centre for Resources and Environmental Studies at the Australian National University to examine state-of-the-art exposure models. This was aimed at assisting the EPA acquire a computer modelling capability through adaptation of some of the currently available models (Gallant & Moore, 1992). Broadly, the main objectives of the project were:

- the selection of 3 to 5 chemical fate models appropriate to the needs of the Chemicals Assessment Section of the EPA; and
- preliminary to the selection, an examination of the model's strengths, weaknesses and data requirements.

Additionally, a workshop was held to discuss issues related to the consultancy (CRES, ANU 1991).

Chemical Fate Models

A range of chemical fate models was identified as potentially suitable for use in hazard assessment modelling using a set of selection criteria. Models selected were required to meet all the essential criteria before the desirable criteria were used to choose between suitable models. The selection criteria used are described in Section 4.3.2 of the document by Gallant and Moore (1992). Four models were selected as the most suitable from each class:

- *Mackay fugacity model* for initial assessment of the steady-state distribution of a chemical from a given use pattern;
- *LEACHM*, a leaching model for detailed assessment of leaching behaviour;
- *GLEAMS*, a surface runoff and erosion model for assessment of surface chemical transport; and
- *EXAMS*, a surface water dispersion and chemistry model for assessment of transport in surface water bodies.

These models were used to predict the fate of chemicals at three selected study sites covering a wide range of climatic conditions, soil types, management practices and chemical properties. Based on the results, the study concluded that only Level 3 of the *Mackay fugacity model* produces realistic predictions that compare well with the predictions of the other models. Both *LEACHM* and *GLEAMS* appear to be capable of handling the range of climatic, soil and management conditions existing in Australia. However, there are some circumstances where the limitations of the empirical hydrology component of the *GLEAMS* model would limit its usefulness, such as the presence of a shallow water table. A detailed discussion of the advantages and shortcomings of both models is provided in the document by Gallant and Moore (1992).

Results

The *GLEAMS* model was run to predict the fate of Atrazine at a New South Wales site (Gallant and Moore, 1992). Atrazine is known to be quite soluble and has a low Koc of around 163, making it susceptible to leaching and runoff losses. The model predicted substantial losses in runoff — 182.6 $g.ha^{-1}$ or 9.1% of the applied chemical. Most of this is lost in the first two runoff events after application. In the first event, 52.3 $g.ha^{-1}$ is lost and the runoff concentration is 1.6 mg L^{-1}, while in the second event 126.3 $g.ha^{-1}$ is lost and the concentration is 0.56 mg L^{-1}. These two events account for 97.8% of the total losses. It was concluded from the modelling results that these concentrations are extremely high and could cause serious problems in downstream water bodies.

The Australian Drinking Water Guidelines state that, as a fundamental principle, pesticides should not exceed the limit of determination. In the case of Atrazine this limit of determination is 0.5 μg L^{-1}. Therefore, the runoff from the first event would need to be rapidly diluted more than 3200 times to be below the limit of determination. Nevertheless, it is recognised that unwanted contamination of water supplies may occur occasionally. Therefore, should contamination occur, the health value has been set at 20μg L^{-1} such that water containing Atrazine at this level could be consumed without risk to health. In this case, the runoff from the first event would need to be rapidly diluted more than 80 times to be below the guideline, or greater than 800 times to satisfy the WHO guideline of 2 μg L^{-1} (refer to the Introduction for an explanation of why there is a difference between the Australian and WHO guidelines). It should be noted that these results are based on an application rate of Atrazine of 2$kg.ha^{-1}$. Consequently, if the current recommended application rates of 4.5kg/yr in sandy soils, and those defined as "highly erodable", and 8kg/yr in clay loams and heavier-textured soils were used, further dilution would be required to meet the guideline for potable water.

Discussion

General Comments

The above example illustrates the utility of using models to predict potential adverse impacts if appropriate ameliorative conditions are unlikely to exist. It will also be relevant to make a comparison, in general terms as the exact conditions will not be replicated, of the findings from this modelling work, with the results of the proposed field trials on the current recommended application rates when they become available in early 1997.

However, as pointed out by Gallant and Moore (1992), the single greatest difficulty in using chemical fate models in the chemical assessment process is the lack of suitable databases. In particular, an appropriate Australian soils database is completely lacking at present. On the other hand, suitable chemical and climatic data are readily available, and some crop management practices information. If chemical fate modelling is to be used regularly by regulatory agencies, a properly structured database holding relevant chemical, soils, climate, crop and management data should be developed and maintained.

The CRES report offers some useful suggestions on how to develop progressively such a comprehensive database. The computer-readable data already available could be obtained *en masse*, such as climate and topographic data, while other data, such as management practices and crop properties, could be collected as the need arises and stored for future re-use. In the case of soil properties, some investment may be required to obtain suitable data for use in chemical fate models. The report further suggests that it may be appropriate to use a geographic information system (GIS) as a vehicle for the development of this database, and describes some of the advantages to be gained from this approach. Fedra (1995) provides an example of modelling chemicals in the environment using a combination of GIS, models, expert systems and visually attractive interfaces with interactive graphics.

There has been a steady increase in the number of computer based models developed in recent years. For example, the Uniform System for the Evaluation of Substances (USES 1.0) was launched in 1994 in support of the Netherlands National Environmental Policy Plan. It is a decision support instrument for use by relevant authorities which enables them to make rapid and efficient assessments of the risks posed by substances, including new and existing substances, agricultural pesticides and biocides. Where possible, USES also quantifies the uncertainties in the derived hazard quotient (which is the ratio of the potential exposure to the substance and the level at which no adverse effects are expected) so that it constitutes a genuine risk assessment. USES 1.0 is the first version of this system and further development is focusing on its current limitations. Acceptance of USES is being pursued amongst EC member states and it is hoped that formal adoption will occur towards the end of 1996.

Government agencies responsible for protecting the environment face difficult decisions due to two problems that must be resolved:

- identification and quantification of a particular environmental problem; and
- determination of 'acceptable' levels of risk for society.

In making regulatory decisions, these agencies have turned to, or are considering using, risk assessment and risk management to identify substances to be regulated; to set budget and resource priorities; and to select final control levels.

Risk assessment is a highly uncertain enterprise. Inferences, data gaps and uncertainties plague assessment processes. The usual approach that is chosen to handle each of these difficulties is to select, from the various plausible options available, the option that yields the highest estimate of risk. Consequently, the result is that the upper bound risk usually calculated vastly overstates realistic potential risk and is usually correct, at best, only for a small fraction of the exposed population.

This approach results from a conscious policy choice to be sure that, in the face of significant scientific uncertainty, risk will not be underestimated. An obvious result of the use of worst case scenarios is that if risks estimated are clearly in the negligible range, then the fact that they are upper-bound estimates creates no problems. However, if the upper-bound estimate of risk appears to be of concern, then it is possible that restrictions will be applied to low levels that are not a problem.

A risk assessment of a chemical involves an integration of the exposure and effects profiles. Risks are generally estimated using one of three approaches:

(1) comparing single effect and exposure values;

(2) comparing distributions of effects and exposure; and

(3) conducting simulation modelling.

The choice depends mainly on the original purpose of the assessment as well as time and data constraints.

The current practice in the EPA is to compare single effect values with predicted environmental concentration values, based on worst case assumptions. The ratio or quotient of the estimated exposure value to the effects value (LC50 for most sensitive species) provides the risk estimate. This estimate is compared to fixed values to ascertain the degree of risk (ie if $Q<0.1$, low risk; if Q is near 0.1, small to moderate risk; if $Q>0.1$, significant risk).

The Quotient Method is the least probabilistic of the approaches described here — ie (1) above. Also, its correct usage is highly dependent on professional judgement, particularly in instances when the quotient is around 0.1. Greater insight into the magnitude of the effects expected at various levels of exposure can be obtained by evaluating the full chemical-response curve instead of a single point and by considering the frequency, timing and duration of the exposure. Such considerations are necessary where Q>0.1.

Comparing distributions of effects and exposure (as opposed to single values) makes probabilistic risk estimates easier to develop. Risk is quantified by the degree of overlap between the two distributions; the more overlap, the greater risk. To construct valid distributions it is important that sufficient data amenable to statistical treatment are available.

Simulation models that can integrate both the chemical-response profile and exposure profile are useful in obtaining probabilistic estimates of risk.

Probabilistic analysis addresses the main deficiencies of the point estimate approach because it imparts a great deal more information to the risk manager. Also, by expressing results as probabilities, it characterises a range of potential risks and their likelihood of occurrence. In addition, those factors which most affect the results can be easily identified.

Atrazine

As previously mentioned, calculations based on an accepted worst case scenario for pesticides (Urban & Cook, 1986) where Atrazine is accidentally oversprayed at the current recommended application rate of 4 $kg.ha^{-1}$ to a shallow (15cm) water body would result in a concentration of 2.7 mg L^{-1} in such water bodies. This level would clearly have the potential to impact on aquatic vegetation and invertebrates, and would exceed the Australian guideline for potable water. Even if the US EPA estimate for spray drift is considered, ie that 10% of the amount of pesticide applied is likely to reach the aquatic environment, then the result still presents some concerns. Under such circumstances, a more refined estimate of the expected aquatic concentration could be obtained using a state-of-the-art exposure model, or the value could be determined from field trials.

It is not economically feasible to run field trials for all chemicals under all possible environmental conditions. However, if data obtained from field trials are used to calibrate and validate an appropriate model, then such a model provides a powerful tool for evaluating the likely behaviour and fate of chemicals under different scenarios. Hence models can provide a cost-effective extrapolation function to limited field trials.

Recommendation

Chemical fate models will allow assessors to obtain a more sophisticated understanding of the environmental fate of chemicals than currently used methods permit. A suitable model(s) should be selected and adapted to Australian conditions. This will then guide the data that will need to be collected to enable the model to be calibrated, validated and used in locations, and at times, other than the ones in which calibration and validation took place.

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Chapter 9

Risks Of The Uncertainty Of Nature

Introduction

The risks inherent in the uncertainty of nature manifest themselves through extreme events: volcanoes; tsunamis; or meteorological extremes. Meteorological events, such as severe storms, tropical cyclones or drought, then produce consequences such as flooding, in the case of storms, or bushfires, in the case of drought. There is a well-founded statistical framework, known as the theory of extreme events (Gumbel, 1958), that provides a unifying basis for their mathematical treatment. This theory relies strongly on the extremal types theorem (Leadbetter et al., 1983) which shows that, when extreme values are drawn from a probability distribution, the resulting probability distribution of the extreme values is one of only three distributions.

The theory of extreme events led to the concept of a return period (or recurrence interval). When annual extreme values are analysed an event that has a probability of occurrence of 0.5 has a return period of 2 years, an event that has a probability of occurrence of 0.1 has a return period of 10 years, and so on. The theory has found numerous practical applications, especially in civil engineering, where it is used to design the height of dams and bridges, the size of culverts and the form of buildings in tropical cyclone prone areas.

The Australian region is the continent most subject to hydrological extremes. The risks associated with these extremes are being monitored continually and the Bureau of Meteorology has in place a sophisticated system of risk communication based on weather forecasts and alerts. These systems have been set up to deal with hazards that have occurred before and are, to a certain extent, familiar. (Beer et al., 1993).

The risks associated with climate change may be novel, in two ways. Present climate models indicate greater climate variability as a result of global warming. This variability will lead to more extreme events of certain types — more floods (Whetton et al., 1993) and more bushfires (Beer & Williams, 1995). In addition, there are risks associated with climate change arising from the uncertainties inherent in the atmospheric and societal response to global warming (Shlyakhter et al., 1995). These raise philosophical issues as well as issues of risk management. After reviewing risk management techniques, the topic of climate change will be considered as a case study of the risks of the uncertainty of nature.

Risk Management

Risk management is the process of forming and implementing a strategy for accepting or mitigating identified risks. It involves evaluating alternative policy options and selecting among them. The United States risk assessment framework of Fig. 3.2 separates, and maintains a clear distinction between, risk management and risk analysis. Once risk assessment moves out of the toxicological area, it is difficult to maintain such a neat distinction. Cox et al. (1994) point out that

> *"The separation of science (risk analysis) and economic and social welfare policy (risk management) on the basis that science deals with facts while economics deals with values is unrealistic and illusory. A clean separation is not possible. The recognition and acknowledgment that facts and values are often inseparable gives a human perspective to the technical nature of risk assessment."*

We agree. They also review the major frameworks used to regulate risk, identifying five. These are:

- Standards

Standards are a centralised process of setting permissible levels of an environmental hazard with the incentive for compliance being liability or a fine. Their advantage is that technological decisions are used to construct a uniform threshold of acceptable risk. The major drawback is that no attention is usually paid to the costs of implementation.

- Taxes and charges

  Market-based mechanisms, such as taxes, tradeable emission permits and subsidies, seek to achieve risk reduction targets by changing the financial incentives faced by individuals in dealing with risk. The emphasis is on economic efficiency by minimising nett costs to society.

- Cost effectiveness

  This seeks to find the least costly method of achieving a pre-determined risk reduction target. The target may be set on some other basis, usually through the political process.

- Benefit-cost analysis

  This is a tool to determine the economic efficiency of various policy options. It attempts to measure the costs associated with risk reduction and the subsequent welfare benefits from that reduction. The nett benefits or costs of policy alternatives are then compared to determine if, and to what extent, the risk will be reduced. The methodology is hampered by controversial issues such as putting explicit values on life and health. Other issues of concern include the choice of a discount rate and equity considerations.

- Information programs

  The provision of information through hazard warnings, labelling and risk communication programs is another market-based framework that may correct perceived market failures. The major benefit is that individuals can make informed choices based on preferences towards risk rather than being forced to accept uniform government bans or regulations.

CASE STUDY: Climate Change

There is no disagreement with the fact that measured atmospheric ambient concentrations of carbon dioxide have been increasing since the time of the industrial revolution. This gas plays a major role in absorbing long-wave radiation which is emitted by the earth and thus plays an important part in maintaining the temperature of the atmosphere. This absorption of long-wave radiation that is given off by the earth is known as the greenhouse effect. The concern related to climate change is that the indisputable increase in the concentration of carbon dioxide will lead to increases in temperature that are greater than those that have previously occurred and that these increases in temperature will then produce changes to the whole atmospheric circulation regime, possibly resulting in dramatic and undesirable impacts.

The issue of the greenhouse effect came into public prominence in the late 1980s. There has been concerted international action on the problem through the Intergovernmental Panel on Climate Change (IPCC), which brought together international groupings of scientists to assess the relevant science, the likely impacts, and to study the appropriate response. The justification for studying this problem in such detail is the precautionary principle. In addition, a second justification underlies much of this work, though it is less often mentioned in the context of climate change. This is the principle of intergenerational equity.

Principles of Environmental Policy

The May 1992 Intergovernmental Agreement on the Environment (IGAE),which was signed by the heads of Australian Governments, contains a summary of the principles underlying environmental policy. These principles are as relevant to the problems associated with climate change as they are to other environmental problems. The

Agreement states that, in order to promote sound environmental practices and procedures, there are four principles that should inform policy making and program implementation:

- precautionary principle;
- intergenerational equity;
- conservation of biological diversity and ecological integrity; and
- improved valuation, pricing and incentive mechanisms.

Precautionary principle
The precautionary principle, as stated in the IGAE, states that:

> *Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.*

The IGAE further states that, in the application of the precautionary principle, public and private decisions should be guided by:

(i) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment;

(ii) an assessment of the risk-weighted consequences of various options.

Intergenerational equity
The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.

Conservation of biological diversity and ecological integrity
The IGAE states that conservation of biological diversity and ecological integrity should be a fundamental consideration.

Improved valuation, pricing and incentive mechanisms
Environmental factors should be included in the valuation of assets and services.

Polluter pays i.e. those who generate pollution and waste should bear the cost of containment, avoidance, or abatement.

The users of goods and services should pay prices based on the full life cycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any wastes.

Environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structures, including market mechanisms, which enable those best placed to maximise benefits and/or minimise costs to develop their own solutions and responses to environmental problems.

Aims of the case study

This case study aims to address the following questions:

1. What form of assessment of the risk-weighted consequences of climate change has been undertaken, as required under the precautionary principle?
2. Reducing the risk due to climate change requires actions on the basis of some combination of environmental integrity, equity or economic efficiency as measured by cost-benefit analysis. Is the concept of intergenerational equity consistent with cost-benefit analysis?

Climate Change and the Precautionary Principle
The issue with respect to climate change is that human activities may already be inadvertently changing the climate of the globe, through the enhanced greenhouse effect, by past and continuing emissions of carbon dioxide and other gases that will cause the temperature of the Earth's surface to increase — a possibility that is generally

termed 'global warming'. If this occurs consequent changes may have a significant impact on society.

The work of the IPCC is the major attempt to provide an ongoing assessment of the risk-weighted consequences of climate change. The IPCC was established by the World Meteorological Organisation (WMO) and the United Nations Environmental Programme (UNEP) in 1988 to:

(i) assess the scientific information related to the various components of the climate change issue and what is needed to evaluate the environmental and socio-economic consequences of climate change;

(ii) formulate realistic response strategies for the management of the climate change issue.

The panel established three working groups on the science of climate change, the impacts expected from climate change, and the response strategies to climate change. The first assessment made by these working groups was reported in 1990 (IPCC 1990 a,b,c), but the process is ongoing and there have been two-yearly supplementary reports issued.

The working group particularly charged with the responsibility of looking at the consequences of climate change was the impacts group (Working Group II). The method that was used was to study the scientific literature and determine likely and plausible scenarios for the state of the atmosphere as a result of climate change. As emphasised by Pittock (1993), a climate scenario is a description of a possible future climate developed for some given purpose and based on a number of assumptions. It is not a prediction. One of the main tasks of the impacts assessment was to determine vulnerabilities, namely, what aspect of the biosphere is most susceptible to the impacts of climate change. Some of the conclusions from the impact assessment are that:

- those communities of the natural terrestrial ecosystem which are most at risk are those with limited options for adaptability (e.g. alpine communities) and those communities where climate changes add to existing stresses;
- change in drought risk represents potentially the most serious impact of climate change in agriculture at both regional and global levels; and
- the most vulnerable human settlements are those especially exposed to natural hazards.

Options for a response to climate change fall into three categories — prevention, mitigation or adaptation.

- Prevention consists of tackling the problem at the source by implementing measures to reduce greenhouse gas emissions
- Mitigation aims to lessen the impacts of climate change by finding ways to assist vulnerable areas. An example of this would be the substitution of an existing crop with a strain able to cope better with the expected weather extremes arising from climate change.
- Adaptation,or even retreat in extreme cases, consists of learning to live with climate change and its consequences.

The risks associated with climate change are sufficiently severe that there is concerted international effort, exemplified by the Framework Convention on Climate Change (FCCC), to set up mechanisms to reduce greenhouse gas emissions. Adaptation measures are also being implemented in case there are adverse impacts. Detailed mitigation measures are not amenable to forward planning until more detailed predictions of climate change are available.

The precautionary principle

Cameron (1993) has identified what he sees as three core questions involved in the precautionary principle:

1. What counts as serious environmental damage ?

2. What measures are justified as regulatory action ?

3. How should questions (1) and (2) be determined ?

The first question is particularly relevant when some eco-systems and human communities may, because of their physical circumstances, face greater risks (in the form of threat of damage) than others from the same global phenomenon. In this way, if an international regulatory standard is introduced, it might be less precautionary for some communities than for others. Cameron (1993), in fact, cites the case of Pacific Small Island States.

> *"These will be very seriously and possibly fatally affected by the consequences of small changes in temperature, especially in relation to coral bleaching and sea-level rise. Efforts to prevent a sea level rise are therefore for these island communities barely precautionary; the threat to these islands is known with considerable certainty. This stresses environmental interdependence. The physical survival of certain communities is dependent on other communities behaving in a precautionary fashion."*

An important issue among the science community is what constitutes full scientific certainty. The above paragraph quotes a lawyer (Cameron) who asserts that the consequences for the Pacific Islands is known with considerable certainty. Scientists intimately involved in the area agree that there is certainly a risk, but are uncertain about the certainty — citing uncertainty about its magnitude and imminence. Scientific certainty is 'almost an oxymoron', to quote Robinson (1993). A more pragmatic approach sees scientific certainty as a function of: (i) the derivation of an acceptable confidence level in scientific work through statistical validation and analysis; and (ii) the acceptability of the work through widespread consensus (or peer review) by, for example, publication in scientific journals (McDonnell, 1993).

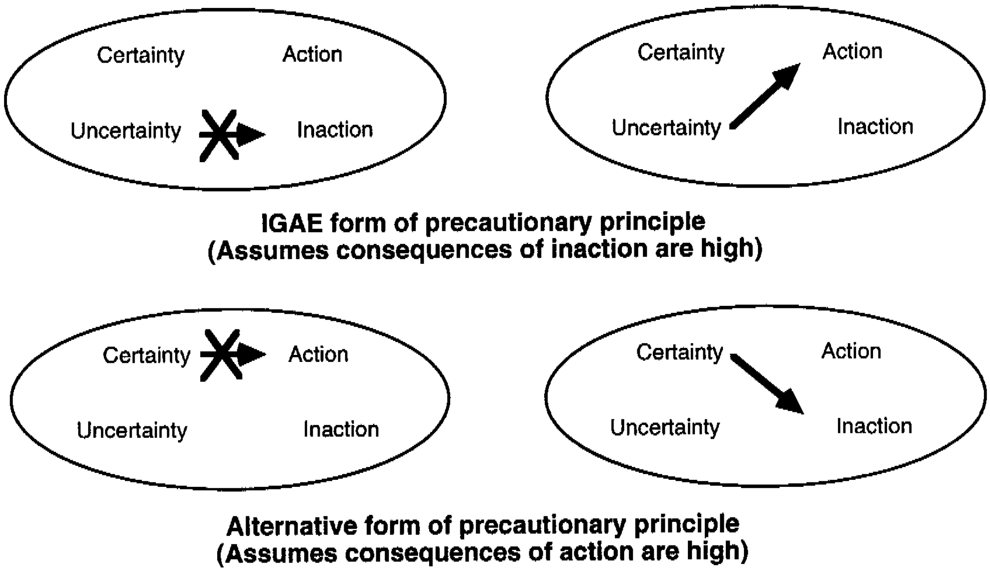
The mammoth process instituted by the IPCC produced reports that would satisfy the above two points, yet it would be virtually impossible to find a scientist who would be bold enough to claim that, therefore, full scientific certainty exists about climate change. Indeed, much of the scientific basis for the scenarios comes from computer modelling running general circulation models. Yet with the rapid evolution of computing power, the present state-of-the-art in computer models (e.g. Alcamo, 1994) will soon be discarded as it becomes possible to run general circulation models with smaller grid sizes, or more vertical levels, or with better representations of the physical processes.

This debate on scientific certainty hardly matters. There is agreement: that the atmospheric carbon dioxide concentration is increasing; that the laws of physics and chemistry predict that changes in the carbon dioxide concentration should be accompanied by changes in the atmosphere; and that there is a possibility that these changes will produce serious or irreversible environmental damage.

Baker (1992) notes that public perception on the climate change issue was galvanized by testimony to the US Senate in 1988 that drew the probable causative link between well-documented greenhouse gas increases and recent warming trends in globally-averaged temperature records. The national and international media, in reporting these remarks, omitted the concepts of probability and causation that were so carefully stated in the original Senate testimony. This predicament poses a dilemma recognised by Immanuel Kant: — concepts without perceptions are empty; perceptions without concepts are blind. Science provides the vision for otherwise blind, perception-based action. Or to rephrase these ideas of Baker (1992) into a risk assessment framework: the perceived risk should be based on the actual risk.

The application of the precautionary principle to climate change reflects its application to a global issue. There seems little argument about its role there. There is, however, extensive argument concerning its role in local issues. Cox et al. (1994: p. 40) use the example of the Superfund, given in Chapter 3, to point out a possible conflict. If a risk assessment indicates that capping, fencing and monitoring a contaminated site is the most cost-effective and efficacious option then such actions would be in contradiction to the criteria for the final state of the sites being set at the precautionary level (defined as soil sufficiently clean so that a well producing potable water could be dug in the middle of it). Australia, not being subject to legislation as inflexible as the US Superfund legislation, does not have such a problem. The IGAE form of the precautionary principle justifies action in the face of uncertainty, but instructs one to use a risk-weighted approach to determine the options.

Figure 9.1 Two Possible Forms of the Precautionary Principle



The IGAE form of the precautionary principle combines two negatives: 'lack of certainty' and 'not be used'. This has been simplified in Fig. 9.1 to indicate that the IGAE form of the precautionary principle implies that, if the consequences of inaction are high, one should initiate action even if there is scientific uncertainty. Many of us were taught in primary school to convert two negatives into a positive. This may be good English, but it is poor logic. In this case it leads to the assertion that scientific certainty should be used as a reason for postponing measures to prevent environmental degradation. Fig. 9.1 depicts this alternative form of the precautionary principle as implying that if the adverse consequences of action are high, then one should be inactive, even if there is scientific certainty. The following is under consideration in a growing number of international forums as a definition of yet another form of the precautionary principle.

> *Appropriate preventive measures must be taken when there is reason to believe that substances or energy introduced into the environment may or are likely to cause harm, even when there is no conclusive evidence to prove a causal relationship between inputs and effects.*

The alternative form of the precautionary principle (Fig 9.2) is invoked when people distrust experts. For example, conservation organisations invoked the precautionary principle during a meeting in March 1995 while discussing the discharge of contaminated water from the Ranger Uranium Mine. In this case, there is as close as one can get to scientific certainty from the Supervising Scientist that the discharge would not be harmful to health or to the environment. Nevertheless, the precautionary principle was invoked during discussions to argue that the release should not take place in case some unforeseen harm occurred. The IGAE permits action when there is a possibility that the consequences of inaction will be high. It does not condone inaction when there is a possibility that the adverse consequences of action will be high.

In the above situation there seems little doubt that the precautionary principle, as a legal principle, did not apply. The case study given by Prokuda (1993) is more debatable. Queensland Nickel wished to build a mooring for ore carriers close to a

Marine Park in North Queensland, and within the 'general use A' zone of the central section of the Great Barrier Reef Marine Park. The Great Barrier Reef Marine Park Authority (GBRMPA, the lead agency) refused the application, citing three areas of uncertainty:

- uncertainty about the quantity of ore that might spill during operations;
- uncertainty about the toxic effects of leachates; and
- uncertainty about the ore dispersion characteristics in the event of a spill.

Queensland Nickel appealed to the Commonwealth Administrative Appeals Tribunal and in terms of evidence for the appeal it advanced its initial EIA by investigating further the relevant issues with numerous expert reports. During the tribunal proceedings, GBRMPA introduced the precautionary principle into the proceedings. To quote Prokuda (1993) "the discussion...demonstrated what appears from the literature itself namely, that the principle is something of a moving feast and appears to have a life of its own."

Both sides agreed with a version of the principle that the assessing authority must be reasonably persuaded that a decision, particularly an irreversible one, will not have unacceptably large impacts. What was contentious was whether the decision maker needs to be satisfied beyond reasonable doubt that the proposed activity will be conducted in a manner that will not lead to harmful effects on the environment. The case was settled beforehand with the result that this issue remains unresolved.

Intergenerational Equity

The concept of intergenerational equity also underpins much of the present concerns about climate change. Climate change and, especially, sea level rise will be a slow process and present actions to avert a potential climatic catastrophe aim to protect future generations more than they aim to protect present generations. This is illustrated in Figures 9.2 to 9.4 (Pittock, pers. comm.) which use future CO_2 stabilisation scenarios and the expected temperature responses (Wigley, 1995) to determine the expected sea level change by the year 2500 for global climate sensitivities to doubled carbon dioxide corresponding to 1.5 to 4.5 degrees (Fig. 9.2), and the likely trends in sea level from the years 2100 to 2500 in the case of CO_2 stabilisation of 450 ppm and 750 ppm, shown in Figs. 9.3 and 9.4 respectively.

Figure 9.2 Sea level change by the year 2500 for different IPCC CO_2 stabilisation scenarios and climate sensitivities (From Pittock, 1993)

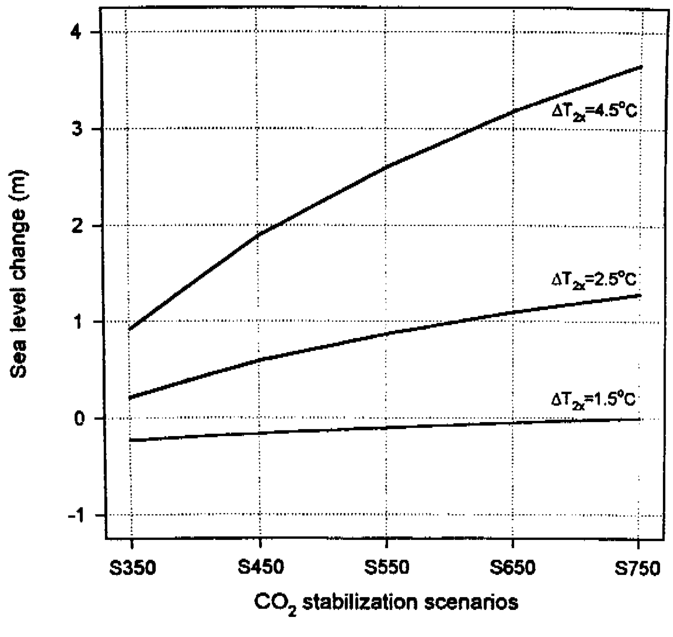


Figure 9.3 High (H), Medium (M) and Low (L) Sea Level Changes for the 450ppm Stabilisation Case. (From Pittock, 1993)

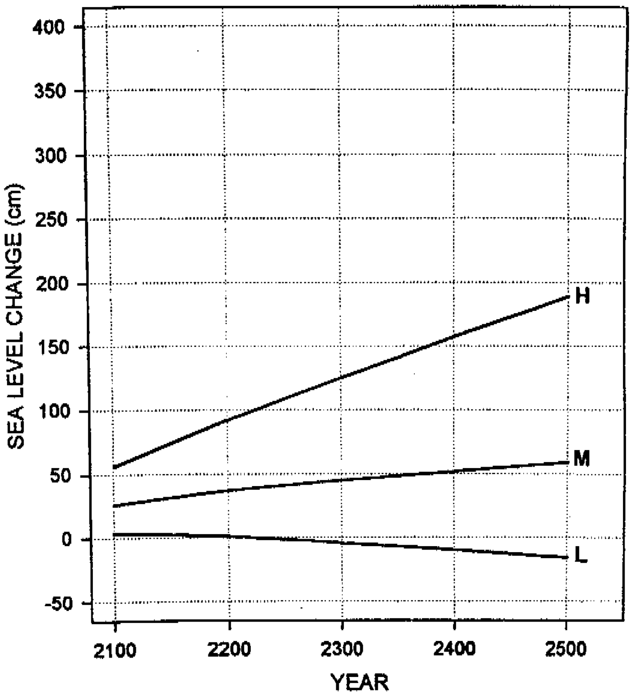
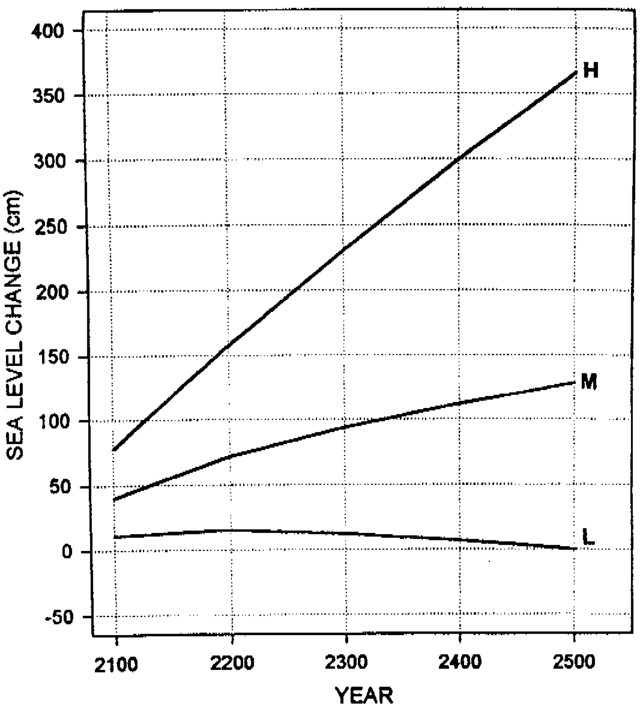


Figure 9.4 High (H), Medium (M) and Low (L) Sea Level Changes for the 750ppm Stabilisation Case. (From Pittock, 1993)



A trial definition of intergenerational equity is:

> *intergenerational equity involves the maintenance of an environment at least as healthy, productive and diverse as now. This involves the retention of the same, or a better, range of options as now, access to the same or better range of resources, quality of environment and amenities as are now available, and solutions to identifiable problems within one generation (thirty years) or, at least, reversal of the problem.*

Young (1993a) notes that acceptance of intergenerational equity as an objective means that the present generation is required to ensure that the health, diversity and productivity of natural resources are maintained or enhanced for the benefit of future generations. Conceptually, if these considerations are accepted, then opportunity to exploit or derive income from Australia's resources is limited by an obligation to leave society as well endowed at the end of a period as it was at the beginning. This implies that society must conserve the value of its asset base and make sufficient investments to compensate for any depreciation or degradation that occurs during the period.

The concept of intergenerational equity, especially when applied to the issue of climate change, highlights the "never-ending debate" (Young, 1993 a,b) over the most appropriate discount rate to use to compare costs and benefits in different time periods. Young (1993a) points out that it is relatively easy to show that the most commonly recommended technique discriminates against future generations. Spash (1994) has done this by showing that almost any positive rate creates insignificant present values for even catastrophic losses in the further future. This problem has received widespread attention. Spash (1994) points out that, in the case of climate change, cost-benefit analysis is inconsistent with the concept of intergenerational equity because one will always be comparing present day costs with discounted future benefits, so that the costs of controlling greenhouse emissions will always exceed the benefits to future generations. An alternative view, expounded by Shlyakhter et al. (1995) is that the appropriate discount rate to use is the same rate as money. The argument, based on that of Raiffa et al. (1977), is that money can be invested now, at the monetary discount rate, to balance the risk over future generations so that by the time the hazard arrives the money has increased appropriately by means of the accumulated interest.

These inadequacies in traditional forms of economic analysis were recognised and given prominence in the US EPA report *Reducing Risk.* (US EPA, 1990). This report made ten recommendations, the last of which was: "EPA should develop improved methods to value natural resources and to account for long-term environmental effects in its economic analyses" because it was recognised that traditional forms of economic analysis systematically undervalue natural resources and the report specifically highlighted the discounting procedure as one of the limitations of the presently available tools of economic analysis.

Young (1993a) has carefully analysed the problems of conventional discount rate and cost-benefit methodologies and pointed out that there exist solutions to all the five problems that he lists. He advocates that the best interim strategy for decision making is to use a combination of techniques to ensure that projects pass the three 'E' tests:

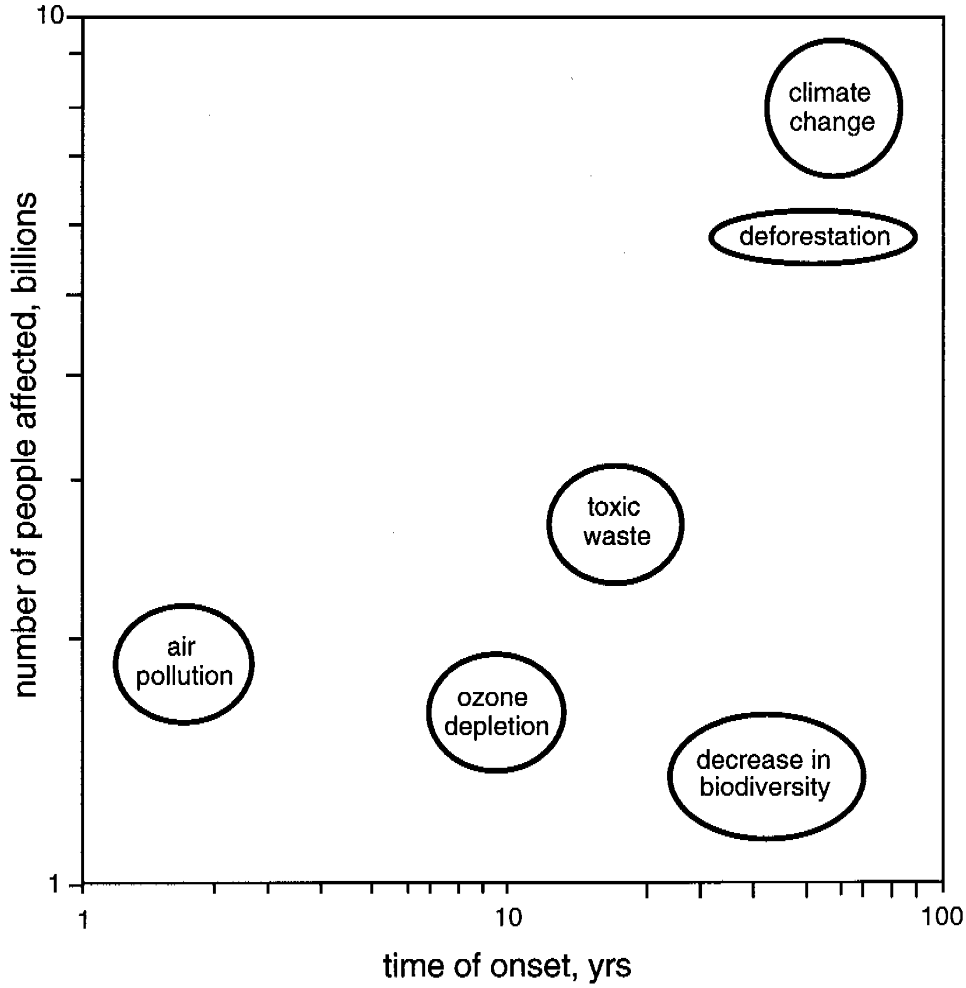
- economic efficiency;
- environmental integrity; and
- equity

Economic efficiency is assessable through conventional cost-benefit analysis. Environmental integrity can be tested by environmental impact assessment or by environmental risk assessment. Equity seeks to distribute the burden of the risk based on some weighting of individual welfare. The risk can be distributed evenly across the whole population or can be distributed based on some other parameter. The issue of appropriate intergenerational equity tests has not yet been determined.

Discussion

Figure 9.5 illustrates why climate change provides the best illustration of both the precautionary principle and intergenerational equity. The figure illustrates the relative ranking of hazards in terms of their potential impact as determined by the US EPA (1990). Climate change gives rise to the highest expected ecological impacts, but takes the longest time to do so.

Figure 9.5 Ranking of environmental risks (EPA 1987, 1990) (From Shlyakhter et al, 1995)



Returning to the aims of the case study, the first question was:

- What form of assessment of the risk-weighted consequences of climate change has been undertaken, as required under the precautionary principle?

Shlyakhter et al. (1995) undertook an integrated risk assessment of climate change. The term, integrated, in this context means that the economic, as well as the technical, aspects of climate change are considered. Even the authors concede that for a risk assessment to be adequate it must be integrated in this sense so that even though the word 'integrated' should be unnecessary, it has acquired this usage in the climate change literature (Dowlatabadi & Morgan, 1993). An important feature of risk management related to climate change noted by Shlyakhter et al. (1995) seems to be the feeling among people that we should take an insurance policy, which amounts to considering the upper limit of a probability distribution of impacts. This upper limit is, in many respects, ill-defined but can be quantified provided one distinguishes between scenarios that are believed possible and those that are rejected as improbable. Empirical evidence suggests that overconfidence in predictions of future developments results in long tails of the distribution and, therefore, in high probabilities of surprise.

The IPCC process is an ongoing risk assessment of the consequences of climate change. But the noteworthy aspect of it is that, for a problem of such global scale and long temporal duration, the appropriate assessment involves: international cooperation; the involvement of numerous scientists; technologists; environmentalists; economists; politicians; lawyers; and other groupings, and as a result takes time and costs money.

Yet there is no doubt that a quick assessment undertaken by a small focused group would fail to win the consensus support that concerted action requires; and fail to spread ownership of the consensus across a sufficiently wide cross-section of the community.

The second question was:

- Is the concept of intergenerational equity consistent with cost-benefit analysis?

We believe that traditional cost-benefit analysis is inconsistent with the concept of intergenerational equity. It seems impossible to obtain economic efficiency (via traditional cost-benefit analysis) in reducing the risk of climate change and, at the same time, maintain intergenerational equity. Young (1993a) notes that the standards derived from the use of conventional cost-benefit analysis will always be less stringent than those derived from most interpretations of the precautionary principle and from consideration of intergenerational equity concepts. In fact, the issue of traditional valuation mechanisms in economic analysis is the fourth principle of environmental policy under the IGAE. As recognised by the US EPA, any attempt to use risk-benefit analysis as a basis for determining national environmental priorities will have to find better ways of valuing the benefits when there is a time delay in the appearance of the benefits.

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Chapter 10

The Risk Associated With Political Decision Making

Introduction

In Australia we live in a parliamentary democracy. Our elected representatives in Parliament are supposed to reflect the concerns of the electorate, voice these concerns during debate and enshrine the valid concerns in legislation. This is right and proper. Yet there is also an assumption of political consistency. Few express surprise when the public, in 1991, considered land degradation to be the third most important environmental issue, yet only two years later ranked it only as the seventh most important environmental issue (see Table 1.1). But if government, or one of the departments implementing government policy, lacks consistency then there are complaints (Coleman, 1994).

There are two aspects of the risk associated with government decision making. The first, which is presently being debated in the United States Congress and Senate, is what is the proper role for risk assessment (or risk analysis in Australian English) within the decision making process. The second, which has been of concern in Australia for a number of years, is how can one evaluate the likelihood of a contentious new project being allowed, modified or disallowed?

There are three issues that impinge on these matters. The first is the establishment of community accepted baselines from which decision making flows; the degree of predictability; and the degree of stability inherent in such a process.

Risk and the United States Congress

The 1995 US Congressional discovery of risk assessment has been outlined in Chapter 2. The surprising aspect of this, viewed through Australian eyes, is that the US EPA — an agency that embraced risk assessment with an eagerness unmatched by its other international counterparts — is now opposing the introduction of risk assessment and risk-benefit analysis by legislation.

Part of the reason for this lies in the subtle nuances of the congressional proposal. Risk assessment has to date been used to justify US EPA regulations. In this role, as a tool of the regulators, there was a tendency to determine upper-bound estimates of risk. A study based on a worst-case scenario would be an example of this. This tendency led certain observers to feel that environmental regulations were over-designed, in the same way that a dam that is too high is over-designed. Over-designed structures waste money and there is a feeling that over-designed environmental regulations waste money. Hence, the desire of Congress not only to have the EPA conduct mandatory risk assessment of new regulations, but also to have the EPA conduct a risk-benefit analysis of new regulations. (Davies, 1995).

Sovereign risk

The term 'sovereign risk' entered the Australian environmental lexicon as a result of the Coronation Hill dispute, which forms the case study for this chapter. The term has a well-defined meaning in international finance and refers to the risk of a sovereign nation defaulting on its loan obligations. Within the Australian environmental context it is used by the mining industry to refer to the risk of plans having to be changed as a result of either change of government or changes of government policy.

Sovereign risk can be evaluated and the changes in sovereign risk over time can be measured. The mining industry publishes regular risk surveys of countries that rank their investment potential (for miners) on the basis of ten categories which include sovereign risk, red tape, green tape (i.e. the bureaucracy associated with environmental approvals), natural disasters, social risk, and various other items shown in Table 10.1. The method is to poll chief executive officers of mining companies who rate countries on a scale of zero (no risk) to 5 (maximum risk) on the above-mentioned ten criteria and then produce a weighted sum of their rankings. The year 1995 was the first year since the Coronation Hill dispute that Australian mining companies have considered Australia to be the least risky country for investment (Treadgold, 1995).

Table 10.1 Mining Industry Risk Survey by Country

Weights	5	4	3	4	3	3	3	3	1	2	
	Sovereign risk	Land access	Green tape	Land claims	Red tape	Social risk	Infra struct-ure	Civil unrest	Natural hazards	Labour dispute	Totals
Australia	1	3	3	3	2	2	1	0	1	2	11.6
Chile	2	2	2	1.5	2	2	2	2	2	2	12
Argentina	2	2	2	1	3	2	3	2	1	2	12.6
USA	1	3	4	2	2	3	1	1	1	2	12.6
Canada	1.5	3	4	3	2	2	1	0	1	2	12.7
Indonesia	2	2	2	2	2	2	3	2	2	2	13
Vietnam	3	3	2	2	4	3	4	2	2	2	17.2
China	4	4	2	2	4	3	4	2	2	2	19
PNG	4	3	2	4	3	3	4	3	3	3	20.4

Case Study - Coronation Hill

Introduction

On 7 December 1988 the Coronation Hill Joint Venture (CHJV) submitted a draft EIS for the development of a gold, platinum and palladium mine at Coronation Hill, in the Alligator Rivers region of the Northern Territory. Coronation Hill is located in the South Alligator River valley approximately 230km directly south-east of Darwin. The area under consideration for the mining project was within the Conservation Zone declared by the Commonwealth Government in June 1987 as a region where mineral resources should be evaluated prior to determining which areas should be put into Kakadu National Park.

In a Joint Statement by the Minister for Resources and Energy and the Minister for Arts, Heritage and Environment of 16 December 1986, it was explained that "A five year exploration programme will be conducted to help determine, by the end of that period, which areas [of The Conservation Zone] should be put into the [Kakadu National] Park" subject to the proviso that "The Government's intention is that ultimately as much of the Conservation Zone as possible will be incorporated in the Park and that only mining projects of major economic significance, not merely economic viability, will be excluded from the Park." This Joint Statement was made in the light of an earlier Joint Statement of 16 September 1986 which "agreed that the economic potential of the Coronation Hill Project is such that provisions should be made for the exclusion from any National Park extension of an appropriate mining lease area, and the Project allowed to proceed subject to normal environmental, Aboriginal heritage and related clearances."

The Coronation Hill Joint Venturers had been given numerous indications by the Government over the previous few years that the mine would be given the go ahead, and that exploration would take place in the surrounding Conservation Zone (Toyne, 1994: p. 137). Yet in the end mining was not permitted.

The mining industry made it plain that they saw the decision as a test case, warning that "if mineral investors in Australia and overseas continue to perceive sovereign risk in Australia as a major and increasing difficulty they will take their investment dollars elsewhere."

Aim

The Coronation Hill saga had a particularly long and tortuous history. Questions of particular relevance are:

1. Could a formalised risk assessment procedure have predicted the probability of a negative outcome in this particular situation?
2. Is it possible to systematise or quantify those factors which lead to the risk of a new project being disallowed or severely constrained?

History

The draft environmental impact statement was open for public comment until 7 March 1989. Over 100 of the 917 comments that were received indicated general misconceptions about the nature of the mine. The most common among the misconceptions was the idea that the Coronation Hill project was a uranium mine. This was not the case. It was to be a gold, platinum and palladium mine. Nevertheless, such a widely held view must, to a certain extent, have played a role in prejudicing people against the mine, because uranium mining has long been viewed with suspicion, and rigidly controlled.

The draft environmental impact statement declares that the resident fauna and flora of the Project Area are not rare or endangered and are not unique in terms of species associations. In February 1989 CSIRO submitted an interim report to the Australian National Parks & Wildlife Service, describing evidence that the area was of outstanding conservation significance, especially in its high diversity of notable species (Braithwaite & Woinarski, 1990). This finding was completely at odds with the statement in the draft EIS.

The environmental assessment report of September 1989 from the Federal Environment Department (DASETT) stated that "... the possibility of rare fauna entering the Coronation Hill area is not unreasonable and, for some species, probable. Of particular concern is the possibility of fauna drinking contaminated water or being adversely affected through mining operations. The Department cannot rule out the possibility of adverse impacts on fauna, however, such impacts are speculative." The assessment report found no environmental grounds on which to reject the report and drew attention to certain Aboriginal issues. It also mentioned that it deliberately failed to assess the environmental consequences of the possible accumulative effects associated with other possible mining development following on the Coronation Hill project.

As pointed out by Toyne (1994), at much the same time as the assessment report, the Aboriginal groups and the environmental groups resolved to offer each other support at the same time as maintaining distinctly separate positions. This meeting promised a new and increased capacity to coordinate the campaign against the mine and a deepened resolve to fight it to the very end.

Resource Assessment Inquiry

The Government, on 5 October 1989, decided to set up two inquiries into the Kakadu Conservation Zone. The reason given by the Prime Minister was that the cumulative impact of possible developments in the region could be of sufficient size and complexity to constitute an unacceptable hazard to the wetlands of the existing World Heritage area. Both inquiries were chaired by Justice Stewart.

The Resource Assessment Commission (RAC) was asked to assess the national economic significance of the possible mining developments in the area, and the environmental values of the area. The other inquiry was asked to examine the question of sacred sites.

According to Toyne (1994: p.138), the explanation for the Government's change in direction was the powerful surge in community concern over the environment and the associated strength of the conservation movement as a result. Further, Kakadu was seen by Labor party tacticians as a vote winner — even an election winner. The Government did not want to go into an imminent Federal election with Kakadu open to miners and with Coronation Hill approved. Yet, even at this stage it appears that both the Prime Minister (Bob Hawke) and the Minister for Environment (Graham Richardson) were convinced that Coronation Hill would eventually go ahead.

The RAC engaged expert consultants to draw up separate reports on the three sets of issues involved: the economic costs and benefits of the proposed mine, the risks to the natural environment and the social impacts. The report set out the ranges of estimates in each area. According to Lowe (1993) the RAC did not essay the sort of simplistic cost-benefit analysis which seeks to express these incommensurables in some common currency. It said that weighing up the economic benefits against the social impacts and the environmental risks was a value judgement which should properly be made in the political domain. Accordingly, the decision went to Cabinet.

The final reports were presented on 1 May 1991. They pointed out that "the dilemma facing the Australian Government is clear: should it set aside the environmental risk that cannot be eliminated, and the strong views held by the Aboriginal people responsible for the Conservation Zone, in favour of securing increases in national income of the order that seems likely from the Coronation Hill project and possibly from other mineral resources in the Zone?" The environmental evaluation supported the CSIRO view by describing the ecological resources of the area as having substantial environmental value. But it supported the mining case by concluding that a single mine, properly managed, would have a small, and geographically limited, direct impact on the known biological resources. It also examined possible effects of multiple mines. Toyne (1994) notes with incredulity that the Federal Environment Department, which had earlier approved the EIS for the mine, opposed mining on environmental grounds in its submission to the inquiry. This view clashed with the comments of the Office of the Supervising Scientist which had extensive experience in the region. On the Aboriginal issue, Justice Stewart (RAC chair) found that the area was indeed a sacred site and to ignore this would require the Commonwealth to override its own Aboriginal heritage legislation.

In fact, the Federal Environment Department (DASETT) in its original assessment merely advised the Minister for Administrative Services that "the environmental impacts of the proposal have been examined as fully as practicable" (DASETT, 1989: p5). Once a decision has been made to deal with a project using the mechanism of an environmental impact statement, then the environmental assessment takes place under the administrative procedures of the Environment Protection (Impact of Proposals) Act. Essentially, the departmental response must determine the adequacy of the process used to generate the proposal, and identify environmental impacts. By contrast, a public inquiry offers the opportunity to state a departmental position.

The Cabinet decision on the issue was taken on 19 June, during a leadership dispute between Bob Hawke and Paul Keating. Hawke opposed mining based on a genuine concern for the Aboriginal people. Political analysts believe that Hawke was in the minority in opposing mining, even with the overwhelming weight of the RAC report behind him. But even those members of cabinet who desperately wanted the mine to proceed realised that they could not vote their shakily affirmed leader down. The view of the minority was adopted.

Risk, risk and more risk

The reports of the Coronation Hill project are replete with risk assessments. To a certain extent an EIA is itself the first stage of a risk assessment in that it is supposed to deal with significant environmental concerns and their consequences. Braithwaite &

Woinarski (1990) claim that there were three major threats arising from the CHJV proposal:

- spillage of contaminants into the South Alligator system either from the mine itself or from transport vehicles;
- the use of tailings dams containing cyanide by fauna for drinking (particularly during times of water scarcity); and
- disturbance to the fauna due to mining and its infrastructure.

They also identified the Kakadu Dunnart, Calaby's mouse, the pig-nosed turtle, and the hooded parrot as being the species most at risk of extinction, but emphasised the difficulty of evaluating the extent of such a risk.

A risk assessment of the engineering aspects of the Coronation Hill project (Resource Assessment Commission, 1990) considered the CHJV proposal to be satisfactory. The more quantitative assessment given in Appendix F17 of Resource Assessment Commission (1991) reports that the risk of a transport-related incident contaminating the South Alligator River with cyanide was acceptable, with a probability of about 10^{-5}.

A story in the 23 August 1991 issue of Engineers Australia (Kannegieter, 1991) points out that both of the above quantitative risk assessments considered the project design to be sound and safe. Yet the Government clearly took more into account than just the scientific evidence in determining the acceptability of the risk. Political and economic considerations played a role. In fact, we may hypothesise that, if one considers the environmental impact process to be that of the first stages of a qualitative environmental risk assessment, then the role of the inquiry was to be analogous to that of the first stages of a qualitative social and economic risk assessment.

Discussion

Many problems in life are a result of poor timing. The Coronation Hill proposal was one of them. To quote Toyne (1994):

> *"Had it not been for the mining industry wanting to tinker with the original boundaries of the Conservation Zone before the gazettal of Stage III proceeded, the whole matter would have been long settled before the 1987 election. Work might even have commenced."*

It is hard to see how the above quote can be correct unless the proponent's submission of the EIS was deliberately delayed until the Conservation Zone boundaries were determined. The presentation of a draft EIS in December 1988 virtually guaranteed that Cabinet would need to make a decision shortly before the 1990 election. The issue became a symbolic one both for the conservation movement and for the Aboriginal people. The government invoked a process to ascertain the facts and to escape the perceptions that had driven earlier forestry decisions. This was the Resource Assessment Commission (RAC), which could undertake functions that the EIS and EIA process could not do — namely to look at the potential cumulative effect of additional exploration or mining. In addition, the inquiry could look at the likely economic significance of the whole area, and at the Aboriginal issues.

There is a continuing perception that EIA procedures are project and site specific and rarely come to grips with cumulative regional and long-term impacts. Neither do they address the collective impact from a large number of developments occurring over time within a particular area. As part of a current review of Commonwealth Environmental Impact Assessment, Court et al. (1994) prepared a report recommending introduction of strategic environmental assessment, incorporating cumulative impact assessment, as the ultimate principal means of achieving ecologically sustainable development.

The RAC was a casualty of the final decision. Lowe (1993) notes the Government of the time's preference for hiding behind the cloak of expert advice and implies that the RAC use of a rational and visible process, thus exposing the nature of the decision to the public gaze, led to its demise. Industry groups were hostile to it as a result of the final decision, and the environment movement had always been divided on its worth.

It lacked support in Cabinet and was left unfunded and with no matters referred to it after ongoing inquiries on Forests and the Coastal Zone.

Another interpretation was given by Kannegieter (1991) who placed much reliance on the wording of the Prime Minister's press statement that "the effect of mining on the Jawoyn people, and to a lesser extent on the environment, outweighs any economic benefit". The conclusion drawn from this statement was that

> *"Hawke could have made his decision on Aboriginal grounds alone, but by including the risk of damage to the environment he signalled that the government considered the level of environmental risk as unacceptable, even though the risk had been described by the Resource Assessment Commission (RAC) as low. The decision highlights the difficulties in determining what risk to the environment is acceptable."*

What is highlighted is that the level of risk to the environment deemed to be acceptable, changed, and changed quickly with time. Thus, even if any formalised risk assessment had been undertaken based on perceived risk, the results would have been out of date as soon as they were printed. To the public, the perceived risk to the environment grew with time and continued to grow as the conservation groups mounted their campaign.

Technically, the decision was made on the Aboriginal issue, but in reality it is unlikely that the issue would have reached the prominence that it did without the support of the conservation groups.

The conclusion from this case study is that the views of the community change, sometimes rapidly. As a consequence, the views of Governments must change. All of the formalised risk assessments undertaken for the Coronation Hill project dealt with the technical risks, and there was no systematic attempt to deal with the perceived risk, and its variation with time, in a formal assessment of the political process.

Quantifying sovereign risk

The above case study was presented with the questions:

1. Could a formalised risk assessment procedure have predicted the probability of a negative outcome?
2. Is it possible to systematise or quantify those factors which lead to the risk of a new project being disallowed or severely constrained?

Issues such as these are being examined by the Australian Centre of Advanced Risk and Reliability Engineering (ACARRE). In the belief that the answer to the second question is yes, the centre is in the process of devising a matrix to examine the risks associated with development projects and has produced a list of those factors which may lead to the risk of a new project failing. Their objective is similar to that of the risk analysis of Table 10.1 — it is to look at all the risk factors that could affect decision making on the project. We applied the Centre's method to the Coronation Hill project as it would have been scored during the preparation of the environmental impact statement.(Table 10.2) The risk score on safety and environment came to 8.44 (out of a possible 100), a score that is low enough that one would assume that the project would go ahead.

Our view is that in the case of Coronation Hill, no formalised procedure would have predicted a high probability of a negative outcome. The above method provides guidance for quantifying the probability of a negative outcome. If the risk scores are treated literally then one could assign a probability of failure on environmental grounds (based on the a-priori judgement of a risk analyst) to be 0.08.

Table 10.1 Coronation Hill Risk Shortlisting Study Using ACARRE Approach

Type of influence	Source of Risk	SCORE	Threat to Concept Viability	Tech, Stnd	Safety/ Envir.	Timing	Costs
Severity of Impact	Potential for major impact on technical standard	1	1	1			
	Potential for major impact on safety / environment	4	4		4		
	Potential for major impact on timeliness of project	1	1			1	
	Potential for major impact on project costs	2	2				2
TOTAL SEVERITY SCORES			8				
AVERAGE SEVERITY SCORES (A)			2	1	4	1	2
Likelihood of impact	Novelty / originality of technology	1	1	1	1	1	1
	Uncertainty of contractor capability	3	3	3	3	3	3
	Environmentally sensitive location	6	6		6	6	6
	Volatility of relevant legislation	2	2		2	2	2
	Political or social sensitivity of project	6	6			6	6
	Political or social volatility	2	2			2	2
	Uncertain industrial relations climate	1	1			1	1
	Uncertainty of sources of finance	1	1			1	1
	Complexity of technology	1		1	1	1	1
	Complexity of hardware	1		1	1	1	1
	Complexity of "software"	1		1	1	1	1
	Hazardous materials (Type and Qty)	3			3		
	Hazardous processes / operations	1			1		
	Uncertain supply of critical equipt / services	1				1	1
	Complexity of financing	3				3	3
	Complexity of proj. organisation / 3rd party reliance	3				3	3
	Large tasks on or near critical path	2				2	2
TOTAL LIKELIHOOD SCORES			22	7	19	34	34
AVERAGE LIKELIHOOD SCORES (B)			2.75	1.40	2.11	2.27	2.27
RISK SCORES (A x B)			5.50	1.40	8.44	2.27	4.53

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Chapter 11

Where To From Here?

Introduction

Risk assessment is a tool for informed decision making. The decision facing Australian environmental agencies is whether to introduce a process of formalised risk assessment; and if so, how should it be done and what should be its scope. Until now this document has been concerned with the technical aspects of risk assessment itself. This chapter will consider the infrastructure needed to undertake successful risk analyses.

A generic Australian framework

The discussion in Chapter 3 examined the difference between an environmental impact analysis and an environmental risk analysis. The key feature is that a risk analysis must deal explicitly with certainties and uncertainties. Indeed, uncertainty analysis provides the common component within a generic framework (Fig. 3.2) that allows risk analysis to be applied in areas as diverse as chemicals, contaminated sites, industrial development, natural hazards, priority setting and politics.

The generic framework provides a model for accomplishing the technical aspects of the risk assessment. But an environmental risk assessment should be but a tool for environmental decision making. Application of a quantitative risk assessment requires capabilities in four primary areas:

(i) a systems analysis capability that can be used for scenario development;

(ii) technical expertise that can be used to quantify hazards;

(iii) statistical skills, possibly in conjunction with computer modelling expertise, that can be applied to uncertainty analysis as in probabilistic modelling, for example; and

(iv) expertise that can be used to quantify the costs and benefits associated with assessing priorities.

Computer models

Certain aspects of risk assessment can be accomplished without recourse to computers and with recourse to only elementary mathematics, for example, setting priority topics for environmental performance reviews (Chapter 5). Nevertheless, in most cases quantitative risk analysis will involve the use of a computer model — in the sense of a surrogate construct of the physical or biological world in which the model behaviour mimics the behaviour of the actual entity. Mathematics provides the language that transforms such models from vague thoughts to precise constructs with precise predictions.

Much of the United States implementation of risk assessment has relied on the regulatory use of computer models. In some cases, such as in air quality assessment, this approach has been adopted in Australia. The Victorian EPA adapted the US EPA model ISCST (Industrial Source Complex — Short Term) to predict the expected concentrations of air pollutants from proposed industrial developments. The resulting model, originally called AUSPLUME and recently revised to AUSPUFF, has won widespread acceptance around Australia as an appropriate means by which to undertake such a task.

The requirements of the US Clean Air Amendment Act of 1990 have meant that the US EPA has also undertaken the next step in the use of such computer models in risk assessment. The ISCST model has been incorporated into the TOXST (TOXic modelling system — Short Term) which is recommended for situations requiring "a more realistic simulation of intermittent sources and combined source impacts" (National Research Council, 1994: Appendix J).

These examples illustrate the use of computer models as tools with which to perform complex calculations. This is the light in which the scientific community sees them. In fact, they also serve a second function that is even more valuable to the environmental practitioner. The models codify which of the myriad complex calculations are the appropriate ones to undertake. Further, an official agency endorsement of a computer program acts in a couple of indirect ways. It minimises a practitioner's risks related to professional negligence. It also guides future investigations into the channels needed to acquire data as inputs to the model. The need for such guidance to emanate from the EPA has been documented in Chapter 8.

There has been a rapid increase in the availability and capacity of computing power in recent years. Advances in computer software in areas such as geographic information systems and expert systems mean that it is possible to combine such elements into environmental decision support systems (Fedra, 1993, 1995; Fedra & Weigkricht, 1995). Groups developing such software have emphasised different aspects of the issue. The group at the International Institute of Applied Systems Analysis (IIASA) in Austria have emphasised visual ease-of-use. The Environmental Resources Information Network (ERIN) of the Department of Environment Sport and Territories has emphasised the integration of environmental databases and remote sensing data, and delivery of their product over the Internet (Slater, 1995).

The Netherlands have developed a computer model to provide a "Unified System for the Evaluation of Substances (USES)" (Jager & Visser, 1994) designed to integrate the hazard and risk assessment of new chemicals, existing chemicals and pesticides. It exists to provide a tool for rapid, quantitative assessment of the risks of organic substances to man and the environment. It is designed for the screening stage and the intermediate (refined) stage of an evaluation and, as such, provides a first-step model that can be used by risk assessors who are not modellers or programmers. If, as we believe, there remains a need for comprehensive examination of a chemical, such as that provided by the suite of US EPA models (Gallant & Moore, 1992) then experienced operators and modellers are required.

The use of, and the role of, computer models is rapidly advancing and rapidly changing. Australia as a nation needs people with the skills and expertise to develop environmental models. Environmental agencies need people with the understanding and knowledge to be able, intelligently, to use the computer models that have been developed. There is a perceived lack of such people, yet a perceived need for such skills. Court et al. (1994) propose that a funded research institution be established to develop programs for cumulative impact assessment and strategic environmental assessment, and undertake associated research. They note that such a body could provide some of the necessary research output that was recently provided by the Resource Assessment Commission. They suggest that the agenda of such an institution should include promoting and developing predictive tools for modelling the biophysical environment, but do not discuss the availability of skilled manpower to undertake their proposed agenda.

Organisation and infrastructure

It has already been noted that the process of undertaking an environmental impact statement constitutes part of an environmental risk analysis. A commission of inquiry, such as the Fox Commission which examined the issue of Australian uranium mining, has greater powers to deal with interactions between uses and activities, with cumulative impacts, and to delve more deeply into public perceptions and attitudes. Such a process fits all the parts of the generic framework for a risk assessment.

The Minister for Primary Industries and Energy, Mr John Kerin, and his staffers experienced "frustration with endless public inquiries" (Kerin, 1990) and in November 1988 the Commonwealth Government established the Resource Assessment Commission (RAC) as a way of providing information for government on resource exploitation issues. The internal guidelines under which the RAC operated required it to identify:

- the extent of the resource and the various uses that could be made of it;
- the environmental, cultural, social, industry, economic and other values involved in those uses; and
- the implications for these values of those uses, including uncertain or long-term implications.

In addition, the Commission was required to make an assessment of losses and benefits involved in the various alternative uses or combinations of uses of the resource, including losses and benefits which are uncertain, long term, or seemingly unquantifiable.

Though slightly long-winded, these points can be summarised in the points of the generic framework: identify the concerns; identify their consequences; undertake calculations; deal with uncertainties; and then undertake both a cost-benefit and risk-benefit analysis. Thus, from 1988 until 1993, when the Government terminated the administrative functions of the RAC, Australia had an organisation devoted to environmental risk assessment. Why did it fail?

A number of commentators have tried to answer this question. Stewart & McColl (1994) — members of the RAC — cite Lowe (1993) who commented on the Coronation Hill dispute (see Chapter 10) that politicians and bureaucrats were unhappy about the transparency of the political process. The Commission's crime (according to Lowe) was to use a rational and visible process, thus exposing the nature of the decision to the public gaze. This analysis, if correct, is disturbing in that it implies that the concept of transparency of process and objectivity of decision making are not benefits but are political drawbacks. In fact, the environmental impact assessment process works on eight guiding principles (EPA, 1994):

- participation;
- transparency;
- certainty;
- accountability;
- integrity;
- cost-effectiveness;
- flexibility; and
- practicality,

with public respondents placing highest value on the first five.

Other views on the reasons for the failure of the RAC that have been given include a perception that the Australian States did not get on well with the RAC and even the procedural reason that the legal background of the chairman meant that proceedings were conducted by interviewing participants sequentially. This contrasts with the consultative process involved in the environmental impact process that deals with participants in a flexible and consultative manner. The difficulties involved in obtaining scientific information from a procession of witnesses interviewed one at a time could have led to an amount of residual ill-will.

Announcement of the decision to cease using the RAC was part of the 1993-94 budget which implies that the principal motive was to reduce expenditure. The RAC must have lost the cost-benefit analysis conducted — either explicitly or implicitly — by the Government during the run-up to the budget.

What organisation should carry out environmental risk assessments? An agency such as the EPA has a legislative role to undertake some form of risk assessment associated with chemicals evaluation, contaminated sites, assessment of environmental impact statements, and in the examination of uranium mining in the Northern Territory.

Dealing with matters such as these would provide ongoing work for a risk assessment unit within the organisation. An extra, valuable, role that seems to be necessary for a risk assessment unit is an ability to act in a strategic role to determine and evaluate the risks associated with issues that have not yet become enshrined in regulation, or matters of public concern. This type of function combines that of the Commission for the Future and that of the State of the Environment (SoE) reporting framework, once the implementation of the SoE is widened from documenting known environmental data to evaluating environmental uncertainties.

The likely name, nature and size of such a risk assessment unit are matters for debate and decision. This document offers suggestions for discussion:

A risk assessment body set up within the EPA in Canberra should have its size determined by its role. Further, it is not clear whether a technical unit, such as that of a risk assessment unit, fits well within a policy oriented department — though DEST presently incorporates ERIN, the Environmental Resource Information Network (Slater, 1995) as a technical unit. Similar concerns within the UK Department of Environment led to their establishing a small group called CIERA (Centre for Integrated Environmental Risk Assessment) as a joint consultancy between Her Majesty's Inspectorate of Pollution and the consulting firm Technica-DNV.

The EPA does, however, already run a technical organisation in Jabiru in the Northern Territory. The work of ERISS, the Environmental Research Institute of the Supervising Scientist, originally concentrated on uranium mining in the Northern Territory (when it was called the Alligators Rivers Research Institute), but recently the Institute has used its expertise to examine other mining related problems, such as those of Mt. Lyell in Tasmania. The institute has expertise in computer modelling and ecology. In addition, research work on radiation has long made use of risk assessment to determine the likely health effects of radiation. The technical background is certainly in existence for a risk assessment unit, but many of the issues that it would need to look at (e.g. chemicals, contaminated sites) on behalf of the EPA emanate from Canberra and require rapid lines of communication.

There are also functions undertaken by State environmental authorities that require risk assessments to be undertaken. The New South Wales Department of Planning, for example, has a major hazards policy unit. Some mechanism for effective and coordinated use of such expertise would be valuable.

The US EPA makes extensive use of the US National Research Council, whose members are drawn from the National Academy of Science, the National Academy of Engineering and the Institute of Medicine. The 1990 Clean Air Act specifically directed the US EPA to arrange for the National Academy of Sciences to review risk assessment methods used in relation to air pollutants. In Australia no similar use is made of the learned academies, despite their ability to provide highly competent people representing organisations widely perceived to be authoritative and unbiased.

The US EPA has a Science Advisory Board (SAB) which is a legislatively mandated group of non-government scientists, engineers and economists charged with providing independent technical advice on environmental issues to the EPA administrator (US EPA, 1994). The SAB clears EPA regulations prior to issue. It was the body that conducted the EPA comparative risk assessments and it is presently undertaking an Environmental Futures project. It has 100 members and is dominated by university representatives.

Finally, there are universities, research organisations and private sector consultants that can offer risk analysis and risk assessment services if required, either on the basis of strategic partnerships or on a fee-for-service basis.

Risk-benefit analysis

This document is but a preliminary step. The next step will be a conference on risk and uncertainty in environmental management. This conference, designated a Fenner conference by the Academy of Science, will be held 13-17 November 1995. The final day of the conference will consist of a workshop which is intended to undertake a risk-benefit analysis of introducing risk assessment. It is anticipated that the costs are quantifiable, once the scope of the process has been determined. The important benefits are expected to be:

- transparency of process;
- informed decision making; and
- input into priority setting.

Thus one purpose of a conference such as this is to decide whether the value of the benefits are likely to exceed the costs.

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Appendix 1

Issue	Likelihood of occurrence	Community concern	Summed score
1. Water Management System			
1.1 Release of mine site water	3	4	7
Retention Ponds (stop RP4 releases)	1	3	4
RRZ	2	2	4
1.2 Tailings Dam	1	4	5
Pipeline corridor	2	2	4
Seepage	2	2	4
Seepage collection system	1	1	2
1.3 Impacts on surface waters	2	4	6
2 Air Quality			
SO_2	1	1	2
Yellowcake dust	1	1	2
Subaerial vs subaqueous tailings	2	2	4
3 Radiation	1	3	4
Employee	1	2	2
Members of the public	1	3	4
Off-site exposure	1	3	4
4 Accidents			
4.1 Explosive magazine blows up	1	2	3
4.2 Tailings dam collapse	1	4	5
4.3 Human injury due to road transport	1	1	2
4.4 Fuel/U carrying road trains crash	1	1	2
4.5 Ammonia tanks crack	1	1	2
4.6 4.1 and 4.5 together	1	4 (ondamage)	5
4.7 Green terrorists	1	1	2
4.8 Trucks collide (OH&S)	1	1	2
4.9 Accidental chemical release into waterways	2	2	4
5 Determine BPT	3	2	5
Rehabilitation	3	4	7
tailings in pit	2	1	3
tailings in dam	2	3	5
6 Water management	4	2	6
Enhanced evaporation			
Filtration			
Boiling off			
Irrigate in bush	2	2	4
16 other options			
RUEI ok'd release strategy versus subsequent veto by traditional owners			
Robustness of water management plan	2	2	4

Determine beneficial uses	2	2	4
7 Radiology			
Hazard analysis assumptions incorrect	2	1	3
Radiation level at high exposure	1	3	4
8.Societal concerns			
Unacceptability of uranium	3	3	6
Linkage of non-causal events (eg. a death and an RP4 release)	2	2	4
Western Arnhem Land open to exploration	3	2	5
Sacred sites preservation	3	2	5
Health preservation (human and ecosystem)	2	3	5
Ecosystems preservation How to measure Biodiversity, productivity, sustainability, resilience	2	3	5
9 Terrestrial ecosystem			
White crust	2	1	3
Measures of ecological health	2	1	3
Alien weed introduction	2	2	4
Impacts on fish communities due to vegetation change	2	1	3
10 Extreme events			
Earthquake	1	2	3
Tropical cyclones	1	3	4
Inadequate design criteria	1	2	3
climatic variability	1	1	2
11 Form of the EPR			
Needs joint development with Company	2	2	4
Questions must focus on performance guidelines	2	2	4
Assess preparedness in absence of a problem	2	2	4

12 Rehabilitation (after decommisioned)	4	2	6
Response of encapsulated tailings (protect groundwater from contamination)	2	2	4
Company will want rapid release	3	3	6
Water releases from abandoned mine site	2	2	4
Stop erosion of waste-rock	2	2	4
surface run-off	2	2	4
maintain Kakadu ecosystem	3	3	6
13 Monitoring System			
Adequacy of sampling	2	2	4
Correct variables being measured	2	2	4
14 Legislative and consultative framework			
Are key groups involved	2	3	5
Does this set decommissioning procedure	2	2	4

Appendix 2

Scoring Risk

The summed score of Appendix 1 adds together the likelihood of occurrence and the community concern. The definitions of risk given in Chapter 2 imply that risk involves a multiplication of factors rather than an addition. Yet the Asian Development Bank framework given in Figure 3.5 sets boundaries that correspond to linear combinations of the axes. Which should it be?

The answer depends on whether the scoring system being used is linear or logarithmic. Notice in Figure 3.5 that the monetary damage scale increases by a factor of ten between each of the four boxes. Now, one of the characteristics of logarithms is that the addition of logarithms corresponds to the multiplication of the numbers represented by logarithms. For example:

$$(1/10) \times 1000 = 10^{-1} \times 10^{3} = 10^{-1+3} = 10^{2} = 100$$

where the logarithm of 1/10 is -1 and the logarithm of 1000 is 3.

We may thus infer that the frequency of occurrence scale in Figure 3.5 must also represent a logarithmic scale of probabilities. We may thus infer probabilities and likely numbers of concerned people represented in the rows of Table 5.1 as given in Table A.2:.1.

Table A.2.1 Quantified probabilities and concerned population implied in rankings of Table 5.1

Likelihood of occurrence	Inferred probability	Community concern	Inferred numbers
Remote, but possible	0.0005	negligible	5
Occasional, sometime occurs	0.005	marginal	50
Reasonably probable, several times	0.05	critical	500
Frequent, repeatable	0.5	unanimous	5000

This method of taking descriptive terms, and assigning quantitative values to them, forms one of the bases of quantitative risk assessment.

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