Risk as a criterion for determining environmental policy priorities

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CHAPTER 1

Introduction

The question of determining acceptable levels of risk has been examined by many risk researchers for a number of years. Much research has centred around the increased understanding of public perceptions of risk for the purpose of developing approaches to reducing the apparent conflict between public perceptions of risk and expert predictions of risk.

Environmental risk issues comprise a particular subset of this research with specific additional problems resulting mainly from the amount of uncertainty that usually surrounds environmental risk issues. This uncertainty has fuelled public scepticism about experts' ability to make accurate assessments and it has proved very difficult to set publicly acceptable levels for environmental risk.

Environmental risk issues often carry a very high public profile. Belated discoveries of considerable health risks such as those posed by abandoned hazardous waste sites, long-term low level radiation exposure and water and air pollution have caused the United States Environmental Protection Agency (USEPA) major problems. The Love Canal site near Buffalo, New York, provided a public mandate for the establishment of the 'Superfund' and also initiated a number of other legislative procedures designed to ensure that responsibility for dump sites can be established and that companies and owners can be held accountable.

Problems with the management of the Superfund and further examination of the hazardous waste disposal question have shown that there are very many more sites requiring some attention in the United States than was envisaged. The realisation that there was likely to be a shortfall in the funds available for clean up along with concern that there was a discrepancy between agency expenditure on different policies and the degree of risk posed initiated a move towards the use of risk **management** as a decision-making tool (Landy *et al.,* 1991). It had become obvious that faulty or poorly managed hazardous waste dumps (now called repositories) pose a significant environment hazard in the United States, the risks involved may actually be considerably less than other environmental risks faced by communities. The question then became how to establish a process for strategic action and the need to set priorities for dealing with environmental hazards.

In 1987, the USEPA produced a report entitled **Unfinished Business** (1987) that comprised a comparative assessment of environmental problems. This report was reviewed in 1989-90 by the Science Advisory Board (SAB) of the USEPA. The SAB's objective was to recommend strategies for reducing major environmental risk by a combination of risk comparison and risk reduction techniques. The emphasis in their review was on establishing a 'science-based' approach to the problem and

significant conclusions were reached about the derivation and use of a 'hard science' framework for comparing risks and setting priorities. Whilst the SAB review was in process, a pilot program was being established in three of the 10 federal regions and in several states implementing the approach outlined in **Unfinished Business.**

One of the problems identified in the United States as a result of the Superfund experience is that piecemeal policy making is expensive and ineffective. William K. Reilly (1990) in a speech to the National Press Club at the time of releasing the SAB report entitled **Reducing risk: setting priorities and strategies for environmental protection** likened the approach taken to environmental risk as similar to the video game Space Invaders: "Every time we saw a blip on the radar screen, we unleashed an arsenal of control measures to eliminate it". Very little attempt was made to assess the success of these measures and the composite nature of environmental risk was seldom considered.

One of the crucial points to arise from the **Unfinished Business** pilot projects is that for this type of priority-setting approach promoted by the SAB to be successful it must have strong (local) political support from a philosophical perspective. This support must be long term because this approach to environmental risk reduction is not a short-term approach. The actions which are recommended as part of the risk reduction strategy must be followed up and evaluated for effectiveness.

The methodology proposed and promoted by the USEPA in a series of pilot projects highlighted some of the difficulties encountered by a policy-making agency in trying to put policy measures into practice. The methodology also has application to strategic planning for institutions - an aspect that has been considered widely and is being pursued by USEPA and some of the states involved in the pilot projects.

1.1 Objectives

The specific objectives for this project are:

> to examine the use of risk reduction techniques as a tool for environmental protection, to develop an appropriate framework for New Zealand conditions, and to test this framework by applying it to the Ministry for the Environment's work programme.

The main thrust of this work consisted of obtaining and reviewing the considerable amount of literature available from the USEPA describing the series of projects undertaken and supported by the Agency as part of its comparative risk programme.

In addition, however, I was fortunate enough to be able to have first-hand contact with Philip Miller from the Washington State Department of Ecology who had been personally involved in the Washington State application of the methodology. Washington State was one of the four states chosen to implement the risk reduction

approach and the preliminary results of this pilot study have been published as a series of reports under the Washington 2010 logo.

Through discussion with Philip during a visit to New Zealand he identified a number of the practical difficulties involved and also indicated the future for the SAB's approach to environmental risk management at least in terms of Washington State's experience. He also brought with him up-to-date information about the pilot study including the **Roadmap** which we would have been unable to obtain without considerable delay. In particular, he provided direction by preventing us from following a number of potential blind alleys. We would like to express our gratitude to Philip and to say that whilst he is no way to blame for any inaccuracies or omissions, his assistance contributed greatly to the approach adopted and outcomes of this project.

The **operational** objective of the project has been stated above. However, the project had a larger purpose or goal: that of exploring in more detail the context of the 'science-based' methodology developed by the USEPA to determine its applicability to environmental management in a broader sense. The results of this overview are detailed in Chapter 8.

1.2 Structure of the publication

In Chapter 2 the classical approach to risk comparisons and risk assessment is briefly summarised. This is followed in Chapter 3 by a summary of the process developed by the USEPA covering the series of reports beginning with **Unfinished Business** and concluding with the **Roadmap** document currently available in draft form. In Chapter 4 some of the pilot projects are examined, with reference being made to the application at Federal region, State and City level. This is followed in Chapter 5 by a review of the EPA **Roadmap** document. In Chapter 6 a framework is proposed for application in New Zealand of the risk comparison approach to environmental management, including recommendations as to suitable areas of application. This framework is expanded on in Chapter 7 where a small case study is constructed. In Chapter 8 the outcomes and potential applications for this methodology and the project itself are considered.

CHAPTER 2

Risk comparisons as an approach to risk assessment

Risk is a composite concept involving both a frequency or probability, and a magnitude. There may be several possible outcomes associated with an action, and actions designed to reduce one risk may cause an increase in other risks. For example, increasing the length of a sewage outfall pipe may reduce the risk of pollution in one area, but increase it in other, more distant areas. In such a case, the human health risk can be measured using estimates of the probability of disease (calculated from water samples) and the probable population affected. Uncertainty is not the same as risk. Uncertainty is a characteristic of some risky situations where lack of information about the risk components or the possible outcomes means that precise estimates of risk cannot be made.

Risk analysis is an information-gathering approach that provides systematic and rational methods for identifying, estimating and managing risk and uncertainty. Risk assessment is one tool used by risk analysts. The application of risk analysis or risk assessment will not by itself reduce or eliminate risk. This function is part of the **management** process which uses the information produced by risk assessment.

This chapter describes and analyses elements of risk analysis fundamental to an understanding of the use of risk comparisons for environmental management.

2.1 Risk assessment

Risk comparison methods have been used for many years both formally and informally as an approach to risk assessment. Risk assessment is a three-stage process of risk identification, risk estimation and risk evaluation. The first two stages are generally undertaken by risk analysts. They comprise analysing the system (activity or proposal) under study, identifying all possible outcomes (new risks and changes in risk) and estimating the probabilities and magnitudes of their occurrence. The third stage involves evaluating the risk information gained from the first two stages, examining the possibilities for risk reduction or risk avoidance and establishing the acceptability of the residual (remaining) risk. This third stage is usually undertaken by a decision maker who may be the risk **manager** or a part of the risk decision-making process. Some researchers differentiate between the **technical** assessment of risk and the **social** assessment of risk where the social assessment of risk equates to the evaluation phase of risk assessment.

The way in which risk is estimated provides us with a way of differentiating between different types of risk. For the purposes of this publication we are concerned with environmental risk which incorporates ecological risk (risk to the natural

environment) as well as human health and social risk (risk to things that society values). Value judgments are incorporated in the study of risk from the original decision that an activity involves risk.

Rowe (1980) describes four categories of risk evaluation approaches. These are:

- risk comparison approaches,
- cost-effectiveness of risk reduction,
- cost-risk-benefit balancing, and
- meta systems.

In brief, risk comparison approaches refer to techniques that involve comparing one risk with another, cost effectiveness of risk reduction looks solely at the cost of **reducing** risk and cost-risk-benefit balancing makes trade-offs between costs, risks and benefits where risks will have cost and benefit attributes. Meta systems use combinations of the three main approaches.

This section of the publication is concerned with traditional methods applied to making risk comparisons. The basic principle is that the risk to be estimated is compared to "benchmarks, criteria or value judgements" (*Ibid.*).

2.2 Risk acceptance

Risk comparison methods may be applied in a number of different ways and for a variety of purposes. In general, they are used when it is not possible to estimate risk directly and surrogate approaches are required to provide information with which to determine the **acceptability** of the risk being studied. Situations where environmental risk is a factor often fall into the category of low probability-high consequence risk. These types of risk are typical of those requiring recourse to risk comparison methods. For example, risks posed by natural hazards such as earthquake and flooding are associated with rare events which may have very severe consequences. Lack of experience of these events means that it is difficult to calculate statistical risk estimates. Similarly, risks with a high degree of uncertainty may be difficult to estimate directly.

As Rowe (*Ibid.*) explains, the objective of many of the methods used to estimate people's **perceptions** of risk is to set a reference point that the public will accept as reasonable against which other risks may be measured. Much of the early research in risk perception concentrated, therefore, on the factors that affect people's perceptions of risk and hence their willingness to **accept** a certain level of risk (either imposed or encountered voluntarily).

The difficulty with this approach is that factors that affect people's perceptions of risk are varied and the public in general is not willing to compare risks that have

widely differing characteristics. Early attempts to set levels of acceptable risk using risk comparison and risk referencing procedures did not recognise this unwillingness and in some cases efforts were made to set acceptable risk levels by comparing widely disparate types of risk.

In an almost apocryphal story, Rothschild (1978) made the statement "So why not produce an index of risks, so that you can decide above what level - road fatalities perhaps - you should get into a panic; and below what level - death from influenza - you should relax". The attractive implication is that it is possible to use statistical and predicted risk estimates to produce a **single** index for decision making.

There are several major fallacies involved. First of all, predicted risk measures (such as those required for estimating nuclear power plant risk) should not be compared with common statistical measures (such as road accident statistics). As pointed out by Kates (1985), the "very complexity of the process of risk estimation weakens its credibility". This will be well understood by those familiar with the many assumptions and the limited amount of raw data available for these processes. In many cases they involve poor statistical practice (and considerable faith in highly uncertain estimates). Equally importantly, it is not valid to compare risks that the public is exposed to voluntarily with risks that are involuntarily. Also, risks with common, well-known consequences should not be compared with risks with unknown, dread-type consequences.

2.3 Risk communication

It is (as pointed out by Roth *et al.*, 1990) very tempting to describe the risks of hazardous technologies by comparing them with other better known risks. It must be remembered, however, that these comparisons reduce a multi-faceted value system to a single dimension (as illustrated by Rothschild's single index). One of the 'puzzles' of the risk communication process centres around trying to find valid comparisons that can be used to provide information about particular risks that may not be well known. When unrelated risks are compared and unrelated analogies are used it is important to make sure that the audience realises the significance of the comparison by making it clear that the comparison is made **for a specific particular purpose**, that is, the risk must be put in context. Comparisons are useful for providing a context for and gaining a perspective of risk, but they should be made between risks that are calculated in similar ways and that reflect similar values.

The risk communication dilemma occurs at several levels. Risk analysts need to communicate their inference and the results of their analysis to decision makers who evaluate, decide upon and implement (directly or indirectly) their decision. Decision makers incorporate many different criteria in their decision-making process as well as straight technical 'riskiness'. Managers (who implement decisions) and public-sector decision makers face different problems and have different criteria but they both require clear, consistent, comprehensible risk information.

Risk comparisons are often used by scientists and decision makers to inform the public about levels of risk. Bean (1988) gives two examples of such comparisons. In the first instance an EPA official was quoted as using the analogy: "the contamination in your drinking water is like one penny in a stack of pennies from here to the moon". The second example is concerned with waste disposal and is given as: "the county produces enough garbage in a day to fill 100 football fields 14 feet deep". Such analogies are useful only if they provide a clear, **accurate** picture. In the first instance, the analogy is both incorrect and incomprehensible (unable to be visualised) and hence likely to offend the recipient of the information. The second analogy is informative, accurate and memorable. The point of using risk comparisons for information is not to try to convince people that they have no need to worry. Risk comparisons should always be directly related to the information required by the recipient and care should be taken to establish this requirement.

2.4 Individual and societal risk

There are two ways of approaching risk estimation. **Individual risk** is defined by the Institution of Chemical Engineers as the **frequency** at which an individual may be expected to sustain a given level of harm from the realisation of specified hazards. Although this definition refers only to frequency, and I would contend that risk should be defined in terms of both frequency (probability) and magnitude, it is appropriate for this **component** of risk. The Institution also defines **societal risk** as the relationship between frequency and the number of people suffering from a specified level of harm in a given population from the realisation of specified hazards.

The important differentiation is between the risk to an individual, and the risk to a specific population sub-group. At present there is no clear consensus on criteria for societal risk or an obvious definition or description. Generally, where societal risk is estimated individual risk estimates should also be calculated since it is difficult to define the population at risk. Risk comparisons have been used to explore the concept of societal risk.

Some of the early work on risk comparisons in this area derives from Starr (1969 and 1972). Starr used economic risk and benefit data to **reveal** patterns of acceptable risk/benefit trade-offs. He prepared graphs of the number of fatalities versus the average annual benefit per person involved and hence deduced bounds for acceptable risks. Starr explored the difference between risk encountered voluntarily and risk encountered involuntarily and concluded that "the public seems willing to accept risks from voluntary activities ... roughly 1000 times greater than it would tolerate from involuntary activities ... that provide the same level of benefit". Subsequent researchers have not been able to reproduce these results, but by different means have reached similar conclusions (Fischhoff *et al.*, 1985).

One of the major difficulties associated with comparing risks depends upon the criteria used to define the consequences of risk. Cohen (1985) refers to Criterion A (the average number of deaths per year) and Criterion B (the potential for low-probability high-consequence events). Cohen's thesis is that while in real world decision making Criterion A is always used in preference to Criterion B, this is itself an unacceptable choice since it results in more deaths (using long-run average likelihood probability estimates). It is probably most important to describe clearly the consequences and criteria being used.

A related concept is that of risk balancing. This occurs when a newly introduced risk has the effect of reducing other risk (most commonly this type of situation occurs in medical treatments). Again, risk balancing is only valid if the group of risks under examination can be compared or measured on similar scales.

A major use of risk comparisons for examining societal risk is in the construction of *f*N curves. This technique is used as a way of presenting societal risk information so that different risks may be compared. The x axis represents the frequency of occurrence of a specified type of incident (f) while the y axis represents the number of occurrences in which N or more people are killed or injured. *f*N curves are usually presented in log-log graph form. The *f*N curve is a difficult concept and it is not always obvious how to compare two *f*N curves for two different situations. Examples of *f*N curves can be seen in Farmer (1967), Cuppola and Hall (1981) and Fernandes-Russell (1988). Although *f*N curves provide an easily presented graphical image of comparative risks they cannot provide information about **effects** and should not be presented without the raw data.

2.5 Equity issues

When risks are compared it is very important to relate the risk to the 'perceived' benefit. The related risk estimate techniques known as cost-risk-benefit balancing and cost effectiveness of risk reduction have been categorised by Rowe. One of the major social difficulties in all of these approaches is that equity issues are not addressed satisfactorily. The group receiving benefit is often separate from the group bearing the risk. In the case of ecological risk the inequity is often even more apparent. The problems are ethical - they involve the validity of comparing immediate benefits to amorphous or long-term costs or comparing "widely diffused benefits to risks that fall heavily on a specific population or place" (Kates 1985).

An individual's judgment or personal comparative risk perception is a **response** to a complex process which takes into account a wide range of factors. Individuals make decisions on the basis of risk comparisons every day and in this sense they choose the risks that they are prepared to tolerate (Thomas 1981).

We cannot simply use the cost of risk reduction as a way of choosing which risks to deal with. Society is aware of the high cost of some risk protection measures and approves of them. Preventative health measures and the vaccination of children provide an example. Generally measures that are seen as preventative are given greater social emphasis than 'cures'.

Wilson and Crouch (1987) suggest comparing and contrasting risks using a series of different criteria such as toxicity, certainty of information, the voluntariness of the activity, the source of risk, availability of common knowledge etc. Many of these criteria are factors widely recognised as affecting risk perceptions.

One way of incorporating the different factors that individuals take into account when assessing the acceptability of risk is to use vectors to characterise the different risks. Each component of the risk being studied represents some measure of a particular type of consequence (number of deaths or injuries, days of work lost, area affected etc.) and different weights can be used to produce an aggregate value (Hansson 1989). However, even this approach is not sufficient to incorporate properly the overlapping factors that contribute to the severity of a risk. Hansson (*Ibid.*) uses eight dimensions of risk (similar to those suggested by Crouch and Wilson) to illustrate his belief that uni-dimensional risk estimates commonly used for comparisons are invalid and that expert assessment should somehow reflect the complexity of risk.

2.6 The future

Many of the issues associated with concepts such as uncertainty, perceived risk and acceptable risk are less of a problem when comparative risk assessment (CRA) is used to set broad priorities than when it is used to make specific regulatory decisions since there is less need for precision in the former. One of the purposes of CRA is to better inform decision-making processes.

For the future it is likely that the use of risk comparisons as an aid to risk communication will become an important area of study and application. Therefore, it is essential that analysts and communicators be made aware of the need to ensure the relevance of their analogies and the comparability of the risks being used as illustrations and referents.

CHAPTER 3

Risk management and the EPA

In 1987, the USEPA (or EPA) produced a report entitled **Unfinished Business: a comparative assessment of environmental problems** (USEPA 1987) which comprised a comparative assessment of environmental problems. This report was reviewed in 1989-90 by the Science Advisory Board (SAB) of the EPA to determine whether the approach could be used to derive strategies for reducing major environmental risk by means of a combination of risk comparison and risk reduction techniques. The emphasis in this review entitled **Reducing risk: setting priorities and strategies for environmental protection** (SAB 1990) was on establishing a science-based approach to solving problems. Significant conclusions were reached about the derivation and use of a 'hard science' framework for comparing risks and setting priorities. While this national level approach to the problem of assessing environmental problems in terms of risk was proceeding, a pilot series of regional, state and local applications of the approach proposed in **Unfinished Business** was being undertaken. This Chapter reports on the findings of these two major national projects, while Chapter 4 concentrates on the regional, state and local projects.

The problems faced by the EPA leading to the initial **Unfinished Business** report are outlined well in Morgenstern and Sessions (1988). Since the establishment of the EPA in 1970, many 'new' problems have either developed or increased in importance. The reasons for this include scientific uncertainty, long-term cumulative effects, the recognition of environmental problem areas and the transfer of risk from one medium to another.

As a result, the EPA has been forced to establish priorities for action so as to "apply its finite resources where they will have greatest effect" (*Ibid.*). Some of the difficulties involved in this priority-setting exercise include the conflict between statutory mandates and public and political pressure.

Environmental problems tend to be long-term problems. Therefore, environmental management requires consideration of long-term perspectives. In an attempt to avoid the 'fire-fighting' approach to environmental protection that was becoming increasingly evident, the EPA initiated a policy approach based on the principles of risk management that was referred to as 'risk reduction'.

The basis of this policy approach was that the reduction of environmental risk would be adopted as an over-riding goal for the agency. One of the requirements for the enactment of this policy is a systematic means of analysing and evaluating risks, effects and actions. However, many activities that pose risk to the environment involve considerable uncertainty and have frequency and magnitude components that cannot easily be quantified. Under a purely technical or quantitative risk

assessment framework there is a fear that these risks may not be given proper consideration. Added to this is the concern that in many cases the cause of disaster or trigger for an event is human error which is particularly difficult to incorporate into quantitative analysis. Therefore, caution is required.

Before proceeding, it is appropriate to discuss the role and the history of the EPA and its subsidiary the SAB. The EPA was established by Congress in 1970 under President Nixon. Its statutory role was as a regulatory authority and in practise it has always operated as a "pollution control" agency. Its roots lay in the recognition of the impact of toxic chemicals on human health and the environment.

At the time of the establishment of the EPA the primary responsibilities of protecting fish, wildlife, forests and other natural resources were already vested in other agencies who were unwilling to give up their responsibilities. The EPA, as it now exists, was effectively a compromise after a proposal for a Department of Environment and Natural Resources was defeated largely as a result of opposition from other agencies who stood to lose much of their function to such a department. The new agency took over: the Federal Water Quality Administration and the Office of Research on Effects of Pesticides on Wildlife and Fish from the Department of the Interior; the Bureau of Water Hygiene, the Bureau of Solid Waste Management, the National Air Pollution Control Administration, the Bureau of Radiological Health and the Office of Pesticides Research from Health Environment and Welfare; the Pesticides Regulation Division from the Department of Agriculture; the Division of Radiation Standards from the Atomic Energy Commission; and the Interagency Federal Radiation Council. Not unexpectedly, given the dissention surrounding its intended function, the EPA had some difficulty in reconciling and meeting the differing expectations of it.

Ruckelshaus, who was appointed the first Administrator of the EPA, took as a priority the enforcement of existing legislation and was successful in greatly increasing the number of infringements prosecuted. The EPA then began getting involved in the process of revising and setting standards. Notable cases included revising the Ozone standard (1977), the Resource Conservation and Recovery Act (RCRA, 1976, amended 1980) and the establishment of Superfund (1979).

The Superfund legislation followed the principle of 'shovels first, lawyers second' and imposed a levy on chemical feedstocks. There was controversy over this approach to the collection of a levy: however, it did greatly simplify the process. The deficiencies of the Superfund Bill were that it did not give any guidance on which sites should be tackled first or how the available limited resources should be allocated. It also did not give any consideration to how much clean up should be done (how clean is clean) or how to determine an acceptable risk. As a result of a political mix-up oil was omitted from the legislation causing considerable political embarrassment.

The direction of the EPA has changed over the years as different Administrators have imposed their own perspective. Through the 1970s the emphasis was on health risks, whilst in the mid 1980s a change occurred in which greater emphasis was placed on ecology. In 1983 Ruckelhaus was re-appointed Administrator for a second term. He made a clear distinction between risk assessment as a scientific tool, and risk management as a political process. He believed strongly in public involvement in determining environmental priorities. Ruckelhaus was succeeded by Lee Thomas who followed this philosophy by promoting risk management as a basis for EPA decision making and commissioned the Office of Policy Analysis under Richard Morgenstern to co-ordinate a report examining the relative risks of the various environmental problems that EPA has a mandate to address. The result was published as **Unfinished Business.**

From its beginnings, the EPA has been noted as a 'reactive' agency responding to public concern via Congress and the legislative process. Different program offices responsible for implementing particular laws have tended to react solely to the specific environmental problems associated with these laws; there has been notably inadequate interaction between offices. **Unfinished Business** therefore reflected a change in perspective and an attempt to come to grips with a longer time horizon, more consistent with the nature of environmental problems and associated risk issues.

3.1 Unfinished Business

3.1.1 Objectives and approach

Unfinished Business was the product of a year-long project that had the objective of determining the comparative magnitude of the types of environmental problems that the EPA might face. The specific assignment was to "compare the risks currently associated with major environmental problems, given existing levels of control" (the concept of residual risk, or risk remaining under current controls).

The approach taken was to use risk assessment methods to assess and compare the risks posed by environmental problems. The first task was to determine a set of 'problem areas'. The intention was that each of these problem areas, shown in Table 3.1, should represent a recognised environmental problem area defined along the lines of existing programs or statutes. These problems were chosen with some thought to the existing work of the EPA. Attempts were made to define the problems as they are perceived by the public at large. As a result, some of the problem areas are diffuse and overlap causing difficulty for both their assessment and ranking.

Table 3.1 **Environmental problem areas**
Source: **Unfinished Business: a comparative assessment of environmental problems (USEPA, 1987)**, Volume 1, Overview, pp.10-11.

1. Criteria air pollutants from mobile and stationary sources (includes acid rain precipitation)
2. Hazardous/toxic air pollutants
3. Other air pollutants (includes fluorides, total reduced sulphur, substances not included above that emit odour)
4. Radon - indoor air only
5. Indoor air pollutants other than radon
6. Radiation - other than radon
7. Substances suspected of depleting the stratospheric ozone layer - CFCs etc.
8. CO_2 and global warming
9. Direct, point source discharges (industrial etc.) to surface water
10. Indirect, point source discharges (POTWs) to surface water
11. Non-point source discharges to surface water
12. Contaminated sludge (includes municipal and scrubber sludge)
13. To estuaries, coastal waters and oceans from all sources
14. To wetland from all sources
15. From drinking water as it arrives at the tap (includes chemicals, lead from pipes, biological contaminants, radiation etc.)
16. Hazardous waste sites - active (includes hazardous waste tanks) (groundwater and other media)
17. Hazardous waste sites - inactive (Superfund) (groundwater and other media)
18. Non-hazardous waste sites - municipal (groundwater and other media)
19. Non-hazardous waste sites - industrial (includes utilities) (groundwater and other media)
20. Mining waste (includes oil and gas extraction wastes)
21. Accidental releases - toxics (includes all media)
22. Accidental releases - oil spills
23. Releases from storage tanks (includes product and petroleum tanks - above, on and under ground)
24. Other groundwater contamination (includes septic systems, road salt, injection wells etc.)
25. Pesticide residues on foods eaten by humans and wildlife
26. Application of pesticides (risks to applicators, which includes workers who mix and load as well as apply, and also consumers who apply pesticides)
27. Other pesticide risks, including leaching and runoff of pesticides and agricultural chemicals, air depositions from spraying etc.
28. New toxic chemicals
29. Biotechnology (environmental releases of genetically-altered materials)
30. Consumer product exposure
31. Worker exposure to chemicals

For each of these 31 problem areas four different types of risk were considered separately: cancer risks, non-cancer health risks, ecological effects, and welfare effects. Within each risk type the 31 problem areas were ranked. No attempt was made to rank across all four types of risk. Where possible, similar methods of risk assessment were used for all four risk areas. Also, where possible, secondary effects and inter-media transfers were considered.

The 31 problem areas were ranked for each risk type (risks were treated synonymously with effects). This ranking was based on secondary information. In a number of areas data were either not available, were incomplete or were not appropriate to use for comparison purposes. In some of these cases additional analysis was performed and in other cases professional judgment was used.

Hence the comparisons relied on a composite quantitative/qualitative approach to risk assessment.

Other structural procedures affected the analysis and the results. The risk assessment for each problem area was based on risks as they exist currently with existing controls in place. This meant that in some cases risks registered as 'low' because current controls prevented them from registering as 'high'. Added to this, a number of assumptions affected the form of the analysis. Rankings are based on risks to the whole population. Risks to particular geographical or demographic groups may be very different.

Four work groups were established - each considered one specific type of risk. They followed a series of basic steps in their analysis.

1. The group agreed on a basic conceptual framework for comparing risk among the problem areas.

2. Existing data were accumulated and organised using "summary sheets". The summary sheets for each problem area described existing information, sources of data and major uncertainties.

3. The data from the summary sheets were combined with the judgment of the group members to produce a relative ranking.

For cancer risk, the problem areas were ranked from 1 to 26 with five problem areas being omitted from the rankings. Five categories were described representing decreasing magnitude of cancer risk. The three areas listed in Category 5 were listed alphabetically rather than ranked, and two areas, discharges to estuaries, coastal waters and oceans, and discharges to wetlands were not ranked or categorised because in the judgment of the group they represented conglomerates rather than individual problem areas.

For non-cancer risk the approach taken was similar to that used to calculate the number of cases expected to result from exposure to a chemical, that is:

exposure x potency = incidence

The aggregation to total risk from that chemical over all health effects is achieved by means of a severity index. Therefore, three scores representing severity, population exposed and potency were calculated and combined.

There are thousands of chemicals and in general very little information is available about their hazards. The information that is available generally relates to estimated safety limits rather than any genuine risk assessment. Therefore, the work group relied heavily on judgment and the results were presented in terms of a group ranking with an associated level of confidence and estimate of the percentage of the problem covered.

Problems areas for non-cancer health risks were grouped in four categories representing high, medium and low risks plus an unranked list.

The methodology developed to analyse and rank ecological risk was very complex. A series of criteria was developed and used by the work group to rank risks into high, medium and low groupings. The 31 problem areas were reduced to 22 and, as a refinement, the high-risk group was divided into three sub-groups and the medium risk category into two. An expert panel considered the types of ecological stress associated with the refined problem areas and examined a series of 'stress agents' in terms of potential impacts - local (ecosystem), regional and global. The group then attempted to rank ecological risk by estimating the impact of the problems on as many different kinds of ecosystem as possible, as well as broader geographical regions and the biosphere. The criteria applied were intensity of impact, scale of impact, ecosystem recovery, control and uncertainty.

It is important to remember that for ecological risk the objective must be to assess the **potential** impact of particular stress agents. In this context therefore risk assessment is applied in a similar fashion to environmental impact assessment. It is rarely quantitative and almost never probabilistic.

The welfare risk analysis relied heavily on monetary estimates of damage, with future damage being discounted. Welfare effects from exposure to environmental pollution are assumed to represent declines in the value of any commercial activity and declines in the value of any other human activities. Five distinct categories were considered:

- soiling and material damage,
- recreational losses,
- damage to natural resources,
- damage to commercial and public property and to ground water supplies, and
- losses in aesthetic and non-user values.

Each member of the group ranked the 31 problem areas separately and then a composite ranking was developed. Twenty-three of the problems were ranked into three groups of high, medium and low effects and the remaining eight problem areas were unranked and placed in a 'minor effect' category.

Only two groups (cancer and welfare) attempted to rank the problem areas ordinally.

An important point about this project was highlighted by the cancer work group. Four of the six problems areas that ranked highest for the cancer risk group are areas in which the EPA has limited jurisdiction. Therefore, the EPA has limited ability to initiate either direct action or a policy response.

3.1.2 The results

The objectives of **Unfinished Business** did not include the setting of priorities for the EPA since when the project was initiated there was no intention that risk alone should be used to set priorities for agency actions.

The major findings listed in the **Unfinished Business** executive summary are that:

1. No problems rank either relatively high or relatively low in all four types of risk;

2. Problems that rank relatively high in three of four risk types or at least medium in all four include criteria air pollutants, stratospheric ozone depletion, pesticide residues on food, and other pesticide risks;

3. Problems that rank relatively high in cancer and non-cancer health risks but low in ecological and welfare risks include hazardous air pollutants, indoor radon, indoor air pollution other than radon, pesticide application, exposure to consumer products, and worker exposure to chemicals;

4. Problems that rank relatively high in ecological and welfare risks but low in both health risks include global warming and physical alteration of aquatic habitats; and

5. Areas related to ground water consistently rank medium or low.

The risk-based rankings did not match the EPA's current program priorities. Nor did the rankings match those estimated from public perceptions. However, the EPA's current priorities did roughly correspond to the public's perceptions.

Perhaps more importantly, the national rankings did not reflect local situations. This is not surprising since it is logical that problem areas are likely to differ in their importance between geographical areas. A further problem when analysing the rankings obtained in any general context is that they were derived from current control conditions, a situation that does not reflect either EPA current priorities or the public's perceptions.

3.1.3 Limitations

All four groups reported difficulty with the set of problem areas in that the dividing lines between them were often fuzzy, especially when trying to consider the secondary effects. Similarities between problem areas meant that categorising problem areas was at times somewhat arbitrary.

The main limitations of this project are a direct result of its structure. A number of areas were not considered at least directly. These were:

1. the economic or technical controllability of the risks,

2. the qualitative aspects of the risks that people find important,

3. the benefits to society of the activities that cause the environmental problems, and

4. the statutory and public mandate for EPA to deal with the risks.

In practical terms risk decisions require making trade-offs. Therefore, whilst it is appropriate to rank problem areas without taking account of economic or technical controllability, or their potential benefits it is necessary to include these issues when making decisions before taking action.

Qualitative aspects are very important when considering environmental risk actions because unless the public is aware of and prepared to support the necessary action it is unlikely that it will succeed. No account was taken of the public's perceptions of the problem areas or the factors that are known to affect perceptions, such as, voluntariness, familiarity and equity.

The problem areas were ranked by risk as **it exists now**. This means that areas where substantial risk is present but where action is being taken by or on behalf of the EPA were ranked lower than areas of less risk where no action is being taken. When the public considers risk it either may not be aware of or it may discount the value of current action. This is one very obvious reason why the expert rankings differed from the public's perceptions. There is thus a danger that future actions may not take adequate account of the effects of current actions.

A further potential difficulty is that in the area of welfare risks future risk was specifically discounted and given less weight than current risk. This is a common technique used extensively in cost-(risk-)benefit-type analysis for evaluating future impacts. However, there is always considerable debate about the discount rate used. In terms of environmental risk, it may even be argued that future risk should be given a **higher** value than current risk (i.e. use of a negative discount rate).

The EPA study looked solely at societal risk, or risk in terms of the whole population. In a number of cases the population risk might rank low, however, individual risk might be very high. Equity issues were not considered. Considerable care needs to be taken, therefore, in considering any actions based on the results of the risk rankings derived from this study.

The individual work groups reported on some specific limitations of their analysis.

The cancer work group made two key statements:

> *"Estimates of true risk are currently not possible; given our limited knowledge of carcinogens."*

and

> *"We relied heavily on our professional judgment, rather than on quantitative methods."*

This group also reported difficulties in that:

- the ranking presented reflects population risk rather than individual risk,
- an ordinal ranking confers false accuracy, and
- rankings may reflect inadequate data rather than a genuine position.

Specific problems noted by the non-cancer risk work group were that higher quality data are required to estimate risk for non-cancer environmental risks and that there is a strong requirement for a dose-based model (as is available for cancer risk estimation). The group also felt concerned that the risk estimates in the different problem areas were not directly comparable because of different modelling techniques and the different quantity and quality of information. Many of the estimates were incomplete and **all** the estimates were subject to uncertainties inherent in this form of analysis.

The EPA does not have jurisdiction or responsibility in many areas that cause extensive habitat alteration and hence high ecological risk. Local and global issues are often more important than national issues. The necessary national perspective adopted in this study therefore caused difficulties and distortions in assessing ecological risk. The ecological work group noted also the absence of an established methodology. Ecosystem science is complex and predictive tools are not available. Further difficulties arise because ecological risks are difficult to define and scientific uncertainty is inherent in any form of ecological risk assessment.

The welfare risk group noted problems in separating effects and overlap between the problem areas. They also felt that there was difficulty in separating the effects attributable to welfare and ecosystems.

As well, all groups expressed concern over the quantity and quality of data available for the risk assessment. Some of the general problems associated with inadequate data are that the risks may be unknown or unidentifiable, variations in the coverage or availability of data may affect the rankings, the definitions and boundaries of the environmental problem areas complicate the ranking process and a variety of analytical methods may have been used within the same area.

All four groups felt that the problem areas selected were not relevant to their own particular risk area. For this reason they felt that it would have been preferable to try to separate problems and risks. As well, there was a general consensus about the lack of methodology. This concern was subsequently reflected by the considerable controversy generated in the scientific community over the quality of the risk assessment methods used in the **Unfinished Business** project. It should be noted, however, that unless the study had been undertaken, it is unlikely that these methodological shortcomings would have been recognised.

3.1.4 Use of the results

It has already been noted that the jurisdiction of the EPA is limited in some of the problem areas that scored high for some risks. The original project was designed specifically so that neither the EPA's mandate nor its current priorities were explicitly considered in the process of defining the problem areas. However, priorities and actions were implicitly incorporated in risks that were assessed according to present controls in place without consideration of their cost or benefit. Any attempt to incorporate the results from **Unfinished Business** into the Agency's strategic decision-making processes would therefore require much more careful consideration of the problem areas with account being taken of other political factors.

3.1.5 Next steps

The specific stated objective of **Unfinished Business** was to compare risks associated with major environmental problem areas. That is, to use risk criteria as a means of ranking environmental problems as a preliminary step towards setting Agency priorities.

It was not intended that the risk-based criteria developed should be used as the sole basis for setting priorities. To this extent, the project has been successful in meeting its objectives. At the same time it proved very useful in indicating areas of deficiencies in both methodologies and data availability.

It must be remembered that the context of this process was the use of risk criteria to set environmental priorities. This was viewed as a two-stage process of risk assessment and risk management. The risk-ranking process described here is therefore an application of risk assessment. **Unfinished Business** was performed by experts without any public involvement process. Therefore it could not be used as the sole factor in risk management decisions that require consideration of many other social, economic, political and cultural factors.

The follow-up to **Unfinished Business** proceeded along two different paths: an independent review and evaluation by the SAB, and a series of pilot projects designed to test both the risk assessment and risk management phases.

3.2 Relative risk reduction

As a follow-up to the **Unfinished Business** report, EPA Administrator William Reilly asked the Science Advisory Board (SAB) of the USEPA to review the report and then to "assess and compare different environmental risks in light of the most recent scientific data". The SAB was also asked to examine strategies for **reducing** major risks. The outcome of the relative risk reduction project was the report entitled **Reducing risk: setting priorities and strategies for environmental protection**, hereafter referred to as the **Reducing risk** report.

This request marked a shift away from the normal function and operation of the SAB. Prior to 1978 the SAB consisted of an informal association of scientists providing information to the EPA on request. In 1978, the SAB was established formally during the course of the setting of the ozone standard. The process used by the SAB was a two-stage one of firstly developing a criteria document and secondly setting the standard. At this time the SAB expressed concern at being asked to take account of 'what constituted a significant health effect', the concept of 'sensitive groups' and social and economic criteria. The normal function of the SAB between 1978 and 1988 primarily involved the review of scientific reports on the basis of scientific and engineering data.

The approach taken by the SAB to the relative risk reduction project involved establishing a committee of 39 scientists and experts entitled the Relative Risk Reduction Strategies Committee. The **Relative risk** project made a more deliberate attempt to address the policy issues associated with reducing environmental risk than **Unfinished Business.** It also attempted to rationalise (if not resolve) the problems of establishing more scientifically-based methodologies for comparing risks.

3.2.1 Objectives and philosophy

In 1989, as a response to the request by the EPA Administrator, the SAB set up a committee entitled the Relative Risk Reduction Strategies Committee which itself was divided into three subcommittees: the Ecological and Welfare Subcommittee, the Human Health Subcommittee, and the Strategic Options Subcommittee.

The objectives established by the parent committee were to:

1. provide a critical review of the report **Unfinished Business**, that reflects any significant new information that bears on the evaluation of risks associated with specific environmental problems,

2. provide, to the extent possible, merged evaluations of cancer and non-cancer risks (i.e. health risks), and of ecological and welfare risks (i.e. environmental risks),

3. provide optional strategies for reducing the major risks, and

4. develop a long-term strategy for improving the methodology for assessing and ranking environmental risks and for assessing the alternative strategies that can reduce risks.

As early as 1983, Ruckelshaus (Ruckelshaus 1983) had actively promoted a science-based approach to establishing a common statutory framework for assessing risk. At the same time, however, he stressed that the scientific process of assessing risk must be separated from the political process of using the assessments to set priorities. Ruckelshaus also recognised the limitations of current risk assessment methodologies in his statement "we need to strengthen our risk assessment capabilities". These limitations became more widely recognised within the EPA as a result of the **Unfinished Business** project.

Part of this reaction was the result of the frustrations that Ruckelshaus experienced during his two terms as EPA Administrator. He had consistently criticised the risk assessment techniques used by EPA analysts as the "stacking of conservative assumptions one on top of another". From the political perspective it proved difficult to defend decisions based on these types of approaches, especially specific

standards, siting or other regulatory decisions, compared with broad policy or priority-setting decisions.

The relative risk reduction project therefore broke new ground in its strong reliance on science-based methodologies. As well as being asked to review the **Unfinished Business** report and examine methodologies, the SAB was asked to **recommend strategies for risk reduction** (as a means of establishing strategies for environmental protection). This was a major step forward from the initial process of ranking environmental problems using risk criteria. As a result of **Unfinished Business** and the pilot projects there has been a steady refinement and improvement in methodologies now reflected in the **Roadmap.**

Part of the philosophy driving this project was the introduction of the concept of environmental risk as a means of providing an integrated approach to environmental management. The objective was to provide common measures and a standardised framework for comparing environmental problems. Central to this concept is the dual process of risk assessment (the estimation of risk) and risk management (risk reduction).

3.2.2 Approaches

The three subcommittees of the relative risk reduction project presented their reports in the form of appendices.

One of the main functions of these sub-committees was to review critically the work presented in **Unfinished Business**. Many of the criticisms reported here were also noted by the sub-committees involved with the original project.

The report of the Ecology and Welfare subcommittee began by being critical of the original approach to risk ranking adopted by the **Unfinished Business** sub-committees because it mixed sources, receptors, media and regulatory obligations. Also, the mandate of the **Unfinished Business** project excluded a number of significant ecological problems that fell outside the EPA's jurisdiction. As a result the rankings were somewhat contrived and incomplete.

This raises an interesting question as to how to set boundaries when assessing comparative risk for this type of process. Is it possible to apply it to a subset of environmental problems in any meaningful form?

While being critical of the original approach, the ecology and welfare sub-committee endorsed the use of a matrix of ecological stress types versus ecosystem types as proposed by Harwell and Kelly (1986). This approach was incorporated into the **Unfinished Business** report but could not be directly applied because of the structure of that project.

The ecology and welfare subcommittee then attempted to develop an improved methodology for evaluating ecological and welfare risk assessments by considering two approaches:

- firstly, they aggregated the original 31 EPA environmental problem areas into a more limited number of categories and ranked these; and

- secondly, they disaggregated the EPA environmental problem areas into environmentally relevant categories of stresses, and then ranked these categories.

The first of these approaches involved aggregating the original 31 problem areas into eight groups which were then ranked using size (scope), hazard (categorised as high, medium or low) and exposure (high, medium, low).

The second approach was a modification of the matrix approach proposed by Harwell and Kelly (*Ibid.*). A series of diagnostic parameters (the intensity of potential effects, the uncertainty of these estimates, the type of ecological response, and the time-scale for recovery) were plotted against the aggregated problem areas using the scale of stress (local, regional, biosphere), the transport media (air, water, terrestrial) and the recovery time (years, decades, centuries/indefinite) as parameters.

The sub-committee redefined welfare effects as "all effects on humans and societies excluding human health effects that may result from environmental problems". That is, the original definition used was expanded to include all aspects of the **quality** of human life. Both indirect (mediated by ecological systems) and direct effects (economic and non-economic) caused by changes to the environment were examined. It was concluded that the rankings for ecological and welfare risks were essentially the same.

The principle conclusions reached were that the original analysis performed by the **Unfinished Business** group was too narrow (hence the expanded definition) and also that it relied too heavily on economic analyses involving unreliable data. Specifically, the group found that the procedure of "... ranking future effects lower than present, all else being constant" is "**not scientifically sound for ecological issues**". They stated that "Economic analyses of environmental issues must take a long-term view with the ultimate goal of sustaining life-supporting ecosystem functions". Discounting devalues the long-term effects of large scale and long-term environmental problems (such as nuclear waste disposal).

As part of their analysis the sub-committee reviewed and adapted the rankings adopted for the original list of problems areas and then proceeded to compare the original rankings with the revised rankings.

The sub-committee reached a consensus on the belief that the risk assessment process is a good mechanism for formulating public policy from a scientific base and recommended that the approach be institutionalised on a regular basis. It noted, however, for this to be effective, credible personnel and data bases would be required. They also reported that in many cases expert judgment was the main criterion used as no other data were available.

The specific goals of the second sub-committee, the human health sub-committee were: to evaluate the **Unfinished Business** methodology for ranking environmental problem areas using risk criteria, to determine the extent to which the risk rankings should be revised or updated, to combine (if possible) carcinogenic and non-carcinogenic rankings into a single aggregate ranking, and to recommend approaches for improving the methodologies for assessing and ranking.

Again, the initial response of this sub-committee was a criticism of the **Unfinished Business** report, primarily in terms of the inadequacy of exposure information on which the risk assessments were based, and the difficulties already noted about the selection of the problem areas.

The sub-committee did not attempt to review or revise the original rankings directly, but focused mainly on methodological problems and the need to develop new approaches. In terms of developing a composite ranking for carcinogenic and non-carcinogenic risk, the committee conceded that this would be possible, but suggested that it would involve so many value judgments and ethical issues **beyond the scope of either the sub-committee or the EPA** that it should not be attempted. However, with that qualification, a possible approach was developed and described.

The sub-committee made a number of practical suggestions for improving methods for setting priorities for action. They suggested that other commonly used techniques such as triage should be reviewed. Whether reactive approaches such as triage are appropriate depends on the goal of the priority-setting process. They noted that the ranking systems used for cancer risk and non-cancer risk in **Unfinished Business** were not entirely consistent (for example, the severity of the effect was not considered for non-cancer risk).

This leaves a slight dilemma - is it better to keep the cancer and non-cancer risk rankings separate (due to the problems in resolving ethical and moral issues required and methodological differences), or should they be combined with clear criteria for weightings established to prevent false comparisons between the risks? It should be noted that the current revision of health care in New Zealand involves some of the value judgments that the Human Health sub-committee did not feel competent to attempt.

The objective of the Strategic Options sub-committee was to identify and analyse a range of the most promising types of risk reduction options that the EPA should consider and to provide a procedure for the EPA to continue working along these lines.

In order to achieve its objective, the sub-committee used a four step process of:

1. selecting a set of environmental problems for study,

2. developing a list of potential risk reduction strategies for each problem,

3. selecting the most promising option for each problem, and

4. developing cross-cutting strategy options and making recommendations for use.

The factors considered by the sub-committee in establishing strategies and options were cost, risk reduction, technical feasibility and implementation requirements.

The aim of the Strategic Options subcommittee was to explore the risk management side of the equation. Throughout **Unfinished Business** and **Relative risk** it was noted that the rankings of environmental problem areas resulting from the risk assessment process should not be viewed as direct priority lists. Many other social and cultural factors must be taken into account in the decision-making process. The risk reduction options examined by this sub-committee were inadequate for this purpose. The assessment and rankings exercise by SAB was used as a basis for broad policy recommendations.

It was, however, recommended that this activity should seek to involve as wide a group of people as possible in developing and considering strategies and options. The advantages are that:

1. a large number of problems and strategies can be considered in a relatively short time,

2. the use of a group covering different interests and agencies forces an overview of a large number of problems and potential solutions,

3. the analyst is released from the constraints of specific legislation or mandate,

4. cross-program analyses providing multiple benefits to several problems are forced, and

5. explicit attention is given to the multiple desirable characteristics of the risk reduction approach.

These advantages derive from the specific mission and cultural environment of the EPA, however, most of them are applicable to a number of different political situations.

The activities of this group were less constrained by the original project than the other groups and therefore it was able to develop directly its own approaches to the problem of determining strategic options.

None of the groups considered specifically the incorporation of public perceptions into the risk-ranking process. Potential conflict between expert predictions and lay perceptions needs to be considered within the strategic option development process. Most of the groups involved in risk-ranking processes have given explicit recognition to the importance of expert judgment due to a lack of 'hard' data. In order to achieve public support, essential for such a program, a major risk communication exercise is mandatory. This involves informing lay opinion with the best possible information and **judgment** of the experts.

3.2.3 The recommendations

The Ecology and Welfare and Human Health sub-committees appeared to have some difficulty reconciling their dual objectives of, firstly, reviewing and revising the rankings in the **Unfinished Business** report and, secondly, of recommending improved methodologies. The dilemma revolved around the 'anchoring' heuristic and the inability to demonstrate creative lateral thinking. In most cases, the groups appeared happier criticising than creating. This may have been due in part to the limited resources available and concern for strict adherence to their terms of reference. Despite this apparent reluctance, however, a number of useful recommendations were presented.

The Ecology and Welfare sub-committee made six recommendations. They were to:

1. formalise an extramural and continuous process for ecological risk prioritisation (categorise not by Agency program but by anthropogenic stress),
2. develop formal methodologies for ecological risk assessment,
3. develop the data bases needed for improving future ecological risk assessments,
4. develop an appropriate methodology for integrating ecological and economic time dimensions,
5. give consideration to non-economic aspects of ecological values and welfare risks, and
6. consider the results from this risk-ranking exercise in the development of future Agency policy and allocation of financial resources.

The Human Health sub-committee stated that in conducting future risk-ranking exercises, the following factors should be taken into account.

1. the effects of uncertainty should be stated explicitly and factored into any risk characterisation,

2. consistent criteria should be developed for the assessment of toxicity and identification of hazards,

3. the distribution as well as the mean should be evaluated when considering the severity of health effects,

4. assessments should consider risks to individuals as well as risks to the general population and to susceptible sub-groups,

5. the Agency should be cautious about combining rankings for cancer and non-cancer health risks,

6. consideration should be given to the time period over which risk reduction strategies may be effective as well as persistence if uncontrolled,

7. it should be recognised that the assessment of relative risk is heavily value-laden, and

8. risk rankings should explicitly recognise the extent to which existing control strategies affect risk reduction and, conversely, the estimated risk in the event that existing programs were not continued at the same level.

This last factor addresses one of the concerns expressed earlier in this report about the consistency of the ranking process. There were also a number of other specific recommendations concerning areas that should be included in the establishment of a more precise and consistent methodology for assessing human health risk. These recommendations included ways of identifying and assessing toxic agents and toxicity.

The specific recommendations of the Strategic Options sub-committee were that:

1. the EPA should establish priorities based on the potential for risk reduction,

2. pollution prevention should be the most important approach for reducing environmental risks over the long term,

3. EPA must broaden its kit of environmental protection tools, especially to emphasise economic incentives and information transfer in order to reduce risk and prevent pollution,

4. environmental protection must be integrated into other policy areas in as fundamental a manner as are economic concerns,

5. a special government mechanism should be created in the Executive Branch in order to integrate environmental policy into other policies,

6. EPA should continue to perform analyses similar to the relative risk reduction project and integrate the results into the Agency's strategic planning process,

7. EPA's annual budget should more directly reflect risk-based priorities, and

8. the Agency should develop an enhanced environmental education and training program for both professionals and the general public.

3.2.4 Where to next?

The relative risk reduction project was critical of a number of areas of the **Unfinished Business** report. Primarily, the individual sub-committees were critical of the methodologies applied and the lack of data on which the risk comparisons were based. At the same time they themselves reported the need to use expert judgment in many cases. Despite increasing knowledge there will remain many areas of uncertainty and lack of information and what is really required is that scientists become more prepared to admit publicly the areas of uncertainty and to be clear about when they are making assessments on the basis of their expertise and experience. As Kunreuther and Patrick (1991) note, however, those involved in both studies felt confident that sufficient data were available to provide **relative** rankings for the given environmental problems. This implies that a higher level of imprecision or uncertainty is acceptable for comparative risk ranking and priority setting than would be the case for risk assessment designed to set regulatory standards.

The public has shown considerable reluctance to make trade-offs in terms of costs and benefits when considering environmental problems. Kunreuther and Patrick (*Ibid.*) suggest that one reason for this may be the disagreements between experts as to the nature of risks (for example, disagreements over toxic levels for chemicals). Another reason is the public distrust of experts arising from situations where experts have been shown to be fallible or just plain wrong. Greater respect and trust between experts and the public needs to be established before the public will accept the types of trade-offs that are required to enhance environmental protection and enhancement procedures and hence take the actions needed.

The trust issue is important for comparative risk assessment from the perspective that the public is being asked to accept that not all environmental issues can be addressed adequately at the same time. How can it be determined where people accept and trust the necessity for setting priorities?

None of the sub-committees for either project seemed to be comfortable with the original 31 problem areas selected. It may be that the problem areas need to be defined separately for each particular risk group being considered. A further step would be to attempt to find overlaps and comparisons between the problem areas.

The individual sub-committees were given clear specific objectives that they were, on the whole, successful in achieving. It is noteworthy that all the recommendations report a need for more data and improved methodologies.

The relative risk reduction project was conducted in parallel with a series of pilot projects in three of the EPA Federal regions and several states. Projects in all 10 of the Federal regions have now been completed and a number of State projects have also been undertaken. Some larger cities have performed analyses. The following chapter describes some of the approaches taken and the problems faced in attempting to implement the **Unfinished Business** and **Relative risk** report recommendations.

CHAPTER 4

Applications

In this chapter a number of applications of the comparative risk assessment (CRA) approach to environmental risk management are reviewed.

Three regional CRA projects sponsored by the EPA began in 1987-88, and a further four in 1988-89. Three of these projects are reviewed here, Washington, Vermont and New England. The original objectives of these projects were to attempt to calibrate the results of the national study (**Unfinished Business**) and to provide a mechanism for regional planning processes.

The Washington State project is given most emphasis since I was (as mentioned earlier) fortunate enough to be able to discuss this project with Philip Miller who was directly involved in the project. Philip was able to provide me with information concerning ongoing work in the Washington State Department of Ecology as well as a project undertaken by the City of Seattle.

This chapter is not concerned with the particular ranking results produced by the analyses. In each case, the objectives of the study are described, the processes that were applied are outlined and an evaluation of the results given. Particular differences between projects will be emphasised.

In the last section of this chapter the approach taken by Washington State Department of Ecology to linking the CRA approach to environmental management with their own internal strategic planning is discussed.

4.1 Washington State

The Washington Environment 2010 project was inaugurated in 1988 as an "exercise in environmental ark building" (Environment 2010: the state of the environment report 1989). One of the key factors in the success of this project was the personal involvement and commitment of the then State Governor, Governor Booth Gardner, and the Director of the Department of Ecology, Christine Gregoire.

In December 1988 the Washington Environment 2010 Advisory Committee was established by Governor's Executive Order. It included directors of 13 state agencies and representatives from two federal agencies. The project was conceived as a **process** with four components: analysis, vision, outreach and action.

The analysis phase was translated as an information and evaluation exercise to identify and assess environmental issues and the condition of the State's environmental resources. The output from this first phase was a State of the Environment report (**Environment 2010: the state of the environment**). It was designed to be the first of a periodic series (of which the second is due out shortly).

In this report the environmental issues in the State of the Environment report were grouped into six major groups: air, water, land, wetlands, fish and shellfish, and wildlife. For air pollutants, criteria (those for which national health standards are established) and non-criteria pollutants were assessed in terms of their effect on human health and effect on plants, wildlife and ecological systems. Point sources and non-point sources were examined in terms of the major pollutants.

Water issues included both quantity, the availability of water when and where it is needed, and quality. Water quality is important in terms of human health and ecological well-being.

Land use issues were balanced between human needs and wildlife and ecological needs. The State's land resources were divided into agricultural uses, forestry, range and recreation. Balances need to be struck between the different major uses, while issues such as erosion, overgrazing and 'old growth' need to be addressed.

Recognition of the importance of wetlands has come too late for many fragile ecosystems. Washington State has a wide diversity of wetlands (fresh and salt) which are coming under increasing pressure from other land uses.

The management of fish and shellfish is split between two agencies, representing fisheries and wildlife. Two major pressures on these resources are degradation and destruction of habitat, and level of harvesting. Similarly, for wildlife, the main issue is the condition of the habitat. Land use factors impinge directly on wildlife habitat and affect survival of species.

In line with the results from both **Unfinished Business** and **Relative risk**, the Washington Environment 2010 program explored the impact of "cross-media issues". Environmental issues seldom have an impact on only one area of the environment. The major issues addressed in this context were pesticides which have harmful effects on both humans and the environment, waste management, materials storage, accidental releases, radioactive releases and litter.

As well as **describing** the environmental issues, the State of the Environment report also attempted an initial assessment of the issues and established some preliminary priorities for action.

The technical committee for the project identified 23 major threats for its CRA which were considered in terms of three risk types: human health risk, ecological risk and economic risk. Ecological risk appears to be consistent with the **Unfinished Business** report, however, welfare risk appears to be incompletely covered under the straight economic risk category.

Because of the short time frame, the CRA analysis used only secondary data. Areas where the data available were of poor quality or simply unavailable in the required form were noted. The data used were treated as the 'best available' and limitations were acknowledged.

After the establishment and analysis of the 23 major threats, a Public Advisory Committee was briefed in detail on the risk analysis and was asked to prepare the preliminary list of risk management priorities for action. This committee included educators, farmers, business people, legislators, environmental advocates and others. Six factors were used to compare and categorise the threats. They were:

1 the relative human health risks associated with the threat,

2. the risks to ecological systems associated with the threat,

3. the threat's potential for causing economic damages,

4. the apparent trend the threat appears to be following,

5. the manageability of the threat, and

6. personal and professional judgment.

The result of this exercise was a list of threats divided into five separate categories based on their priority for action. For example, the first group, which included ambient air pollution, point source discharges to water, and non point source discharges to water, was established as "Priority level 1".

Threats were not ranked within the priority-level categories.

Although the CRA part of the project was treated as a preliminary step it was a very important one. It is only when an attempt is made to perform the analysis that the full requirements for data and methodology can be assessed and determined. This type of analysis must be viewed as a dynamic process or a continuously evolving process to which there is no 'correct' answer.

The State of the Environment report (SER) tackled the 'analysis' phase of the process envisaged as Washington Environment 2010. It also served as a foundation for 'vision' and 'outreach'.

The SER was released in October 1989, and it was followed in July 1990 by **Toward 2010: an environmental action agenda.** This second report, which included aspects of vision and 'action', was prepared through an extensive 'outreach' process and was an attempt to provide approaches and standards for tackling the environmental problems established and prioritised in the first report. The process used to determine the actions and targets in the "action agenda" included extensive public consultation with interest groups and individuals. Workshops were held in different parts of the State and attracted wide interest. Pamphlets and fact sheets were some of the other information channels employed.

In October 1990 the first stage of the process was completed when the Environment 2010 action agenda was incorporated into Executive Order EO 90-06. This Executive Order included a requirement for biennial State of the Environment reports to be published.

It is sometimes difficult to maintain the momentum in projects of this nature, especially in the area of public interest. Implementation of most recommendations is highly decentralised by design and is proceeding successfully. The Washington State Department of Ecology publishes a newsletter that invites public contribution, incorporates issues of public interest and concern, and is generally designed to maintain public interest. Other publications of the Department of Ecology reinforce the theme of direct public involvement in decision-making processes.

The second SER is due out in early 1992 and will include a progress report on actions taken to implement the "Action Agenda". This is an interesting departure from normal State of the Environment reporting which has traditionally been of a more objective form, concentrating on statistical reporting alone.

The next stage in the process of managing environmental risk is to examine the tools available to the decision maker. In most cases, legislation has been viewed as the most appropriate means of establishing and maintaining policies and programmes concerned with or directed at environmental quality. Washington State is now establishing and implementing legislation covering aspects of air quality, water resources conservation, energy strategies, transportation management, environmental education and sustainable agriculture. The use of economic incentives (economic instruments) to encourage environmental protection is being explored.

4.2 Vermont

The material presented here is derived from **Environment 1991: risks to Vermont and Vermonters** (Vermont Agency of Natural Resources 1991). The goals of the project, planned to be undertaken over a two-year period, were to:

1. develop a more accurate understanding of the risks posed by Vermont's environmental problems,

2. share that information with Vermonters, and

3. use that shared understanding to reduce risks.

Three types of risk were considered: risk to ecosystems, risk to human health, and risk to Vermonters' quality of life.

The project was constructed as a two-phase process. The specific objectives of Phase 1 were to:

1. identify the most serious environmental problems,

2. identify Vermonters' values relating to environmental risks,

3. estimate the risks posed by each environmental problem, and

4. rank the problems in order of the seriousness of the risks.

The project was initiated by the Secretary of the Agency of Natural Resources and was funded by the EPA. A Public Advisory Committee of 16 people was set up, and background information for this group was provided by three technical work groups, supplemented by consultants. Public outreach was an important component of the program.

Working with a wide range of experts, the technical work groups established a list of 17 problem areas. At the same time, the Advisory Committee conducted a series of public fora to determine the issues of greatest concern to the public. The final group of problems for consideration was established by the Advisory Committee who added four problems and subtracted one from the technical work groups' recommendations.

Methods and criteria for analysis were developed by the technical work groups then data were collected and analysed and the information circulated as widely as possible. Finally the technical work groups ranked the problems and presented their judgment to the Advisory Committee. The Advisory Committee met to review the data and rankings and then applied its own aggregated ranking process. In the final report three members of the committee noted personal disagreement with some of the final rankings.

Seven recommendations were made as a result of this process. They were that:

1. the primary goal of Vermont's environmental policy should be to reduce risks to ecosystems, human health, and Vermonters' quality of life,

2. Vermont's state and local officials should provide more information about environmental risks to the public at large, and should present it in terms that the public can understand,

3. Vermont's policy makers and officials should be explicit about uncertainty whenever they discuss environmental risks with the public, stating both what is known and what many be suspected but not proven,

4. Vermont's environmental policy should place as much importance on reducing risks to ecosystems as it does on reducing risks to human health,

5. Vermonters should seek ways to reduce risk to the people and environment of Vermont, and to the human and natural communities with which they share or will share the planet,

6. Vermont's environmental policy should place particular emphasis on maintaining or enhancing the state's bio-diversity and the integrity of its ecological communities, and

7. Vermont's environmental policies should value natural resources not just at their market prices, but also for their long-term social and ecological importance.

It is perhaps interesting to note in comparison to the Washington State project that the most important environmental problem areas for Vermont were considered to be global climate change and indoor air pollution.

The second stage of this project should be well underway. The objectives of Phase 2, as stated in the Phase 1 report, are to:

1. decide which risks to address,

2. develop action plans to reduce those risks,

3. develop ongoing monitoring programs to see if the risks are being reduced effectively, and

4. prepare the way for a similar two-phase evaluation in 1995 and 1996.

4.3 New England

The New England study was one of the three pilot projects by USEPA's 10 regional offices, and was one of the first projects undertaken; concurrently with the **Relative risk** project. It evolved around the concept of 'residual risk' or "the risk posed by a problem given current levels of control" (a similar approach to that used in **Unfinished Business**). The group undertaking this project consisted of 35 people representing different environmental programs and expertise within the USEPA regional office. The group was divided into three work groups studying public health risks, ecological risks and risk management factors. The methodology used was described by the group as "systematically generating informed judgments".

Twenty-four problem areas were defined to correspond with existing EPA programs or statutes, and these were assessed for public health risks (cancer and non-cancer health risks) and ecological risks. Risk management factors such as public participation, available resources, legal authority, available technology and economic impact were also considered. The risks were analysed separately and no attempt was made to weight the risks.

The list of problem areas chosen was similar to that used by the **Unfinished Business** project, modified slightly for regional concerns by the addition of lead exposure (a significant public health problem in New England), asbestos exposure and lakes, ponds and impoundments. Some areas considered to be important but not within the jurisdiction of regional authorities were excluded.

Both work groups attempted to use existing data and to point out areas of limitation. Estimates of uncertainty and the percentage of the problem covered were included and, where possible, **sources** of risks (pathways and stresses) were identified.

The procedure involved technical work group members, EPA headquarters staff and consultants. Information and analysis generated were presented to the group who undertook the process of ranking the problem areas.

The methodology followed for public health risk assessment was similar to that applied to **Unfinished Business.** The report acknowledged that the most difficult part of the process was the combining of the separate rankings for cancer and non-cancer risk into a composite ranking, because of the implicit weightings required.

A semi-quantitative approach similar to that used for the **Unfinished Business** report was adopted for the assessment of ecological risk.

The innovative feature of this project involved the use of a Risk Management Work Group, which developed and applied its own methodology to assess and evaluate risk management issues. The factors chosen for evaluation were public perception, available resources, economic impact, effective technology and legal authority

(12 factors were initially considered but were reduced to five). Ranking criteria for each factor were assessed for each problem on a scale of 1 (relatively difficult to manage) to 5 (relatively easy to manage). Group discussion was used to adjust the rankings for consistency between the five factors. The results were presented to allow the reader to compare the original ranking (by the groups specifically assessing the factor) and the adjusted ranking after discussion by the full work group.

The risk management work group did not attempt to combine the rankings for the five factors into a single ranking.

The "lessons learnt" from this application were presented as a series of "broad observations".

1. the process of this project is as valuable as the results (in terms of planning),

2. the risk reduction project is a first step towards developing a more analytical approach to planning and priority setting (in Region I),

3. the inconsistency of problem definitions complicated the analysis,

4. regional data are often inaccessible,

5. ranking is easiest when there are good supporting data, more difficult when we had to rely on best professional judgment and most difficult when values and personal judgment entered into the ranking,

6. high ranking public health problems in general differ from high ranking ecological problems,

7. rankings based solely on residual risk given present exposure pattern may underestimate the importance of ground water as an environmental resource.

8. the effectiveness of ongoing base programs has a great impact on the relative ranking results,

9. the results of the **Unfinished Business** project and this project are similar, except for the treatment of ground water, and

10. the Risk Management Work Group results are the key elements linking the ecological and public health rankings to the regional planning process.

The New England project was being undertaken at about the same time as the **Relative risk** project. Therefore both of them are derived from the same base. It is notable that the New England group was prepared to combine the cancer and non-cancer health risks (although admitting difficulty), whereas the **Relative risk** group was hesitant to do so.

On the basis of available information it is not possible to establish whether or not the results of this project have been translated into action targets.

4.4 The City of Seattle

In October, 1991 the City of Seattle published a report entitled **Environmental risks in Seattle: a comparative assessment** (City of Seattle Office for Long-range Planning 1991). The project manager for the City had previously worked with Washington Environment 2010.

The project was constructed similarly to the Washington State and Vermont applications. A technical advisory committee with four sub-groups was established and this was overseen by a public advisory committee.

The City sought to address five key issues:

1. the need for improved cohesion and co-ordination among local, state and federal environmental agencies,

2. the need to set clear environmental priorities in light of budget constraints,

3. concern about growth and its impacts on the environment,

4. the need to adjust to the changing nature of environmental challenges facing the City, and

5. concern about the City's expanding role in implementing and paying for environmental protection.

Budgetary goals were more explicitly stated in this project than in the State and Federal area projects.

Environmental problem areas were grouped and studied by four technical work groups responsible for air issues, water issues, land issues and cross-media issues. Three types of risk were considered: human health, ecological and quality of life. The criteria used to rank the problem areas addressed by the groups in each risk type were:

1. the relative magnitude of the problems,

2. the need for further action (considering the relative risk and adequacy of on-going efforts to reduce that risk), and

3. the City's relative ability to solve the problems.

The rankings in all three types of risk considered were aggregated to a single ranking within each issue area. It is not clear how this aggregation process was achieved. Rankings of problems for the three risk types are not presented.

The material in the report represented the findings of the technical work groups under the umbrella of the Technical Advisory Committee. The next step will involve review by the Public Advisory Committee. It is not clear if the public will be directly involved in this process. Once the review is completed an environmental action plan will be established by mid-1992 that will influence the city's budget process and decisions.

4.5 Characteristic features

One of the important findings coming out of the Federal area and State projects is that environmental priorities are different in different parts of the United States. Therefore, it is appropriate that the process of these CRA projects should reflect local expectations and differences. This is particular important because of the local social and political support required to implement the findings.

Some of the different characteristics of the approaches are noted here.

Washington State project

1. An overall ranking combining all risk types was not attempted by the Technical Committee b t **was** completed by the Steering and Public Advisory Committees.
2. Decisions were made by consensus, during joint meetings of the Steering Committee of agency leaders and the Public Advisory Committee representing diverse constituencies.
3. The public was **directly** involved in the decision-making process.
4. The ability to mange the risk was one of the criteria used in the assessment.
5. An action plan was prepared and is being implemented.
6. A new SER is being prepared.
7. There has been strong political support for the project's principles and process.

Vermont project

1. Rankings were made individually in each of the three 'risk' categories and then a combined risk ranking was attempted.
2. Problems were ranked ordinally for the individual risks but in five categories for the aggregated ranking.
3. Risks to quality of life were considered directly.
4. The technical work groups and the Public Advisory Group functions were well delineated and separated. The effective veto power given to the Public Advisory Group emphasises the judgmental nature of the CRA process.
5. An action plan is being prepared.
6. A revision of the process is planned.

New England project

1. Risks were assessed separately: no attempt was made to compare between risks, and no attempt was made to add risks for a problem type.
2. Present and future effects were estimated, and future effects were not discounted.
3. Cancer and non-cancer health risk rankings were combined into a single composite ranking.
4. The concept of risk management was explicitly introduced by a Risk Management Work Group.
5. No specific attempt was made to incorporate the public (although the public perception factor analysis did involve some public input).
6. Quality of life or direct welfare risks were not included.

City of Seattle project

1. Three types of risk were considered for four different groups of problems (note that the Washington State project grouped problems by issue to construct the SER report, but ranked all problem areas together).
2. Aggregate rankings over all risks were presented for each group of problems.
3. Risk to quality of life was considered explicitly.

4.6 Risk assessment and risk ranking

Little has been said in this chapter about the particular **methods** used to assess and rank risk. The material published by Washington State and the City of Seattle concentrates on process and is not explicit about methodology. Washington State generally followed EPA risk assessment methodologies as they existed at the time, with adaptions as required for the specific application.

For the Vermont study, the methods used to assess cancer risk followed the EPA guidelines, and the no-threshold assumption. Similarly for non-cancer health risks, EPA guidelines were followed. Cancer potency factors were used for carcinogens and reference doses for non-carcinogens. These were combined with exposure estimates and estimated numbers exposed to produce 'population risk' estimates. Environmental risk estimation used four factors: structure, function, recovery time, and space or scale. Problem areas were divided into 'stressors' and analysed the effects of each stressor on the different types of Vermont ecosystem. These results were plotted against recovery time and scale factors. Seven criteria were used to evaluate or assess risks to quality of life. These were grouped as aesthetics, economic well-being, fairness, future generations, peace of mind, recreation, and sense of community. Subjective judgments and weightings were an intrinsic part of this process.

The Vermont integrated ranking was established during a series of open sessions of the Public Advisory Committee. Recourse was made to the results of the 'Vermonters' priorities questionnaire' circulated by the Business Roundtable. Personnel judgment and beliefs were the main criteria used. The group agreed strongly in certain areas such as a sense of obligation to future generations, and that natural systems are more than just resources for human use. However, there was disagreement about the relative importance of human health risk and ecosystem risk.

The methods used by the New England CRA project are stated as being similar to that used by the EPA for **Unfinished Business** except in the case of the Risk Management Work Group, where a new methodology was required. This is described well in the reports.

The perceived lack of methodology was expressed by many of the technical work groups associated with CRA projects. Since the completion of the **Relative risk** report EPA has commenced the huge task of establishing methodologies in a document entitled the **Roadmap** that sets out appropriate methodologies for assessing risks in different categories. This document is reviewed in Chapter 5.

4.7 Strategic planning and management

In most cases, the EPA has used the CRA approach in terms of examining risk according to current levels of control (the residual risk concept). Whereas it is difficult to try to turn the clock back to imagine the situation if certain base controls were not in place, it should be recognised that in many cases vast amounts of effort and resources are achieving relatively minor reductions of risk. In some cases this lack of impact is the result of historical factors, related to previous levels of knowledge, and in other cases it is politically related.

The important point about the general CRA approach is that although it is described as a 'science-based approach' all reports on applications have noted the importance of professional judgment, particularly in the ranking processes. This is not a contradiction; rather it is a recognition that science is not a purely quantitative 'game'. Good science involves professionals using their experience to assess and evaluate information and to make decisions based on that experience.

Comparative risk assessment is not new. Nor is it applicable only to the evaluation of environmental risk.

It is a valuable management tool for the systematic assessment and communication of disparate information.

The Washington State Department of Ecology has recognised this wider perspective of CRA and is planning to link the Environment 2010 project objectives and process to its own internal planning and management process.

The comprehensive planning section of the Department of Ecology has designed an approach consisting of four parts: mission planning, strategic planning, biennial operations planning, and monitoring and evaluation. These four components are closely linked together.

Mission planning focuses on long-term goals established at an agency-wide level. The Mission Statement of the Department is:

> *"to protect, preserve and enhance Washington's environment and promote the wise management of our air, land and water for the benefit of current and future generations".*

The goals established as a means of achieving this mission are also derived from vision statement contained in the Environment 2010 action plan. They emphasise the need for prevention and conservation. Strategic planning establishes strategies for accomplishing the goals that are in many cases directly linked to the broad action recommendations of Environment 2010. These objectives entail establishing long-, medium- and short-term objectives and success measures for each program of the Department. They provide the link between long-term planning and the

biennial planning process required for internal budgetary and management processes.

Linking internal strategic planning processes to Environment 2010 has important advantages to the Department allowing it to use the medium of the SER to re-evaluate its own internal goals and achievement of objectives in terms of environmental results over time. It is expected that the whole process of establishing vision, analysing problems, setting priorities using CRA, and determining recommended actions will need to be revisited periodically (i.e. every five to six years).

CHAPTER 5

The Roadmap

The methodologies used in CRA projects are not firmly established and most groups undertaking these applications have expressed concern about the apparent lack of established methodology and the inconsistencies inherent in the approaches that are currently being used. Therefore, the EPA has produced a document entitled a **Roadmap** (EPA 1991) (currently available in draft form only) that describes some of the 'best' available methodologies.

The stated purpose of the **Roadmap** document is "to serve as a guide to environmental protection and natural resource organisations planning to conduct comparative risk projects". The intended audience is environmental agencies within the United States and overseas.

The remainder of this Chapter briefly describes the contents of the **Roadmap** document under chapter headings and titles, and concludes with a brief summary statement. Personal comments are included in italics.

Chapter 1: Introduction

This chapter provides a summary of the purpose of the **Roadmap,** a description, and some notes about the way in which the **Roadmap** was produced.

Chapter 2: Organisational structure and process

The recommendations for personnel include a project manager, a Steering Committee, a Public Advisory Committee and a series of Technical Work groups.

Chapter 3: General analytical issues

Chapter 3 is concerned with 'ground rules' including establishing consistent sets of definitions and analytical goals.

People working on these types of projects are likely to come from very different backgrounds with different personal/professional goals and experience. There is no single 'right way' of approaching CRA. However, it is important that within a CRA project there should be clear understanding of the issues and approach.

The **Roadmap** notes that traditionally three types of risk have been considered: human health risks, ecological risks, and social and economic effects. The **Roadmap** document states that **all** of these risks should be considered as otherwise distortions are likely.

The document lays out a set of principles or "analytical goals" that are stated as crucial. They are consistency, explicitness, efficiency, coherence (of all the parts) and relevance to the organisational goals.

Each organisation undertaking CRA is likely to have different specific goals and objectives. Each project, therefore, needs to be designed with these in mind. There should be two main aims for any CRA project: the first is to assess and rank the risks, and the second is to determine strategies for reducing risk. These two components are referred to here as **risk assessment** and **risk management** and are clearly delineated.

The reason given for this separation is that the risk assessment process should be kept as "objective and scientific as possible". It is, however, acknowledged that "substantial use of judgment is inevitably necessary" in the assessment and ranking process.

The **Roadmap** recommends that the scope of the CRA project be defined in line with the project objectives. This will require consideration of the temporal and geographic boundaries of the problem and is essential for the establishment of the problem areas. There is a question with respect to the EPA-sponsored projects as to whether areas beyond the regulatory scope of the EPA should be included. Further, a difficult problem may be to determine whether risks should be assessed in the light of current controls - especially as a prerequisite is an open mind.

Problem areas should be defined in line with project objectives. Six different ways of delineating problem areas are listed: along organisational lines, by source type, by pollutant or stressor, by affected resource, by geographic area and by economic sector. The choice will depend upon the nature of the project and will to some extent be determined by the types of risk that are chosen.

Desirable characteristics of problem areas are:

1. comprehensiveness,
2. a consistent level of aggregation,
3. minimum overlap,
4. ease of analysis,
5. ease of implementation, and
6. ease of communication with the public.

*In practise, I believe that it important that the **subjectivity of the CRA be explicitly established.***

Perhaps more importantly, the risk assessment (ranking) and risk management phases are separable because different groups of analysts and decision makers will be involved. It may be desirable to include some overlap, but in general, the assessment phase will be undertaken by technical experts, whereas the management phase will be the responsibility of decision makers (public involvement may occur in both phases).

Some of the issues that require further investigation are whether rankings should be combined across risk categories, and how to deal with differing uncertainties in the ranking process. It is unlikely that any definitive approach will be developed that will provide solutions to all the problems associated with these issues. Therefore, open acknowledgement of the difficulties and the incorporation of uncertainty estimates into rankings are important.

Chapter 4: Assessment of environmental risks to human health

The next three chapters describe methodologies for assessing specific risks. Recommendations as to the type of data to be collected are included. Rather than describing the methods here some of the issues to be considered when discussing risk types are introduced.

Whilst it is acknowledged that the relationship between cause and effect may not be clear, the **Roadmap** group believes that recorded incidence data are likely to be better than calculated incidence data when estimating health risks. Two other approaches are extrapolation from existing data and the estimation of risk based on modelling at individual sites. Whenever estimating health risk the availability of data will be the determining factor for the method.

There are four steps involved in human health risk analysis: hazard identification, dose-response assessment, exposure assessment, and risk characterisation. This last step involves combining the information from the first three steps before ranking the problem areas. Risk characterisation for cancer risk and non-cancer risk is discussed separately. Individual risk and population risk are also calculated separately for cancer risk.

It is recommended that the ranking process initially be undertaken by the technical work groups who have established the risk assessments, since they are more fully informed about the uncertainty involved and the quality of the estimates. It may be appropriate for the ranking to be performed by a composite group of decision makers and technical experts.

A series of factors to be considered for the risk-ranking process are listed and discussed. For cancer risk ranking these include specifically cancer incidence and individual risk. Factors to be considered in non-cancer risk ranking are the magnitude of the reference dose exceedance and the number of people exposed. Factors common to both ranking processes are: the size of the sensitive sub-population, the severity of the health effects, (known) omissions in the analysis, the quality of the data and the analysis, and other uncertainties.

The thorny question of whether to combine cancer and non-cancer health risks remains. It is suggested that such a combined ranking would be more useful from a planning perspective than individual rankings and more consistent with the ecological and welfare risk approaches. Two broad approaches are described, both rely heavily on judgment and value issues.

> *Methodologies for estimating and assessing human health risks are well known and commonly used in many contexts. Therefore this Chapter has a significantly quantitative base. In general, the main limitation is likely to be the quantity and quality of data available. In terms of combining rankings, I have some concern about whether this is appropriate or not. It is probably best left to the specific application with consideration of who (is doing the ranking) and when (it best fits into the process).*

Chapter 5: Comparative ecological risk assessment

The process of estimating ecological risk is technical and complex. An important distinction between the estimation of **potential** impacts (due to physical overlap of stressors and receptors) and **actual** risk and impacts (requiring exposure of a receptor to a stressor) is made. It is the former that is being estimated in this case.

Two options as to a means of deriving an ecological classification system are described: the eco-region approach proposed by the EPA Environmental Research Laboratory in Corvallis, Oregon, and an ecosystem approach based on existing land use patterns.

Once the set of problem areas is selected then a set of physical and biological stressors needs to be identified and analysed. This set, that may for practical purposes be a subset of a full set of stressors, provides the base for determining end effects on ecological receptors.

The evaluation process is complex and requires considerable recourse to professional judgment, particularly when it is necessary to extrapolate effects.

The set of recommended evaluative criteria includes: area of impact, severity of impact, reversibility of impact, uncertainty and, optionally, the ecological value of the ecosystem and the geographic scale of the impacts.

The recommended approach to ranking is described as the semi-quantitative approach. The effects of the selected stressors on each ecosystem or ecoregion are evaluated according to the above set of criteria which results in a score for each stressor within a problem area. Risks from all stressors are then aggregated (using a variety of analytical approaches) and modified to reflect the amount of the problem area not covered. The resultant matrix of aggregate risks by problem area and ecosystem or ecoregion is used for ranking.

> *This chapter also points out the importance of risk communication and makes some practical suggestions about the type of information that should be communicated, and ways of approaching presentation and communication.*

Chapter 6: Welfare effects

The chapter discusses economic effects as those social effects to which a monetary value can be attributed,[1] whereas social costs are damages to which no monetary value can be attributed (it is noted that Vermont used the term 'risks to quality of life').

The Chapter is divided into five sections:

1. direct measures of economic damage,
2. alternative measures of economic damage,
3. special cases and analytic issues,
4. establishing a social and economic damages ranking, and
5. illustrative examples of economic damage assessment.

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[1] Washington State Energy Office is making a considerable effort to quantify environmental values in monetary terms as part of an attempt to incorporate environmental costs into energy planning.

In the first two sections common methodologies including non-market valuation techniques are discussed and examples given. Economic losses due to decreased property value and the economic cost of restoring contaminated resources are included.

Under special cases, two issues are introduced: (1) the need for procedures to incorporate future damages into an annual damage estimate (some environmental problems may have huge future cost, and (2) how to assess in economic terms the services provided by complex ecosystems.

The problem of establishing a social and economic damages ranking is likely to be complicated by the considerable uncertainty associated with the estimated economic damages data. It is noted also that ranking these dollar values excludes social damages. A series of "qualitative adjustments" or criteria to be incorporated in the ranking process is: equity issues, reversibility, geographic extent of damage and effects on local economies. This list is not exhaustive and the criteria selected will depend on local objectives and social conditions.

The problems associated with incorporating all the information to provide a ranking of welfare risks requires consideration of the interpretation of complex, overlapping dollar damage estimates, the synthesis of quantitative and qualitative information, and the organisation of the information into a format suitable for presentation to decision makers.

This latter point is crucial to all risk-based decision making.

The last section of this Chapter provides some specific examples of economic damage calculations.

Chapter 7: International application of the comparative risk assessment methodology

This Chapter begins by addressing why other countries seek to apply this methodology. All countries face environmental choices of different kinds and the CRA approach can be applied to a number of different issues and for a number of different purposes.

There are likely to be significant differences in the approach taken to CRA in different countries as also occurs within the United States. There will be variations in problem areas, data, specific objectives and institutional structures.

A section on Project Development is included. This is not restricted to international projects, but contains elements that require consideration for any similar type of project or analysis.

Methodologies appropriate to the United States may not be appropriate in other countries for a number of reasons, including availability of data and social and cultural conditions.

> *This Chapter is important because it addresses some of the philosophical questions that must be addressed when initiating any CRA project. The questions and issues raised are not unique to international projects and should be the subject of debate for all applications.*

Chapter 8: Risk management

In the version of the draft **Roadmap** document available to this study, Chapter 8 appears in rough outline form.

Risk management is described as that process where "one decides what to do about the environmental problems that have been evaluated and ranked during the risk assessment phase".

It is likely that the people involved in this phase will be different to those involved in the earlier assessment phase. Although risk management does not involve any re-ranking of the problem areas it may require consideration of further criteria such as available resources and general ability **to do** anything about the problem areas. The priorities set for action may be different from the assessed rankings.

The objectives of the risk management process should ideally be established before commencing the CRA, and a process for linking the two phases should be considered. Risk management is a social process and should always include some form of public involvement or debate (depending on the scope of the process). Consideration of the tools available to risk managers is important. These may include regulation, enforcement, economic incentives (economic instruments), technical assistance and provision of information. Other tools should be assessed where possible.

> *The management process is crucial and its output must include actions. Some aspects of the process are subjective and evaluative, and others involve technical innovation (for risk reduction). An 'action plan' must include elements of monitoring to determine the effectiveness of the applied strategies.*

Final comment

The **Roadmap** is a well organised and carefully worded document that will provide a useful aid to groups intending to apply CRA. However, there is a danger that this type of document can become a 'cookbook' that is followed blindly in order to achieve a predestined conclusion. This is particularly a problem with ecological risk. For this reason, I believe that Chapter 7, which addresses some philosophical questions and issues, is probably the most important.

The methodologies presented for assessing and ranking particular risk types are derived from what is by now considerable experience in dealing with complex systems problems. Although minor modifications will be required, these methodologies will provide a consistent base for the process of environmental risk assessment. It is likely that in the United States effort will now be directed towards improving the quality of data required for implementing these approaches.

Comparative risk assessment is not a static, one-shot technique. As acknowledged by the commitment made by Washington State to regular production and publication of SERs, it must be an on-going, regularly updated process. The resources required to undertake such studies are considerable. Decisions about commitment to such a process must therefore include careful consideration of its objectives and the required and available resources.

CHAPTER 6

Comparative risk assessment as a tool for environmental risk management

The experience of the United States has shown that the adoption of a science-based risk comparison methodology is appropriate to setting priorities for action for managing (and reducing) environmental risk. The projects undertaken by the USEPA have demonstrated that the approach can also be applied at different institutional levels and that in co-operation with local interest groups and individuals it is possible to set targets for reducing environmental risk.

The applications and research to date have also shown that there are a number of different ways of approaching CRA as described in **Unfinished Business** and **Relative risk.** Two of the main difficulties noted in the original **Unfinished Business** report were a lack of quality data and a lack of methodology. The EPA has made a brave attempt to counter the latter deficiency in its most recent **Roadmap** document, reviewed in Chapter 5. Data deficiencies can only be remedied over time.

More importantly it must be recognised that in many environmental problem areas there will always be a lack of data to some degree, for example, incomplete monitoring data, inconclusive or non-existent epidemiological studies, lack of field studies confirming local ecosystem characteristics etc. Therefore, it may be better if we apply our scarce human resources to the area of expert judgment. This will only be successful if firstly, experts are willing to use their judgment in areas where they may previously have felt reluctant, secondly, if the public are directly involved in the process and, thirdly, if there is a political willingness to make basic changes in the way in which we manage scarce environmental resources.

Unfortunately there are still a number of influential people within the US administration and scientific hierarchy who view public involvement in decision-making processes as a one-way street where the public is 'informed' and 'educated'. For example, William K. Reilly (EPA, 1991) is quoted as saying "we must improve the translation of scientific knowledge into the vernacular of politics and public opinion, to make rational risk assessment a part of every citizen's common sense" (p.4).

Personally, I believe that risk assessment is part of every citizen's common sense and that the inclusion of 'rational' is simply an attempt to imply that value judgments have no part in decision making. In any case, this process of knowledge transfer is only one side of the equation (does education imply rationality?). Risk management is much more powerful and effective when it is applied as a co-operative tool. It

is a means of incorporating public beliefs and values into the decision-making process.

In *Ibid.* a number of prominent members of the two US groups - leaders in the environmental field and scientists - were asked to comment on two questions. The answers were published as a forum.

Environmentalists were asked to address the question:

> *"Should Congress and by implication EPA revise the current ordering of the nation's environmental program priorities to better match scientific assessment of the relative risk of the various threats to the environment?"*

Scientists were posed the following:

> *"Is the science of estimating risk sufficiently advanced so that we can rely on it to help order our priorities and allocate resources for environmental programs?"*

Not unexpectedly a variety of opinion was expressed ranging from unqualified 'yes' to unqualified 'no'. The variety in response is perhaps an answer in itself.

In general, however, environmentalists discussing the policy implications acknowledged that "risk analysis can't replace moral values", and there was an acceptance that there is a need to set priorities for action. Several commentators stressed the point that prevention is more important than risk reduction (the precautionary approach) and that prevention cannot be considered directly within the risk assessment framework. (As noted by Philip Miller, prevention can be a response to risk assessment and priority setting). There was also a concern that CRA approaches might lead to 'triage' for the environment. Triage may be appropriate at certain times, but it is not a responsible long-term management practice.

Nicholas Reding, Executive Vice President of Monsanto, summarised a number of responses when he stated that, given an ideal world, the answer to the first question should be 'yes'. However, within the real world the answer **must** be 'yes, but', hinging around the rewording of the second question - "do we really have the ability to scientifically assess relative risk?".

The scientists who dealt specifically with the question about the quality of the methodologies were also divided in their response and tended to shy away from their specific question and qualify it with the ethical question. It was clearly agreed that CRA cannot solve questions such as how much should be spent on the environment and with what priority. At best, the methodologies can provide informed guidance to decision makers.

Several scientists brought up the problem of defining the endpoints of the risk and the difficulties we have in defining end points for human risk (death, injuries?), let alone ecological end points. It was also repeatedly acknowledged that CRA is not a purely scientific approach and that if it is to be used effectively policy makers must clearly understand its limitations.

So let us consider some ground rules.

What is CRA?
According to the EPA it is "a framework for assessing environmental risk issues and highlighting important differences among them that can help us establish priorities and focus limited time and money where they are most needed". It is an analytical process involving a set of methodologies for assessing and ranking environmental risk.

What can CRA do?
Comparative risk assessment can provide a systematic approach and framework for assessing and comparing risks. The EPA approach focuses on the basic objectives of environmental agencies at different levels, describing these as: the reduction of risks to human health and ecological systems, and the 'beneficial' uses of environmental resources.

Because CRA takes a broad-based approach to assessing and comparing risks rather than focusing on specific problem areas or risks it can be used to provide information for medium and long-term strategic planning. It can provide rough comparisons across problem areas for different specified risks and hence can be used as an **aid** to decision-making processes. It can also help to inform the public and hence include the public in decision-making processes.

What can CRA not do?
Comparative risk assessment is not an answer to all environment problems. **It is not** risk assessment and, while it uses the principle of quantitative risk assessment, it is less value-free than other approaches and does not generate precise measures for the risks associated with environmental problems. Environmental risk assessment is particularly susceptible to problems of lack of appropriate data, uncertainty and incomplete methodology.

It **cannot** generate precise measures for comparisons between risk types and it **should not** be used as the sole basis for setting environmental priorities.

As stressed throughout the literature available, it is often the **process** of conducting the CRA that is as important as the results.

6.1 Comparative risk assessment and environmental risk management in New Zealand

In this section the use of CRA as a general strategic management tool is considered. It is discussed in the context of risk reduction and risk management.

It is seldom appropriate to adopt without modification a management approach or established and tested in a different environment. This is particularly true of areas such as environmental management that are closely intertwined with social structures and value systems.

The purpose of this section, therefore, is not to promote uncritically the use of CRA for environmental risk management, but to outline a general framework derived from the EPA experience which is appropriate to the application of CRA in New Zealand. Concentration is on the positive aspects of CRA and the benefits that might accrue from the use of such an approach. The limitations have already been stated clearly.

In Chapter 7 a limited case study of a New Zealand application is described and in Chapter 8 further recommendations are made about the process and its potential application. It must be remembered that although these comments are based on the experience of the USEPA and other US agencies they represent the value judgment, perceptions and interpretation **of one person.**

CRA and risk management - the process

The basic steps of CRA and risk management are to:

1. establish the specific objectives of the project,
2. determine a set of problem areas to be assessed,
3. determine a set of risks to analyse,
4. determine the stratification of the problem areas,
5. perform risk assessments for each risk type,
6. rank the problem areas in terms of risk,
7. rank the problem areas in terms of risk assessment and other risk management factors,
8. analyse and incorporate the options available for risk reduction, and
9. establish an action plan.

Steps 1 to 6 form the base of CRA and Steps 7 to 9 complete the risk management process.

Each of these steps requires amplification.

The specific objective of the particular application drives the whole risk management process; it affects the boundaries, the problem areas, the risk types, the data, the methodologies, the options and the action to be taken. Therefore, time must be taken to discuss the objective as broadly as possible and to state it carefully to avoid any misunderstanding. Any process where a number of different interest groups are involved must ensure that all groups understand and can reach consensus on the objective.

The process of determining problem areas and risk types is likely to be complex and iterative. It may be prudent to establish different sets of problem areas for each risk type to be considered. Many of the studies cited were restricted by different risk work groups that felt constrained by a set of problem areas which they felt were inappropriate to their area of expertise. Certainly there will be some problem areas that are not common to all risk types. Although it may appear desirable that the final results should reflect some consistency **between** the problem areas for the risk types, it may be better to forgo this to achieve consistency **within** risk types. United States experience suggests that the best way to determine problem areas is to involve a large number of experts and lay people with interests ranging over a broad perspective.

The selection of risk types must reflect social, institutional and cultural concerns. The United States studies have attempted to aggregate and reduce the number of risk types. This may not necessarily be appropriate. The range of risk types for New Zealand conditions includes cancer risk, non-cancer health risk, ecological risk (incorporating sustainability as an objective), quality of life risk (incorporating economic factors), and cultural risk.

There are several different ways of segregating problem areas - geographical area, media, source etc. If problem areas are stratified then care should be taken to ensure that the segregation is appropriate to the risk type and is administratively feasible.

The risk assessment step involves data collection and application of methodologies. Without full-scale investigation it is not possible to say whether the methodologies applied by the EPA and promoted in the **Roadmap** are appropriate to New Zealand conditions. However, the basic methodological principles are sound and would probably require only minor modification.

Ranking the problem areas is an extension of the risk assessment step and brings its own methodologies. It is important to remember that the rankings are guides only and that the categories into which the different problem areas are placed

should be limited to a number appropriate to the level of analysis. At this stage, also, the question of aggregating rankings must be considered. It is difficult to aggregate rankings if the problem areas are different for different risk types. Aggregation of rankings over risk types is not recommended.

Overall, risk management ranking is a tool for communicating with the wider public and helping to focus the eventual action plan on the highest risk management priorities.

State of the Environment reporting is good identifying and commenting on providing a context for the problem statements and initial risk management ranking, however, an action plan requires a separate report base. No risk management process is complete until an action plan has been established and implemented with its own complete framework for monitoring, evaluation and revision. The tools applied will depend upon the options selected for risk reduction. The most appropriate vehicle is some form of SER.

The participants

The objectives of a CRA-based environmental risk management project will determine the participants. However, some general rules apply. It is probably fair to say that as many people as are technically possible should be included. The basic requirements of CRA are for a general steering committee, a series of technical work groups responsible for the risk assessments, and some form of public advisory committee. Some overlap of function is possible and it may be appropriate to establish a separate group responsible for assessing and evaluating the risk reduction strategies available.

It is also beneficial to the credibility of the project and its practical success if the public at large can be consulted (obviously depending on the scope and resources of the project). This provides a means for the Public Advisory Committee to check results with their constituencies and hence gain greater confidence or caution on how to proceed.

The functions of the different groups need to be clearly delineated to avoid confusion over responsibility and accountability. Veto power may be given to one group or other.

Rankings

It is very unlikely that for any particular risk type the data available over all problem areas will be of similar quality. As a result, the process of ranking problem areas within a risk type must involve considerable subjectivity. Ordinal ranking is seldom appropriate. Ranking should be restricted to a maximum of five categories

(and preferably fewer), since any more than this implies an unrealistic expectation of accuracy.

The problem of determining the risk types to be studied also includes judgment as to whether some risk types are to be composites. For example, the original **Unfinished Business** report considered four types of risk: cancer risk, non-cancer human health risk, ecological risk and welfare risk. In subsequent studies cancer and non-cancer human health risks were aggregated and welfare and ecological risks were aggregated (this was one of the objectives of the **Relative risk** project). Technical work groups expressed concern at these aggregations because of the value judgments required. Methodological differences and difficulties and disparity between data quality and availability suggest that although aggregation may apparently aid planning processes it is better to avoid it.

In addition, the issue exists as to whether rankings over all risk types should be combined. For similar reasons to those described above this appears to be a bad practice for technical experts, however the decision may depend upon the specific objectives of the process and the willingness of the study group to make the necessary value judgments. Policy and budget processes will affect those types of decisions and it may be appropriate for Public Advisory Committees to provide guidance.

The assumptions

In the US studies a number of assumptions were made about the objectives of the CRA process that had implications for the general application of results.

These included the ranking of risk according to current levels of control. Although this was a practical tactic in that the data used reflected the current context, it meant that the final rankings tend to mask the effects of some severe environmental problems. This was pointed out in a number of the applications.

The difficulty in dealing with long-term effects is another complication. The original EPA process discounted future risk. It is now accepted that this is not an appropriate practise for dealing with environmental problems because of the intrinsic long time delays involved in ecosystem analysis and effect, and the importance placed by the public on the needs of future generations.

The implications of such limiting assumptions need to be studied alongside the objectives of the project to ensure that the objectives are not jeopardised by the assumptions.

Tools

The tools available for risk management and risk reduction are those available for general environmental management. They include regulation, economic incentives, standards, voluntary compliance and education and communication strategies. Each requires its own monitoring process. The choice of tool is often a political consideration.

Output

The output from a CRA risk reduction process is two-fold and should include both an assessment of the selected problem areas, and an action plan. The example provided by the Washington State is useful here. The output from the initial CRA project was an SER and an Action Plan. Follow-up to the action plan requires some form of monitoring to determe whether targets are being met. In the case of Washington State, the SER is planned as a continuing exercise and will include progress reports on implementation of recommended actions.

Risk assessment and risk management

The CRA approach to risk reduction is based on the concept of risk management. The EPA approach stresses the need to separate the process into two components involving a technical step of risk assessment and risk ranking (CRA), and a subsequent management step involving generating and evaluating options for risk reduction. The reason for this separation is given as being in order to give greater scientific credibility to the risk assessment process.

The emphasis on 'science' with the implication of objectivity is questionable. All scientific groups involved in the risk assessments indicated that because of lack of data, inconsistent methodologies and considerable general uncertainty the risk assessments themselves contained many value judgments and subjective elements. When environmentalists were asked to address the question "is the policy appropriate?" and scientists were asked to consider "is the science adequate?" both groups referred to the companion question. The science and the evaluation should not be separated. Similarly, the generation and evaluation of options must interact with the assessment and ranking process.

CRA in New Zealand

Should we be considering the use of CRA in New Zealand? In order to answer this question we need to be clear about our basic objectives for environmental management, whether the main emphasis in policy should be on risk reduction (risk management) or prevention. The two need not be mutually exclusive. A focus in

risk assessment and risk reduction can provide an information base for prevention. Actions derived from risk reduction objectives may involve prevention. We also need to consider whether, as a society, we believe that it is ethically appropriate to use risk criteria to set priorities for action on environmental problems.

These issues require value judgments which are beyond the scope of this publication and which could be resolved only after extensive public debate.

The framework outlined above describes the technical steps to be followed for CRA and emphasises some of the factors to be taken into account if such an approach is considered appropriate. Chapter 8 follows up with recommendations to explore more directly the concept of risk reduction as a tool for environmental management in New Zealand.

CHAPTER 7

Case study

This chapter proposes a case study based on the Ministry for the Environment's objectives and mission. It outlines the way in which the risk management approach to environmental protection might be used by the Ministry for the Environment (MfE) as part of its own internal strategic planning.

The purpose is to examine whether it is appropriate to apply CRA and risk reduction approaches developed by the USEPA for environmental management to the process of setting priorities for environmental research. The case study is presented as an outline that describes the required process for setting priorities using this basic approach and looks at functional requirements and structural linkages between the components of the process.

The presentation of this case study follows the framework described in Chapter 6.

Background

The role of the USEPA is primarily as a regulatory agency. Its mandate requires it to prepare, promote and monitor legislation directed towards protecting certain environmental features (not all encompassing). It undertook the risk reduction program as part of its legislative requirement to protect and enhance the environment. The EPA's role in the risk reduction program involved setting national objectives for environmental management/protection and establishing success measures. The EPA was not directly involved in the application of the risk reduction process.

The Ministry's role in environmental management is a little different to that of the EPA. The Mission of the Ministry is:

> *to ensure natural and physical resources are managed to sustain and enhance environmental quality and human well being.*

The original role of the Ministry required it to take an **objective** role towards the environment and to assist in enabling the viewpoints of all concerned sectors to be heard before public sector decisions involving the environment are made. This contrasted directly with the EPA which acts as an **advocate** for the environment, and in recent months the Ministry has itself adopted a more advocacy-oriented role.

The Ministry also has an important legislative function. Ministry **outputs** are direct **inputs** to law, policy and advice affecting the environment. The Ministry has responsibility for monitoring the impacts of these laws and policies. This is done by linking outputs to outcomes, which are measured in terms of their effect on the environment.

Although the EPA was not directly involved in the application of the risk reduction approach to environmental management, it has actively promoted and provided funding for a number of risk reduction projects within the United States. It has been consistently stressed that the risk assessment phase of the approach (CRA) is only one input into a larger social and political decision-making process. There is a danger, however, that the pseudo science 'respectability' given to the rankings of environmental problem areas may overwhelm some of the other important factors involved with the larger decision-making process. Philip Miller comments that this is not apparent yet and he believes is not likely to occur because too many other factors are very real and acknowledged.

The two main outputs from a relative risk project are some form of SER and an 'action plan' that must include targets that will be monitored. These are very similar to the products of any strategic planning exercise. An important aspect of the targets established to be monitored will be a time frame for this process.

The Washington State Department of Ecology, which has been a major player in the process of applying the relative risk reduction process to Washington State under the framework of Environment 2010, has linked its own medium-term strategic planning processes to the objectives and tasks of Environment 2010. The benefits of this include a consistent approach to environmental management and a sharing of mission and objectives that can be tested in the context of public opinion and awareness.

The Washington State Department of Ecology is taking an active role in promoting environmental awareness and providing leadership in the search for solutions to environmental problems. It is also an advocate for the environment.

The advocacy role does not mean that an agency is necessarily required to show bias towards the environment. Whether it does or not will probably depend on political factors. However, it means that there should be a tendency towards prevention and caution in the face of uncertainty. The extent of this tendency depends on the influence and legislative 'clout' of the agency.

The advocacy-oriented role of MfE does not directly affect the use of CRA for environmental management. The relative risk reduction framework can be used to address a number of different types of objectives. It is not necessarily limited to setting priorities for reducing environmental risk. However, equally it should not be used as the sole tool for setting environmental priorities because of the limiting assumptions that are required, and because the risk management framework does

not take sufficient account of uncertainty (inherent in environmental management) nor provide scope for consideration of creative preventative approaches.

There is still considerable concern within the US about whether the risk assessment methodologies available are sufficiently rigorous and robust to allow valid comparisons (and hence rankings), and also whether, given appropriate methodologies, it is morally valid to use these rankings as a basis for environmental protection.

This case study seeks to answer the question as to whether the relative risk reduction process could be used to **improve** the way in which MfE goes about its legislative role of providing Government with input to law, policy and advice.

Application

(1) The objective

> *The objective of this case study is to test the framework established for the application of relative risk reduction techniques as a tool for environmental management by applying it to MfE's work programme.*

The boundaries of the case study relate to the function and purpose of MfE and the components of its work programme, as stated in published environmental research agendas and corporate plans.

The specific information used for this case study has been derived from the following documents published by MfE.

1. Profile statement (1989),
2. Ministry for the Environment Corporate Plan 1989-90,
3. Ministry for the Environment Corporate Plan 1990-91,
4. Ministry for the Environment Corporate Plan 1991-92,
5. Environmental Research Agenda 1989-92 (January 1989), and
6. Environmental Research Agenda 1990 (January 1990).

One of the key features of the application of CRA and risk reduction is that a large number of people from different technical and social backgrounds are involved. When risk reduction criteria are used for internal analysis and strategic planning the involvement of a large group is less of a requirement. Even so, a core group of

agency staff should be involved in determining problem areas, applying risk assessments and analysing strategic options. This report makes some suggestions as to how this might be achieved.

The objectives of a relative risk reduction project may be set at a number of different levels such as an organisational or political level and at an operational level.

In New Zealand, the **organisational** objectives derive from the mission statement of MfE and the long title of the Environment Act. These elements provide the basis for setting long-term strategies for environmental management. The evaluative process for determining the success of these strategies requires the comparison of their effects against these organisational objectives.

The **operational** objectives of MfE are directly related to the MfE work programme. They derive from the organisational objectives, but usually have a different time frame. The operational objectives are used to set priorities for short- and medium-term environmental management.

Operational objectives are also directly influenced by political inputs, client group inputs and the public at large. The priorities set for the organisational and operational objectives must be translated into action. The effects of these actions are measured as effects on the environment that are compared with the relevant objectives. Figure 7.1 describes the relationships between operational and organisational objectives of the inputs and outputs to the process.

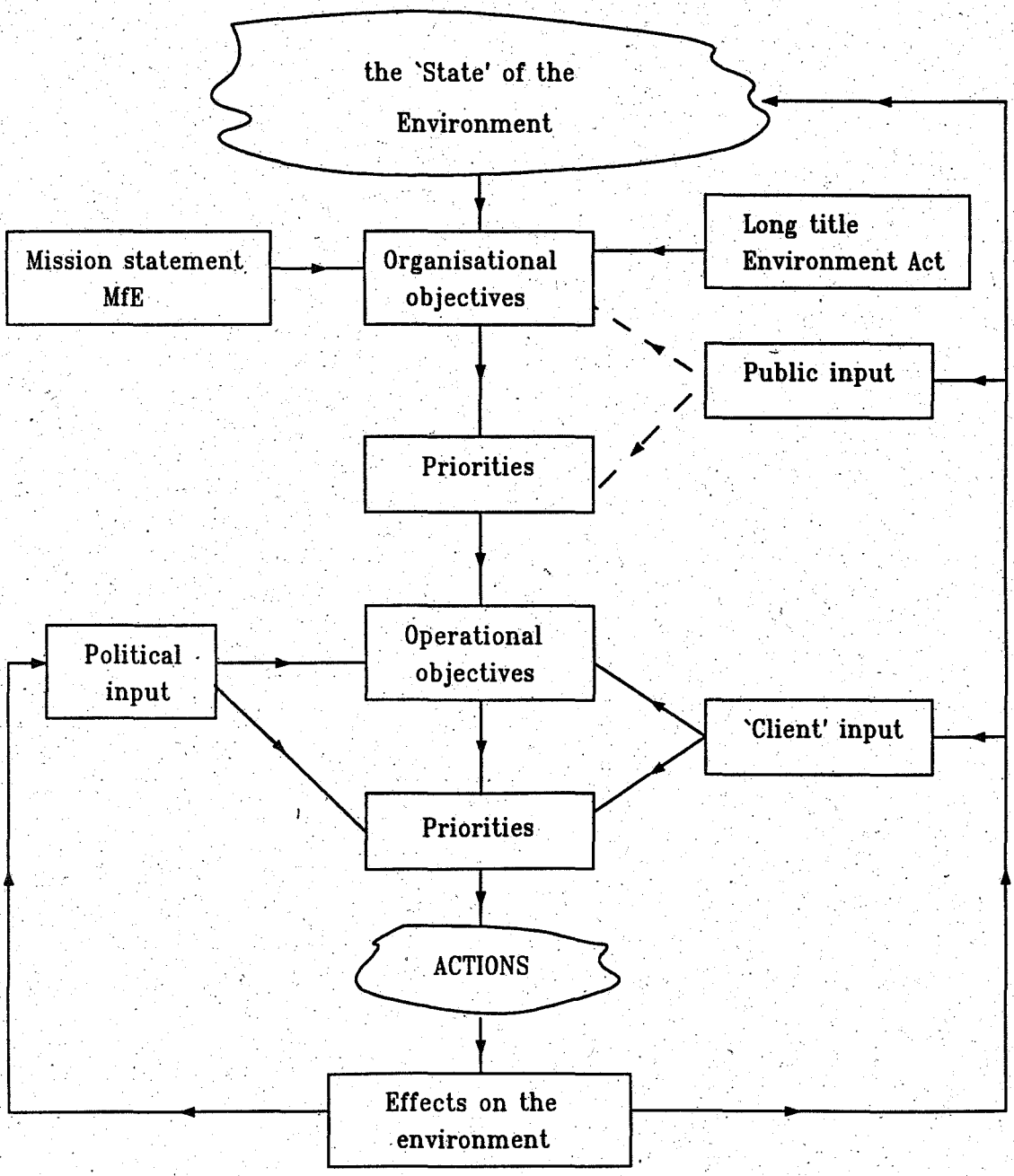

Figure 7.1 Operational and organisational objectives.

Linkages and policy implications

Relative risk reduction as pioneered by the EPA has been primarily directed towards operational objectives, however, the Washington State Department of Ecology is currently linking its internal organisational objectives and planning to the broader operational perspective. This does not imply a separate process - internal strategic management is linked directly to the external public process through goals, objectives and success measures (i.e. outcomes).

> **Recommendation**
>
> **MfE should explore the process of establishing organisational and operational goals as part of the process of promoting the relative risk reduction concept as a tool for environmental management.**

(2) Problem areas

Problem areas should ideally cover as broad a base as possible. For this case study a series of problem areas have been extracted from the MfE corporate plans and research agendas. They cover a broad range of topics at global, national and regional levels. They include areas of public concern derived from surveys conducted by the Ministry. However, the list is far from complete and contains some overlap.

Sample problem areas include:

PCBs in the environment,
lead in petrol,
anti-fouling paint,
food irradiation,
sewage treatment,
wastewater treatment,
soil erosion,
hazardous substances control,
nuclear impacts,
waste management - toxic wastes,
waste management - non toxic wastes,
wahi tapu (sacred sites),
deforestation,
loss of biological diversity,
control of pests,
impacts of mining,
loss of wetlands,
ozone depletion, global warming,

marine pollution (coasts and oceans),
air pollution,
noise pollution,
water pollution (inland waterways), and
agricultural pollution (medium waterways).

One of the difficulties in creating a list of this nature relates to problem areas that are not discrete in their effects on the environment. For example, the impacts of mining will involve wastewater treatment, toxic and non toxic wastes as well as possibly wahi tapu and deforestation. Soil erosion and deforestation are directly interlinked in effect.

It should be noted also that the problem areas listed here are very broad and are likely to cause problems for data collection for risk assessment.

In general, groups with experience in the different risk types selected (see below) should evaluate the problem list and work together to rationalise the list. Even so, there will be items on the final problem list that will not be relevant to all risk types.

Linkages and policy implications

The selection of environmental policy areas has organisational and operational implications. Problem areas derive from the organisational objectives and goals established to support these objectives. These problem areas and the priorities established for them will drive the operational activities of the agency or organisation.

> **Recommendation**
>
> **As wide a group as possible should establish problem areas that cover the fullest possible spectrum of current and potential environmental problems. This group should include agency staff and members of client groups and the public at large. The list should be regularly revised and updated as part of the ongoing monitoring process.**

(3) Risk types

Risk types are the criteria used to evaluate environmental problem areas and provide the basis for setting priorities for action. Therefore, they should reflect social and cultural aspects of environmental management (since as a society we choose our own risks).

For the purposes of this project risk types are derived from the mission statement of MfE and the objectives of the Environment Act. The Environment Act defines environment as including not only the natural elements, but people, their communities and their cultural beliefs (and includes consideration of future generations).

Therefore, the risk types selected are:

1. human health risk,

2. ecological risk, and

3. social risk.

This latter category must take account of economic effects, cultural values, and social and community values. This analysis is similar to the 'quality of life' analysis attempted for Vermont. Considerable difficulty in reconciling these areas into a single ranking for social risk is foreseen.

Linkages and policy implications

It must be stressed continually that the process of relative risk reduction views risk-based priorities as one input into the environmental decision-making process. The advantage of using risk criteria so commonly touted (by policy makers) is that it offers an objective science-based approach to setting priorities. People involved in particular projects, however, are at pains to stress the judgmental basis of the apparently objective risk assessment phase. Leaving this aside, one way of incorporating 'other' factors (such as voluntariness, equity etc.) into the risk comparison process is by assessing 'quality of life' aspects of risk. There are, however, considerable difficulties due to the lack of 'hard' data and the problems of effectively aggregating several different types of risk. Operational and organisational criteria are identical in this context. Political influence may well determine the final choice of risk types to be considered.

Recommendation

Environmental problem areas and risk types cannot be effectively established independently of each other. Initial examination of the problem areas from the perspective of the selected risk types (maybe getting the technical work groups to provide input) is likely to result in improved definition of problem areas in turn allowing for greater consistency within the risk-type rankings.

(4) Stratification

The mission and objectives of MfE and the Environment Act do not provide direct guidance for the stratification of the problem areas.

There are several possible approaches that could be taken. One might be to group problem areas according to the groupings of the Resource Management Act, for example, issues pertaining to water, coastal areas, air, hazardous installations, soil conservation and global issues. There is, however, no obvious advantage to this.

One reason for stratifying problem areas is to establish aggregate rankings over all risk types within these broad groups. This may be appropriate for short-term decision making, but it is not appropriate for long-term decision making.

Therefore, without greater consultation with MfE it is difficult to recommend stratification of problem areas or to determine MfE preferences.

Linkages and policy implications

Stratification of problem areas can be used as a way of addressing operational goals in the short term.

> **Recommendation**
>
> **Problem areas should be kept discrete except for data collection and aggregation purposes.**

(5) Risk assessment

The risk assessment phase of the relative risk reduction process must be undertaken in a systematic disciplined manner. It involves considerable human resources in the form of technical working groups. The risk assessment requires the identification of all possible outcomes (effects), the collection of data, and some form of (relative) quantification.

The first stage of the risk assessment process following the relative risk reduction approach requires the collection of data for a base SER. This is also the first step in the process of establishing an environmental policy. Much of the data are likely to be available from secondary sources, however, the task of data collection, synthesis and presentation is likely to be very time consuming. Data deficiencies (quality and quantity) must be tagged for subsequent evaluation.

Risk assessment will be the same for both operational and organisational objectives.

Linkages and policy implications

The basis of the relative risk reduction process is the risk assessment process. Although substantial professional judgment may be required in terms of assessing the risks and estimating the associated uncertainties, the process cannot be short cut. It must be undertaken by professionals who are experienced in assessing the specific risks being examined.

Recommendation

The use of the relative risk reduction approach to assess operational objectives requires access to risk assessment information for all of the identified environmental problem areas. Therefore, MfE should investigate the availability of data for all problem areas identified within its jurisdiction.

(6) Risk ranking

The technical work groups or professionals responsible for risk assessment within each of the risk types should also be responsible for the initial ranking of the selected problem areas. This is intuitively obvious, because these groups will have the best understanding about relative quality of data, uncertainty, and knowledge about effects.

Linkages and policy implications

Comparative risk ranking between risk types requires access to transparently prepared risk assessments. These will have been undertaken by the work group members who will hence be in a position to make appropriate judgments on the validity and quality of the assessments.

(7) Management ranking

Either a general steering committee or a public advisory group should then establish and re-evaluate the risk rankings established by the technical work groups. Additional criteria may then be taken into account. For the purposes of internal strategic planning, the Research Advisory Group of MfE would be an appropriate body to undertake this review.

Linkages and policy implications

The ranking process undertaken by the steering committee or public advisory groups will incorporate additional criteria to the initial ranking. Ranking for operational objectives may differ from ranking for organisational objectives.

> **Recommendation**
>
> **Criteria to be taken into account by the secondary ranking process should be established as part of the process of specifying the project objectives.**

(8) Analyse and incorporate options for risk reduction

The process of analysing options for risk reduction has only been touched upon in this report. There are a number of value judgments that need to be made. The question of aggregating rankings for different risk types may need to be addressed here too. This may require giving weights to different risks.

Linkages and policy implications

The value judgments made in connection with organisational objectives may be different to those required for operational objectives. However, the common basis for those objectives requires some consistency in the process.

> **Recommendation**
>
> **Public and client input should be incorporated into the process of determining options for risk reduction.**

(9) Create an action plan including targets for evaluation

An action plan directed towards either environmental management (organisational objectives) or strategic research priorities (operational objectives) requires establishing priorities, setting targets to be achieved, and determining an approach towards meeting those targets. Monitoring strategies will also be required.

Linkages and policy implications

The two outputs from a relative risk reduction project must be an SER and an action plan. The action plan should contain specific targets associated with environmental indicators that can be used to measure the state of the environment and the degree of success of the action plan. Environmental monitoring is a key element of the relative risk reduction process.

> **Recommendation**
>
> **Care should be taken to establish links between targets for organisational and operational goals so as to avoid unnecessary duplication of effort. State of the environment reporting should be used to monitor both approaches.**

Conclusion

The relative risk reduction approach to environmental management can be linked to an agency's approach to its own internal strategic planning as a means of evaluating operational goals and objectives.

However, the relative risk reduction process cannot be used to evaluate operational goals independently of a major planning process, because the basic requirements of the relative risk reduction approach are independent of the application.

If risk criteria are applied to the setting of strategic (operational) priorities in the way described without recourse to a larger (organisational-based) activity the **objectivity** of the scientific approach may be lost.

Thus, for credibility, the application of the relative risk reduction approach to the achievement of internal operational goals requires that close links be established between the two with an overall risk reduction process directed towards organisational goals. As well, the following points must be noted:

1. the organisational and operational goals must be consistent,

2. the time frame adopted for the strategic management analysis must be consistent with, and able to be directly linked to, organisational goals and objectives,

3. a common basis for the two levels of goals must be the establishment of a comprehensive SER from which two levels of action plan (organisational and operational) can be developed, and

4. relative risk reduction is only one of the available tools for environmental risk management. It requires the use of many value judgments.

In the case of MfE, the direct application of the relative risk reduction technique to internal strategic planning will require personal commitment on the part of staff, and considerable interaction between different groups within the Ministry.

CHAPTER 8

Conclusions and recommendations

The objective of this publication was to:

> "examine the use of risk reduction techniques as a tool for environmental protection, to develop an appropriate framework for New Zealand conditions and to test this framework by applying it to MfE's work programme".

As stated earlier, the main task was the collection and review of some of the immense amount of literature produced by the USEPA environmental relative risk reduction projects that have been undertaken over the past five years.

Another source of information and advice was Mr Philip Miller of the Washington State Department of Ecology. Mr Miller discussed some of the practical problems involved in implementing one of these projects, and supplied additional literature including a draft copy of the USEPA **Roadmap** document.

From this material it was possible to establish a clear picture of the aims of CRA and its role in the process of risk reduction, and its strengths and weaknesses.

The operational objective of the project has been stated above. However, the project had a larger purpose or goal - to explore in more detail the context of the 'science-based' methodology developed by the USEPA to determine its applicability to environmental management in a broader sense. The results of this overview are presented here.

These results draw on the approach being taken by the Washington State Department of Ecology, which is currently linking its own strategic planning processes into its ongoing risk reduction programme entitled Environment 2010. The SER component of the risk reduction programme is being used to evaluate progress made towards achieving the internal goals and objectives of the Department.

8.1 Comparative risk assessment as an environmental management and policy-making tool

Comparative risk assessment is one component of the risk management process known in the US as 'relative risk reduction'. It involves assessing and ranking environmental problems according to a specified set of risk types. This ranking is

then used as an input to the process of setting priorities for action for environmental protection and enhancement.

Comparative risk assessment is a conceptual framework for assessing **environmental risk issues**, and ranking environmental problems within selected risk types. It can be used as part of an overall priority-setting process.

It has two components: an analytical science-based risk assessment component, and an evaluative ranking process based on professional judgment.

- CRA **is not** a purely scientific (objective) process,
- CRA **can** provide a systematic approach for assessing and comparing risk,
- CRA **cannot** provide definitive answers to all environmental problems, and
- CRA results **should not** be used as the sole criterion to set priorities for action on environmental problems.

Comparative risk assessment is a useful tool yielding further information about the spectrum of environmental risk issues and it provides a context for the comparison of environmental problem areas within risk types. It has been used successfully by the EPA to analyse and assess environmental problems for current levels of control at national, regional, state and local (city) levels.

It is appropriate to use CRA to prioritise broad groups or categories of environmental problems within different risk types. That is, to put problems into 'buckets'. However, it is **not appropriate** to use CRA to rank environmental problems ordinally, or to aggregate rankings for risk types with quite different characteristics that have been assessed by different methodologies.

It is **not appropriate** to use CRA in a 'cook-book' approach to environmental management.

The specific context for this publication is to assess the use of risk reduction techniques as a tool for policy making and environmental protection.

As many scientists and environmentalists have pointed out, the **best** approach to environmental protection is prevention. Prevention cannot be considered directly within the context of CRA or the risk reduction approach, but CRA **can** be used to help focus preventative strategies.

Risk criteria can provide a tool for setting priorities for action for environmental protection including prevention. In this sense the relative risk reduction approach must be viewed as one way of looking at the process of environmental management. There is a danger that tunnel vision or a lack of lateral thinking may channel

environmental managers into using only one tool. If this tool is inadequate or inappropriate for the particular purpose then harm to the environment may result. Therefore, managers and policy makers must be aware of alternative approaches to setting priorities and the need to establish their own environmental management objectives before selecting a particular approach. The full set of criteria selected will be directly related to the objectives of the specific problem.

Comparative risk assessment is particularly useful in that it is not definitive; it is an approach rather than a method. Hence it allows for considerable latitude in approach and application, as shown by the different regional projects that have been undertaken in the US. Different applications require different scales of effort. However, used wisely and in the correct context the outputs from this process can provide scientifically valid input to environmental decision-making processes.

The use of CRA to study subsets of environmental problems has not been analysed in this publication. However, if the context of the decision-making process is open, then CRA can be applied to properly bounded subsets of problems or issues. The criteria used to establish the subset then become part of the decision criteria.

8.2 Issues associated with the application of comparative risk assessment

Comparative risk assessment is not a static, one-shot technique. As acknowledged by the commitment made by Washington State to regular production and publication of SERs, it must be an ongoing, regularly updated process. The resources required to undertake such studies are considerable. Decisions about commitment to the process must therefore include careful consideration of the required and available resources.

A number of issues need to be taken into account when considering the use of CRA and risk reduction techniques that derive from the US experience.

Relative risk reduction processes require ongoing support and the commitment of substantial resources. Therefore, it is crucial to have:

- strong political support for the process,
- public and 'client' support,
- agency commitment to the process, and
- an ability to action the results.

Although relative risk reduction, and in particular CRA, is described as a 'science-based approach' all reports on applications have noted the importance of professional judgment, particularly in the ranking processes. This is not a contradiction, rather it is a recognition that science is not a purely quantitative

'game'. Good science involves professionals using their experience to assess and evaluate information and to make decisions based on that experience.

The methodologies developed in the US for CRA are a significant advance on what has been previously available. Although there is very little that is 'new', the emphasis has been on improving the consistency of the methodologies and on examining data sources to determine where effort should be directed. There has also been an explicit recognition of uncertainty.

The CRA approach can involve considerable interaction with the public and a greater acceptance of the need for public involvement in environmental decision making. The MfE is aware of the need to consult with both specific 'client' groups and the public at large. This consultation process provides a structured mechanism for the Ministry to incorporate both scientific knowledge and public perceptions into action leading to strategies for environmental management.

The output from CRA and the relative risk reduction approach is thus input to environmental decision-making processes.

Outcomes are measured in terms of their effects on the environment, resulting from actions taken. To effectively implement and monitor these outcomes the process of risk assessment must be understood by decision makers, managers and the public at large.

The **benefits** of CRA and relative risk reduction derive as much from the application of a consistent and repeatable process as from the results themselves.

The direct results are:

1. greater understanding of environmental processes,

2. a consistent, scientifically-based framework for the comparison of different environmental problems,

3. a mechanism for incorporating public opinion into environmental decision-making processes,

4. a way of analysing differences between expert opinion/prediction and public perception of environmental problems,

5. a way of measuring the success of actions taken for environmental protection, and

6. a catalyst for focusing political and public opinion.

8.3 Recommendations to the Ministry for the Environment

Recommendation 1

That MfE should consider carefully where the CRA approach could be used for its own internal decision making.

Recommendation 2

That MfE should promote the use of CRA and the risk reduction process either nationally or regionally in New Zealand in conjunction with its environmental policy programme to determine data requirements and availability, and to explore further its potential as an environmental management tool.

Recommendation 3

That relative risk reduction strategies be used to aid the process of prioritising within groups or subsets of environmental issues to determine where the use of standards might be appropriate.

Recommendation 4

That the framework of CRA be used to help identify areas of potential concern where preventative techniques may be appropriate.

Recommendation 5

That lateral thinking be employed to determine where risk assessment and risk management techniques can be used for other purposes in enhancing and protecting the environment.

Recommendation 6

That CRA be linked to the concept of an environmental policy statement similarly based on the production of regular SERs and the establishment of consistent environmental monitoring techniques.

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