REPORT ON JOINT ANSTO/CSIRO SEMINAR

ON

ECOLOGICAL RISK ASSESSMENT

R F Cameron

August 1996

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ECOLOGY; ENVIRONMENTAL EXPOSURE PATHWAY; RISK ASSESSMENT; ANSTO; AUSTRALIAN ORGANIZATIONS; COASTAL WATERS; COST-BENEFIT ANALYSIS; DOSE-RESPONSE RELATIONSHIPS; INTERAGENCY COOPERATION; MATHEMATICAL MODELS; MEETINGS; PUBLIC INFORMATION; REPORTING REQUIREMENTS; SEWAGE; URANIUM MINES; WATER POLLUTION

SUMMARY

A joint ANSTO/CSIRO seminar was held at Lucas Heights on 10-11th April 1996. Its aim was to describe the current state of research and assessment capabilities within the scientific research organisations, to identify the gaps in these capabilities and to determine the opportunities for collaborative research. The seminar took the form of invited presentations outlining the work of each agency, together with case studies which presented an application of the ecological risk assessment process.

The seminar provided a timely opportunity for discussion of scientific capabilities and collaboration in ecological risk assessment. The issue is currently being debated within the organisations represented and within the community. The contributions of the speakers were of a high standard and evoked significant discussion of a wide range of issues. All participants expressed a desire to continue the exchange of information and discussion of ongoing work.

There was positive and enthusiastic support for the need to develop better mechanisms for collaborating in research and in establishing co-ordination of activities in this area.

The agreed conclusions of the seminar were :

1. There is an urgent need to develop a national framework for ecological risk management and protocols for undertaking the various assessment stages within this framework..
2. An ecological database should be made a high priority by all the agencies.
3. A national communication network should be established as soon as possible to allow information exchange and co-ordination of activities. Tom Beer undertook to see if the CSIRO network system could be made available to a wider range of agencies. In the medium to longer term, there was considered to be great value in establishing a national co-ordination centre for ecological risk, which would be separately but jointly funded by the agencies and industry.
4. In the short term, a list of capabilities among the agencies should be established. This should also indicate contact people for the various topics.
5. A National Case Study was considered to be important in giving focus to the development of methods and in allowing collaboration on a well-defined project.
6. A Task Group was proposed to progress these issues and the various recommendations of the working groups.
7. Support should be sought from senior management in the various agencies for furthering the collaboration.

1. INTRODUCTION

A joint CSIRO/ANSTO seminar on Ecological Risk Assessment was held at the Lucas Heights Science and Technology Centre from 10-11th April 1996. The aims of the seminar were to describe the current state of research and assessment capabilities within the scientific research organisations, to identify the gaps in these capabilities and to determine the opportunities for collaborative research. The seminar program is attached as Appendix 1.

The seminar was attended by representatives from the Australian Nuclear Science and Technology Organisation (ANSTO), the Commonwealth Scientific Industrial Research Organisation (CSIRO), the Australian Institute of Marine Science (AIMS), the Environmental Research Institute of the Supervising Scientist (ERISS), the NSW Environment Protection Agency (EPA) and the Commonwealth Environmental Protection Agency (EPA). A list of attendees with their contact addresses is attached as Appendix 2.

The seminar was opened by Professor Garnett, Executive Director of ANSTO, who gave the background to the seminar and encouraged the participants to look for areas of collaboration in scientific research and in exchange of information.

2. FORMAT OF THE SEMINAR

The application of ecological risk assessment is rapidly expanding and is being increasingly used in decision-making at all levels of government. This reflects both an increasing understanding of the processes and a growing awareness of the importance of environmental protection. A number of frameworks have been proposed for performing the assessment, but these generally involve the steps of :

- hazard identification and characterisation
- environmental pathway analysis
- exposure/effects assessment
- determination of dose-response relationships
- risk characterisation, comparison and management.

The focus of the seminar was on determining the extent of current effort in the various areas and identifying where there are gaps and, therefore, opportunities to initiate new work.

The format involved plenary sessions and working groups. In the plenary sessions presentations were given of the current work within the various agencies and case studies were presented outlining particular applications of ecological risk assessment. In the working groups discussions concerned current capabilities in particular techniques, identification of gaps and setting of priorities for future collaboration.

The findings of the working groups were presented in a plenary session on day 2. Discussion on these findings resulted in a number of conclusions which were agreed by the meeting.

2.1 Presentations on current activities within ANSTO, CSIRO, ERISS and AIMS.

The opening talks provided an opportunity for each of the four science agencies, ANSTO, CSIRO, AIMS and ERISS to present the status of ecological risk assessment research within their agencies. The notes or papers which accompanied these talks are attached as Appendix 4.

These overview talks were presented by :

Dr Tom Beer, CSIRO
Dr W Zuk/Dr R Cameron, ANSTO
Dr T Done, AIMS
Dr M Finlayson, ERISS.

The range of applications of ecological impact assessment is very wide, including many aspects of wildlife ecology, fisheries, wetland management, coastal protection, impacts from mining activities and climate change. Additionally, it is clear that a wide array of capabilities exist within the agencies on topics which are central to ecological risk. However, none of the agencies routinely applies the full range of the ecological risk assessment process and each tends to focus on parts which are most immediate to their areas of interest. Representatives from CSIRO also pointed out that teams are often assembled for particular projects and then move on to other issues, without the opportunity to generalise their approaches.

In reviewing the activities, the presenters outlined some of the difficulties in applying ecological risk assessment. Dr Tom Beer discussed some joint work between CSIRO and the EPA and the need for agreed terminologies in risk assessment, since they vary from country to country. Dr Beer highlighted some capabilities requiring development. These were computer modelling, system analysis (particularly scenario development), technical skills to quantify hazards and analyse uncertainties and risk cost-benefit analysis. Dr Ron Cameron discussed the difficulties in determining the acceptability of ecological risk, because of the multiple endpoints and the lack of clear views on how to compare ecological risk with other risks. This is particularly important with accidental releases, where the likelihood of the release might be very low but the consequence could be high. Dr Max Finlayson raised the issue of the applicability of US data on ecological effects to Australian conditions and considered that this should be discussed by the working groups. Dr Terry Done suggested that an ecological risk assessment approach could have various applications in the marine area, such as in the risk of dislodging corals during cyclones.

3 CASE STUDIES ON APPLICATIONS OF ECOLOGICAL RISK

As illustrations of some of the current work in ecological risk assessment and the difficulties in applying the process to specific sites, case studies were presented by a number of participants.

The presentations in the plenary sessions on the two days were :

1. Environmental Risk Assessment In Sydney Water - Therese Manning, NSW EPA
2. Ecological Risk Assessment In The Finniss River - Dr R Jeffree, ANSTO

3. Communicating Risk Assessment Concepts to Decision Makers - Dr G Symes, CSIRO
4. CSIRO - Case Studies in Resource Management, Climate Change and Wildlife & Ecology by Tony Smith, Tom Beer and Steve Cork.
5. Using Risk Assessment In Environmental Management In City Rail - Howard Witt

The notes or papers supplied by the various speakers are attached as Appendix 4.

Ms Therese Manning, NSW EPA described the risk assessment done by Sydney Water on sewage treatment plant outfalls. The presentation focused on how risk was evaluated for aquatic life. A screening level assessment was done first with conservative assumptions on dilution to determine which pollutants would require detailed assessment. Both short-term acute exposure and chronic exposures were considered. Water quality guidelines were used as the effects values and the risk was quantified using a hazard quotient approach. If HQ > 1 the chemical was included in the detailed risk assessment. Due to time restrictions the hazard quotient approach was also used for the detailed risk quantification. The effects values, based on the water quality guidelines, are based on overseas data and so the question of how protection they are for Australian ecosystems was an unresolved issue.

Dr Ross Jeffree discussed the ANSTO work in the Finniss River, which had been heavily contaminated as a result of acid mine drainage from the former U/Cu mine at Rum Jungle. Following remediation, the contaminant loadings have dropped by an order of magnitude, but are still appreciable. The system was now recovering and the knowledge of the source, transport and effects of the heavy metals was providing important information for the ecological risk assessment process. It was suggested that, because of the large amount of data available on water quality, the Finniss River system could provide an excellent tropical site for determination of dose-response relations.

Dr Geoff Symes of the Australian Research Centre for Water in Society (ARCWIS) discussed the importance of involving a wide cross-section of people in arriving at judgements on acceptability of risk. He also emphasised the biases that are often attached to existing processes for communication, which have broken down trust between the public and technical groups. The public seek accountability from organisations and industry. In the area of ecological risk, he pointed out the lack of study of public perceptions and the preliminary nature of any attempts to characterise these perceptions.

Dr Tony Smith, Dr Steve Cork and Dr Tom Beer discussed several applications of ecological risk within CSIRO. In fisheries management, strategies are devised which assess the consequences of a range of management options and present the results in a way that makes the trade-offs obvious. This is a form of risk-benefit analysis. Uncertainties in models, in frameworks and in objectives are a difficult issue in many of the problems tackled by CSIRO. In harvest strategies for gemfish, a Bayesian assessment is used to give distributions of possible states of fish and Monte Carlo simulations are used to predict future harvests under a range of strategies. Global climate change studies also use ecological risk assessments in predicting the effects of climate change on wildlife and ecology. This requires both tactical and strategic risk assessment. Strategic risk integrates science, policy and economics. In Wildlife and Ecology, assessments are undertaken of biodiversity in native forests. This requires predictions of the security and stability of forest areas via mapping of expected plant distributions.

Howard Witt, ANSTO presented some work done for City Rail on developing a system for evaluating ecological risk and assessing how best to spend money to reduce risk. This was based on a risk ranking approach for postulated accident scenarios, which have been assessed in terms of their likelihood and consequences. The method is presented as a computer database and allows the effect of different mitigation measures to be incorporated and the risk re-assessed. Although such an approach involves a number of 'expert' judgements, it has merit in being systematic and transparent with regard to assumptions. The framework could be combined with detailed assessments if such information were available.

4. WORKING GROUPS

Three working groups were formed to cover the stages in ecological risk assessment outlined in section 2. The three groups were :

- Environmental Pathways And Exposure Assessment, chaired by Dr Ross Jeffree and Dr Max Finlayson (days 1 and 2, respectively).
- Ecological Effects Assessment, chaired by Dr John Chapman and Dr Terry Done (days 1 and 2, respectively)
- Risk Characterisation, Comparison And Management, chaired by Dr Ron Cameron and Dr Tom Beer (days 1 and 2, respectively).

The groups met on three occasions to discuss existing capabilities in each of the agencies represented, the gaps in capabilities to perform the appropriate stage of ecological risk assessment and the proposed way forward through research and collaboration.

Some attempt was made by each of the groups to draw up a list of capabilities within each organisation. This proved difficult for the CSIRO participants because they were not aware of all the activities being undertaken, but a revised version was send in later and is presented at the end of Appendix 3. The capabilities which were known are summarised in tabular format for groups 2 and 3 and as a list for group 1. These are attached as Appendix 3. It was felt important by the seminar participants that more effort should be put into generating a list of capabilities across the agencies with specified points of contact for particular areas. This would encourage collaboration as well as allowing information to be exchanged.

4.1 Working Group 1 - Environmental Pathways And Exposure Assessment

In Working Group 1, the capabilities were subdivided into hazards, transport and fate processes and exposure of receptors. The participants were from ANSTO, CSIRO, AGSO, ERISS and NSW EPA. Appendix 3 provides some details of the areas covered by the agencies and the type of research undertaken. There was general agreement that, at a generic level, there was a capability to perform all aspects of ecological risk assessment. However, the requirements of particular projects would identify specific gaps in either knowledge or expertise.

The group identified a number of gaps both in data, in modelling and in co-ordination of funding for research. The key issues were :

- the need to improve the databases available for assessments
- the need to validate models over different time scales

- the lack of co-ordination of effort to bring together appropriate teams for particular projects
- the lack of standardisation on protocols for QA, assessment, sampling, monitoring, validation of models, reporting etc.
- the need to identify funding sources for any co-operative research.

The group discussed the possibility of choosing a small number of projects which could form the basis for development of methodologies in a collaborative way. Nominations were Rum Jungle (mining, radioisotopes, heavy meals), Ocean outfalls (heavy metals, pathogens, organics, nutrients, urban pollution, coastal zone, corals, riverine outflows), Climate change (very diffuse) and Impact of exotic species (pesticides, biodiversity, release of bioengineered species).

In looking to further collaboration and development, the Group proposed a number of key issues to be tackled.

a) Establishing mechanisms which will enable the agencies to work together, both in research and in commercial consultancy.
b) Industry and government departments need to be made aware of the benefits of a risk assessment capability, in terms of improved decision making and more adequate use of resources and money.
c) A directory of expertise would be helpful and identification of the major areas to which current expertise can be applied.
d) Science gaps need to be identified within the context of major projects.
e) Support will be needed from CEOs if any collaboration is to be successful.

Suggestions for improving the interface between interested groups and making progress on the scientific issues were :

1. Setting up an Inter-agency Ecological Risk Network, to allow exchange of information, a bulletin board for queries and notification of events.
2. Establishing a national database for ecological risk assessment.
3. Establishment of an Inter-agency Ecological Risk Coordination centre, jointly funded by the science agencies and other industry sources.
4. Identification of major projects to provide a test of the methodologies.
5. A small task group to flesh-out and progress these proposals.

These latter points were taken up in discussion in the report back session on day 2.

4.2 Working Group 2 - Ecological Effects Assessment

Group 2 discussed capabilities in determining the effects of pollutants on the ecology, including the determination of dose-response relationships for Australian species in Australian conditions. These capabilities were written up as a table for each agency and are included in Appendix 3.

The group suggested 4 measures of Ecological "Performance", which could be used in assessment of impacts and ecological value.

- Recovery time - eg coral age sea abundance;
- Uniqueness of ecosystem;
- Trophic structure/function eg fisheries;
- Endangered species (IUCN red list).

In discussion of the scientific gaps, the following issues were noted :

a. Lack of Australian ecotoxicological and ecological data eg tropical (aquatic and terrestrial) systems, baseline data, predator-prey relationships.
b. Application of risk assessment techniques in Australia
   - limited use and access to ecological models;
   - limited use of appropriate ecological settings
c. Lack of understanding of mechanisms/processes that underlie ecotoxicological and ecological impacts
   - lack of appropriate ecological theories for the Australian context (e.g. disturbance equilibrium differs from the classic textbook succession model for vegetation)
   - limited predictive capabilities and poor understanding of basic ecotoxicological and ecological response.
d. Knowledge of the risk of population extinctions and their long-term viability
e. What is the acceptable level of detriment to an ecosystem (i.e. what proportion of decline is acceptable for a given species).

Some more specific issues within the above frameworks were :

i. Lack of agreed standards for impact on ecosystems eg key ecology processes; key stone species.
ii. Determining between the statistical versus the biological significance of detriment to an ecosystem.
iii. The need for a standardised approach to determine toxicological endpoints (i.e. choice of NOECs or LC_{50} etc.)
iv. How to manage risk with inadequate or missing information.
v. Choice of methods to extrapolate toxicity data to practical guideline values.
vi. Ecological processes/mechanisms.
vii. Compounding of Uncertainty v's Precautionary Principles.
viii. Probabilistic evaluation of effects.

In the third session on setting priorities for future work, the main areas identified were :

1. The need to develop mechanisms for communicating between specialists in risk assessment.
2. Better integration of ecological and ecotoxicological data to address risk assessment issues. The obvious gaps were in power analysis, and chronic versus acute effects.
3. Improved ecotox/ecology data for :
   - terrestrial;
   - sediments;
   - tropical;
   - estuaries;
   - stochastic models.

4. Broader scope of RA - not just chemicals.
5. Use of risk assessment in conservation planning.
6. Improved mechanistic understanding of environmental stress/response/driving forces.

The key gaps were considered to be in knowledge of extinction risk/viability of populations and community indices to arrive at acceptable risk.

4.3 Working Group 3 - Risk Characterisation, Comparison And Management

The third working group only contained participants from ANSTO, CSIRO and THE EPA. The group sub-divided the area into :

- risk characterisation (routine releases, accidental releases and contaminated sites)
- risk quantification (analysis of uncertainties, probabilistic methods)
- risk acceptability - decision making
- risk benefit analysis
- risk communication.

ANSTO has much experience in risk assessment, firstly from nuclear safety and secondly from non-nuclear consultancy over many years. Their involvement in ecological risk assessment was more recent, but was growing. They had recently compiled a framework for ecological risk assessment for accidental releases from operation of hazardous industry, which was being recommended by State agencies. They had not been involved extensively in applying risk assessment to contaminated sites or routine releases. Some work has been done in risk assessment applied to environmental management, in terms of risk-benefit analysis. ANSTO has an ongoing interest in risk communication and, through its work in the Northern Territory in risk communication of ecological risks.

CSIRO have been involved in various areas where risk characterisation was required e.g. in pesticides and in pollutant flow via groundwater. There were a number of groups within CSIRO looking at quantification of risk e.g. from climate change. Most of this expertise resided in Maths/Stats and Biometrics divisions. Geoff Symes of ARCWIS and John Thomas of Eng&Eco&Sociology were very involved in risk communication and acceptability.

EPA mentioned the need for training of regulators in risk assessment and its value in the decision making process.

The group identified a number of gaps in capabilities :

1. Lack of background of decision makers to be able to use ERA numbers in making management decisions.
2. Lack of integration/co-ordination between people in appropriate disciplines.
3. Lack of appreciation of ERA at the policy level within organisations.
4. Skills not well enough hounded eg not enough economists.
5. Lack of knowledge of public perception of risk and how the public rates risk.
6. Lack of agreed criteria for assessing environmental risk in terms of value of an ecosystem.
7. Lack of ability to define generally accepted end points for ecological impacts (of human deaths, dam failure etc).

8. Lack of integration/communication between scientists and sociologists.
9. Need for scientists to provide leadership in community debate.
10. Need for nationally consistent approach.

There was strong agreement that scientists must be more involved with advising decision-makers and in the decision-making process more generally. The results of the risk assessment cannot be divorced from community values and expectations.

Summary Of Needs In Risk Characterisation, Comparison And Management

Technical

- Lack of general criteria for assessing environmental risk in terms of value of an ecosystem.
- Need to be able to define generally accepted end points for ecological impact.
- Need to develop agreed technical methods for ecological risk management.

Educational

- Decision makers lack background to be able to use environment risk assessment numbers in making management decisions.
- Lack of appreciation of environment risk assessment at the policy level within organisations.

Coordination

- Need for a nationally consistent approach.
- Need for integration/coordination between people in all appropriate disciplines (scientists, sociologists, economist).

5. SUMMARY AND CONCLUSIONS

The seminar provided a timely opportunity for discussion of scientific capabilities and collaboration in ecological risk assessment. The contributions of the speakers were of a high standard and evoked significant discussion of a wide range of issues. All participants expressed a desire to continue the exchange of information and discussion of ongoing work.

There was positive and enthusiastic support for the need to develop better mechanisms for collaborating in research and in establishing co-ordination of activities in this area.

The conclusions of the seminar were agreed by all to be :

1. There is an urgent need to develop a national framework for ecological risk management and protocols for undertaking the various assessment stages within this framework..
2. An ecological database should be made a high priority by all the agencies.
3. A national communication network should be established as soon as possible to allow information exchange and co-ordination of activities. Tom Beer undertook to see if the CSIRO network system could be made available to a wider range of agencies. In the

medium to longer term, there was considered to be great value in establishing a national co-ordination centre for ecological risk, which would be separately but jointly funded by the agencies and industry.

4. In the short term, a list of capabilities among the agencies should be established. This should also indicate contact people for the various topics.
5. A National Case Study was considered to be important in giving focus to the development of methods and in allowing collaboration on a well-defined project. Various suggestions for this project were mentioned in the report of Working Group 1.
6. A Task Group should be set up to progress these issues and the various recommendations of the working groups. Ross Jeffree undertook to draft a short paper on these issues.
7. Support should be sought from senior management in the various agencies for furthering the collaboration.

APPENDIX 1 - SEMINAR PROGRAM

A Joint ANSTO/CSIRO Seminar on

ECOLOGICAL RISK ASSESSMENT BRIDGING THE SCIENTIFIC GAPS

DAY 1

1. Introduction and purpose of the seminar
   Prof H Garnett, Executive Director, ANSTO (15 minutes)

2. Ecological risk assessment activities in :
   CSIRO - Dr Tom Beer (30 minutes)
   ANSTO - Dr W Zuk/Dr R Cameron, ANSTO (30 minutes)

3. Morning coffee (10.15 - 10.45 am)

4. Ecological risk assessment activities in :
   AIMS - Dr T Done (30 minutes)
   ERISS - Dr M Finlayson (30 minutes)

5. Discussion on presentations

6. Case Study 1
   Environmental risk assessment in Sydney Water - Therese Manning, NSW EPA

7. Lunch (12.30 -1.45 pm)

8. Case Study 2
   Ecological risk assessment in the Finniss River - Dr R Jeffree, ANSTO

9. Outline of working group aims (15 mins)

10. WORKING GROUP SESSIONS A - ESTABLISHING CURRENT CAPABILITIES (2.30 -3.30 pm)

Group 1	Environmental pathways and exposure assessment Chair : Dr R Jeffree, ANSTO
Group 2	Ecological effects assessment Chair : Dr J Chapman, NSW EPA
Group 3	Risk characterisation, comparison and management Chair : Dr R Cameron, ANSTO

11. Coffee (3.30 - 4.00 pm)

12. WORKING GROUP SESSIONS B - IDENTIFYING THE GAPS
(4.00 - 5.00 pm)

SEMINAR PROGRAM
DAY 2

1. Introductory remarks Dr R Cameron, ANSTO (9.00 - 9.15am).

2. Communicating Risk Assessment Concepts to Decision Makers - Dr G Symes, CSIRO (9.15-9.45am)

3. Case Studies 3 and 4 (9.45 - 10.25am)
CSIRO - Case Study - tba
Using risk assessment in environmental management in City Rail - Howard Witt, ANSTO

3. Morning coffee (10.25 - 10.45am)

4. WORKING GROUP SESSIONS C - ESTABLISHING PRIORITIES (10.45 - 12.30 pm)

Group 1	Environmental pathways and exposure assessment Chair : Dr M Finlayson, ERISS
Group 2	Ecological effects assessment Chair : Dr T Done, AIMS
Group 3	Risk characterisation, comparison and management Chair : Dr Tom Beer. CSIRO

5. Lunch (12.30 - 1.45pm)

6. PLENARY SESSION - WORKING GROUP REPORTS (1.45 - 3.30 pm)
Chair : Dr Graham Harris
Groups 1 - 3
General discussion on opportunities

7. Coffee (3.30 - 3.45pm)

8. FUTURE DIRECTIONS AND SUMMARY OF SEMINAR
Chair : Dr W Zuk
Speakers : CSIRO, ANSTO, AIMS. ERISS, EPA

Overall Purpose of Working Groups

The introductory presentations will provide overviews of organisational activities related to ecological risk assessment. The objectives of the Working Groups will be to dig deeper into the operational capabilities in order to identify the scope for collaboration, the gaps in capabilities and determine the priorities for further research.

WORKING GROUP 1 - ENVIRONMENTAL PATHWAYS AND EXPOSURE ASSESSMENT

Aim : The objectives of the Working Group will be gain more detailed information on the operational capabilities available in environmental pathway analysis and exposure assessment. To identify the interests and capabilities of the organisations represented, the gaps in collective capabilities and those areas that are regarded as pivotal to the further development of robust ERA capabilities in Australia.

Scope : The identification of interests, capabilities, research programs, methodologies etc. that are relevant to the definition and quantification of :

- pollution sources
- pollution transport and fate, and :
- exposure of receptors to pollutants.

Format : A representative from each organisation will be asked to provide a concise technical summary of their collective activities in this area. The presentations should also present an assessment of gaps in the current capabilities for performing ecological assessments and identify the areas where most important uncertainties and inadequacies exist. A capability v organisation matrix will be developed, along with a list of issues to be followed up.

Background material

(a) Suter, G W II (1993). Ecological Risk Assessment. Lewis.
(b) Bartell, SM, Gardner, R H and O'Neill, R V Ecological Risk Estimation, Lewis, 1992

WORKING GROUP 2 - ECOLOGICAL EFFECTS ASSESSMENT

Aim : To determine the current capabilities for assessing ecological responses. To consider the relevance of the current processes to Australian conditions and to identify where and how appropriate databases should be developed.

Scope : To review the current capabilities in determining the relationships between the magnitude of the applied stress and the response of exposed organisms, populations and ecosystems. Appropriateness of existing literature, laboratory and field work. To consider current trends in endpoint selection, toxicity data selection and extrapolation, dose-response determination and characterisation of effects. To suggest areas for further development and identify opportunities for collaborative work.

Format : Each participant should be prepared to present the interests of their organisation in this topic and to outline what they see as areas for improvement, collaboration or further work. A short report will be prepared for presentation to the main meeting. A capability v organisation matrix should be developed, along with a list of issues requiring further development, collaboration or research.

Background material :

(a) USEPA(1992) Framework for Ecological Risk Assessment, EPA/630/R-92/001
(b) Gorsuch, J W, Dwyer, F J, Ingersoll, G I and La Point, T W (eds) Environmental Toxicology and Risk Assessment, ASTM, 1993
(c) J Cairns, B Niederlehner and D Orvos (eds). Predicting Ecosystem Risk, Princeton, 1992.

WORKING GROUP 3 - RISK CHARACTERISATION, COMPARISON AND MANAGEMENT

Aim : To identify the opportunities for determining measures of risk to ecological systems, to decide how such information can be used in risk communication and decision making and to determine what work should be done within the research organisations in this area.

Scope : Review of the current capabilities within the organisations in risk estimation, comparison and management. Consideration of parameters for quantifying risk and risk-benefit analysis. Should risks and benefits be costed. Understanding the nature of the calculated risk and the associated uncertainties. How can such information be integrated with value judgements and risk perception. What place has risk in decision making or in regulatory processes. Risk communication.

Format : A speaker will be asked to present topics for consideration or particular applications which could raise topics for discussion. Each participant should be prepared to present the interests of their organisation in this topic and to outline what they see as areas for improvement, collaboration or further work. A short report will be prepared for presentation to the main meeting. A capability v organisation matrix should be developed, along with a list of issues.

Background material : Risk characterisation is now an established part of many risk assessment methodologies. The US EPA methodology is perhaps the primary example of this in ecological risk procedures but guideline documents from the European countries may also be useful. Some references are given below.

(a) USEPA(1992) Framework for Ecological Risk Assessment, EPA/630/R-92/001
(b) A Guide to Risk Assessment and Risk Management for Environmental Protection, UK Dept of the Environment, HMSO, 1995.
(c) J Cairns, B Niederlehner and D Orvos (eds) Predicting Ecosystem Risk, Princeton, 1992.
(d) Royal Society, Risk - analysis, perception and management, London, 1992.

Appendix 2 - Names and Contact Details for Participants.

NAME	POSITION	ORGANISATION	ADDRESS	TELEPHONE	FACSIMILE	EMAIL ADDRESS
AIREY Peter	Environment Division	ANSTO	Private Mail Bag 1 MENAI NSW 2234	(02) 717 3272	(02) 717 9260	pla@ansto.gov.au
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BATLEY Graeme	Centre for Advanced Analytical Chemistry	CSIRO	Private Mail Bag 7 MENAI NSW 2234	(02) 710 6830	(02) 710 6837	graeme.batley@syd.dcet o.au
BEER Dr Tom	Division of Atmospheric Research	CSIRO	Private Bag No 1 ASPENDALE VIC 3195	(03) 9239 4546	(03) 9239 4444	tom.beer@dar.csiro.au
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BUTLER Dr Edward	Division of Oceanography	CSIRO	GPO Box 1538 HOBART TAS 7000	(002) 32 5276	(002) 32 5123	ed.butler@ml.csiro.au
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JEFFREE Ross	Counsellor (Nuclear)	Nuclear Branch Australian High Commission	Australia House The Strand LONDON WC2B 4LA ENGLAND		(0011) 44 171 873 9026	raj@anst.gov.au
JOHNSTON Arthur	Director	Environment Research Institute of the Supervising Scientist	Locked Bag 2 JABIRU NT 5796	(089) 79 9700	(089) 79 2499	arthurj@eriss.erin.gov.au
KEARNS Allen	Division of Wildlife and Ecology	CSIRO	PO Box 84 LYNEHAM ACT 2602	(06) 242 1600	(06) 241 3343	allen.kearns@dwe.csiro.
MANNING Therese		Environmental Protection Authority	Locked Bag 1502 BANKSTOWN NSW 2200	(02) 795 5370	(02) 795 5004	manning.therese@epa.ns ov.au
MARKEY Dr Bruce	Senior Risk Specilaist Contaminated Sites	Environment Protection Authority	PO Box 1135 CHATSWOOD NSW 2057	(02) 325 5723	(02) 325 5788	markey.bruce@epa.nsw. au
MARKICH Scott	Environment Division	ANSTO	Private Mail Bag 1 MENAI NSW 2234	(02) 717 3137	(02) 717 9260	sjm@ansto.gov.au

PETERSON Sharon	Centre for Advanced Analytical Chemistry	CSIRO	Private Mail Bag 7 MENAI NSW 2234	(02) 710 6807	(02) 710 6837	s.peterson@syd.dcet.csii
SIMPSON Colin	Chief Environmental Geoscience & Groundwater	Australian Geological Survey Organisation	GPO Box 378 CANBERRA ACT 2601	(06) 249 9368	(06) 249 9970	csimpson@agso.gov.au
SMITH Dr Tony	Senior Research Scientist	CSIRO	Marine Laboratories Castray Esplanade HOBART TAS 7000	(002) 32 5482	(002) 32 5199	tony.smith@ml.csiro.au
STAUBER Jenny	Centre for Advanced Analytical Chemistry	CSIRO	Private Mail Bag 7 MENAI NSW 2234	(02) 710 6808	(02) 710 6837	j.stauber@syd.dcet.csiro
SYME Dr Geoff	Australian Research Centre for Water in Society	CSIRO	PO Private Bag WEMBLEY WA 6014	(09) 387 0141	(09) 383 7193	geoff@per.dwr.csiro.au
TWINING John	Environment Division	ANSTO	Private Mail Bag 1 MENAI NSW 2234	(02) 717 3060	(02) 717 9260	jrt@ansto.gov.au
VAUGHAN Gary	Centre for Advanced Analytical Chemistry	CSIRO	Private Mail Bag 7 MENAI NSW 2234	(02) 710 6832	(02) 710 6837	gary.vaughan@syd.dcet. o.au
WITT Howard	Safety and Reliability Centre	ANSTO	Private Mail Bag 1 MENAI NSW 2234	(02) 717 3490	(02) 717 9264	hhw@ansto.gov.au
ZIOLKOWSKI Frank		Office of Supervising Scientist	2nd Floor, Tourism Hse 40 Blackall Street BARTON ACT 2600	(06) 274 1655	(06) 273 5019	fziolkow@mgdestmx01. gov.au
ZUK Dr Wally	Director, Environment Division	ANSTO	Private Mail Bag 1 MENAI NSW 2234	(02) 717 3241	(02) 717 9260	wmz@ansto.gov.au

Appendix 3 - Capabilities from Working Groups

Working Group 1

CAPABILITIES

Note : AIMS was not represented in the group. NSW EPA capabilities expressed by Graeme Batley CSIRO.

	ANSTO	CSIRO	NSW EPA	ERISS	AGSO
HAZARD SOURCES	Heavy metals from U fuel cycle - mine, reactor, repository Other radioactive materials Erosion / deposition Airborne particulates -	Pesticides Nutrients Pollutants Atmospheric releases Salinization Chemicals Ballast water Marine pests Logging'Grazing Fragmentation Nutrient addition Minesites	Have a position as regulators in the control of emissions	U tailings Erosion studies Introduced pests - weeds, toads Herbicides (early days) Salt intrusion	Non-mining sources of metals Soils (esp acid sulphate) Natural hazards (seismic (macro & micro), flooding, tsunami, volcanic)
SOURCE OF HAZARD	Accidental Contaminated sites	All	Routine, contaminated sites	Routine Accidental	Routine Accidental

TRANSPORT & FATE

ANSTO	CSIRO	NSW EPA	ERISS	AGSO
Geochemical modelling - Physical dispersion - - Marine - Atmospheric, - Erosion & deposition (137Cs, 210Pb)	Geochemical (non-nuclear) Physical dispersion Atmospheric, natural & agricultural processes Marine, esturaine & freshwater Sediment water interface, resuspension, colloids Biology chemistry interface, bioaccumulation nutrients, HM etc Modelling - physical processes, climate change,	Paper study capability	U tailings fate & dispersal Water borne particulates Wetlands processes - natural & artificial Radiochemistry - air, water & biota Climate change & sealevel effects Bioaccumulation & foodchain modelling	Groundwater characterisation and contamination assessment Marine chemistry (incl. real time monitoring eg oilrig formation water) Sediment geochemistry

EXPOSURE OF RECEPTORS

ANSTO	CSIRO	NSW EPA	ERISS	AGSO
Radio-ecology Eco-toxicology - impacts of U mining, bio-monitors, bio-indicators	Eco-toxicology - fish, algae, bacteria Vertebrate studies Human exposures	Aquatic eco-toxicology Airborne studies (eg BHP)	HM, radionuclides & herbicides Stream bio-monitoring - species D & A Water quality assessment and guideline setting Radiological studies - bioaccumulation, critical group assessments	Modelling capability Advice on mitigation of hazards

***ECOLOGICAL* EFFECTS**

	ANSTO	**CSIRO**	**AIMS**	**ERISS**	**NSW EPA**
End point selection	Field/Lab Metals Radionuclide Bioaccum	Aquat Terrest Chems/effl Forest/range Climate change	Coral reefs Mangroves Seagrass Pelagic	Aquatic enviro	Aquat Terrestrial Sediments
Dose-response relationships - toxicity data - extrapolation methods	LC50/EC50 Factors Stat Distrib Models	LC50/EC50 Responses on ecosystem modelling`	Corals - light & sed Fish - asymmetry Algae Models (transition matrix)	Lowest NOEC Factors	LC50/EC50 NOEC/LOEC Probability dit
Characterisation of effects	Community structure	Biodiversity indices Comm Structure - forests Ecol - economics Landscape - social/econ Disease incidence Influence diagrams	Community structure Biodiversity Seascape structure	Field evaluation In-Situ Community Structure	Community structure In-Situ Air modelling

SUMMARY OF CSIRO CAPABILITIES

HAZARD IDENTIFICATION/RISK CHARACTERISATION

Hazard	Medium	Division/department
Pesticides	Waterways	Division of Water Resources Centre of Environmental Mechanics
Nutrients	Port Philip Bay	INRE Project Office
Pollutants	Jarrosite Dumping	Fisheries
Atmospheric releases	Vehicles and stacks	DCET Atmospheric Research
Salinization	Effects on soils/trees	Division of Soils
Chemicals	Environment	DCET(at LH) DWR
Ballast water		Fisheries
Marine Pests		

ACCIDENTAL RELEASES

Release type	Division/department
HC in waterways	DWR
Diseases/pests	W&E
Dam failure	DWR

ECOSYSTEM MODELS - IMPACTS ON LANDSCAPES

Impact	Division/department
Logging	W&E
Grazing	W&E
Fragmentation	W&E
Nutrient addition	W&E
Minesites	W&E

RESTORATION ECOLOGY

Health risks to humans and wildlife from diseases - patterns of spread	W&E

RISK QUANTIFICATION

Issue	Division/Department
	INRE Biometric Unit
Impacts of climate change on wildlife	Climate Change Research Program

MDP on Management of marine Living resources	Fisheries and Oceanography
Population viability analysis	W&E
Regional identification of plant/animal communities at risk	W&E

RISK ACCEPTABILITY - decision making

Alternate wastewater disposal	DWR
Decision support system for assisting stakeholders to negotiate outcomes where economic benefits and other land use objectives compete with ecological risk	W&E

RISK BENEFIT ANALYSIS

Tradeoffs of exploitation and conservation	Fisheries / W&E
Resource economics	DWE
Water quality/economics tradeoffs	DWR

RISK COMMUNICATION

General	ACWIS, Geoff Syme
Resource Futures program	W&E

Appendix 4 - Summaries of Presentations and Case Studies given by Agencies

Presentations by :
CSIRO - Tom Beer
ANSTO - Wally Zuk/Ron Cameron
ERISS - Max Finlayson
AIMS - Terry Done

Case Studies by :
Therese Manning, NSW EPA
Ross Jeffree - ANSTO
Tony Smith/Tom Beer - CSIRO.
Geoff Symes - ARCWIS
Howard Witt - ANSTO

Science Adviser

Risk assessment review of national environment priorities

EPA

Environment Protection Agency

Approach

- Literature Review
- Consultation
  - Australian Practice
  - International Best Practice
- Case Studies in areas of current concern
- Produce generic framework

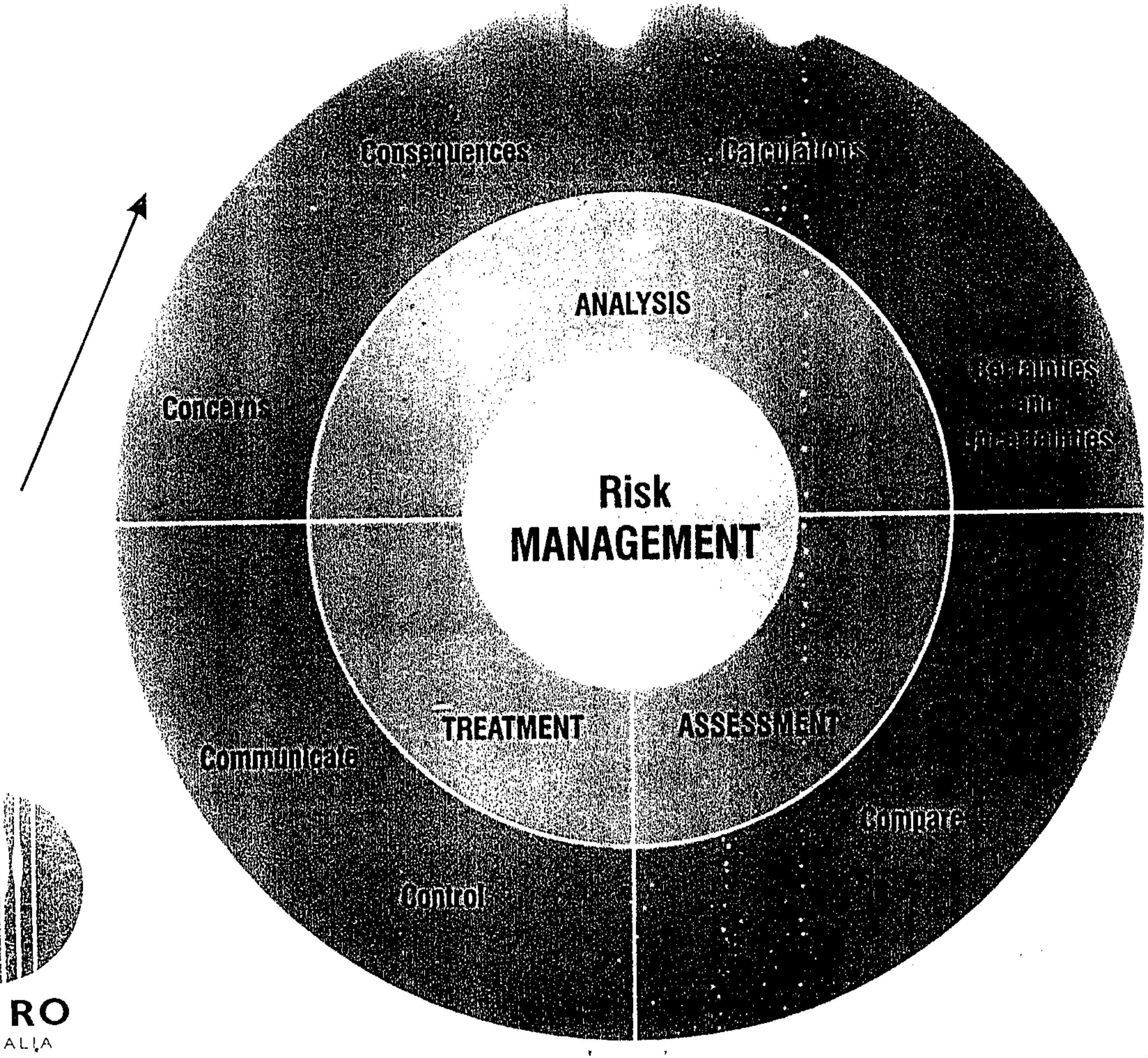
Environment Protection Agency

Risk during a given Time
(of the scenarios under consideration)

=

{Consequences} U {Probabilities}

Environment Protection Agency



CSIRO
AUSTRALIA

Examples of the application of the generic framework

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

Risk Assessment

Ecological risk assessment

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

EXAMPLE
ECOLOGICAL RISK ASSESSMENT
METHODOLOGY

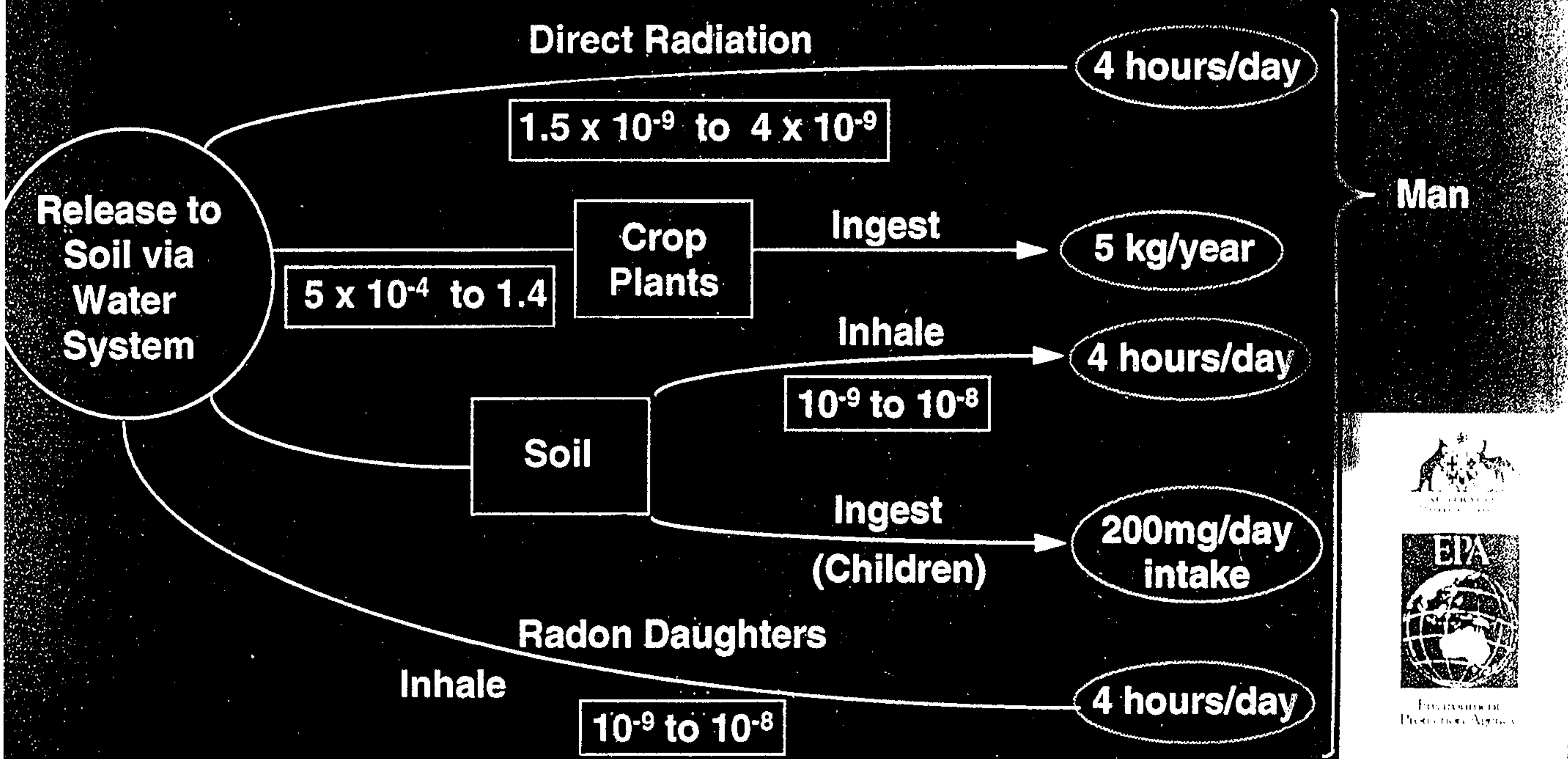
Taken from pages 69 – 74

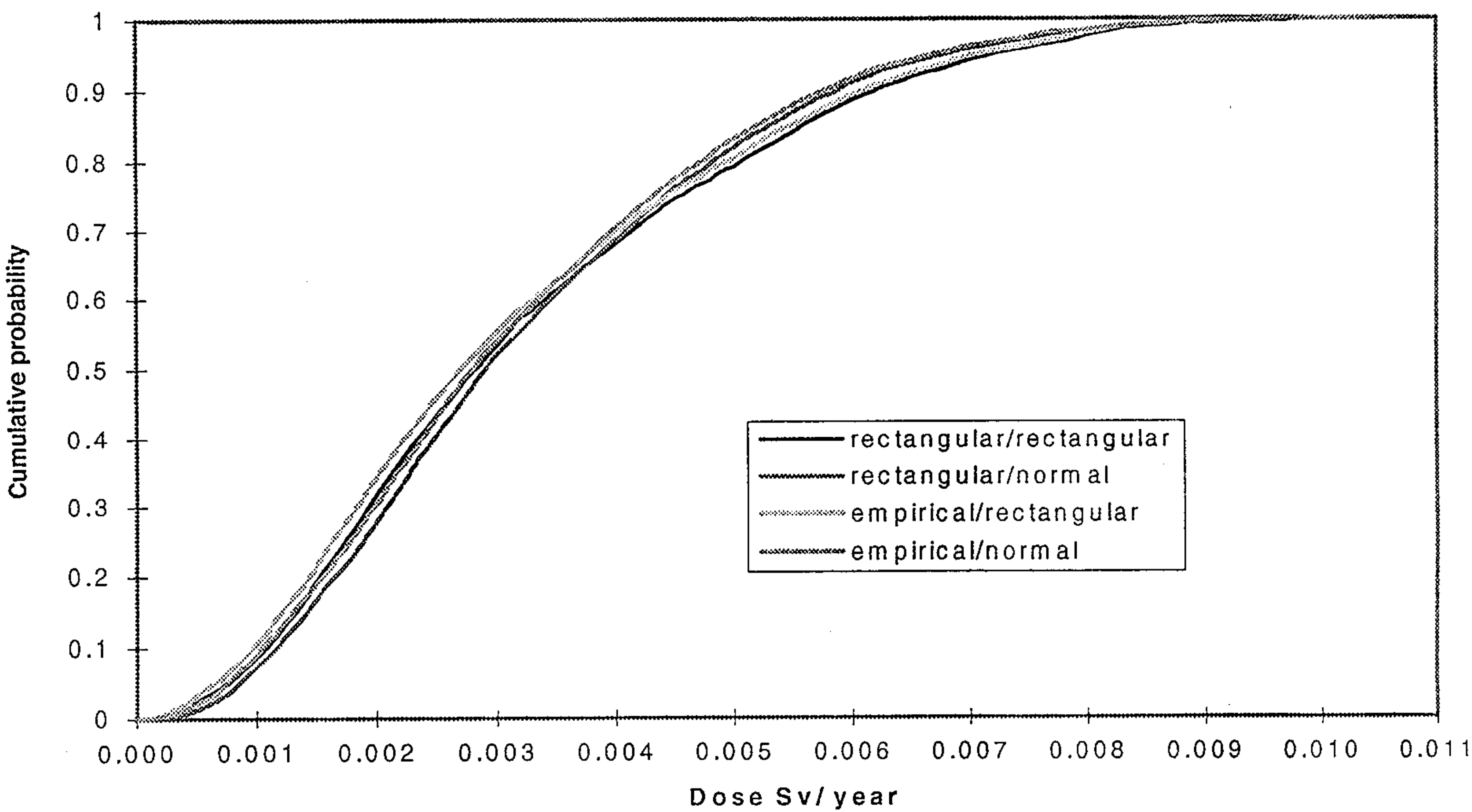
T. BEER & F. ZIOLKOWSKI
ENVIROMENTAL RISK ASSESSMENT
AN AUSTRALIAN PERSPECTIVE

Report # 102, Supervising Scientist

Uncertainty Analysis

TOTAL = Σ PARAMETERS x ACTIVITY x CONSTANTS





Cumulative probability
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
0.010
0.011
Dose Sv/ year
rectangular/rectangular
rectangular/normal
empirical/rectangular
empirical/normal

CSIRO

Commonwealth

Scientific

Industrial

Research

Organisation

Division of Atmospheric Research
A Division of the Institute of Natural Resources and Environment

107 -121 Station Street, Aspendale, Vic 3195, Australia
Postal Address: PMB1 Aspendale, Vic 3195 Australia
Telephone: 61 3 9239 4400 Facsimile: 61 3 9239 4444
Email:chief@dar.csiro.au
Chief of Division: Dr Graeme Pearman

CSIRO
AUSTRALIA

PROGRAMME
CSIRO ENVIRONMENTAL RISK NETWORK MEETING
29 MARCH 1996, CSIRO ASPENDALE

0900-0915 Background to CERN - the CSIRO Environmental Risk Network
0915-0945 CSIRO Risk and Audit Office - Mike O'Loughlin
0945-1015 CSIRO New Structures - Brian Sawford

Morning tea

15 minute presentations

1045-1100 CEM - Peter Coppin
1100-1115 Fisheries - Tony Smith
1115-1130 INRE Biometrics Unit - Ray Correll
1130-1145 Exploration & Mining - Cliff Mallett
1145-1200 DCET - Bronwyn Duffy
1200-1215 ARCWIS - Geoff Syme
1215-1230 Entomology - Waterford/Pratt

Lunch

1330-1345 AAHL - Gordon Abraham
1345-1400 CCRP - Barrie Pittock
1400-1415 Soils - Elisabeth Bui/Christopher Moran
1415-1430 Wool Technology (Leather Research) - Katherine Money

1430-1530 Discussion

1. CSIRO interaction - Form and activities for CERN.
2. Australian interaction - ANSTO meeting on Ecological Risk Assessment 10/11 April
3. International interaction - Millenium project

Programme as at 28 March, 1996

CSIRO Environmental Risk Network

- Wildlife and Ecology
  - Minimise risk of extinction
  - Assess risks to flora and fauna
  - Risk of diseases (GMO)

  - Environmental Futures Project

CSIRO Environmental Risk Network

- Fisheries
  - Risks associated with Jarrosite Dumping
  - Fish management strategy evaluation

CSIRO Environmental Risk Network

- INRE Biometrics Unit
  - Fire risks
  - Risk to aquifers from pesticides
  - Risk of root diseases in nurseries

CSIRO Environmental Risk Network

- Environmental Mechanics
  - Process studies at small scale
    Pesticides pathways
    Air flow through chicken sheds
    Dust in coal mines

CSIRO Environmental Risk Network

- Atmospheric Research
  - Fate of Waste Emissions
- Climate Change Research Program
  - Impacts of climate change extreme events, vulnerabilities

Risk from chemicals and contaminated sites

- Computer models
- Field trials
- Laboratory investigations

All need to be integrated

Insufficient Australian use of computer models.

Risk Assessment Implementation Requisite Capabilities

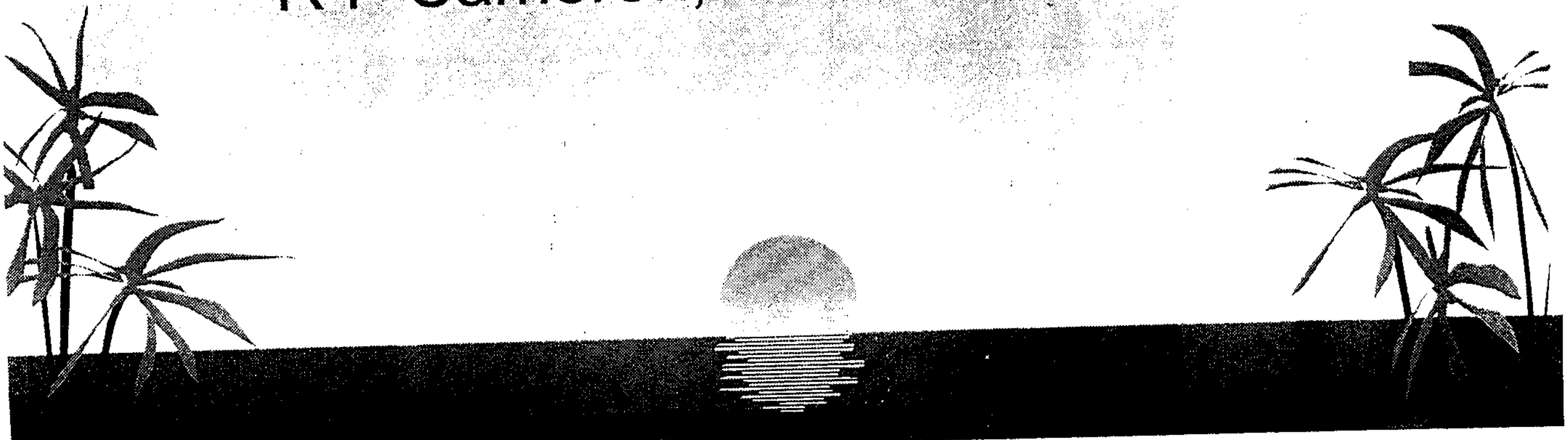
- Systems Analysis
(Scenario Development)
- Technical Skills (Quantify Hazards)
- Statistical/Computing Knowledge
(Uncertainty Analysis)
- Risk–Cost–Benefit Analysis

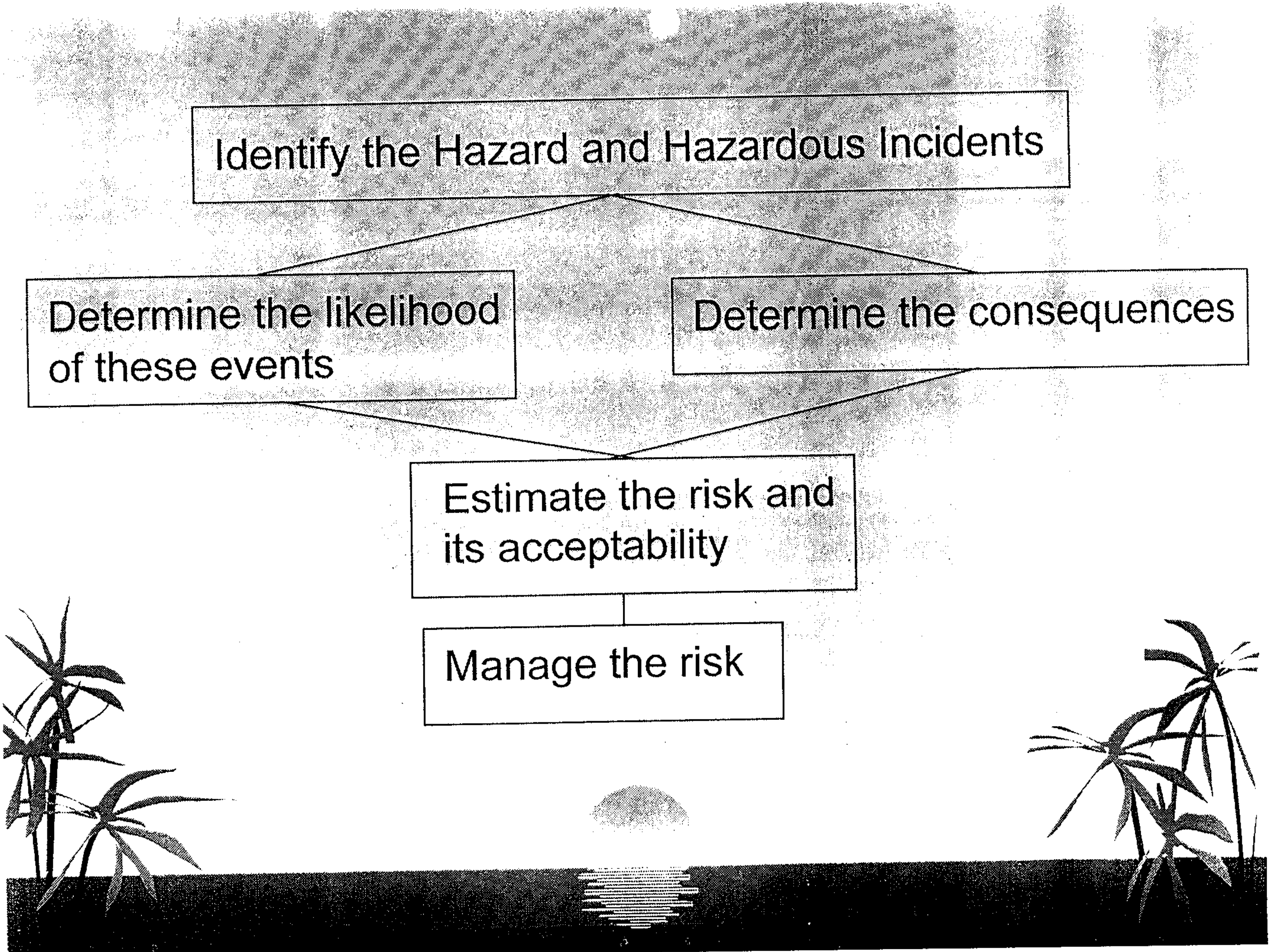
Environmental Protection Agency

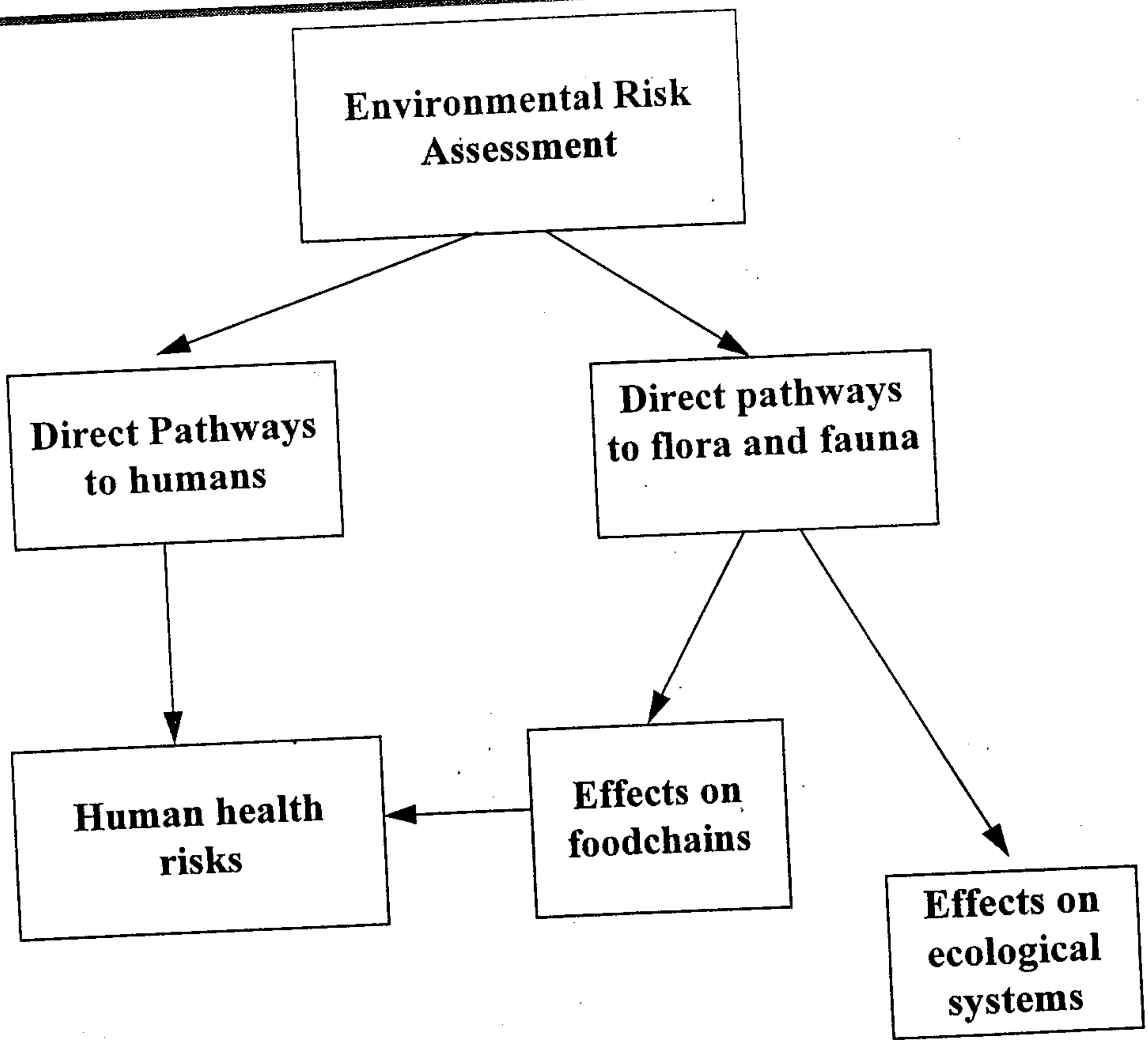
ANSTO/CSIRO Seminar on Ecological Risk Assessment, April 1996

ANSTO activities in Ecological Risk Assessment

R F Cameron, W M Zuk, ANSTO

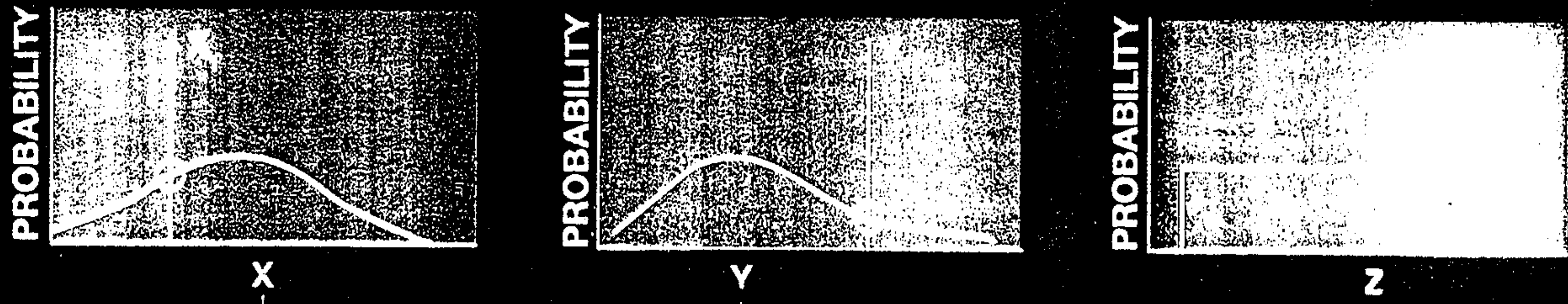



Identify the Hazard and Hazardous Incidents
Determine the likelihood of these events
Determine the consequences
Estimate the risk and its acceptability
Manage the risk


Environmental Risk Assessment
Direct Pathways to humans
Direct pathways to flora and fauna
Human health risks
Effects on foodchains
Effects on ecological systems

PROBABILISTIC ANALYSIS

- Develop parameter distribution

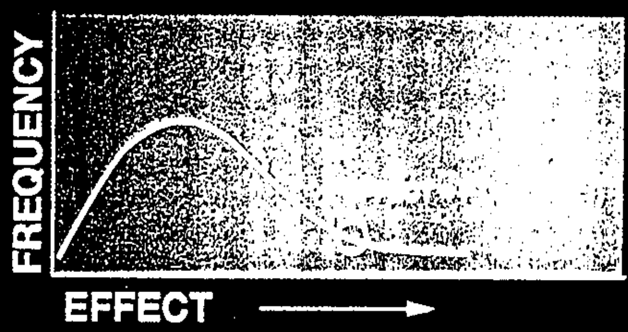


- Input distributions to model

Model

$$EFFECT = F (X_1, Y_1, Z_1)$$

- Produce a distribution of model predictions



The aims of the study were to provide information to answer the questions as to :

1) when should an industry initiate an environmental risk assessment ?

2) how should such an assessment be done ?

3) how should the acceptability of environmental risks be judged ?

Consensus on the aims of the analysis

Hazard ID
Frequency estimation

Problem formulation

- ecosystem data
- ecosystem effects
- endpoint selection
- release model

Review necessity for ERA

Analysis

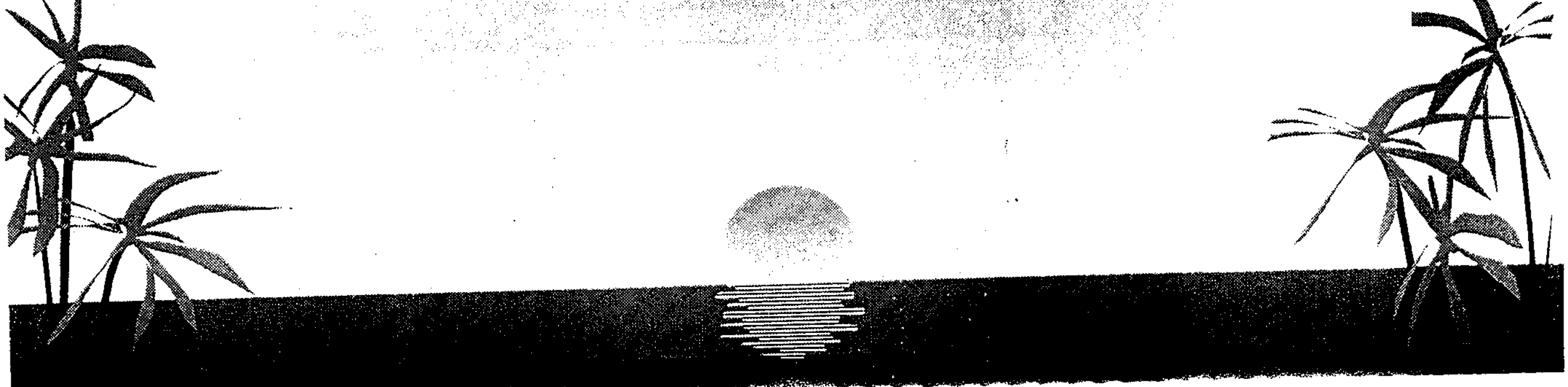
- exposure assessment
- ecosystem effects

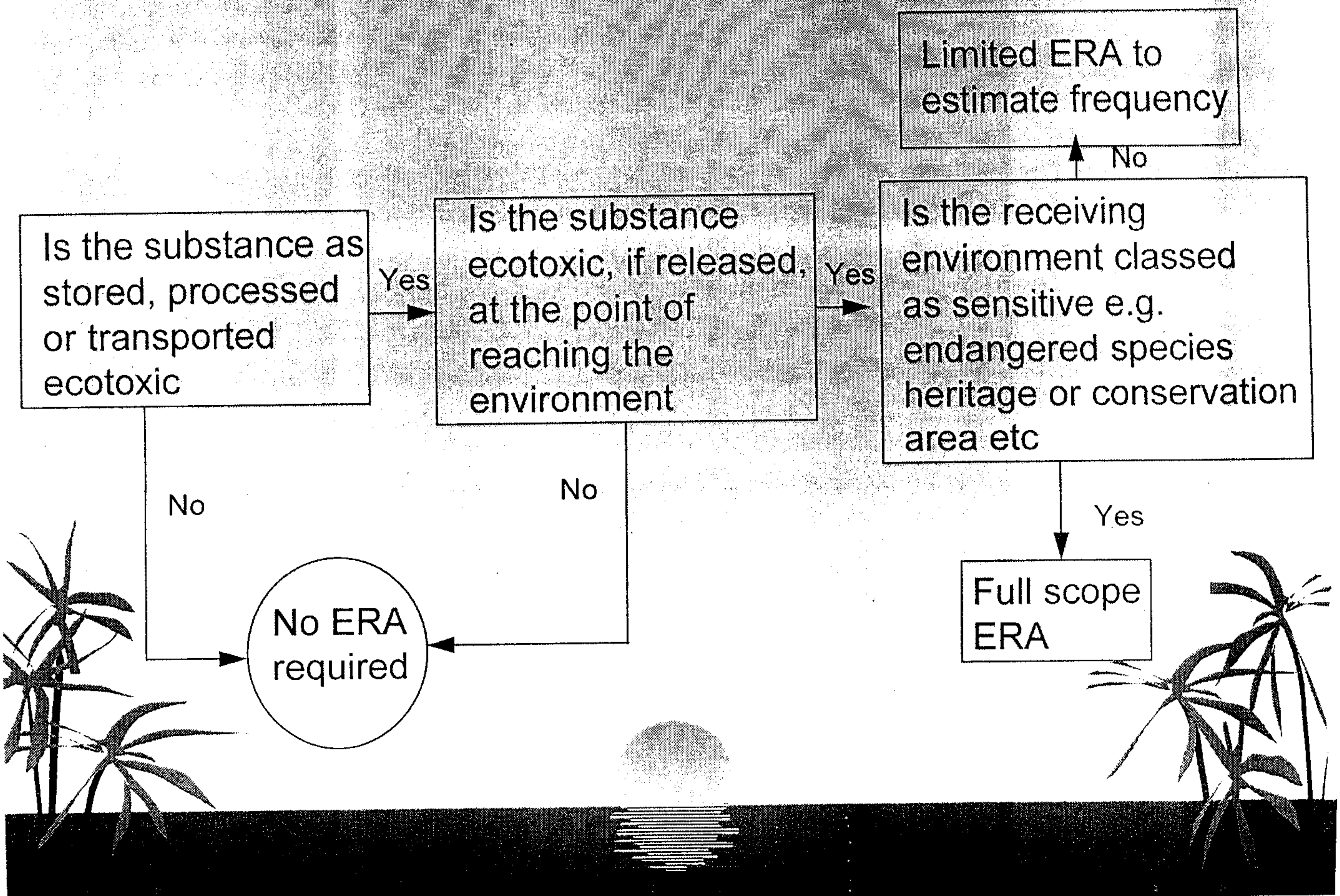
↓

Risk characterisation

↓

Risk acceptability




Limited ERA to estimate frequency
No
Is the substance as stored, processed or transported ecotoxic
Yes
Is the substance ecotoxic, if released, at the point of reaching the environment
Yes
Is the receiving environment classed as sensitive e.g. endangered species heritage or conservation area etc
No
No
Yes
No ERA required
Full scope ERA

BASIC INFORMATION

MATERIAL DATA

Nature and quantities
Known ecotoxic effects
Storage or containment methods

↓

TOXICITY

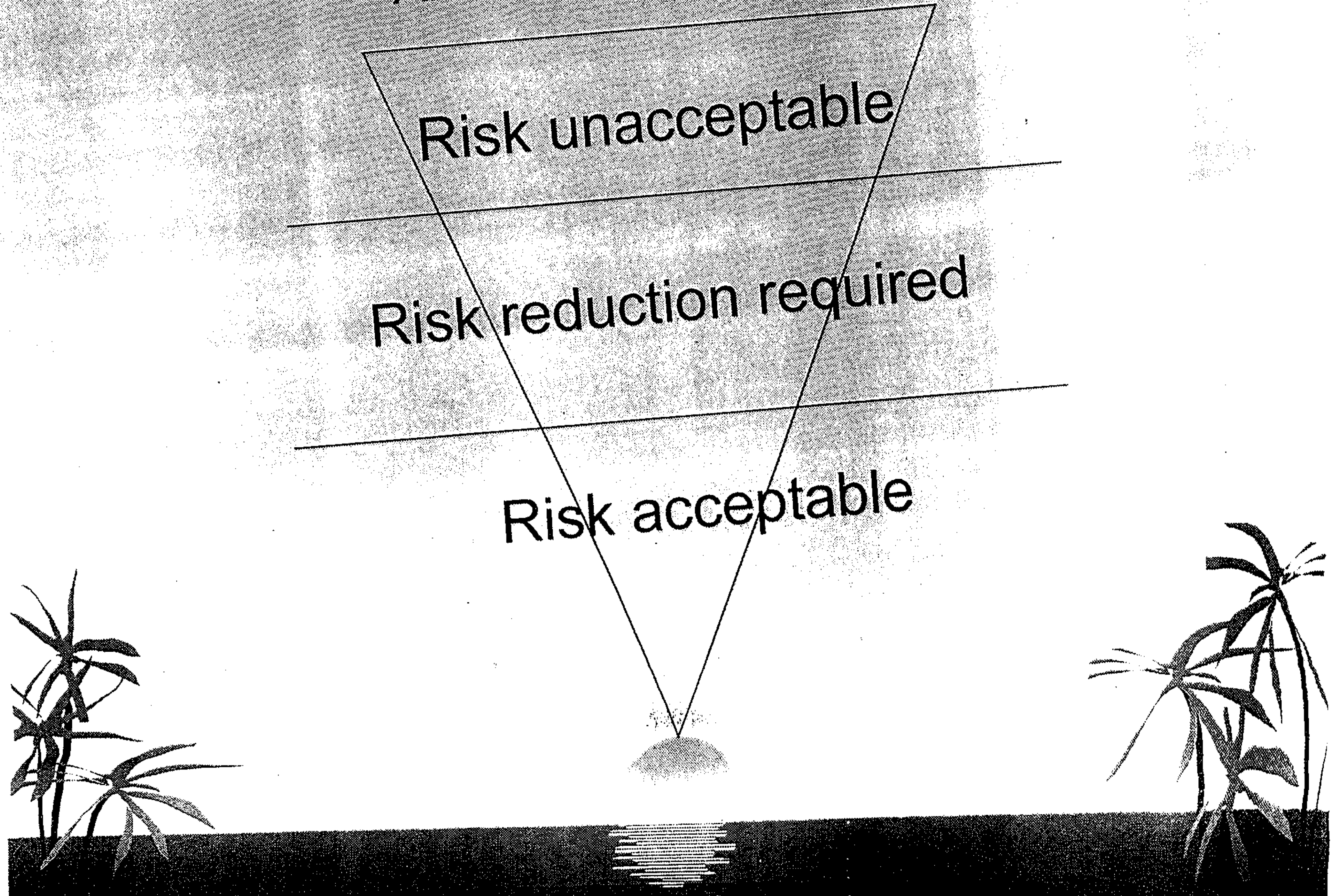
ENVIRONMENTAL DATA

Description of site & environs
Classification of ecosystem
Known features or species
Pathways for exposure

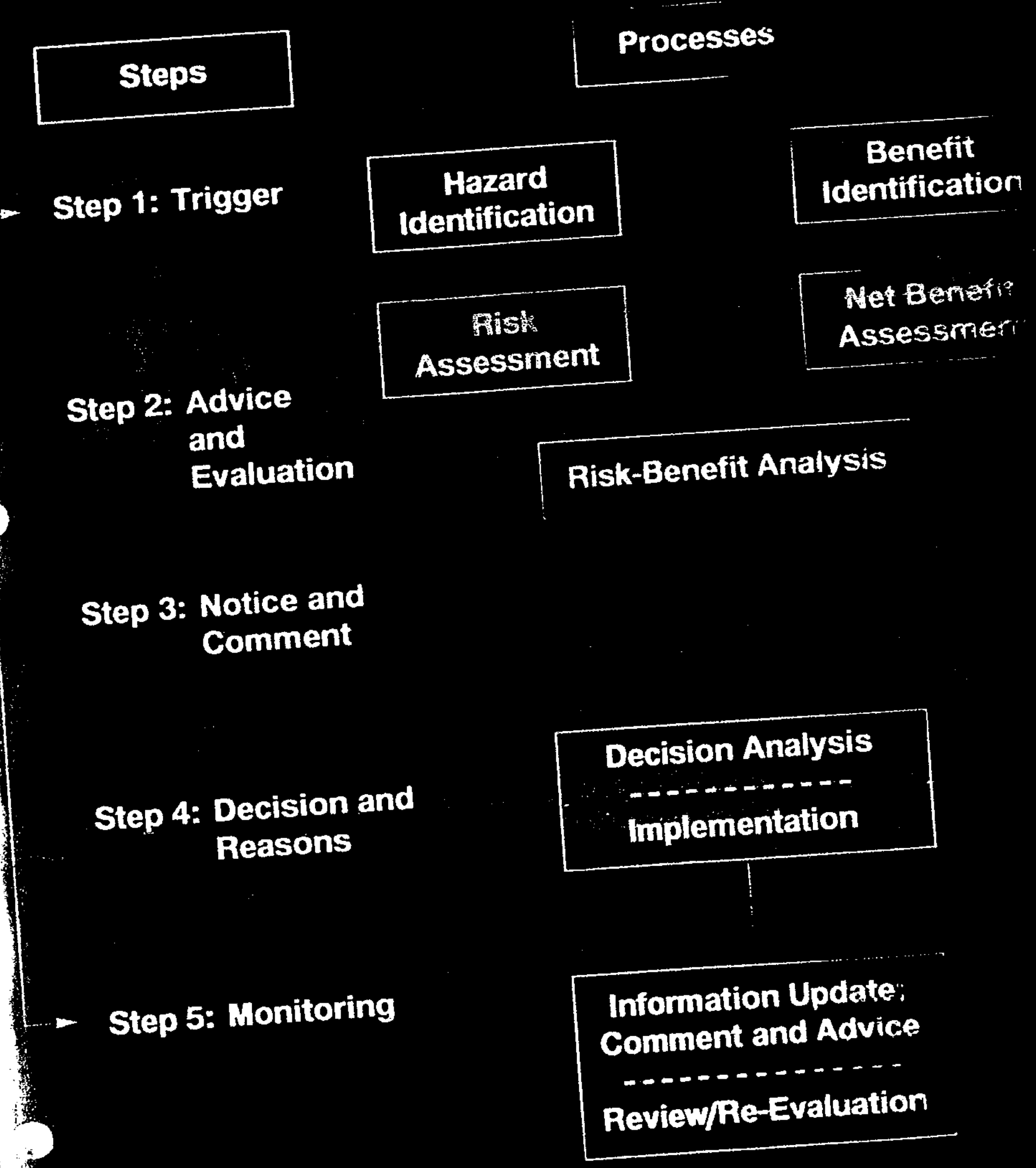
↓

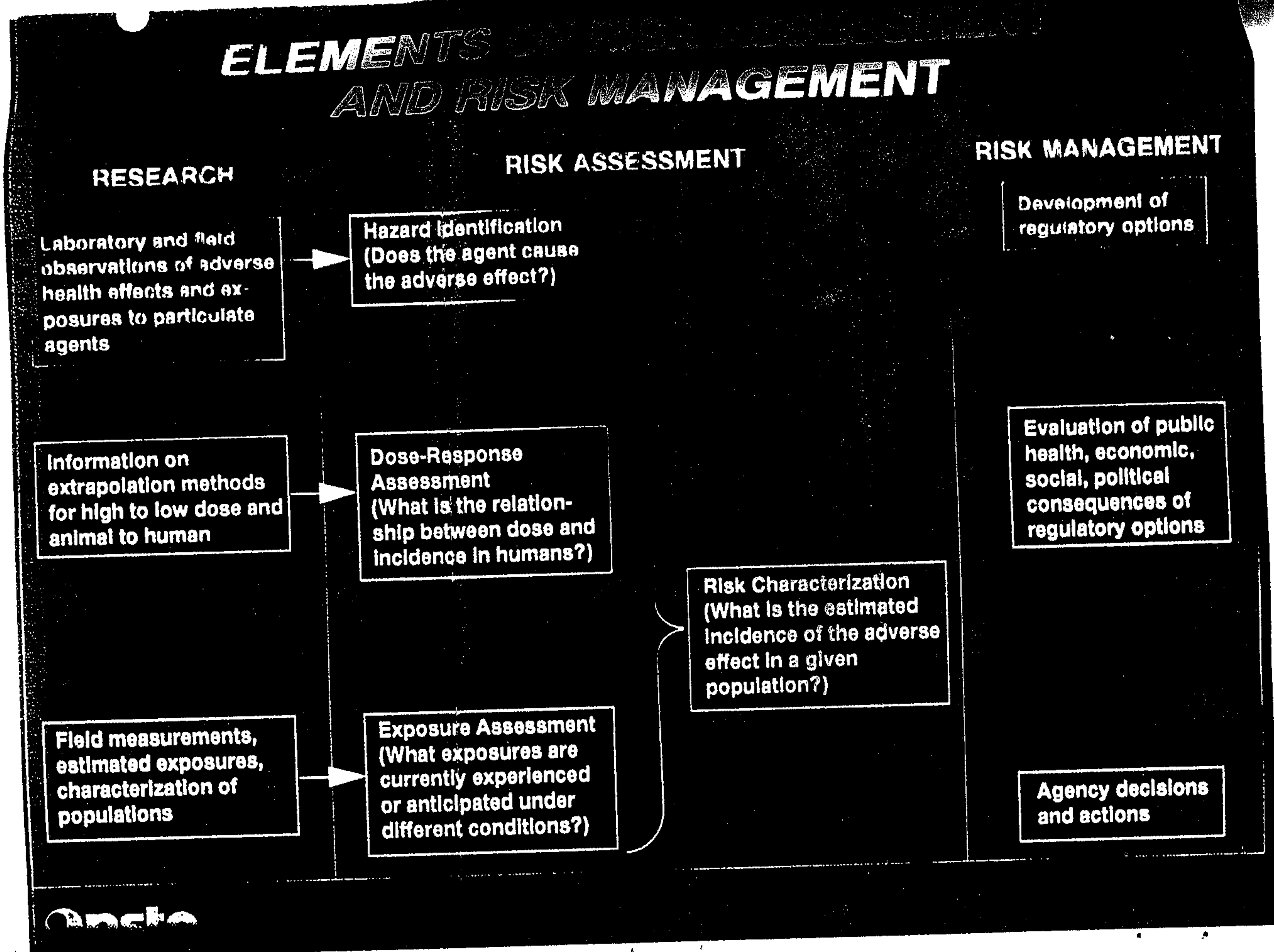
SENSITIVITY

ALARA PRINCIPLE

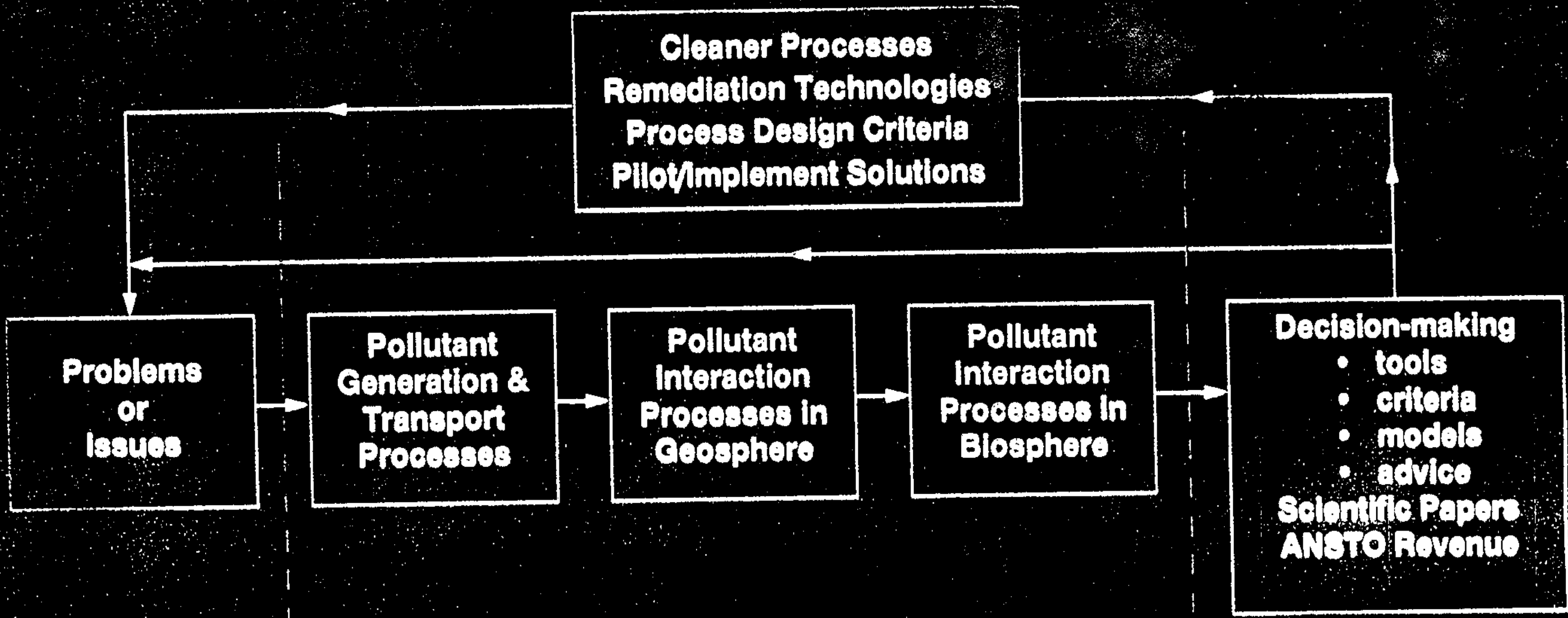


THE RISK MANAGEMENT PROCESS




ELEMENTS
AND RISK MANAGEMENT
RESEARCH
RISK ASSESSMENT
RISK MANAGEMENT
Laboratory and field observations of adverse health effects and exposures to particulate agents
Hazard Identification (Does the agent cause the adverse effect?)
Development of regulatory options
Information on extrapolation methods for high to low dose and animal to human
Dose-Response Assessment (What is the relationship between dose and incidence in humans?)
Evaluation of public health, economic, social, political consequences of regulatory options
Risk Characterization (What is the estimated incidence of the adverse effect in a given population?)
Field measurements, estimated exposures, characterization of populations
Exposure Assessment (What exposures are currently experienced or anticipated under different conditions?)
Agency decisions and actions

ENVIRONMENT DIVISION: S&T FRAMEWORK

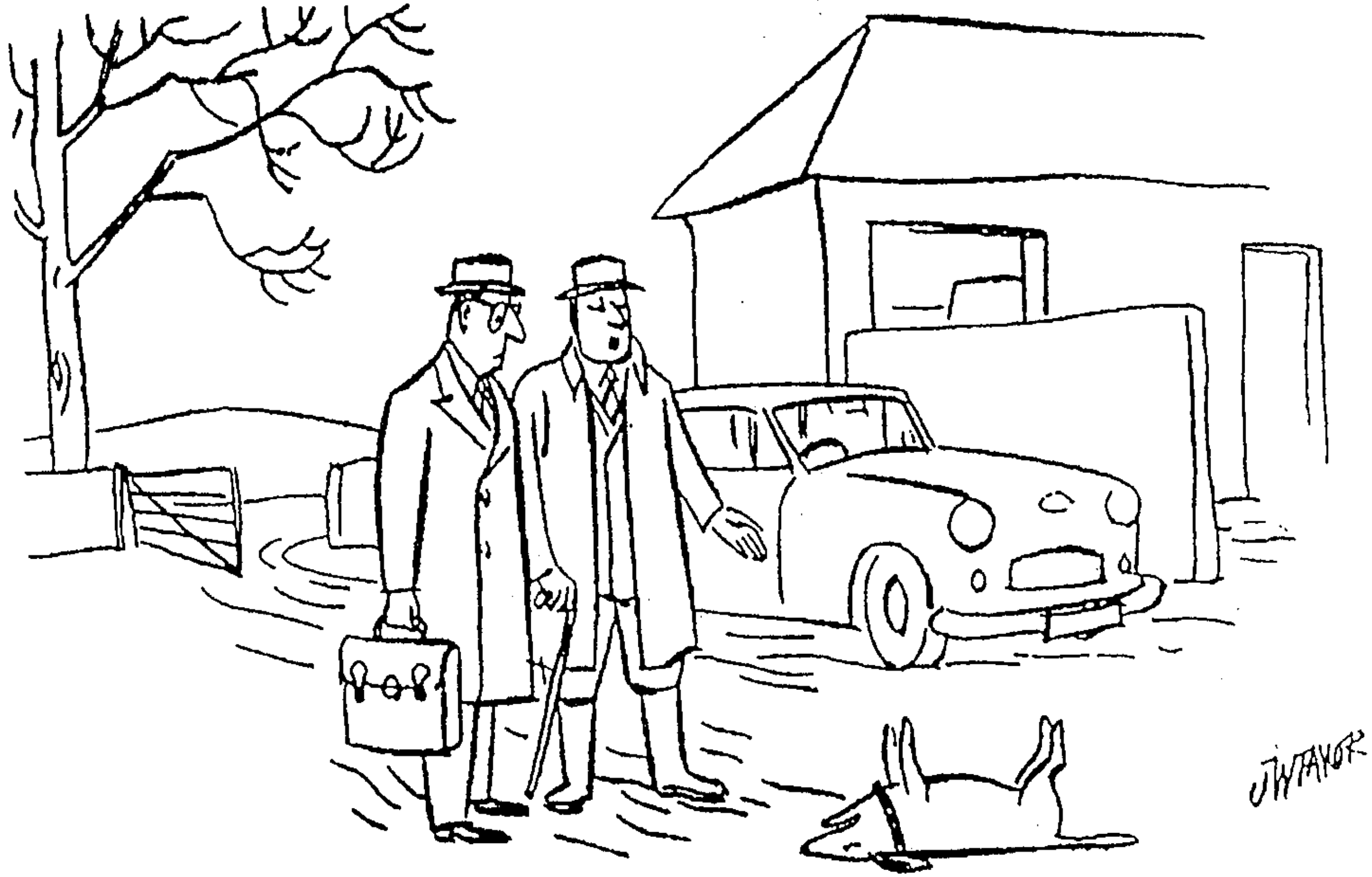


DRIVERS
- Government strategies priorities
- Industry needs
- International issues

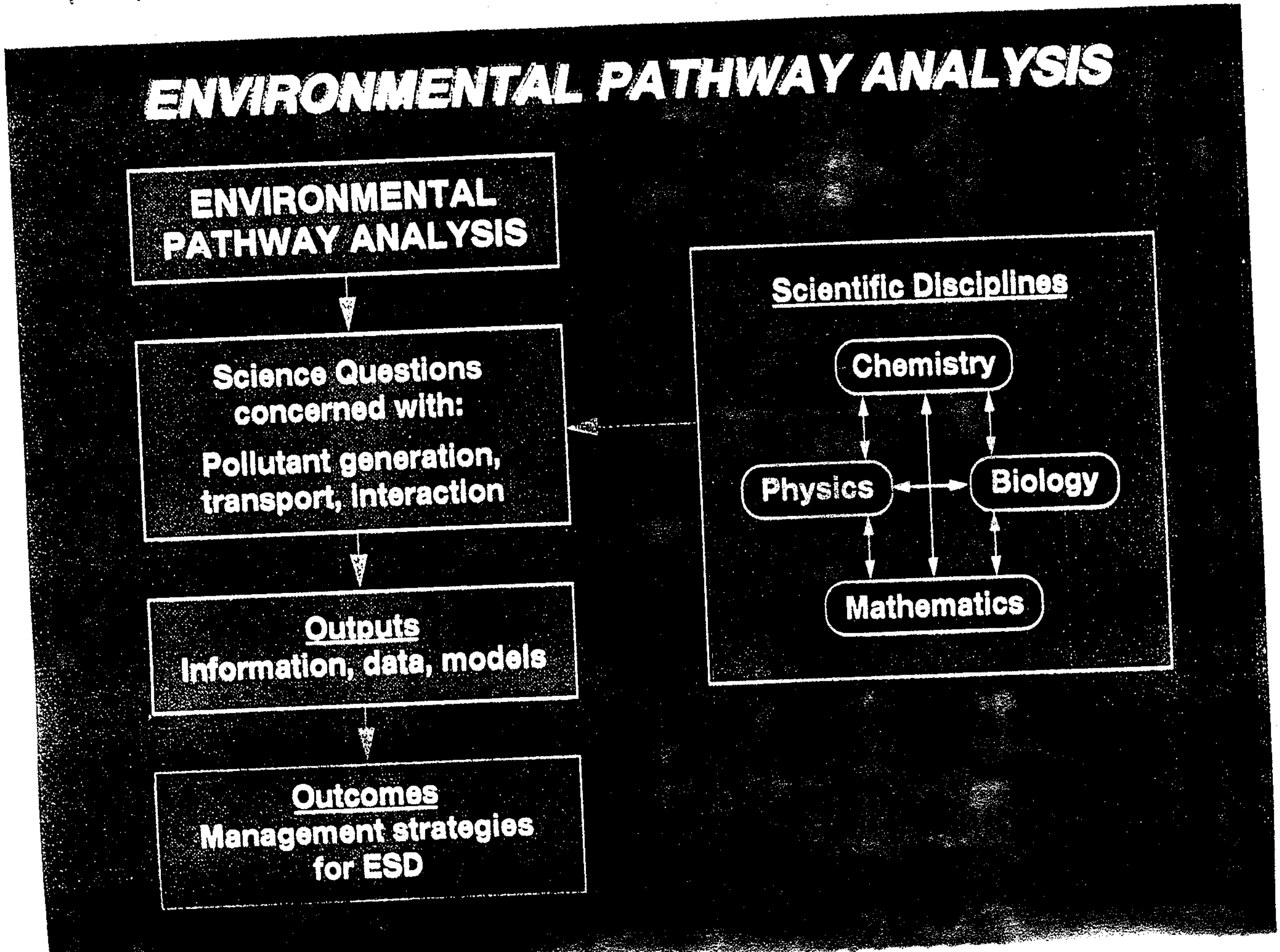
CORE S & T FOCUS
- Mandate-related
- Significant existing capability
  - expertise
  - facilities
- Identified capability need
- Collaboration with other S&T Organisations

OUTCOMES

ENVIRONMENTAL PATHWAY ANALYSIS



"This is the dog that bit the cat that killed the rat that ate the malt that came from the grain that Jack sprayed"


ENVIRONMENTAL PATHWAY ANALYSIS
ENVIRONMENTAL PATHWAY ANALYSIS
Science Questions concerned with:
Pollutant generation, transport, interaction
Outputs
Information, data, models
Outcomes
Management strategies for ESD
Scientific Disciplines
Chemistry
Physics
Biology
Mathematics

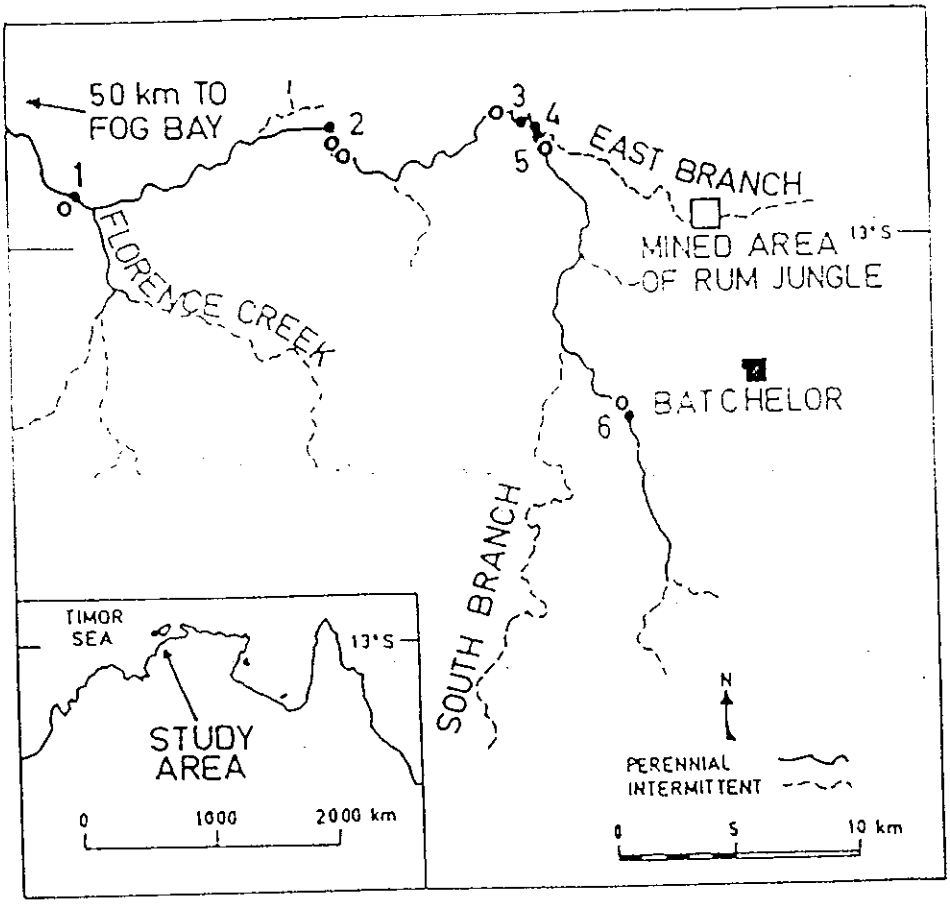
The Risk To An Individual Exposed To Ionising Radiation Is Often Expressed As

RISK = r x P x H

where: P is the probability of receiving a dose H

r is a coefficient that relates dose to a deleterious health effect

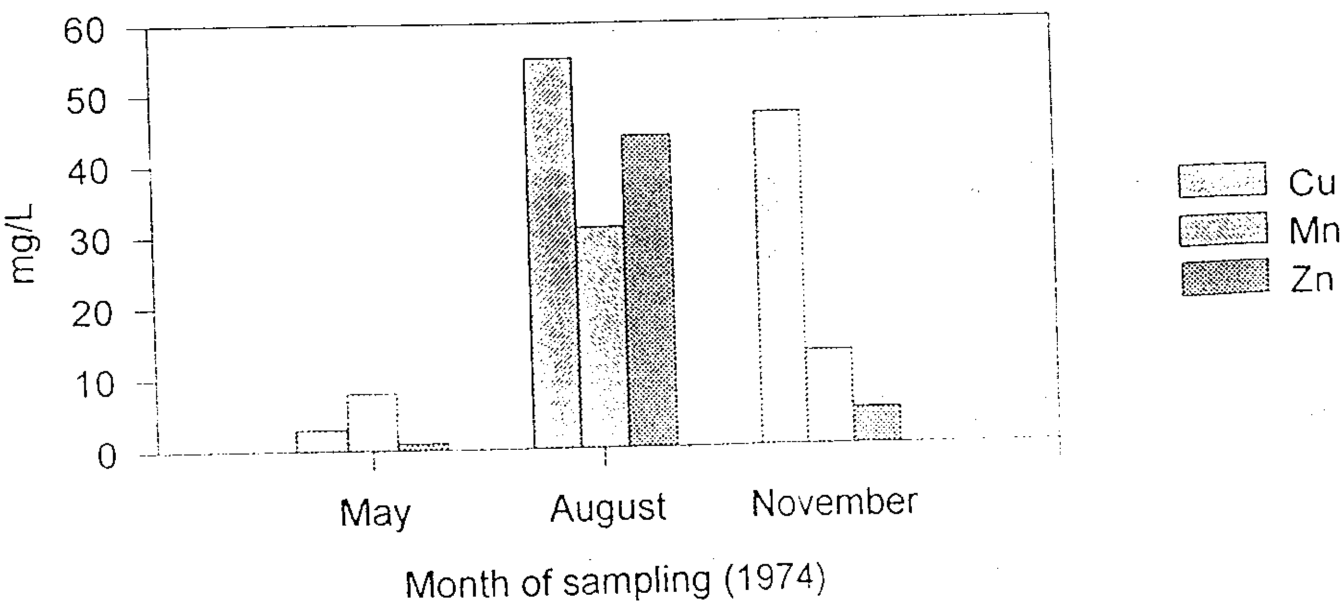
i.e. Risk is the probability of a health effect



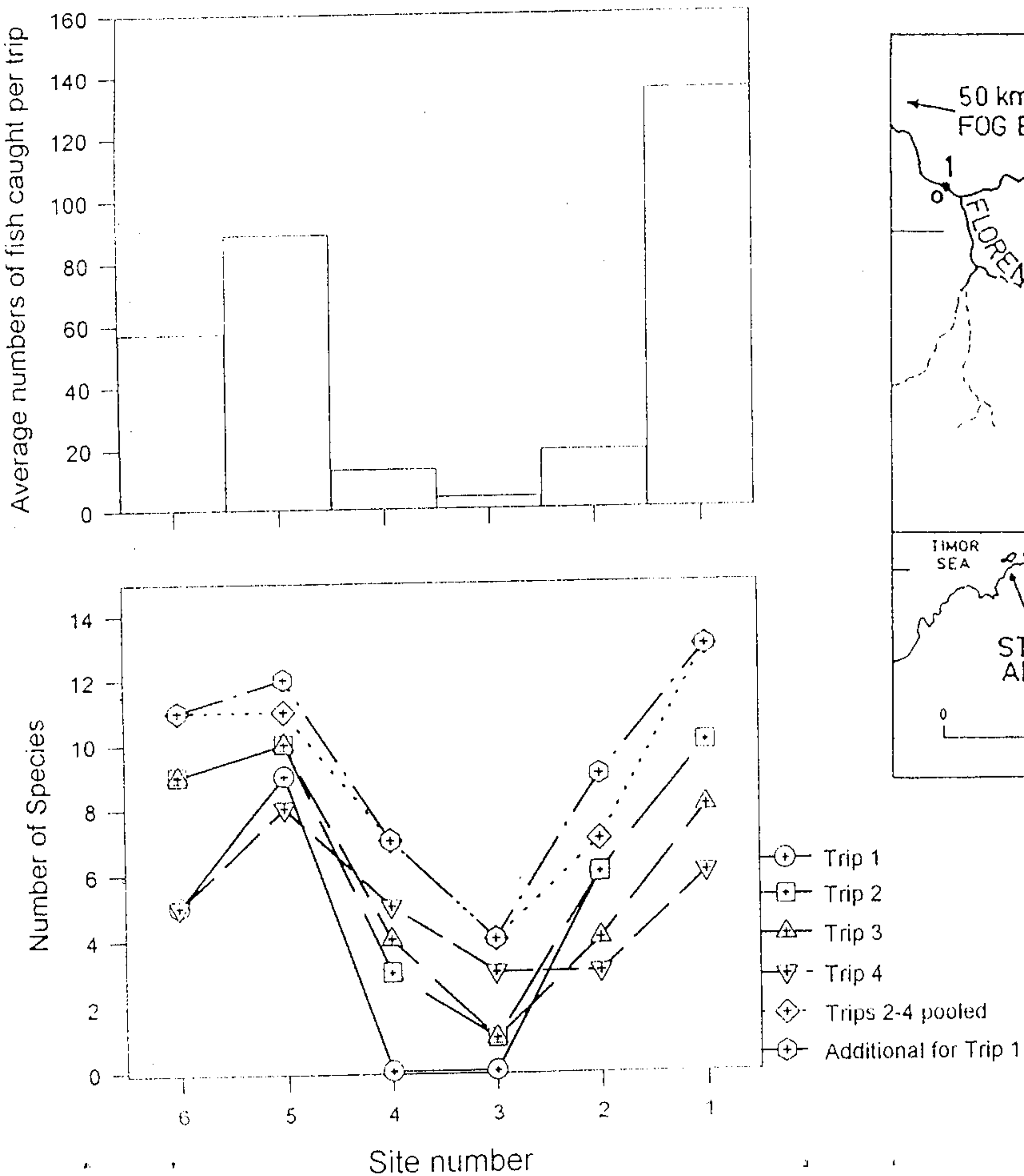
Biological Status of the East Branch

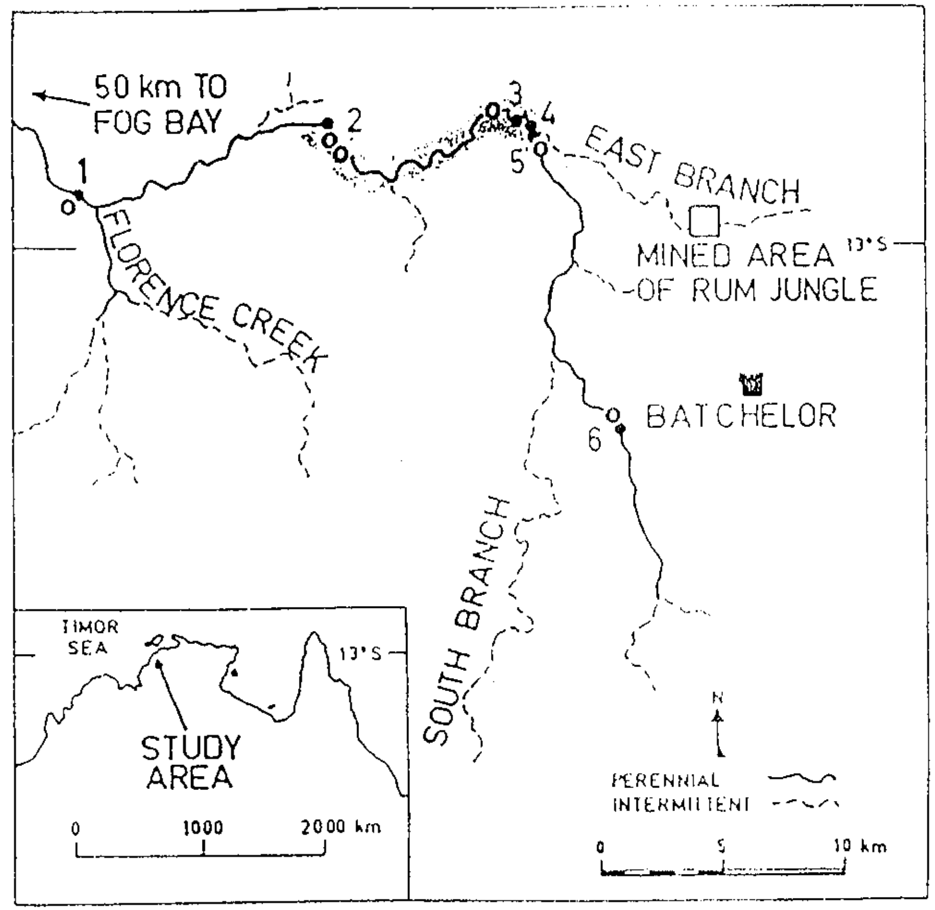
Fish: Few species in low abundance; many individuals dead or dying following colonisation from side streams.
Macroinvertebrates: few Crustacea (prawns & crabs) dead or moribund; several types of Insecta present (Gerridae, Dytiscidae, Gyrinidae, Hydrometridae, Notonectidae, Hydrophilidae).

WATER QUALITY OF THE EAST BRANCH (1974)

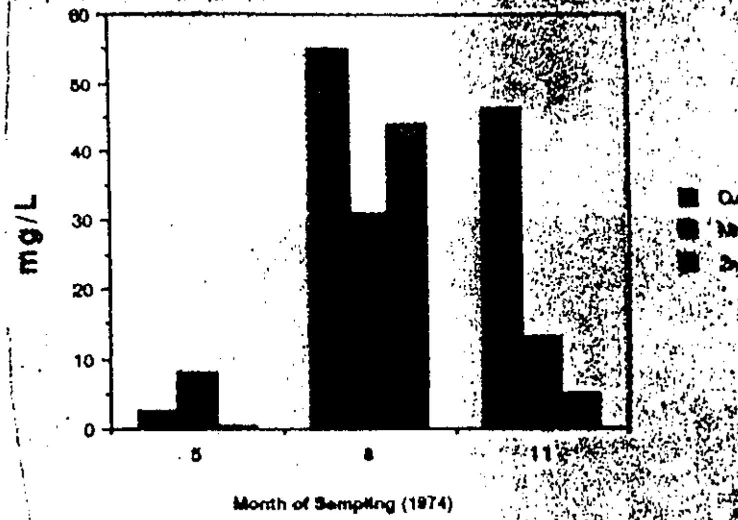


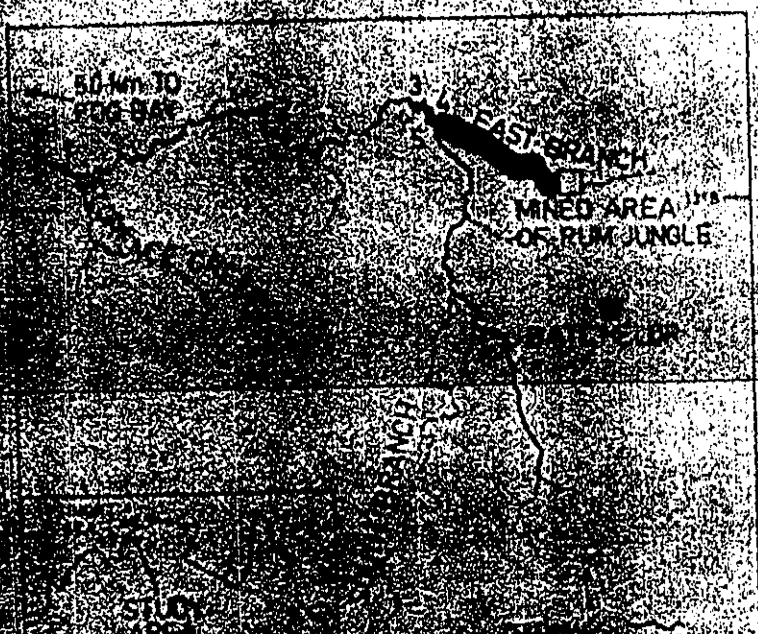
IMPACT OF MINE EFFLUENT ON FISH SPECIES AND ABUNDANCE (1974)





WATER QUALITY OF THE EAST BRANCH (1974)



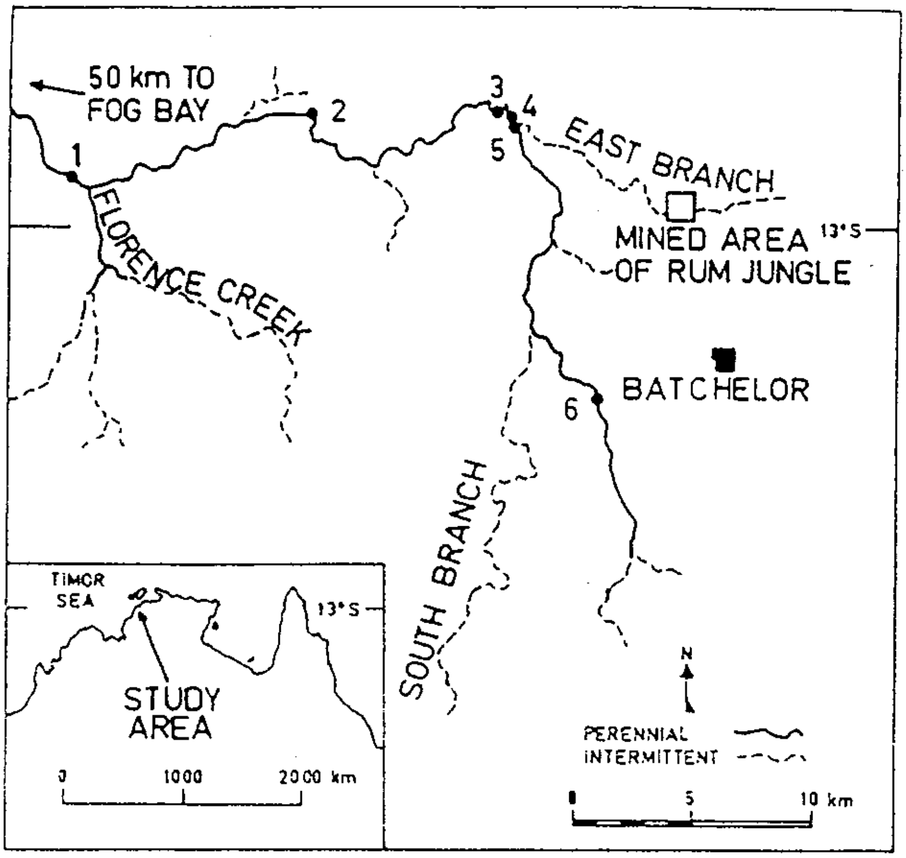


Biological Status of the East Branch

Fish: few species of low abundance, many dead or dying following colonisation from side streams

Macroinvertebrates: few Crustacea (prawns), many dead or moribund, several types of insects (Gerridae, Dytiscidae, Gyrinidae, Hydrometridae, Notonectidae, Hydrophilidae)

THE EFFECTS OF REMEDIATION OF ACID MINE DRAINAGE FROM RUM JUNGLE ON THE BIOTA OF THE FINNISS RIVER



YEARLY POLLUTION LOAD during 1973/74	Tonnes
Cu	50
Mn	50
Zn	20

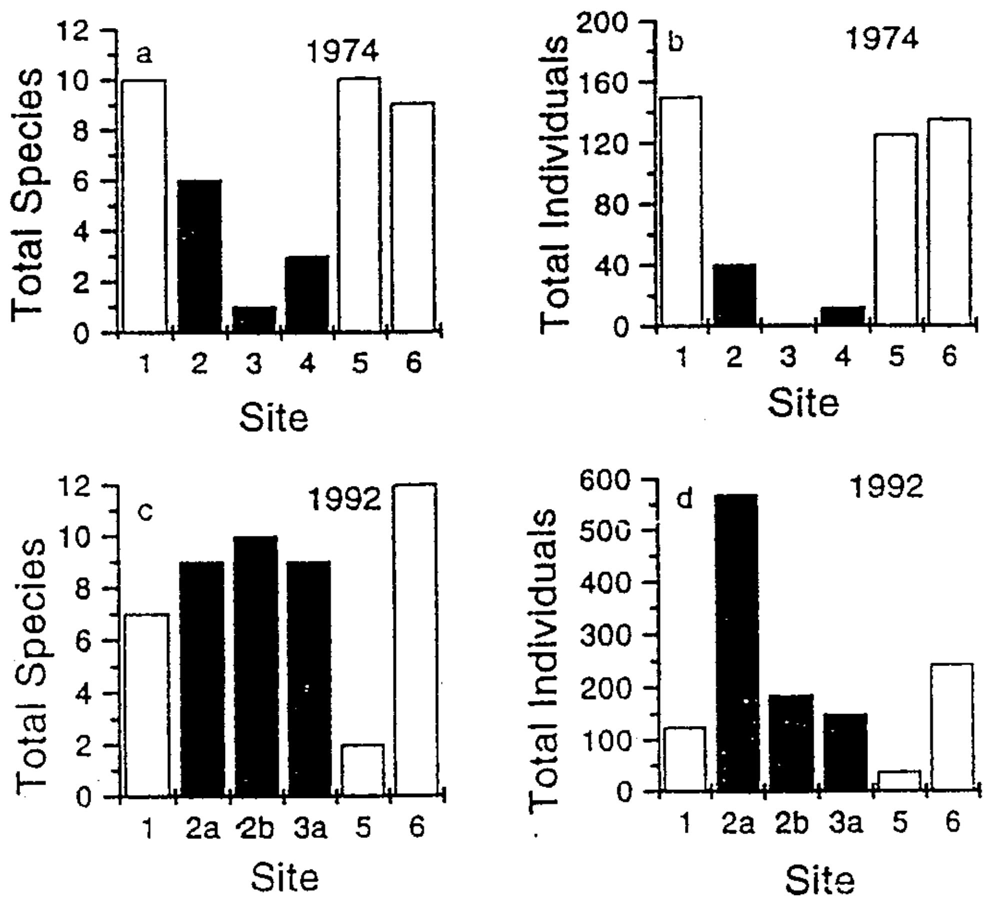
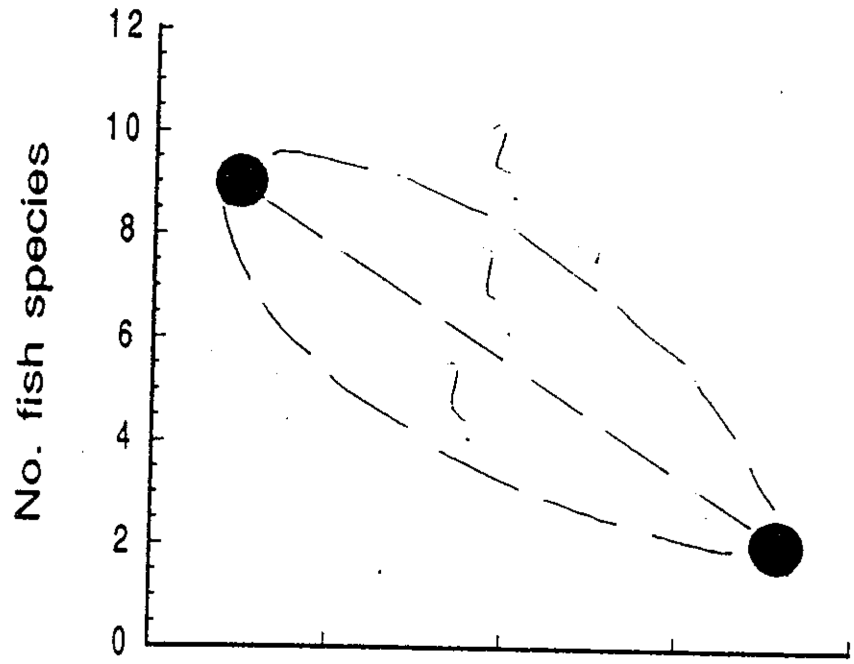


Fig. 2. Showing total numbers of species and individual fish taken at each sampling site within the impacted (■) and un-impacted (□) zones of the Finniss River during May/June 1974 and July/August 1992.

ECOLOGICAL SUSTAINABILITY

??? What loads of metals/acidity can be released into tropical freshwater environments without biological impact???



1991/92	1973/74
5 ton Cu	50 ton Cu
5 ton Mn	50 ton Mn
2 ton Zn	20 ton Zn

ERISS

ECOLOGICAL RISK ASSESSMENT

CM Finlayson
Head of Wetland Protection and Management
10 April 1996

CONTENTS

1 ERISS - ROLE AND OBJECTIVE

1.1 The Environmental Research Institute of the Supervising Scientist (ERISS) is part of the federal Department of Environment. It is a branch of the Environment Protection Agency (EPA) and has a close association with the Office of the Supervising Scientist (OSS). ERISS and OSS are both administered by the Supervising Scientist, Barry Carbon, who is also Executive Director of the EPA.

1.2 ERISS is based entirely in Jabiru in the Northern Territory and has a staff of 40. Its *objective* is

> ***through environmental research, provide advice on the protection and management of sensitive areas nominated by Government so that the Australian community can be assured that regions which it values highly are being protected.***

1.3 The primary reason for the Institute's existence is to carry out independent research, on behalf of the Australian community, to establish the best methods available for the protection of people and ecosystems of the Alligator Rivers Region both during and after mining (uranium) in the region. The OSS provides advice to the Government on supervision of mining.

1.4 As we also recognise that there is a need to contribute to the broader well-being of the community we also carry out research on the protection and management of wetlands in the region. The wetland research is intricately linked to the mining impact research and is used to place potential impacts from mining in a broad management context. This recognises that management of any particular environmental issue (change or impact) can not be done in isolation of other issues. This is a major change from the past when the Institute was narrowly focussed on environmental impact of mining in almost complete isolation of other management issues in the region. This change has enabled staff from the Institute to contribute to the broader spectrum of environmental issues that affect the region and place issues of mining impact in a broader spectrum.

1.5 The Government has also decided that the Institute should undertake more general environmental research as a special contribution to the wellbeing of the community of northern Australia. Thus, in line with international initiatives the Institute is leading the development of holistic and integrated information bases for environmental management. This is a key feature of the Institute's research strategy. Reductionist or single-issue environmental management is being increasingly recognised as being less and less appropriate and not compatible with the goals of ecologically sustainable development (ESD). ERISS is at the forefront of promoting holistic research in line with ESD. We are also aware that we may need to further justify this approach as single issues still feature prominently in the public environmental conscience.

1.6 The research strategy being developed by ERISS is not static - it is evolving in line with community attitudes, available resources and opportunities. The strategy is being developed in consultation with environmental regulators, resource owners, developers and users, and researchers from across northern Australia and elsewhere as appropriate. This is being done through an emphasis on communication with stakeholders both locally and nationally. ERISS has both held its own workshops (eg a workshop on *Wetland Research in the Wet-Dry Tropics* held in March 1995) and supported others (eg workshop on *Sustainable Harvest of Wetland Resources* organised by the NT Parks and Wildlife

Commission in March 1996). Special publications detailing research done by ERISS staff and collaborators are freely available and a new series of popularised scientific notes is being developed.

2 INSTITUTE RESEARCH PROGRAM

2.1 To meet both the expectations of the community and ourselves to provide high quality advice through research we have instigated the following environmental research objectives

- *research on the environmental impact of mining, particularly uranium mining, to enable the development of standards, practices and procedures that will ensure protection of the environment both during mining operations and following rehabilitation.*

- *research on tropical freshwater and estuarine ecosystems, to provide advice on the conservation and sustainable development of wetlands in northern Australia.*

- *general environmental research as requested by Government or in collaboration with other research organisations which would benefit from the unique location of ERISS or its specialised knowledge and expertise.*

2.2 The research program is based on two administrative multi-disciplinary groups each with three components. These components have evolved to reflect the major tasks being undertaken by the Institute and provide a core staff for general environmental research in northern Australia and elsewhere.

Mining Impact	**Wetland Protection & Management**
Impact on people	Ecological characterisation of wetlands
Impact on ecosystems	Risk assessment and restoration of wetlands
Development of protection mechanisms	Monitoring changes in the ecological character of wetlands

2.3 The research programs have undergone a number of internal and external reviews and are subject to regular assessment by an external Technical Panel. Key achievements of the research programs are given below

Mining Impact	Wetland Protection & Management
Ecotoxicological protocols for effluent discharges from mine sites	Biological monitoring methods for the NRHI
Methods for the estimation of radiation exposure of people as a result of radon dispersion	Recommendations for safe metal concentrations for inclusion in the revision of the ANZECC Water Quality Guidelines
Chemical and radionuclide standards for aquatic ecosystems	Review of wetland research and development issues for the LWRRDC wetland program
Biological monitoring protocols	Review of the conservation status of NT wetlands
Models to assess the long-term stability of tailings repositories and rehabilitated landforms	Assessment of the vulnerability of the wetlands of Kakadu National Park to climate change and sea level rise
Hydrological models for a tropical stream and floodplain	Drafting of guidelines for interpreting change in the ecological character of wetlands for the Ramsar Convention

2.4 Future research issues that ERISS plans to address are given below

Mining Impact	Wetland Protection & Management
Development of methods for the removal of radionuclides from mine waters	Assessment of weed hazards on coastal floodplains
Optimising sulphate reduction in constructed wetland filters	Assessment of risks associated with the use of herbicides in coastal floodplains
Assessing the radiological significance of resuspended dust at rehabilitated minesites	Development of remote sensing techniques for wetland inventory and assessment
Assessing the radiological exposure following rehabilitation at Nabarlek	Development of toxicologically based recommendations for water quality guidelines for metals
Assessing radiological and ecological impacts that could arise following long-term dispersal of tailings at Ranger	The establishment of biological methods to assess the health of Australian rivers
Assessment of alternatives for the long-term disposal of tailings at Ranger	The establishment of a National Reference Centre for assessing the effect of climate change on the wetlands of Kakadu
Assessment of impacts arising from Jabiluka and Koongarra	Assessment of the impact of cane toads

2.5 General environmental research has also been undertaken and will continue. Key achievements and future general environmental research issues are presented below

Key achievements	Future issues
Assessment of the radiological hazards associated with phosphate mining on Christmas Island	Model the future chemical characteristics of the Queen and King Rivers downstream from Mt Lyell
Design and management the Mt Lyell remediation research and development program	Undertake whole effluent toxicity testing to estimate the effectiveness of various acid drainage neutralisation scenarios at Mt Lyell
Assessment of the origin of radium in NT bore water	Conduct a revision of the ANZECC water quality guidelines for fresh and marine waters

3 WETLAND MANAGEMENT ISSUES IN NORTHERN AUSTRALIA

3.1 Wetland research and development issues in northern Australia have been reviewed by a number of groups. These reviews have identified core issues that are of concern for wetland managers and could profit from appropriate forms of risk assessment.

Major wetland management issues
Invasion of feral animals and alien plants
Fire and burning regimes
Overgrazing
Tourism and recreational activities
Pollution and contaminants
Water regime and physical modification

3.2 It is anticipated that these activities will be addressed through a number of strategies that all require underpinning by appropriate research and, in places, risk assessment. It is anticipated that risk assessment will be placed in the context of the overall conservation strategy(ies) for northern Australia. Thus, risk assessment will provide the analyses for management decisions and reviews and it can not be effectively done independently of the overall conservation (management) strategy.

Conservation strategy objective	Strategic issues for wetland management
Understanding	Develop and maintain a comprehensive wetland inventory Characterise and quantify the physical and ecological linkages that occur between wetlands Characterises the processes that maintain the ecological character and values of wetlands
Public awareness	Develop community awareness of the extent, values and benefits of wetlands
Protection and management	Implement catchment-wide land use planning Instigate specific management arrangements for wetland conservation and sustainable utilisation Enhance the level of control and planning of specific activities such as grazing Enhance the reservation and management of wetlands within a systematic framework
Monitoring	Develop and implement monitoring programs that provide early warning of any potential adverse impacts
Restoring	Assess the extent of ecological degradation caused by specific pest species, salinisation, grazing etc
Reviewing	Develop and implement a regular and systematic reporting process

4 ECOLOGICAL RISK ASSESSMENT AT THE INSTITUTE

4.1 ERISS has not specifically undertaken environmental risk assessment with the assistance of specific and formalised models. However, given the nature of the research programs conducted at ERISS over the past 15 years we have significant experience that could form the basis of a more formalised approach to risk assessment and even the development of risk assessment models. Research investigation at ERISS has principally been conducted along the lines given as a framework for generalised risk assessment

- hazard identification and characterisation
- environmental pathway analysis
- exposure/effects assessment
- determination of dose-response relationships
- risk characterisation, comparison and management

4.2 Whilst a great deal of attention has been focussed on some aspects of risk assessment (eg hazard identification, pathway analysis, exposure/effects assessment) very little statistical analysis has been conducted. The major exception to this is the determination of potential radionuclide impact on the traditional diet of Aboriginal people in the vicinity of uranium mining operations. Despite major gaps in the information an assessment on possible exposure through a traditional diet was made.

4.3 The research program at ERISS has been briefly described as a basis for assessing the potential for risk assessment in relation to mining and wetland environmental management, primarily, but not totally in northern Australia. Some of the major wetland environmental issues have been identified for a similar purpose.

4.4 Risk assessment has been undertaken for a number of research programs at ERISS. Several key projects are listed below.

- Water release from Ranger Uranium Mine
- Vulnerability assessment of wetlands to climate change

These programs were conducted along the lines of formalised risk assessment models although this was not actually stated. A series of logical assessments were put in place and used to identify the hazards and gaps in information for management planning. In the case of water release from Ranger general standards were established and a sophisticated regulatory and biological monitoring program developed. The climate change project was based on an assessment of current knowledge and scenarios of change. Management related responses included a proposal to establish a more effective and utilitarian monitoring program.

4.5 Formalised risk assessments are now proposed. These will follow established approaches and build on the scientific expertise at ERISS. Given the expertise and the critical nature of weed invasions of wetlands it is planned to commence with a risk assessment of wetland weeds and their control. Both the ecological and economic impacts will be assessed and the information presented to managers and funding bodies when they need to allocate resources and/or priorities. Similarly, the control measures will also be subjected to a risk assessment with a view to providing locally relevant information based on toxicological assessments. In both cases the goal is to provide managers with more rigorous information for making decisions.

Some Ecological Risk Assessment Activities at the Australian Institute of Marine Science

Terry Done
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The Australian Institute of Marine Science (AIMS) has run ecological research projects on coral reefs, mangroves and seagrasses since its inception in the early 1970s. It recently became a major partner in the CRC for Ecologically Sustainable Development of the Great Barrier Reef. Program 1 of this CRC has as one of its goals the assessment of status of, and threats to, the ecological systems, habitats and processes of the Great Barrier Reef. Ecological risk assessment (ERA) is recognised as a valuable tool in AIMS and CRC research.

AIMS has applied, and is currently applying, elements of ecological risk assessment (ERA) in a number of research areas These are:

- predicting the likelihood of coral destruction by cyclone waves as a function of depth and latitude in the Great Barrier Reef (Massel and Done 1993)
- predicting the likelihood of exposure of coral reefs to flood plumes (B. King and E. Wolanski - in progress)
- developing indices of 'ecological values' for coral reefs for use in a decision support framework for management of activities which may damage reefs (Done 1995)
- investigating the frequency and intensity of impacts by crown of thorns starfish on which can be sustained by massive corals without long-term detriment to their size-frequency distributions and thus, their reef-building potential (Done 1987;1988).

Exposure of coral reefs to cyclone waves:

Massel and Done (1993) used the meteorological record of cyclones along the Great Barrier Reef to determine that there are latitudinal trends in the severity and frequency of cyclones. Wind and wave hindcasting techniques were used to predict the depth profiles of wave forces generated by cyclones of known intensity. The final outcome was a prediction of the life expectancy of corals at different depths and latitude, based on their shapes and strength of attachment.

Exposure of coral reefs to flood plumes:

Coral reefs have different community structures and physical structures depending on the frequency and extent of their exposure to riverine influence. The 'classic' coral reef of the brochures is never exposed to influence of rivers, whereas nearshore reefs vary in their exposure, depending on distances from rivers, the flow characteristics and loadings of the rivers, and the ocean hydrodynamics. Reef scientists currently have a problem in sorting out whether these loadings are having a detrimental effects, since the 'nearshore' reef has natural characteristics which in an offshore context, can be considered evidence of degradation (e.g. high abundances of macro-algae). At AIMS, Brian King and Eric Wolanski are currently tuning a state of the art 3D hydrodynamic model against field data on salinity between Townsville and Cairns during the 1981 flood of the Burdekin River (Wolanski and Jones 1981). The intention is to then use historical river flow data, along with tidal and wind records, to drive the model in both hindcasting and forecasting modes. In hindcasting mode, the model will be predicting which the reefs exposed to flood plumes at specific times in the past. Coral reef ecologists can then investigate benthic community structure for signals of riverine influence. In forecasting mode, the likelihood that projected future river loadings under various scenarios for coastal development will increase the geographical spread of rivers under riverine influence can be predicted.

Indices of ecological value for coral reefs

Indices combining 'time for replacement' and 'uniqueness' have been developed to assist coral reef managers in evaluating potential losses associated with development on coral reefs. A risk assessment approach is advocated in the context of the decision making process used by managers, which takes into account both the value of the threatened reef in its regional context , and the risk of minor or major damage posed by the proposed activity. The same indices may also be used to incorporate ecological criteria in the design of marine protected areas.

Exposure of coral reefs to crown of thorns starfish

During COTS outbreaks of the early 1980s , field data were collected which characterised the size- specific damage regime for massive corals, which are important reef builders. Leslie matrix models were used to estimate the sustainability of the 1980s intensity of impact if it were to recur at intervals from 10 to 30 years. Fifteen years, the interval between the 1960s and 1980s outbreak on the GBR, appeared to be marginal, based on a number of reasonable model assumptions (Done 1987; 1988).

References:

Done, TJ (1987). Simulations of the effects of crown of thorns starfish on the population structure of massive corals in the genus *Porites*: evidence of population resilience. *Coral Reefs* 6:75-90.

Done TJ (1988). Simulating recovery of pre-disturbance size structures in populations of massive *Porites* spp. damaged by the crown of thorns starfish *Acanthaster planci* . *Marine Biology* 100:51 - 61.

Done TJ (1996) Ecological criteria for evaluating coral reefs and their implications for managers and researchers. *Coral Reefs* 14:183 - 192

Massel, S, Done TJ (1993). Effects of cyclone waves on massive coral assemblages on the Great Barrier Reef: meteorology, hydrodynamics and demography. *Coral Reefs* 12: 153 - 166.

Wolanski E, and Jones M (1981). Physical properties of the Great Barrier Reef lagoon waters near Townsville. I Effects of Burdekin River floods. *Aust J Mar Freshwater Res* 32: 305 - 319.

FISHERIES MANAGEMENT

- **balancing exploitation and conservation**

FISHERIES ASSESSMENT

- **fitting models to data**
- **assessing current status of the stock**
- **predicting consequences of future management**

FISHERIES RISK ASSESSMENT

- **defining risk**
- **encompassing uncertainty**

MANAGEMENT STRATEGY EVALUATION

- **dealing with multiple objectives**

DEFINING RISK

- stock or fishery collapse
- probability of "something bad" happening
- OR expected loss (probability x consequence)
- probability (B < 20% B_0)
- other "sustainability indicators"

SOURCES OF UNCERTAINTY

- observation error
- process error
- parameter uncertainty
- model structure uncertainty
- management implementation uncertainty

CURRENT DEVELOPMENTS

- Bayesian approaches
- Management procedures

  data+model+decision rule

  simulating future assessment and management

  deep and shallow models
- Evaluating future research

RELEVANCE FOR ENVIRONMENTAL RISK ASSESSMENT ?

- model uncertainty generally greater
- management framework more complex
- objectives less clearly defined

MANAGEMENT STRATEGY EVALUATION

Management strategy evaluation involves assessing the consequences of a range of management strategies or options, and presenting the results in a way which lays bare the tradeoffs in performance of each strategy across a range of management objectives.

The output often takes the form of a decision table.

HARVEST STRATEGY EVALUATION FOR GEMFISH

- **Bayesian stock assessment gives distribution of possible current states**

- **Monte Carlo simulation of future harvest strategies**

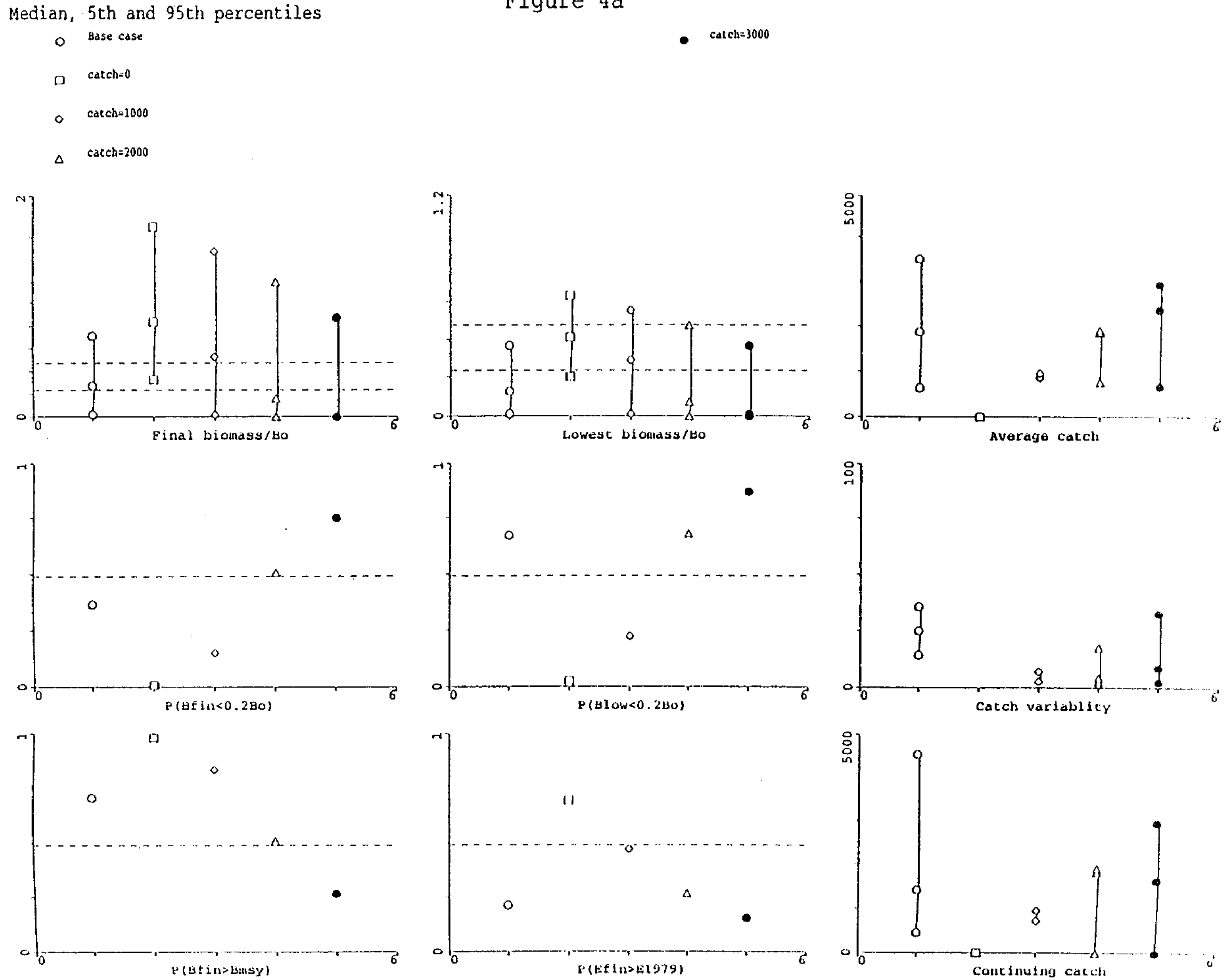
  simulate future data

  annual assessments

  future management

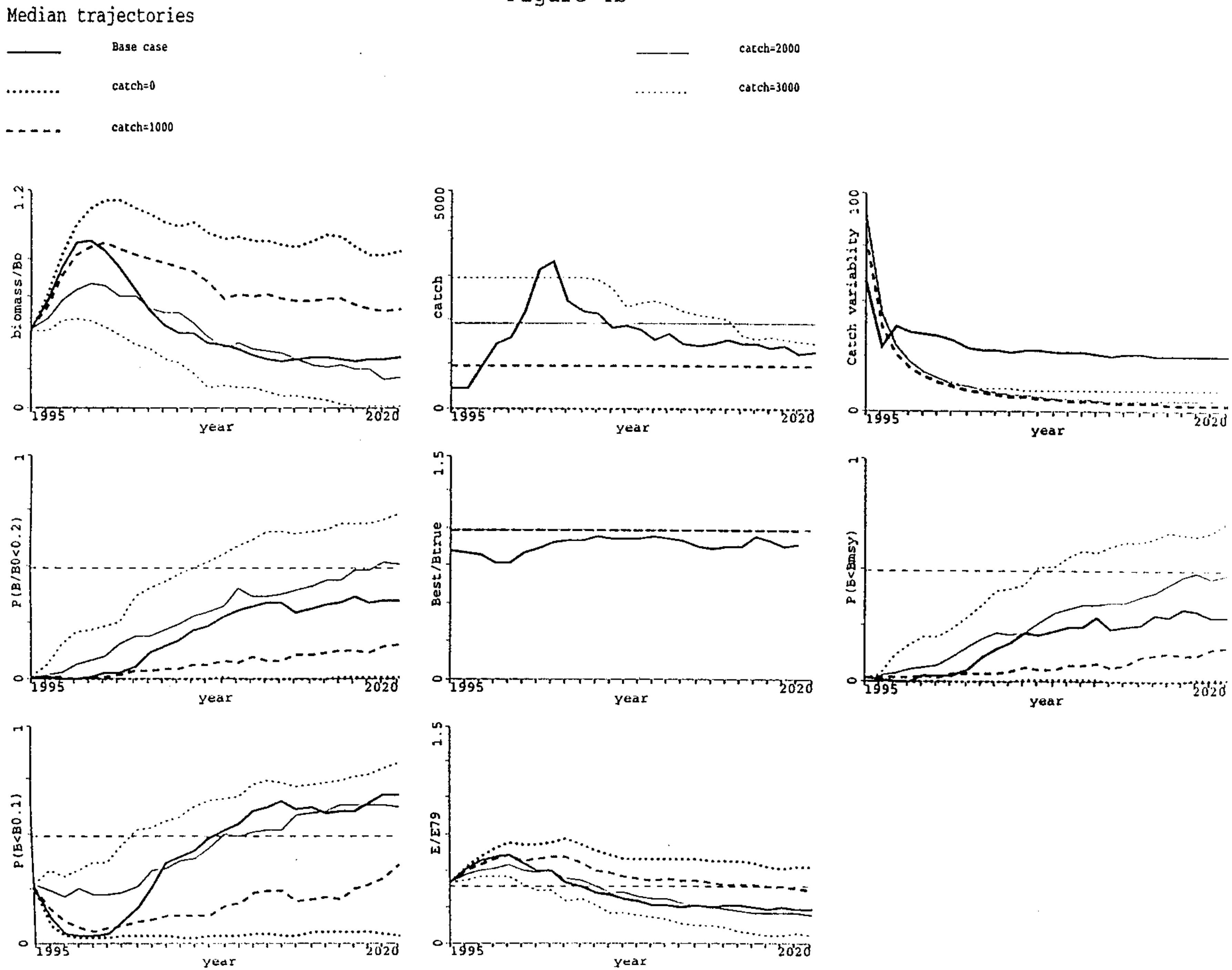
- **evaluate strategies against a range of performance indices**

Figure 4a



Median, 5th and 95th percentiles
Base case
catch=0
catch=1000
catch=2000
catch=3000
Final biomass/Bo
Lowest biomass/Bo
Average catch
P(Bfin<0.2Bo)
P(Blow<0.2Bo)
Catch variablity
P(Bfin>Bmsy)
P(Bfin>B1979)
Continuing catch

Figure 4b


Median trajectories
Base case
catch=0
catch=1000
catch=2000
catch=3000
biomass/Bo
catch
Catch variablity
P(B/B0<0.2)
Best/Btrue
P(B<Bmsy)
P(B<B0.1)
E/E79
year
1995
2020
0
1.2
5000
100
1
1.5

SYDNEY WATER 'S ECOLOGICAL RISK ASSESSMENT- A CASE STUDY

INTRODUCTION

- Public interest in the effect of the discharge of sewage effluent
- The Water Board was corporatised at the beginning of 1995
- During the drafting of the bill enabling corporatisation a number of additional requirements were included
- Additional requirements included a number of studies to assess the impact of the discharge of effluent

WATER BOARD (CORPORATISATION) ACT 1994

- s.23 2(c) The Corporation is to conduct ecological risk assessments in relation to Schedule 10 substances discharged into waters from each of the Corporation's sewage treatment plants.
- s.23 2(d) Ecological risk assessments are to be carried out in accordance with a methodology for the time being approved by the EPA in accordance with section 24.

WATER BOARD (CORPORATISATION) ACT 1994

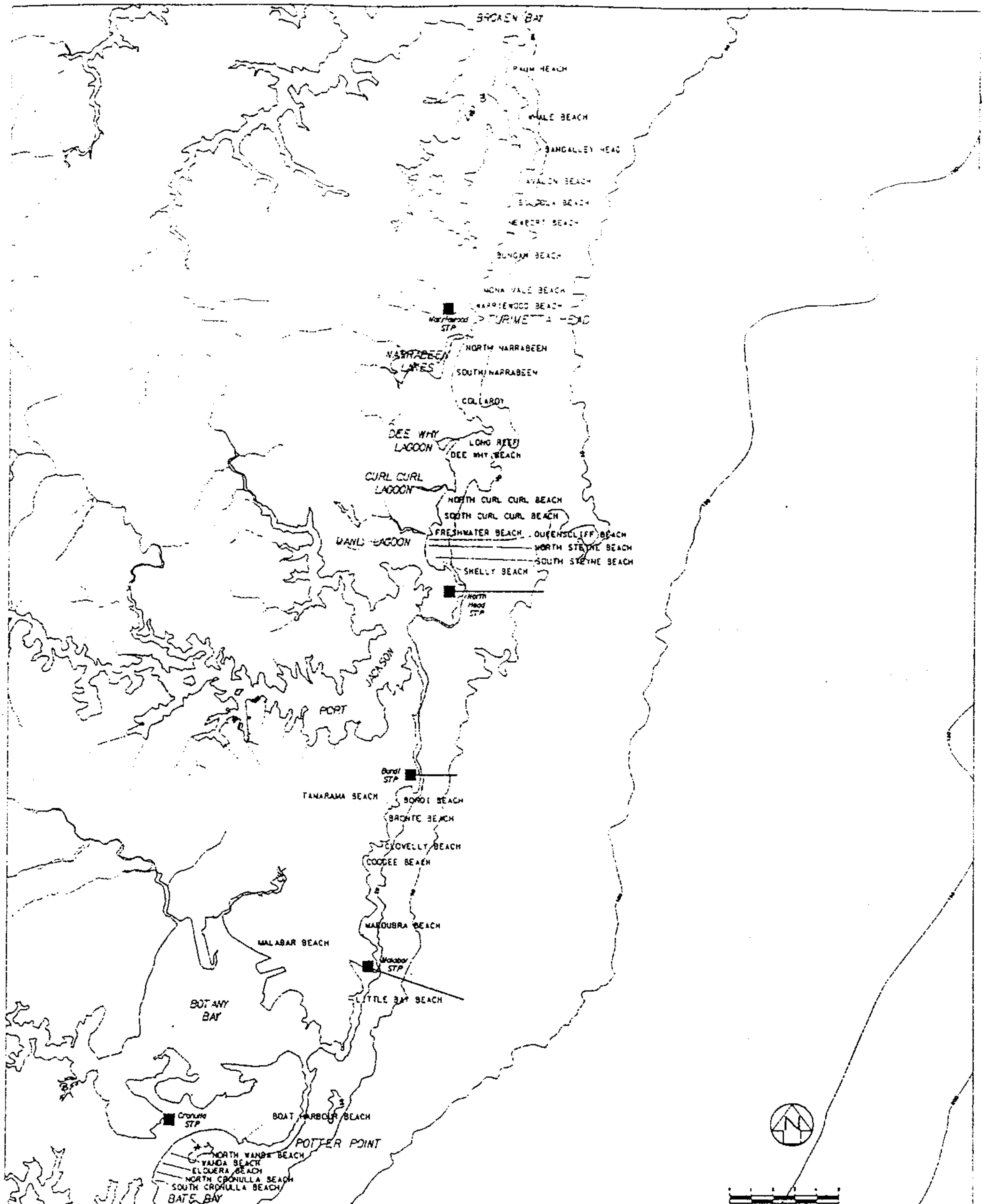
- **s.23 2(e) Reports on ecological risk assessments are to be provided to the EPA as follows:**
  - (i) reports on assessments for the ocean are to be provided by 31 December 1995; and
  - (ii) reports on assessments for the Hawkesbury-Nepean catchment are to be provided by 30 June 1996; and
  - (iii) reports on the remaining assessments are to be provided by 30 June 1997.

OVERVIEW OF THE SWC RISK ASSESSMENT

- The risk assessment included the following steps:
  - problem formulation
  - screening level risk assessment
    - exposure assessment
    - effects assessment
    - risk characterisation
    - uncertainty assessment
  - detailed risk assessment
    - exposure assessment
    - effects assessment
    - risk characterisation
    - uncertainty assessment

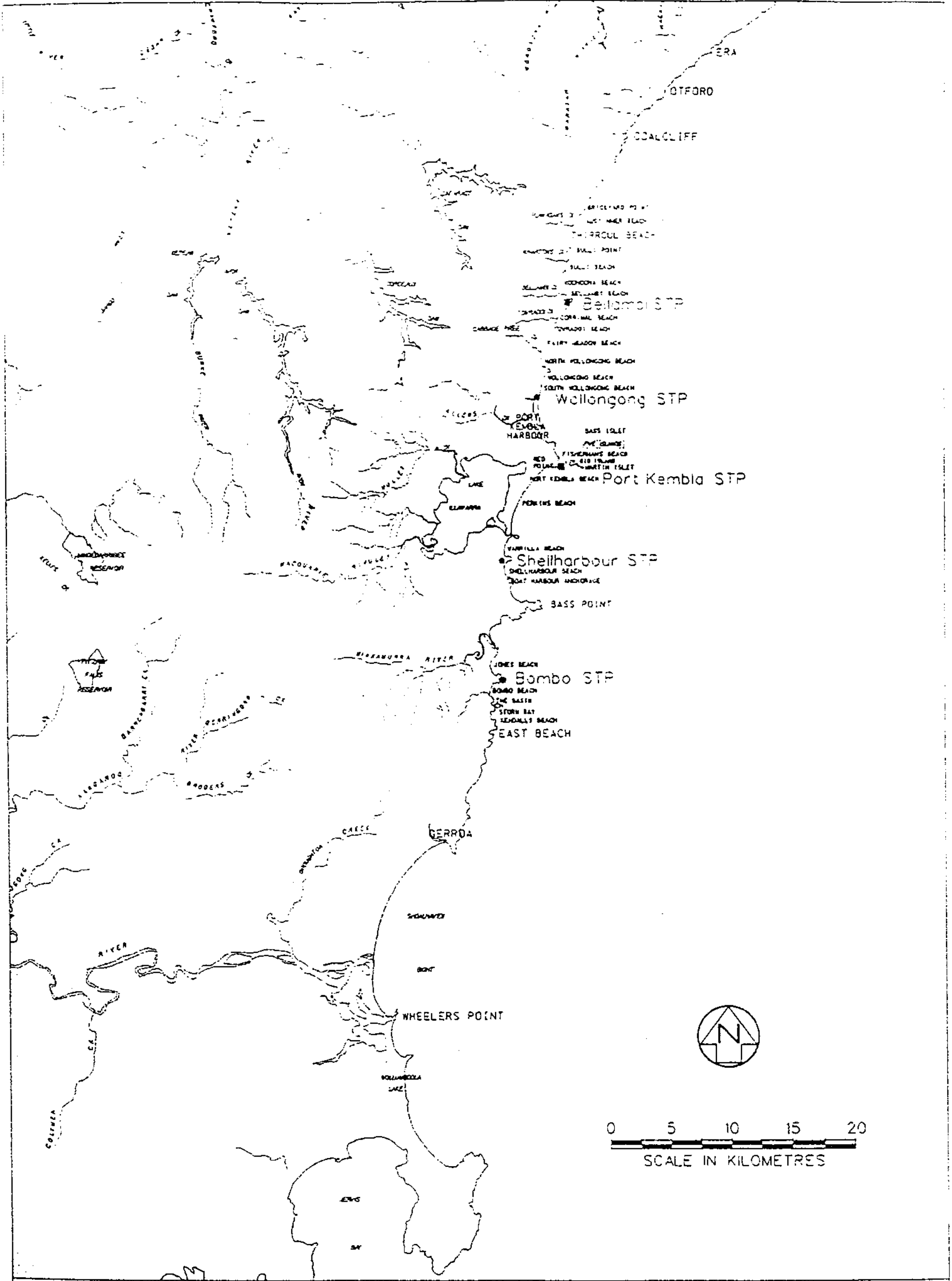
PROBLEM FORMULATION

- **Problem formulation in this risk assessment included:**
  - documenting each of the STPs which discharge to the ocean
  - documenting the characteristics of each of the chemicals
  - consideration of the assessment and measurement endpoints to be studied
  - consideration of the receptors to be assessed
  - development of hypotheses to be tested
- **Receptors included aquatic life, people and wildlife. This presentation will concentrate on mainly how risk was evaluated for aquatic life. A brief description of how the risk to wildlife was assessed will also be presented.**



PACIFIC OCEAN STP OUTFALLS SYDNEY REGION

FIGURE 1-1



PACIFIC OCEAN STP OUTFALLS
ILLAWARRA REGION

FIGURE 1-2

USER: pc5 DATE: 22-JAN-1996 10:24

SCHEDULE 10 SUBSTANCES

- **The Schedule 10 substances include:**
  - polynuclear aromatic hydrocarbons
  - monocyclic aromatic compounds
  - metals and inorganics
  - organochlorine pesticides and PCBs
  - halogenated aliphatic compounds
  - organophosphate pesticides
  - herbicides
  - conventional compounds such as chloride, sulfate, H2S etc
  - other chemicals including acrylonitrile, benzidine, carbaryl, dichlorobenzidine, diphenylhydrazine, MBAS, and nonyl and octyl phenol ethoxylates

Schedule 10 Substances

Polynuclear Aromatic Hydrocarbons
acenaphthene
acenaphthylene
anthracene
benzo(a)anthracene
dibenzo(a,h)anthracene
chrysene
coronene
fluorene
fluoranthene
benzo(b)fluoranthene
benzo(k)fluoranthene
napthalene
benzo(ghi)perylene
phenanthrene
pyrene
benzo(a)pyrene
benzo(e)pyrene
indeno(123-cd)pyrene
perylene
1-chloronapthalene
2-chloronapthalene
trichloronapthalene
tetrachloronapthalene

Monocyclic Aromatic Compounds
benzene
phenol
3-methylphenol
2-methylphenol
4-methylphenol
toluene
ethylbenzene
m+p-xylene
o-xylene
styrene
chlorobenzene
1,4-dichlorobenzene
1,3-dichlorobenzene
1,2-dichlorobenzene
hexachlorobenzene
monochlorophenol
2,4-dichlorophenol
2,4,5-trichlorophenol
tetrachlorophenol
pentachlorophenol

Metals and Inorganics
aluminium
arsenic
barium
boron
cadmium
chromium
cobalt
copper
iron
lead
manganese
mercury
molybdenum
nickel
selenium
silver
tin
vanadium
zinc

Organochlorine Pesticides
aldrin
alpha-BHC
beta-BHC
gamma-BHC(lindane)
chlordane
p,p'-DDT
p,p'-DDE
p,p'-DDD
dieldrin
endosulfan(alpha + beta)
endrin
heptachlor
heptachlor epoxide
methoxychlor
PCBs

Halogenated Aliphatic Compounds
dibromochloromethane
1,1-dichloroethane
1,1-dichloroethene
1,2-dichloroethane
1,1,1-trichloroethane
trichloroethene
tetrachloroethene
carbon tetrachloride
chloroform
bromoform
dichloromethane

Organophosphate Pesticides
chlorpyrifos
dem S-methyl
diazinon
guthion (methyl azinophos)
malathion
parathion

Conventionals
chloride
ammonia
nitrate
nitrite
cyanide
sulfate
chlorine
chloramines
sulfide (as H2S)

Other Organics
acrylonitrile
benzidine
carbaryl
dichlorobenzidine
diphenylhydrazine
MBAS
nonylphenol ethoxylates
octylphenol ethoxylates

Herbicides
glyphosate
2,4-D
atrazine

SCREENING LEVEL RISK ASSESSMENT - EXPOSURE ASSESSMENT

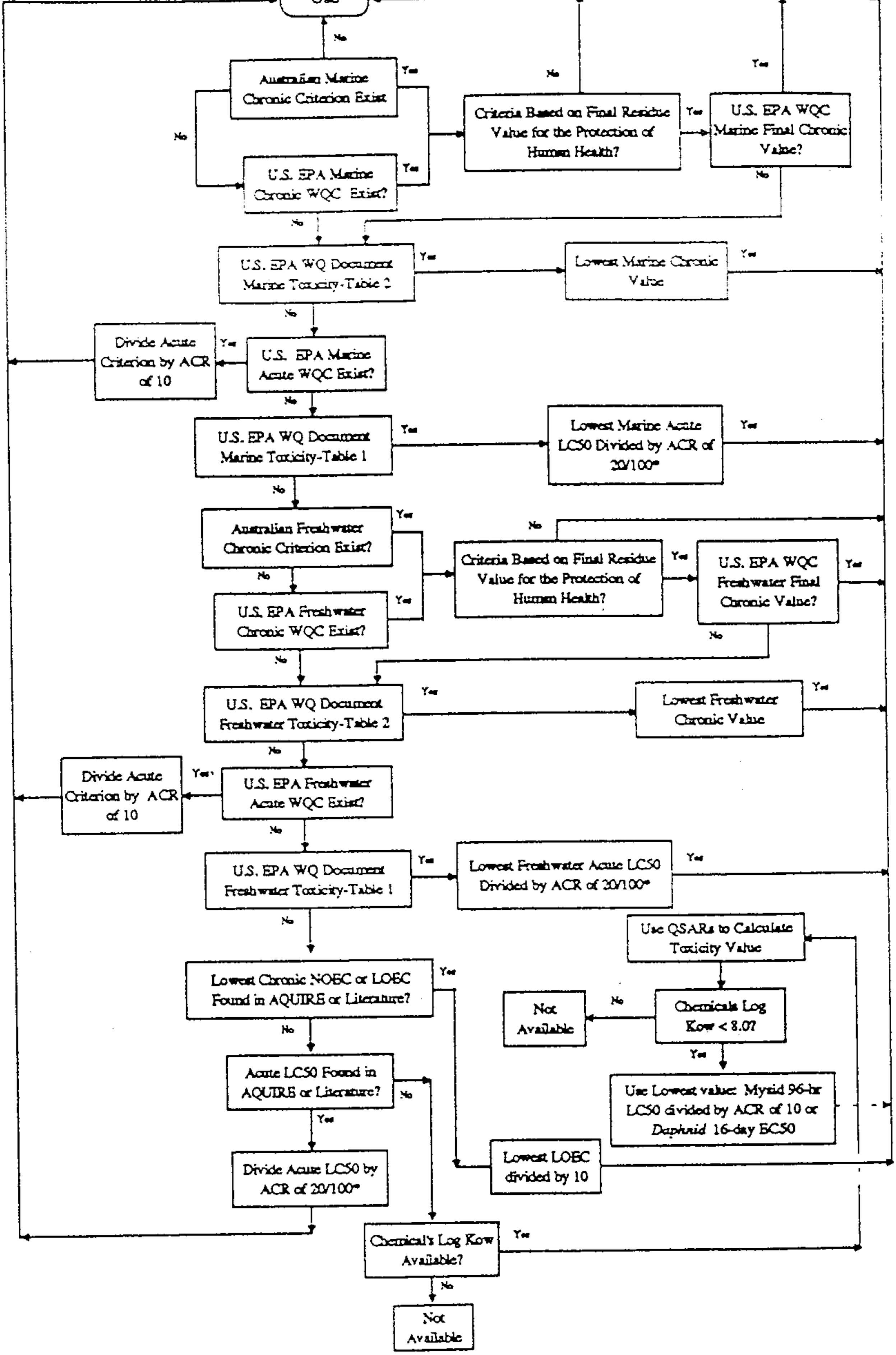
- **Due to the complications of doing trace analysis in seawater the concentration of each chemical in the receiving environment was determined by analysing the effluent prior to discharge and combining this figure with the dilution around each outfall.**
- **In the screening level risk assessment a very conservative estimation of dilution was used. A twenty fold dilution was assumed for the shoreline discharges and 150 fold was assumed for the 3 deepwater outfalls.**

SCREENING LEVEL RISK ASSESSMENT - EXPOSURE ASSESSMENT

- Two levels of exposure were determined. These correlated with short-term acute exposure and longer term chronic exposure.
- Acute exposure was assumed to be the observed maximum or the 95% confidence limit of the distribution of all samples, whichever was larger.
- Chronic exposure was assumed to be the 95%confidence limit of the median of the distribution

SCREENING LEVEL EFFECTS ASSESSMENT

- Water quality guideline values were used as the effects values.
- Chronic guidelines were based on the ANZECC water quality guidelines firstly. If the chemical had no ANZECC guideline the Canadian or USEPA guidelines were used, whichever was more recent. If no guideline existed from these sources a literature survey was conducted mostly using the AQUIRE database. This flowchart shows the decision process.



(Use) = use the resulting value in the screening-level risk assessment
U.S. EPA = United States Environmental Protection Agency
WQ = water quality
WQC = water quality criterion
NOEC = no observed effect concentration
LOEC = lowest observed effect concentration
ACR = acute-chronic ratio
Log Kow = logarithm of the octanol-water partition coefficient
QSAR = quantitative structure activity relationship
* = 20 for non-persistent /100 for persistent chemicals

Figure C-2.
Methodology for Deriving Chronic Toxicological Effects Criterion

SCREENING LEVEL EFFECTS ASSESSMENT

- The acute effects criteria were based on USEPA guidelines which have both chronic and acute values. If no USEPA guideline existed then a literature survey was conducted. The following flowchart again shows the decision process.
- There were a number of chemicals for which no information could be found either for an acute or a chronic criteria or both.

SCREENING LEVEL RISK CHARACTERISATION

- Hazard quotients were used to determine the risk.
- HQ=estimated environmental concentration/ effects criteria
- An acute and a chronic HQ were determined for each chemical
- If HQ>1.0 the chemical was included in the detailed risk assessment
- For chemicals that act similarly if HQ>0.3 then these chemicals were also included in the detailed risk assessment

DETAILED EXPOSURE ASSESSMENT

- For the detailed risk assessment more site specific dilution patterns were used to determine dilution at 50m from each outfall.
- Around the shoreline outfalls dilution patterns were determined using changes in conductivity.
- Around the deepwater outfalls the EMP study provided information about dilution.
- The same set of chemical analyses of the effluents was used for each plant.
- Consideration of dissolved metal concentrations etc would have been used if appropriate.

DETAILED EFFECTS ASSESSMENT

- Initially a probablistic risk characterisation step was proposed which would have required a more detailed assessment of the available literature about the toxicity of each chemical.
- Due to time restrictions etc the detailed risk characterisation step remained deterministic so no new data were included at this stage.

DETAILED RISK CHARACTERISATION

- Again the hazard quotient was used.
- Only those chemicals for which HQ>1.0 were considered to be a potential risk.
- Whole effluent toxicity tests were conducted on each effluent and the dilution required to reach the NOEC were determined.
- Where biosurvey data existed this was assessed.
- The risk at the edge of the initial mixing zone at each outfall was assessed by considering the HQs for each chemical, the whole effluent toxicity test and any biosurvey data.

RESULTS OF THE SWC RISK ASSESSMENTS

- Chlorpyrifos, parathion and hydrogen sulfide were found to be a potential risk at Cronulla, Port Kembla and Bellambi STPs.

WILDLIFE RISK ASSESSMENT

- Due to the lack of information on the effects of many of the Schedule 10 substances on birds and marine mammals the wildlife risk assessment was very limited.
- SWC had analysed samples of penguins, terns and dolphins over the last few years for some of the Schedule 10 substances. The residues found in these organisms were compared to residues found in similar organisms from other industralised and pristine areas. The organisms found off Sydney had residue levels the same or lower than those found in organisms from other industrialised areas.

ISSUES RAISED BY THESE RISK ASSESSMENTS

- **Time constraints on SWC limited what they were able to do in these risk assessments. Some of the areas which were limited include:**
  - detection limits
  - time period over which effluent chemistry data was collected
  - effects criteria determination
  - sediment risk assessment
  - probabilistic vs deterministic
  - uncertainty assessment

ISSUES RAISED BY THESE RISK ASSESSMENTS

- **Detection limits**
  - for a small number of chemicals the detection limits were not low enough and so the chemicals were estimated to be a risk even though they were never detected.
- **Short Time Period for Data Collection**
  - the data for the assessment of risk at the ocean plants for most of the chemicals was collected over a 2-3 month period and so the distributions may not be as representative as might be preferred.
- **Ecological Effects Data**
  - an assumption was made that if the environmental concentration did not exceed the water quality guideline then the hazard was minimal. The water quality guidelines are mostly based on overseas data so there is a question about how protective they are of our ecosystems. Some data is available to show they are protective in most situations.

ISSUES RAISED BY THESE RISK ASSESSMENTS

- **Sedimemt Risk Assessment**
  - limited data were available to assess the risk to benthic organisms so only a screening level assessment could be completed. Also, as was found in the EMP study, the North Head outfall is in the deposition zone from Sydney Harbour. As a consequence no conclusions could be drawn about the risk to benthic organisms at North Head or Malabar outfalls. The other outfalls showed no predicted risks even with the limited data.
- **Probabilistic vs Deterministic Risk Characterisation**
  - Risk assessment is moving more and more towards the use of probabilistic techniques for estimating risk as it can give risk managers more useful information. The method initially proposed by SWC had difficulties and due to the time constraints no other methods were assessed for use.

ISSUES RAISED BY THESE RISK ASSESSMENTS

- **Uncertainty Assessment**
  - only a qualitative description of uncertainty was undertaken by SWC. Quantitation of uncertainty in the results of the risk assessment would have been preferable but was not possible with the data and the time available.

CONCLUSION

- Sydney Water Corporation have undertaken a large risk assessment on the risk to aquatic life and other receptors of the chemicals being discharged from sewage treatment plants.
- As information becomes more available and the techniques become more routine such risk assessments can be used to provide even more environmental management input than this set of risk assessments was able to do.

THE FINNISS RIVER SYSTEM

A NATURAL LABORATORY FOR ECOLOGICAL RISK STUDIES

by

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Introduction

The objectives of my presentation are threefold, namely to:

a) provide summary results of our investigations into the ecological impacts of metal/acid pollution loads from the former U/Cu mine at Rum Jungle, Northern Territory, on the receiving waters of the Finniss River System; and the recoverability of the aquatic fauna that has followed from remedial activities at the mine-site with the consequent reduced pollution inputs to the aquatic environment;

b) outline the fortuitous suitability of the general environmental system for both the *performance and field validation of ecological risk assessment* (ERA), which is primarily due to-

- the very well characterised pollution loadings delivered to the system, in conjunction with,

- a variety of ecological end-points available to provide different foci for ERA studies and the consequent honing and development of ERA methodologies;

c) elaborate on our strategy for improving the resolution and hence predictive strength of ERA studies at this site. The aim is to conjoin the findings of our mechanistic studies on metal kinetics in freshwater fauna to the water quality databases in a way- that will refine the actual measure of dose to the aquatic fauna, which is a fundamental requirement of ERA.

Ecological Impacts on the Finniss River System of Acid-Mine Drainage and Its Abatement

During unabated contamination from the Rum Jungle mine site, generated by the well understood mechanisms broadly described as 'acid-mine drainage', average annual pollution loads of 50 tonnes of Cu and Mn and 20 tonnes of Zn at low pH produced an ecological impact measured primarily in terms of ;

i) geographical scale and degree of severity of detriment, as defined by a) fish diversity, b) total abundances of fishes and c) relative abundances of individual fish species, with

ii) the occurrence of fish-kill events where there was well-characterised water chemistry.

These results also provided an environmental benchmark against which to quantify the ecological benefits of the future remedial activities.

Following remediation of the Rum Jungle mine site, annual contaminant loadings reduced by an order of magnitude but are still appreciable, as judged by contemporary National water quality criteria. Our subsequent ecological investigations have indicated (to date) a substantial recovery in the Finniss River and partial recovery in the more severely degraded East Branch, using most of the ecological end-points of detriment that were employed in our pre-remedial study.

For the Finniss River proper these results are indicative of the low ecological risk posed by the contemporary annual load of contaminants. However, the following ecological end-points that have arisen or are now under investigation may enhance the ecological significance of the contemporary annual loadings;

• the recent discovery of two small and localised populations of a new species (and genus) of freshwater grunter (Fam. Theraponidae), one of which is exposed to contemporary contamination levels,

• benthic algal-mat diversity, abundances of sensitive species of macro-crustacea and the abundance and diversity of benthic macro-invertebrates.

The Virtues of the Finniss River System for ERA studies

The cardinal virtue of this system is the existence of voluminous sets of data on water quality data resulting from daily samplings at gauging stations on both the East Branch and Finniss proper downstream of pollution inflow; these datasets have been generated and managed by the Water Resources Division of the Northern Territory Government over the past 20 years.

It follows that this site must represent one of the most comprehensively known tropical sites in the World with regard to the characterisation of exposure by aquatic fauna to contamination, in the context of;
a) duration of exposure,
b) temporal dynamics of exposure,
c) appreciable variation in annual total load in time,
and at two different scales of contemporary detriment in the East Branch and the Finniss River proper.

In our initial treatments of the databases at ANSTO we have generated probability density functions for dissolved Cu water concentrations measured in the East Branch over recent years. From these functions we can estimate the likelihood of occurrence and duration of water concentrations that exceed particular water quality criteria. Predictions of detriment can then be assessed against field investigation of detriment, and if it has not occurred, contrasted against known Cu concentrations at which fish-kills have been observed to occur. These procedures can provide calibration factors for the ERA.

As outlined above environmental detriment can be defined according to a variety of available ecological endpoints under investigation.

Use of Mechanistic Understanding to Refine Dose Estimation

One of the core pieces of science needed to generate a realistic ERA is to establish a dose-response relationship, where dose is often -taken as being equivalent to exposure. If dose can be more accurately defined then more realism can be injected into the ERA. From our mechanistic studies over the past 15 years on radionuclide/metal kinetics in freshwater organisms, one of the fundamentals distilled out is a definition of that quality of metal in water that best determines its bioavailability and hence real organism exposure, *viz* ;

> *the ratio of the water concentration of the free metal ion: Ca water concentration*

This definition follows from our well-validated finding that many metals are absorbed from the aquatic medium via the Ca pump as metabolic analogues of Ca. Through a combination of metal speciation modelling and this mechanistic understanding the existing databases of water chemistry can be used to recalculate probabilities of exposure to Cu or other metals in a more refined way, with an expected increase in predictability of detriment, again for further validation in the field.

An ERA methodology that is mechanistically underpinned also has the appeal of enhanced transportability to other mine sites, especially those with similar faunas in tropical Australia.

A potential disadvantage of the Finniss River System for ERA studies

Field validation of ERA predictions may be confounded by the following observations in the zone of current ecological recovery within the East Branch. Two species of small rainbowfish are now occurring at high abundances at Cu water concentrations as high as 1-5 mg/L; concentrations observed to have been associated with fish-kills during the 1973/74 studies. One obvious hypothesis to explain this phenomenon is that these populations have evolved a resistance to these pollution loadings over their 40+ years of exposure. Both species have high natural rates of increase, due to their capacity to complete 2-3 life cycles per year, providing in the vicinity of 120+ generations that have been exposed. If this interpretation is correct, and these two species represent the 'tip of the iceberg' of a resistant fauna, then the use of the fauna in the validatory phase of ERA may provide an underestimate of the likelihood of detriment, especially if the outcomes were transported to comparable but unexposed fauna. This possibility needs to be evaluated.

RISK COMMUNICATION TO DECISION MAKERS: SOME NOTES

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Informing decision makers about communicating with their community

It is now well known that the community and decision makers employ more than probability times size of effect judgements in assessing acceptable risk in terms of developments and technologies. Otherwise, risk standards for all structures would be much more similar. The problem has been seen by many professionals as one in which the general community needs to be communicated with to ensure that with accurate information is given and appropriately understood by the community and therefore professional judgement will be accepted.

Such a philosophy is in line with the early psychological work on community assessment of risks which tended to show that the community over-estimated low probability risks and underestimated high probability risks. This apparent inability to view risks objectively has led to a large psychological and sociological literatures attempting explain the "non rational" means upon which the community make decisions. Thus psychological concepts such as "dread" and "vividness" have become commonplace. Social psychologists have classified groups with categories such as NIMBY. Risk communicators have waxed lyrical about "outrage" and have developed models of risk amplification and criteria (although yet unproven) against which risk communications can be evaluated. Consultancy fortunes have been made by individuals hired to assist agencies to enable the community to "see the light". Once this occurs a return to rational and orderly planning for the public good can be expected.

From this perspective what we, as social scientists, should be doing is to develop methods in which enough information is presented to the community in persuasive ways, so that public comment will assist in the development of best rational plans. The social scientist's job in regard to the decision makers is to make them aware of their approach and information gathering techniques so that institutional support to credible risk communication and public involvement plans can be confidently given.

This has been demonstrated by Fischhoff (1995) in his succinct analysis of the development of the risk communication literature. The stages identified by Fischhoff are shown in the Table below.

Table 1 Development Stages in Risk Management (from Fischhoff,1995)

- *All we have to do is get the numbers right*-experts develop probability in an in house setting.
- *All we have to do is tell them the numbers*-experts clarify the uncertainties surrounding probability estimations.
- *All we have to do is explain what we mean by the numbers*-experts match the information to people's mental models of the risk issue.
- *All we have to do is show them they've accepted similar messages in the past*-risk comparisons are given to emphasise rational aspects of acceptable risk.
- *All we have to do is show them that its a good deal for them*-emphasis is given to the benefits of accepting risks
- *All we have to do is treat them nice*-emphasis is placed on ensuring that the community is treated respectfully and mutual trust developed
- *All we have to do is make them partners*-active public involvement is encouraged
- *All of the above*-any program may require a combination of approaches

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While active listening to the community obviously increases at each stage the emphasis is still on getting technically good projects through. "Other things being equal, risk data should be collected, vetted, and presented in ways that suit the audience they are intended to convince" and "attracting the interest of people whose minds are still open will require very special efforts" (Fischhoff, 1995). Nevertheless, Fischhoff acknowledges risk communication should not "paper over situations (or conflicts) where people are getting a bad deal".

This view of risk communication, despite its sophistication, assumes that the decision maker should be relying on expert judgement. There are many however who would dispute this view. They do not see the decision makers or their professional advisors as particularly rational nor the communications between them as very well organised. Freudenberg (1992) for example, suggests that "institutional muck up" is the greatest potential threat for major catastrophe when risk decisions are made and implemented.

Communications with and between decision makers.

It is often overlooked that quite early studies of professionals, even statisticians, showed that their decisions relating to probability and risk showed the same biases as those evident in the general community (e.g. over extrapolating from small amounts of data). In the mainstream managerial literature it has been clearly demonstrated that values and experience modify decision making.

Farrands (1993), for example has shown that some scientists can over-emphasise risk components of issues which pertain to their own interests. Politicians tend to attend to those issues which are politically significant and have been brought to their attention by a variety of stakeholders. Engineers can design to improbably high standards to avoid professional liability (as some currently think is the case for dam safety). Chief Executive Officers (CEOs) of government departments are wont to attempt to get investment in their areas of influence, and this includes safety.

Thus the conversations and negotiations between decision makers are biased by the usual personal values. Institutional cultural and power struggles between government agencies also often occur and these can be as "emotive" as those associated with the interaction between the bureaucracy and the public. There are always a series of value judgements in deciding what levels of safety are sufficient whether its made explicit or not. The size of the buffer zone for the Kwinana Industrial site, for example, was set more by a CEO's perceptions of what standards a future community might desire than direct community information from an intensive survey of local residents. It is interesting to note that on this particular occasion the community was more risk accepting than the expert. It is the fear of the reverse that has caused decision makers to become interested in risk communication.

In summary the decision making styles of the community and the bureaucracy is more alike than has been often admitted. Rationality, values and emotions are used by both parties.

So how do we negotiate risk problems?

One's initial response to the arguments that when it comes to information processing there is no best logic on either side is to throw up one's hands in despair. Will we ever get it right? While such a reaction is understandable it is too despairing. The problems in risk decision making parallel those in all other spheres. All decisions have elements of probability and uncertainty. The risk communication literature sharpens these problems as it often separates the risk dimension from other aspects of a multi-objective or multi-faceted decision making. The risks of death or illness, once highlighted frame the problem in a way in which the consequences of failure or mistakes are vivid. (Interestingly some risk communicators suggest avoiding vividness to minimise prospects of risk amplification.)

For example, framing housing siting questions in areas where there is heavy industry could include issues such as local employment, needs for local infrastructure, aesthetics, transport as well as personal risks associated with living near industry. Discussing only air quality or industrial accidents in the absence of such wider issues highlights uncertainty and personal vulnerability. The extraction of risk from other areas of decisions is a relatively new cultural phenomenon.

There is obviously no easy fix to this problem. There is the need for bureaucracies (especially those associated with science and technology) to go back to the basics of their role in the community. This will include the development of consistent communication policies so that trust can be developed. This trust will enable a healthy and accountable professional leadership role to be evolved (e.g. Syme,1994, Leiss,1995). Our research (Syme and Williams, 1994), on the public acceptance of drinking water quality showed that trust was more important than physical water quality parameters when judgements of acceptability were made. The maintenance of trust will allow the establishment of effective public discussions on issues relating to professional liability and the definition of informed consent.

The concept of informed consent is one which has not been well dealt with by professionals. Australian research on dam safety (Bishop and Syme 1992) has shown that the public do not necessarily want unfettered involvement but insist on a certain level of public accountability. If this accountability is not shown there is a much more unsympathetic view of the fate of the decision maker if accidents do occur! As yet there is insufficient social research which will enable us to define procedural justice in this area despite the increasing urgency of the problem (e.g. see Chess et al, 1995).

What is Ecological Risk?

These notes have pertained to risk in general without focusing on the precise topic of this meeting: ecological risk. As yet there has been little in the way of empirical study on exactly what ecological risk is perceived to be. Attached are some details of some very preliminary research which parallels the early psychological research on risk perceptions generally (McDaniels, et al. ,1995). Perhaps the list of risks and consequences tested should be the subject of critical discussion for this meeting.

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Table III. Ratings of 65 Items on Overall Risk to Natural Environments[a]

Item	Mean
Nuclear war	2.69
Loss of animal species	2.53
Depletion of ozone layer	2.51
Loss of habitats for animals/fish	2.51
Loss of plant species	2.51
Deforestation (permanent removal of forest cover)	2.43
Loss of wetlands	2.42
Air pollution	2.26
Disposal of untreated sewage in oceans	2.25
Emission of ozone depleting gases (CFCs)	2.22
Clearcutting forests	2.11
Climate change (e.g., global warming)	2.06
Acid rain	1.99
Conventional warfare	1.99
Production and disposal of toxic chemicals	1.99
Belief that humans have dominion over nature	1.77
Waste production in modern society	1.68
Consumption levels in modern society	1.63
Population growth	1.61
Lack of regard for nonhuman rights	1.60
Nuclear power plants	1.57
Intensive commercial fishing	1.50
Value system oriented toward material wealth	1.44
Aerosol cans	1.43
Driftnet fishing	1.39
Energy production from nonrenewable resources	1.38
Drought	1.33
Driving automobiles	1.28
Earthquakes	1.28
Urbanization (continued growth of large cities)	1.28
Poaching (illegal harvest of wild animals)	1.26
Transporting oil	1.15
Cigarette smoking	1.15
Disposal of treated sewage in oceans or lakes	1.11
Burning of waste materials (incineration)	1.07
Society's desire for continued economic growth	1.07
Soil erosion	1.06
Floods	1.04
Large scale/multinational business	1.04
Disposal of municipal waste in landfills	1.03
Increasing reliance on technology	.99
Biotechnology (genetically altering plants and animals)	.99
Development of land for housing	.92
Pesticides	.90
Meteors colliding with Earth	.89
Dams on rivers	.86
Hunting of animals	.85
Volcanos	.82
Mass production farming practices	.82
Disconnection of modern life from natural environments	.76
Beef production	.75
Air conditioning	.75
Mining	.74
Capitalism	.61
Fertilizers	.53
Urban water usage	.50
Irrigated agriculture	.47
Transplanting of animal and plant species	.32
Collecting wilderness souvenirs (e.g., plants, seashells)	−.53
Television	−.56
Golf courses	−.72
Tourism and travel	−.86
Fireplaces	−1.42
Scuba diving	−1.78
Outdoor recreation (e.g., skiing, hiking, climbing)	−1.85

[a] Scale ranged from −3 (poses no risk) to +3 (poses great risk).

high associations between some scales (e.g., social benefit and personal benefit, $r = .96$) and no association between others (e.g., social benefit and availability of alternatives, $r = .03$). More than half of the characteristics had correlations of .80 or higher with general riskiness, and five scales (i.e., certainty of impacts, destructiveness, emotionality, goodness, and acceptability) had correlations of .90 or higher.

The bottom row of Table IV shows that several scales had relatively low correlations with general risk to nature including avoidability ($r = .13$), controllability ($r = -.22$), ability to regulate ($r = .11$), and availability of alternatives ($r = .21$). Interestingly, these four scales all reflect aspects of society's ability to manage the risk. The findings of such low associations with risk to nature is a contrast with studies of perceived risk to humans, where controllability over the item has been found to be highly correlated with overall riskiness (e.g., Ref. 16).

3.3. Factor Analysis of Scale Intercorrelations

The matrix in Table IV indicated a substantial degree of correlation for many pairs of scales. This suggests that there may be some underlying dimensions that could more compactly explain the overall variance in the data. Factor analysis has been employed in many human

Table IV. Intercorrelations Among 31 Judgment Scales

	Certainty	Adaptability	Avoidability	Relevance to life	Controllability	Duration of impacts	Societal benefits	Personal benefits	Scope of impacts	Number of people	Species loss	Destructiveness	Emotionality	Equitableness of outcomes	Ethicality of event	Immediacy of effects	Infringement on rights	Reversibility of impacts	Human suffering	Animal/plant suffering	Understandability	Predictability	Recognition of impacts	Observability of impacts	Media attention	Regulatability of risk	Availability of alternatives	Goodness	Human health risk	Generally acceptable event	General riskiness
tainty	—																														
ptability	−.92	—																													
idability	.15	−.21	—																												
evance to life	.52	−.45	.04	—																											
trollability	−.12	.08	.79	.20	—																										
ation of impacts	.81	−.81	.27	.68	.13	—																									
ietal benefits	−.58	.54	−.08	.02	.42	−.29	—																								
sonal benefits	−.51	.49	−.12	.18	.38	−.23	.96	—																							
pe of impacts	.64	−.62	.12	.69	.02	.85	−.28	−.16	—																						
nber of people	.63	−.53	.09	.77	−.11	.76	−.22	−.07	.90	—																					
cies loss	.83	−.87	.24	.47	−.04	.85	−.53	−.48	.74	.60	—																				
tructiveness	.90	−.92	.06	.47	−.26	.84	−.61	−.55	.74	.69	.93	—																			
otionality	.87	−.88	.36	.52	.03	.82	−.64	−.59	.68	.59	.88	.89	—																		
itableness of outcomes	−.63	.69	−.24	.01	.27	−.46	.80	.79	−.41	−.27	−.69	−.73	−.76	—																	
cality of event	−.76	.80	−.56	−.35	−.17	−.74	.65	.61	−.62	−.45	−.81	−.78	−.93	.79	—																
ediacy of effects	−.48	.47	.25	.10	.60	−.12	.67	.65	−.09	−.13	−.41	−.55	−.45	.68	.37	—															
ngement on rights	.74	−.79	.47	.17	.23	.77	−.40	−.40	.59	.43	.90	.78	.83	.62	.82	−.27															
ersibility of impacts	−.77	.86	.17	−.34	.15	−.77	.48	.45	−.61	−.50	−.77	−.84	−.74	.66	.69	.37	−.65	—													
an suffering	.77	−.64	.14	.34	−.48	.56	−.74	−.65	.61	.70	.63	.80	.70	−.68	−.58	−.64	.43	−.58	—												
mal/plant suffering	.82	−.84	.15	.27	−.19	.72	−.62	−.60	.58	.47	.93	.91	.84	−.78	−.78	−.58	.89	−.72	.69	—											
erstandability	−.76	.78	.01	−.13	.37	−.42	.72	.71	−.25	−.20	−.67	−.76	−.71	.72	.61	.75	−.60	.65	−.65	−.79	—										
ictability	.80	−.82	.19	.27	−.08	.54	−.56	−.55	.33	.31	.73	.77	.77	−.61	−.66	−.58	.73	−.61	.59	.80	−.88	—									
ognition of impacts	.44	−.37	.36	.10	−.61	.04	−.60	−.57	−.05	.02	.29	.45	.31	−.47	−.20	−.84	.18	−.23	.55	.48	−.73	.58	—								
ervability of impacts	.67	−.64	.31	.71	−.52	.37	−.50	−.47	.25	.32	.54	.68	.55	−.53	−.36	−.82	.41	−.47	.63	.65	−.78	.71	.77	—							
ia attention	.79	−.65	.00	.42	−.20	.52	−.56	−.49	.47	.57	.56	.69	.68	−.54	−.53	−.46	.49	−.54	.77	.62	−.68	.72	.39	.59	—						
ulatability of risk	.24	−.27	.67	.28	.81	.37	.29	.24	.16	.11	.15	.06	.25	.05	−.31	.33	.37	−.20	−.18	.06	.07	.21	−.40	−.20	.16	—					
ilability of alternatives	.24	−.31	.88	.39	.83	.48	.03	.04	.38	.19	.35	.18	.48	−.16	−.60	.32	.53	−.21	−.07	.18	.03	.20	−.41	−.24	.06	.72					
dness	−.80	.78	.23	−.22	.24	−.61	.88	.84	−.52	−.44	−.74	−.82	−.88	.86	.87	.64	−.66	.67	−.81	−.80	.79	−.73	−.51	−.57	−.68	.01	−.21	—			
an health risk	.74	−.59	.09	.38	−.37	.53	−.67	−.59	.57	.68	.54	.71	.66	−.57	−.55	−.54	.36	−.52	.95	.58	−.59	.54	.48	.52	.76	−.07	−.02	−.77	—		
erally acceptable event	−.84	.84	−.42	−.33	.00	−.73	.77	.72	−.61	−.48	−.83	−.85	−.94	.83	.96	.49	−.81	.73	−.73	−.84	.73	−.73	−.36	−.47	−.64	−.20	−.45	.95	−.69	—	
eral riskiness	.93	−.89	.13	.43	−.22	.80	−.70	−.64	.70	.66	.87	.95	.91	−.77	−.83	.57	.75	−.80	.87	.88	−.78	.78	.46	.64	.78	.11	.21	−.91	.83	−.91	—

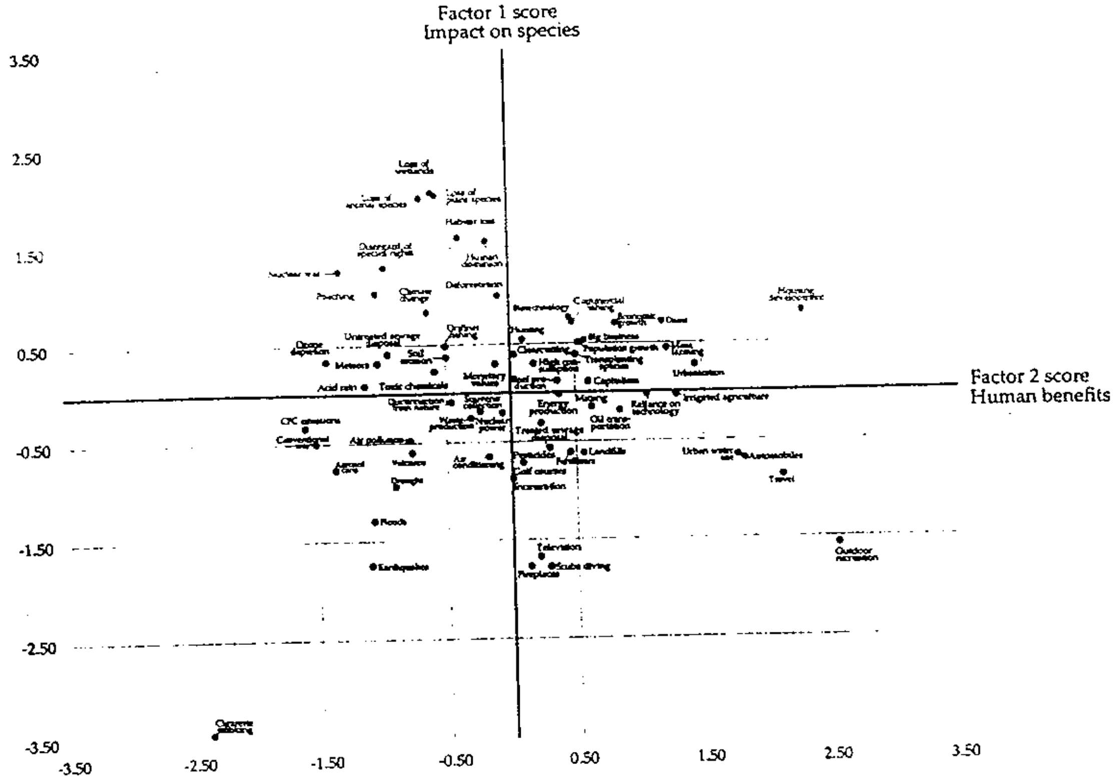

Fig. 1. Map of Factor 1 vs. Factor 2.

perceived as having a high impact on nature and low *human benefits* include nuclear war, poaching, and the belief that humans have dominion over nature.

The relative position of each item in terms of Factor 1 (*impact on species*) and Factor 3 (*impact on humans*) can be seen in Fig. 2. On this map, the vertical axis represents Factor 1 and the horizontal axis represents Factor 3. Items in the upper right quadrant are those which are construed as posing high impacts on nonhuman species and high *impact on humans*. This quadrant consists of the most notable environmental threats including climate change, ozone depletion, population growth, and nuclear war. The right lower quadrant displays items that have minimal *impact on species*, but are seen as having high *impact on humans*, including cigarettes, television, and air pollution. In the upper left quadrant are the items that greatly affect species while at the same time have limited *impact on humans*, including the loss of animal and plant species, the loss of wetlands, poaching, and hunting. Finally, in the lower left quadrant are the items that have minimum impact on both species and humans, including collecting wilderness souvenirs, golf courses, scuba diving, and fireplaces.

3.5. Relationships Between Factors and Perceived Risk to Nature

Next, we consider how these factors are correlated with the respondents' perceptions of the overall riskiness of items for natural environments. Although it will eventually be important to investigate the relation of this factor structure and expert assessment of ecological risks associated with each item, currently we only have data regarding the relation between the factors and our respondents' ratings of general ecological risk. *Impact on species* (Factor 1) not only accounted for the greatest amount of variance in the factor model, it also had the strongest correlation with general riskiness ($r = .58$; $p < .01$). In addition, perceived human benefits ($r = -.51$; $p < .01$), and *impact on humans* ($r = .48$; $p < .01$) were strongly correlated with general ecological risk.

In contrast with other risk perception studies focused on technological hazards and human health, no correlation was found between perceived avoidability/controllability and perceived general ecological risk. This result suggests that *avoidability* may be seen as more associated with those activities involved in risk

APPLICATION OF ENVIRONMENTAL RISK EVALUATION TO INDUSTRY

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SUMMARY

Funds available for environmental risk reduction are limited. An organisation with many sites with environmental risks, needs an effective and efficient system to generate and evaluate improvement options. ANSTO Safety and Reliability has developed such a system, based on postulated hazardous scenarios, which uses three main environmental factors. These are the intrinsic hazard of the material, the sensitivity of the site environs and the effectiveness of the transfer route used by the material to reach receptors in the environment.

The environmental risk of each postulated accident scenario is calculated from incident specific estimates and these factors, and the scenarios are ranked. Proposals for risk reduction can then be ranked by effectiveness (reduction in risk score) or efficiency (reduction in risk score per dollar). The calculations and estimated parameters are fully available to the user, enabling the results to be easily checked and verified by another person.

This method enables an organisation to plan the spending of its environmental budget to achieve maximum impact without spending excessive resources quantifying the issues. It is consistent with the risk management process described in section 4 of AS 4360 - 1995 and provides a framework for management to demonstrate that they have been systematic in their assessment of environmental risk.

INTRODUCTION

AS/NZS 4360:1995 provides a generic guide to assist in the risk management process and particularly in the identification, analysis, assessment, treatment and ongoing monitoring of risks. This general guide could be used for all types of risks and thus could be used for environmental risks. In this paper we present a system which assesses environmental risks from accidents and is compatible with AS/NZS 4360:1995.

Many organisations have a number of sites with various surrounding land types and use a wide variety of environmentally hazardous materials. With an intention to reduce the environmental risk from possible accidental releases from their operations, the organisation needs to be able to assess which site and which particular improvement options should be addressed first. Management has a duty to spend the environmental improvement budget in an efficient and cost effective fashion. Naturally, sufficient funds need to be provided to comply with legal requirements but many organisations desire to do better.

The problem could be typified by an example where two sites are considered. The first could be located near a local creek which flows into a wetland area and uses aromatic solvents in its process. The second site could use mercury in its process and be bounded on one side by a State Park with many less common species of birds. With a limited budget, the organisation needs to decide which of the various options for these two sites to choose. This choice is difficult to make and also difficult to justify, either to staff within the organisation or to external agencies. These difficulties arise from the value judgements inherent in assessing whether a kill of fish is more or less acceptable than a kill of birds, how to balance short term and long term effects and the intrinsic uncertainty in assessing the likelihood of accidents occurring which would damage the environments. This choice is made even more difficult when local human populations are also considered.

BACKGROUND

Cameron (1995) states that no country examined had a well developed methodology for ecological risk assessments (ERA) for accidental releases and that studies on ecological effects tend to concentrate on contaminated land. In most cases, studies had concentrated on the frequency of release as the risk determinant. This was assessed as due to the newness of the subject and the difficulty associated with multiple targets and endpoints for determining the consequences. Cameron recommended a screening approach for determining whether an ERA was required. The screening approach was based on the toxicity of the released material, the pathways for reaching the receptors and the sensitivity of the environment.

The method described in this paper follows the approach of Cameron and can be used for screening but is specifically targeted to ranking accident scenarios by environmental risk and includes human effects as well as both local and global environmental effects.

Conceptual Framework of Consequence Assessment

In 1992, Brown and Reinert provided a conceptual framework for ecological risk assessment that uses three primary considerations: contaminant variables, site-specific factors and exposure pathways. For a significant ecological event to occur, all three of these considerations must favour transport of harmful materials to the affected environment. Three similar considerations are suggested by Norton, et al. (1992) who advocate incorporation of the stressor (the material that causes stress within the environment), the ecosystem at risk and the effects of the stressor on the ecosystem. Consideration of the pathway and effectiveness of the stressor's transport along the pathway to the ecosystem is implicit within their suggestion. We have chosen to use three factors: a hazard (a material that would have adverse effects on some aspect of the ecosystem), an environment local to the site where the hazard is stored or used and the transfer routes that are used by the hazard to reach the environment. This requires production of information on each hazard, the environment around each site and the transfer route that would be used by the specific hazard to reach the receptor organisms in the local environment.

Different techniques exist to combine the primary factors (hazard, site environs and transfer route) to form a consequence description for an accident scenario. Obviously any of the factors could be sufficiently low so that there is no significant effect on the environment. This could be due to the material being innocuous, the environment impervious to harm or there being no pathway for the material to reach the receptors in the environment (Cameron 1995). Whether different scores should be added, multiplied or combined with weightings has been discussed at length in the literature without consensus being reached (Garetz 1993; Keenan, Finley & Price 1994; Nicholls 1992; Zach & Keey 1995). Discussion also exists on whether the qualitative information in the scenarios is lost by the use of scores or whether "a means of adding or comparing risks of different types is needed if an aggregate criterion is to be met, alternatives compared or priorities set." (Nicholls 1992, p5/19). In the model presented here we have chosen to multiply numerical scores for hazard, site sensitivity and transfer routes to generate consequence scores. Multiplication was applied as a high consequence score could only be generated if all the individual factors were high, while a low consequence score could be generated if only one of the factor scores was low.

Value Judgements

Another area fraught with difficulty is the limitation presented by missing data and the necessity for the incorporation of value judgements. AS/NZS 4360:1995 advises that the information to be searched includes historical records, operating records, published literature and site audit reports. This list of information will contain qualitative data as well as quantitative data and can be supplemented by staff memories. Nicholls (1992) suggests using quantitative scores for effects that are qualitative and using weightings to combine different aspects of the scenarios. These aspects could include the assignment of a higher or lower weighting to a human carcinogen or a fish toxin as discussed by Zach & Keey (1995). They recommend the use of a technical panel to generate the scores, taking account of the data limitations and acknowledging the value judgements inherent in the scoring. Aesthetic values are one area where it is both difficult to quantify and the use of value judgements can not be avoided. However, it is generally acknowledged that where value judgements are included in an assessment, they must be recorded and open for examination (Norton 1992). The anthropogenic orientation inherent in most environmental assessments is also being questioned with the US EPA recommending that ecological risks should be ranked equally with human health risks (US EPA 1992).

The model presented here uses a technical panel to produce the scores used for ranking the accident scenarios. The reasoning for assessments and the data used in the assessment is documented to allow for revision and checking. There are three consequence scores that are developed, one for human health effects, one for the local environment and one for the global environment (global warming and ozone depletion). We have chosen to explicitly allow the assignment of weightings for each of these consequence scores and have combined these scores by addition. The explicit assignment of weightings enables the degree of anthropogenic orientation to be documented. The addition of consequence scores results in a single total consequence score which can be used for consequence ranking of the scenarios.

Uncertainty

Keenan, Finley and Price (1994) state that the uncertainty in exposure assessments used as part of the environmental risk assessment process possess less uncertainty than other steps in the assessment, such as hazard identification and dose response of receptors within the local environment. The question of uncertainty and presentation of error bars or uncertainty ranges is also not resolved in the literature. Part of the difficulty lies in the interpretation of two overlapping values with uncertainty ranges. It can be argued that even though the "real" results have the uncertainty ranges shown, the ranking of the results does not change due to similar assumptions and processes being involved in the determination of both values. Alternatively, if different people have been involved in the determination of the values, completely different assumptions may have been used and the uncertainty ranges may reflect the uncertainty in the relative values as well as the "real" values.

Elliott and Horowitz (1994) advise that ranges of risk, rather than single-value conservative risk estimates should be communicated to legitimise risk analysis whereas Garetz (1993) advocates the use of single point estimates in order to simplify the analysis and reduce the disputation on what the results mean. Nicholls (1992) discusses the use of sensitivity studies or Monte Carlo simulations. However he points out that the results of sensitivity studies are difficult to effectively communicate to decision-makers and the general public. In the model presented here, we have chosen to use single best estimate values. This was done to simplify the assessment results and one of the clients insisted on the use of single point values and not ranges of risk. This was argued on the basis of simplicity for effective communication to the managers and other staff in the organisation. We consider effort is better directed towards ensuring consistency rather than estimating and processing uncertainty bounds.

Risk Estimation

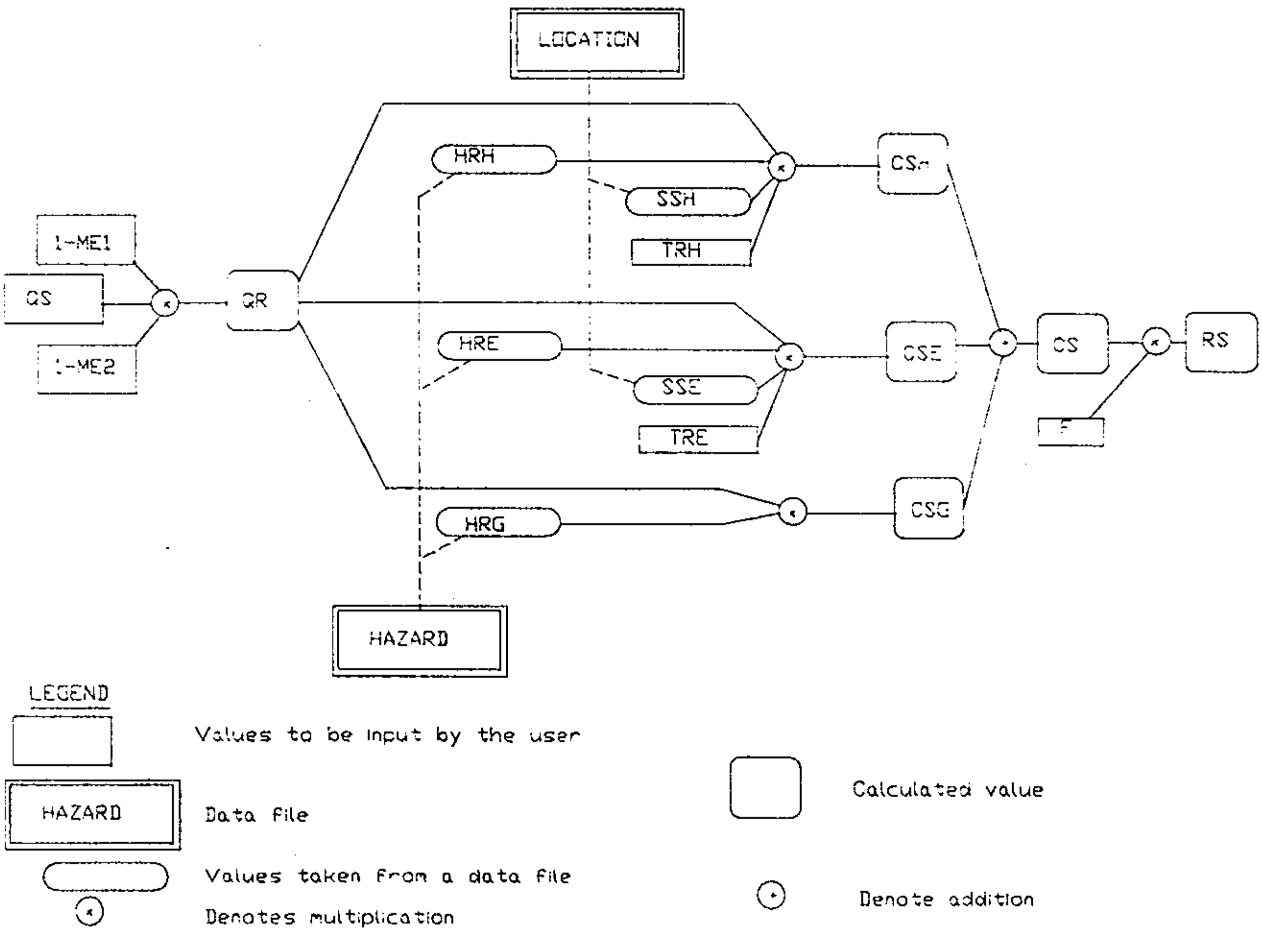
The use of environmental risk assessments for resource allocation has been discussed by the US EPA (1990) and they recommended that efforts should be targeted on the basis of opportunities for the greatest risk reduction. This implies that sites with high environmental risks should be examined first for ways to reduce environmental risk and then sites with lower environmental risk should be examined. Garetz (1993) advocates a risk-based resource allocation system where the amount of money allocated to reduce risk is directly proportional to the risk score. The approach we have adopted is to rank proposals for risk reduction by both total site risk reduction and risk reduction per dollar spent on a risk reduction proposal.

The decisions on which sites and which accident scenarios will be addressed first and how much money should be allocated is not made by this method. The decision is a political one which will include factual data, technical opinions and emotional views. The method described in this paper provides the decision makers with factual data and some qualified technical opinions.

METHOD

The overall method is graphically displayed in Figure 1 which sets out the interaction of the various estimated parameters. The differing expertise of personnel within the organisation is utilised in estimation of different factors incorporated into the technique. The expertise of environmental specialists is used to produce hazard ratings for the different chemicals used on the sites and site sensitivity ratings, while site based personnel's knowledge is used in the estimation of accident scenario size and frequency.

The environmental hazard score for the chemicals is estimated by considering the toxicity to flora and fauna, biodegradability and the propensity to affect habitats through fire, visual impact, degradation of the soil, etc. As ecotoxicity develops the methods for estimating the environmental hazard score may become less dependent on judgements by environmental experts. The hazard rating for effects on humans is estimated by summing weighted scores for the toxicity, fire risk, aesthetic impact and public perception. The global hazard score is estimated by the materials ozone depletion capacity, greenhouse contribution and bioaccumulation. Bioaccumulation is included in the global hazard rating as it will affect flora and fauna for a long time and is very likely to extend for a considerable distance around the site.



Codes are defined at the end of the paper

Figure 1 Model for estimating environmental risk

Technique Application

The technique developed builds on lists of hazardous substances and operating practices at each site in the organisation. This could be generated during environmental audits, other site visit reports or by site staff. Using an experienced analyst, the site knowledge of local staff and various identification techniques such as a Rapid Ranking Study or brainstorming, a list of potential incidents is generated. This is consistent with AS/NZS 4360:1995 para. 4.2 which lists some steps in risk identification. An incident record is created for each postulated release at each location in which a hazardous material is stored or used. The likely quantity to be released is calculated from estimates of the quantity spilt and estimates of the effectiveness of mitigation systems. If historical data are not available, the frequency (or likelihood) of the event is based on industry experience. This work is best done by a team, or drafted by one individual and reviewed by a multidiciplinary team. The approach can be similar to the Rapid Ranking approach advocated by Tweeddale, Cameron & Sylvester (1992), with the team comprising a vertical slice of the organisation, including persons with shop floor knowledge of operating practice. In large operations the team membership would change as different activities are covered.

Incident records are linked to the material and site data files. Incident consequence scores are computed using the material and site ratings from these files and incident specific data (other than estimated incident frequencies). These ratings are prepared separately from the incident records as different expertise is needed. The incident consequence score and an estimate of the incident frequency are combined to give the incident risk score. All proposals are examined to determine the reduction they would make to the sum of risk scores. This risk reduction estimate gives the benefit element of proposal cost benefit assessment.

Ratings

The consequence score for each identified potential incident is developed from incident specific estimates using numerical ratings, which although being much simpler, are similar in nature to those of the Hazard Ranking System used for the Superfund sites in the USA (USEPA 1992). The ratings, described below, provide a relative ranking (rather than an absolute measure). Expertise from a range of disciplines is combined to produce these values.

Hazard Rating. Each material is given a rating of its hazard to people, the local environment and the global environment. These ratings are developed from weighted scores of the material's toxicity, flammability, bio-accumulation, propensity for habitat destruction and persistence in the environment. These weightings and scores are explicitly assigned by the user of the model so that the results can be checked, factor by factor. The weightings for the human, environment and global scores may be varied. This enables the three scores to be given different weightings depending on the desired anthropogenic orientation of the analysis.

Site Sensitivities. Each site is given a rating representing the extent to which the local environs are sensitive to the release of hazardous material, with respect to nearby people and the nearby environment. These ratings are developed from weighted scores, for relevant specific characteristics, assigned by environmental scientists and site staff with local knowledge. The population density around the site and any relevant demographic features are used to assign the site sensitivity for people.

Transfer Routes Score. For each incident, transfer route effectiveness scores are assigned for the effectiveness of transfer of the hazardous material to the local human population and the local environment. These scores take account of the nature of the material (gas, liquid, solid, etc) and the pathways that the material could take to reach the receptors (groundwater, stormwater, air, drinking water, the biota, etc).

Equations Used

The quantity released is an estimate of the amount of material released from the site per incident, taking into account the effectiveness of the mitigation systems.

Quantity released (QR) = Quantity spilt x fraction not contained by mitigation systems

The algorithms for the consequence scores (CS) are:

CS (human) = QR x HR(human) x SS(human) x TR(human)

CS (ecological) = QR x HR(ecological) x SS(ecological) x TR(ecological)

CS (global) = QR x HR(global)

where: HR = material hazard rating;
SS = site sensitivity rating;
TR = transfer route score.

The total incident consequence score is the sum of the consequence scores for each of the three types of effects. This total score, multiplied by the estimated incident frequency yields the incident risk score which is used to rank the environmental risk of the incidents.

CS = CS (human) + CS (ecological) + CS (global)

RS = CS x Frequency

A fictitious example could be a site using aromatic solvents stored in a bunded tank located in Gosford next to a stream leading to wetlands. Details of the calculations are given in table 1.

Proposal Prioritisation by Risk Reduction

In essence, improvement proposals reduce one or more of the incident specific variables eg:

- Reduce the hazard rating by a change to a less toxic material;
- Reduce the quantity of hazardous material stored and thus the quantity released on failure;
- Reduce the probable quantity or likelihood of spills by improved handling practice;

- Reduce leakage by improved isolation equipment;
- Reduce site sensitivity rating or transfer route scores by equipment relocation;
- Improve the effectiveness of the mitigation systems (in the case of bunding or traps).

Table 1: Sample calculations for fictitious environmental risk

Quantity spilled from tank	10 000L			
Effectiveness of bund in containing spill	90%			
Quantity Released	1 000L			
Likelihood of spill	0.01 p.a.			
		human	**local environment**	**global environment**
Aromatic Solvents hazard ratings		0.40	0.70	0.10
Gosford site environs sensitivity		0.30	0.60	—
Transfer routes efficiency		0.20	0.90	—
Consequence Scores		0.024	0.378	0.1
Total Consequence Score	0.502			
Risk Score	0.005 p.a.			

With each capital expenditure proposal for reduction of the risk, a new consequence score and a new risk score are generated based on estimates of the reduction of these variables. Reduction of risk per unit cost of the proposal is calculated for each proposal and these results are ranked, thereby showing which improvements would give greatest value for money.

Decision Making

There is always a trade-off between speed of analysis and level of precision (Travis 1991). To keep the resources expended on the decision process (rather than the actual improvements) to an appropriate level it is often necessary to use estimates or judgements, rather than obtaining accurate statistics. Thus the results produced by this method and the outputs are heavily based on estimates of a technical panel. However, an initial ranking of the risk allows a focus to be made on those potential incidents that have the highest risk. With this approach, further work can always be performed to refine the estimates of the high risk incidents.

APPLICATION OF AND RESULTS OF TECHNIQUE

This technique has been applied within multi-site organisations in Australia and has been demonstrated to have applicability and has been well received. Small groups within the organisations were assigned the tasks of assembling the available data, making the value judgements and estimates, and running the model to determine the high risk sites. Once the small groups had obtained the ranked list of sites, these results were reviewed by a second group to check that there were no errors and that the results obtained were reasonable.

One of the implementations of this system was at a large Australian organisation. Their transformers and substations were assessed using this model (see Hutchison, et al. 1996). The incident specific data were acquired using environmental audit reports (where available) in consultation with staff including environmental scientists and managers responsible for different transformer substations, and electrical engineering personnel with considerable experience in maintaining such equipment. The age of the transformer and type of electrical fault protection system were considered to be key factors in determining the likelihood of major and minor spillages. The hazard ratings for transformer oil and transformer oil contaminated with PCBs were assessed and the site sensitivities for 100 transformer substation sites were estimated in consultation with environmental scientists and managers.

In this study, major failure of a transformer vessel was the most significant type of event to lead to possible pollution of the environment outside the site boundaries. In all cases the most cost effective types of risk reduction proposals involved improvements to the spill mitigation systems.

One of the proposals, made prior to the application of this model, was the bunding of every site with an estimated total cost of in excess of $4 million. Alternative mitigation systems ranged from full bunds with oil/water separators, drip trays and spill containment facilities through to no immediate action.

The cost effectiveness of this range of choices was examined at each site and in many cases full bunding was not cost effective. The chance of transformer failure was invariably very low and adequate protection could be obtained by simpler methods. The installation of unnecessary bunds would also have had the effect of increasing operating and maintenance costs.

Alternative proposals were then assessed using this model and the final set of risk reduction proposals were estimated to cost less than $500 000, a reduction of greater than 80% from the cost of the initial proposals to bund all transformer substations. The output of this model was then assessed for 'reasonableness' and consistency in order to check that assumptions, judgements and estimates were consistent throughout the study. This 'reasonableness' check involved visits to the top 10 and the bottom 10 environmental risk sites and confirmed the approach of this model. Implementing the final set of risk reduction proposals would reduce the total risk score by over 70%.

The proposals for risk reduction were examined on the basis of risk with higher risk sites getting more extensive capital works such as bunding and oil/water separators, while lower risk sites were allocated spill containment kits and drip trays. This is in contrast to the individual site environmental audit reports which recommended bunding for almost every site to reduce environmental risk. Part of the benefit of this work was the increased level of awareness of the environmental risks that were present on the sites and the different levels of risk on different sites, even though similar equipment was installed. The importance of site specific factors was emphasised through this work.

The cost of development of this model and associated training was less than $100 000 and the work to obtain all the necessary data, to use the model and to check the results for consistency required approximately one half of a person-year of effort. Even though the task of evaluating every site and hazard, and considering every incident may seem daunting, the initial implementation at this organisation has proved to be very worthwhile, enabling expenditure of the environmental budget to be planned in an efficient and cost effective fashion while maximising the reduction in environmental risk.

Once the results were available, managers and other staff of the organisation were invited to a workshop to discuss the technique and the results achieved. The attendees found the technique and the results it presented easy to understand, accepted the necessity for value judgements and agreed with the priorities for action as estimated using the system. The comments from staff demonstrated that the basic approach used was justified and that the overall system was well received.

CONCLUSIONS

The following observations were made on the application of this preliminary risk ranking model.

- The use of a relatively simple model for ranking environmental risks has advantages in enabling results to be generated in a relatively short time and with relatively low costs.
- This model enabled the knowledge of both site personnel and environmental specialists to be effectively utilised.
- The prioritised list of the sites' environmental risks was accepted as the calculations and value judgements used in the model were explicit rather than implicit.
- The results from a model of this type must be assessed for reasonableness in order to check that assumptions and estimates are consistent throughout the model.
- This model is a management tool which aids the decision making process but does not remove the need for value judgements and difficult decisions. However, if applied consistently, the value judgements can still lead to reliable rankings.

The approach used for this model has been demonstrated to be efficient and effective. Decisions on the allocation of available funds for environmental risk reduction can be made on a systematic scientific/engineering basis. It also enables operators to improve their understanding of the environmental issues associated with the operations.

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DEFINITION OF SYMBOLS

SSH = Site sensitivity (human)
SSE = Site sensitivity (ecological)
ME = Mitigating effectiveness
QS = Quantity spilt
QR = Quantity released
HRH = Hazard rating (human)
HRE = Hazard rating (ecological)
HHG = Hazard rating (global)
TRH = Transfer route effectiveness (human)
TRE = Transfer route effectiveness (ecological)
CSH = Consequence score (human)
CSE = Consequence score (ecological)
CSG = Consequence score (global)
CS = Consequence score
RS = Risk score
F = Frequency