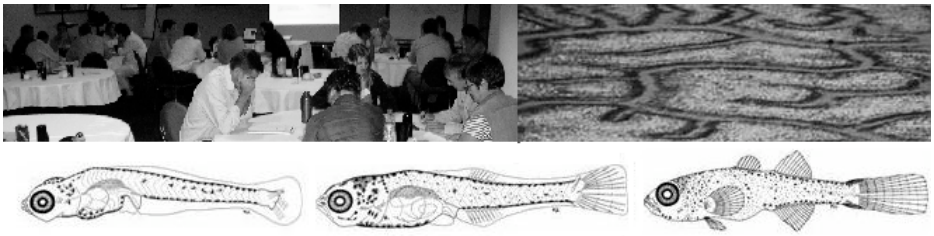
Report No 1

NPSI Project UMO45: Delivering Sustainability through Risk Management

PROSPECTS FOR ADOPTION OF ECOLOGICAL RISK ASSESSMENT IN THE AUSTRALIAN IRRIGATION INDUSTRY



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The National Program for Sustainable Irrigation focuses research on the development and adoption of sustainable irrigation practices in Australian agriculture.
The Program has 14 funding partners: Land & Water Australia (managing partner); Sunwater, Queensland; Horticulture Australia Limited; Goulburn-Murray Water, Victoria; Cotton Research and Development Corporation; Harvey Water, Western Australia; Lower Murray Water Authority, Victoria; Wimmera Mallee Water, Victoria; Ord Irrigation Cooperative, Western Australia; Australian Government Department of Agriculture, Fisheries and Forestry; Department of Natural Resources, Mines and Water, Queensland; Department of Primary Industries and Resources South Australia; Department of Environment Water and Catchment, Western Australia; and Department of Agriculture and Food, Western Australia.

EXECUTIVE SUMMARY

Although Ecological Risk Assessment (ERA) can provide a basis for making the vague tenets of sustainability operationally meaningful, the capacity for its adoption among irrigation industries and stakeholders is unproven. This report details insights in the adoption process afforded through delivery of nine ERA awareness workshops delivered in irrigation regions throughout Australia.

Two workshops were conducted in Townsville and others in Brisbane, Deniliquin, Mildura, Shepparton, Bunbury and Darwin. At each workshop, key principles and concepts in ERA were explored using a case study of regional interest. In total, approximately 200 irrigation stakeholders registered their attendance at these workshops, with representation including government agencies, research bodies, the irrigation industry, community NRM organizations, landholders, environmental groups, and consultants. Two of these workshops explored the use of ERA in the sustainability framework being developed under the NPSI-funded project, Northern Australia Irrigation Futures.

Feedback from workshop participants regarding their perceptions of ERA was formally captured through evaluation questionnaires administered at the conclusion of six of the workshops. The questionnaire responses of 98 individuals were collated for analysis.

Findings indicated that the majority of participants saw ERA as a sound approach to sustainability for irrigation. There was strong support for including stakeholders in the process and strong agreement that ERA helps identify management priorities. However, there was some evidence that a substantial proportion of respondents viewed the time, data or expertise demands of ERA as onerous. Telephone interviews undertaken 2 months post-workshop with a subset of 28 questionnaire respondents suggested no significant modification in perceptions.

Questionnaire feedback was also interrogated to identify any distinguishing characteristics among those more enthused (or more sceptical) about ERA. There was weak suggestion in the analysis that workplace and education level may be associated with attitude, however we do not regard these suggestive findings as a sound basis to inform targeted investment in the encouragement of ERA adoption.

The processes involved in ERA adoption are complex and multi-faceted. They involve elements of cultural change, technology transfer and institutional issues. ERA challenges the prevailing culture of science and management to acknowledge uncertainty in decision-making. Technology transfer involves equipping organizations with the tools and techniques of ERA. Institutional issues include the tension between private property rights and the public good, and the possibility that ignorance of environmental risks may be preferable to knowledge in litigious settings.

The collective insights documented in this report suggest that ERA is generally regarded as a better approach to environmental planning and management than currently available tools, but that there are tangible and intangible costs associated with its adoption. Until the magnitude of net benefits is clarified, it is not unreasonable for individual organizations to

exercise the option of delaying uptake. Organizations more likely to adopt in the near future are likely to hold one or more of following views;

- Commercial viability is sought over the long term and is dependent on sustainability of the resource base;
- The polluter-pays principle has at least some legitimacy;
- Consumer and stakeholder perceptions are important factors shaping access to markets and resources; and
- Risk assessment is an effective means of demonstrating due diligence in environmental responsibilities.

Future directions for targeted encouragement of ERA adoption involve cultural change, technology transfer and addressing institutional issues. Investment in further training in ERA will be especially worthwhile where an organization's culture is supportive of ERA, and a range of approaches could be explored including further workshops, case study partnerships and formal University-based education.

CONTENTS

1. INTRODUCTION

The National Program for Sustainable Irrigation (NPSI) is committed to improving the sustainability of current and proposed irrigation schemes throughout Australia.

In support of this aim, NPSI has funded project UMO45 **Delivering Sustainability through Risk Management**, which is designed to raise awareness of the Australian irrigation industry in adopting risk-based environmental management approaches. The adoption of risk-based approaches is considered to be vital if the industry is to achieve its goal of long-term sustainability. This project is a logical extension of an earlier NPSI project (UMO40) that developed an Ecological Risk Assessment framework for the Australian irrigation industry (Hart et al., 2005.

This **Delivering Sustainability through Risk Management** project aims to achieve an improved level of adoption of risk assessment and risk management approaches in environmental management and a greater capacity to use such approaches, within both the irrigation industry and regulatory authorities in Australia.

The project has three components:

- to undertake a series of ***regional awareness workshops*** aimed at explaining the aims of this project, how risk management might be adopted by the irrigation industry and how this will assist in them achieving the ultimate aim of long-term sustainability of the industry,
- to establish *case study partnerships* involving the irrigation industry and appropriate State irrigation regulators, and work with these partnership to develop capacity within the individual organizations to use risk assessment and risk management procedures to improve the ecological sustainability of the irrigation region,
- to work with *selected Sustainable Irrigation projects* (and their key stakeholders) in trailing different methods and approaches for adopting risk management procedures into their projects.

Five reports have been produced by this project:

- Summary Report - *Delivering Sustainability through Risk Management* (Hart et al., 2006).
- Report 1 – *Prospects for Adoption of Ecological Risk Assessment in the Australian Irrigation Industry* (Walshe et al., 2006).
- Report 2 – *Ecological Risk Assessment Case Study for the Murray Irrigation Region* (Pollino et al., 2006).
- Report 3 - *Ecological Risk Assessment Case Study for the Lower Loddon Catchment - Bayesian decision network model for predicting macroinvertebrate community diversity in the Lower Loddon River* (Westbury et al., 2006).

- Report 4 - *Ecological Risk Assessment Case Study for the Lower Loddon Catchment - Bayesian decision network model for predicting grey-crowned babbler population abundance in the Lower Loddon catchment* (Chan & Hart, 2006).

These reports are all available at www.sci.monash.edu.au/wsc.

This document is Report 1 of the series and describes the activities undertaken under the regional awareness workshops component of the project. Additionally, we provide some insights regarding prospects for adoption of ERA by the Australian irrigation industry and associated stakeholders. These insights were gained principally through evaluation feedback provided by participants in ERA awareness workshops conducted throughout Australia.

2. BACKGROUND

2.1 Ecological Risk Assessment – beyond the Australian Standard

As noted above, NPSI is committed to improving the sustainability of current and proposed irrigation schemes throughout Australia. However, although it has become a centrepiece of public and corporate policy, the notion of 'sustainability' is vague and its application inconsistent (Beckerman 1996). Panell and Schilizzi (1997) comment on inconsistencies in use of the term 'sustainability', noting that it is 'at once extremely important and practically useless'. These authors regard sustainability as a valuable emblem that represents a broad range of related and important issues, but consider it operationally meaningless in the absence of measurable objectives.

In concept, Ecological Risk Assessment (ERA) provides a basis for making the vague tenets of sustainability operationally meaningful. That is, ERA provides a framework for demonstrating progress in sustainability through compliance with socially relevant and ecologically important measurement endpoints that encapsulate the essential elements of stakeholder values. Although conceptually appealing, the capacity for broad adoption of ERA among irrigation industries and stakeholders is unproven.

Risk assessment has been a common element of planning and management in occupational health and safety, engineering and process industries for several decades, and an Australian Standard has been developed for its application (AS/NZ 4360; AS/NZS 2004). The awareness workshops advocated an approach to risk assessment that extends that described in the Australian Standard. Here we briefly outline the nature of these extensions and their motivation. Further details are available in Hart *et al.* (2005).

Ecological Risk Assessment is the process of estimating likelihoods and consequences of the effects of human actions or natural events on plants, animals and ecosystems of ecological value, that is, the study of risks to the natural environment (Barnthouse and Suter 1986). This is not as straight forward as it might appear. The multitude of perspectives that people bring to the environmental debate makes it difficult to clearly identify ecological values of broad social relevance. Even when values are unambiguously identified, the task of estimating the likelihood and consequences of various hazards is hampered by the ignorance and uncertainty that characteristically accompanies our scientific understanding of ecological systems. Peters (1991) regards ecology as a satisfactory 'explanatory' science, but is less impressed by its achievements as a 'predictive' science.

The process of risk assessment helps decision-making when we are uncertain about the prediction of future events or actions, and the risk analyst's job is to evaluate and communicate the nature and magnitude of risks. The outcomes of a risk assessment can inform where investment in management action is warranted and where it is of low priority. Where uncertainty is high, it can also identify knowledge gaps that might require research or monitoring.

In essence, risk assessment is about the considered evaluation of what might compromise identified values. Few would argue that this is a sensible and reasonable thing to do in planning and management. But when done poorly, risk assessment can be seen as a process which attempts to make the illegitimate exercise of power by vested interests and scientists acceptable (O'Brien 2000). It has the potential to alienate stakeholders by placing social decisions in the hands of the technical people who conduct the assessments (Fischer 2000).

The Australian Standard details protocols for identifying values and hazards and for estimating the magnitude of risk associated with each hazard. Inferring the relative risk of hazards involves use of a matrix of consequence and likelihood. Outcomes depend on the capacity of the analyst to (a) identify socially relevant values, (b) elicit an exhaustive list of potential hazards, and (c) use subjective judgment for each potential hazard to estimate the likelihood that an event will occur and the severity of its consequences. Although the approach has a number of frailties, it is important to recognize that a process that encourages the considered identification and assessment of values and hazards is a distinct improvement on *ad-hoc* environmental planning and management. Advantages of the 'minimalist' approach to risk assessment described in the Australian standard include:

- It's simple and fast
- It accounts for probability of harm and magnitude of harm
- It communicates environmental risk in the same language used for financial and social risk
- It provides an informal means of combining data and expert judgment
- It provides an auditable record of priorities

Frailties associated with a minimalist approach include the personal and professional biases of the analyst, the ambiguity of language inherent in qualitative subjective assessment, and the distinct tendency for overconfidence in description of the likelihood and consequences of hazards.

Tools and techniques exist to address these frailties (Burgman 2005). In their development of a framework for application in irrigation industries, Hart *et al.* (2005) sought to extend the Australian Standard through incorporation of a selection of tools and techniques in a way that the authors thought represented a reasonable trade-off between rigor and ease of application. Two themes are especially prominent in the approach advocated by Hart *et al.* (2005) relative to that of the Australian Standard; (a) a greater emphasis on stakeholder involvement, and (b) explicit quantitative description of uncertainty in estimates of the consequence and likelihood of hazards. The central idea motivating the extensions described by Hart *et al.* (2005) is to help decision-making in a way that stays faithful to the priorities of those who carry the burden of the risks, while at the same time making the full strength of technical risk analysis available.

Stakeholder involvement is important because scientific inquiry is commonly politicized in environmental controversies involving strongly contested values (Sarewitz 2004). The notion of what is an acceptable or unacceptable level of risk is a social (and political) judgment rather than a technical judgment. Our personal experience and beliefs have a strong influence on our perception of risk. Cultural differences also contribute substantially to perceptions and acceptance of risk, so that different social groups react differently when confronted by the same hazards (Pidgeon *et al.* 1992).

In emphasizing the social basis of risk perceptions, Slovic (1999) regards risk assessment as inherently subjective and representing a blending of science and judgment with important psychological, social, cultural and political factors. In this context, Slovic (1999) sees public participation in risk assessment as a way to improve the relevance and quality of technical analyses, and to increase the legitimacy and public acceptance of the resulting decision. ERA seeks to document different perceptions of risk and distinguish socially and psychologically constructed perceptions from the uncertainties that arise from vague language, scientific inference, and ignorance (Regan *et al.* 2002).

Garvin (2001) found that different groups of decision-makers or lobbyists employ different (though equally legitimate) forms of rationality. For example, scientists, policy makers, and the public employ scientific, political and social rationality, respectively. Garvin (2001) concludes that failure to recognize these different forms of rationality leads to misunderstanding and misinterpretation. A core aim of Hart *et al's* (2005) approach to ERA is to encourage stakeholders to cross-examine the bases of their perception of risk. In doing so, the approach seeks to engender reciprocal respect for internally consistent rationalities among stakeholders, while putting in plain view those perspectives that lack a coherent basis.

Structured stakeholder interaction can minimize language-based uncertainty in the description of values and hazards. Assessment of the consequence and likelihood of hazards requires the risk analyst to form links between cause and effect, which is subject to uncertainties associated with natural environmental variability and lack of knowledge. Experts and non-experts alike are predisposed to overconfidence in their capacity to predict. Lewandowsky and Kirsner (2000) notes that although exceptional performance is a defining attribute of expertise, experts sometimes exhibit striking errors and performance limitations. Hart *et al.* (2005) recommend the use of conceptual models to document assumptions regarding cause and effect and the quantification of these models to explicitly communicate uncertainty in a risk assessment.

Burgman (2005) emphasizes stakeholder involvement and quantitative approaches in his summary argument for more rigor in risk assessment:

> *'It is beyond the capabilities of technical risk analysts to anticipate the full range of legitimate points of view and ideas about cause and effect. The role of risk assessment is to cross-examine the ideas of stakeholders, to ensure internal consistency, to eliminate linguistic uncertainty and other sources of arbitrary disagreement, to clarify the implications of assumptions, and to leave honest disagreements in plain view. This role depends on partnerships between stakeholders and scientists (Poff et al. 2003) in which the position of the analyst is subordinate to the stakeholder. In this context, quantitative risk assessment has an essential role to assist people to critically examine their ideas and to understand the ideas and values of those with whom they disagree.'*

The willingness of organizations to incur additional costs to decision-making through adoption of more rigorous approaches to ERA is unclear. A central focus of evaluation of the awareness workshops was therefore to gauge the extent to which irrigation stakeholders are prepared to go beyond a minimalist ERA in securing robust benefits.

Before reporting on the awareness workshops, it is worthwhile canvassing aspects of adoption that may influence the uptake of ERA.

2.2 Elements of adoption

Adoption of the ERA framework advocated by Hart *et al.* (2005) involves both cultural change and technology transfer.

The greater involvement of stakeholders and the acknowledgement of uncertainty can be an affront to the prevailing culture of management and science. Because we're ignorant of many of the cause and effect relationships that operate in natural systems, uncertainty can go beyond probabilistic uncertainty, where the structure of a problem is well-defined and only the value of the parameters within that structure are unknown, to a deeper 'systemic' uncertainty (Blockley 1980). Systemic uncertainty arises when the very structure of a model or world-view is incomplete or open to doubt in critical respects. Pidgeon (1998) stresses the pervasiveness of systemic uncertainty in 'the peculiar versions of 'reality' that develop and persist within some organizational or institutional settings.' It is not easy for scientists and managers to accept that better decisions may be made through an open cross-examination of ideas involving a broad range of stakeholders.

Technology transfer is more straight-forward. It involves equipping prospective adopters with the tools and techniques of risk assessment, including those that deal with stakeholder interactions and describing uncertainty. It's reasonable to expect that the degree to which potential adopters will be receptive to technology transfer will be related to the willingness to embrace cultural change, and the motivations underpinning cultural change implicitly advocated by Hart *et al.* (2005).

Education and extension have been used widely to promote adoption. Marra *et al.* (2001) distinguish between,

- learning which allows the potential user to make better decisions about the new innovation, and
- learning which improves the ability of potential users to implement the new innovation.

Learning which allows better decisions informs the potential user's perceptions about the benefits and costs of the new innovation relative to the *status quo*. Adoption is unlikely when an individual's learning results in a belief that the current way of doing things is better than the new. For ERA adoption, the evaluation of benefits and costs will be substantially influenced by perceptions of the desirability of cultural change.

Learning which improves the ability of potential users to implement the innovation is essentially about technology transfer. It will be most effective where the net benefits of the innovation are perceived to be better than the *status quo*. But even where the new innovation is regarded as better, uptake may be delayed because potential users may see an option value in delaying where there are costs involved in transition to the new innovation (Marra *et al.* 2001).

While the Lower Loddon case study, the Murray Irrigation case study, and the awareness workshops undertaken as part of this project sought outcomes related to both aspects of learning described by Marra *et al*. (2001), the relative emphases of each activity were different. This report focuses only on the awareness workshops conducted under the project. Workshops sought principally to equip participants with an improved capacity to make decisions regarding the merit of ERA relative to environmental planning and management mechanisms currently in use. In doing so, their emphasis was more about cultural change and less about technology transfer. Time constraints meant that the tools and techniques of ERA were explored only as a means of illustrating the conceptual underpinnings of ERA rather than equipping participants with a working competency in their use.

The relative emphases of technology transfer and cultural change promoted in case studies and awareness workshops is illustrated in Figure 1.

The remainder of this report is presented in four sections. In Section 2, an overview of the regional awareness workshops is provided including two workshops that directly linked with the NPSI funded project, Northern Australia Irrigation Futures. Section 3 presents findings of formal evaluation of the approach to ERA advocated in awareness workshops. In Section 4 key issues that emerged from evaluation questionnaire responses are discussed in more detail, together with further exploration of the 'elements of adoption' briefly outlined here. Finally, Section 5 canvasses future directions for encouraging broader adoption of ERA among irrigation stakeholders and catchment managers.

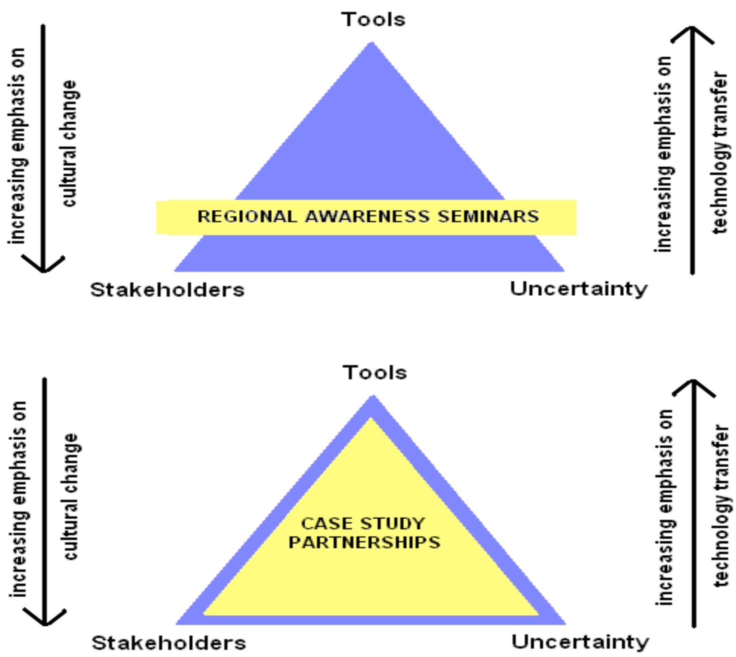

Figure 1: The relative emphases on cultural change and technology transfer in the project's main activities. The regional awareness seminars sought mainly to encourage cultural change through recognition of the importance of stakeholder involvement and acknowledging uncertainty in environmental decision-making. Additional emphasis was given to the development of an understanding of the tools of ERA in the Lower Loddon and Murray Irrigation case study partnerships (Westbury et al., 2005; Pollino et al., 2005)

3. THE REGIONAL AWARENESS WORKSHOPS

3.1 Objectives

The primary objective of the regional workshops was to raise awareness of the processes of ERA among irrigation stakeholders. As introduced in the preceding section, the motivation of an individual organization to uptake ERA will be founded on (a) perceptions about the net benefits to be derived from ERA-based decision-making versus the *status quo*, and (b) perceptions about the option value of delaying where there are substantial costs associated with adoption. To address these considerations, secondary objectives of the workshops and seminars were:

- to make the benefits of ERA more readily visible and accessible to irrigation stakeholders; and
- to encourage the adoption of ERA in the short term through emphasis on implementation flexibility.

The format of the workshops involved a full-day exploration of core principles and tools, including how ERA can:

- Identify socially relevant and environmentally important values
- Address multiple threats in a catchment-wide context
- Estimate the likelihood of adverse events that lead to environmental degradation
- Provide a framework for the development of conceptual models that underpin explicit and transparent description of ecological risks in the face of uncertainty

Typically, content included the following modules involving a mix of formal presentations, small group exercises and general discussion:

- Introduction
  - Overview - Why do ERA?
  - The ERA framework; the Australian standard and beyond
  - ERA case study – problem formulation, elicitation of ecological values, endpoints and hazards
- Qualitative risk assessment
  - Ranking risks – consequence and likelihood
  - Strengths and weaknesses of qualitative assessment
- Building on qualitative risk assessment
  - Introducing quantitative techniques
  - Conceptual models
- Quantitative risk assessment
  - Dealing with uncertainty – Interval Arithmetic, Monte Carlo and Bayesian Belief Networks
  - Revisiting the ERA framework

For each location in which workshops were held, these modules were explored through a case study of regional interest. Where possible, case studies involved environmental issues associated with NPSI-funded projects. Although specific case studies were used to stimulate practical thinking about how the ERA framework can be applied to real problems, it is important to note that outcomes sought from the workshops did not include direct contributions to planning and management beyond problem formulation. In their emphasis on equipping attendees with an overall understanding of core ERA concepts and principles, all of the awareness workshops devoted insufficient time to the elicitation, description and ranking of risks for outcomes to be considered robust enough for decision-making. Also, the open nature of invitations meant that representation among stakeholder groups at the workshops was not necessarily consistent with sound participatory decision-making .

Invitations to the workshops were loosely targeted, whereby initial contact was made to NPSI project leaders to identify key stakeholders. Direct phone calls or personal visits were made to these key stakeholders to 'seed' interest in the workshops, and email invitations distributed. Invitations encouraged identified stakeholders to forward the workshop details to wider contacts they thought might be interested in attending. An example of the electronically distributed invitation is included in Appendix 1.

3.2 Overview of the workshops

The location, date, case study theme, and number of registered participants for the eight full day regional awareness workshops delivered under the project are shown in Table 1. In total, 200 irrigation stakeholders registered their attendance at the workshops. This total underestimates the actual number of attendees because some participants did not register (we estimate a further 20 attended without registering). Representation among stakeholders was substantially biased towards government agencies, with reasonable representation from researchers, the irrigation industry and Community NRM agencies (Table 2). Relatively poor representation was seen among landholders and environmental groups, and limited interest was evident among consultants and other industries marginally affected by water resource issues.

Table 1: Full day regional awareness workshops delivered as part of the project

Where	When	Theme	Attendees
Brisbane	9 Dec 2003	Deep drainage	18
Deniliquin	31 Mar 2004	Murray Irrigation Ltd irrigation region	30
Deniliquin	11 Aug 2004	MIL drainage management plan	16
Mildura	20 Oct 2004	Open hydroponics	20
Townsville	10 Nov 2004	Lower Burdekin irrigation	19
Shepparton	17 Nov 2004	Broken Creek irrigation	21
Bunbury	15 Mar 2005	Peel-Harvey irrigation	26
Darwin	18 May 2005	Daly River irrigation	28
Townsville	1 Jun 2005	Wetlands, the Great Barrier Reef and irrigation	22
Total			**200**

Brisbane

The Brisbane workshop was organised by the Department of Natural Resources and Mines mainly to provide an opportunity for a number of their staff (research and regional) to become aware of ERA procedures. A number of others from CRC Irrigation Futures, EPA and regional NRM groups also attended.

Deniliquin

The 31 March 2004 workshop in Deniliquin was attended by around 30 stakeholders. The workshop introduced the ERA process to participants and then undertook a qualitative ERA to identify the high priority ecological risks associated with the MIL region. These high risk issues were then used to determine the details of the MIL case study. Full details of the process can by found in Pollino et al. (2005).

A second workshop was also held in Deniliquin on 11 August 2004 largely for MIL staff. The workshop used the ERA process to identify the high priority risks associated with the MIL drainage system. This information was then used in the development of the MIL drainage management plan.

Table 2: Pooled representation of irrigation stakeholder groups at the nine regional awareness workshops 'Irrigation industry' describes stakeholders with a direct interest in irrigation including water providers and grower groups reliant on irrigation water. 'Community NRM' refers to representatives of regional NRM groups involved in the development and administration of regional strategies under the Natural Heritage Trust and National Action Plan for Salinity & Water Quality. 'Environmental groups' refer to representatives from environmental organizations that have an emphasis in political advocacy.

Stakeholder group	***n***
Government agencies	89
Researchers	26
Irrigation industry	38
Community NRM	21
Landholders	16
Environmental groups	7
Consultants	2
Other industry	1
Total	**200**

Mildura

The 20 registered participants at the Mildura workshop represented the organizations listed in the table below and included participants from NSW, Victoria and South Australia. The workshop case study examined environmental hazards that may arise from open hydroponics, an approach to irrigation currently being researched through the NPSI funded project, 'Open Hydroponics: Risks and opportunities (DAN22)'.

Mildura workshop – Organizations represented
Government agencies
Agriculture Victoria
NSW Agriculture
South Australian Department of Water Land & Biodiversity Conservation
Victorian Department of Primary Industries
Victorian Department of Sustainability & Environment
Research
CSIRO
South Australian Research & Development Institute
Irrigation industry
Lower Murray Water
Community NRM
Mallee Catchment Management Authority
Kulkyne Way LandCare Group
Landholders
Yandilla Park

At the time of the workshop the operational details of an open hydroponics irrigation system were yet to be determined and the regions in which it might best perform were still to be identified. We formulated the risk assessment problem using a hypothetical scenario where an open hydroponics system was established in the traditional irrigation district immediately adjacent to the town of Mildura and in close proximity to Murray River wetlands.

Workshop participants involved in the Open Hydroponics project were keen to explore the application of ERA further and subsequently visited Monash University's Water Studies Centre to strengthen their technical skills. The workshop also included researchers involved in the NPSI project, 'Impact of Salinity on Horticulture in the Lower Murray (DEP15)'. The use of ERA in this project was considered only marginally relevant.

Townsville 1

The first of two Townsville workshops looked at impacts of land uses in the Burdekin catchment, with a particular focus on the Lower Burdekin where irrigated sugar cane production dominates. Environmental values of the region include wetlands, the near-shore marine environment and the Great Barrier Reef. Organizations represented at the workshop are listed below.

Townsville 1 – Organizations represented
Government agencies
Great Barrier Reef Marine Park Authority
Queensland Department of Natural Resources & Mines
Queensland Department of Primary Industries & Fisheries
Queensland Environmental Protection Agency
Northern Territory Department of Infrastructure Planning & Environment
Research
Australian Centre for Tropical Freshwater Research
CSIRO
Irrigation industry
Bureau Sugar Extension Station
CSR
Ord Irrigation Co-operative
Community NRM
Burdekin Dry Tropics Board
Burdekin Bowen Integrated Floodplain Management Advisory Committee
Consultants
Private consultant

Apparent deterioration of the reef environment has attracted national media attention and the feeling among many participants was that this attention sometimes distorted views on the magnitude and importance of impacts arising from one land use or another. In this context, the use of ERA at a whole-of-catchment scale was seen as a positive step toward reconciling stakeholder views on what are the most important hazards to community values.

The majority of participants were supportive of ERA and keen to see its application further explored through the NPSI funded Northern Australian Irrigation Futures project. Those articulating support included representatives of CSIRO's Townsville-based Davies Laboratory, the Northern Territory Department of Infrastructure Planning & Environment, and the Ord Irrigation Co-operative. This support provided motivation for a second Townsville workshop and the Darwin workshop.

Shepparton

Representation among irrigation stakeholders at the Shepparton workshop is tabled below. Participation from the irrigation industry was especially strong in this workshop, largely due to the enthusiasm for ERA evidenced at Goulburn Murray Water.

The workshop case study examined environmental hazards within the Broken Creek catchment, including those associated with irrigation. Of the eight workshops outlined in this report, the prior awareness of ERA principles and tools was greatest among participants at Shepparton. This awareness was largely nurtured through previous collaboration involving members of the ERA Project Team, Goulburn Murray Water and the Goulburn Broken Catchment Management Authority, and through progress made in the NPSI funded project, 'Goulburn-Broken Irrigation Futures (VPI3)'. The workshop served to strengthen regional stakeholders' views on the benefits of ERA as well as provide greater appreciation of its potential weaknesses.

Shepparton – Organizations represented
Government agencies
Local Government
Victorian Environment Protection Authority
Victorian Department of Primary Industries
Victorian Department of Sustainability & Environment
Irrigation industry
Goulburn Murray Water
Goulburn Valley Water
Shepparton Water Services Committee
Community NRM
Goulburn Broken Catchment Management Authority
North Central Catchment Management Authority
Landholders
Local Landholders
Environmental groups
Greening Australia
Consultants
Sinclair Knight Merz

Bunbury

Participants at the Bunbury workshop were predominantly representatives of Western Australian government agencies (see table below).

The NPSI funded project, 'Changing Irrigation Systems and Management in the Harvey Irrigation Area (SOU3)' is focused on the paddock scale and was considered too localized for use as an ERA case study. Instead the workshop looked at issues surrounding an informal proposal to convert pine plantation immediately west of the current Harvey irrigation district to horticulture. Environmental values that may be sensitive to the horticultural development identified in the workshop included the Yalgorup Lakes and remnant patches of Tuart-dominated vegetation.

Bunbury – Organizations represented
Government agencies
Western Australian Department of Agriculture
Western Australian Department of Conservation and Land Management
Western Australian Department of Environment
Western Australian Forest Products Commission
Western Australian Water Corporation
Irrigation industry
Harvey Water Irrigation Co-operative
Community NRM
Serpentine Jarrahdale Landcare
Western Australian NRM Council

Generally, feedback received from government representatives was positive, with two suggestions to further explore applications of ERA in the assessment of small-scale groundwater-sourced irrigation proposals in the north of the state, and in assessment of deep drainage aimed at treating the loss of agricultural productivity on salt-affected land. Feedback from the Harvey Water Irrigation Cooperative was less enthusiastic. Its representative considered the scope of ERA outlined in the workshop to be beyond the day-to-day operational needs of the Cooperative.

3.3 Collaboration with Northern Australia Irrigation Futures

The Northern Australia Irrigation Futures (NAIF) Project aims to develop and deliver a Sustainability Framework for use by policy makers, regulators, community organizations, managers, and investors to support more robust debate and improved decision-making regarding the merit of irrigation development in tropical Australia. The project also encompasses details on how tropical irrigation systems might operate, and how they could be managed to meet social, cultural, environmental and economic sustainability objectives.

Development of the Sustainability Framework is a central component of a thesis being undertaken by PhD student, Bart Kellett. The framework's development to date includes three elements – a visioning tool, planning and assessment tool, and a monitoring and reporting tool. The NAIF project is keen to explore ways in which the principles and tools of ERA could be embedded in the Sustainability Framework. As a means of progressing this exploration, the second Townsville workshop and the Darwin workshop were delivered jointly with NAIF, principally through collaboration with Bart Kellett.

The two workshops maintained their focus on awareness objectives, but were extended to include substantially more ambitious aims toward securing outcomes in the problem formulation and value and hazard elicitation stages of ERA.

Darwin

The Darwin workshop explored the politically sensitive issue of agricultural development within the Katherine-Daly catchment. Background material distributed to workshop participants outlining problem formulation and the role of ERA is provided in Appendix 2a. Relative to other workshops, the breadth of stakeholder representation was better, including participation from grower groups, landholders and environmental groups as well as government agencies and researchers (see table below).

The sensitive nature of the case study resulted in protracted and at times vigorous discussion regarding the potential for workshop outcomes to distort planning processes currently in progress. We consequently failed to achieve substantial progress in the more ambitious workshop objectives associated with value and hazard elicitation and ranking. In retrospect, the likelihood of better outcomes from the day would been enhanced by addressing the concerns of stakeholders through greater pre-workshop consultation.

Darwin – Organizations represented
Government agencies
Northern Territory Department of Business Industry & Resource Development
Northern Territory Department of Infrastructure Planning & Environment
Research
Charles Darwin University
CSIRO
Environmental Research Institute of the Supervising and Scientist
Irrigation industry
Northern Territory Agricultural Association
Northern Territory Horticultural Association
Landholders
Local landholders
Environmental groups
Greening Australia
Northern Territory Environment Centre
Other Industry
Northern Territory Cattleman's Association

Despite these difficulties, many participants were sufficiently interested in the potential benefits of ERA to support its further use in NAIF, as well as in Land & Water Australia's Tropical Rivers Program and the Northern Territory's water allocation planning process.

Townsville 2

A second Townsville workshop was delivered in an effort to strengthen synergies between ERA and the Northern Australian Irrigation Futures project. The workshop revisited issues in the Lower Burdekin with a particular emphasis on management of the region's wetlands. The workshop sought to use ERA as a framework for examining any conflict in the intrinsic ecological values of wetlands and their use as sediment and pollutant filters for the marine environment. Background material prepared for workshop participants is included in Appendix 2b.

Organizations represented at the workshop are shown below. Representation from local landholders was especially strong, with four participants (from a pooled total of seven for all the workshops).

There was clearly strong agreement among a broad range of stakeholders that the region's wetland values needed better management. There was notably less agreement on what might be entailed in 'better' management. Much of the workshop was dedicated to problem formulation as participants grappled with the idea of a trade-off between intrinsic ecological values of wetlands and their use as sediment and pollutant filters for protection of marine values. Again, progress toward hazard elicitation and ranking that could meaningfully inform decision-making was limited. And again, our retrospective view is that outcomes would have been much improved if greater time was invested in one-on-one consultation with participants prior to the workshop.

Townsville 2 – Organizations represented
Government agencies
Great Barrier Reef Marine Park Authority
Queensland Department of Natural Resources & Mines
Queensland Environmental Protection Agency
Research
Australian Centre for Tropical Freshwater Research
CRC Irrigation Futures
CSIRO
Monash University
Irrigation industry
North Burdekin Water Board
South Burdekin Water Board
Community NRM
Burdekin Dry Tropics Board
Haughton Catchment Committee
Landholders
Local landholders
Consultants
Earth Environmental Consulting

Despite slow progress the workshop made a substantial contribution to problem formulation. A grouping of wetlands was made according to biological and physical attributes and their susceptibility to adjacent land uses and associated hazards. This grouping can provide the basis for future work investigating compatibilities and conflicts in wetland values.

As a result of insights gained at the workshop, Bart Kellett is keen to improve the sociological aspects of the ERA framework (and the NAIF Sustainability Framework) through better incorporation of the cultural and political dimensions of stakeholder interaction. A draft CSIRO Technical Report detailing outcomes of the workshop has been prepared (Kellett *et al*. 2005).

4. IMPACT OF REGIONAL WORKSHOPS

4.1 Approach to assessing impact

Structured and formal evaluation from six of the workshops was undertaken through questionnaires administered to participants at the end of the day. Questionnaires were designed to provide insights regarding:

- The perceived benefits and limitations of ERA,
- Distinguishing characteristics of potential adopters and opinion leaders,
- Perceptions of the applicability of ERA in the workplace of respondents,
- Perceptions of what level of rigor might be appropriate for respondents' workplaces,
- The desirability of future training.

The questionnaire was refined after three workshops. Appendix 3a shows the questionnaire distributed at the Mildura, Townsville 1 and Shepparton workshops. Appendix 3b provides the questionnaire distributed at the Bunbury, Darwin and Townsville 2 workshops. The number of responses from each of the workshops is shown in Table 3.

Table 3: The number of questionnaire responses received from each of six awareness workshop

Workshop	*n* registered attendees	*n* respondents	Response rate
Mildura	20	11	55%
Townsville 1	19	12	63%
Shepparton	21	17	81%
Bunbury	26	24	92%
Darwin	28	18	64%
Townsville 2	22	16	73%
Total	**136**	**98**	**72%**

4.2 Findings

4.2.1 Perceptions of the benefits and limitations of ERA

Question 7 of both questionnaires directly addresses perceived benefits and limitations of ERA among respondents. It provides nine statements regarding ERA, for each of which the respondent is asked to indicate the degree to which they disagree or agree on a scale of 1-5, where a score of 1 indicates disagreement, 2 a tendency to disagree, 3 neutral, 4 a tendency to agree, and 5 indicates agreement (Appendix 3a and 3b).

Two questionnaire respondents did not answer Question 7. The findings pooled from 96 individuals for each statement are shown in Figure 2.

Overall perceptions

The first statement, ***(A) ERA helps achieve 'environmental sustainability'***, coarsely indicates overall opinion on the value of ERA. Although eight respondents disagreed with the statement and 16 were neutral, 75% (or 72 responses) indicated agreement. Of those that agreed, the majority *tended* to agree rather than fully agree, which suggests that while there is broad support for ERA, many workshop participants had some reservations.

ERA as a framework for eliciting values and threats
The next three statements in Q7 of the questionnaire relate to the merit of ERA in identifying stakeholder values and the threats, stressors or hazards associated with those values.

Of the three statements, the clearest response was that associated with ***(D) ERA is an effective way to identify values and threats,*** where 96% of respondents either agreed or tended to agree. Only one participant tended to disagree and three were neutral. The approach used to identify values and threats in the awareness workshop was fairly simple and unstructured, involving open brainstorming in large and small groups. The almost unanimous support for statement D is likely to be linked to a broad appreciation for the need to canvass views widely among stakeholders rather than having values and threats articulated by a single individual or organization.

For statement ***(B) ERA treats people's values inappropriately,*** 69 workshop participants disagreed, 9 agreed, and 18 were neutral. While these responses suggest reasonable faith in the ERA framework's capacity to place stakeholder values in plain view to decision-makers, a substantial proportion of respondents held negative or equivocal opinions. One notable aspect that emerged consistently in workshop discussions was the unease that some participants felt in translating general values to specific endpoints. That is, participants were not always convinced that selected endpoints preserved the substance of identified values.

The responses to statement ***(C) ERA cannot avoid bias in representing people's values*** likewise indicated a dominant supportive view of ERA, but with a substantial minority holding a less favorable or neutral view. In total, 51 participants disagreed with the statement, 20 agreed, and 25 were neutral. The concern around bias is perhaps justified given that methods to minimize the risk analyst's imprint on an assessment are not especially well developed.

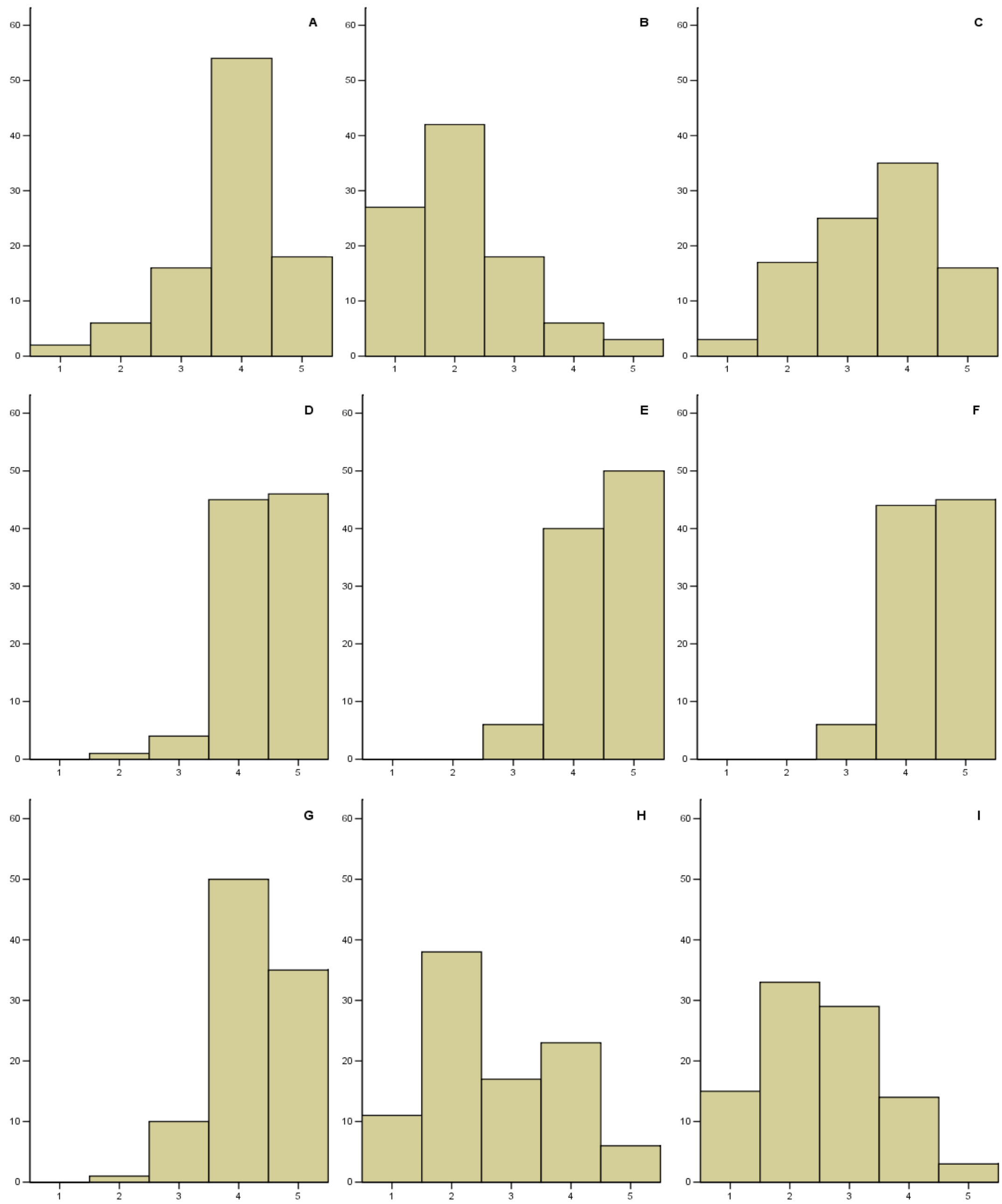

Figure 2: The response of workshop participants (*n* = 96) to statements regarding the (purported) benefits and limitations of ERA. **A** ERA helps achieve 'environmental sustainability'; **B** ERA treats people's values inappropriately; **C** ERA cannot avoid bias in representing people's values; **D** ERA is an effective way to identify values and threats; **E** ERA assists environmental decision-making; **F** ERA reveals knowledge gaps and uncertainties; **G** ERA identifies where research and monitoring is needed; **H** There is rarely enough data to undertake a risk assessment that helps decision-making; **I** The time and expertise demands of ERA are too onerous. The *x*-axis indicates level of agreement, where 1 = disagree, 3 = neutral, and 5 = agree. The *y*-axis is the number of respondents scaled from 0 – 60.

ERA as a framework for informing allocation of management resources

Statements E, F and G sought responses concerning the capacity of ERA to inform management decisions on where investment in action, research or monitoring may be warranted. There was strong support for all three statements.

The 90 participants tended to agree or fully agree with statement ***(E) ERA assists environmental decision-making,*** and six were neutral. No responses indicated disagreement. Responses to ***(F) ERA reveals knowledge gaps and uncertainties*** were almost identical, although of those that generally agreed, a slightly higher proportion tended to agree rather than fully agree. There was marginally less support for statement ***(G) ERA identifies where research and monitoring is needed,*** with 85 agreeing, one participant disagreeing, and 10 neutral.

The data, time and expertise demands of conducting an ERA

The last two statements in Q7 sought perceptions on the demands of conducting ERA. While the majority of responses were again supportive of ERA, there was a distinct spread of opinion relative to responses received for most other statements (Figure 2).

For statement ***(H) There is rarely enough data to undertake a risk assessment that helps decision-making*** approximately one-third of respondents agreed, just over a half disagreed, and 17 participants were neutral. The substantial proportion of unfavorable or equivocal responses may in part reflect a reluctance to acknowledge uncertainty in NRM and irrigation management. This is despite a consistent emphasis throughout the workshops on the central role of uncertainty in informing risk-based decision-making.

Responses to statement ***(I) The time and expertise demands of ERA are too onerous*** reflected similar levels of support for ERA, with 48 disagreeing, 29 neutral and the balance agreeing. The content of the workshops unambiguously advocated a more substantial investment in stakeholder interactions and the description of risks than is commonly the case in NRM planning and management. To encourage broader adoption of ERA in the future, these findings suggest it may be preferable to avoid an overly prescriptive approach to ERA implementation in favor of greater emphasis on flexibility in methodological detail.

4.2.2 Structured evaluation of perception modification

A critical issue for the organisers of stakeholder workshops is that of *perception modification*. While positive responses on a feedback questionnaire are desired, such an outcome does not necessarily mean the workshops have been successful in modifying opinions. This will almost certainly be the case if the question or proposition is perceived to be a 'motherhood' type statement. For example, few people would disagree with the proposition that "the objectives of an ERA are commendable" - irrespective of whether they attended an ERA workshop or not. We would therefore expect to see a high proportion of respondents agreeing with such a statement both before and after attending a workshop and thus no conclusions concerning the workshop's effectiveness can be made. With a judicious choice of questions and appropriate survey design, it is possible to statistically test the significance of *shifts* in attitudes and opinions as a result of having attended a workshop. The method requires workshop participants to score the same questionnaire items *on at least two occasions* using an ordinal scale (eg: 1 = disagree; 2 = neutral; 3 = agree). The questionnaire

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workshop. Subsequent surveys are administered *to the same group of respondents* at pre-determined follow-up intervals. The set of responses can then be summarized and analysed as a *contingency table*. Table 4 below shows the generic layout for a two-level response item, administered on three occasions.

Table 4: Generic layout for 2-level response item administered on three occasions

		Time 2			
		Agree		Disagree	
		Time 3		Time 3	
		Agree	Disagree	Agree	Disagree
Time 1	Agree	N_{111}	N_{112}	N_{121}	N_{122}
	Disagree	N_{211}	N_{212}	N_{221}	N_{222}

In Table 5, N_{ijk} is the number of respondents in category *i* at time 1; category *j* at time 2; and category *k* at time 3 where $\{i, j, k\} = \begin{cases} 1 & \text{for "agree"} \\ 2 & \text{for "disagree"} \end{cases}$.

In most situations, there will only be a single follow-up and so Table 4 will only have two time periods. The generic layout for a *k*-level response item administered on two occasions is shown in Table 5.

Table 5: Generic layout for *k*-level item administered on 2 occasions.

		Time 2			
		1	2	…	*k*
Time 1	1	N_{11}	N_{12}	…	N_{1k}
	2	N_{21}	N_{22}	…	N_{2k}
	⋮	⋮	⋮	…	⋮
	k	N_{1k}	N_{2k}	…	N_{kk}

The square matrix of responses in Table 5 allows us to test two hypotheses which are of particular interest in the context of perception modification. The hypothesis of *marginal homogeneity* states that the probability of a respondent choosing category *i* at times 1 and 2 is the same. The hypothesis of *symmetry* states that the probability of a respondent selecting category *i* at time 1 and category *j* at time 2 is the same as the probability of a respondent selecting category *j* at time 1 and category *i* at time 2. Thus the first hypothesis is essentially a test of ‘no effect’ due to the workshop while the second hypothesis tests whether the shift in opinion from ‘low’ to ‘high’ is the same as the shift in the reverse direction. A number of other more specific hypotheses can be tested (for example, that the probability of a category 1 response at time 1 is the same as the probability of a category 1 response at time 2) through the construction of an appropriate *hypothesis matrix* (see Appendix 4).

Example

We conducted follow-up telephone interviews with attendees that completed the questionnaire to assess the extent to which respondents maintain the views they held on ERA at the time of the awareness workshop. In total, the views of 28 of the 98 questionnaire respondents were collated through telephone interviews. Responses to nine questions were sought, although the analysis of only one of these is presented here.

The issue analysed here deals with the data requirements for ERA and is examined in terms of the responses to the proposition: "There is rarely enough data to undertake a risk assessment that helps decision-making". Initially, responses were coded as: Disagree (1); Tend to disagree (2); neutral (3); Tend to agree (4); and Agree (5). Due to difficulties with the experimental design and non-responses, this classification was subsequently collapsed to a three-point scale: Disagree (1); Neutral (2); and Agree (3). The results are summarised in Table 6.

Table 6: Data summary for ERA responses.

		Time 2			Total
		Disagree	Neutral	Agree	
Time 1	Disagree	8	4	2	14
	Neutral	2	0	0	2
	Agree	2	4	6	12
	Total	12	8	8	28

As mentioned above, an overall test of the effectiveness of the ERA workshop in terms of its impact on responses to the data requirements issue can be formally examined using the test of marginal homogeneity. The null hypothesis states that the probabilities associated with each of the three marginal classifications (agree, neutral, disagree) at time 2 are the same as the corresponding marginal probabilities at time 1. More formally, we let μ_{ij} be the probability of response *i* at time 1 and response *j* at time 2. Thus, the statement "the probability of a respondent disagreeing at time 1 equal to the probability of a respondent disagreeing at time 2" can be expressed mathematically as: $\mu_{11} + \mu_{12} + \mu_{13} = \mu_{11} + \mu_{21} + \mu_{31}$. Similarly, "the probability of a respondent being neutral at time 1 equal to the probability of a respondent being neutral at time 2" can be expressed mathematically as: $\mu_{21} + \mu_{22} + \mu_{23} = \mu_{12} + \mu_{22} + \mu_{32}$. The last hypothesis (concerning probabilities of agreement) does not need to be explicitly stated since it is implied by the truth of the other two hypotheses. The two hypotheses can be compactly written in matrix notation as $H_0 : h\underline{\mu} = \underline{0}$ where the hypothesis matrix ***h*** has elements

$$h = \begin{bmatrix} 0 & 1 & 1 & -1 & 0 & 0 & -1 & 0 & 0 \\ 0 & -1 & 0 & 1 & 0 & 1 & 0 & -1 & 0 \end{bmatrix}$$

and $\underline{0}$ is a 2 x 1 vector of zeros.

Results

The Pearson test statistic (see Appendix 4) is used to test the significance of the observed result. For the data in Table 6 the value of the Pearson statistic is 5.025. Under the null hypothesis, this statistic follows a chi-square distribution with 2 degrees of freedom. The *p-value* is computed to be 0.081 which is not significant at a 5% level of significance, suggesting that, overall, the ERA workshop had no significant impact on this responses to this particular issue. Similar analysis of all questionnaire items revealed no significant effect due to the workshops ($p > 0.05$ in all cases).

The results from this exercise should be regarded as tentative as a number of design and implementation issues were subsequently identified and these may be contributing to the non-significant result. In future exercises aimed at evaluating perception modification, we recommend (a) questionnaires be first administered *immediately prior* to a workshop (time 1) and a follow-up survey administered *to the same group of respondents* at a pre-determined follow-up time after the workshop (time 2); (b) greater statistical power through use of larger sample sizes (for questionnaires involving five response categories, we suggest a minimum sample size of 100 respondents, and for three categories a sample size of 50 respondents); and (c) questions be framed in a way that avoids 'motherhood' statements.

4.2.3 Distinguishing characteristics of potential adopters and opinion leaders

The collective impression from findings presented in Figure 2 is one of general support for use of ERA in the planning and management of irrigation. For these positive impressions to gain traction through organizational adoption, a key factor is the identification of opinion leaders that may catalyze broader uptake. It is also important to establish whether those less enthusiastic about ERA are associated with any particular stakeholder group.

Responses to Q7 were again used to summarize the position of individual workshop participants regarding ERA. Responses to each of the statements A-I were collapsed as being favorable, unfavorable or neutral. Here, a favorable response equates to 'agree' or 'tend to agree' for positively framed statements (A, D, E, F, G) and 'disagree' or 'tend to disagree' for negatively framed statements (B, C, H, I). The reverse equates to an unfavorable response.

For each participant's response to each statement, we denoted a favorable response 1, an unfavorable response -1, and a neutral response zero. The sum of these scores for the nine statements indicates an individual's overall enthusiasm for ERA, where a summed score of 9 is the potential maximum (indicating strong enthusiasm) and -9 the potential minimum (indicating strong skepticism). We sought to identify the attributes of ERA skeptics and enthusiasts through exploration of any clustering in the demographic attributes of workshop participants. The questionnaires asked respondents to provide details on their age and gender, workplace organization and level of education (Questions 1, 3 and 4; Appendix 3a and 3b).

The distribution of summed scores for the pool of 96 workshop participants that completed Q7 of the questionnaire is shown in Figure 3. The mode of the distribution occurs around a summed score of 5 to 7 (58 respondents, or 60%) indicating moderate to moderately high support for ERA. The shape of this distribution is notably similar to responses provided for the general statement, ***(A) ERA helps achieve 'environmental sustainability'*** (Figure 2-A).

The extremes of the distribution include eight respondents with summed scores of 8 or 9, and five respondents with a summed score of -1 or zero. No distinct clustering in attributes is evident in these extremes, although it's worthwhile noting:

- A representative of the irrigation industry fell within both the low extreme and the high extreme.
- There was relatively high proportional representation of younger respondents (age <30) in both extremes.
- Of the seven landholders in the entire pool, two were included in the more skeptical extreme and none in the enthused extreme.
- There is some suggestion of a trend in attitude with education level. The skeptical extreme comprised two secondary educated individuals and three tertiary educated. The enthused extreme included five tertiary educated and three individuals with postgraduate qualifications.

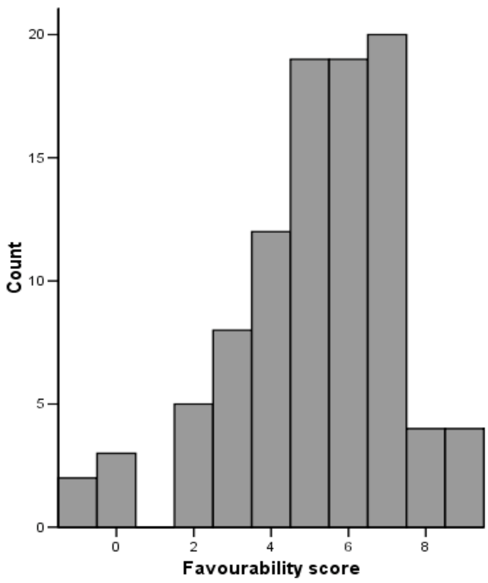

Figure 3: Summed 'favorability scores' for individual respondents to Q7, n = 96. The potential range of summed scores is -9 (strong skepticism toward ERA) to 9 (strong support for ERA). The observed range was -1 to 9 with a high proportion of responses from 5 to 7, indicating generally moderate to moderately-high support for ERA. See text for details.

To some extent, the level of enthusiasm or skepticism regarding ERA may be associated with interpretations of sustainability. Q6 of the questionnaires (Appendix 3) asks respondents to describe what 'environmental sustainability' means to them in the context of irrigation. The more enthused extreme provided responses that indicated an appreciation of ecological values and/or their societal context. For example, *'People set acceptable parameters - these will change over time - irrigators adopt practices that minimize or eliminate offsite environmental impacts.'*

The more skeptical extreme tended to interpret sustainability through productive values. For example, *'It does not mean 'less is better'; ongoing supply and quality is maintained.'*

However, it would be simplistic to assert that those relatively critical of ERA completely ignore environmental values. One respondent at the lower extreme interpreted sustainability to mean, *'sustainable water use that minimizes impacts on the environment while maximum production with regard to irrigation…and ensuring long term use does not adversely affect the environment.'*

Interpretation of extreme responses may mask trends present in the overall data. We categorized the entire pool of respondents' favorability scores as being either high or low and looked for any pattern in attributes. Here, 'high' represents a score of 6 or more and 'low' a score of 5 or less. Although no contrasts in opinion were apparent for age or gender, there was some suggestion that perceptions of the benefits of ERA were associated with workplace and level of education.

Figure 4(a) shows high and low summed scores broken down by workplace organization. The number of respondents whose workplace was characterized as 'landholders', 'environmental groups', 'consultancies' or 'other industry' (Table 2) was too small for graphing and were excluded. Figure 4(a) indicates that irrigation industry representatives tended to view ERA less favorably, while Community NRM representatives were distinctly inclined toward an enthusiastic view. Researchers and government employees were more or less evenly split between high and low favorability. The statistical significance of this suggested pattern was examined using a chi-square test of association. After omitting irrigation industry and community NRM respondents because of insufficient sample size (Sokal and Rohlf 1995), the test reported a non-significant association at $\alpha = 0.05$.

In Figure 4(b) the association between education and favorability suggested in the extremes of the distribution is again evident. Secondary-educated participants fell exclusively within the 'low' favorability category. Marginally fewer postgraduate-educated participants were included in the 'low' category, and tertiary educated participants were more or less evenly-split between 'high' and 'low'. The chi-square test reported non-significance at $\alpha = 0.05$, after omitting secondary-educated participants because of insufficient sample size.

Non-significant results for suggested patterns is consistent with the caution emphasised by Cary *et al*. (2002) in their review of studies that seek to identify the characteristics of 'innovators', 'leading adopters' or 'laggards' in the context of agricultural innovation. These authors note that while occasional relationships have emerged from some empirical studies, the meaningful identification of characteristics is difficult and sometimes tenuous. We see little in the findings presented here that can inform targeted investment in the encouragement of ERA adoption.

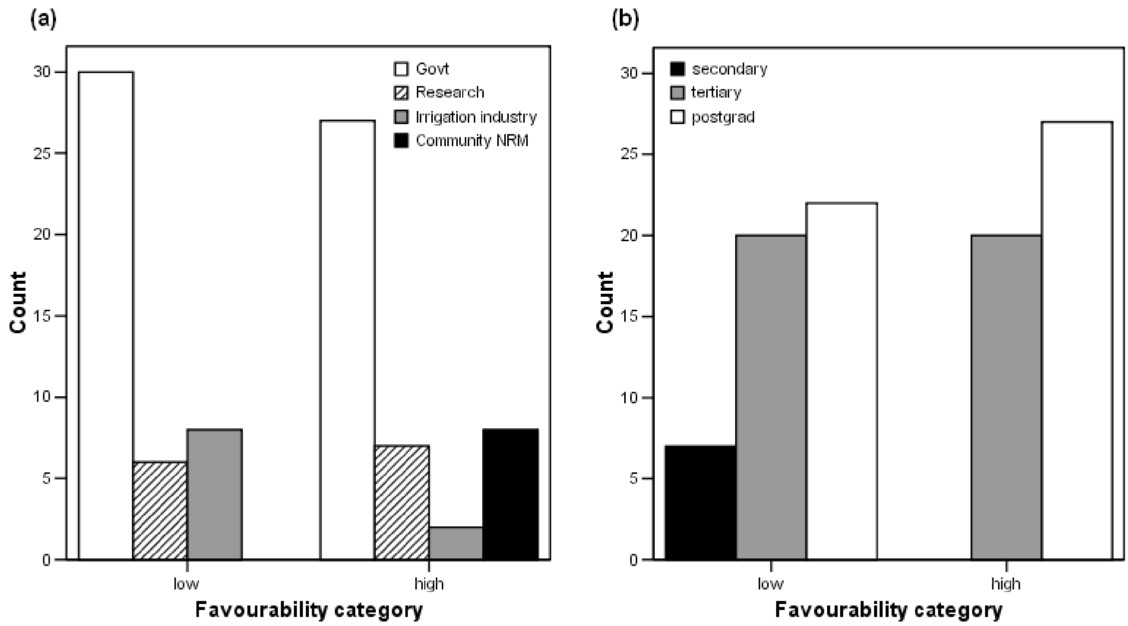

Figure 4: Representation of high and low favorability scores according to respondents' (a) workplace type, and (b) level of education.

4.2.4 Tiers of rigor

Workshops emphasized the desirability of broad stakeholder consultation in the identification of values and hazards. They also highlighted pitfalls associated with a minimalist 'qualitative' approach to risk analysis based on the Australian Standard (AS/NZS 2004). The use of conceptual models and an emphasis on quantitative techniques was advocated as antidotes to many of these pitfalls.

Broader stakeholder consultation and greater rigor in the description of risks entail greater costs in ERA. The intuition of the ERA Project Team is that the benefits from more detailed approaches to ERA almost always justify the more substantial costs associated with their adoption. The extent to which this view is shared among workshop participants was assessed in the evaluation questionnaires.

Questionnaires distributed at the Mildura, Townsville 1 and Shepparton workshops asked directly what level of detail should be adopted for ERA (Q.9a, Appendix 3a). Collated responses are shown in Table 9. The clear majority of workshop attendees considered the involvement of a broad range of stakeholders important in ERA. Quantitative approaches to risk analysis attracted marginally more support than qualitative approaches.

In evaluation questionnaires distributed at the Bunbury, Townsville 2 and Darwin workshops, respondents were asked extended response questions in regard to preferences in the way ERA is conducted (Questions 13a – 13d, Appendix 3b). The general pattern in responses followed those received at the Mildura, Townsville 1 and Shepparton workshops.

Table 9: The number of respondents (*n*) that favored each of the four ERA 'tiers of rigor' included in Q9a of the evaluation questionnaires for the Mildura, Townsville 1 and Shepparton workshops. In total, 34 individuals responded to Q9a. The sum of responses over the four categories is greater than 34 because some respondents indicated a preference for multiple approaches.

Tier	Values and hazards	Risk Analysis method	*n*
1	Identified by a single individual or organization	Qualitative	4
2	Identified by a single individual or organization	Quantitative	5
3	Identified by a broad range of stakeholders	Qualitative	19
4	Identified by a broad range of stakeholders	Quantitative	23

Of responses received to questions asking whether more confidence can be attributed to an ERA conducted alone or one conducted in a stakeholder workshop, just over twice as many respondents indicated a preference for stakeholder workshops. Common comments among those preferring to conduct ERA alone were the confidence in their own expertise and the perception that investing time in broader stakeholder consultation was not worth the cost.

Q13c asks respondents to choose between use of a qualitative OR quantitative approach to ERA. Q13d asks whether more confidence might be attributed to an ERA that uses a combination of qualitative AND quantitative approaches. No distinct preference was evident in responses that required a choice between qualitative and quantitative approaches, with several participants qualifying their answer with an emphasis on the context in which the ERA was conducted. In contrast, there was clear support for a mixed approach to ERA, with 36 respondents indicating a preference for combined approaches to describing risk, and only two articulating a particular preference for a quantitative approach.

4.2.5 The applicability of ERA in the workplace

Questionnaires explored participants' perceptions of the applicability of ERA in the workplace through a variety of questions.

Table 10: Responses to question 8 (Appendix 3a) – 'What organization(s) do you think should take principal responsibility for undertaking ERA in irrigation?'

Who should conduct ERA's ?	Number of respondents
Government, industry and community groups	14
Government and industry	11
Government and community groups	3
Industry and community groups	0
Government only	8
Community groups only	2
Industry only	1
Other (research organizations)	1
Total	**40**

Participants at the Mildura, Townsville 1 and Shepparton workshops were asked what organizations should take responsibility for conducting ERA's (Q8, Appendix 3a). Of the 40 participants that provided a response, most identified a preference for some form of collective responsibility involving government, industry and/or community groups (Table 10).

Questions 8 – 12 of the questionnaire distributed at the Bunbury, Darwin and Townsville 2 workshops asked participants to consider how ERA might be incorporated in their workplace.

In response to the question about how the ERA process would 'fit' with the way participants' organizations currently undertake planning, comments were generally positive, with many noting that ERA would complement currently available tools. It was also commonly noted that basic forms of risk assessment already in use made ERA reasonably accessible.

In response to addressing ideas about the benefits of ERA in the workplace, comments were again positive, focusing on the encouragement of dialogue among stakeholders, promoting transparency, focusing decision-making, and provision of a sound basis for continuous improvement.

Common themes that emerged in the identification of difficulties anticipated in the use of ERA included the time commitment needed, complexities in resolving stakeholder positions, and the potential for biased outcomes. Some respondents identified entrenched cultural attitudes within their organization as an impediment to ERA adoption.

Q11 of the revised questionnaire (Appendix 3b) sought to gauge whether participants could translate workshop learnings into specific ERA applications in their workplace. Approximately 40% of responses identified specific applications and about 25% recorded generic applications such as 'planning' or 'decision-making'. About one third of questionnaire respondents did not answer the question. Overall, findings suggest that while many participants saw how ERA would help address real problems of concern to their workplace, the aims and methods of ERA were perceived to be of limited or vague relevance to a substantial proportion of participants.

When asked to identify requirements for incorporating ERA into the workplace, the most common responses were the introduction of a policy directive that made ERA core business, and further training.

4.2.6 The desirability of future training

A detailed ERA requires access to a suite of sociological and technical skills that are neither routinely taught at undergraduate level nor readily available among working professionals. We asked attendees at the Bunbury, Townsville 2 and Darwin workshops to indicate their interest in further training in ERA (Questions 14a and 14b; Appendix 3b).

Forty responses were received for the question, *What kind of training would you require to be able to incorporate ERA into your workplace?*, of which five participants indicated no interest. Notable emphases among those that articulated an interest included;

- Longer workshops that treat the various themes explored in the one-day awareness workshops in greater detail (11 responses)
- Guidance in working through real case studies (9 respondents)

- Focus on modeling and quantitative description of uncertainty and risk (6 respondents)

The duration of training sought by participants included;
- 2 days (32 respondents)
- 1 week (8 respondents)
- 2 weeks (3 respondents)
- On-going case study based training (4 respondents)

Overall, findings indicate moderately strong interest in further training. It is notable that this apparent demand exists despite 78% of questionnaire respondents stating some pre-workshop familiarity with risk-based approaches to decision-making (Question 5a, Appendix 3a). Investment in further training in ERA is likely to be worthwhile, and a range of approaches to training could be explored including further workshops, case study partnerships and formal University-based education.

4.2.7 General comments
Comments on the organization and running of the workshops were again generally positive and suggested many participants were interested and thinking how they might incorporate aspects of ERA in their workplaces. A common criticism was that the content was too rushed, and suggestions were made to run future workshops over two days, dedicating more time to group work and discussion. Favorable comments were received on prepared presentations, particularly the introductory overview of ERA, where the value of ERA was emphasized in the context of limitations associated with current planning and management approaches and practices.

5. DISCUSSION

Cultural impediments to adoption

Stakeholder involvement and the quantitative description of uncertainty are central themes of extensions to a minimalist ERA approach advocated by Hart *et al*. (2005). In Section 1 of this report it was speculated that these extensions may challenge the prevailing culture of science and management and hence act as impediments to adoption. Here we explore this speculation further.

The value of greater stakeholder involvement in ERA may be in ensuring public support and acceptance of management decisions, as a source of value judgments, or because stakeholders may possess important factual knowledge (Perhac 1998). For those that hold scientific evidence and opinion in high esteem, the idea that stakeholders can provide reliable value judgments or important information is of little merit. The view may also be held that stakeholder involvement aimed at ensuring public support is a cynical exercise in political expediency that compromises scientific rigor (Finkel 1996).

Elements of these criticisms of stakeholder involvement were occasionally evident in respondent's comments, but the clearer message from evaluation feedback was one of strong support for stakeholder involvement. This level of support is somewhat surprising because the ERA framework of Hart *et al*. (2005) is vague about the exact role of stakeholders, and further refinement is a priority of the ERA Project Team.

Evaluation feedback on the merit of including quantitative description of uncertainty in risk assessment was unclear. Encouragingly, there was no direct comment to the effect that communication of uncertainty would undermine confidence in management decisions. But equally, there was only sparse feedback that demonstrated a clear appreciation of the role of uncertainty in decision-making. About half of respondents favoured qualitative assessment and half quantitative, with many noting the importance of context in their preference. For those inclined toward qualitative assessment, there may be an associated perception that its outcomes are more easily communicated, or, that the time and expertise demands of quantitative techniques are too onerous. But again, the perceptions underpinning preferences were unclear.

Beyond feedback received from workshop participants, we canvassed the views of six senior managers regarding the merit of stakeholder involvement and the description of uncertainty in ERA. Telephone interviews were conducted with:

Manager, South Burdekin Water Board
General Manager, Harvey Water
Chief Executive Officer, Goulburn Broken Catchment Management Authority
General Manager, Water Supply Services, SunWater
Chief Executive Officer, Ord Irrigation Co-operative
Manager, National Parks & Conservation Research, Parks Victoria

Each of these individuals was asked to indicate the extent to which they agree with a number of statements. A summary of responses is shown in Table 11. Essentially, responses were consistent with those provided by workshop participants. Although Table 11 gives the general impression that stakeholder consultation and the description of uncertainty are considered sound extensions to risk assessment, there is considerable variability suggesting at least some senior managers hold substantial reservations. Despite reservations, all the senior mangers contacted were confident that staff would be supportive of the extensions should they be made an organisational directive. These observations emphasise that adoption of ERA is likely to be sensitive to the outlook of individual organisations and their senior management.

Table 11: The response of six senior managers to including stakeholder consultation and the description of uncertainty in ERA. D = disagree, TD = tend to disagree, TA = tend to agree, and A = agree. Note that one respondent considered the question, 'How do you think personnel in the organization would react to a directive requiring a description of uncertainty in scientific assessments?', to be irrelevant because scientific assessments were outsourced to consultants.

Statement	**D**	**TD**	**TA**	**A**
Stakeholder consultation in risk assessment invites unnecessary criticism	2	1	2	1
Stakeholder consultation in risk assessment nurtures trust	0	0	6	0
Stakeholder consultation in risk assessment can help identify environmental values and environmental hazards that may be missed by an in-house assessment	0	1	1	4
Stakeholder consultation in risk assessment diminishes the scientific credibility of the assessment	3	2	1	0
The description of scientific uncertainty helps effective decision-making	0	1	2	3
The description of scientific uncertainty retards effective decision-making	1	3	2	0
Statement	**Hostile**		**Supportive**	
How do you think personnel in the organization would react to a directive requiring broader stakeholder consultation in risk assessment?	0		6	
How do you think personnel in the organization would react to a directive requiring a description of uncertainty in scientific assessments?	0		5	

Benefits, costs and the option to delay uptake

Speculation that organizational culture acts as an impediment to adoption assumes that ERA is in itself worth adopting. Vanclay and Lawrence (1994) observe that the notion of a barrier to adoption only logically exists if new technologies or practices are demonstrably beneficial to end-users or the environment. Section 1 of this report outlined how the prospects for adoption of ERA will be influenced by (a) perceptions about the net benefits to be derived from ERA-based decision-making versus the *status quo*, and (b) perceptions about the option value of delaying where there are substantial costs associated with adoption. Here we explore benefits and costs in adopting ERA and the factors that may make delaying uptake an appealing option to the irrigation industry.

The feedback received from workshop participants indicated that ERA is generally regarded as an improvement on current approaches to environmental planning and management, with only a small minority expressing skepticism. However, feedback also suggests that many respondents were unsure of the magnitude of benefits and that they considered the costs of adoption to be significant. For example, although 75% of respondents agreed that ERA helps achieve 'environmental sustainability' (Figure 2A), only about 50% of respondents saw no substantial constraints in the data, time or expertise demands of conducting an ERA (Figure 2H and 2I).

The overarching benefits of ERA adoption include:

- Improved sustainability of the resource base *and* non-market ecosystem services; and
- Improved market or resource access (or maintenance of market/resource share) through a positive consumer and stakeholder image.

Costs may include:

- Equipping the organization with the capacity to implement ERA;
- Ongoing costs in the implementation of ERA; and
- Any perception that information has a negative value.

Industry and government are unlikely to view these benefits and costs in the same way. For private irrigation industry organizations, the nature of benefits needs to support a profit motive. In a review article exploring the adoption of agricultural innovations by farmers, Lindner (1987) found that, 'there is compelling empirical support for an emerging consensus that the final decision to adopt or reject is consistent with the producer's self-interest.' Sindner and King (1990) conclude that, 'while the stewardship motivation and personal factors encourage perception and recognition of a problem, economic factors promote actual adoption.'

For the irrigation industry, sustainability of the resource base is about the productive capacity of the soil and the quality and quantity of irrigation water. Commitment to improvement in resource condition will be sensitive to the planning time horizon of individual industry organizations. Investment in resource improvement will be more attractive to organizations that see themselves operating over longer time horizons, and less attractive to those whose short to medium-term viability is uncertain.

Although self-interest may motivate industry to improve sustainability of the resource base where its prospects for viability over the longer term are strong, its responsibility for non-market ecosystem services is less compelling. At the core of the argument over who should be responsible for non-market ecosystem services is a larger debate over the boundary between private property rights and the duty to protect the public good (Productivity Commission 2001, Bates 2001).

Pannell (2004) outlines arguments for approaches using the user-pays and polluter-pays principle. The user-pays approach says that members of the community should pay in proportion to the benefits they accrue from environmental protection. The polluter-pays principle requires costs to be borne in proportion to the damage caused to the environment. The polluter-pays principle mirrors similar arguments made in occupational health and safety, where it is asserted that failure to manage workplace injury acts to unfairly inflate the need for community public resources providing remedial support to injured workers (Toohey 1987).

The choice between a user-pays or polluter-pays principle is not simple. It involves community attitudes to notions of rights and fairness. Pannell (2004) notes that these notions are flexible over time, and open to the influence of politics and power. Boyd and Simpson (1999) put it more plainly: 'Reasonable persons may differ regarding which groups are more morally deserving of bearing or escaping the burden of payment. But someone must pay.'

The argument that industry can enhance or maintain market or resource access through demonstrated commitment to sustainability to some degree rests on the assumption that the polluter-pays principle has greater legitimacy than the user-pays principle. Industry may feel that through seeking market and consumer recognition for its commitment to sustainability beyond the immediate resource upon which it relies, it may be giving tacit and unwitting support to the polluter-pays principle. In any case, the market access argument rests on the influence of 'green' stakeholders and consumers in mobilizing broader public sentiment and consumer preferences. Industry will weigh this influence together with a raft of other factors that shape market forces and resource access.

Ambiguity in private property rights and duty to the public good can amplify perceptions of the costs of ERA. If industry sees the user-pays principle as more reasonable than the polluter-pays principle, it will be reluctant to bear the costs of improvement to non-market ecosystem services. If a government agency sees greater merit in the polluter-pays principle, it will be reluctant to incur costs it considers are more appropriately borne by industry. This debate it is unlikely to be resolved in the near future. Until greater clarity emerges, both government and industry organizations may choose to delay ERA uptake despite a belief that it represents an improvement to current planning and management.

The intuition of the ERA Project Team is that ERA 'pays' as a preventative strategy in the management of environmental harm, and that this makes it consistent with the profit motive of private industry. If industry sees expenditure on ERA as a good investment they will have a financial incentive to improve risk assessment procedures. In so far as industry embraces this view, the need for government to pursue a regulatory approach for the industry's activities will be minimized (Hopkins 1999).

Even were sound evidence to exist that ERA pays, adoption is not assured. In occupational health and safety, despite strong evidence of benefits to employees and the organization, Hopkins (1995) argues that policies aimed at encouraging adoption by emphasizing 'safety pays' are ineffective. Rather, uptake is more commonly motivated by the threat of prosecution.

The principles of risk assessment are consistent with the demonstration of due diligence as a defence to charges of environmental negligence. However, the information elicited through an ERA may not always have a positive value. Viscusi (2000) provided an example of the negative private value of information. He surveyed the attitudes of almost 500 jury-eligible citizens towards cases involving risk and compensation. He found that if the group responsible for a hazard had completed a systematic analysis of risks and costs, and had decided the benefits of proceeding with some activity outweighed the risks, it triggered a bias against the defendant. Juries were likely to penalize a defendant for having undertaken a risk analysis, substantially increasing the chance of punitive damages.

Where environmental harm occurs, it may be difficult to insulate an otherwise progressive industry from the powerful and symbolic tendency for blame entrenched in our institutions and more particularly, in our legal system (Horlick-Jones 1996). Blame brings positive and negative possibilities for environmental sustainability. Responsibility without accountability for accidents and disasters is likely to fail in motivating organizations to act in good faith. On the other hand, seeking a culprit whenever an error has occurred may promote the avoidance of blame rather than critique and honesty. In this sense, efforts to motivate people to adopt risk assessment may be self-defeating. Pidgeon (1998) emphasizes the need for better political, cultural, symbolic and institutional arrangements that support learning and continuous improvement over corporate myopia. Again, the possibility that information gathered in an ERA will be used to apportion blame rather than demonstrate diligence makes it reasonable for organizations to delay adoption until greater clarity emerges.

The themes explored in this discussion suggest a number of factors beyond an immediate appraisal of the merits of ERA may impede uptake in the irrigation industry. However, individual organizations will vary in their perceptions of the importance and relevance of these factors. More immediate adoption of ERA can be expected where organizations hold the following views:

- Commercial viability is sought over the long term and is dependent on sustainability of the resource base;
- The polluter-pays principle has at least some legitimacy;
- Consumer and stakeholder perceptions are important factors shaping access to markets and resources; and
- Risk assessment is an effective means of demonstrating due diligence in environmental responsibilities.

Interest in ERA shown by organizations that hold some or all of these views should be made a priority in progressing adoption.

6. FUTURE DIRECTONS

The growing debate on water resource management in Australia suggests the irrigation industry needs to be proactive in demonstrating tangible progress in sustainability. However, the themes explored in this report illustrate that arguments for adopting (or delaying adoption) of ERA are complex and multi-faceted. Progressing adoption involves cultural change, technology transfer, and a requirement to address broader institutional issues.

In many respects these complexities have only been made apparent through dialogue with irrigation stakeholders involved in the regional awareness workshops and the Murray Irrigation and Lower Loddon case studies undertaken as part of this project. Comments and avenues for further progress in ERA adoption are listed below. These suggestions encourage a more targeted approach to catalyzing ERA adoption.

Cultural change

- Although there appears to be widespread support for greater stakeholder involvement in planning and decision-making, the exact role of stakeholders in ERA requires clarification and refinement. Failure to address this weakness in the ERA framework (Hart *et al.* 2005) is likely to undermine progress made in adoption over the medium to long term.
- The acknowledgment and transparent description of uncertainty in risk assessment as a means of overcoming overconfidence and myopia is inherently challenging to managers. Efforts to nurture an appreciation of the role of uncertainty in decision-making will be better directed toward researchers and policy-makers.
- As an interim strategy for irrigation industry managers, advantages of a minimalist approach to ERA should be emphasized. Extensions that address weaknesses and pitfalls can be phased in over time.
- As ERA becomes progressively embedded in the policy landscape, incrementally greater effort should be made in the inclusion of stakeholder involvement and the description of uncertainty in risk assessment protocols.

Technology transfer

- An emphasis on equipping an organization with *competency* in the tools and techniques of ERA is unlikely to be effective where the culture of an organization is hostile to the core principles of ERA.
- A coarse *awareness* of tools and techniques can encourage better risk assessments by demonstrating common pitfalls in conducting ERA and how they can be addressed. Web-based materials and occasional 1-2 hour presentations are sufficient for this purpose. Powerpoint presentations included in Appendix 5 provide a starting point.
- Innovations that are observable and trialable are generally more quickly adopted than practices that are unobservable or untrialable (Cary *et al.* 2002). A number of workshop participants identified workplace case studies as a preferred mode of training. Where possible, requests from industry and government to form case study partnerships should be supported, but only where the culture of the organization is supportive of ERA.
- There is reasonable evidence of demand for further formal training among irrigation stakeholders. Training options include extended 2-3 day workshops, university-based coursework and higher degree training.

Institutional issues

- The role of the private and public sectors in the sustainability of non-market ecosystem services needs clarification.
- The capacity for ERA to act as a demonstration of due diligence against charges of environmental negligence requires administrative and legal clarification. In the absence of clarification, industry may be discouraged from adopting ERA because of fear of litigation where elicited information indicates any risk of environmental harm.
- These broader institutional issues are unlikely to be resolved in the near future. In the meantime, the choice of an industry organization to delay adoption of ERA should be respected.

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References

AS/NZS (2004). *Risk Management (AS/NZS 4360:2004)*. Standards Australia International, Sydney.

Barnthouse L. W. & Suter G. W., II. (Eds) (1986) *User's Manual for Ecological Risk Assessment*. ORNL-6251. Oak Ridge National Laboratory, Oak Ridge, TN.

Bates, G. 2001. *A Duty of Care for the Protection of Biodiversity on Land*. Consultancy Report to the Productivity Commission, AusInfo, Canberra.

Beckerman, W. (1996). A skeptical view of sustainable development. In: *Proceedings, Global Agricultural Science Policy for the Twenty First Century, Invited Papers, 26-28 August 1996, Melbourne, Australia, pp. 153-170.*

Blockley, D.I. (1980). *The Nature of Structural Design and Safety*. Ellis-Horwood, Chichester.

Boyd J. and Simpson, R.D., 1999. Economics and biodiversity conservation options: an argument for continued experimentation and measured expectations. *The Science of the Total Environment*, **240**: 91-105

Burgman, M.A. (2005). *Risks and Decisions for Conservation Environmental Management*. Cambridge University Press, Cambridge.

Cary, J.W., Webb, T.J. & Barr, N.F. (2002). *Understanding landholders' capacity to change to sustainable practices. Insights about practice adoption and social capacity for change*. Canberra: Bureau of Rural Sciences.

Finkel, A.M. (1996). Comparing risks thoughtfully. *Risk: Health, Safety and Environment*, **7**: 349 [online]: www.piercelaw.edu/risk/vol7/fall/

Fischer, F. (2000). *Citizens, Experts, and the Environment*. Duke University Press, Durham.

Garvin, T. (2001). Analytical paradigms: The epistemological distances between scientists, policy makers, and the public. *Risk Analysis,* **21:** 443-454.

Hart, B., Burgman, M., Webb, A., Allison, G., Chapman, M., Duivenvoorden, L., Feehan, P., Grace, M., Lund, M., Pollino, C., Carey, J. and McCrea, A. (2005). *Ecological Risk Management Framework for the Irrigation Industry*, Report to National Program for Sustainable Irrigation (NPSI) by Water Studies Centre, Monash University, Clayton, Australia.

Hopkins, A. (1995). *Managing Safety Work. Getting Management Commitment to Occupational Health & Safety*. Allen & Unwin, St. Leonards.

Hopkins, A. (1999). *Managing Major Hazards*. Allen & Unwin, St. Leonards.

Horlick-Jones (1996). The problem of blame. In: C. Hood and D.K.C. Jones (eds), *Accident and Design: Contemporary Debates on Risk Management*. University College Pres, London. pp. 61-71.

Kellett, B.M., Walshe, T.V. and Bristow, K.L. (2005). *Northern Australia Irrigation Futures. Report on the Ecological Risk Assessment workshop for the wetlands of the Lower Burdekin*. Draft CSIRO Land & Water Technical Report.

Marra, M., Pannell, D.J. and Ghadim, A.A. (2001). The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: Where are we on the learning curve? *Agricultural Systems* **75**: 215-234.

Lewandowsky, S. and Kirsner, K. (2000). Knowledge partitioning: Context-dependent use of expertise. *Memory and Cognition*, **28:** 295-305.

Lindner, R.K. (1987). Adoption and diffusion of technology: an overview. In: B.R. Champ, E. Highly, and J.V. Remenyi (eds). *Technological Change in Postharvest Handling and Transportation of Grains in the Humid Tropics*. ACIAR Proceedings No. 19, pp. 144-151.

O'Brien, M. (2000). *Making better environmental decisions: an alternative to risk assessment*. MIT Press, Cambridge, Massachusetts.

Pannell, D.J. (2004). Heathens in the chapel? Economics and the conservation of native biodiversity, *Pacific Conservation Biology*, **10:** 88-105.

Pannell, D.J. and Schilizzi, S. (1999). Sustainable agriculture: A question of ecology, ethics, economic efficiency or expedience? *Journal of Sustainable Agriculture*, **13**:57-66.

Perhac, R.M. (1998). Comparative risk assessment: where does the public fit in? *Science Technology and Human Values*, **23**:221-241.

Peters, R.H. (1991). *A Critique for Ecology*. Cambridge University Press, Cambridge.

Pidgeon, N. (1998). Safety culture: key theoretical issues. *Work and Stress*. **12:** 202-216.

Pidgeon, N., Hood, C., Jones, D., Turner, B. & Gibson, R. (1992) Risk perception. In: *Risk: Analysis, Perception and Management*. Report of a Royal Society Study Group. The Royal Society, London, UK. Ch. 5.

Poff, N. L., Allan, J. D., Palmer, M. A., Hart, D. D., Richter, B. D., Arthington, A. H., Rogers, K. H., Meyer, J. L. and Stanford, J. A. (2003). River flows and water wars: emerging science for environmental decision making. *Frontiers in Ecology and the Environment* **1:** 298-306.

Pollino, C. A., White, A. and Hart, B. T. (2005). *Ecological risk assessment case study for the Murray Irrigation region*, Report 2, NPSI Project UMO45, Water Studies Centre, Monash University (www.sci.monash.edu.au/wsc), Melbourne.

Productivity Commission, 2001. *Constraints on Private Conservation of Biodiversity*. Commission research paper. AusInfo, Canberra.

Regan, H.M., Colyvan, M. & Burgman, M.A. (2002) A taxonomy and treatment of uncertainty for ecology and conservation biology. *Ecological Applications*. 12: 618-628.

Sarewitz, D. (2004). How science makes environmental controversies worse. *Environmental Science and Policy,* 7: 385-403.

Sinden, J.A. and King, D.A. (1990). Adoption of soil conservation measures in Manilla Shire, New South Wales. *Review of Marketing and Agricultural Economics*, **58:** 179-192.

Slovic, P. (1999). Trust, emotion, sex, politics, and science: Surveying the risk assessment battlefield. *Risk Analysis*, **19:** 689-701.

Toohey, J. (1987). Managing health and safety effectively? Or is it all a bit technical? Journal of *Occupational Health and Safety – Australia and New Zealand*, **3:** 235-239.

Vanclay, F. & Lawrence, G. (1994). Farmer rationality and the adoption of environmentally sound practices: A critique of the assumptions of traditional agricultural extension. *European Journal of Agricultural Education and Extension,* **1:** 50–90.

Viscusi, W. K. 2000. Corporate risk analysis: a reckless act? Harvard Law School Discussion Paper 304 (11/2000) [online]: http://www.law.harvard.edu/programs/olin_center/

Westbury, A.M., Chan, T., Putt, C., Tiller, D. and Hart, B. T. (2005). *Ecological risk assessment case study for the lower Loddon River*, Report 3, NPSI Project UMO45, Water Studies Centre, Monash University (www.sci.monash.edu.au/wsc), Melbourne.

APPENDICES

Invitation to a one day workshop exploring

ECOLGICAL RISK ASSESSMENT

Toward a sustainable future for irrigation industries of southwest Western Australia

Irrigation-dependent industries are increasingly scrutinised for their environmental sustainability. In southwest Western Australia, utilisation of surface and ground water resources will need to consider the catchment -scale context of environmental impacts associated with current management and proposed new practices.

Effective environmental ma nagement is often hindered by vague objectives and a poor understanding of the links between threats and values. Ambiguity and uncertainty can lead to decision -making paralysis, or, the allocation of scarce resources toward socially irrelevant or environmentally unimportant values and assets.

Ecological Risk Assessment (ERA) is a quantitative process for determining priorities associated with protecting, maintaining and restoring the health of ecosystems. ERA provides a framework for stakeholders to clear ly define the problem and desired outcomes. The process explicitly incorporates complexity and uncertainty into decision -making, and provides transparency in the identification of management actions and knowledge gaps.

ERA is becoming a common requiremen t for industry proponents. This workshop emphasises the benefits of adopting a rigorous ERA and highlights the pitfalls associated with its naïve application. Although a central focus will be the treatment of ecological risks posed by irrigation practices , the concepts and methods are equally applicable to other aspects of water and natural resource management.

The workshop will address how ERA can:

- Identify socially relevant and environmentally important assets in the context of changing water management and practices in southwest Western Australia
- Address multiple values and multiple threats in a catchment-wide context
- Estimate the likelihood of adverse events that lead to environmental degradation
- Provide a framework for the development of conceptual mo dels that underpin explicit and transparent description of ecological risks in the face of uncertainty

WHEN	9.30 am – 4.30 pm, Tuesday 15 March 2005
WHERE	Function Room 3, Sanctuary Golf Resort, corner of Old Coast Road and the Australind Bypass, Bunbury
RSVP (and further info)	Terry Walshe tel. 08 9842 0809 email terryw@cyllene.uwa.edu.au

NATIONAL PROGRAM FOR Sustainable Irrigation

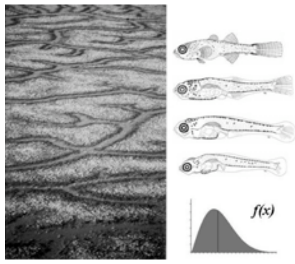
Water Studies Centre

THE UNIVERSITY OF MELBOURNE

Background to the 18 May workshop

ECOLGICAL RISK ASSESSMENT for

Current and proposed irrigation in the Katherine-Daly region



OVERVIEW

Proposals for irrigation in the Katherine-Daly region need to consider the cumulative catchment-scale environmental impacts of current and proposed land uses. A considerable amount of work has already been done on environmental water requirements and the scale of irrigation that might be accommodated if these requirements were adopted. We'll use this work as a basis for formulating the problem to be addressed in exploring risks to environmental values.

Effective environmental management is often hindered by vague objectives and a poor understanding of the links between threats and values. Ecological Risk Assessment (ERA) is a quantitative process for determining stakeholder-derived priorities associated with protecting, maintaining or restoring the health of ecosystems. When done well, the process can explicitly incorporate complexity and uncertainty into decision-making, and provide transparency in the identification of management actions and knowledge gaps. ERA is becoming a common requirement for industry proponents. This workshop emphasises the benefits of adopting a rigorous ERA and highlights the pitfalls associated with its naïve application.

Risk assessment is directly or indirectly a part of ongoing work to assess the potential for expanded irrigation in the Top End. The main aim of this workshop is to equip decision-makers, scientists and community stakeholders with a better appreciation of the strengths and weaknesses of ERA to promote improved planning and management.

KATHERINE-DALY REGION: THE HALF-COOKED UNDERSTANDING OF A RISK ANALYST

About 200,000 ha or 4% of the Katherine-Daly region has been cleared (WWF/NTEC 2004). Land uses in the region include cattle grazing for beef production on native and improved pastures, non-irrigated and irrigated cropping, irrigated horticulture, urban centres, and parks and reserves (DIPE 2003). In the workshop, we'll need to be mindful of all these land uses, but of particular interest are the additional risks to environmental values posed by irrigated agriculture.

The Daly River is perennial and its flow and chemical characteristics are distinctly seasonal. Its tributaries include the King, Katherine, Flora, Ferguson, Douglas and Fish Rivers (Figure 1). Surface runoff dominates stream flow in the Wet season and is characterised by low electrical conductivity and relatively high turbidity, nutrient and organic matter levels. Flows in the Dry season are maintained by groundwater sources that are typically high in bicarbonate content and low in nutrients and suspended material. The beginning of the Dry season sees a marked change in the turbidity of the river as bicarbonate-dominated groundwater flocculates suspended sediment. The seasonal interplay of water volume and water chemistry associated with rainfall and aquifer recharge and discharge are likely to have important implications for species, communities and ecological processes (Erskine et al. 2003).

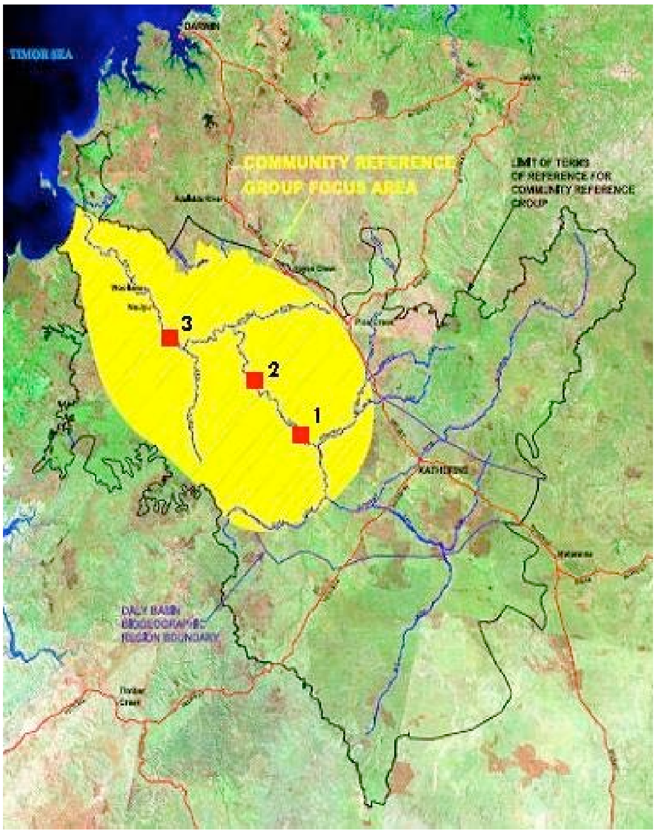


Fig. 1 Major streams of the Katherine-Daly region. The delineated areas refer to the scope of the Daly Region Community Reference Group. Red squares indicate locations specifically referred to in recommended Environmental Water Requirements (see Fig. 2). 1 = Dorisvale Crossing, 2 = Oolloo Crossing, 3 = Mount Nancar. (Source: http://www.ipe.nt.gov.au/whatwedo/dalyregion/)

The potential scale of development for the Katherine-Daly Region is the subject of debate. Although the NT Department of Infrastructure Planing and Environment currently has over 50 applications for water access awaiting determination, the extent to which these and further applications will be accommodated or encouraged is yet to be decided. In part, the issue's resolution awaits outcomes from further work in water allocation planning, research on tropical rivers, and research on what sort of irrigation systems might work in the Top End.

The main objective of the workshop is to explore the strengths and weaknesses of ERA. To do so, we'll use a scenario for proposed development that uses provisional recommendations made from previous work. The scenario comprises two main elements:

1. Environmental Water Requirements (Erskine et al, 2004)
2. The potential extent of irrigated agriculture (Smith et al 2004)

Environmental Water Requirements

Identifying Environmental Water Requirements (EWR's) in highly variable ecosystems is unsurprisingly difficult. As an interim arrangement, the following framework applies for water allocation planning in the Top End:

All available scientific research directly related to environmental water requirements for the water resource, and all available research and information on cultural water requirements, are applied in setting environmental and cultural water allocations as the first priority. Allocations for consumptive use are made subsequently within the remaining available water resource.

In the absence of research directly related to environmental water requirements and cultural water requirements, the following contingent allocations are made for environmental water provisions and consumptive use:

Rivers	**Aquifers**
at least 80% of flow at any time in any part of a river is allocated to the environment; and extraction for consumptive uses will not exceed the threshold level equivalent to 20% of flow at any time in any part of a river	at least 80% of annual recharge is allocated to the environment; and extraction for consumptive uses will not exceed the threshold level equivalent to 20% of annual recharge

In the event that current and/or projected consumptive use exceeds the 20% threshold levels, then:

New Surface Water Licences	**New Groundwater Licences**
will not be granted unless supported by directly related scientific research into environmental water requirements.	will not be granted unless supported by either: preferably, directly related scientific research into groundwater dependent ecosystem requirements; or in the absence of such research, hydrological modelling confirming that total groundwater discharge will not be reduced by more than 20%.

The ecological basis for EWR's for the Daly River between Dorisvale Crossing and Mt Nancar (see Figure 1) has subsequently received greater attention. Erskine et al. (2003) summarise a suite of studies that explored the ecology of riparian vegetation, a macrophyte, periphyton and phytoplankton, and the pig-nosed turtle, and their dependence on flow and water quality attributes.

After revision, a number of recommendations for EWR's were made from this body of work (Erskine et al 2004). The specific flow recommendations for the main channel of the Daly River are summarised in Figure 2. Additionally, recommendations were made that existing discharge rates from aquifer-sourced springs be maintained, and that water quality guidelines detailed in ANZECC and ARMCANZ (2000) be applied to the Daly River.

In the workshop scenario, we'll use these recommendations as a basis for exploring risk.

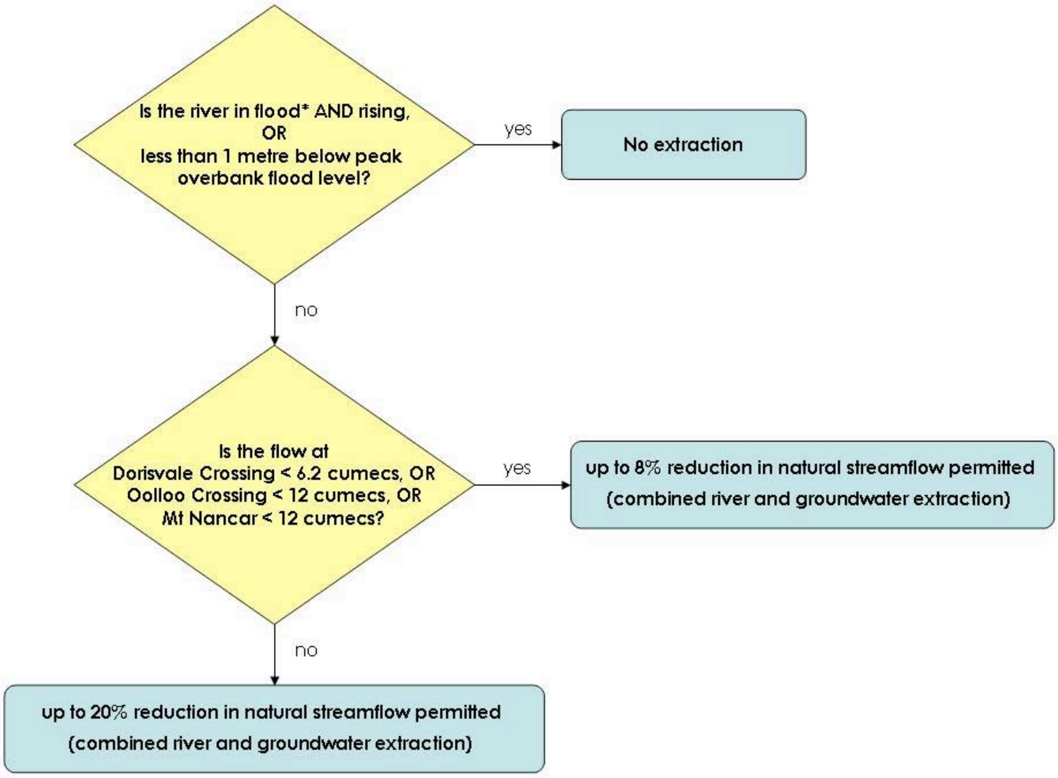


Fig. 2 Decision tree describing recommended Environmental Water Requirements for surface waters of the Daly River between Dorisvale Crossing and Mt Nancar. Adapted (and simplified) from Erskine et al. (2004). * A flood is defined by a gauge height > 7m at any gauging station.

The potential for irrigated agriculture

The approach of Smith et al. (2004) was to identify candidate areas within the region where water could be sourced. For surface water, it was assumed that extraction, storage and use would be restricted to a 3 km corridor along sections of the river that flowed permanently (Figure 3). The volume of extraction permitted by the EWR recommendations described above requires detailed calculation, but as an estimate Smith et al (2004) thought that up to 300,000 ML/year may be available from wet season flood harvesting and off-stream storage. (Note that current stock and domestic and licensed use totals about 10,000 ML/year). Assuming use of 10 ML/ha/year and making an allowance for losses in storage and delivery, it was estimated that enough water may be extracted to supply 20,000 ha of irrigated agriculture from surface flows.

For groundwater, Smith et al. (2004) assumed only high yielding zones of aquifers would be available for extraction. Using a threshold of 10 L/s, parts of the Oolloo and Tindall aquifers were identified as candidate areas (Figure 3). Using water balance estimates and a 20% recharge volume constraint for extraction, it was thought that about 100,000 ML/year would be available from the two aquifers in total. (Note that current stock and domestic and licensed use totals about 34,000 ML/year). Again assuming use of 10 ML/ha/year, an estimated 10,000 ha of irrigated agriculture could be supported by groundwater.

So for the workshop scenario, we'll look at a 'proposal' for 30,000 ha of irrigated agriculture – 20,000 ha of which is supplied from surface water, and 10,000 ha from ground water. We'll have a closer look at what this might entail on the day.

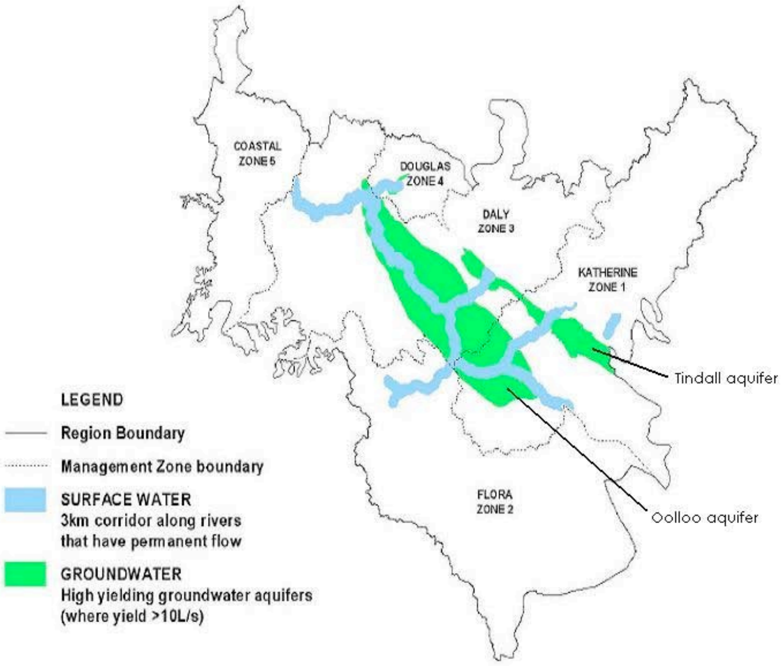


Fig. 3 Broad areas within which water could be sourced for irrigated agriculture. (Source: Smith et al 2004)

A BIT MORE ABOUT ECOLOGICAL RISK ASSESSMENT

ERA seeks to explicitly describe the uncertainty and risks associated with inferred environmental impacts. In acknowledging uncertainty, planning for the Katherine-Daly region has sought to clarify the confidence in predictions underpinning EWR's, and has emphasised the importance of adaptive management and monitoring. When done well, ERA can provide a framework for addressing these issues.

But when done poorly ERA can be seen as a process which attempts to make the illegitimate exercise of power by vested interests and scientists acceptable (O'Brien 2000). It has the potential to alienate stakeholders by placing social decisions in the hands of the technical people who conduct the assessments (Fischer 2000). Better assessments involve stakeholders throughout the whole process and ensure their views are considered. The central idea is to help decision-making in a way that stays faithful to the priorities of those who carry the burden of the risks, while at the same time making the full strength of technical risk analysis available.

Scientific inquiry is commonly politicised in environmental controversies involving strongly contested values (Sarewitz 2004). The EWR recommendations of Erskine et al (2004) are based on sound science. But implicitly there is an assertion that water extraction that complies with these EWR's represents an acceptable risk to environmental values. The notion of what is an acceptable or unacceptable level of risk is a social (and political) judgment rather than a technical judgment. Stakeholders will vary in their perception of the magnitude and importance of risk to environmental values. A core aim of ecological risk assessment is to place uncertainty and risks in plain view, and to encourage stakeholders to cross-examine the bases of their perception of risk.

Risk assessment has been carried out in engineering and process industries for several decades. Ecological Risk Assessment is the process of estimating likelihoods and consequences of the effects of human actions or natural events on plants, animals and ecosystems of ecological value, that is, the study of risks to the natural environment (SA/NZ 2000). The process of risk assessment helps decision-making when we are uncertain about future events or actions, and the risk analyst's job is to evaluate and communicate the nature and extent of uncertainty. Risk assessment is a 'continuous improvement' cycle. Its main components are illustrated in Figure 4.

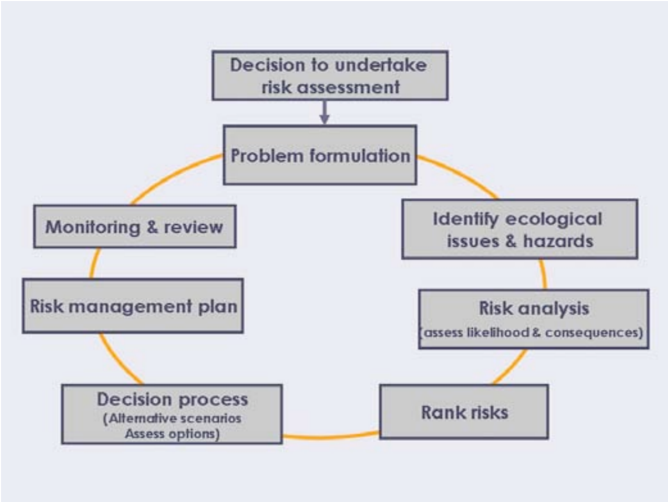


Fig 4. Key elements of the risk assessment framework. (Source: SA/SNZ 2000).

In the workshop, we'll use the scenario described above as a basis for the 'problem formulation' stage. From there, the workshop will mainly focus on identifying ecological values and hazards, risk analysis and risk ranking (Figure 4). We'll canvass other aspects dealing with decision-making, risk management plans and monitoring and review, but we won't have time to look at these in detail.

The identification of ecological values to be examined in an ERA can be difficult. A distinction between cultural and environmental values may be cumbersome when addressing Aboriginal views (Erskine et al 2004, Jackson 2004). To some extent, the same can be said of attempts to classify environmental values associated with broader society. The environmental values documented for the Katherine-Daly is a very long list (DIPE 2003, Jackson 2004, Kennedy 2004, WWF/NTEC 2004). Within the constraints of typical budgets, a weakness of ERA is that not all values can be treated in detail. This is a weakness of any approach based on 'adaptive management' where monitoring biological and physical conditions underpins continuous improvement.

A good ERA identifies ecological endpoints that capture the values of a broad range of stakeholders. A good endpoint is one that is

- ecologically important,
- socially and culturally relevant, and
- amenable to measurement.

Examples of endpoints are shown in Table 1. One of the first tasks of the workshop will be to identify values and endpoints that will serve as a focus for our exploration of ERA throughout the day.

Table 1. Examples of different ecological effects and assessment endpoints used to assess the risks to ecosystem values (Source: Hart et al. 2005).

Ecosystem Value	Ecological effect	Assessment endpoint
Protection of wetland	• Loss of biodiversity due to	• Reduction in the abundance and diversity of

health	increased salinity	macroinvertebrates • Reduction in the abundance and diversity of fringing macrophyte vegetation
	• Loss of aquatic macrophytes due to changes to the flow	• Reduction in the abundance and diversity of macrophytes
Protection of river health	• Reduction in native fish numbers due to cold water releases from a dam	• Reduction in the abundance and diversity of native fish
	• Toxicity to biota due to pesticide runoff	• Reduction in the abundance and diversity of native fish • Reduction in the abundance and diversity of macroinvertebrates
	• Blue-green algal blooms due to increased nutrient release from an irrigation area	• Increased frequency of cyanobacterial blooms, measured as the number of days the cyanobacterial cell numbers were >15,000 cells/mL
	• Loss of a threatened species due to loss of in-stream and riparian habitat	• Decline in the population size of the threatened species

Individual values of the environment may be threatened by one or more hazards, threats or stressors. These may be physical, chemical or biological entities or threatening processes such as the clearing of land or the discharge of waste. They may include socio-political, economic or administrative elements. Threats commonly associated with the activities of irrigation systems are shown in Table 2.

Table 2 is not an exhaustive list of hazards or threats. After eliciting threats associated with the particular circumstances of the Katherine-Daly region, a key theme for the workshop is gathering views on what are the more important threats and what are less important.

Conceptual models link ecological processes and management practices to ecosystem condition. Models are abstractions, representing how we think the world works. Intrinsically, a decision to undertake any management action involves a conceptual model that, in the face of considerable uncertainty and ignorance, suggests one course of action is preferable to another. Often these conceptual models and the values that underpin them remain unspoken, unspecified and undocumented. Alternative models and courses of action may be entirely plausible, and on consideration, may prove preferable. But again, these alternatives are left unrecorded.

Table 2. Checklist of potential off-site ecological issues associated with irrigation systems. (Source: Hart et al. 2005).

Activity	Hazard/Threat/Stressor	Potential ecological effect
Flow-related	• Changed flow regimes and reduced flows • Barrier (weirs, dams) • Poor water quality (low temperature, low dissolved oxygen)	• Reduced biodiversity – interferes with breeding cycles; loss of habitat • Reduced biodiversity – interferes with fish migration • Toxicity to fish, alien species take over
Contaminants	• Increased nutrients (P,N) • Increased toxicants (biocides, heavy metals) • Increased turbidity and suspended	• Increased frequency of algal blooms • Reduced biodiversity – due to toxic effects • Reduced primary production, smothering of benthic habitat

	particulate matter	
Salinity	• Increased salinity	• Reduced biodiversity due to toxic effects on aquatic biota and terrestrial plants

Explicit documentation of the conceptual models that underpin decisions are (a) essential to stakeholder involvement and transparency, and (b) a prerequisite to the use of monitoring in 'continuous improvement' and 'adaptive management'. Using the framework provided by ERA, we'll encourage stakeholders to cross-examine the thinking and logic underlying their conceptual models of how the Katherine-Daly functions.

Perceptions of risk and how a system works are very much an individual matter, and are affected by a variety of factors. Our personal experience and beliefs have a strong influence on our perception of risk. Cultural differences also contribute substantially to perceptions and acceptance of risk, so that different social groups react differently when confronted by the same hazards (Pidgeon et al. 1992). ERA seeks to document different perceptions of risk and distinguish socially and psychologically constructed perceptions from the uncertainties that arise from vague language, scientific inference, and ignorance (Regan et al. 2002).

OUTCOMES SOUGHT FROM THE WORKSHOP

There are many ways in which an ERA can be undertaken. This workshop seeks to highlight the strengths and weaknesses of different approaches so that decision-makers, scientists and community stakeholders are better equipped to contribute to further work exploring the merit of agricultural development and its impacts on environmental values within the Katherine-Daly region.

The workshop will address how ERA can:

- Identify socially relevant and environmentally important values in the context of current and proposed irrigation practices in the Katherine-Daly basin
- Address multiple threats in a catchment-wide context
- Estimate the likelihood of adverse events that lead to environmental degradation
- Provide a framework for the development of conceptual models that underpin explicit and transparent description of ecological risks in the face of uncertainty

Decisions about land use and water allocation planning for the Katherine-Daly region are not direct objectives of the workshop. However, we hope that insights from the day help to shape future work.

Terry Walshe
10 May 2004

References

ANZECC and ARMCANZ (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.* National Water Quality Management Strategy Paper No. 4, ANZECC and ARMCANZ, Canberra.

DIPE (2003). *Draft Conservation Plan for the Daly Basin Bioregion.* August 2003. Northern Territory Department of Infrastructure Planning & Environment. Darwin.

Erskine, W.D., Begg, G.W., Jolly, P., Georges, A., O'Grady, A., Rea, N., Dostine, P., Townsend, S. and Padovan, A. (2003). *Recommended environmental water requirements for the Daly River N.T., based on ecological, hydrological and biological principles.* Report produced for the Northern Territory Department of Infrastructure Planning & Environment. by Supervising Scientist Division, Supervising Scientist, Darwin, NT.

Erskine, W., Jolly, P. and Smith, I. (2004) *Environmental water requirements of the Daly River: Revisions of recommendations of Erskine et al (2003)*. Report 30/2004D Northern Territory Department of Infrastructure, Planning and Environment, Palmerston.

Fischer, F. (2000). *Citizens, Experts, and the Environment.* Duke University Press, Durham

Hart, B., Burgman, M., Webb, A., Allison, G., Chapman, M., Duivenvoorden, L., Feehan, P., Grace, M., Lund, M., Pollino, C., Carey, J. and McCrea, A. (2005). *Ecological Risk Management Framework for the Irrigation Industry*, Report to National Program for Sustainable Irrigation (NPSI) by Water Studies Centre, Monash University, Clayton, Australia.

Jackson, S., (2004). *Preliminary Report on Aboriginal Perspectives on Land-Use and Water Management in the Daly River Region*, Northern Territory. CSIRO, Winellie.

Kennedy, S. (2004). *The Daly Report. Part One. An assessment of the terrestrial conservation values of the Daly River Catchment and the threats posed by land clearing and agricultural development.* Prepared for the Environment Centre Northern Territory & The Wilderness Society, October 2004.

Jolly, P., George, D., Jolly, I., Spiers, Z. (2000). *Analysis of groundwater fed flows for the Flora, Katherine, Douglas and Daly Rivers.* Report 36/2000D. Northern Territory Department of Lands Planning & Environment. http://www.ipe.nt.gov.au/whatwedo/dalyregion/reports/Jolly1.pdf

O'Brien, M. (2000). *Making better environmental decisions: an alternative to risk assessment.* MIT Press, Cambridge, Massachusetts.

Pidgeon, N., Hood, C., Jones, D., Turner, B. & Gibson, R. (1992) Risk perception. In: *Risk: Analysis, Perception and Management*. Report of a Royal Society Study Group. The Royal Society, London, UK. Chapter 5..

Regan, H.M., Colyvan, M. & Burgman, M.A. (2002) A taxonomy and treatment of uncertainty for ecology and conservation biology. *Ecological Applications.* 12: 618-628.

Sarewitz, D. (2004). How science makes environmental controversies worse. *Environmental Science and Policy,* 7: 385-403.

SA/SNZ (2000) *Environmental risk management - principles and processes.* (HB 203:2000) Standards Australia International Ltd, Sydney, and Standards New Zealand, Wellington.

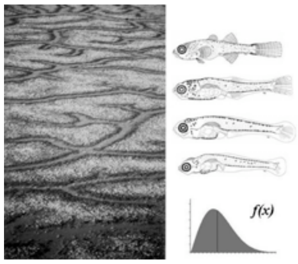
Smith, I., Faulks, J., Tickell, S. and Kirby, S. (2004). Water Allocation Plan for the Daly Region. Powerpoint presentation to Public Meeting held 29 March 2004. http://www.ipe.nt.gov.au/whatwedo/dalyregion/waterplan/pdf/Douglas-Daly-Public-Meeting-290304.pdf

WWF/NTEC (2004). *Aquatic conservation values of the Daly River Catchment, Northern Territory*. Draft report for Discussion. November 2004. WWF-Australia and the Environment Centre of the Northern Territory.

Background to the 1 June workshop

ECOLGICAL RISK ASSESSMENT for WETLANDS OF THE LOWER BURDEKIN

Exploring priorities in the context of multiple values



OVERVIEW

Wetlands are valued for all sorts of reasons. In the Lower Burdekin, wetlands are valued ecologically as habitat for a range of plants and animals and as a buffer that protects the marine environment from sediments, nutrients and other contaminants. The workshop seeks to document the perspectives of various stakeholders regarding the compatibility of these values. The problem will be formulated and explored using 'ecological risk assessment', a framework that encourages stakeholders to cross-examine each others thinking and to make plain the uncertainty associated with different management options. Follow-up research will use insights from the workshop to provide decision-support for identifying management priorities in the presence of uncertainty.

THE LOWER BURDEKIN

Land uses of the Burdekin catchment include irrigated horticulture, beef cattle grazing, dryland copping, aquaculture, nature conservation, towns, and mining. In the workshop, we'll need to be mindful of all these land uses, but of particular importance is management of irrigation systems in the Lower Burdekin.

Irrigation is more or less provided exclusively for growing sugar cane. Water is sourced from groundwater, the Burdekin Falls dam and directly from the main channel of the Burdekin River. The way water moves through the lower catchment, both above and below the surface, has immediate implications for the way in which wetlands are exposed to land use impacts. Significant wetlands and watercourses of the Lower Burdekin region are shown in Figure 1, and an aerial image of the area is provided in Figure 2.

The Burdekin Falls dam was constructed in 1987 and its management increases dry season river flows down the river. These flows are pumped from the Burdekin River through wetlands, such as Sheep Station creek, to deliver water for irrigation. Prior to the construction of the dam, water in the river was only turbid during periods of high flow, but dam and river water now typically remains turbid throughout the year. This means that wetlands used for water delivery, such as Sheep Station creek, maintain elevated flows with higher sediment loads.

Some wetlands of the Lower Burdekin receive irrigation tail water, and therefore also maintain elevated flows. Loads of nutrients, pesticides and sediment received by these wetlands have increased since the development of irrigation. The Barratta creeks, The Haughton River, and Horseshoe Lagoon all receive irrigation tail water.

For five or six months of each year the Haughton River flows into Bowling Green Bay. During more extreme flows, water breaches the banks of the Haughton and Burdekin Rivers and passes into the RAMSAR listed saltpans and swamps of Bowling Green Bay National Park. During these events, large sediment plumes can be observed extending kilometres offshore (Figure 2).

In the Burdekin Delta, water is pumped from the Burdekin River into recharge pits to maintain a high water table so that groundwater can be drawn for irrigation. This high water table also prevents sea water from intruding inland. Sand dams in the Burdekin River are used to maintain practical operating levels at river pump stations. Salt water barrages allow irrigation and grazing closer to the coast by maximising the reach of freshwater into what were once intertidal zones.

Figure 1 Map of the Lower Burdekin showing major streams, Ramsar wetlands and other important wetlands. (Source: http://www.deh.gov.au/water/wetlands/epbc/databases.html).

A LOOK AT A COUPLE OF VALUES OF THE REGION'S WETLANDS

Wetlands are an important resource for agriculture, recreation, education, science, ecological and cultural values. They are the transport corridors for, and suppliers of, water for irrigation, stock and aquaculture. Fishing, boating and canoeing are popular activities in some wetlands, but all hold value for aesthetic and scientific reasons. They are ecosystems which support a large diversity of life, including fish, crocodiles, tortoises, birds, mammals and vegetation. Indigenous people value wetlands as places to live, places that provide opportunities to practice traditions like fishing, hunting, initiation, as well as resources for the establishment of ecotourism businesses. Seasonal wetlands protect against flooding by absorbing and slowly releasing floodwater. This also helps to filter nutrients and sediment, both of which can damage the Great Barrier Reef.

Figure 2 Satellite image of the Lower Burdekin region (Source: Qld Department of Natural Resources & Mines).

Here we restrict ourselves to just the *ecological* values of the wetlands of the Lower Burdekin. Wetland groups of the Lower Burdekin include those of the RAMSAR-listed Bowling Green area, and the nationally important aggregations of the Burdekin Delta and Upstart Bay (Australian Government 2004, Figure 1). In particular, we're interested in the degree to which the habitat quality for wetland-dependent plants and animals is consistent with the notion that wetlands can act as 'kidneys' for the reef and broader marine environment.

Threats to wetlands

Cattle grazing is a hazard for the shallow seasonal wetlands of the Lower Burdekin, especially during the dry season (Congdon no date). Cattle disrupt plant and animal populations and affect water quality (Congdon no date).

Weeds such as water hyacinth, salvinia and para grass are extensive throughout the wetlands of the Lower Burdekin (Congdon no date). These weeds can reduce the flow of water and increase sedimentation. In the wetlands of Townsville's town common, cattle are being reintroduced to control Para grass infestations.

Levee banks, drains, dams and barrages result in changes to wetlands, drying up some areas, increasing the size of some and reducing seasonality in flows (Condong no date).

Channels that are used for the deliver of irrigation water maintain elevated flows and increased turbidity and nutrient loading (Perna and Burrows 2005). These factors facilitate growth of weeds, such as water hyacinth, which reduce dissolved oxygen, one of the most important water quality variables for aquatic fauna (Perna and Burrows 2005).

Seasonal flow of freshwater into estuaries has been suggested as an important element for sustainable fish populations. Staunton-Smith et al. (2004) found correlations between abundance of barramundi year classes and quantity of freshwater flowing into an estuary during spring and summer, when barramundi spawn and young-of-the-year recruit to nursery habitats. The authors suggested a possible, but unproven, causal mechanism for the relationship: the quantity of freshwater flowing into the estuary during spring and summer increases the survival of juvenile barramundi by altering accessibility, productivity and or carrying capacity of nursery habitats.

The riparian zone acts as a filter to reduce concentrations of nutrients, pesticides and suspended sediment in runoff (Arthington et al. 1997). Roots of riparian plants bind stream bank materials and help to reduce slumping of banks (ibid.). Riparian vegetation also provides woody debris which can be the major habitat for invertebrates in large sandy rivers and is subsequently also important as feed habitat and shelter for fish (ibid.). Riparian vegetation provides shade and reduces the light transmitted to streams. Thus, without riparian vegetation, stream water heats up and dissolved oxygen is reduced (ibid.). Oxygen depletion is exacerbated by in-stream decomposition of organic material. The combination of warm dry winter conditions and the addition of cane residues have been blamed for fish kills in northern Queensland cane growing districts.

Clearing the riparian zone decreases inputs of leaf litter, which sustain aquatic invertebrate populations (Knight and Bottorff 1981 cited in Arthington et al. 1997). Other inputs include falling insects, which are important food for whirly-gig beetles, freshwater turtles and many species of fish (Pusey and Kennard 1995).

Wetlands are important habitat for fish, water birds and mammals. They constitute the breading grounds for many commercially important fish species and often harbour a greater diversity of birds and mammals compared to adjacent ecosystems.

Wetland vegetation acts as a trap for suspended particles and increases aggradation, followed by the establishment of plants. Accumulation of sediments in caneland streams can exceed depths of 2.5 m and a significant loss of channel capacity (Bunn et al. 1997 cited in Arthington et al. 1997). But these streams probably represent only a temporary store for sediments as high discharge events inevitably lead to scouring of the channel and downstream transport of sediment and associated plant matter (Arthington et al. 1997).

Suspended sediments often lower water temperatures which may affect water sensitive species (Ryan 1991 cited in Arthington et al. 1997). When organic matter and sediment are transported together dissolved oxygen may decline (Guy and Ferguson 1970 cited in Arthington et al. 1997). Further, suspended solids reduce light penetration and therefore photosynthesis and fish foraging (Bruton 1985). Suspended matter may also clog fish and invertebrate gills and interfere with gas exchange (Ryan 1991 cited Arthington et al. 1997).

Sediment fills pools, degrades the normal pool-riffle sequence of streams and fills the spaces between particles in the stream bed which are used by benthic invertebrates and fish (Ryan 1991; Koekn 1992 cited in Arthington et al. 1997). This may reduce the density of filter feeders and reduces the hatching success of eggs and survival of larvae of some fish species (Bruton 1985; Auld and Schubel 1978 cited in Arthington et al. 1997).

Nutrients and pesticides are washed into streams from irrigation and rainfall runoff. High concentrations of nitrogen and phosphorus can cause problems of eutrophication, such as algal blooms, fish kills and excessive growth of aquatic macrophytes (Henry 1966; Wood 1975 cited in Arthington et al. 1997). Catchment runoff generated by large rainfall events significantly increases concentrations of nutrients, which are attached to suspended sediment (Hunter et al. 1996 cited in Arthington et al. 1997). The long term consequences of trace concentrations of pesticides in aquatic ecosystems remain unclear, particularly concerning chronic, sublethal effects and the sensitivity of native flora and fauna (Arthington et al. 1997).

Acid sulphate soils result when high concentration of pyritic minerals is drained or oxidised. After oxidisation, soil pH levels typically drop to less than 3.8 and soluble forms of aluminium and iron are mobilised (Ford and Calvert 1970 cited in Arthington et al. 1997). Acidified drain waters causes kills of fish, crustaceans and annelid worms (Easton 1989 cited in Arthington). However, mobile aquatic fauna can escape the acidic water when not impeded by barrages and floodgates (Sammut et al. 1993 cited in Arthington et al. 1997).

Wetlands and the marine environment

Crossland et al. (1997) suggests that much of what we understand about agricultural production and the receiving marine environment is from inference rather than hard data, particularly with reference to the Great Barrier Reef. The following points review some of the ambiguities associated with establishing quantifiable cause and effect links between Lower Burdekin land use activities and marine environment consequences (Crossland et al. 1997):

- Phosphorus can inhibit coral growth, but weakening of coral skeletons has only been observed at concentrations unlikely to occur in any scenario for agriculture;
- Algal growth, promoted by high concentrations of nitrogen and phosphorus, can kill corals, but the only experimental attempt in the GBR using episodic, high concentrations of P and N did not observe this result;
- Worldwide, reduced grazing of coral by changes in fish and invertebrate populations is the major cause of algal overgrowth of coral reefs, rather than elevated levels of nutrients;
- Light exclusion, resulting from suspended sediment, can kill coral, but near shore coral reefs can persist in very turbid waters;
- Corals can also be smothered and killed by settling sediments, but again corals from inshore reefs appear well adapted to surviving significant sediment loads;
- Sediments that accumulate on coral reefs can prevent settlement of microscopic coral larvae, but many coral larvae settle on the silt-free undersides of reef cavities or can occupy silted areas by asexual reproduction (fragmentation or budding).

The workshop will encourage participants to explore the validity of these inferences in the context of use of the region's wetlands to buffer the marine environment.

ECOLOGICAL RISK ASSESSMENT

Management for the immediate ecological values of the wetlands and their extended role in protecting the reef is not straight forward. The altered conditions brought about by irrigation and other catchment land uses suggests a blanket management objective involving restoration of wetlands to 'natural' or 'pristine' condition may be misplaced. For example, removing para grass to improve habitat quality for wetland dependent native plants and animals may inadvertently result in increased sediment and nutrient contamination of adjacent sea grass beds (Bunn *et al.* 2002).

Planning and actions may need to consider the ecological values of degraded and non-degraded wetlands. The capacity of the wetlands to filter pollution needs to differentiate between the nearshore and offshore reef and marine environments. The key issue is the extent to which different values are compatible (or non-compatible) with one another. The workshop will use the framework of ecological risk assessment to explore these complexities.

Risk assessment has been carried out in engineering and process industries for several decades, and similar procedures are now increasingly being applied to ecological questions. Ecological Risk Assessment is the process of estimating likelihoods and consequences of the effects of human actions or natural events on plants, animals and ecosystems of ecological value, that is, the study of risks to the natural environment (SA/NZ 2000). The process of risk assessment helps us to make decisions when we are uncertain about future events or actions, and the risk analyst's job is to evaluate and communicate the nature and extent of uncertainty in order to improve decision-making. Risk assessment is a continuous improvement cycle and its main components are illustrated in Figure 3.

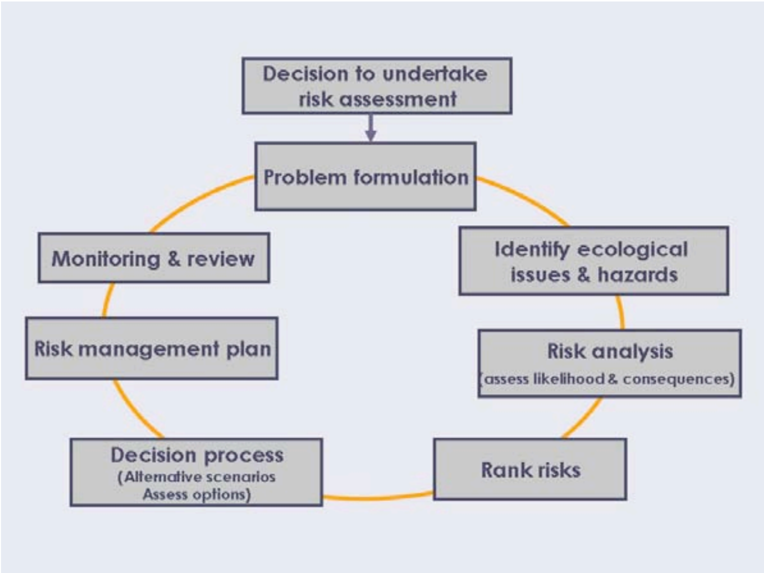


Figure 3 Key elements of the risk assessment framework. (Source: Hart et al. 2005).

When done poorly, risk assessments can alienate stakeholders by placing social decisions in the hands of the technical people who conduct the assessments (Fischer 2000). Better assessments involve stakeholders throughout the whole process and ensure their views are considered (Borsuk *et al*. 2001). The central idea is to help decision-making in a way that stays faithful to the priorities of those who carry the burden of the risks, while at the same time making the full strength of technical risk analysis available.

Individual values of the environment may be threatened by one or more hazards, threats or stressors. These may be physical, chemical or biological entities or threatening processes such as the clearing of land or the discharge of waste. They may include socio-political, economic or administrative elements. The Queensland EPA believe that the greatest threats to the state's wetlands are decisions made without co-ordinated planning and management, inadequate buffers between wetlands and surrounding lands, and changes to wetland drainage and water flow (EPA 2005). Some other general threats are given in Table 1. Threats commonly associated with the activities of irrigation systems are shown in Table 2.

Collectively, Tables 1 and 2 are not an exhaustive list of hazards or threats to the wetlands. After exploring and listing threats associated with the particular circumstances of the Lower Burdekin's wetlands, a key theme for the workshop is gathering views on what are the more important threats and what are less important.

Table 1. Threats to Wetlands (Source: EPA 2005)

Threat	**Description**
Reclamation	Wetlands are drained and to provide land for development
Dredging	Sand in pumped from wetlands

Propellers	Boat propellers chop up seagrass beds
Dykes & Barrages	Infrastructure to prevent the flow of saltwater into wetlands or to capture water in channels
Heavy metals, insecticides, fertilizers and sewerage	Wastes of industry, agriculture and residential development that enter wetlands in runoff
Sediment	Soil is transported in runoff to wetlands
Water use	Water is drawn from wetlands by industry, agriculture and other users
Flood control and conservation works	Works that may inundate or divert water from wetlands
Vegetation clearing	Clearing for development
Wildfires	Fires
Feral animals	Feral pigs graze and dig soil in wetlands
Introduced plants	Weeds like Water Hyacinth and Para Grass
Introduced fish	Predation, competition with native fish; habitat degradation
Cyclones and storms	Strong wind and surging water
Dams and water storages	Infrastructure for storing water and modifying river flows

Conceptual models link ecological processes and management practices to ecosystem condition. Models are abstractions, representing how we think the world works. Intrinsically, a decision to invest in any management action involves a conceptual model that, in the face of considerable uncertainty and ignorance, suggests one course of action is preferable to another. Usually, these conceptual models and the values that underpin them remain unspoken, unspecified and undocumented. Alternative models and courses of action may be entirely plausible, and on consideration, may prove preferable. But again, these alternatives are left unrecorded.

Table 2. Checklist of potential off-site ecological issues associated with irrigation systems. (Source: Hart *et al*. 2005).

Activity	Hazard/Threat/Stressor	Potential ecological effect
Flow-related	• Changed flow regimes and reduced flows • Barrier (weirs, dams) • Poor water quality (low temperature, low dissolved oxygen)	• Reduced biodiversity – interferes with breeding cycles; loss of habitat • Reduced biodiversity – interferes with fish migration • Toxicity to fish, alien species take over
Contaminants	• Increased nutrients (P,N) • Increased toxicants (biocides, heavy metals) • Increased turbidity and suspended particulate matter	• Increased frequency of algal blooms • Reduced biodiversity – due to toxic effects • Reduced primary production, smothering of benthic habitat
Salinity	• Increased salinity	• Reduced biodiversity due to toxic effects on aquatic biota and terrestrial plants

We regard explicit documentation of the conceptual models that underpin investment preferences and decisions as (a) essential to stakeholder involvement and transparency, and (b) a prerequisite to the use of monitoring in ‘continuous improvement’ and ‘adaptive management’. Using ecological risk assessment, we’ll encourage stakeholders to cross examine the thinking and logic underlying conceptual models of how the Lower Burdekin’s wetlands function.

Perceptions of risk and how a system works are very much an individual matter, and are affected by a variety of factors. Our personal experience and beliefs have a strong influence on our perception of risk. Cultural differences also contribute substantially to perceptions and acceptance of risk, so that different social groups react differently when confronted by the same hazards (Pidgeon *et al*. 1992). Ecological Risk Assessment seeks to document different perceptions of risk and distinguish between socially and psychologically constructed contrasts and uncertainties that arise from scientific uncertainty and ignorance (Regan *et al*. 2002).

OUTCOMES SOUGHT FROM THE WORKSHOP

Selection of priority wetlands for management intervention is an important outcome sought by the Great Barrier Reef Coastal Wetlands Protection Programme, the Great Barrier Reef Water Quality Protection Plan, and the Burdekin Dry Tropics NRM Plan. The workshop will assist these planning processes through better understanding of any trade-offs that need to be made in managing for multiple objectives. There will be a number of themes explored throughout the workshop that touch on trade-offs. For example, to what degree are wetlands effective at buffering the marine environment? Do the habitat requirements of migratory birds differ substantially from resident fauna? Are 'natural' flow regimes ecologically desirable in today's landscape?

The workshop will focus on:

- Identification of management endpoints for values associated with wetlands
- Identification of hazards/threats/ to those values and endpoints
- Capture of key hazards, threats and trade-offs in conceptual models
- Initial assessment of the compatibility of values and endpoints

Follow up research will develop conceptual models into a Bayesian network to quantify the risks to management endpoints and to inform investment in management actions. Bart Kellett from CSIRO will be principally responsible for this research.

Bart Kellett
Terry Walshe

25 May 2005

References

Arthington, A.H., Marshall, J.C., Rayment, G.E., Hunter, H.M., Bunn, S.E. (1997). Potential impact of sugarcane production on riparian and freshwater environments. In: Keating, B.A. and Wilson, J.R. (eds). *Intensive Sugarcane Production: Meeting the Challenges Beyond 2000*. CAB International, Wallingford, UK, pp. 403-421.

Auld, A., Schubel, J.R. (1978). Effects of suspended solids on fish eggs and larvae: A laboratory assessment. *Estuarine Coastal and Shelf Science*. **6**: 153-164.

Australian Government (2004). *Directory of Important Wetlands in Australia*. Department of Environment & Heritage, Canberra. http://www.deh.gov.au/water/wetlands/epbc/databases.html

BBIFMAC (2000). *A Community-based Natural Resource Management Strategy for the Burdekin-Bowen Floodplain Subregion of the Burdekin Dry Tropics*. Report to the Burdekin-Bowen Integrated Floodplain Management Advisory Committee.

Bjornsson, K.T., Brodie, A., Dyer, B., Lukacs, G., Vella, K., Walker, D., Werren, G. (2002). *Riparian areas and on-farm wetlands in the Australian sugar industry. A review for the CRC Sustainable Sugar Production*. Townsville.

Blackman, J.G., Perry, T.W. and King, S.M. (2002). *Wetlands Component: Northern Brigalow belt – priorities for remnant vegetation protection (Project No. NHT 973132). Volume IV, Significant Wetland Sites, Technical Report*. Environmental Protection Agency, Queensland.

Bruton, M.N. (1985). The effects of suspensoids on fish. *Hydrobiologia*. **125:** 221-241.

Bunn S.E., Davies, P.M., Kellaway, D.M. and Prosser, I. (1998). Influence of invasive macrophytes on channel morphology and hydrology in an open tropical lowland stream, and potential control by riparian shading. *Freshwater Biology* **39:** 171–178

Cappo, M. and Kelly, R. (2001). Connectivity in the Great Barrier Reef World Heritage Area – an overview of pathways and processes. In: Wolanski, E. (ed.). *Oceanographic Processes of Coral Reefs: Physical and Biological Links in the Great Barrier Reef*. CRC Press, New York. *pp*. 161-187.

Congdon, B. Undated. Defining Threats to Tropics. http://ramsar.org/wurc_library_research.html. Accessed May 2005.

Crossland, C.J., Done, T.J., Brunskill, G.J. Potential Impacts of Sugarcane Production on the Marine Environment. In: Keating, B.A. and Wilson, J.R. (eds), *Intensive Sugarcane Production: Meeting the Challenges Beyond 2000*. CAB International, Wallingford, UK, 1997.

Easton, C. (1989). The trouble with the Tweed. *Fishing World*, March 1989, pp. 58-59.

EPA (2005). Mangroves and Wetlands. http://www.epa.qld.gov.au/nature_conservation/habitats/mangroves_and_wetlands/#Wetlands%20are%20a%20critical%20resource. Website accessed 14th April 2005.

Fischer, F. (2000). *Citizens, Experts, and the Environment*. Duke University Press, Durham

Ford, H.W., Calvert, D.V. (1970). A method for estimating the acid sulphate potential of Florida soils. *Soil and Crop Science Society Florida Proceedings*. **30:** 304-307.

Guy, J.P., Furguson, G.E. (1970). Stream sediment: An environmental problem. *Journal of Soil and Water Conservation*. **25:** 217-221.

Hart, B., Burgman, M., Webb, A., Allison, G., Chapman, M., Duivenvoorden, L., Feehan, P., Grace, M., Lund, M., Pollino, C., Carey, J. and McCrea, A. (2005). *Ecological Risk Management Framework for the Irrigation Industry*, Report to National Program for Sustainable Irrigation (NPSI) by Water Studies Centre, Monash University, Clayton, Australia.

Henry, L. (1966). *Pollution of Coastal Streams in Queensland.* Unpublished Report, Queensland Department of Local Government, Brisbane, Australia.

Hunter, H.M., Walton, R.S., Russell, D.J. (1996). Contemporary water quality in the Johnstone River catchment. In: Hunter, H.M., Eyles, A.G., Rayment G.E. (eds), *Downstream Effects of Land Use*. Department of Natural Resources, Brisbane, Australia, pp. 339-345.

Koehn, J. (1992). Habitat: the essential component of fisheries management. *Freshwater Fisheries in Victoria: Today and Tomorrow Symposium*. 11 Oct 1992, Victorian Department of Conservation and Natural Resources, Melbourne Australia. pp. 5-20.

Knight, A.W., Bottoroff, R.L. (1981). The importance of riparian vegetation to stream ecosystems. In: Warner, R.E., Hendrix, L.M. (eds). *California Riparian Systems Ecology*. University of California Press, Davis, California, USA, pp.160-167.

Perna, C., Burrows, D. (2005). Improved dissolved oxygen status following removal of exotic weed mats in important fish habitat lagoons of the tropical Burdekin River floodplain, Australia. *Marine Pollution Bulletin*. **51**: 138-148.

Pidgeon, N., Hood, C., Jones, D., Turner, B. and Gibson, R. (1992) Risk perception. In: *Risk: Analysis, Perception and Management*. Report of a Royal Society Study Group. The Royal Society, London, UK. Chapter. 5.

Prosser, I.P., Morgan, C.J., Lu, H., Scott, A., Rustomji, P., Stevenson, J., Priestly, G., Roth, C.H., and Dost, D. (2002). *Regional patterns of erosion and sediment transport in the Burdekin river catchment*. Final Report on Project NAP3.224. Meat and Livestock Ltd, Sydney.

Pusey, B.J., Kennard, M.J. (1995). The Direct Utilisation of Allochthonous Plant and Animal Matter by Australian Freshwater Vertebrates. Report for the Land and Water Resources Research and Development Corporation, Canberra, Australia.

Queensland and Commonwealth Governments (2003). *Reef water quality protection plan for catchments adjacent to the Great Barrier Reef World Heritage Area*. October 2003. Queensland Department of Premier and Cabinet, Brisbane.

Regan, H.M., Colyvan, M. & Burgman, M.A. (2002) A taxonomy and treatment of uncertainty for ecology and conservation biology. *Ecological Applications*. **12:** 618-628.

Roth, C.H., Lawson, G. and Cavanagh, D. (2002). *Overview of the key natural resource management issues in the Burdekin catchment, with particular reference to water quality and salinity*. *Burdekin Catchment Condition Study Phase 1*. Report commissioned by the Department of Natural Resources and Mines on behalf of the Burdekin Dry Tropics Board. CSIRO Land and Water, Townsville.

Ryan, P.A. (1991). Environmental effects of sediment on New Zealand streams: a review. *New Zealand Journal of Marine and Freshwater Research*. **25:** 207-221.

SA/SNZ (2000). *Environmental Risk Management - Principles and Processes*. (HB 203:2000) Standards Australia International Ltd, Sydney, and Standards New Zealand, Wellington.

Sammut, J., Callinan, R.B. Fraser, G.C. (1993). The impact of acidified water on freshwater and estuarine fish populations in acid sulfate environments. In: Bush, R. (ed.), *Proceedings of National Conference on Acid Sulfate Soils*. Coolangatta, 24-25 June, 1993, New South Wales Agricultural Research Institute, Wollongbar, Australia, pp.26-40.

Staunton-Smith J., Robins J.B., Mayer D.G., Sellin, M.J., Halliday, I.J. (2004). Does the quantity and timing of fresh water flowing into a dry tropical estuary affect year-class strength of barramundi (*Lates calcarifer*)? *Marine and Freshwater Research,* **55:** 787-797.

Wood, G. (1975). *An Assessment of Eutrophication in Australian Inland Waters*. Australian Water Resources Council Technical Paper No. 15, Australian Government Publishing Service, Canberra, Australia.

ECOLOGICAL RISK ASSESSMENT WORKSHOP
EVALUATION QUESTIONNAIRE

Q1. What organization are you representing today?

Q2. What's your position within the organization?

Q3. What is your education level?

_ Primary school
_ Secondary school
_ Tertiary qualification
_ Post-Graduate qualification

Q4. What is your age and gender?

_ under 30 _ Female
_ 31-40 _ Male
_ 41-50
_ 51-60
_ 61+

Q5a. Were you familiar with the use of risk-based approaches for decision-making before this workshop?

_ Yes _ No

Q5b. If yes, how did you become aware of risk-based approaches?

Q6. What does 'environmental sustainability' in the context of irrigation mean to you?

Q7. Ecological Risk Assessment (ERA) has supporters and critics. Some of the benefits and limitations that have been attributed to ERA are listed below. Please indicate the degree to which you agree or disagree with these statements.

ERA helps achieve 'environmental sustainability' **Comments**

Disagree neutral Agree
1 2 3 4 5

ERA treats people's values inappropriately **Comments**

Disagree neutral Agree
1 2 3 4 5

ERA cannot avoid bias in representing people's values **Comments**

Disagree neutral Agree
1 2 3 4 5

ERA is an effective way to identify values and threats **Comments**

Disagree neutral Agree
1 2 3 4 5

ERA assists environmental decision-making **Comments**

Disagree neutral Agree
1 2 3 4 5

ERA reveals knowledge gaps and uncertainties **Comments**

Disagree neutral Agree
1 2 3 4 5

ERA identifies where research and monitoring is needed **Comments**

Disagree neutral Agree
1 2 3 4 5

There is rarely enough data to undertake a risk assessment that helps decision-making

Comments

Disagree		neutral		Agree
1	2	3	4	5

The time and expertise demands of ERA are too onerous

Comments

Disagree		neutral		Agree
1	2	3	4	5

Q8. What organization(s) do you think should take principal responsibility for undertaking ERA in irrigation?

_ Government regulatory agencies
_ Other government agencies
_ Industry
_ Community groups
_ No-one. ERA is not worth undertaking.
_ Other (please specify)

Q9a. In undertaking ERA, what level of detail should be adopted by the organization(s) identified in Q8?

Level of detail (PLEASE CIRCLE)	**Identifying values and hazards**	**Risk Analysis method**
1	Identified by a single individual or organisation	Qualitative
2	Identified by a single individual or organisation	Quantitative
3	Identified by a broad range of stakeholders	Qualitative
4	Identified by a broad range of stakeholders	Quantitative

Q9b. Why?

Q10. Is the broader adoption of ERA useful to the development of sustainability in irrigation?

Q11. Do you have any comments or feedback on today's workshop (eg. content, structure, catering, facilities)?

Q12. What was the best thing(s) about the workshop?

Q13. What was the worst thing(s) about the workshop?

Q14. How would you change the workshop to make it more effective?

ECOLOGICAL RISK ASSESSMENT WORKSHOP
EVALUATION QUESTIONNAIRE

Q1. What organization are you representing today?

Q2. What's your position within the organization?

Q3. What is your education level?

_ Primary school
_ Secondary school
_ Tertiary qualification
_ Post-Graduate qualification

Q4. What is your age and gender?

_ under 30 _ Female
_ 31-40 _ Male
_ 41-50
_ 51-60
_ 61+

Q5. What motivated you to attend today's workshop?

Q6. What does 'environmental sustainability' in the context of irrigation mean to you?

Q7. Some of the benefits and limitations that have been attributed to ERA are listed below. Please indicate the degree to which you agree or disagree with these statements.

ERA helps achieve 'environmental sustainability' **Comments**

Disagree		neutral		Agree
1	2	3	4	5

ERA treats people's values inappropriately **Comments**

Disagree		neutral		Agree
1	2	3	4	5

ERA cannot avoid bias in representing people's values **Comments**

Disagree		neutral		Agree
1	2	3	4	5

ERA is an effective way to identify values and threats **Comments**

Disagree		neutral		Agree
1	2	3	4	5

ERA assists environmental decision-making **Comments**

Disagree		neutral		Agree
1	2	3	4	5

ERA reveals knowledge gaps and uncertainties **Comments**

Disagree		neutral		Agree
1	2	3	4	5

ERA identifies where research and monitoring is needed **Comments**

Disagree		neutral		Agree
1	2	3	4	5

There is rarely enough data to undertake a risk assessment that helps decision-making **Comments**

Disagree		neutral		Agree
1	2	3	4	5

The time and expertise demands of ERA are too onerous **Comments**

Disagree		neutral		Agree
1	2	3	4	5

Q8. How does the ERA approach ‘fit’ with the way your organization currently undertakes planning?

Q9. What would be benefits of incorporating ERA into your workplace?

Q10. What would be the difficulties?

Q11. Can you identify an **example** of where ERA could help in your organization?

Q12. What would it require for your organization to incorporate ERA into its operations?

Q13. The ERA workshop explored both qualitative and quantitative methods for conducting a risk analysis. It also touched on the benefits and costs associated with undertaking a risk assessment as a single individual or organization versus a collective approach involving multiple stakeholders.

Q13a. Are you more confident in an ERA that you do alone? If so, why?

Q13b. Are you more confident in an ERA that you do as part of a stakeholder workshop? If so, why?

Q13c. Are you more confident in an ERA that uses **either** quantitative **or** qualitative data and analysis? If so why?

Q13d. Are you more confident in an ERA that **combines** quantitative **and** qualitative data and analysis? If so why?

Q14a. What kind of training would you require to be able to incorporate ERA into your workplace?

Q14b. If you were interested in further training in ERA, how long do you think the training program should be?

_ 2 days
_ 1 week
_ 2 weeks

Q15 Do you have any comments or feedback on the information in today's workshop (eg. content, structure,

Q16 Considering the material covered, what key ideas or information will you take away from the workshop?

Q17 Considering the material covered, what ideas or information did you find least useful?

Q18 How would you change the workshop to make it better?

Q.19 Do you have any comments or feedback on the catering or facilities?

As part of an evaluation of how successfully ERA is being used, we plan to conduct telephone interviews in about two months time. These calls will be confidential and the information gained in them will contribute to improving the ERA process.

Would you be willing to participate in a follow-up telephone interview?

_ Yes   _ No

Name:
Telephone number:
Email:

Thank you

Outline of statistical method for evaluating workshop effectiveness in modifying opinions

This appendix relates to the material presented in section 3.2.2 and provides computational details for testing hypotheses of marginal homogeneity and symmetry.

The general layout of responses associated with a *k*-level questionnaire item administered on two occasions is given in the table below.

		Time 2			
		1	**2**	**…**	***k***
Time 1	**1**	N_{11}	N_{12}	…	N_{1k}
	2	N_{21}	N_{22}	…	N_{2k}
	⋮	⋮	⋮	…	⋮
	k	N_{1k}	N_{2k}	…	N_{kk}

In the following, we let μ_{ij} be the probability of response *i* at time 1 and response *j* at time 2.

Hypothesis of marginal homogeneity

The statement "the probability of a category 1 response at time 1 equal to the probability of a category 1 response at time 2" for *k*=3, can be expressed mathematically as: $\mu_{11} + \mu_{12} + \mu_{13} = \mu_{11} + \mu_{21} + \mu_{31}$. Similarly, "the probability of a category 2 response at time 1 equal to the probability of a category 2 response at time 2" can be expressed mathematically as: $\mu_{21} + \mu_{22} + \mu_{23} = \mu_{12} + \mu_{22} + \mu_{32}$. The last hypothesis (concerning probabilities for a category 3 response) does not need to be explicitly stated since it is implied by the truth of the other two hypotheses. The two hypotheses can be compactly written in matrix notation as $H_0 : h\underline{\mu} = \underline{0}$ where the hypothesis matrix ***h*** has elements

$$\boldsymbol{h} = \begin{bmatrix} 0 & 1 & 1 & -1 & 0 & 0 & -1 & 0 & 0 \\ 0 & -1 & 0 & 1 & 0 & 1 & 0 & -1 & 0 \end{bmatrix}$$

and $\underline{0}$ is a 2 x 1 vector of zeros.

Listed below are the marginal homogeneity hypothesis matrices for the cases *k= 3, 4, 5 and 6.*

Hypothesis matrices for testing marginal homogeneity

k=3

0 1 1 -1 0 0 -1 0 0

0 -1 0 1 0 1 0 -1 0

k=4

0 1 1 1 -1 0 0 0 -1 0 0 0 -1 0 0 0

0 -1 0 0 1 0 1 1 0 -1 0 0 0 -1 0 0

0 0 -1 0 0 0 -1 0 1 1 0 1 0 0 -1 0

k=5

0 1 1 1 1 -1 0 0 0 0 -1 0 0 0 0 -1 0 0 0 0 -1 0 0 0 0

0 -1 0 0 0 1 0 1 1 1 0 -1 0 0 0 0 -1 0 0 0 0 -1 0 0 0

0 0 -1 0 0 0 0 -1 0 0 1 1 0 1 1 0 0 -1 0 0 0 0 -1 0 0

0 0 0 -1 0 0 0 0 -1 0 0 0 0 -1 0 1 1 1 0 1 0 0 0 -1 0

k=6

0 1 1 1 1 1 -1 0 0 0 0 0 -1 0 0 0 0 0 -1 0 0 0 0 0 -1 0 0 0 0 0 -1 0 0 0 0 0

0 -1 0 0 0 0 1 0 1 1 1 1 0 -1 0 0 0 0 0 -1 0 0 0 0 0 -1 0 0 0 0 0 -1 0 0 0 0

0 0 -1 0 0 0 0 0 -1 0 0 0 1 1 0 1 1 1 0 0 -1 0 0 0 0 0 -1 0 0 0 0 0 -1 0 0 0

0 0 0 -1 0 0 0 0 0 -1 0 0 0 0 0 -1 0 0 1 1 1 0 1 1 0 0 0 -1 0 0 0 0 0 -1 0 0

0 0 0 0 -1 0 0 0 0 0 -1 0 0 0 0 0 -1 0 0 0 0 0 -1 0 1 1 1 1 0 1 0 0 0 0 -1 0

Hypothesis of symmetry

The symmetry hypothesis is concerned with directional shifts in opinion. The null hypothesis states that the probability associated with classification {*i, j*} is the same as the probability for classification {*j, i*}. For *k*=3, this can be expressed mathematically as: $\mu_{12} = \mu_{21}$ *and* $\mu_{13} = \mu_{31}$ *and* $\mu_{23} = \mu_{32}$. In matrix notation this is $H_0 : h\underline{\mu} = \underline{0}$ where the hypothesis matrix ***h*** has elements

$$\boldsymbol{h} = \begin{bmatrix} 0 & 1 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & -1 & 0 \end{bmatrix}$$

and $\underline{0}$ is a 3 x 1 vector of zeros.

Listed on the following page are the symmetry hypothesis matrices for the cases *k*= *3, 4 ,5, 6.*

Test Statistic

A test of either hypothesis (marginal homogeneity or symmetry) may be constructed around the Pearson test statistic, *PR* defined as:

$$PR = \sum_{i=1}^{k} \sum_{j=1}^{k} \frac{N_{ij}(p_{ij} - \hat{\mu}_{ij}^{*})^2}{\hat{\mu}_{ij}^{*}}$$

where p_{ij} is the sample proportion of responses in category {*i, j*} and $\hat{\mu}_{ij}^{*}$ is the constrained maximum likelihood estimate of the corresponding cell probability (subject to the constraint imposed by the null hypothesis). The Pearson test is

accept H_0 if $pr \leq c$
accept H_1 if $pr > c$

where *pr* is the sample realisation of the quantity *PR* defined above and *c* is a critical value of the chi-square distribution having degrees of freedom equal to the number of rows in the hypothesis matrix ***h***.

Hypothesis matrices for testing symmetry

k=3

0 1 0 -1 0 0 0 0 0

0 0 1 0 0 0 -1 0 0

0 0 0 0 0 1 0 -1 0

k=4

0 1 0 0 -1 0 0 0 0 0 0 0 0 0 0 0

0 0 1 0 0 0 0 0 -1 0 0 0 0 0 0 0

0 0 0 1 0 0 0 0 0 0 0 0 -1 0 0 0

0 0 0 0 0 0 1 0 0 -1 0 0 0 0 0 0

0 0 0 0 0 0 0 1 0 0 0 0 0 -1 0 0

0 0 0 0 0 0 0 0 0 0 0 1 0 0 -1 0

k=5

0 1 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

0 0 1 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0

0 0 0 1 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0

0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0

0 0 0 0 0 0 0 1 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0

0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 -1 0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 -1 0 0 0

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 -1 0 0

***k*=6**

0 1 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

0 0 1 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0

0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0

0 0 0 0 0 0 0 0 1 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 -1 0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 -1 0 0

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 -1 0