Irrigation Ecological Risk Assessment Framework
Linkage Project

Progress Report 1
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1. Introduction

1.1 Background

Irrigated agriculture is a major contributor to the economic and social well being of Australia. Each year these activities produce around $10 billion of agricultural output or 50% of the country's net agricultural profit.

However, the sustainability of this important activity is currently under serious challenge. Irrigation uses 75% of the water extracted from Australia's rivers and groundwater systems. It also contributes to the pollution load in these rivers.

In response to these challenges, National Program for Sustainable irrigation (NPSI) has established an *Ecological Risk Assessment Project*, the overall objective of which is to develop a generic framework for assessing the ecological risks associated with Australian irrigation systems. This new decision support tool should assist the Australian irrigation industry in quantifying and prioritising the ecological risks from their activities, and also to better focus their management actions to minimise these risks. Additionally, this information should also provide an opportunity for regulatory authorities (such as EPA's) to better determine what needs protection and to use this as the basis for licensing and monitoring requirements.

This tool will contribute to the Australian irrigation industry's thrust towards more knowledge-based management.

1.2 The Project

The Project has four components - a coordinating linkage project being run by the Water Studies Centre (WSC) and CRC for Freshwater Ecology at Monash University, and three case studies located in irrigation regions on the Goulburn-Broken, Ord and Fitzroy rivers. The key players involved in the case studies are:

- Goulburn-Broken – Monash University, CRC for Freshwater Ecology & Goulburn Murray Water
- Ord – Edith Cowen University and Rivers & Water Commission
- Fitzroy – Central Queensland University & Department of Natural Resources & Mines.

The Project is being undertaken in three phases. The first phase – problem formulation - was completed in mid 2001. The second phase, to undertake further detailed investigations designed to provide specific information on key issues identified in Phase 1 is currently underway. A brief progress report on these activities is given below. The final phase of developing the ERA protocol will be completed in 2004.

2.Progress

2.1 Workshop 1

A two-day Workshop was held at WSC Monash University in Melbourne on 17 and 18 June 2002 to review progress to date. The Workshop had three objectives:

- To review the processes used and outcomes from Phase 1
- To review the progress of the Phase 2 case study investigations

- To review the very preliminary draft ecological risk assessment protocol being developed for Australian irrigation regions

A report on the Workshop outcomes is available on the WSC web site (www.wsc.monash.edu.au/sresearch).

2.2 Review of progress with case study projects

The Phase 1 studies identified a small number of priority ecological issues associated with irrigation in each of the three regions. In Phase 2, each of the Case Study Teams is undertaking a detailed ecological risk assessment (including additional work where this is necessary) of the priority issues.

These three case study projects (Phase 2) commenced in 2002 and are planned for completion in 2004.

The detailed research plans and initial progress was reviewed at the July 2002 Workshop. The research plans are available at www.wsc.monash.edu.au/sresearch.htm, and the reviews are contained in Workshop 1 report.

Further progress with each of the Case Study projects to December 2002 is reviewed in this report. *Goulburn-Broken irrigation region*

The Goulburn Broken team identified two ecological issues that required further research to provide information necessary for the detailed risk assessment:
the influence of irrigation on the abundance and diversity of native fish in the Goulburn River,
the influence of irrigation on the occurrence of blue-green algal blooms in the river.
Research into both these issues is currently underway. A summary of what is being done in each of the projects is available from the WSC web site (www.wsc.monash.edu.au/sresearch).
Most recent progress is contained in Milestone Report No 3 (Dec 2002).

Comments:
Influence of irrigation on the abundance and diversity of native fish

- By December 2002, this project sought to achieve:
    - Document what is known about each of the risk factors associated with fish survival
    - Prepare a semi-quantitative ecological effects ranking table
    - Develop a preliminary ecological model to quantify relationships between key risk factors and identified risk

- Excellent progress has been made on all the above components. See Goulburn-Broken Project Milestone Report No 3 (patf@g-mwater.com.au) for a detailed report on each component.
- The first of the Bayesian networks (for the Goulburn only) are operational, and will be presented to the River Research and Applications conference in Albury in July 2003 (oral paper accepted).
- This project has been able to establish excellent links with two staff in the Computer Science Department at Monash University. As a result, a 2003 Honours Student will work

with the project team to further improve the existing Bayesian networks (to include uncertainty and perhaps to incorporate time).

Influence of irrigation on the occurrence of blue-green algal blooms

- There is some conflict between the project agreement and the milestone and payment schedule for the GB Project regarding this component. The milestone and payment schedule appears to assume this component would be completed by December 2002, while the project agreement anticipates the work will be completed by September 2003. The Project Team have requested that the September 2003 deadline is the most appropriate.
- A progress report to December 2002 is available as part of the Goulburn-Broken Project Milestone Report No 3. This report summarises progress on two parts:
    - *Deterministic model* - The work on this algal model has centred on redressing specific concerns raised about the model when it was reviewed for publication. In particular, laboratory rates for maximum population growth rates have been incorporated in place of estimates derived from the field data. The modelling of light climate has been re-done in order to explicitly model light limitation in accordance with laboratory studies, and the alteration of light climate throughout the year and within each day. The effect of this work has been to improve the performance of the model against the data set for which it was first validated, and to make it more generally applicable to other environments. It has also been peer reviewed, which means that the resulting NPIRD risk assessment will be more scientifically rigorous.
    - *Decision tree* - An evaluation of the Phase I report decision tree found that it did not perform well when tested against another data set (Bourke Weir), when using the original thresholds. Optimisation of the model greatly improve its performance. This procedure highlighted several issues that surround the process of optimisation, namely the dependence of thresholds on: the aim of the optimisation, the threshold for an algal 'bloom', and the data available. Should all other modelling attempts fail for the Goulburn-Broken sites, the decision tree (optimised using data from another local site) could serve as a 'last resort' method for risk assessment.

- The project has recently employed a new Research Fellow (Terrance Chan). Terry's background is in algal modelling, and he will be able to bring these skills to the NPIRD project. Terry starting work at the WSC in February 2003.

Linkage team comments:

- Overall this project is proceeding very satisfactorily.
- The fish component has done an excellent job in consolidating existing knowledge on native and exotic fishes within the catchment. Additionally, the Bayesian Network modelling approach being developed to link native fish abundance and diversity to stressors (both irrigation and non-irrigation related) shows great potential. Good collaboration has been achieved between the WSC and GMW.
- The blue-green algal component of the project is progressing well and is on track for completion in September 2003. The Linkage Team recommends that this date be adopted as the completion date. Insights from this component of the project have already proved useful to GMW in predicting possible algal problems due to the recent drought. It seems likely that progress will accelerate with the appointment of a new Research Fellow (Terrance Chan).

- It is clear that both components of this project will contribute predictive tools that will significantly advance the Irrigation ERA framework.

Ord irrigation region
The Ord team also identified two ecological issues that required further research to provide information necessary for the detailed risk assessment:

- influence of irrigation (and associated eutrophication) on biological diversity in the Ord river (to be determined by measuring changes in the macroinvertebrate populations)
- influence of irrigation on the occurrence of blue-green algal blooms in the lower Ord river and further downstream in the Ord estuary (this being undertaken in collaboration with CSIRO Land & Water).

Research into both these issues is currently underway. A summary of what is being done in each of the projects is available from the WSC web site (www.wsc.monash.edu.au/sresearch).

Review:
- Phase 2 of this project commenced in May 2002 and will be completed in June 2004.
- The first three sampling trips have been completed (June, September and December 2002) with samples for macroinvertebrates, macrophytes, biofilms, sediments and water taken at 12 sites. Samples from the first two trips have been processed and a preliminary analysis of the data undertaken. Details are available in Ord Project Milestone Report No 3 (M.Lund@cowan.edu.au).
- A range of biocides (organochlorine pesticides, triazine herbicides, organophosphate pesticides) have been analysed in the sediments sampled. All results were below the analytical detection limits. However, the detection limits are rather high (10-100 ug/L). The investigators propose that sediment samples for pesticide analysis only be collected from the two drains in future field trips.
- Apparently, it has not proven practical to estimate the relative abundances of bacteria, algae and fungi in biofilm samples. Presumably this is because the biofilms have been found to consist mainly of inorganic material, with insufficient organic matter to permit identification of the sub-components.
- There have been some problems with the installation of the autosamplers. It is expected that these will be operational in March 2003.
- The investigators are confident on the basis of a preliminary analysis of the data from the first two sampling occasions, that it will be possible to tease out the effects of irrigation return drainage from inherent site differences.

Linkage Team comments:
- The biodiversity component of this project is progressing satisfactorily. We still have concerns about the lack of data on nutrient loads.
- A great deal is being learned from each field trip about the feasibility of the different components of the study.
- As noted above, the Linkage Team is still concerned at the time taken to install the autosamplers and the lack of nutrient load data. We are assured that the problems have been resolved and the autosamplers should be installed and operative during April 2003. Provided the autosamplers perform as expected, a full 12 months of data will be collected by the end of this project. This is the absolute minimum of data required. Three years of data would be optimal.

- The Linkage Team is also concerned at the lack of pesticide data. The use of sediment for tracking the long-term levels of pesticides is appropriate. However, it is not surprising that all results so far are below the rather high detection limits achievable by the analytical laboratory used. We recommend:
  - That efforts are made to seek another laboratory that can achieve better pesticide detection limits
  - That the investigators liaise with Dr Leo Duivenvoorden (Fitzroy Project) to determine the feasibility of using passive samplers to obtain a better idea of pesticide levels.
- Additionally, it is not clear to the Linkage Team exactly how these pesticide data will be linked to the biodiversity information in order to predict the risks of adverse effects on the biota from pesticides. We recommend that the Ord Team contact Dr Rai Kookana (CSIRO Land & Water, Adelaide, rai.kookana@csiro.au) to obtain advice on how this might be done.
- The Linkage Team looks forward to the Ord Team providing specific details on how they expect to link the irrigation runoff with changes in biodiversity in the receiving water. This (quantitative) predictive tool will be an essential element of the Irrigation ERA framework.

Fitzroy irrigation region
The major ecological issue identified by the Fitzroy team for detailed risk assessment was the influence of irrigation runoff on biological diversity in the Dawson River. This is being determined by measuring changes in the macroinvertebrate populations (see www.wsc.monash.edu.au/sresearch.htm for details).
This research project is currently underway (see Milestone Report No 4 – Dec 2002 - L.Duivenvoorden@cqu.edu.au).

Review:
- A pilot study was undertaken in the 2001/2002 irrigation season when sample methodology (water, macroinvertebrates) and analytical methods were tested.
- Following the pilot study, four 'low impact' sites (upstream of the irrigation area) and three 'impacted' sites (downstream of the runoff entry point - Gap Creek), have been selected. The four downstream include sites 5 and 6 and one a further 32 km downstream of site 6. This arrangement of sites should provide a gradient of response to the expected gradient of pesticide concentration along this length of the river, and should also provide much needed information about the magnitude of the response to impact, important for later predictive models.
- Two other sites have been chosen to address the question in the original proposal about the extent of the impact (if any) downstream of the irrigation area (one is located about 4 km downstream of the Theodore weir and the other about 8km downstream of site 6). These are being sampled twice before and twice after the wet-season flows as specified in the original proposal.
- The sample sites (upstream and downstream of irrigation runoff) have been sampled three-weekly for macroinvetebrates over the period August – December 2002, to establish a 'pre-wet season' baseline.
- An autosampler has been obtained and was set up in Gap Creek prior to the 2002/2003 irrigation season – this has enabled runoff water samples to be obtained for pesticide analysis.

- The drought in central Queensland has caused some problems with macroinvetebrate and water sampling.
- A small runoff event over the Christmas-New Year period (2002-2003) was followed by a larger flow event (4-5 days) in early February 2003 in the Gap Creek area that triggered the autosampler and collected samples for pesticide analyses. Malfunction of the refrigerator unit of the autosampler and problems with the height recorder over the Christmas-New Year period did not allow adequate monitoring of the small runoff event during this period. Sampling of macroinvertebrates and use of field based direct toxicity tests (snails only) has continued at two to three week intervals since the flows.

Linkage Team comments:

- Overall this project is on schedule and progressing satisfactorily, although the drought created problems at some sites owing to the sites completely drying up.
- The pilot study was very useful in providing information of relevance to the main study.
- The Linkage team agreed with the modifications made to the to sample locations.
- Considerable work is still needed to link the irrigation runoff (pesticides, nutrients, SPM) with changes in biodiversity in the receiving water. This (quantitative) predictive tool will be an essential element of the Irrigation ERA framework.
- The Linkage Team looks forward to working with the Fitzroy Team in developing this predictive model.

2.3 Draft ERA Framework

The major output from the linkage project will be a framework to guide those wishing to undertake ecological risk assessments of irrigation schemes. It is anticipated that a draft framework will be available around May-June 2003, with the final framework dependent upon the completion of the three case studies.
Here we summarise progress towards the development of the draft framework.

Vision for the Irrigation ERA

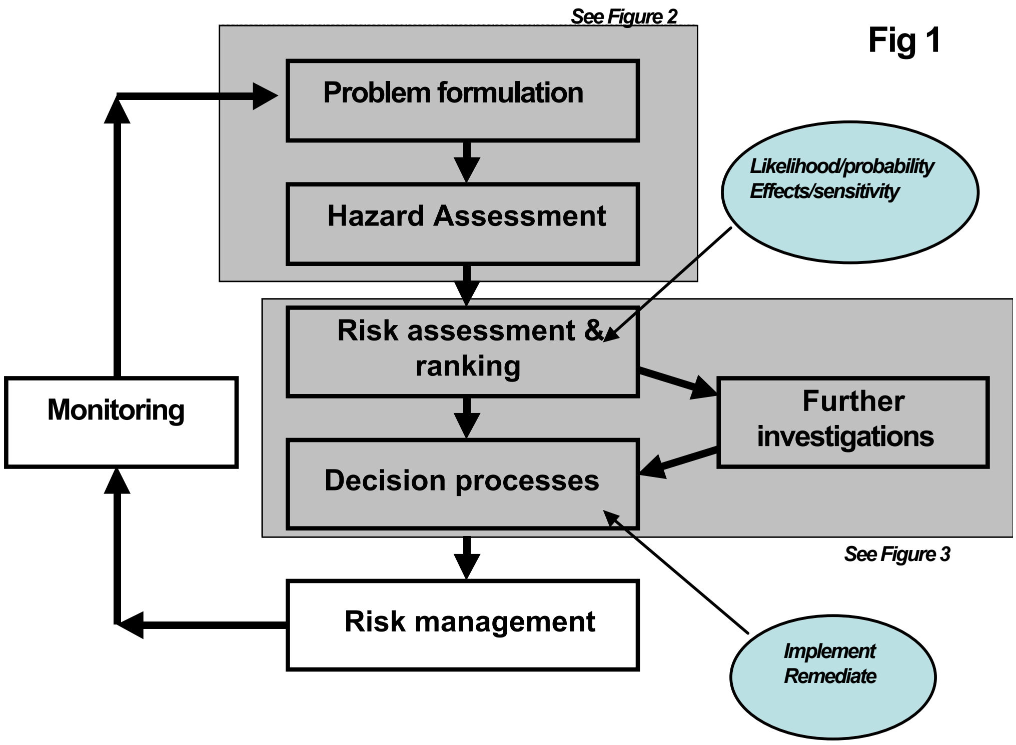
- The primary audience will be natural resource management agencies, CMA's and consultants.
- It is expected that the Australian framework will build upon existing ERA protocols (in particular the US EPA protocol).
- The framework document will provide advice on how to approach each step, and will provide lots of examples/illustrations from our experiences with the 3 case studies and other studies currently underway (e.g. salinity ERA being developed for the Goulburn-Broken CMA).
- In a separate document, we expect to outline how this ERA methodology can assist in defining research priorities.

What will the framework look like?

Risk is often defined as the product of the *probability or likelihood* of a hazard and the *consequence* if that hazard occurs, so that: Ecological risk = likelihood of ecological effect x consequence of that effect.

Thus, an ERA provides a basis for comparing and ranking risks, so that natural resource managers can focus attention on the most severe risks first. Our challenge will be to develop a framework that is able to assess the level of risk to the health of river ecosystems posed by multiple stressors (e.g. salinity, toxicants, nutrients, temperature, flow, habitat, exotic fish species) within a catchment context.

Figure 1 provides a flow diagram of the major steps that will be involved in the risk assessment framework. Ideally, the ERA process should be iterative, allowing new information to be incorporated into the risk assessment as it becomes available. The various steps involved are briefly outlined below.

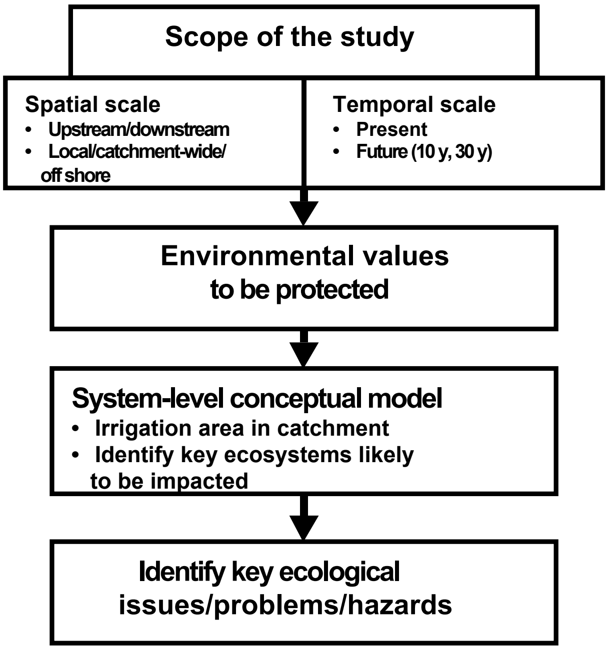


(a) Problem formulation
This is the planning phase that establishes the goals, breadth and focus of the risk assessment. Key outputs from this stage are identification of the ecosystem(s) to be considered, their ecological values, the stressors that threaten these values, and the main measurement endpoint that will be used to quantify the risks. It is highly desirable that this step be undertaken with *stakeholder involvement*.

We have been impressed with the usefulness of *conceptual models* in helping to focus the risk assessment process, and in providing a basis for discussions about a particular ecosystem with stakeholders. Such models are representations of our present understanding of the overall ecosystem or components of the system. We expect to recommend preparing two types of conceptual models: (a) a 'big picture' (or macro-scale) model for the catchment showing the important components of the system and the regions in this landscape where the identified risks (e.g. salinity) are likely to be greatest, and (b) system-specific (or meso-scale) conceptual models, where the key stressors are linked to the ecological effect (these will form the basis of the quantitative predictive models that will form the basis of the risk assessment in most cases).

A number of important learnings regarding the Problem Formulation step of an ERA emerged from a review of Phase 1 of this project. A slightly more details view of the steps involved in this process is given in Figure 2.

Fig 2: Problem formulation & hazard assessment



Particular points to come from this review were:

- Stakeholder workshops are essential, but the purpose of the exercise must be clearly identified before the workshop is run. These workshops obviously have a primary aim to inform the ERA process, but they are also very useful for informing the stakeholders on the range of issues associated with their operations.
- The success of these workshops is dependent upon the knowledge-base of the stakeholders, the mix of stakeholders attending and the way in which the workshop is facilitated.
- It is important to have good technical/scientific information available, but this should not dominate the workshop – the purpose is to solicit the views of the stakeholders. Perhaps best to think of the stakeholders as providing information on the *ecological values* they wish to achieve and the scientists as proving information on the *ecological consequences* of particular actions.
- It is important for the credibility of the process to get ALL the issues on the table. For example, issues associate with the fact that reservoirs have been built in the past to service for most irrigations schemes need to be included in the discussions.
- Generally, it has been found that stakeholder workshops are most successful if there has been prior interaction between stakeholders (particularly irrigators) and the ERA technical group – the building of TRUST between the players is extremely important.
- The Linkage Project should produce a generic list (check list) of potential ecological issues associated with irrigation systems. This would be of considerable assistance to those running future stakeholder workshops.

(b) Risk analysis

During this phase, information relevant to each key issue (e.g. loss of wetland biodiversity due to salinity increase; increased frequency of cyanobacteria blooms; fish kills) is gathered on the two components of risk - likelihood and consequence of the effects – and this information is combined to provide estimates of risk.

Effects characterisation - The purpose here is to identify and quantify the adverse effects on the environmental value of concern caused by a stressor(s).

Likelihood characterisation - Here the objective is to measure (or predict) the spatial and temporal distribution of the stressor (e.g. salinity, pesticide). For quantitative risk assessments, some modelling (or estimation) of the stressor concentration distributions is normally undertaken, particularly to obtain information relevant for future scenarios.

(c) Risk characterisation

Here we consider how best to combine the two components of risk – the effects or consequences and the likelihood. Where possible a Probabilistic Risk Assessment (PRA) approach will be recommended. This approach determines system-specific species sensitivity distribution (SSD) for the stressor of interest (salinity), using data for as many species as possible that live in the system, and then estimates the proportion of these species likely to be subjected to intolerable salinity levels given the expected salinity concentration distribution. This method works well with toxicants.

However, in many cases this will not be possible because of a lack of knowledge about the links between the stressor(s) and the ecological effect. In these cases we will provide examples where both quantitative and semi-quantitative models can be used to predict the likelihood of adverse effects.

(d) Risk investigations

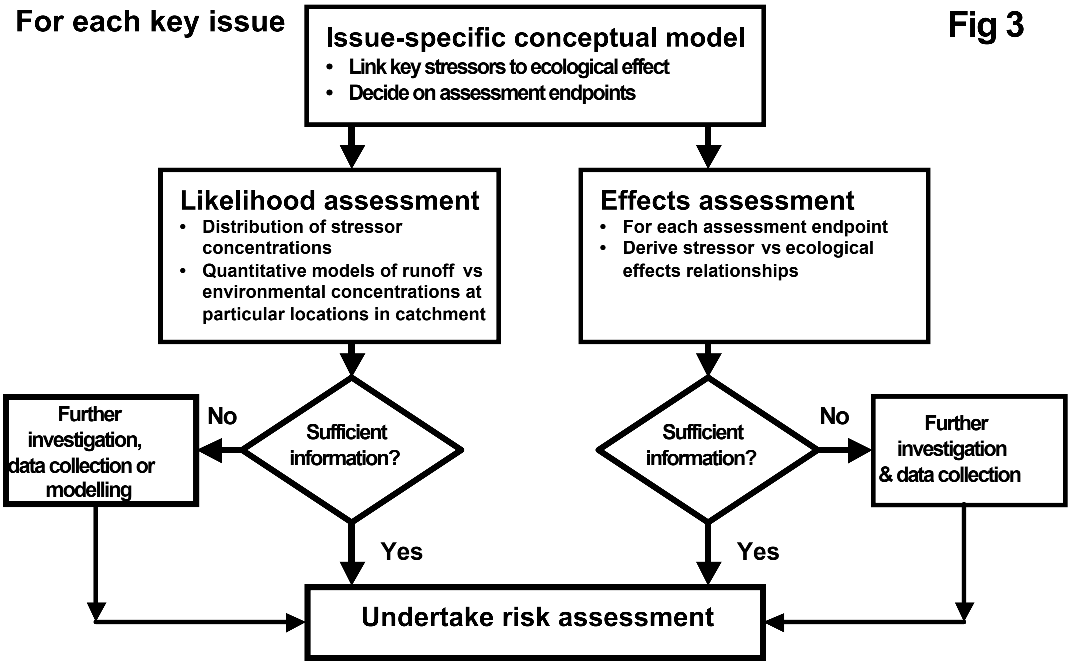
In undertaking a risk assessment, it is often found that further investigations are needed to provide more information before the detailed assessment can be undertaken. The three case study investigations are examples of further studies being undertaken to provide more specific information on key issues in each of the catchments (see www.wsc.monash.edu.au/sresearch for details on each).

The Irrigation ERA framework will provide guidance on how to identify knowledge gaps and how to determine what types of investigations are needed to fill these gaps.

In particular, we expect to highlight the differences between ‘normal’ (hypothesis testing) scientific investigations and those required for risk assessments. Risk investigations are focused on quantifying the relationships between cause and effect – or more often, between indicators of cause and effect, rather than in determining whether statistically significant effects have occurred due to the imposition of a stressor on the ecosystem. Given the complexity and variability of most natural systems and the inherent considerable level of uncertainty, a statistically significant finding often requires that many samples are collected over a long period of time. This often results in prohibitively expensive investigations that are either done poorly or not at all. Studies based on hypothesis testing also rarely concentrate on quantifying effect size of a certain level of stressor. This information is essential to develop the cause-effect relationships described above.

For these reasons, Bayesian methods are gaining increased favour for risk investigations. Bayesian methods have a number of advantages, the most important being that probabilistic predictions can be obtained, that existing information and knowledge (via expert opinion) can be used, and that predictions can be obtained even in situations that are data-poor, a situation that exists for many ecosystems we are required to manage.

A review of Phase 1 of this project identified a number of important lessons regarding identification of the important knowledge gaps that need further investigation. The steps involved in this process is shown in Figure 3.



Particular points to come from this review were:

- It is desirable to separate the two processes of identifying the ecological issue and of identifying knowledge gaps
- The best outcomes will result if the technical/scientific team is multidisciplinary and able to adequately assess all aspects (this minimises the potential for the scientific team to 'bias' the knowledge needs to their particular interests)
- The process needs to be transparent with all data and information relevant to each issue clearly identified, collated and analysed, and this information base documented.
- It is desirable for the final conclusions on the main information needs to be peer reviewed. In many cases, there is enough information already available to undertake a risk assessment, perhaps with the addition of some site-specific information.

We intend to probe further the experience gained from the Phase 1 at Workshop 2 in August 2003.

(e) Decision processes

A powerful feature of the risk assessment process is that consistent information on the risks associated with a number of possible scenarios or management options can be provided to the manager. For example, there are now many cases in Australia where high value wetlands are being adversely impacted by rising salinity levels, and possible management (rehabilitation) options are being investigated. These include short-term engineering options, such as groundwater pumping, or the construction of deep drains to divert groundwater from entering the wetland, and longer-term options, such as catchment revegetation. ERA provides a rigorous and consistent framework for comparing the likely ecological benefits of such options.

(f) Risk management

The information developed in the previous stage can then be used with economic, social and cultural information to develop a management plan to minimise the risk to the particular ecosystem. Generally, ecosystems at risk fall into one of four broad management categories

- *Protection* – for ecosystems that are assessed as being at low risk of adverse effects in the medium to long term. Previous research has estimated that it is at least 10 times cheaper to protect and maintain existing ecosystems than to restore and repair lost ecosystem function.
- *Active management* – for ecosystems that are assessed at high risk now or will be in the near future.
- *Rehabilitatation* – systems that are currently in poor to reasonable condition.
- *Low priority for any action* – systems that are currently in poor condition and at high risk of further adverse effects. The exceptions here are aquatic systems that are highly valued by the community.

Possible management actions that might be contemplated in response to information on risk and the present condition of the system are shown in Table 1. Information derived from the risk assessment, and particularly that derived from a well-constructed conceptual model of the system, will assist the natural resource manager in deciding those factors (or stressors) that contribute most to the risk, and which of these are possible targets for management action.

Table 1: Risk management matrix

		Present condition		
Risk of adverse effect		Good	Reasonable	Poor
	Low	P	P/R	R
	Moderate	AM	AM/R	AM/R
	High	AM	AM/R	D

P = protect R = Rehabilitate AM = active management D = Discard

(g) Monitoring

Without a robust monitoring and assessment program, it is impossible to know whether the various management actions have had the desired effect. Additionally, information derived from the monitoring program will be vital in determining the trajectory of any change, i.e. is the system improving, getting worse or being maintained? Such information is an essential component of adaptive management. Unfortunately, in many situations too little effort is expended in monitoring the behaviour of the system.

How will the Case Studies inform the framework?

We expect the experience and outputs from the three Case Studies will feed into the Irrigation ERA Framework in three ways (Figure 4).

Problem formulation - Phase 1 of this overall project sought to identify the six priority ecological issues associated with each of the three irrigation districts. Stakeholder workshops were used to assist this process. In a review of Phase 1 undertaken at Workshop 1, the project team identified a number of important lessons regarding this process that will be used to improve this step in the final Irrigation ERA Framework. We intend to probe further the experience gained from the Phase 1 at Workshop 2 in August 2003.

Risk assessment and ranking - In this phase, information relevant to each key issue (e.g. loss of riverine biodiversity due to irrigation runoff) is gathered on the two components of risk - likelihood and consequence of the effects – and this information is combined to provide estimates of risk. Where possible a probabilistic approach will be recommended and further, all uncertainties will be identified and if possible accounted for. In many cases this is difficult because of a lack of knowledge about the links between the stressor(s) and the ecological effect. We expect the three Case Studies to provide examples of both quantitative and semi-quantitative models for predicting the likelihood of adverse ecological effects, that can be used to help those using the final Irrigation ERA Framework.

Specific investigations – It is common in risk assessments that further investigations are needed to provide more information before the detailed assessment can be undertaken. The three Case Studies are currently undertaking risk investigations as part of Phase 2 of the project. These investigations are highlighting the differences between 'normal' (hypothesis testing) scientific investigations and those required for risk assessments. Risk investigations are focused on quantifying the relationships between cause and effect – or more often, between indicators of cause and effect, rather than in determining whether statistically significant effects have occurred due to the imposition of a stressor on the ecosystem. Fact Sheet 2 currently being prepared will address this differences.
The Irrigation ERA framework will provide guidance on how to identify knowledge gaps and how to determine what types of investigations are needed to fill these gaps.

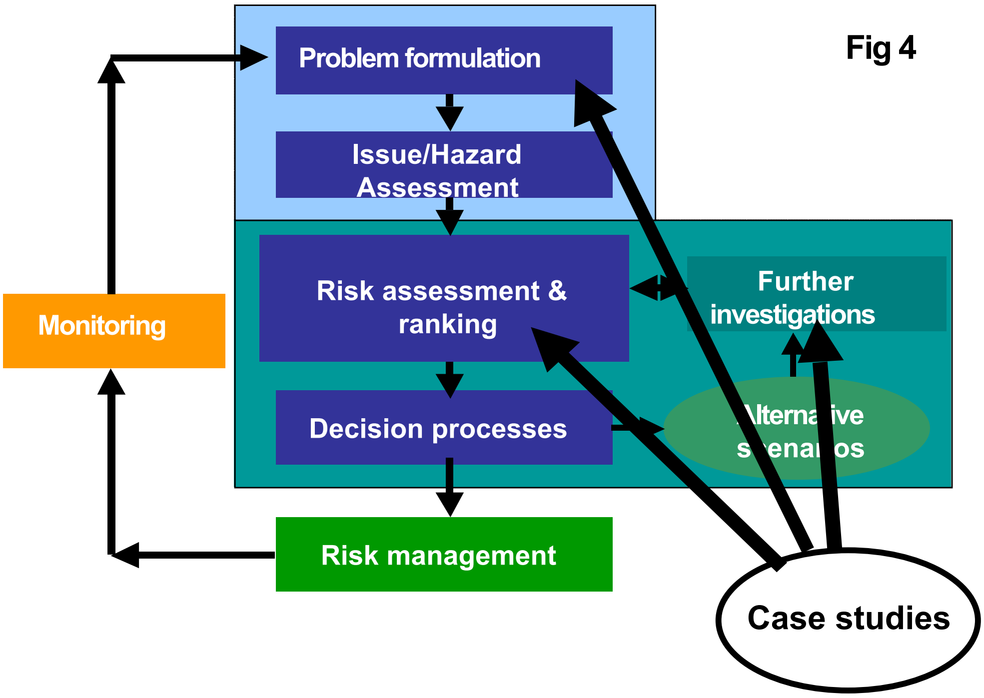


Fig 4

3. What next?
We plan to hold the second Workshop in August 2003, subject to all team members being able to attend. The following aspects will be discussed:

- Revisit the Phase 1 problem formulation step to ensure we have captured all the relevant risks associated with each of the three irrigation case studies
- Progress with the three case study investigations, focusing particularly on how the results will be used in the detailed ecological risk assessments
- Review the draft Irrigation ERA framework prepared by the Linkage Team
- Investigate opportunities for promotion of the framework.

Further information
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