ECOLOGICALLY SUSTAINABLE IRRIGATION DEVELOPMENT

Issues Paper

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National Program *for*
Irrigation Research and Development

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1.0 INTRODUCTION

Background

There has recently been significant discussion across Australia, both within the community and in federal and state governments, over the potential development of new major irrigation schemes (e.g. Australian Financial Review 1998). Some states, such as Queensland, have openly pursued a pro-development path, announcing the Water Infrastructure Planning and Development Implementation Program in 1997 (QDNR 1997a), following submissions from the community via a Water Infrastructure Task Force (QDNR 1997b). Equally, there have been calls from the community for the Queensland government to proceed more cautiously and with greater rigour (eg. Roberts 1996a, b, c).

In recognising the apparent move by some States toward new investment in irrigation infrastructure, the Land and Water Resources Research and Development Corporation (LWRRDC) commissioned the Australian Centre for Tropical Freshwater Research (ACTFR) to prepare an issues paper on best practice, with respect to ecological issues and the development of new irrigation schemes in Australia. It was agreed that the priority area for discussion was to be biodiversity and conservation, in the context of new irrigation scheme development.

This paper is the result of 1) reviewing mainly Australian literature, the bulk of which exists as “grey material”, 2) undertaking discussions with key industry personnel, particularly in new or refurbished irrigation areas, and 3) documenting the author’s experience in the development of one of Australia’s largest and most intensive irrigation areas, the Burdekin River Irrigation Area (BRIA).

Irrigation in Australia

A global comparison of water use shows that Australia’s annual total runoff and diversions are small, but with a significant proportion being devoted to agricultural production (Table 1). There is little doubt that irrigated agriculture in Australia contributes significantly to the national economy and the nature of agriculture in Australia. Irrigated land now covers 2 million hectares in Australia, accounts for 70% of the nation’s water use, produces $6 billion at the farmgate, and represents 25% of all agricultural production (Schofield *et al.* 1998).

Table 1. A global comparison of water use (Nix 1995)

	Annual Total Runoff (km^3)	Annual Withdrawal (km^3)	Sectoral Withdrawal (%)		
			Domestic	**Industry**	**Agriculture**
Australia	398	17.80	15	10	75
Canada	2901	36.15	18	70	12
USA	2478	467.00	12	46	42
Brazil	5190	35.04	43	17	40
China	2800	480.00	6	7	87

The area of land committed to irrigated agriculture has grown steadily over the last half of this century, with annual diversions in the Murray Darling Basin increasing more than fourfold since 1920 (Table 2).

Table 2. Annual diversions (GL) in the Murray Darling Basin (Blackmore 1995)

	Total	*NSW*	*VIC*	*SA*
1920	2000	<1000	<1000	<500
1990	9500	~5000	~3500	~500

Unfortunately, the economic returns on assets for government gravity irrigation schemes has been poor, and in 1990/91, all states returned a negative result: NSW -1.9%, VIC -0.34%, QLD -1.73%, WA -5.13%, SA -5.10%, TAS -1.14% (Langford 1995). Given the complex history of motivations and priorities of water infrastructure development in Australia – it is not surprising that many schemes have been unable to return a positive return on their operation. For example, Powell (1991) documented the Queensland fascination and drive for water development between 1824-1990 and provides a thorough review of the history of water development and management in the state. From the early European appraisals of water development potential, through the inter-basin transfer of the Mareeba-Dimbulah scheme and the development of Emerald, Eton and St George irrigation areas, to the "taming of the Burdekin" in the 1980's, it is clear that water development in Queensland has been seen by many as a challenge of nature – which may not be given up till all major storages have been developed and the vision of "plains of promise and rivers of destiny" is implemented (Powell 1991).

In looking toward the future, Smith (1998) has presented estimates of national water demand by sector to 2051 with agriculture demand to increase from ~15,000 to almost 25,000 gigalitres per year (based on CSIRO Ecumene project data). However, Smith (1998) also makes the point that it is "the end of an era" of large dam development in Australia. The nature of the projected demand and how this would be filled, if it is truly the end of an era, is not suggested by Smith.

The water demand trend scenarios outlined by Smith are similar to those of Thomas (1999). Thomas states that recent trends indicate that water supply for all purposes has increased by 25% since 1983-84, with gross water supplied in 1995-96 being 20,000 gigalitres. It is claimed that the most of this increase in water use (ie. two-thirds) is due to "licensed private diversions from groundwater, unregulated streams and farm dams". The remaining one-third is due to "conventional surface water diversions initiated by governments and constructed with public money".

However, it suggested that under an "adaptive management scenario", further growth in water use could be met. This utilises an approach that is based on:

- transfer of water from low value to high value uses

- large scale improvements in water-use efficiency (saving 1.6% of annual water use but with some going to the environment)

- intensive irrigated cropping is responsible for the growth – but with some of this being outside Murray Darling Basin.

- ¾ of all new growth in the cotton industry is in coastal Queensland and ¼ in Kimberley

- there is interstate trading of water.

Thomas (1999) assumes this further development would be in accordance with traditional irrigation scheme development; however, the development and implementation of a best practice approach to environmental management in the design and operation of any new irrigation is likely to further constrain available land, the use of water, and hence potential development. Simply adopting the results of past impact assessments and management measures as a yard stick for what is appropriate a new development is not likely to be acceptable to the community.

As part of these discussions about new developments, a variety of conflict resolution mechanisms and assessment processes (NLWA 1999) are also being promulgated to demonstrate clear and accountable decision making. Handmer *et al.* (1991) edited a collection of examples of conflict resolution in Australian water management - and this documents the environmental/development issues through the introduction of water planning and allocation legislation, to the current day premise of sustainable development. The Multi Objective Decision Support System (MODSS) being introduced by the Queensland government is one the latest tools in an attempt to provide a clear and efficient mechanisms on which to base decisions. However, all such systems require knowledge of both the environmental impacts from further development options and the mechanisms available for mitigation of such impacts. It is the latter of these two information demands that this paper addresses. Best Management Practice (BMP) is currently a much touted phrase, and considerable work has been undertaken to address BMP for productivity purposes or for mitigative measures; however, very little has so far been documented in relation to BMP for biological conservation within the irrigation areas - either in the development of new areas or for the refurbishment of existing areas.

2.0 BEST MANAGEMENT PRACTICE

Planning of New Irrigation Schemes

Almost 15 years ago, Sewell *et al.* (1985) documented current views on water infrastructure planning in Australia on a state by state basis. The need for improved planning practices was advocated by all state representatives; however, only Queensland and Western Australia placed emphasis upon investment in new irrigation areas. Most notably, Queensland stated that although significant opportunities still exist for water resource development, planning emphasis needs to change to include other issues such as catchment management and water quality (Fenwick 1985). Additionally, regional assessments were emphasised to better determine the likely future requirements and timings for water for urban, industrial, agricultural and recreational purposes.

Fenwick (1985) stressed that clear policies are required by the state in relation to the development of new resources, including;

- criteria by which new water conservation projects are measured and accepted,
- scale of development desirable, ie. a few large projects or a greater number of smaller projects, and their impact on state economic benefit and resource development,
- development of public works on the one hand against encouragement of private development on the other, and
- resource-based policies which should apply to new developments, as scarce water resources in the state are progressively harnessed.

Fenwick (1985) also advocated improved planning at the project level, with full assessments of potential users, engineering and hydrologic aspects, environmental impacts, and cost/benefit analysis being required. However, in 1985 determining best ecological practice was not a consideration at the project level.

Today, Environmental Management Plans (EMPs) are developed for the construction and operation of irrigation areas but these generic documents generally fail to integrate the management of the irrigation scheme with catchment or local issues (see DNR 1998a, DNR 1998b). The guidelines also do not reference the protocols for environmental management in the irrigation area. For example, although volumes of work have been undertaken on habitat fragmentation for the forest industry – planning of irrigation projects have generally not taken note of this material. To demonstrate this, a case study on habitat fragmentation and irrigation scheme development is provided in Appendix 1.

In an attempt to address this deficiency, the Queensland government acknowledged the recommendations of the Water Infrastructure Task Force in the Water Industry Planning and Development Implementation Plan (WIPDIP), and agreed to review procedures for water infrastructure planning with increased emphasis upon;

- the market demand for water,

- improved hydrologic modelling,
- early identification of environmental issues,
- the WAMP process,
- processes for allocation of water and water user understanding of these processes,
- sustainable land and water management planning,
- financial negotiation and funding options, and
- determination of water user's entitlements. (from DNR 1998)

Whilst many of these individual issues have been taken up by the DNR (eg. WAMPs), the issue of a transparent process to guide overall project planning has not been forthcoming. The commitment was given by the Department of Natural Resources to produce a revised procedural manual covering all phases of water infrastructure planning in Queensland. It would address issues such as the need for baseline data, for example, on freshwater fisheries, and land and water planning, environmental assessment and consultation (p5.12). This was to be completed by the end of 1997; however, at the time of writing, this has still not been compiled and only an outline of the proposed planning process exists.

A sequential checklist of tasks required as part of the infrastructure development process has been compiled by the DNR (unpublished); however, environmental assessments are only considered under "Development and Analysis of Strategies", and within the context of impact assessments. The checklist is as follows:

- Literature/Data Collection/Review
- Consultation with Communities and Stakeholders
- Hydrological Assessment
- Hydrogeological Assessment
- Agricultural System and marketing Analysis
- Existing Water Development and Utilisation
- Water Demand Assessment
- Alternative Options for Development
- Preliminary Analysis and Screening of Options
- Interim Report Preparation
- Development and Analysis of Strategies
- Evaluation of Strategies
- Preferred Development Plan
- Final Report Preparation
- Project Management

Nevertheless, under the WIPDIP the DNR are committed to undertaking a number of Catchment/Regional Planning Studies (eg. Burdekin, Atherton Tablelands, Herbert River and Gulf Region). These studies seek to determine potential storage sites and land uses together with ecological and social constraints. The process used to guide these studies is not known but a Multi Objective Decision Support System is being utilised to compare short-listed development options (DNR 1998).

As part of its WIPDIP commitments, and in collaboration with industry, the DNR have also undertaken to develop industry best practice guidelines for irrigated farming developments. The guidelines were to provide information and guidance to assist land-holders in developing land and water management plans (LWMP). A LWMP is required for all irrigation developments which involve government funding or when new or additional water allocations are purchased at auction. Fact sheets have been developed (see DNR 1998) that briefly address a variety of issues, such as;

- property mapping,
- soils and land suitability,
- water management,
- land management and cropping practices, and
- nature and heritage conservation.

Integral to nature conservation, a LWMP should demonstrate that the development "will protect environmentally sensitive places such as riparian vegetation, endangered ecosystems, endangered flora and fauna and wetlands" (DNR 1998). However, the LWMP does not extend to regional/scheme planning and are hence unable to include issue such as groundwater management, vegetation corridors etc. Additionally, the controls afforded by LWMPs can only be enacted as part of an allocation of water. There is nothing stopping pre-emptive clearing (ahead of receiving the allocation) on farms that intend to utilise government funded water supplies or new allocations in the future.

Regional Land and Water Management Plans

In comparison, a number of regional LWMPs have been developed in the Murray Darling Basin to address environmental issues at a district or regional level. More than 10 such plans have been developed in Victoria (eg. Sunraysia, Shepparton) and a further 8 in New South Wales (eg. Berriquin, Cadell). Whilst these plans understandably place much attention upon salinity and drainage, the plans define the nature of each irrigation district (eg. agriculture types, economic profiles, natural resources, infrastructure) and outline existing pressures (eg. groundwater, salinisation, socio-economic projections). The plans also outline options for dealing with these issues through;

- on-farm practices,
- sealing the supply system,
- surface drainage,
- institutional arrangements,
- integration of plan components,
- impacts from Plan implementation,
- monitoring and review, and
- cost sharing arrangements.

Biodiversity issues are discussed in terms of the potential impacts of implementation of the plans, not as an objective of the plans. For example, in the Berriquin and Cadell plans – the need to protect conservation areas is highlighted and it is stated that tree planting along major roads and supply channels, in depressions and as shelterbelts will occur to encourage biodiversity. However, the plan does not contain measures to implement this nor does it strategically address conservation as an element within the plan. Unfortunately, little attention is also placed on the management of remnant flora and fauna, and the ecology of the region. Given that the community's priority environmental issues are concerned with rising watertables and drainage – this is somewhat understandable.

Similarly, the Shepparton Irrigation Region Surface Drainage Strategy did not utilise the opportunity as part of the drainage works to build in conservation and biodiversity opportunities through tree planting, linking of remnant habitats, etc. However, an attempt was made as part of the refurbishment program to improve flow regulation conditions in creeks, to minimise flow levels in summer months and to protect existing wetlands and other habitats. Guides to tree planting in the Shepparton Irrigation Region have also been produced by the state government (DNRE 1997).

Currently, the only documented approach to best practice in the development of new irrigation regions and for on-farm management is that compiled by the Kimberley Development Commission for the Ord River Irrigation Area (McKinnon 1998). Best practice in the context of the ORIA is discussed with respect to 4 main areas:

Managing soil retention and surface water quality

- Sediment traps, mulching techniques, cover cropping, minimum tillage, chemical mechanisms, tailwater return

Managing groundwater resources and groundwater quality

- Soil permeability mapping, groundwater pumping and conjunctive water use
- Irrigation management, sub-surface drainage, tree cropping

Environmental Buffers

- Constructed wetlands
  - Technical and construction specifications
  - Engineering design objectives for a constructed wetlands
  - Plant species selection and establishment
  - Industry contacts

- Riparian buffer strips
  - Benefits
  - Design and effective use of riparian buffers
  - Industry contacts

Planning and Policy

- Industry contacts

Again, biodiversity and conservation planning has not explicitly been targeted as part of best practice management, and the information available in relation to the proposed Stage 2 expansion of the ORIA does not indicate whether such practices are mandatory in the development of the scheme (DRD 1997).

Benchmarking

In the report of the LWRRDC NPIRD Benchmarking Project (Barraclough & Co. 1998), environmental management was used as one set of criteria to establish benchmarks between six irrigation providers (Goulburn Murray Water, Murrumbidgee Irrigation Corporation, Murray Irrigation Limited, Renmark Irrigation Trust, Sunraysia Rural Water Authority and Western Murray Irrigation Limited).

Environmental management criteria used were:

- Water quality (both entering and leaving the irrigation system) – salinity, nutrients, turbidity pesticides
- Water table levels and salinity of groundwater
- Soil salinity status
- Environmental risk assessment and management
- Relationships of organisations with land and water management plans

With respect to Land and Water Management Plans, benchmarks were:

- Utilisation of LWMP as part of pollution reduction programs pollution for discharge licenses
- Annual environmental reporting.

Whilst such an approach is useful to describe environmental management processes, the benchmarking project did not assess ecological outcomes. A more comprehensive approach to benchmarking irrigation providers is required that also includes ecological criteria within a Pressure-State-Response indicator framework (see DEST 1996).

Nevertheless, the Benchmarking Project (Barraclough & Co. 1998) does outline potential improvements in the resource management of irrigation providers in both New South Wales and Victoria. In NSW, the recommended approach was that an annual review of licenses be implemented to ensure priority issues meet the objectives of the regional LWMP. However, the challenge to irrigation providers is to extend the issues covered by an existing LWMP to also contain conservation/habitat issues, with implementation continuing to be tied to annual reviews of licenses.

Similarly, in Victoria, Barraclough & Co. (1998) believe there is still considerable opportunity for better integration of EPA, Catchment and Land Protection, Water, Local Government Planning, and Flora and Fauna Guarantee legislation. It should be noted that some irrigation providers, such as Goulburn Murray Water, do have close contact with catchment management authorities, implement groundwater management plans, etc. Evidence of this is the relationship between the Institute for Sustainable Irrigated Agriculture (comprised of staff from Agriculture Victoria - Department of Natural Resources and Environment) and G-M Water at Tatura. Benefits of this synergy are seen in the implementation of the regional salinity plan, as well as wetland rehabilitation, revegetation initiatives and improved waterway management. This collaboration also results in the publication of extension material that illustrates best practice measures for irrigated farming, such as optimising fertiliser application (DNRE 1998). Matching fertiliser supply with demand, leaving a buffer zone when fertilising, delaying irrigation until after fertilisation, preventing run-off for two irrigations after fertilising and re-using run-off are all covered in such publications. This type of material is also what is required for best practice in relation to on-farm biodiversity and conservation management.

Cooperative Catchment Management

Barraclough & Co. (1998) also make the point that the success of a LWMP is dependent upon cooperative input by State and Federal EP agencies. Given the COAG water reform agenda, it is difficult to see how further Commonwealth involvement in the operation of irrigation schemes can be justified; however, the Sugar Industry Infrastructure Packages (SIIP) that are being implemented in Queensland, are an example where Commonwealth investment is ensuring greater environmental protection.

For example, the Project Management Agreement for the Riversdale-Murray Valley Water Management Scheme (January 1999), is a voluntary agreement between industry, local government, state agencies (EPA, DNR) and the federal government (EA). The agreement details undertakings by the parties to:

- consult over all scheme design elements (eg. drainage moduli, constructed wetlands),
- determine development constraints (eg. based on regional ecosystem and soils mapping for existing protected areas, medium and high value conservation areas, areas of acid sulphate soils, land suitability, land tenure)
- finalise expansion regions (utilising the local government planning scheme),
- monitor scheme operation and expansion impacts through a negotiated Environmental Management Plan,
- develop natural resource databases,
- implement the catchment rehabilitation plan (including incentives packages for retention of vegetation by landholders),
- protect and maintain downstream wetlands and fish habitats, and
- manage specific and general cultural heritage impacts.

Such an integrated and comprehensive approach to water management on the floodplain would not be possible without Commonwealth investment. The opportunity for industry to obtain a subsidy for improved drainage was sufficient incentive, even within the context of greater catchment management and controls on land use, for the infrastructure scheme to be implemented. The conservation and biodiversity outcomes from this agreement are significant, and this is a useful example of regional planning using water management as the driver for the inclusion of broader ecological issues. The inclusion of local government planning controls and industry support should also ensure pre-emptive clearing does not occur.

Indicators of Sustainability

In a discussion on sustainability, irrigation and catchment management, Allison (1995) lists performance targets for irrigation schemes as part of an Integrated Catchment Management approach. These targets, which include biodiversity, nutrient and sediment targets, aesthetic and ecological values and water quality, should be "stringent, legally enforceable goals". Allison (1995) also suggests these targets should be part of an overall indicator framework for the sustainability of agriculture (see Table 3).

Table 3. Sustainability of agriculture

Key Indicators	Major Attributes			
Long-term Real Net Farm Income	Net farm income	Productivity	Terms of trade	Numbers of farms over time
	Water/Soil Balance		*Biological Resilience*	
Land-Water Quality to Sustain Production	Water use efficiency of crops/stock	Nutrient balance of farm	Area of native vegetation	Degree of fragmentation of vegetation
Managerial Skills	Farmer education level	Skills index	Landcare attitude index	Farm planning capacity
Off-site Environmental Impacts	Food chemical contamination level	River outfall turbidity	Dust storm frequency	Length of contact zone with non-agric. areas

(Source: Sustainable Agriculture - SCARM Report No 51, in Allison 1995)

This is a useful framework to consider the attributes of sustainable irrigated agriculture. There is much evidence to suggest that in the in the design, development and management of new schemes the focus has been mostly upon Water/Soil Balance issues and much less about Biological Resilience (see previous discussion on BMPs).

Currently, there is very little information to support the integration of concepts such as Biological Resilience in irrigation scheme planning. For example, integrated pest management could be seen to be a critical component, yet guidelines do not exist to allow practical decisions to be made about vegetation management (retention, fragmentation, revegetation) to support key predator species, buffer spray drift, contain runoff, etc. Similarly, very few pest eradication strategies exist that integrate other ecological issues. An exception is the work undertaken by the Bureau of Sugar Experiment Stations (BSES) at Tully in north Queensland, that is developing a holistic approach to cane rat management (BSES 1996). Results from trials indicate that through the revegetation of on-farm riparian zones, there is a reduction in grass biomass, and hence a reduction in available habitat for rats. When such an approach is coupled with catchment revegetation strategies and the construction of owl boxes (to increase predator numbers) – there are multiple gains to the ecology of the farming region.

Proposed Irrigation Schemes

However, it is the failure to incorporate any such approaches into the planning of new schemes that needs to be addressed. A case in point is the development of the

Burdekin River Irrigation Area (BRIA). The destruction of all extant vegetation in some sections (eg. Mulgrave region) has resulted in a landscape akin to some of the worst in the Murray Darling Basin (eg. Denniliquin region). Whilst planning in Queensland has improved, particularly in the detail of surveys undertaken prior to any development, the protection of important regional ecosystems, the inclusion of vegetation corridors and the management of waterways (eg. retention of riparian zones, on-farm recycling, creation of constructed wetlands) – there is still little information to support farm layouts and operations at a regional scale.

Another example is the recent appraisal by the Australian Society for Limnology (ASL) of the draft impact assessment for irrigation development at Currereva on Cooper Creek. (ASL 1999). The ASL highlighted deficiencies in the following areas:

- Impact on flows in Cooper Creek
    - absence of ecological assessment
    - flow implications on Cooper Creek
    - local flow impacts
- Significance of Cooper's Creek catchment
    - international
    - national (eg. biodiversity, national heritage, COAG water reforms)
- Floodplain harvesting
- Groundwater
- Whole of catchment approach
- Flora and fauna information
    - general information
    - impacts on flora and fauna
- Pesticides and herbicides
- Socioeconomic impacts
- Adequacy of scientific resources
- Crops grown
- Additional water use and other uncertainties

These perceived deficiencies in the Currereva development proposal provides additional impetus for the need to utilise a best management practice approach to designing the irrigation area, and to utilise an established assessment process with transparent guidelines for the development and assessment of such proposals. Similar concerns were raised by the Australian conservation foundation over the proposed Fitzroy dam and irrigation scheme in Western Australia (ACF 1997).

The work undertaken by Gill and Lukacs (1999) for the National Land and Water Resources Audit to develop an Integrated Assessment Process and Guidelines for Water Resource Development Projects is an example of such a process (see Appendix 2). The comprehensive ecological criteria within that document would allow the community to evaluate the merits of the proposal and provide the proponent with an indication of what is regarded as best practice management in the development of new irrigation schemes. However, ecological assessment criteria can not substitute for established guidelines, and the necessary research and development still needs to be undertaken.

3.0 LOOKING AHEAD

Ecological Planning Principles

Recently, an independent working group discussed the roles of science and technology for managing Australia's inland waters and identified six major areas where science can contribute to the management of water resources (PMSEC 1996). However, discussions were limited to the Murray Darling Basin and Great Artesian Basin "to provide a clear geographic focus to the consideration of issues – however, the pressures they face are not unique; similar situations have arisen across most of the continent" (PMSEC 1996). Unfortunately, such artificial limitations do not recognise the pressing demands of northern Australia, where many novel water resource management issues exist, and little information is currently available. Ecological considerations in the development of new irrigation areas are just one example.

There has been a variety of research overseas which has tried to better integrate ecological considerations in agricultural production systems. The field of agro-ecology (Gliessman 1990, and others) is an example of one paradigm. Such approaches mostly focus upon the benefits to agricultural production by the re-introduction of trees into the landscape, their role in integrated pest management, nutrient management and energy budgets. Whilst these are all important and valuable considerations, the context for their use is generally in association with the rehabilitation of degraded agricultural landscapes to improve productivity. There are very few examples of the benefits of ecological planning as part of new developments or for non-production benefits – such as increasing biodiversity within a landscape dominated by a agricultural monoculture. An exception is the attempt by the Canadian government to implement a strategy for environmentally sustainable agriculture (Government of Canada 1997). The strategy explicitly seeks to integrate agriculture and biodiversity objectives through use of "agroecosystem biodiversity" planning and a program to manage landscape biodiversity.

In Australia, Breckwoldt (1996) edited the proceedings of conference which discussed approaches to bioregional planning, and in which a variety of industries (forestry, tourism, grazing, mining) were provided the opportunity to outline their respective views on how their operations integrate ecological planning and management. Whilst the irrigation industry was not represented, Saunders *et al.* (1996) did address the issue of bioregional planning in agricultural regions, using a dryland farming in Western Australia as a case study. Blackmore and Lawrence (1996) also discussed integrated catchment management, using the Murray Darling basin as a case study. Whilst these two case studies were useful discussions, they do not suggest a mechanism (or the information requirements) to allow for the incorporation of ecological planning in irrigation systems. However, Pressey (1996), whilst emphasising the need for further research, does provide a framework for the *in situ* protection of biodiversity in the context of bioregional planning. The framework outline is presented below.

1. Compile data on components of biodiversity
    - define regional boundaries
    - subdivide region into planning units to which will be allocated levels of classification and management
    - compile data on the biodiversity of each of the planning units

2. Assess threatening processes and their effects
    - assess the distribution of past, current and likely threatening processes in the region
    - identify the biodiversity attributes that have been affected by threatening processes or are vulnerable to them

3. Identify levels of management required and mechanisms available
    - identify levels of management required to control extractive or destructive land uses and other threatening processes
    - review the availability, security and effectiveness of existing mechanisms to implement levels of management

4. Set targets for levels of management
    - decide on the specific planning units that need specific forms of management or set targets for the areas or number of occurrences of each biodiversity attribute to receive each level of management
    - decide whether and how conservation management should be applied to discrete replicates
    - decide whether effective application of a management level requires a particular configuration of that level
    - decide whether effective application of a management level requires a particular spatial configuration relative to other levels

5. Select the specific planning units to which management levels will be applied
    - assess to what extent the goals for each level of management have already been achieved
    - identify optional planning units to achieve representation and replication targets
    - viability and manageability criteria for making choices
    - spatial criteria for making choices: relationships between planning units with the same levels of management
    - spatial criteria for making choices: relationships between planning units with complementary levels of management

6. Implement management levels
    - decide on the feasibility of applying to specific planning units each of the possible mechanisms for achieving each level of management
    - decide on the relative timing of application of management levels to specific planning units

7. Maintain attributes in planning units
    - assess and, if necessary, enhance political bureaucratic and financial security, and the support of local and regional residents
    - assess and, if necessary, enhance size, shape, connectedness, types of boundaries and buffer zones
    - manage units to retain biodiversity values within them and monitor results
    - manage units to adjust their influences on other units due to natural or anthropogenic influences.

This comprehensive approach to biodiversity planning at the regional scale is the type of framework required to allow for the integration of ecological planning as part of irrigation scheme development. A significant amount of research is required to provide the necessary information for the planning units and management measures; however, the planning principles are necessary if irrigation scheme development is to be considered at the catchment or bioregional level.

Visions for Irrigated Agriculture

Alexandra (1993) has proposed a national R&D strategy to facilitate the wider adoption of sustainable agriculture using innovative, low input and organic farming systems as a model. However, the proposed R&D did not specifically address the role of irrigation systems. Alexandra (1994) has promoted the role of trees in the sustainable management of irrigated land using the example of high water tables in Victorian irrigation regions. It was proposed that through mass revegetation, water tables could be reduced sufficiently to allow higher value land uses to be introduced. Unfortunately, the area required for revegetation was regarded as not economically viable.

A variety of workshops conferences have also been conducted to discuss visions of sustainable agriculture. For example, the Queensland Department of Primary Industries documented key visions agreed upon by a diverse groups of stakeholders (grain, livestock, cane, peanut, cotton, conservation and government representatives). The consensus was that the following eight scenarios were integral to a sustainable agricultural landscape:

- Well educated farmers/community/scientists/governments
- Profit in sustainable agriculture for producer and consumer
- Land capability assessment and use
- IPM for all pest/crop systems
- On and off-site degradation minimised
- An environment that allows farmers to practise sustainable agriculture: markets, tenure and legal and social environments
- Whole-farm planning within integrated catchment management
- Safe and healthy food

(DPI 1990)

However, the mechanisms required for implementation of each vision were not specified and there is little evidence of the impact of the workshop. More recently, the Queensland Departments of Primary Industries and Natural Resources convened a workshop to review the research, development and extension needs of the irrigation industry (QPI 1998). Again, the issue of sustainability underpinned much of the discussion and a key outcome was the need to better link information providers with users, either through the establishment of a network or a research centre. However, regardless of the mechanism used, the need to identify gaps in knowledge and to undertake the necessary research was paramount. The challenge remains to develop a best practice approach which can integrate the accumulated knowledge and ensure that it is efficiently disseminated to irrigators.

4.0 RECOMMENDATIONS

Key Themes

What are the fundamental principles in ecological planning for irrigation areas?

What elements of agriculture practice are ecologically sustainable?

The development of a "vision" for ecologically sustainable irrigated agriculture.

Key Issues in the Management of Irrigation Schemes

The following 8 points are the key habitat/conservation issues which are not adequately being addressed in the planning of new schemes or the refurbishment of existing schemes.

1. *The principles of wildlife corridor design for habitat connectivity and wildlife management.*

2. *The role of vegetation in the design and subsequent management of groundwater in new irrigation areas*

3. *The role of remnant vegetation in planning for Integrated Pest Management*

4. *The opportunities and limitations for organic farming in conventional broad-acre irrigation areas.*

5. *The required strategies for longterm ownership and management of reserves*

6. *Planning for the protection of significant species in fragmented agricultural landscapes.*

7. *The required water management design to limit downstream impacts*

8. *Principles in the identification and protection of wetland habitats within irrigation areas*

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APPENDIX 1.

Case Study: THE PRINCIPLES OF WILDLIFE CORRIDOR DESIGN FOR HABITAT CONNECTIVITY AND WILDLIFE MANAGEMENT

Introduction

The natural vegetation cover of every continent, except Antarctica, has been extensively modified (Saunders et. al. 1991). Australia has been no exception to this trend. Indeed no other continent has
been more severely affected by Europeans in as short a time as Australia (Adamson & Fox 1982, Recher 1994; Recher & Lim 1990). Of Australia's 1 600 species of terrestrial vertebrates, 26 species have gone extinct in the past 200 years and a further 300 species are of concern (Kennedy 1990; Recher 1990; Recher & Lim 1990). This pattern is similar for native plants where of 22 000 known species, 100 are presumed extinct and 3 300 are considered endangered, vulnerable, rare or threatened (Briggs & Leigh 1988). These figures are probably conservative given the volume of species which remain undiscovered, or simply 'lost' *i.e.* remaining unrecorded due to extinction. The figures would also become increasingly concerning when the status of Australian freshwater fish and invertebrates are also taken into account.

The loss and fragmentation of native habitats is one of the most serious environmental problems currently occurring throughout the world. Many consider habitat fragmentation as one of the most serious threats to biodiversity and the primary cause of the present extinction crisis (Noss 1987). Habitat fragmentation is the process whereby continuous areas of vegetation are subject to clearing, creating a series of remnant patches of vegetation. Resultant patches are generally surrounded by a matrix of habitat unlike that of the original (Lovejoy et. al. 1986; Primack 1993; Saunders *et. al.* 1991; Wilcove et. al. 1986).

Very few studies have been dedicated to the development of pro-active strategies which aim to conserve the biodiversity of virgin areas destined for fragmentation (Laurance & Gascon 1997). Although this paper in no way advocates further deforestation, it does aim to provide theoretical guidelines to assist managers in the pro-active design of responsible land clearance programs. In meeting this aim, it is hoped to minimise the impacts of fragmentation and maintain a biodiversity representative of a pre-fragmented landscape. In doing so, this paper will consider the baseline theories and models (Theory of Island Biogeography and Metapopulation Model) widely used by conservation biologists in designing nature reserves. Building from these seminal theories and more recent studies, the paper will then provide guidelines for the conservation of biodiversity in a fragmented landscape by addressing concepts such as the ideal size, shape and location of remnant patches as well as highlighting the importance and design of corridors. However, before one discusses the concepts of minimising the impacts of fragmentation, it would seem appropriate to firstly address the consequences and processes involved in habitat fragmentation.

Impacts of Fragmentation

One of the more obvious impacts of fragmentation is the loss of vast areas of native vegetation. However, the clearing and fragmentation of native habitat is not only destructive to the individual plant species, the ramifications of vegetation loss can have cascading effects on other species remaining in the disturbed forest patches. The time since isolation, the size of the remnant, distance between adjacent remnants, and the degree of connectivity between remnants are all important determinants of the biotic response to habitat fragmentation (Saunders *et. al.* 1991).

The impacts of fragmentation have been recognised worldwide with a number of studies being dedicated to remnant habitats and isolated nature reserves (*e.g.* Leck 1979; Lynch 1987; Lynch & Whigham 1984; Moore & Hooper 1975; Shreeve and Mason 1980; Opdam *et. al.* 1984; Soule *et al.* 1979). In Australia the effects of habitat fragmentation have been studied for birds (Howe 1984; Loyn 1987; Saunders & Hobbs 1989; Saunders & Ingram 1987; Serventy & Whittell 1976; Howe *et. al.* 1981; Kitchener *et al.* 1982;), mammals (Bennett 1987, 1990ab; Suckling 1982; Kitchener *et. al.* 1980a; Pahl *et. al.* 1988), and reptiles (Caughley & Gall 1985; Kitchener & Howe 1982; Kitchener *et. al.* 1980).

The three major consequences of habitat loss and resultant fragmentation include: (1) Changes to the number of species in fragments; (2) Changes to the composition of species assemblages; and (3) Changes to the ecological processes in fragments (Bennett 1990c). The following provides a brief outline of each consequence.

(1) Changes to the number of species in fragments

Isolation combined with a reduction in total habitat area results in a reduced number of species in a fragment relative to that of the original area. A significant relationship usually exists between the area of a fragment and the number of species present - with increasing area an increasing number of species (Bennett 1990). The species-area relationship has been discussed at length in the literature (*see e.g.* Preston 1962; Connor & McCoy 1979; MacArthur & Wilson 1967) and can be best explained in three ways:

> A larger area is likely to contain a greater sample of the original habitat and therefore also likely to contain a *greater sample of the original suite of species* than a smaller area of habitat;
>
> A larger area is capable of supporting a *larger population size* and therefore more species are likely to maintain a viable population; and
>
> With increasing area, there is usually a *greater diversity of habitats* for animals to occupy, and consequently the number of species reflects the diversity of habitats that are available.

Additional factors which can affect the number of species in a fragment include the spatial and temporal isolation of the remnant and the degree of disturbance (Loyn 1987; Askins *et. al.* 1987; Hobbs *et. al.* 1987).

(2) Changes to the composition of species assemblages

Different species respond in different ways to fragmentation. Consequently, fragmentation causes the relative composition of species assemblages to change. For example, a study conducted by Pahl *et. al.* (1988) on the responses of arboreal marsupials to fragmentation in north eastern Australia found that species diversity increased with the area of the patch. The study also found that individual species responded differently to a reduction in habitat. Two species (coppery brushtail possum and green ringtail possum) appeared to be unaffected by a reduction in total habitat area, whereas the Herbert River ringtail and Lumholtz tree kangaroo were found to only persist in some smaller patches. Furthermore, it was also concluded that the lemuroid ringtail possum had resource requirements (habitat and food) which were less available in small patches and was therefore unable to persist in smaller habitat patches (Pahl *et. al.* 1988).

Species that naturally occur at low population densities are usually the species most susceptible to habitat fragmentation (Diamond 1984). Species with low population densities usually become extinct from a fragment due to the remnant not being sufficiently large enough to support a viable population. These species tend to be large, high order species (*e.g.* large carnivores or herbivores), or species with specialised food or habitat requirements (Bennett 1990c).

(3) Changes to the ecological processes in fragments

Landscape Level

Fragmentation results in changes in the physical and chemical fluxes across the landscape, including fluxes of radiation, wind, water, and nutrients (Hobbs 1993; Saunders *et. al.* 1991; Hobbs 1992**-RFL??**). A fragmented landscape is subject to higher daytime and lower night-time temperatures than heavily vegetated land, exposing upper layers to a widened daily temperature range (Deeker 1993; Saunders *et. al.* 1991). This in turn can alter the performance of soil micro-organisms and the nutrient cycling processes they perform (Deeker 1993; Saunders *et. al.* 1991). The vegetation in remnants are also subject to increased exposure to wind, resulting in increased physical damage, increased evapotranspiration and desiccation (Saunders *et. al.* 1991). Changes to the hydrological regime have wide reaching effects, including changes to soil moisture levels and increased ground surface water flows. Elevated surface water flows can cause erosion and transportation of nutrients, while increased ground water can lead to water logging and secondary salinity (Hobbs 1993; Saunders *et. al.* 1991).

Invasion by non-native species is a further important consequence of fragmentation (Bennett 1990c; Deeker 1993; **Hobbs *et. al.* RFL**). The invasion by non-native species, combined with the loss of native species, can modify ecological process such as food chains, predator-prey interactions, plant-animal pollination and dispersal associations, and nutrient cycling pathways, because important elements of these processes can disappear (Bennett 1990c).

Patch Level - Edge Effects

The impacts of fragmentation on ecological processes are particularly significant on the edges of fragments. These impacts are often referred to as “edge effects”. Edge effects are most severe when the edge-to-area ratio is high. Therefore, edge effects are particularly prominent in small, irregular shaped and narrow patches of habitat. The impacts of edge effects can include:

> Changes in micro-climate such as solar radiation levels, incident light, humidity, temperature, and wind speed (Forman & Baudy 1984; Forman & Godron 1986);

Changes in the composition and structure of plant communities compared to interior species (Wales 1972; Ranney *et. al.* 1981);

Increase in edge specialists from surrounding disturbed habitats which can increase levels of predation, competition, and parasitism of interior species (Yahner 1988); and

An increased vulnerability/exposure to disturbance events from the adjacent matrix such as drift from fertilizers and chemicals, trampling and grazing by farm animals, escaped fires, weed invasion, access tracks and recreational disturbances (Bennett 1990c).

Design Theory

The underlying goal of nature reserves is the conservation of biodiversity. The two theories most commonly consulted in the design of nature reserves are the Theory of Island Biogeography and the Metapopulation Theory. The following outlines these theories and specific attributes (*e.g.* remnant patch size, shape) involved with reserve design.

Island Biogeography and Metapopulation Theory

Remnant forest patches are often viewed as islands in a sea of unfavourable habitat (*e.g.* Brown 1971; Diamond 1975, 1976; Wilcox 1980; Margules *et. al.* 1982; Whitcomb *et. al.* 1976**)**. This view led to the realisation that the dynamics of fauna in such patches could be interpreted in terms of MacArthur & Wilson's (1967) theory of island biogeography. The theory implies that the number of species occurring on an island tends towards an equilibrium, determined by a dynamic balance between the rates of colonisation and extinction of species (MacArthur & Wilson 1967). Colonisation is primarily determined by the degree of isolation from the mainland. While extinction is determined by the average population size, which itself is determined by the total area of the island (Caughley & Gun 1996).

The important influence of isolation on the predicted number of species a patch may contain, suggested that steps taken to reduce the degree of isolation would contribute to the conservation of the patch, by increasing the rate of colonisation (Bennett 1990). Therefore, the rate of decline of a species could potentially be reduced by connecting isolated patches with strips of habitat (or corridors) (Diamond 1975).

Metapopulation Concept

The metapopulation model is now replacing equilibrium island biogeography as the theoretical framework for understanding processes in fragmented habitats. The metapopulation model focuses on changes to populations of species, rather than on the number of species in an isolate (Bennett 1990c).

The metapopulation concept rose from the recognition that natural environments are never homogenous, but are comprised of areas of habitat that vary in suitability, to any one species, on both a temporal and spatial scale (Bennett 1990). Some species occur naturally in a number of small populations separated by areas of less suitable habitat. Small populations are particularly vulnerable to variations in population size, genetic change and environmental fluctuation, and local extinctions can be common. In a metapopulation several small patches function as a single demographic unit, and therefore interaction between patches is of great importance (Meriam 1991). Movement between patches allows recolonisation after a local extinction, or supplementation of a declining population.

Populations in a fragmented landscape have also been viewed as metapopulations, given that some interaction between remnants occurs (Bennett 1990). The ability to move between isolated populations is vital for the functioning of a metapopulation and steps to increase interaction will decrease the likelihood of extinction. The metapopulation concept is therefore reliant on the use of corridors to facilitate movement between patches, thus stabilising the system.

Concepts Of Design

What Size Should A Remnant Be

A large quantity of literature has been dedicated to the debate of whether species richness is best preserved by a single large nature reserve or several smaller ones of an equal area (Diamond 1975; Simberloff & Abele 1976, 1982; Terborgh & Winter 1980). This argument is known as the "SLOSS debate" (single large or several small). The proponents of large reserves argue that different species have different area requirements, and large fragments will often be the only refuge for species which exist at low densities (such as high order predators and herbivores) or for specialists whose requirements are only satisfied in large areas (Wilcove *et. al.* 1986). Also, a large reserve minimises edge effects, encompasses more species, and has greater habitat diversity than a small reserve (Primack 1993). It has also been argued that many species in a community only live in temporary habitats that are part of a successional stage. If any successional stage disappears, even temporarily, the species that depend on that stage will be lost, as will other species that depend on those species. Managing a reserve so that all successional stages are maintained at all times is a difficult process, probably impossible in small reserves (Deeker 1993).

The actual size of a remnant patch large enough to support large or high order species will be dependent on specific characteristics of the target species. For example, the area required to support a community of Western Australian macropodid marsupials was calculated to be 207 km^2 (Main & Yadav 1971). This figure is less by a factor of *ca* 40 than the figure represented by Diamond (1976) for minimal area requirements for many New Guinea lowland bird species.

Opposing the viewpoint of single large reserves, proponents of several small reserves argue that well-placed small reserves are able to include a greater variety of habitat types and more populations of rare species than one large block of the same area (J_rvinen 1979; Simberloff & Gotelli 1984). There is also evidence emerging that a collection of remnants may constitute a conservation network for species such as the kangaroos and some birds (Saunders & de Rebeira 1991; Arnold *et. al.* 1991). Furthermore, many scattered patches would be less susceptible to impacts of epidemic diseases or analogous disasters (*e.g.* fires) (Diamond & May 1976).

The general consensus on the optimal reserve size is that it is dependent upon the species under consideration. It is widely accepted that large areas are better able than small reserves to maintain many species because of their larger population sizes and greater variety of habitats and successional stages. However, small nature reserves combined with the judicious use of corridors also have value, particularly for the protection of many species of plants, invertebrates and small vertebrates. In reality, both small and large reserves have a role to play in the conservation of biodiversity (Primack 1993; Boeklen & Bell 1987; Margules & Stein 1989; Wilcove *et. al.* 1986).

What Shape

It is generally agreed that reserves should be as nearly circular in shape as practically possible (Diamond 1975; Diamond & May 1976; Wilson & Willis 1975). Such maximisation of the area-to-perimeter ratio minimises dispersal distances within the reserve, and avoids “peninsular effects” whereby dispersal rates to outlying parts of the reserve from more central parts may be so low as to perpetuate local extinctions, thus diminishing the reserve's effective area (Diamond & May 1976). Some authors have argued that long narrow reserves across an environmental gradient (*e.g.* isoclines of rainfall and altitude) would contain a greater number of habitats and therefore hold more species. However, the more habitats contained within a reserve, the smaller the area occupied by a given habitat and the fewer the number of associated species, thus greatly increasing the likelihood of a non-viable population size (Caughley & Gun 1996). Minimising the perimeter-to-edge ratio also reduces the impact of edge effects on a remnant.

Selecting Areas For Reserves

The goal of maintaining maximum biological diversity is implicit in the literature discussing the selection of areas for nature reserves (*e.g.* Abele 1976, 1982; Diamond 1975; Higgs 1981; Diamond & May 1981; Higgs & Usher 1980; Margules *et. al.* 1982; Margules *et. al.* 1988). A number of algorithms have been published for choosing the minimum reserve network that will capture a given percentage of species in a region (Pressey *et. al.* 1993). One set gives preference to rare species (Margules & Nicholls 1987; Pressey & Nicholls 1989a; Margules *et. al.* 1988) and another to areas containing many species (Kirkpatrick 1983; Kirkpatrick & Hardwood 1993; Scott *et. al.* 1988), but nonetheless they tend to end up with much the same selection (Pressey & Nicholls 1989b).

An alternative approach to selecting nature reserves is to use environments rather than populations, species, or communities as the unit of choice (Caughley & Gunn 1996). Using this approach, a network of sites is selected to include a given proportion of each environment, the rationale being that if all environments are selected, then most species will also (Belbin 1993). The end result is a habitat mosaic which is representative of the original landscape. However, detailed ecological studies of the area of concern would be required before any decisions on the selection sites could be made.

Corridors

A corridor can be defined as a naturally existing or restored native linear landscape feature that connects two or more larger tracts of essentially similar habitat and functions as either a movement route for individuals or an avenue for gene flow among native fauna and flora (Harris & Scheck 1991). Networks of corridors are increasingly promoted as key elements for the conservation of biodiversity and have received considerable attention in the literature (Bennett 1990; Harris 1984; Merriam

1984; Noss 1987; Fahrig & Merriam 1985; Forman & Baudry 1984; Noss & Harris 1986; Simberloff & Cox 1987; Wegner & Merriam 1979). It has been proposed that the dispersal of individuals along corridors would help gene flow between reserves, increase effective size of the component populations, and encourage metapopulation dynamics whereby a declining population in one reserve might be rescued by dispersal from another (Coates 1991; Dendy 1987; Hess 1994; Caughley & Gunn 1996; Inglis & Underwood 1992; Simberloff & Cox 1987; Simberloff *et. al.* 1992).

Although most authors acknowledge the principles of maintaining and establishing corridors, some disadvantage of corridors have also been highlighted. Possible disadvantages include facilitating the spread disease and fire, and increasing exposure to predation, unauthorised hunting, and competition with domestic animals (Simberloff & Cox 1987).

Design of Corridors

Their is limited information pertaining to the design of corridors, however, general principles can be obtained. The following provides a brief outline, mainly adapted from Bennett (1990c), of the general principles to consider when developing or designing corridors.

Corridor Width
The width of a corridor is a particularly important consideration in corridor design as it influences most aspects of corridor function. Maximising the width of corridors is one of the best methods of increasing the effectiveness of corridors (Bennett 1990c). Increasing corridor width incorporates a greater area and thus provides the opportunity for a greater diversity of habitats and greater abundance and diversity of species. Increased width can also make a corridor more suitable for those species which have greater spatial requirements or specialised feeding and habitat requirements, as well as decreasing edge effects. The optimal dimensions of a corridor are too difficult to define as it is dependent upon the objective of the corridor, the ecology and movements of the target species, and the structure of the landscape in which the corridor is located. However, as mentioned, corridors should be as wide as practically possible.

Structural Connectivity
Variables that can influence the structural connectivity of a corridor system include the presence, number and dimensions of gaps, the length of corridors, and the presence of nodes.

Corridor Gaps
Gaps in a corridor can severely interfere with the function and efficiency of a corridor. The level of impact from a gap is a function of the how different the gap habitat is to the original habitat, and the behaviour of the species concerned. Gaps in corridors should therefore be minimised. Features such as roads are common cause of gaps in a both corridors and between remnant patches (*e.g.* Mader 1984), and should accounted for in landscapes design.

Corridor Length
There are a number of ways corridor length can influence the effectiveness of a corridor. With increasing length there is a decreasing likelihood that the length of a

corridor will be traversed by an individual, and therefore increased reliance on self-sustaining populations in the corridor. Increased length also exposes animals to greater edge effects and greater vulnerability to predation and disturbance events that can cut the corridor.

Habitat Nodes
Incorporation of nodes (small patches) of habitat along the corridor can increase its effectiveness by providing additional habitats in which animals can pause during lengthy movements (*i.e.* act as stepping stones), or maintain a larger breeding population. The presence of habitat nodes also has some relevance to the SLOSS debate mentioned earlier. A network of small patches (or nodes) can assist in the maintenance of habitat mosaic representative of the pre-fragmented state.

Quality Of Habitat
The availability and reliability of essential resources (*e.g.* food, shelter) are critical if animals are to live in corridors and use them as pathways for movement. In the design of corridors it is best to maintain existing vegetation as opposed to creating habitat. This allows the original density, composition and age classes of resource species to be maintained in their pre-fragmented state. The designation of buffer areas surrounding the corridor may also be advantageous by assisting in the protection of sensitive interior species from the surrounding matrix of transformed habitat. This point is to some degree also relevant to the location of corridors (*see below*).

Location Of Corridors
Corridors should generally be located along natural environmental gradients to ensure continuity of habitats and therefore effective habitat size. However, corridors may sometimes be required to cross environmental gradients to link two different habitats *e.g.* upland and lowland forests. Positioning corridors in areas which are likely to have a protective buffer is also advantageous to the quality of the habitat in the corridor.

Conclusion
The impacts of fragmentation are clearly evident in the alarming rates of species decline witnessed in both this country and world wide. As well as there being a need to consolidate existing fragmented landscapes, it is equally, and in some senses more vital, that we learn from past mismanagement and adopt a more responsible approach to land management. The ability to pro-actively design the fragmentation pattern of a landscape destined for clearance is undoubtedly a more effective method of conserving biodiversity than trying to reactively consolidate an often “ecologically hopeless” situation.

Design Principles for the Maintenance of Biodiversity in a Fragmented Landscape

One of the foundation goals in any reserve network is the conservation of biodiversity. The following is a summary of the key principles to consider in maintaining biodiversity in a fragmented landscape:

> The preservation of a combination of interconnected large and small patches of remnant habitat

Sufficient areas of large habitat are necessary for the preservation of many of the larger and higher order species, as well as the maintenance of important ecosystem functions.

A number of smaller patches are necessary to help maintain pre-fragmentation habitat mosaics and thus increase pre-existing habitat representation.

All habitat remnants, regardless of size, should be designed so as to minimise edge-to-area ratios and therefore decrease the impact of edge effects.

A network of judiciously located corridors connecting habitat remnants, in combination with the strategic positioning habitat nodes (or stepping stones), will assist the reserve network in functioning as a single demographic unit by supplementing declining populations.

Corridors and remnant patches should ideally aim to include buffer areas in their design so as to reduce the impact of edge effects on interior species.

Detailed ecological studies are required to assist the decision making process of choosing the most effective location and management of reserve networks.

Conclusion

The impacts of fragmentation are clearly evident in the alarming rates of species decline witnessed in both this country and world wide. As well as there being a need to consolidate existing fragmented landscapes, it is equally, and in some senses more vital, that we learn from past mismanagement and adopt a more responsible approach to land management. The ability to pro-actively design the fragmentation pattern of a landscape destined for clearance is undoubtedly a more effective method of conserving biodiversity than trying to reactively consolidate an often "ecologically hopeless" situation.

One of the foundation goals in any reserve network is the conservation of biodiversity. In an area to be fragmented this is only possible through the preservation of a combination of interconnected large and small patches of remnant habitat. Sufficient areas of large habitat are necessary for the preservation of many of the larger and higher order species, as well as the maintenance of important ecosystem functions. A number of smaller patches are necessary to help maintain pre-fragmentation habitat mosaics and thus increase pre-existing habitat representation. All habitat remnants, regardless of size, should be designed so as to minimise edge-to-area ratios and therefore decrease the impact of edge effects. Additionally, a network of judiciously located corridors connecting habitat remnants, in combination with the strategic positioning habitat nodes (or stepping stones), will assist the reserve network in functioning as a single demographic unit by supplementing declining populations. Corridors and remnant patches should ideally aim to include buffer areas in their design so as to reduce the impact of edge effects on interior species. Detailed ecological studies are required to assist the decision making process of choosing the most effective location and management of reserve networks.

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APPENDIX 2. ENVIRONMENTAL ASSESSMENT CRITERIA

1.0 Introduction

Given the large spatial and temporal variability in water availability and accessibility, an ecological assessment process can best address any proposed water infrastructure development within the context of different biogeographic scales and units of management. This is achieved through considering such proposals at four distinct levels: national, bioregional, catchment and scheme. This allows for the application of agreed national policies and principles but also provides for the statutory obligations and responsibilities of States and local governments.

Generally, criteria and guidelines to steer any approval process should be based upon the best available information and result in a mechanism that can both direct and assist a proposal. However, ecological issues are often open to some interpretation, both by the proponent and the assessor. Essentially, many ecological paradigms are not indisputable, nor can they deliver instantly achievable outcomes. Often, established concepts such as 'a precautionary approach' and 'stewardship' underpin notions of environmental responsibility, and whereas these terms reflect community expectations and are explicit in government policy, they may not be attributable to individual actions or processes.

With this in mind, the following criteria place much emphasis upon established principles and accepted ecological theory, as well as formal policy and legislation. Proper application of the criteria requires stakeholders involved in assessment negotiations to uphold such principles throughout the process. Without this commitment to the assessment framework, it is difficult to foreshadow outcomes that are equitable and can justly provide for environmental needs.

The criteria have been derived from various documents (including the impact assessment guideline documents from the NSW Department of Urban Affairs and Planning) and are reflected in a range of national policies and principles.

2.0 Assessment Criteria

2.1 National Issues

The following criteria should serve as the starting point for the assessment of a proposed project and the proponent should provide formal evidence of the project's compatibility with these criteria.

Criteria

Would the implementation of the proposal:

- not foreclose on options for future generations with regard to the use of natural resources;
- use resources as efficiently as practicable given best available technology;
- not result in or present a significant risk of environmental damage that can only be repaired by future generations;
- not exceed the assimilative capacity of the environment;
- not lose or present a significant risk of loss of or change in natural resources including biodiversity and ecological integrity;
- result in no 'free' use of any aspects of the environment with an appropriate valuation of the resources to be used or affected by the proposal being fully costed and considered;
- result in the costs of any pollution or environmental degradation being internalised;
- result in the applicant being willing to pay the costs of compliance, compensation for non-compliance and a performance bond as guarantee;
- result in energy, water and other resources savings and the use of renewable sources being maximised;
- result in maximising recycling of material when it is resource efficient;
- result in maximising output from the proposal per unit energy input?

In making decisions about the proposal:

- Have worst case outcomes been considered in the estimates of environmental benefits and costs?
- Have risks to ecological integrity been identified? Have the scope and scale of risks been assessed? Are all risks considered acceptable?
- Has a risk averse approach been adopted? Has a safety margin been applied and best available technology used? Can performance bonds or other incentive mechanisms be applied?
- Is there scientific uncertainty about the outcomes? If certainty is low, are the potential impacts likely to be serious or irreversible?
- Are there information uncertainties about outcomes? If gaps appear, what is their legitimacy? (ie. Does information exist and applicant has ignored or not known about it, or is it really a gap in human knowledge?) Where knowledge does not exist has the worst-case scenario been considered?
- Have valuation methods been appropriately used in weighing up the costs and benefits? Has scarcity been appropriately factored into valuation and assessment of resources proposals? Have appropriate factors been considered when considering compensation for non-sustainable use of renewable resources or resource rents and royalties for the use of non-renewable resources?
- Can consent conditions provide for early-warning of environmental degradation?
- Does prospective water pricing reflect all the costs of supply and service (including environmental and eventual decommissioning costs) with all government subsidies or community service obligation payments made transparent?

- Have the proposed environmental requirements, wherever possible, been determined on the best scientific information available and do they have regard to the inter-temporal and inter-spatial water needs required to maintain the health and viability of river and wetland systems and groundwater basins?
- Are the prospective natural resource managers satisfied that the environmental requirements of the river system will be adequately met before any harvesting of the water resource occurs?
- Have the proposed environmental water provisions for ecosystems been based on the best scientific information available on the water regimes necessary to sustain the ecological values of water dependent ecosystems?
- Will the proposed environmental water provisions be legally recognised?
- In systems where there are existing water users, does the provision of water for ecosystems go as far as possible to meet the water regime necessary to sustain the ecological values of aquatic ecosystems whilst recognising the existing rights of other water users?
- Where environmental water requirements cannot be met due to existing water uses, are actions (including re-allocation) currently being taken to meet environmental needs?
- Would further allocation of water for any use only be on the basis that natural ecological processes and biodiversity are sustained (ie. ecological values are sustained)?
- Are the accountabilities in all aspects of management of environmental water provisions transparent and clearly defined?
- Are the proposed environmental water provisions responsive to monitoring and improvements in understanding of environmental water requirements?
- Will all proposed water uses be managed in a manner which recognises ecological values?
- Will all relevant environmental, social and economic stakeholders be involved in water allocation planning and decision-making on environmental water provisions?

2.2 Bioregional Issues

At this level, the assessment process seeks to establish criteria which can determine the potential impacts of the project at a scale consistent with an ecological framework that reflects the interests of the nation or multiple regions (eg. Great Barrier Reef Marine Park). Criteria generally relate to the potential of a project to trigger a response from the Commonwealth or authorities responsible for several jurisdictions (eg. Murray-Darling Basin Commission). However, the need to consider the bioregional context may equally apply to one or more States, and occasionally even to a single local government authority (eg. Cook Shire which is responsible for much of Cape York).

For example, water infrastructure proposals which seek to transfer or trade water across catchments, have a cumulative impact across catchments, impact upon areas of national interest (ie. World Heritage Areas, sites listed under international conventions, Commonwealth reserves, etc) or which trigger Commonwealth government legislation (eg. Endangered Species, Regional Forest Agreements, etc), will need to be assessed at the

bioregional scale. The proponent should provide formal evidence of the project's compatibility with these criteria.

Criteria

- Are there any areas within the study bioregion that are important for conservation? Has the extent these components are protected elsewhere and the extent they need protection been identified? Has there been consideration of whether they should be retained and whether they require repair?
- Are there landscape components that are inadequately understood (lack of data, lack of research)? Have components where a high level of risk exists because of natural or induced sensitivity (because of cumulative or other effects) been identified? Given the level of confidence in the environment resilience or impact predicability, will these components be put at risk if the project proceeds?
- Have the long term implications been considered in relation to future options for land use in the bioregion? Is any loss of future options acceptable?
- Have project alternatives been considered which minimise the disturbance of landscape components? Has an analysis of the need for an alternative site(s) or site layout to avoid disturbance been undertaken?
- Can biodiversity and ecological integrity be conserved? If not, can compensation be made?

2.3 Catchment Issues

At this level, the assessment process seeks to establish criteria that can determine the potential impacts of the project at a catchment scale. Criteria generally relate to the potential of a project to trigger a response from State or local governments and empowered community organisations (eg. Catchment Coordinating Committees).

For example, water infrastructure developments which are proposed in catchments with existing catchment management plans or water allocation management plans or which trigger relevant government legislation (eg. state environmental protection or planning policies, endangered species, etc), will need to be assessed at the catchment scale. The proponent should ideally provide formal evidence of the project's compatibility with these criteria.

Criteria

- Is the site located in an area of conservation value identified under relevant legislation or an environmental planning instrument including:
    - national park, historic sites or reserves for environmental protection (eg aquatic, nature, karsts);
    - other areas protected under relevant legislation, identified or declared wilderness areas,
    - zoned for environmental protection purposes eg. scenic or natural heritage values, wetlands?

- Are there any existing air quality problems? Is the development likely to contribute to this problem (eg. cane/trash burning)?
- Are the rainfall patterns, prevailing wind directions and topography in combination likely to result in microclimate conditions which could cause management difficulties (eg. managing aerial spray drift)?
- Will the location of the proposal result in significant impacts on downstream water users or environmental flow regimes?
- Are there any existing site constraints which make on-site water management difficult (including tailwater or storm water)? Does the site have adequate area and capacity for storage, treatment and disposal of waste water?
- Is the activity located so as to be likely to contribute to degradation of water quality of any natural waterbodies?
- Are there risks of surface water pollution due to proximity to natural waterbodies or wetlands, in particular water bodies used for drinking water supply or aquaculture downstream?
- Is the site within an identified drinking water catchment areas (surface or groundwater) eg. land mapped or nominated as “special or protected areas” by local supply authorities?
- Are there salinity risks due to shallow or rising water tables?
- Are there risks to groundwater due to the proximity to recharge areas or to areas classified as having a high vulnerably to pollution?
- Is the site subject to natural hazards such as flooding or storm inundation? Is it likely to cause management difficulties from erosion or inundation? Are there natural topographical characteristics that will assist in minimising impacts?
- Can any separation distances from waterbodies (under any relevant legislation or guidelines) be complied with?
- Are the soils highly erodable?
- Are the soils suitable for construction of ponds or dams or drainage systems? Are there any risks associated with the underlying strata? Are there risks of infiltration into groundwater because of highly permeable soils?
- If wastewater irrigation/disposal to land is proposed, are the soils suitable for the proposed disposal methods?
- Are there existing or potential soil problems (eg contaminated soils, acidity, sodicity or salinity)?
- Are there risks to native aquatic species (eg from blockage of passage, changes to water quality or environmental flows, spray drift) associated with the location of the facility?
- Can clearing native vegetation be avoided? Is a development application required under relevant State legislation?
- Can clearing of native vegetation of high significance be avoided? eg. vegetation used for visual screening, riparian vegetation, vegetation used as corridors for movement of fauna, vegetation communities containing threatened species, populations or ecological communities, or their habitats or land that is critical habitat?
- Are any threatened species under relevant fisheries legislation likely to be affected?
- Is the location likely to affect the health, feeding, breeding or migration activities of terrestrial or aquatic animals?
- Is the proposal likely to be compatible with surrounding existing or proposed land and water uses, or any sites of natural or environmental values?

- Are there likely to be problems with meeting sustained compliance with water, noise and air quality requirements because of the proximity of the proposal to nearby land uses?
- Implications of changed flow regime, temperature and land use on estuarine and marine systems [eg triggers to prawn movement etc]
- Is the proposal at this site likely to contribute to any existing cumulative environmental problems within the catchment? Does it consider the following:
  - existing or proposed irrigation activities in the area or region?
  - nearby activities with similar impacts (eg other aquaculture facilities, feedlots or sewage treatment works)?
  - advantages (such as service provision and specialisation), or disadvantages (such as cumulative impacts) of clustering similar projects in the area?
  - likely long-term and short-term cumulative impacts having regard to surface water and groundwater issues, soils issues, vegetation or fauna habitat?
  - the receiving environment's ability to achieve and maintain the objectives established for the river system or in any salt action or land and water management plan?

2.3 Scheme Issues

At this level, the assessment process seeks to establish criteria that can determine the potential impacts of the project at the scheme scale. Criteria generally relate to the potential of a project to trigger a response from local governments and empowered community organisations (eg. Catchment Coordinating Committees) but also from miscellaneous local organisations (eg. Landcare organisations).

For example, water infrastructure developments that are proposed in local government areas with existing development control plans, previously identified industrial/agricultural precincts, or which trigger relevant government legislation (eg. local government ordinances, planning policies), will need to be assessed at the scheme scale. Issues which are project specific or which are best managed at the scheme level are also best considered in this context. The proponent should provide formal evidence of the project's compatibility with these criteria.

Criteria

Project Sustainability

- Has a "whole of life-cycle" approach been adopted in the formulation of the objectives for the project?
- Have the ongoing implications of the operation of the proposal and the use and disposal of any products from the proposal been considered?
- Has rehabilitation or reuse of the site following decommissioning of the proposal been considered?
- What is the proposed water budget for the irrigation scheme during crop, seasonal and climatic cycles? Have off-site and on-site water sources and potential volumes been identified?

Water Management

- Is there provision for any reuse water sources including on-site surface or sub-surface drainage schemes and return runoff from the irrigation area; have temporary storage needs, management and use protocols been established?
- Has the quality of water from the proposed sources and the likely seasonal variation been established? If so, do the proposed parameters relate to the specific site requirements, the suitability of the water for specific irrigation uses, and any potential management issues in relation to the quality of the water?
- Has the method of transfer of water to the irrigation site (channels, drains, pipes etc) been identified; has the design, operation and maintenance of any existing or proposed, new or augmented system and procedures for the detection of leaks or seepage been described?
- Have storage weirs, dams or other structures (proposed or existing) to be included in the scheme and total storage capacity been described, including (for in-stream structures) proposals to allow fish passage?
- Have the management strategies for maintenance of quality of water in storages been outlined?
- Have proposed farm drainage plans (including surface and sub-surface drainage) been described? What is the relationship of the farm drainage to natural surface drainage, any on-site reuse scheme and its relationship to the irrigation network, any district drainage system? If so, has the disposal of the water to the district drainage system been justified?

Irrigation Management

- Have the proposed total irrigation areas (hectares) been identified? If relevant, have the existing area currently under irrigation or proposed new areas or any staged expansion into new areas been described?
- Have the proposed crop types to be irrigated (pasture, vegetables, rice, cotton, stock, woodlots, etc) been identified (as area per crop type)?
- Have the proposed management regime detailing rotations, harvesting and waste management cycles, and irrigation program been described?
- Have management and control systems including the method of water application, volume of water to be used and an estimate of timing of use been described?
- Have proposed irrigation scheduling and frequencies taking into consideration seasonal and soil differences; design parameters in terms of water balance taking into consideration crop characteristics, precipitation, evapotranspiration, percolation and surface runoff, been described?
- Have the proposed fertiliser or soil enhancement application regimes, design parameters and the proposed maximum nutrient loading rates been estimated?
- Have the proposed pesticide application regime program and control protocols to minimise application and impacts been estimated?
- Have methods of disposal of saline water, waste water or contaminated water including any evaporation basin systems been described?

- Have measures to minimise and recycle waste material associated with the harvest been described?
- Have measures to deal with the disposal of construction spoil or any solid waste material during the construction or operational phases been described?

Previous or Existing Irrigation Schemes

- Has any relationship of the proposal to any existing irrigation schemes on the site been described?
- Are the past irrigation areas, water usage rates (per annum for the last 3 years) and environmental performance of facilities known?
- If there are existing salinity problems, have areas (ha) which have been redeveloped over the last 10 years been identified?
- Does the proposal seek to integrate with the existing scheme? Are any alterations to the existing facilities to ensure compliance with current best practice or requirements for farm drainage, salinity management, vegetation or water quality management required?

Construction Program

- Are environmental controls proposed during the construction of:
    - any dams, weirs, evaporation ponds
    - any in-stream works
    - any bores, wells, spear points
    - any channels, drains, pipelines
    - any laser leveling or other land formation works (such as clearing, levees, bunds etc)
    - works to upgrade existing facilities?

Consideration of Alternatives and Justification for the Preferred Alternative

- Has an assessment been made of the environmental costs and benefits of adopting alternative options in the siting, design and operation of the scheme? This should include:
    - alternative water volumes, sources or balance of water from various sources including reuse
    - alternative irrigation site locations
    - alternative storage locations
    - alternative design or layout options
    - alternative cropping (pasture, field crops, woodlots etc)
    - alternative irrigation management practices
    - alternative end uses of the land post-irrigation scheme.

Planning Context, Site Description and Locality Information

- Have local council, zoning and permissibility of irrigation schemes and associated facilities been obtained?
- Is there compatibility with planning provisions and land use constraints including:

- easements, covenants or other restrictions affecting the site, including heritage or environmental protection provisions or conservation agreements
- existing land and water use on the site or in the vicinity of the site
- relevant provisions of any existing strategy including:

- government policies, such as those for floodplain or wetland management
- state environmental planning policies, regional or local environmental plans, or development control plans;
- relevant land or water management plans or approved farm plans
- catchment plans, regional or resource strategies for the area
- Has a site description and maps, plans or aerial photographs to clearly identify the location of the proposal been prepared? Particularly, in relation to:
    - drainage or river systems, existing dams, weirs, pump sites or bores and other water users in the locality
    - natural features and principal vegetation communities likely to be affected by the proposal
    - activities in the vicinity which may affect the proposal or, along with the proposal may generate cumulative impacts (eg which may contribute to salinity) or may be affected by the proposal.

Overview of the Affected Environment

- Has an overview of the environment been provided in order to place the proposal in its local and regional environmental context?
- If a land and water management or catchment plan has been prepared for the region, has reference been made to the information included in this document?
- Has the following general information been provided as an overview of the proposal?
    - geomorphological factors such as major landform features, site contours, terrain stability, slope gradient and length
    - meteorological characteristics which may influence flooding, erosion, evaporation and the management of dust or water quality impacts - these may include wind direction and intensity, rainfall intensity, frequency, duration and seasonal distribution
    - drainage patterns, evidence of historical changes associated with the drainage system; the use and vulnerability of water bodies likely to be affected by the proposal; if relevant, general hydrological and water quality characteristics including flow characteristics; flood liability of the site and surrounding land
    - the use and vulnerability of ground water, if relevant, general hydrological and water quality characteristics; evidence of historical changes associated with the groundwater depth in the area
    - general soil characteristics - identify any existing soil problems including salinity, acidity, sodicity and highly erodable; the capability and suitability of the site for agricultural purposes
    - predominant vegetation communities, and their potential habitat and conservation values.

Overview of the Methodology

- Has a review of relevant information sources been undertaken? Potential issues and sources should include:
  - any relevant Land and Water Management Plans or farm management plan
  - any environmental guidelines produced by State government authorities; other States and overseas guidelines or standards; any industry guidelines or Codes of Practice
  - EISs for similar projects, any relevant commission of inquiry reports, determination reports and conditions of approval
  - relevant research and reference material
  - relevant strategic plans or policies
  - preliminary studies

Surface Water Issues

Does the proposal :

- provide a description and location of any natural water bodies (such as rivers, creeks, stream lakes, anabranches, swamps, lagoons, billabongs, lakes etc), wetlands or drainage lines in the vicinity of the project or associated with the project? If relevant, does it outline:
- physical characteristics including width and depth of the water bodies or wetlands, details of the bed and bank material, bed and bank slope?
- bed, bank and riparian zone vegetation, any snags, any algal blooms; seasonal variation, identify any proposed vegetated buffer zones on or near water bodies or wetlands including details of location, width, length and species?
- environmental flows, flooding patterns and water levels in the natural water bodies such as how often or what flow level occurs during storm events and flooding, how often the water body dries or ceases to flow?
- provide a description of the water quality of any natural water body or wetlands likely to be affected by the proposal (including justification for selected parameters)?
- consider the adequacy of the supply security and any on-site storage facilities to deal with seasonal fluctuations in supply and requirements? If relevant, does it consider:
  - the need to upgrade or augment any water storage or reticulation systems?
  - the affect of the project on other users (immediate vicinity and down stream)?
- assess the efficiency of water use, considering:
  - the efficiency of water delivery systems?
  - any cropping, scheduling and application protocols and monitoring programs?
  - any laser levelling and drainage networks?
  - any recycling or reuse schemes and any storage facilities?
- assess the potential impacts on water bodies or wetlands from the proposed water usage rates and method of extraction, drainage networks or in- or off-stream storage facilities during various climatic and environmental flow regimes? If relevant, does it assess the impacts considering:

  - environmental flows in water body sources? If involving unregulated waterways, does it estimate the current percentage of flow to be diverted to the facility as well as the percentage required to meet future needs?
  - bed or bank erosion?
  - groundwater reserves?
  - other users of the water body or wetlands?
  - aquatic ecological systems?
- consider issues in relation to the seasonal and long term water quality? Does it assess the adequacy of the design and management measures to minimise water quality impacts, including:
  - minimising use and runoff of nutrients or chemicals?
  - on-site management of waste, contaminated or saline water?
  - erosion and sedimentation controls?
  - containment and treatment of any algal bloom in the storage facilities?
  - maintenance of adequate environmental flows?
  - maintenance of vegetated riparian buffer zone?

Groundwater Issues

Does the proposal:

- outline the overlying geology, depth, quantity and quality of groundwater (including justification for selected parameters)?
- raise the issue of potentially rising ground waters?
- describe any rate of rise (if known) and location of monitoring bores or piezometers? Is reference made to any land and water management plan or groundwater survey for the area or site?
- assess the potential for the irrigation scheme to contribute to the rising of groundwater levels?
- outline any proposed sub-surface drainage, location of spearpoints or tube wells, pumping capacity and the proposed method of disposal of the water? If a disposal basin is proposed, does the proposal identify the site, the volume capacity, design characteristics and the likely effectiveness?
- outline any additional mitigation measure in relation to the design and management of the irrigation, drainage and storage system or vegetation management?
- consider the potential effect of the proposed usage rate or sub-surface drainage measures on existing and future users of groundwater in the area as well as any related wetlands?
- assess the adequacy of proposed measures to ensure no contamination of the groundwater from the use of fertilisers or chemical sprays?

Flooding Issues

Does the proposal:

- consider the impact of any works to collect and store flood flows on flooding downstream and environmental flows?

Soil Issues

Does the proposal:

- consider the general soil type of the storage and irrigation areas (eg. sand, loam, clay, rocky)?
- consider soil or subsoil profile characteristics which may affect the viability of the irrigation scheme, such as: depth of profiles, soil drainage, aeration, nutrient uptake, surface sealing, nutrient deficiencies, existing soil salinity or contamination, permeability?
- consider soil texture - including water holding capacity?
- consider the depth of top soil and the depth to clay layer?
- the potential impacts on the soil characteristics in response to management regimes taking into consideration the soil type, water characteristics, chemical use, crops and rotation regimes? Changes may relate to nutrient balances, salinity, chemical contaminants, sodium adsorption ratios, organic loadings, etc.
- identify any potential salinity problem on the site? Reference should be made to any land and water management plan or groundwater survey for the area and any existing soil salinity survey for the site. If salinity is a potential or existing issue, has any existing or proposed farm management plan to control the problem been identified?
- identify the potential for soil erosion given the proposed land formation works and the climate, topography, soil characteristics and proposed management of off-site and on-site surface water?

Air Issues

Does the proposal:

- identify potential sources of dust (ploughed paddocks, soil stock piles, dam/levee walls etc)? Has an assessment been made of the potential for soil loss from wind erosion?
- identify periods when climatic conditions will increase the likelihood of dust generation?
- identify protocols to minimise wind erosions including wind breaks, paddock layout and management, ploughing methods and timing, ground cover?
- outline proposed use of chemicals, their method of application and chemical characteristics including toxicity?
- assess the potential for drift from any chemical spraying?
- describe proximity to sensitive receivers and identify meteorological conditions under which receivers are likely to be affected (including the frequency of exposure)?
- assess the potential impact on receivers?
- assess the adequacy of measures to mitigate impacts including spraying protocols, alternative management regimes, buffer zones, etc?

Fauna and Flora Issues

Does the proposal:

- identify existing vegetation types (using accepted protocols) and the general condition of the site or in the vicinity?

- identify current or likely weed or feral infestations, over grazing, dieback or other existing problems?
- identify the area to be cleared, disturbed or indirectly affected by the proposal, for example by changing the surface or sub-surface drainage patterns or environmental flows?
- describe the dominant vegetation species, populations and communities in areas that may be affected by the proposal? Does it indicate the extent and condition of the vegetation within the area and surrounding it, including any significant largely unmodified or semi natural flora or fauna habitat eg wetlands, riparian areas, remnant vegetation? Does it indicate the local and regional scarcity of these habitats, ecological communities, populations and species?
- if relevant, identify any of the following from existing records and if relevant, indicate their incidence on the site:
  - threatened species, populations or ecological communities listed in relevant legislation?
  - rare plant species listed in relevant legislation?
  - areas protected under environmental planning instruments?
  - fish or vegetation protected under relevant fisheries legislation or listed as threatened by the Australian Society of Fish Biologists? An indication of the economic significance of any potentially affected species should be included.
- assess the potential impacts of the proposal on numbers and distribution of species, populations or ecological communities or their habitats (including aquatic species if relevant)? Does it consider the sensitivity of species, populations or communities to disturbance and potential impacts of disturbance on biodiversity?
- assess the impact of any construction in any watercourse including the hindrance of passage of water or aquatic species? Does it assess the adequacy of controlled releases, bank and bed restoration works or devices such as fish ladders in mitigating the impacts?
- assess the impacts on any migratory birds?
- outline any revegetation or rehabilitation proposals and their role in mitigation of impacts such as rehabilitation with indigenous species? Is there potential for recolonisation by fauna (terrestrial and aquatic if relevant) following rehabilitation or provision of new appropriate habitat? Has the timing of major disturbances been considered?
- identify existing weed or feral problems in the district or on the site? Does it assess the potential for the proposal to contribute to or reduce the problem or consider the adequacy of any proposed management strategies to mitigate any potential problem?
- propose monitoring to determine effectiveness of mitigation and to verify predictions?

Mitigation Measures

Does the mitigation strategy for the proposal:

- contain environmental management principles which would be followed when planning, designing, constructing and operating the proposal, including locational, layout, design or technology features?

- contain an outline of an environmental management plan (EMP) which provides a framework for the ongoing management and monitoring of potentially significant impacts? Does the proposed EMP address the following:
- management of construction impacts
- management of operational impacts; if relevant include:
- management of water as a resource
- management of the irrigation systems including crop and soil management
- management of salinity
- protection of surface and subsurface water quality
- soil erosion and sedimentation controls
- protection of heritage and biodiversity
- management of chemicals used on the site
- emergency procedures
- strategies to feedback information from the monitoring program into the management practices and action plans to improve the environmental performance and sustainability of all components of the scheme
- training programs for operational staff and incentives for environmentally sound performance
- indication of how compliance with licensing and approval requirements will be achieved and due diligence attained
- if applicable, reporting mechanism on environmental performance and performance bond and relevant performance parameters?

Monitoring Outline

Does the proposal include a monitoring framework, and if so, does it include:

- performance indicators in relation to critical operational issues including:
- environmental flows and water quality in affected water bodies
- salinity and groundwater
- evidence of ponding, erosion or any other soil degradation
- if relevant, quantity and quality of any water releases to waterbodies or wetlands
- if relevant, change of any surrounding bushland or wetlands vegetation;
- monitoring of complaints received?

The proposed program outline should also describe the following monitoring details:

- the key information that will be monitored, their criteria and the reasons for doing so (which may be compliance with regulatory requirements)
- the monitoring locations, intervals and duration
- procedures to be undertaken if the monitoring indicates a non-compliance or abnormality
- internal reporting and link to management practices and action plans
- reporting procedures to relevant authorities and, if appropriate to the consent authority and the community.