NORTHERN AUSTRALIA IRRIGATION FUTURES

Providing new knowledge, tools and processes to support debate and decision making regarding irrigation in northern Australia

National Program for Sustainable Irrigation

CDS23 – FINAL TECHNICAL REPORT

December 2007

Copyright and Disclaimer

Important Disclaimer:

---

[1] The Project Partners are: CSIRO, Land and Water Australia, National Program for Sustainable Irrigation, CRC for Irrigation Futures, and the Governments of Australia, Queensland, Northern Territory and Western Australia.

EXECUTIVE SUMMARY

Northern Australia holds an iconic status for many Australians. The interplay between the landscapes, rivers, groundwater and strongly monsoonal weather patterns has resulted in unique and diverse ecological systems that will need special attention to ensure that their integrity is retained if any changes are made to the system. At the same time, with some 60 to 70 per cent of Australia's fresh water discharging from tropical rivers, the region faces significant environmental challenges associated with increasing pressure to develop land and water resources, catchments and coastal environments, as well as managing existing threats, including weeds, pests, feral animals and fire.

There is a unique and historic opportunity to ensure that management and use of Australia's northern land and water resources takes place within a strategic, ecologically, culturally and economically sustainable framework. Deciding on whether to expand irrigation in northern Australia, and if so what irrigation should look like, where it should be located, and how it should be managed, requires improved understanding of groundwater, river and catchment attributes and of the risks and benefits associated with irrigation.

The Northern Australia Irrigation Futures (NAIF) project was established in 2003, with initial funding through Land and Water Australia's National Program for Sustainable Irrigation (NPSI) and CSIRO to address the above issues. In doing so NAIF has worked closely with the WA, NT, QLD and Australian governments and a range of other researchers and stakeholders to learn lessons from the history and current state of irrigation in northern Australia, to improve understanding of the hydrology of the north, to examine the pros and cons of irrigation mosaics (patchworks of irrigation) as an alternative to more traditional methods, and to develop frameworks that support government and community decision makers.

This report is the Final Technical Report for the NPSI CDS23 project and summarises the key science reports and papers from the NAIF project. For each of the reports and papers it provides a short summary, conclusions and knowledge assets, recommendations, and a few references as suggestions for further reading. The reports and papers themselves are appendices to this report. This Final Technical Report is part of and should be read in conjunction with the NPSI CDS23 Final Report, which contains a synthesised view of all the NAIF work carried out to date and a summary of the key take home messages.

List of Acronyms

BHWSS	Burdekin-Haughton Water Supply Scheme
CRC IF	Cooperative Research Centre for Irrigation Futures
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ERA	Ecological Risk Assessment
ESD	Ecologically Sustainable Development
FRDC	Fisheries Research and Development Corporation
GBR	Great Barrier Reef
ISAF	Irrigation Sustainability Assessment Framework
KDDA	Katherine-Douglas-Daly Area
LB	Lower Burdekin
LBKP	Lower Burdekin Knowledge Platform
LBWF	Lower Burdekin Water Futures Group
LWA	Land and Water Australia
NAIF	Northern Australian Irrigation Futures
NPSI	National Program for Sustainable Irrigation
NRW	Department of Natural Resources and Water
NT	Northern Territory
ORIA	Ord River Irrigation Area
QLD	Queensland
SC	Steering Committee
SI	Sustainability Indicators
SN	Stakeholder Network
SRG	Stakeholder Reference Group
TBL	Triple-bottom-line
WA	Western Australia

Table of Contents

NORTHERN AUSTRALIA IRRIGATION FUTURES

LWA / NPSI FINAL TECHNICAL REPORT

1 Land & Water Australia Reference: CDS23

2 Principal Investigator and Other Project Leaders

Principal Investigator	**Joint Project Leader**
Dr Keith L. Bristow CSIRO Land and Water PMB Aitkenvale Townsville QLD 4814 Phone: 07 4753 8596 Mobile: 0408 468 941 Email: Keith.Bristow@csiro.au	Jeff Camkin CSIRO Land and Water Locked Bag 5 Wembley WA 6913 Phone: 08 9333 6398 Mobile: 0409 082 341 Email: Jeff.Camkin@csiro.au

3 Project Partners and Collaborators

The NAIF Project Partners include:
- Land and Water Australia (LWA)
- National Program for Sustainable Irrigation (NPSI)
- CRC for Irrigation Futures (CRC IF)
- Australian Government
- Queensland Government
- Northern Territory Government
- Western Australian Government
- CSIRO.

Most of the Project Partners are represented on the NAIF Steering Committee (SC).

Collaborators
Collaboration with a wide range of organisations and individuals is a feature of the NAIF project through the SC, Stakeholder Reference Group (SRG), Stakeholder Network (SN) and other project activities.

4 Project Title

Northern Australia Irrigation Futures - *providing new knowledge, tools and processes to support debate and decision making regarding irrigation in northern Australia.*

5 Date Final Technical Report Prepared

31 October 2007.

6 Reporting Structure

This report is the Final Technical Report for the NPSI CDS23 project and summarises the key science reports from the NAIF project. The science reports themselves are appendices to this report. This Final Technical Report is part of and should be read in conjunction with the NPSI CDS23 Final Report to Land and Water Australia. The structure for the NPSI CDS23 Final Report is attached (Appendix 1). The NAIF publications list is attached in Appendix 2.

7 Project Objectives

The final objectives of the NAIF project were:

1. To delineate key landscape attributes (including soil & water resources, climate, vegetation, rivers, near shore marine environments, and where appropriate links to people, industries, markets) relevant to ecologically sustainable irrigation across northern Australia

2. To use key landscape attributes to develop sustainability indicators and associated management criteria covering a range of scales (field, farm, district, irrigation scheme, catchment) for northern Australia

3. To develop an overall framework that, through their involvement, is embraced by policy makers, regulators, investors and managers, to help ensure any irrigation is managed in a consistent, ecologically sustainable manner in northern Australia

4. To use a number of linked case studies and stakeholder input to support and inform development and testing of the framework

5. Through provision of a robust framework, contribute tools and knowledge to support considered debate, decision making and long term strategic planning for northern Australia and Australia as a whole.

8 Reports on the Context for Irrigation in Northern Australia

In addition to the reports discussed in this section, a template to help develop a report on existing irrigation has been distributed to the WA, NT and QLD governments as a means of providing an overview of irrigation across northern Australia.

8.1 Analysis of the Lower Burdekin, Ord and Katherine-Douglas-Daly Irrigation Areas: Implications to future design and management of tropical irrigation

Correct Citation
Petheram, C., Tickell, S., O'Gara, F., Smith, A., Bristow, K.L. & P. Jolly. 2007. Analysis of the Lower Burdekin, Ord and Katherine-Douglas-Daly Irrigation Areas: Implications to future design and management of tropical irrigation. CSIRO Land and Water Science Report No.??/07, CRC for Irrigation Futures Technical Report No. 04/07 xx pp.

Key Words
Tropical irrigation – northern Australia – Hydrology - Ord River – Daly River – Lower Burdekin – Northern Australian Irrigation Futures

Summary
There is increasing pressure for development and use of the water resources of northern Australia for irrigation. Decisions on whether to irrigate, where it should be located, and how it should be designed and managed require sound understanding of river and catchment attributes and the risks and benefits associated with irrigation.

This study examines three well known but different irrigation areas in northern Australia and draws out key 'learnings' of relevance to existing and future irrigation in the north. The three areas are the Lower Burdekin (LB), Ord River Irrigation Area (ORIA), and Katherine-Douglas-Daly-Area (KDDA).

Conclusions / Knowledge Assets
Large carry-over storages on the Burdekin and Ord Rivers have substantially modified the flow regimes of these rivers. Flow regulation and irrigation tail water drainage have resulted in morphological and ecological changes to downstream river reaches and riparian and aquatic ecosystems in both schemes. The concerns now being expressed over the environmental impacts of irrigation in these regions in part reflect changes in understanding and community values.

The ORIA was designed as a flow through system, while tail water in the lower Burdekin (particularly the Burdekin-Haughton Water Supply Scheme, BHWSS) was until recently largely discharged by natural drainage lines. Irrigation tail water can transport salts, nutrients and agro-pollutants from irrigated fields. These parameters can result in ecological change, highlighting the need to account for water quality in the management and modification of existing and design of future irrigation systems, especially in light of changed community values.

Assessing the extent of change in river morphology and ecology has been hampered by a lack of base-line information prior to the development, despite recommendations that such information should be collected.

In the BHWSS and the ORIA, water tables are rising in several 'districts' because of poor water efficiency and inadequate deep drainage management. Secondary salinity is also being observed in some areas. This appears to have resulted from a low importance placed upon hydrogeology in planning these schemes. Relative to studies of soil, land capability and tail water drainage infrastructure, few hydrogeological investigations were made.

The LB and ORIA highlight the need for site specific hydrogeological assessment and that the quantity of water should not be the only parameter of interest. Timing of release and water quality should be considered equally, especially in areas where water quality plays a large role in ecosystem function.

Experience in the ORIA and KDDA suggests extrapolating data from other regions is often unreliable. Crops and farming systems need to be evaluated at specific locations to assess true yield potential and risks, and to determine appropriate management practices before these are applied on a large commercial scale.

The ORIA experience is that unexpected problems can occur when scaling up operations. It is inevitable that some unforeseen issues will occur with new irrigation developments. Ongoing monitoring is required and management systems need to be flexible and responsive to ensure problems are addressed in a timely manner.

Recommendations

Recommendations identified through this study include:

- a different approach to irrigation development is required to that of the past
- irrigation planning should consider learning's from past experience and data available from the north, as well as ideas modified from southern Australia
- early identification and rectification of unwanted problems requires vigilant monitoring of systems and performance
- careful design and management of irrigation drainage water is critical to the success of irrigation in the north, just as it is in any other part of the world
- if irrigation is to be sustainable in the north, expansion of existing and development of new irrigated areas must include sub-surface drainage unless the local hydrogeological investigations show clear evidence to the contrary
- need to better account for water quality and the timing of releases and return flows in the design of drainage for existing and future irrigation systems
- it is essential that baseline information be collected in future irrigation developments in the north prior to irrigation development or expansions
- the scope for new high value trees is an area that warrants further study.

Further Reading

A full list of references is provided in the Report. From that list, the authors suggest the following further reading as a starting point:

Fleming PM, Gunn RH, Reece AM and Mc Alpine JR (1981) Burdekin Project Ecological Study. CSIRO and Department of National Development and Energy. Australian Government Publishing Service. Canberra 1981.

O'Boy CA, Tickell SJ, Yesertener C, Commander DP, Jolly P, Laws AT (2001) Hydrogeology of the Ord River Irrigation Area. Water and Rivers Commission. Hydrogeological Record Series Report HG 7 2001.

Tickell SJ (2002) Groundwater resources of the Oolloo dolostone. Department of Infrastructure Planning and Environment. Natural Resources Division. Report 17/2002.

Woinarski J, Dawson F (1997) Limitless lands and limited knowledge: coping with uncertainty and ignorance in northern Australia. In *Ecology, Uncertainty and Policy: managing ecosystems for sustainability*. (eds.) Norton, T.W., Handmer, J.W. & Dovers, S.R. Cambridge University Press, Cambridge.

Wood IM (1985) Katherine Research Station. Chapter 3 in 'The Northern Challenge. A history of CSIRO crop research in northern Australia' (Eds. J Basinski, I Wood, J Hacker). Published by CSIRO Division of Tropical Crops and Pastures.

8.2 A guide to institutional, legislative and policy frameworks relevant to irrigation and water management in northern Australia

Correct citation

Hegarty et al. 2007. A guide to institutional, legislative and policy frameworks relevant to irrigation and water management in northern Australia. CSIRO Land and Water Science Report No.??/07, CRC for Irrigation Futures Technical Report No. 05/07 xx pp.

Key Words

Irrigation and water management – governance - Northern Australia Irrigation Futures

Summary

Decisions about irrigation and subsequent management practices do not take place in a vacuum: they are influenced by a wide range of legislative, policy, institutional, customary and other social structures in operation at the time. These influences, referred to as control structures, operate at the international, national, state/territory, local government and other levels to constrain, control and guide what can be done and place requirements as to what must be done. The control structures influence, and are influenced by, visioning, planning and assessment, monitoring and reporting processes and other processes. They are different to the physical structures (eg weirs, dams etc) that control water level and flows.

This report presents a range of current international, national and state/territory control structures relevant to irrigation and water management in northern Australia. There are also numerous and differing approaches to environmental and water legislation on the local level but it is not possible to capture all of them in this document. For this reason this document focuses only on the international, national, state and territory levels. Where possible, the information contained in this guide is drawn directly from the organisation, generally through the relevant website.

The role of this document is to provide a snapshot of the current institutional, legislative and policy frameworks affecting northern Australia's water resources management and development. Recognising that control structures are constantly changing, a second report (Hegarty et al., 2007b) presents a prototype of a tool which could be used to identify the control structures which exist for a given jurisdiction at a particular point in time.

Conclusions / Knowledge assets

There are four levels of frameworks affecting environmental and water legislation in Australia; the international level, the national level, the state and territory level and the local level. The four tiered framework is constantly evolving.

Key findings from the review of control structures are:

- An understanding of the control structures relevant to a particular location is important to those managing current irrigation systems and to those proposing irrigation developments, to stakeholders with an interest in the proposals and to decision-makers
- Control structures are not static, they change frequently. Any attempt to comprehensively document the full complement of control structures is likely to be challenging and products will be out of date very quickly

- Control structures differ widely between jurisdictions
- Mechanisms to support proponent, stakeholder and community understanding of the contemporary control structures relevant to their area of interest are an important part of a sustainability framework.

Recommendations

This document should be read in conjunction with 'A Hotlink Directory to Northern Australia's Irrigation and Water Management Institutional, Legislative and Policy Frameworks', a tool which links to updated information.

8.3 A hotlink directory to northern Australia's irrigation and water management institutional, legislative and policy frameworks

Correct Citation
Hegarty et al. 2007. A hotlink directory to northern Australia's irrigation and water management institutional, legislative and policy frameworks. CSIRO Land and Water Science Report No.??/07, CRC for Irrigation Futures Technical Report No. 06/07 xx pp.

Key Words
Irrigation and water management – governance - Northern Australia Irrigation Futures

Summary
Decisions about irrigation and subsequent management practices do not take place in a vacuum: they are influenced by a wide range of legislative, policy, institutional, customary and other social structures in operation at the time. These influences, referred to as control structures, operate at the international, national, state/territory, local government and other levels to constrain and control what can be done and place requirements as to what must be done. The control structures influence, and are influenced by, visioning, planning and assessment, monitoring and reporting processes and other processes.

Hegarty et all (2007a) presented a snapshot of international, national and state/territory control structures relevant to irrigation and water management in northern Australia. Recognising that control structures are constantly changing, this report provides a prototype of a tool which could be used to identify the control structures which exist for a given jurisdiction at a particular point in time.

This report contains a set of hotlinks, allowing the user to navigate to websites of the institutions and mechanisms that control or influence irrigation and water management in northern Australia. The links are categorised into three levels:

1) International level
2) National level
3) State / territory level.

Each of these levels is divided into sections that allow you to navigate through the relevant government agencies, government policies and initiatives, water and environmental legislation and organisations that control water in northern Australia.

A brief overview of water arrangements in Australia and common trends emerging in irrigation and water management in northern Australia is outlined.

9 Reports on Northern Australia's Water Systems

9.1 *Towards an understanding of the hydrological factors, constraints and opportunities for irrigation in northern Australia: A Review*

Correct Citation
Petheram, C and K.L. Bristow. 2007. Towards an understanding of the hydrological factors, constraints and opportunities for irrigation in northern Australia: A review. CSIRO Land and Water Science Report No.??/07, CRC for Irrigation Futures Technical Report No. 07/07 xx pp.

Key words
Hydrology – irrigation - northern Australia - Northern Australia Irrigation Futures

Summary
There is growing interest in developing the water resources of northern Australia for irrigation. This trend is partly being fuelled by widespread perceptions of abundant water resources in northern Australia, perceptions of declining rainfall trends, and recognition that some water resources in the southern states are over allocated. This study presents an overview of the landscape of northern Australia with respect to soil and water resources, with special emphasis on attributes relevant to irrigation. The purpose of this report is to address community perceptions and misconceptions about northern Australia, highlight key issues, constraints and opportunities for irrigation in the north and to provide a broad knowledge base that will enable all stakeholders the opportunity to partake in debate over irrigation in northern Australia. Particular emphasis has been placed on illustrating the differences between water systems in northern Australia and those found in temperate southern Australia; to which most Australians are familiar. The report sets the context for understanding the distribution of water and soil resources across northern Australia by examining the broad scale geological history and the evolution of key landscape features of the region. It discusses the climatic processes that drive precipitation and evaporation. Key aspects of the terrestrial water balance and resulting regional scale streamflow observations are examined, and the challenges posed by a highly seasonal water balance and the connectivity between surface and groundwater systems and the time lags associated with lateral groundwater flow are discussed.

Conclusions / Knowledge Assets

Geology and geomorphology

- Because Australia has experienced relatively little glaciation or volcanism, many of the landscapes of the north are very old and with prolonged erosion have become relatively flat.

Soils

- Australian soils have been exposed to a variety of climates over geological time scales, resulting in a complex pattern of highly weathered soils generally low in nutrients. While difficult to make north-south regional scale distinctions, it has been noted that soils in large parts of southern Australia have been extensively modified through cultivation and application of fertilisers.

Climate

- Rainfall across northern Australia is considerably more seasonal than that of southern Australia. The prevalence of cyclonic depressions as rain generating mechanisms means that many regions across the north are characterised by a high inter-annual variability in rainfall. Northern Australia has some of the highest daily rainfall intensities in the world and potential evaporation is much greater in northern Australian than in the south.

Hydrology

- Sixty (60) to 70% of Australia's runoff occurs in the north. Climate is the primary driver controlling the seasonality of streamflow at the regional scale and most externally draining rivers in the north tend to be ephemeral. The very few perennial rivers that do exist have strong connections to groundwater systems and are fed by them.

Ecological dependence on water

- The few groundwater fed perennial river systems support unique natural ecosystems dependent upon the quantity and quality of flow in the dry season

Irrigation in northern Australia

- High evaporation rates in northern Australia, intermittent streamflow and very low relief suggest it is seldom viable to build storages that are able to reliably supply water through the dry season

Other considerations

- The north offers a number of opportunities, including the opportunity to plan proactively and not be reactive to problems and failures

Recommendations

Protecting unique aspects of tropical environments will present new challenges to sustainable irrigation. Aspects of irrigation design needing attention include:

- Salt and drainage management in regions of large seasonal watertable fluctuations
- Social, economic and biophysical costs and benefits of irrigation mosaics
- Aquifer Enhanced Recharge within an irrigation context in a highly seasonal tropical environment
- Management of tail water in highly ephemeral systems
- The potential for water harvesting in the wet-dry tropics of northern Australia.

Further Reading

A full list of references is provided in the Report. From that list, the author suggests the following further reading as a starting point:

Allen, A.D. (1997). Groundwater the strategic resource. A geological perspective of groundwater occurrence and importance in Western Australia. Geological Survey of Western Australia.

Flannery, T.F. (1994). The future eaters – an ecological history of the Australasian lands and people. Reed Books: Port Melbourne.

Horn, A.M. (1995). Surface water resources of Cape York Peninsula. Cape York Peninsula Land Use Strategy, Office of the Co-ordinator General and the Department of Primary Industries, Government of Queensland, Brisbane and the Department of Environment, Sport and Territories, Canberra

Horn, A.M., Derrington, E.A., Herbert, G.A., Lait, R.W. and Hillier, J.R. (1995). Groundwater resources of Cape York Peninsular. Cape York Peninsula Land Use Strategy. Office of the Co-ordinator General, Brisbane, Department of Environment, Sport and Territories, Canberra, Queensland Department of Primary Industries, and Australian Geological Survey Organisation, Mareeba.

Petheram C, McMahon TA, Peel MC (2007). Flow characteristics of rivers in northern Australia: implications for development. Journal of Hydrology (submitted)

9.2 Assessment of the practicality and benefits of developing a groundwater flow classification system for irrigation in northern Australia

Correct Citation

Bristow, K.L. and C. Petheram. 2007. Assessment of the practicality and benefits of developing a groundwater flow classification system for irrigation in northern Australia. Report to the NAIF Steering Committee.

Key words

Groundwater flow – classification system – Northern Australia Irrigation Futures

Summary

The NAIF project is drawing on past experience of irrigation to develop new knowledge of groundwater systems and irrigation mosaics to build understanding of risks and benefits associated with irrigation, and of the key landscape attributes critical to sustainable irrigation in northern Australia. An emphasis has been placed on groundwater because irrigation typically causes groundwater imbalances (in terms of quantity and quality), and groundwater is often a key conduit for the transport of solutes and the cause of many of the externalities associated with irrigation.

The potential benefits of a groundwater classification system were identified in Stage 1 of the NAIF project (2003-2004). While this issue is not a major component of NAIF, the SC did request advice and recommendations on the practicality and benefits of developing such a system. This report summarises the understanding of attitudes to and potential benefits of developing a groundwater classification system.

This work found that a groundwater flow classification system may be a useful management and communication tool for those responsible for water, irrigation and catchment planning and management. Because resources to make on-site assessments of proposals may be limited, some form of framework to guide initial evaluation and decision-making may also be of considerable benefit. A classification system may help deal with the emerging interest in irrigation mosaics in northern Australia.

Conclusions / Knowledge assets

Irrigation has been practiced for many centuries now but we are not aware of any groundwater classification systems specific to irrigation. One reason may be that there are usually large resources associated with major irrigation developments and, typically, considerable investment in identifying potentially suitable areas, including water availability and water quality characteristics, which could reduce the need for a classification system.

Assessment of hydrogeological conditions are normally included in studies investigating suitable areas for irrigation but, given the problems associated with many irrigation systems around Australia and internationally, perhaps insufficient attention has been given to the studies and/or the resulting hydrogeological information during the planning, design, approval and early management phases. The question remains as to whether different, potentially more successful, approaches would have been taken if suitable groundwater classification systems were available.

Most State based groundwater maps already have much more detail than is likely to ever be captured in any groundwater classification system. Our research has also shown that most State/Territory based hydrologists seem much more interested in increasing the level of detailed understanding of groundwater systems rather than investing energy in developing classification systems that are unlikely to contain sufficient detail for highly managed irrigation systems.

Groundwater classification systems may, however, be a useful management and communication tool for those responsible for water, irrigation and catchment planning and management. This has yet to be fully tested as most discussions about groundwater classification systems for irrigation in northern Australia have, to date, largely been with hydrologists.

There is growing interest in irrigation mosaics, involving smaller patches of irrigation distributed across the landscape, as an alternative to large contiguous areas of irrigation in northern Australia. The ability for highly trained Government and consultant hydrogeologists to make on-ground assessments for every small area of irrigation may be limited. If this is the case, some form of classification system to guide initial evaluation and decision-making may be of considerable benefit.

Recommendations

NAIF is completing a review of the hydrological features and associated groundwater systems of the three key irrigation areas across northern Australia (Ord, Katherine-Douglas-Daly-Area and Lower Burdekin). The lessons that emerge from this review serve as further background to future discussions and decisions regarding the potential benefits of a groundwater classification system for irrigation purposes.

Further Reading

A list of web sources and links is provided in the Report. From that list, the authors suggest the following as a starting point:

Catchment Classification (A groundwater flow systems framework for salinity management)
Home Page: http://www.ndsp.gov.au/catchclass/index.html

GW flow system classification:
http://www.ndsp.gov.au/catchclass/whatisf/gwclass.htm

EU Water Framework Directive
Home page: http://ec.europa.eu/environment/water/water-framework/index_en.html

WA Aquaculture Groundwater Resource Atlas
Home Page: http://www.fish.wa.gov.au/docs/pub/AquaGroundWater/index.php?00

International Groundwater Resources Assessment Centre
Home page: http://www.igrac.nl/

Connected Water Systems (managing linkages between surface water and Groundwater)
Home page: http://www.connectedwater.gov.au/

9.3 *Managing on-farm and regional water and salt balances in Mona Park*

Correct citation
Petheram, C., Charlesworth, P.B. and K.L. Bristow. 2006. Managing on-farm and regional water and salt balances in Mona Park. CSIRO Land and Water Technical Report No. 23/06, July 2006. 50 pp.

Key Words
Irrigation – water and salt balance – Mona Park – Northern Australia Irrigation Futures

Summary
Since the establishment of the Burdekin Haughton Water Supply Scheme in 1987, some observation bores in the Mona Park district have experienced rapidly rising groundwater levels and rising salt concentrations. It was anticipated that diffuse deep drainage and channel leakage were the dominant processes driving the rise in watertables.

A field and desktop study was conducted to build understanding of the processes driving these trends. The objectives of this study were to: (1) ascertain the causes of rising water tables and salinity levels in the Mona Park area; (2) identify management strategies that meet required water table and salinity targets; and (3) investigate appropriate incentive and support mechanisms that allow transition from the current situation to a more sustainable system.

Qualitative analysis of groundwater trends in the Mona Park region suggest that under current management practices, groundwater levels in Mona Park will rise further during future wet periods. Because of a reduction in specific yield and the confining nature of the material in the upper aquifer it is likely that unless groundwater levels fall further, future responses to increased recharge are likely to be rapid and large.

There is a need to know the likely impacts of the above options on the biophysical system before proceeding with work on incentive and support mechanisms to underpin longer term sustainability of Mona Park as a profitable and sustainable irrigation district. Recommendations for further work are provided in the report.

Conclusions
High levels of diffuse deep drainage and channel leakage appear to be the main factors leading to rising groundwater levels in Mona Park. Without access to information on surface water usage and channel flow it is difficult to partition the relative contribution of each of these processes and hence to quantify the likely impact of alternative management scenarios.

The prominent mound in Mona Park in early 2000 is thought to be a result of the groundwater system changing behaviour to that of a confined system as the watertable reached the confining clay layer in the very wet period of 2000. Groundwater levels in Mona Park have since fallen somewhat but exhibit large seasonal fluctuations due to increased groundwater pumping and an apparent reduction in the effective porosity (i.e. specific yield) of the upper aquifer material.

A well calibrated groundwater flow model is needed to help further analyse the groundwater system and the likely response to future wet or dry periods and changes in management practise. The groundwater model initiated as part of this study could not be calibrated or further developed because key data were not available to allow this to happen.

There is potential to reduce diffuse deep drainage in the Mona Park region. This will require review of and if need be implementation of improved strategies for management of gypsum in the area and improved irrigation practices. This could involve: a reduction in field lengths; more efficient delivery systems (e.g. overhead or trickle irrigation); improved irrigation scheduling to meet crop water requirements and improved conjunctive water use rules (need to meet water table and water quality targets for irrigation).

Other options for managing groundwater levels could involve dewatering arrays. This would require access to and application of a robust groundwater model to carry out analysis of the effectiveness of various options and if it was not possible to re-cycle this water, approval for the disposal of water of various qualities into the river system would need to be sought.

Recommendations

Based on analysis and findings of this study we provide the following recommendations (in no particular order):

- Conduct a geochemical investigation to identify source of salts and their pathways of movement
- Continue deep drainage measurements using lysimeters to gain further understanding of the root zone water balance
- Investigate the benefits of reduced furrow lengths and more efficient delivery systems
- Investigate channel leakage
- Investigate rising groundwater levels in the Mulgrave region
- Investigate options for disposal of saline groundwater
- Resolve issues associated with accessing data
- Re-visit the Digital Elevation Model for the Lower Burdekin
- Instrument representative bores in the Burdekin Haughton Water Supply Scheme with data loggers to capture data at a finer resolution than that currently available through the NRW database
- Capture data from shallow observation bores installed as part of this study in the NRW groundwater database.

Further Reading

A full list of references is provided in the Report. From that list, the authors suggest the following further reading as a starting point:

Petheram C, Charlesworth PB, Bristow (2004b) Managing on-farm and regional water and salt balances in Mona Park. Milestone 2. CSIRO Land and Water Client Report.

Shaw, R. (1988) Predicted deep drainage loss under dryland and irrigation managements for Burdekin soils. In Soils of the Burdekin River Irrigation Area. Workshop Proceedings Ayr, August 1988.

SKM (1993) Environmental review of the Burdekin River Irrigation Area. Volume 1.

10 Reports on Irrigation Mosaics

10.1 Review of the current understanding of irrigation mosaics

Correct Citation

Paydar, Z., Cook, F.J., Xevei, E. and K.L. Bristow. 2007 Review of the current understanding of irrigation mosaics. CSIRO Land and Water Science Report No. 40/07, CRC for Irrigation Futures Technical Report No. 08/07. 31 pp.

Key Words

Irrigation mosaics – sustainable irrigation - Northern Australia Irrigation Futures

Summary

Irrigation mosaics, involving smaller discrete patches of irrigated land dispersed across the landscape, may offer an alternative to traditional large-scale contiguous irrigation systems. Existing knowledge on irrigation mosaics and implications within the context of sustainable development is very limited. However, there are some findings and lessons learned from studies of other systems, dealing with spatial patterns in the landscape, which can be used to help improve analysis and understanding of irrigation mosaics.

It appears that irrigation mosaics could have both negative (higher evapotranspiration, increased operational losses) and positive (reduced water-table height, reduced water-table spread, reduced solute spread, improved filtering of surplus nutrients, reduced erosion) effects on the environment. These potential impacts need to be studied carefully, and design criteria in terms of size, shape, density, connectivity and spatial arrangement in harmony with the landscape need to be established.

This document provides an overview of existing knowledge and current biophysical understanding of systems with natural spatial patterns in the landscape. It provides a framework for further study on irrigation mosaics and its environmental impacts in the future. In particular, there exists the need to study the effect of patch number, size and connectivity on evapotranspiration rate from irrigated land in a mosaic set up, fate of solutes, recharge to groundwater and the surrounding land, salinisation, groundwater quality, system losses and biodiversity.

Conclusions / Knowledge Assets

From ecological research we can see that patch size, shape and spatial arrangement are important characteristics in landscape analysis. They affect processes, patterns and organisms in different ways. To measure these landscape attributes several indices are available. Some simple indices exist to describe attributes such as area, perimeter and patch shape.

Ecotones, which are zones of transition between adjacent ecological systems, are important characteristics of mosaics and play an important role in energy and material fluxes. Irrigation mosaics could be used to create or enhance ecotones in the landscape for greater biodiversity, improving microclimate, preventing erosion, and in absorption of surplus nutrients flowing from irrigated lands. On the other hand, fragmentation, which is discontinuity of patches, can be detrimental for biodiversity.

Effect of advection on enhancing evapotranspiration and water use in irrigated mosaics seems to point to an approximately 10% increase (compared to larger irrigation schemes) which might not be a desired feature in northern tropical Australia, particularly in the dry season when one would want to irrigate.

The size of irrigation units has some implication in terms of system losses in transporting water. For example, the obvious engineering economies of scale and potentially lower unit costs result in cost-effective provision of infrastructure and services in large irrigation schemes as well as encouraging more government support and being easier to organize. On the other hand, smaller schemes give greater opportunity to farmers to participate in planning and management of the system; they are better adapted to supplying local markets, and they incur smaller risk of adverse environmental and social impacts, such as displacement of settlements or disruption of wildlife habitats.

Recommendations

Ecological and hydrological research has provided tools for studying landscape spatial patterns but careful study and adaptation of these to irrigation mosaics will be required, particularly for northern tropical Australia.

Multiple capture wells have been used to prevent contamination of surface and groundwater systems and the design criteria for these may be useful in assessing the spacing of irrigation mosaics. Geostatistical methods used in precision farming may be useful in analysis of where to site irrigation in the landscape. Numerical models that are designed specifically for analysing mosaics are scarce. However, existing process based numerical models could be adapted and applied to mosaics because they have the capability to overlay map layers of soil, land use and weather and other spatial information suitable for analysing mosaics.

In particular, there exists the need to study the effect of patch number, size and connectivity on evapotranspiration rate from irrigated land in a mosaic set up, fate of solutes, recharge to groundwater and the surrounding land, salinisation, groundwater quality, system losses and biodiversity.

Further Reading

A full list of references is provided in the Report. From that list, the author suggests the following further reading as a starting point:

FAO Technical Paper No. 11-1996. Guidelines for Planning Irrigation and Drainage Investment Projects. FAO Investment Centre Technical Papers, 184 pp

Farina, Almo 1998, Principles and Methods in Landscape Ecology, Towards a Science of the Landscape. Landscape Series, Vol. 3

Nilsson and Grelsson, G 1995, ‘The fragility of ecosystems: a review’, *Journal of Applied Ecology*, Vol. 32, pp. 677-692.

Noordwijk, MV, Poulsen, JG and Ericksen PJ 2004, ‘Quantifying off-site effects of land use change: filters, flows and fallacies’, *Agriculture, Ecosystems & Environment*, Vol. 104(1), pp. 19-34.

Petheram, C and Bristow, K.L. 2007. Towards an understanding of the hydrological factors, constraints and opportunities for irrigation in northern Australia: A review. CSIRO Land and Water Science Report No. ??/07, CRC for Irrigation Futures Technical Report No. 07/07 xx pp.

10.2 Analysis of biophysical processes with regard to advantages and disadvantages of irrigation mosaics

Correct Citation

Cook, F.J., Xevi, E., Knight, J.H., Paydar, Z. & K.L. Bristow. 2007. Analysis of biophysical processes with regard to advantages and disadvantages of irrigation mosaics. CSIRO Land and Water Science Report No.??/07, CRC for Irrigation Futures Technical Report No. 09/07 63 pp.

Key Words

Irrigation mosaics – sustainable irrigation– groundwater mounds – waterlogging – salinity - Northern Australia Irrigation Futures.

Summary

Irrigation mosaics are irrigation schemes in which small patches of irrigation occur within a region rather than irrigation of one contiguous area. This report investigates methods for analysing irrigation mosaics in terms of their biophysical effects and impacts compared with a large contiguous area of irrigation.

A range of new analytical and numerical solutions and programs which considerably reduce computation time were developed. These will be useful in analysing spatial and temporal issues associated with irrigation mosaics.

To estimate the effect of irrigation size and impact a scaling method was developed which calculates the marginal impact of mosaics compared to one large contiguous area. It showed that only one parameter is required to determine whether irrigation mosaics will result in positive, neutral or negative effects on the environment for a particular property of the irrigation system, compared with one contiguous irrigation scheme of equal area. Numerical solutions were also used and these show the same basic results as for the analytical solutions, and are able to deal with more realistic site specific issues than analytical methods.

This report shows that the case for and against irrigation mosaics is one where the weight of evidence is supportive on biophysical grounds. However, further research is required on the biophysical, ecological, social and economic advantages and disadvantages of irrigation and recommendations are provided.

Conclusions / Knowledge Assets

This report presents the results of the development and application of a range of existing and new methods for analysing irrigation mosaics. Numerical results show similar effects to analytical solutions but are able to include more realistic field conditions in the analyses, such as periodicity in the recharge. These show the same basic features with a rise in water table height with time, and depending on the spacing, suggest mosaics can result in lower water table rise. Numerical results can allow for heterogeneity that is not easily included in analytical results. The analytical solutions can be used to quickly assess possible mosaic arrangements and then more detailed can be carried out using the numerical methods. This combination of methods should provide an efficient means of obtaining useful information for designing and assessing irrigation mosaics and other proposals.

Some key results from this work are:

- water table rise under an irrigation patch is strongly dependent on the size (radius) of the patch
- in an idealised system water table rise is linear with time until the system starts to come into an approximate steady-state with the surrounding area
- numerical solutions of more realistic field conditions show that the water table rises more slowly and exhibits more periodicity than it would with steady-state recharge, but that the same inevitable rise in water table height can occur
- radius impacted by solutes increases as the radius of the patch increases
- isolated patches may evaporate more water to the atmosphere due to advective effects caused by heat coming from surrounding dry areas
- as more patches are added into the landscape it is likely that the evaporation rate will approach that of a contiguous irrigated area
- it is likely that the amount of advection will increase as both the patch size and number of patches decreases but further research is required.

Recommendations

There is a need for further research and development of:

1. periodic solutions to provide a means to investigate the periodicity of Northern Australian climate on the results
2. analytical solutions for periodic recharge of ground water
3. solute transport using particle tracing methods
4. finite arrays of mosaics
5. effect of advection on evaporation rate as effected by size and number of irrigated patches
6. water balance and irrigation requirements of sites throughout northern Australia.

Further Reading

A full list of references is provided in the Report. From that list, the author suggests the following further reading as a starting point:

Cook F.J., Jayawardane N.S., Rassam D.W., Christen E.W., Hornbuckle J.W., Stirzaker R.J., Bristow K.L. and Biswas T.K., 2007. The state of measuring, diagnosing, ameliorating and managing solute effects in irrigated systems. *Cooperative Research Centre for Irrigation Futures, Technical Report No*. 04/06, 47p.

England, H.N., 1963. Problems of irrigated areas. *In* Water Resources and Land Use, Melbourne University Press, 399-418.

Knight J.H., Gilfedder M. and Walker G.R., 2002. Impact of irrigation and dryland development on groundwater discharge to rivers: A unit response approach to cumulative impacts analysis. *CSIRO Land and Water, Technical Report*, 3/02, 16 p.

Pearce F., 2006. When the rivers run dry: water – defining crisis of the twenty-first century. Beacon Press books, 324p.

11 Reports on the Development of an Overall (Sustainability) Framework for Irrigation Decision-Making

11.1 Indicator frameworks for assessing irrigation sustainability

Correct Citation
Kellett, B., Bristow, K.L. and P.B. Charlesworth. 2005. Indicator Frameworks for Assessing Irrigation Sustainability. CSIRO Land and Water Technical Report No. 01/05. 52 pp.

Key Words
Sustainability indicators – indicator frameworks – irrigation sustainability – ecological risk assessment – sustainability framework – Northern Australia Irrigation Futures

Summary
This report summarises knowledge of sustainability, indicators, and particularly sustainability indicator frameworks.

The functions required for indicators to assess irrigation systems are introduced and discussed, criteria to analyse sustainability indicators proposed, and nine sustainability indicator frameworks analysed. Sustainability and sustainability indicators are introduced and discussed.

Recommendations are made on the role of sustainability indicators and sustainability indicator frameworks in the NAIF sustainability framework.

Conclusions / Knowledge Assets
To assess the sustainability of an irrigation system, sustainability indicators (SIs) must have the following desirable functions:

- Gauge sustainability of system elements (social, cultural, economic, environmental, institutional)
- Gauge sustainability of system attributes (e.g. groundwater, crops) and processes (e.g. deep drainage, cultivation) that make system elements and
- Gauge sustainability at a range of spatial scales (field, farm, district, scheme, and catchment).

How sustainability indicators are structured and related in a framework determines the possible uses of a sustainability indicator framework. The reports proposes criteria to analyse sustainability indicator frameworks:

- Identifies system attributes and distinguishes them from sustainability indicators
- Identifies system processes and distinguishes them from sustainability indicators
- Identifies sustainability indicators that gauge system processes and different aspects of each attribute
- Structures sustainability indicators according to spatial scales
- Identifies system capacity by proposing threshold values for system attribute and process sustainability indicators
- Illustrates balance between states of sustainability indicators.

Nine natural resource sustainability indicator frameworks are analysed. Each sustainability indicator framework is described, its use explained, and tested against the criteria listed above. Benefits and shortcomings of sustainability indicator frameworks are presented. Eight key criteria for assessing the usefulness of sustainability indicators frameworks are developed:

1. Incorporates or allows the incorporation of threshold values
2. Illustrates balance between states of sustainability indicators
3. Identifies specific relationships between sustainability indicators
4. Uses hierarchy to promote systemic thinking and assist in sustainability indicator selection
5. Can be used to review systems at a range of spatial scales
6. Facilitates participatory research
7. Integrates scientific and experiential knowledge
8. Simulates and tests planning and management scenarios.

Bayesian Belief Networks satisfy seven of the eight assessment criteria. A Bayesian Belief Network is a conceptual representation of a system that links indicators with arrows that represent the flow of cause and effect.

The AMOEBA satisfies six of the eight assessment criteria. The AMOEBA is a sustainability presentation tool that displays sustainability indicators around a sustainability zone 'ring'.

Recommendations

To progress development of the NAIF Sustainability Framework, the following recommendations are made:

1. Adopt the AMOEBA SI Framework to accomplish the following: facilitation of SI development; facilitation of threshold setting; presentation of sustainability assessments; and facilitation of stakeholders' understandings of sustainability
2. Adopt Bayesian Belief Networks to simulate and test planning and management scenarios.

Further Reading

A full list of references is provided in the Report. From that list, the author suggests the following further reading as a starting point:

Bell, S. & Morse, S. 1999. Sustainability Indicators – Measuring the immeasurable., earthscan Publications Limited, London.

Cain, J., Batchelor, C., Waughray, D. 1999. Belief Networks: A framework for the participatory development of natural resource management strategies. Environment, development and Sustainability. Vol. 1. pp. 123-133.

Rennings, K., Wiggering, H. 1997. Steps towards indicators of sustainable development: linking economic and ecological concepts. Ecological Economics. Vol.20. pp.25-36.

Ten Brink, B.J.E., Hosper, S.H., Coljin, F. 1991. A Quantitative Method for Description and Assessment of Ecosystems: The AMOEBA Approach. Marine Pollution Bulletin. Vol.23. pp.265-270.

Walker, J. & Reuter, D.J. 1996. Indicators of catchment health – A technical perspective. CSIRO Publishing.

11.2 *Ecological risk assessment of wetlands of the lower Burdekin*

Correct Citation
Kellett, B.M., Walshe, T. and K.L Bristow. 2005. Ecological Risk Assessment of the Wetlands of the Lower Burdekin. CSIRO Land and Water Technical Report No. 26/05. 30 pp.

Key Words
Ecological risk assessment – Lower Burdekin – Northern Australia Irrigation Futures.

Summary
An Ecological Risk Assessment (ERA) was conducted for wetlands of the Lower Burdekin involving a broad range of stakeholders. The workshop was to progress development of the Sustainability Framework for the NAIF Project and to scope the potential for using the Ecological Risk Management Framework (Hart et al, 2005). The study sought to use ERA to test: (i) stakeholders perspectives on the degree to which the wetlands of the Lower Burdekin protect the Great Barrier Reef (GBR); and (ii) the compatibility of two wetland values: habitat for plants and animals, and a buffer to protect the reef. An underlying objective was to use ERA to understand how differences in ecological values for a particular environment influence the selection of management alternatives.

The problem formulation stage of the ERA workshop did not accept and use stakeholders' social and economic values. In doing this, ecological protection appeared to take priority over other social and economic matters. As a result stakeholders, particularly from the irrigation sector, expressed distrust in the process. Workshop observations suggest that the irrigation sector saw the ERA as a threat.

Four recommendations for conducting ERA were made – the first two are consistent with existing literature, while the second two suggest a change to the process.

Conclusions / Knowledge Assets
There is much dialogue in natural resource management about the value of wetlands for habitat for a range of plants and animals and about their capacity to filter sediment, nutrients and pesticides. We thought that a one day ERA workshop would allow us to test aspects of the claim that the Lower Burdekin wetlands are important because they "protect" the reef. We were unable to investigate stakeholders' thoughts on the degree to which the wetlands protect the reef, but we did gain some insights into stakeholders' various positions on this concept. The workshop also provided an opportunity to use ERA to assess the compatibility of ecological values. To identify the implications of value compatibility for management alternative selection, we planned to use risk analysis to compare the magnitude of risks to wetlands under two management regimes (i) to protect and enhance habitat and (ii) to protect and enhance buffering capacity. We envisaged that this exercise would demonstrate risk analysis as a mechanism for trading ecological values.

The workshop revealed that stakeholders like to contribute their social and economic values to the process, but the problem formulation stage of ERA doesn't provide an avenue to accept and use them. By rejecting social and economic values early in the process, ERA can appear disconnected with reality and untrustworthy.

Some stakeholders, particularly land and water managers, expressed concern about the necessity of defining and using endpoints for risk assessment. This conflict may represent the opposing ideologies of the scientist and the manager. The scientist has a tool to reduce the system to something measurable and definable, such as an endpoint. However, the manager's intuition gives preference to an upfront consideration of a wider system, which is a complex combination of 'endpoints' and relationships. The significance of the opposing ideologies may lie with the issue of credibility. Any management recommendation that arises from a single point risk assessment has little credibility for those who manage for more than just a particular endpoint. Community on the other hand, do want to know the performance of management in terms of ecological protection, so identifying endpoints by which this performance can be measured does have benefits.

The results of semi-quantitative risk analysis can reflect the political preferences of stakeholders. It is very easy, in the absence of conclusive evidence, for stakeholders to ascribe high risk to activities in which they have little understanding and/or no involvement. It also seems that the semi-quantitative risk analysis method can provide a 'window of opportunity' for politically driven and/or vested interest risk quantification. This suggests that ERA must aim to engage a full range of stakeholders to achieve more transparent risk analyses.

The workshop was attended by collections of individuals who may not necessarily represent samples of society. Stakeholders expressed concerns about this issue. These issues are common for research projects and excuses are often raised, including limited time and budgets. The problem is more complex than this. It's also about the researchers knowing who the stakeholders are, the preferences of the researchers in selecting the level of stakeholder engagement and which stakeholders to invite, stakeholders' capacity to be involved or attend workshops, and the stakeholders' perceived benefits of attending or perceived costs of not attending.

Recommendations

The report makes four recommendations for conducting ERA. The first two are consistent with existing literature; the second two suggest a change to the process:

- project teams should not pre-determine focus hazards (e.g. irrigation tail water) prior to conducting participatory problem formulation
- stakeholders should continue to be involved with identifying hazards, but through the development of conceptual models. Semi-quantitative risk analysis should be avoided to allow more time for the construction of conceptual models that challenge ways of thinking, assimilate group knowledge and provide a structured opportunity for learning
- the elicitation and documentation of stakeholders' social and economic values should not be delayed until management alternatives are being selected, but brought forward as a problem formulation task and
- a stakeholder engagement plan should be developed for each Ecological Risk Assessment to make transparent how and why particular stakeholders need to be engaged at different stages of the process.

Further Reading

A full list of references is provided in the Report. From that list, the authors suggest the following further reading as a starting point:

Burgman, M. 2005. Risks and Decisions for Conservation and Environmental Management. Ecology, Biodiversity and Conservation Series. Cambridge University Press, Melbourne.

Suter, G.W. 1993. Ecological Risk Assessment. Lewis Publishers, Chelsea MI.

11.3 Reflecting on stakeholders' perceptions in an ecological risk assessment workshop

Correct Citation
Kellett, B.M., Beilin, R., Bristow, K.L., Moore, G. and F. H. S. Chiew. 2007. Reflecting on stakeholders' perceptions in an ecological risk assessment workshop: Lessons for practitioners. The Environmentalist. 27:109–117.

Key Words
Ecological Risk Assessment - Stakeholders' perceptions - Lessons for practitioners – Northern Australia Irrigation Futures.

Summary
A new form of ERA aims to improve environmental decision-making through strong stakeholder engagement, often in workshop situations. This wider focus increases interaction between workshop practitioners and stakeholders for reflecting on, and learning from, each others perceptions. In this article, we analyse and discuss a one day workshop that was concerned with trialling this method of deriving an ERA. We found that stakeholders had issues with some elements of the workshop process. The decision problem was formulated prior to the workshop and without consultation among all the stakeholders. Consequently, the original decision problem was rejected for a mutually derived broader focus and this resulted in a loss of clarity and purpose. Stakeholders did not wholly concur with the prioritising of ecological values over social and economic values and some stakeholders objected to defining assessment endpoints, because it implies a reductionist approach that doesn't capture significance and understanding of systems. ERA workshops are complex and require significant practitioner and stakeholder development to provide useful and mutually derived outcomes.

ERA is a process designed to support decision-making by providing a basis for comparing and ranking ecological risks, so that managers can attend to the most significant risks. It provides a framework for trading off management alternatives so that risks to ecological values are minimised. ERA is finding wider application in catchment contexts, where focus is on assessing and managing risks that link multiple hazards with multiple ecological values (Hart et al., 2005).

ERA has four stages in which key stakeholders are involved: planning the ERA; formulating the problem; analysing the risks; and characterising the risks. Outputs from this process inform a decision making process, which involves the development of a risk management plan and monitoring the implementation of the plan to facilitate evaluation. For catchment management issues, the risk assessment and risk management processes should engage stakeholders who share the burden of the risks.

The problem formulation stage of ERA is commonly undertaken with stakeholders in a workshop situation. One of the initial steps is the identification of ecological values, which are the basis for the following steps in the process. This stage can lead to passionate discussion and is important for developing widely shared objectives for the decision problem. In ERA, these objectives are called assessment endpoints. The first, second and third authors of this article have participated in a number of ERA problem formulation workshops and it is apparent that stakeholders find difficulty with, or objection to, parts of the process. Therefore the aim of this research is to reflect on these issues, so that practitioners can learn from them.

This paper focuses on an ERA conducted for the wetlands of the Lower Burdekin. It outlines the management, hydrology and values of the wetlands and introduces the ERA workshop, details how results were gathered, presents observations of the process, discusses the observations and provides recommendations for practitioners.

Conclusions / Knowledge Assets

Learning and respecting the perceptions of stakeholders is essential for adopting a new and more interactive form of ERA. The paper identified a series of issues that stakeholders had with the process in an ERA workshop and suggested ways to prevent or mitigate these issues for future applications.

In an ERA workshop there are multiple stakeholders, each with their agenda and each at a different level of commitment for, and awareness of, ecological risks, but each representing real world values that need to be considered. It is in this context that the following recommendations were made for practitioners: it is important to triangulate problem formulation across a spectrum of stakeholders prior to and during workshops so that decision problems find stronger support; ERA must be clearly introduced and applied as one of many research processes that contribute information for catchment management; and the workshop process needs to be flexible, allowing debate over issues such as 'assessment endpoints don't capture systems', where multiple perspectives are not only heard, but used for supporting, qualifying and/or refuting qualifying risk models and risk magnitudes.

As well, it is important that practitioners acknowledge that there are also multiple agendas among their colleagues. Transparency of purpose can alleviate misunderstandings and clarify desired outcomes. It is important to have real scenarios for the testing of new risk assessment tools, and equally important that the real scenarios are acknowledged as having a context beyond a particular experimental assessment process for the different practitioner agencies involved.

Participatory processes are clearly multi-faceted and require extensive stakeholder and practitioner development in order to provide useful and mutually derived outcomes. At the outset it is important that practitioners and stakeholders have agreed goals and a staged framework that allows the development and understanding of the ERA workshop and provides an on-going strategy for assessing outcomes from the particular workshop to the larger regional context.

Further Reading

A full list of references is provided in the Report. From that list, the author suggests the following further reading as a starting point:

Berkes, F., Colding, J., and Folke, C. (eds.): 2003, *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*, Cambridge University Press, Cambridge, 393 pp.

Douglas,M. and Wildavsky, A.: 1982, *Risk and Culture*, University of California Press, California, 221 pp.

Gregory, R., Lichtenstein, S., & Slovic, P. 1993, 'Valuing Environmental Resources: A Constructive Approach,' Journal of Risk and Uncertainty 7, 177-197.

Gregory, R., McDaniels, T., and Fields, D.: 2001, 'Decision Aiding, Not Dispute Resolution: Creating Insights Through Structured Environmental Decisions,' *Journal of Policy Analysis and Management* 20(3), 415–432.

Sutter, G.W. 1993, *Ecological Risk Assessment*, Lewis Publishers, Michigan, 538 pp.

11.4 *Northern Australia Irrigation Futures: Origin, evolution and future directions for the development of a sustainability framework*

Correct Citation

Camkin, J.K., Kellett, B.M. and K.L. Bristow. 2007. Northern Australia Irrigation Futures: Origin, evolution and future directions for the development of a sustainability framework. CSIRO Land and Water Science Report No.??/07, CRC for Irrigation Futures Tech. Report No. 10/07 37 pp.

Key Words

Sustainability framework – knowledge platform – ecologically sustainable development –irrigation – component trees – Northern Australia Irrigation Futures.

Summary

A key objective of NAIF is *"To develop an overall framework that, through their involvement, is embraced by policy makers, regulators, investors and managers, to help ensure any irrigation is managed in a consistent, ecologically sustainable manner in northern Australia"*. This became known as the sustainability framework.

Early research followed a prescriptive path when it was thought that a set or framework of biophysical indicators with guidelines on how they should be used would be a useful product. Guidance from stakeholders and research suggested this would be insufficient to address the complexity, subjectivity and site specific nature of irrigation decision-making. The research shifted to a more detailed analysis of decision-making processes and the natural and human context for decisions. From this research we identified opportunities to utilise emerging understanding of learning models and new on-line technology to deal with complex problems. As the research evolved, six versions of a conceptual sustainability framework were presented. The sixth was endorsed by the NAIF SC in November 2006 and the development of a prototype for the lower Burdekin requested.

This report summarises the findings of the research to November 2006. It documents the international and national context, summarises the research and development of conceptual models, and sets the future direction. The further research, development and testing of the prototype framework will be documented in a subsequent report.

Conclusions / Knowledge Assets

Key findings from a review of Visioning and Scenario Planning were:

- Visioning that involves development of alternative future scenarios can help communities prepare for change
- Computerised visualisation tools can support the development of visions and development scenarios and aid in discussions on their consequences.

Key findings from the development of a Bayesian Network Model were:

- Models can be viewed as tools for advising, educating, or mutual learning
- Modelling with existing communities of practice can build trust and cooperation, facilitating integration and adaptation of management practice.

Key findings from an evaluation of Ecological Risk Assessment were:

- ERA requires extensive stakeholder and practitioner discussions and negotiations in the planning stage

- ERA can appear to prioritise ecological over social and economic objectives, which can reduce some stakeholders' support for the process

Key findings from an evaluation of Indicator Frameworks were:
- Like models, indicator frameworks can be applied in different ways: for advising; for educating; and for mutual learning
- Measuring sustainability with indicator frameworks implies what constitutes sustainability is known. Getting to this stage requires a systems approach

Key findings from the Implementation of Triple Bottom Line (TBL) Reporting were:
- Applying the CRC IF TBL Project ISAF involves organisations adapting it for local conditions. This adaptation process is an important part of the learning.
- The project recommendations for using the ISAF are practical ideas based on experiences of project members collaborating with case study organisations.

Key findings from a Review of Control Structures were:
- An understanding of the control structures relevant to a particular location is important to proponents, stakeholders and decision-makers
- Control structures are not static, they change frequently.

Key findings from a Review of Web-based Frameworks were:
- Resource decisions are often made with whatever information is readily at hand, regardless of whether it represents a full and accurate picture
- There is rapid growth in the development of new approaches to learning, sustainable management and supporting communities of practice to resolve complex issues.

Recommendations
Matters to be addressed in further research were:
- Approaches taken in other industries to develop sustainability frameworks
- Assessment of the practicality and benefits of the proposed approach
- Refinement of the sustainability framework
- Technical and management options and issues
- Cost and funding options and issues
- Links with other research.

Further Reading
A full list of references is provided in the Report. From that list, the authors suggest the following further reading as a starting point:

Chesson, J. Whitworth, B. Stewart, J and Yapp, G. 2005. Signposts for Australian Agriculture, Stage 2a: Refinement of preliminary framework and industry profiles to include pathways to ESD. Final report to the National Land and Water Resources Audit, September 2005.

Christen, E., Shepheard, M., Jayawardane, N., Davidson, P., Mitchell, M., Maheshwari, B., Atkins, D., Fairweather, H., Wolfenden, J. and Simmons, B. 2006. The Sustainability Challenge: A Guide to Using Triple Bottom Line Reporting as a Framework to Promote the Sustainability of Rural and Urban Irrigation in Australia. CRC for Irrigation Futures, Tech. Report No.03-1/ 06.

Haddad, T., Wright, D., Dailey, M., Klarin, P., Marra, J., Dana, R., and Revell, D. 2005. The tools of the Oregon Coastal Atlas. In: Wright, D.J. and Scholz, A.J. (eds.), Place Matters: Geospatial tools for Marine Science, Conservation and Management in the Pacific Northwest, Corvallis, OR: Oregon State University Press, 134-151.

11.5 An ESD component system to support irrigation decision making in northern Australia

Correct Citation
Camkin, J.K. and J. Story. 2007. An ESD component system to support irrigation decision making in northern Australia. CSIRO Land and Water Science Report No.??/07, CRC for Irrigation Futures Technical Report No. 11/07 xx pp.

Key words
Sustainability framework – knowledge platform – ecologically sustainable development – irrigation – component trees - Northern Australia Irrigation Futures.

Summary
A key objective of NAIF is *"To develop an overall framework that, through their involvement, is embraced by policy makers, regulators, investors and managers, to help ensure any irrigation is managed in a consistent, ecologically sustainable manner in northern Australia"*. This became known as the sustainability framework.

The nature and objectives of the sustainability framework have adapted throughout the NAIF project as new research findings have emerged. Moving away from the idea that the sustainability framework should be a set of biophysical indicators the research identified the need for a greater emphasis on dealing with the issues of complexity, uncertainty and risk to support irrigation decision making. Research began on approaches taken in other locations and industries which were aimed at building confidence by addressing these issues. Ecological Sustainable Development (ESD) Component Trees is one method that was found to have been successfully used in fisheries, agriculture and irrigation. Because of their previous successes and demonstrated benefits, ESD Component Trees were seen as a way to enhance irrigation decision-making in northern Australia. Previous irrigation and water resources decisions were analysed and a generic ESD Component Tree for irrigation in northern Australia developed.

This report documents an ESD Component Tree system for irrigation in northern Australia. The report also documents new applications for the system and the accompanying NAIF ESD Component Trees Toolkit provides a range of tools to support its use.

Conclusions / Knowledge Assets
First researched by Fisheries Research and Development Corporation in early 2000, ESD Component Trees aim to help breakdown the concept of ESD into understandable components and aid in allowing the concept of ESD to be implemented in a full and practical manner. ESD Component Trees are a set of all issues, impacts or factors (positive and negative) which may be of interest when considering a particular activity (e.g. irrigation). Each issue is a separate component, is part of a hierarchical tree, and is connected to other components through that tree. ESD Component Trees allow the user to navigate through the myriad of issues that may be relevant (eg to irrigation decisions) in a systematic way.

Through application in wild fisheries, aquaculture, agriculture and irrigation, ESD Component Trees have been shown to have several key benefits including:

- Comprehensiveness: a common, comprehensive starting point reduces the chance of bias and of relevant factors not being considered

- Transparency: documenting the reason why a component is not relevant allows all stakeholders to see how each issue has been addressed
- Consistency: consideration of each activity starts from the same set of potential issues which are then either accepted or rejected
- Dealing with complexity: all potential issues are processed in a structured way and are systematically prioritised.
- Understanding and managing risk: factors identified as relevant are prioritised so that the issues of high importance are addressed first.
- Capacity Building: users are guided in a way that encourages them to consider all issues relating to an activity or proposal, not just familiar ones.

The ESD Component Tree system is intended to enhance rather than replace decision-making procedures. By ensuring that all the relevant factors have been identified, ESD component trees can help reduce complexity and help build confidence in the community and decision makers. Rather than increase the level of regulation, which is a common stakeholder concern, the experience in fisheries has been that ESD Component Trees have helped reduce regulation by identifying overlaps, redundancies and omissions for correction.

ESD Component Trees have largely been used in triple-bottom-line or ESD reporting to date, although the potential applications for irrigation in northern Australia include:
1. Catchment and irrigation visioning and planning
2. Developing irrigation proposals
3. Assessing irrigation proposals
4. Improvement of existing irrigation
5. Triple-bottom-line or ESD reporting
6. Identifying and managing knowledge gaps.

Recommendations

This document and the accompanying 'NAIF ESD Component Trees Toolkit' support the NAIF ESD Component Trees system by guiding users on its application in relation to a particular location, proposal or planning process. The Toolkit includes:
1. Generic ESD Component Trees set for irrigation in northern Australia
2. Formatted Excel spreadsheet to assist in documenting components which are or are not identified as being an issue and why
3. Process guide description
4. Power Point Presentation
5. Example of application: The Lower Burdekin
6. Example of use: Construction of the Lower Burdekin Knowledge Platform 2

Further Reading

A full list of references is provided in the Report. From that list, the author suggests the following further reading as a starting point:

Australian Government (2007) *A National Plan for Water Security*, Available: http://www.pm.gov.au/docs/national_plan_water_security.pdf

Cullen, P. (2004) Irrigation Association of Australia Annual Conference, Adelaide, May 2004 The Journey to Sustainable Irrigation.

Fletcher, W.J., Chesson, J., Fisher, M., Sainsbury, K.J., Hundloe, T., Smith, A.D.M. and Whitworth, B., 2002. *National ESD Reporting Framework for Australian Fisheries: The 'How To' Guide for Wild Capture Fisheries*. FRDC Project 2000/145, Canberra, Australia. 120 pp.

11.6 Dealing with complexity and uncertainty: Frameworks to support irrigation decision-making in northern Australia

THIS REPORT HAS NOT YET BEEN DRAFTED

12 Acknowledgements

A large number of people have contributed to the success of the NAIF project over the last four years and we thank them all for their various contributions, including reviewers of this Final Report. We would like to thank in particular:

Current Steering Committee Members
Ian Atkinson, Tom Crothers, Kevin Devlin, Andrew Kelly, Ian Lancaster (Chair), Anwen Lovett, John Ruprecht and Christine Schweizer.

Past Steering Committee Members
Tom Aldred, Fiona Bartlett, Murray Chapman, Greg Claydon, Allan Dale, Ross Dalton, Mathew Durack, John Loney, Jos Mensink, Wayne Meyer, Ian Prosser, Grant Sadler and Ian Smith.

Current and Past Stakeholder Reference Group Members
Gianni D'Addario, Robert Boshammer, John Etty, Dan Halloran, Patricia Julien, Barry Louvel, Geoff Strickland, Vern Veitch, Graham Webb and Marc Wohling.

Project Team Contributors
Keith Bristow, Jeff Camkin, Di Popham, Cuan Petheram, Freeman Cook, Zahra Paydar, Emmanuel Xevi, Philip Charlesworth, Patrick Hegarty, Justin Story, Katrina Annan and our PhD students Bart Kellett, Peta Dzidic, Steve Marchant and Lucy Reading.

Other key contributors to the NAIF concept and project
Peter Cullen, Peter Gilbey, Andy McCrea, Ivan McLeod, Wayne Mollah, Lois Hunt, Gareth Evans, Glen Starkey, Matt Darcey, Pushpa Onta, Tanya Vernes, John Williams and John Logan.

The core collaborating partners
The WA, NT, QLD and Australian Governments, Land and Water Australia and the National Program for Sustainable Irrigation, CRC for Irrigation Futures, and CSIRO.

13 List of Appendices

Appendices 1 and 2 are attached to this report. The remaining appendices are provided as separate documents.

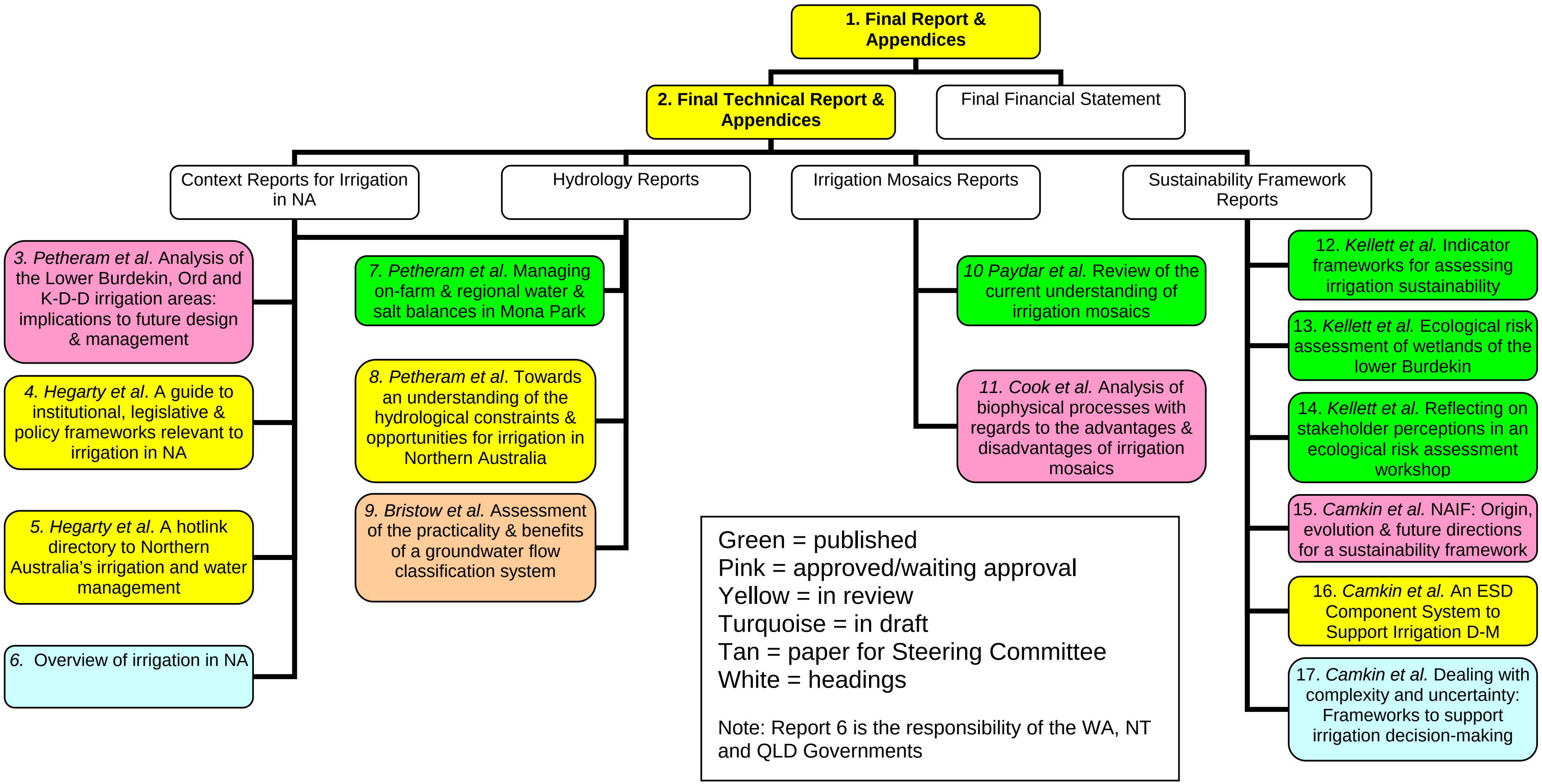
1. NAIF CDS23 Final Report Structure (Also attached below)
2. NAIF Publications List (Also attached below)
3. Analysis of the Lower Burdekin, Ord and K-D-D Irrigation Areas: Implications to future design and management of tropical irrigation
4. A guide to institutional, legislative and policy frameworks relevant to irrigation and water management in northern Australia
5. A hotlink directory to northern Australia's irrigation and water management institutional, legislative and policy frameworks
6. Towards an understanding of the hydrological factors, constraints and opportunities for irrigation in northern Australia: A review
7. Assessment of the practicality and benefits of developing a groundwater flow classification system
8. Managing on-farm and regional water and salt balances in Mona Park
9. Review of the current understanding of irrigation mosaics
10. Analysis of biophysical processes with regard to the advantages and disadvantages of irrigation mosaics
11. Indicator frameworks for assessing irrigation sustainability
12. Ecological risk assessment for the wetlands of the lower Burdekin
13. Reflecting on stakeholders' perceptions in an ecological risk assessment workshop: Lessons for practitioners
14. Northern Australia Irrigation Futures: Origin, evolution and future directions for a sustainability framework
15. An ESD component system to support irrigation decision-making in northern Australia
16. Dealing with complexity and uncertainty: Frameworks to support irrigation decision-making in northern Australia

NORTHERN AUSTRALIA IRRIGATION FUTURES

NPSI CDS23 FINAL REPORT STRUCTURE

DECEMBER 2007

NAIF NPSI CDS23 FINAL REPORT STRUCTURE



NORTHERN AUSTRALIA IRRIGATION FUTURES

PUBLICATIONS LIST

DECEMBER 2007

NPSI Final Reports

1. Northern Australia Irrigation Futures. National Program for Sustainable Irrigation (CDS23) – Final Report.

2. Northern Australia Irrigation Futures. National Program for Sustainable Irrigation (CDS23) – Final Technical Report.

Irrigation in Northern Australia Context Reports

3. Petheram, C., Tickell, S., O’Gara, F., Smith, A., Bristow, K.L. and P. Jolly. 2007. Analysis of the Lower Burdekin, Ord and Katherine-Douglas-Daly Irrigation Areas: Implications to future design and management of tropical irrigation. CSIRO Land and Water Science Report No. ??/07, CRC for Irrigation Futures Technical Report No. 04/07 xx pp. *(Waiting approval).*

4. Hegarty et al. 2007. A guide to institutional, legislative and policy frameworks relevant to irrigation and water management in northern Australia. CSIRO Land and Water Science Report No. ??/07, CRC for Irrigation Futures Technical Report No. 05/07 xx pp. *(Report under external review through Sub-Committee).*

5. Hegarty et al. 2007. A hotlink directory to northern Australia’s irrigation and water management institutional, legislative and policy frameworks. CSIRO Land and Water Science Report No. ??/07, CRC for Irrigation Futures Technical Report No. 06/07 xx pp. *(Report under external review through Sub-Committee).*

6. An overview of irrigation in northern Australia
   This report is now the responsibility of the WA, QLD and NT governments for their completion. The NAIF project team has completed what it can and provided a template to the governments for their use.

Hydrology Reports

7. Petheram, C., Charlesworth, P.B. and K.L. Bristow. 2006. Managing on-farm and regional water and salt balances in Mona Park. CSIRO Land and Water Technical Report No. 23/06, July 2006. 50 pp.

8. Petheram, C. and K.L. Bristow. 2007. Towards an understanding of the hydrological factors, constraints and opportunities for irrigation in northern Australia: A review. CSIRO Land and Water Science Report No. ??/07, CRC for Irrigation Futures Technical Report No. 07/07 xx pp. *(In review).*

9. Bristow, K.L. and C. Petheram. 2007. Assessment of the practicality and benefits of developing a groundwater flow classification system for irrigation in northern Australia. *(Internal report to the NAIF Steering Committee).*

Irrigation Mosaics Reports

10. Paydar, Z., Cook, F.J., Xevei, E. and K.L. Bristow. 2007 Review of the current understanding of irrigation mosaics. CSIRO Land and Water Science Report No. 40/07, CRC for Irrigation Futures Technical Report No. 08/07. 31 pp.

11. Cook, F.J., Xevi, E., Knight, J.H., Paydar, Z. and K.L. Bristow. 2007. Analysis of biophysical processes with regard to advantages and disadvantages of irrigation

mosaics. CSIRO Land and Water Science Report No. ??/07, CRC for Irrigation Futures Technical Report No. 09/07 61 pp. *(Approved).*

Sustainability Framework Reports and Papers

12. Kellett, B., Bristow, K.L. and P.B. Charlesworth. 2005. Indicator Frameworks for Assessing Irrigation Sustainability. CSIRO Land and Water Technical Report No. 01/05. 52 pp.

13. Kellett, B.M., Beilin, R., Bristow, K.L., Moore, G. and F. H. S. Chiew. 2007. Reflecting on stakeholders' perceptions in an ecological risk assessment workshop: Lessons for practitioners. The Environmentalist. 27:109–117.

14. Kellett, B.M., Walshe, T. and K.L. Bristow. 2005. Ecological Risk Assessment for the Wetlands of the Lower Burdekin. CSIRO Land and Water Technical Report No. 26/05. 30 pp.

15. Camkin, J.K., Kellett, B.M. and K.L. Bristow. 2007. Northern Australia Irrigation Futures: Origin, evolution and future directions for the development of a sustainability framework. CSIRO Land and Water Science Report No. ??/07, CRC for Irrigation Futures Technical Report No. 10/07 xx pp. *(Approved).*

16. Camkin, J.K. and J. Story. 2007. An ESD component system to support irrigation decision-making in northern Australia. CSIRO Land and Water Science Report No. ??/07, CRC for Irrigation Futures Technical Report No. 11/07 xx pp. *(In review).*

17. Camkin, J.K., Bristow, K.L. and J. Story. 2008. Dealing with complexity and uncertainty: Frameworks to support irrigation decision-making in northern Australia. *A proposed paper to describe the NAIF sustainability framework and 2nd generation Lower Burdekin Knowledge Platform. This is <u>not</u> a commitment under the NPSI contract. (Outline prepared).*

END OF REPORT