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 REPORT

December 2007

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[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. This is the Final Report for NAIF activities funded through the initial NPSI grant.

Top 20 Take Home Messages

NAIF has worked closely with the WA, NT, QLD and Australian governments and a range of other researchers and stakeholders, to deliver new knowledge, tools and processes to support debate and decision making about irrigation in northern Australia. Take home messages from this work include:

1. Research processes which effectively contribute to the integration of science, policy and stakeholders are valued highly by a wide range of stakeholders
2. The land and water resources of northern Australia are already being used and decisions are about redirecting these resources to different uses
3. Generating localised short term benefits from irrigation are 'easy'; delivering catchment scale long term sustainability is the challenge
4. We need to develop the capacity to view, understand and manage northern Australia through a 'northern lens' which takes account of the national and international context
5. Groundwater can be critical to base flow and maintenance of ecological function
6. Water quality is as important as quantity, especially in meeting ecological needs
7. Irrigated systems are complex systems and we need to accept, understand and manage that complexity
8. Water availability and storage needs for irrigation in event driven tropical systems are poorly understood
9. We need to ensure policies and management strategies make sense for event driven tropical systems
10. Irrigation must be preceded by catchment scale salt and nutrient management plans to deliver on long term sustainability objectives

11. We must set and meet groundwater quantity (level) and quality targets in irrigated systems and adjust management practices to meet those targets
12. "Efficiency" is not the answer to everything; the aim is to build and maintain resilience in irrigated systems
13. Irrigation and water management is an individual and collective responsibility
14. There is growing interest in irrigation mosaics as an alternative approach to traditional large-scale contiguous irrigation systems
15. Irrigation mosaics may have both negative and positive biophysical effects compared with more traditional systems, with a possible net positive impact
16. Further research is required on the biophysical, ecological, social and economic advantages and disadvantages of irrigation mosaics
17. Dealing with complexity, uncertainty and risk in irrigation decision making emerges as a shared need and responsibility for catchment communities, proponents and governments
18. Dealing successfully with the complexity of irrigation in northern Australia to achieve long term ecologically sustainable development will require decision-making and irrigation management systems that better utilise existing and emerging technologies and approaches
19. Implementing frameworks (including catchment knowledge platforms and ESD component tree systems) which effectively integrate science, policy and stakeholders will support more comprehensive, transparent and consistent planning and decision-making
20. Above all else, decisions about the future of irrigation in northern Australia are about people and their relationships with the environment

NAIF has highlighted the importance of developing a system-wide understanding of the context for irrigation in northern Australia and a shared vision for its future. NAIF has also demonstrated that while no single framework can hope to ensure sustainability, it is possible to deliver knowledge, tools and processes that can help governments and catchment communities charged with making decisions about these complex issues. According to the feedback received, NAIF has had significant impact and influence on the thinking about irrigation in northern Australia.

Stakeholder Feedback

Feedback from stakeholders is scattered throughout this Final Report but the following perhaps sums it up best: "*While each of the take home messages are important, it is important not to lose the connectivity between them. Probably the biggest take home message is the complexity of the (irrigation) system and the need to manage that complexity.*" Doug Hall, Irrigation Australia.

Future Directions

Substantial opportunities exist to support implementation of the National Water Initiative and the National Plan for Water Security in northern Australia by building on the NAIF platform: *"The (NAIF) project has already had a significant positive impact on inter-jurisdictional cooperation between the 3 governments in the North but also with community and industry stakeholders and other research programs. The sub-committee agrees that the continuation of this project model would contribute greatly to help to ensure that any expansion of irrigation in the north of Australia is done in a sustainable manner."* Draft NAIF Sub-Committee Communiqué (October 2007).

List of Acronyms

ANCID	Australian National Committee on Irrigation Drainage
CRC IF	Cooperative Research Centre for Irrigation Futures
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DoW	Department of Water (WA)
ERA	Ecological Risk Assessment
ESD	Ecologically Sustainable Development
LBKP	Lower Burdekin Knowledge Platform
LBWF	Lower Burdekin Water Futures Group
LWA	Land and Water Australia
M&E	Monitoring and Evaluation
NAIF	Northern Australian Irrigation Futures
NPSI	National Program for Sustainable Irrigation
NPWS	National Plan for Water Security
NRETA	Department of Natural Resources, Environment and The Arts (NT)
NRW	Department of Natural Resources and Water (QLD)
NT	Northern Territory
QLD	Queensland
SC	Steering Committee
SN	Stakeholder Network
SRG	Stakeholder Reference Group
SE&C	Stakeholder Engagement and Communication
TRaCK	Tropical Rivers and Coastal Knowledge
WA	Western Australia

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1 Land & Water Australia Reference: CDS23

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3 Project Partners and Collaborators

Project Partners
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 Report Prepared

31 October 2007

6 Reporting Structure

This CDS23 Final Report is supported by a Final Technical Report. The full structure for this Final Report is attached (Appendix 1).

7 Project Objectives

The NAIF SC was established on 11/03/04. Changes to the original project objectives were agreed by the SC on 14/2/06 and approved through the NPSI Milestone reporting process. The final objectives (with additions underlined and deletions shown in italics in brackets) 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 *(development)* across northern Australia [2]

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 *(developed and)* managed in a consistent *(and)*, ecologically sustainable manner in northern Australia

4. To use a number of linked case studies and stakeholder input to support and inform development and *(enable)* 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 Methods and Modifications

8.1 Background and General Approach

NAIF was launched by the Hon Warren Truss MP, Minister for Agriculture, Fisheries and Forestry at the Australian National Committee on Irrigation Drainage (ANCID)

[2] For the purpose of this project northern Australia is defined as the area of Australia north of the Tropic of Capricorn.

conference in Shepparton in August 2003 with initial funding through LWA's NPSI program and CSIRO. NAIF was to focus on northern catchments (defined as the area above the Tropic of Capricorn) and take a long-term, strategic view with an outlook of 50 years plus. Not a traditional research project, the focus was on NAIF being a journey of discovery in which important processes and products would be developed as the project evolved. It was expected that new activities and funding sources would be added as others were completed over time.

Steering Committee (SC)
A representative and skills based SC, currently comprising of individuals from the WA, NT, QLD and Australian Governments, NPSI, CRC IF, SunWater and the North Burdekin Water Board, provides strategic guidance to the project team. Terms of Reference and SC membership are attached (Appendix 2).

Project Team
The small NAIF project team comprises of contributions from a range of CSIRO and CRC IF researchers. While contributions from individual staff have varied over time, the total staff time on this project was approximately 0.3 full time equivalents per annum during Stage 1 and up to 2.4 full time equivalents per annum during Stage 2. The project team has also involved four CRC IF funded PhD students.

Stakeholder Reference Group and Stakeholder Network
A ten member SRG, consisting of three members from each of WA, NT and QLD and one from NSW, was established to provide a point of reference for the project team and SC. A stakeholder network with more than 300 individuals and organisations around Australia and overseas were kept informed about NAIF through the electronic newsletter NAIFNEWS, providing an additional source of input and feedback on the research.

Case Studies
The Lower Burdekin, Ord and Katherine-Douglas-Daly areas were established as case studies to help ground the research, enable direct feedback and testing of ideas and frameworks being developed, and help ensure their practicality, suitability and likelihood of adoption.

8.2 Stage 1 Research

Stage 1 focussed on engaging with clients to: (i) identify a broad range of project stakeholders; (ii) identify data required and data sources; and (iii) determine the willingness of stakeholders to participate in project activities. Three reports[3] summarising the stakeholder engagement outcomes were posted on the NAIF project website at http://www.clw.csiro.au/naif/. A workshop of WA, NT, QLD and Australian government agency staff and some of the key project stakeholders (including NPSI and CRC IF) was held in Darwin on 26-27 May 2004.[4] The workshop recommended that a Stage 2 work plan be developed that recognised the important linkages of existing and prospective State and Commonwealth initiatives. Major challenges identified for the future of NAIF were: (i) developing a consultation process that would achieve outcomes in a suitable timeframe; and (ii) developing a

[3] Report of Stakeholder Consultations in Western Australia (31 May 2004), Report of Darwin Workshop (22 June 2004) and Report on the Brisbane Workshop with Queensland Government Agencies (3 August 2004).
[4] See Report of Darwin Workshop (22 June 2004) at http://www.clw.csiro.au/naif/reports.html.

framework that while focussed on biophysical aspects of sustainability demonstrated clear linkages with the socioeconomic aspects of sustainability.

The NAIF Milestone 2 Report noted that because of limited time and resources, NAIF would need to be clear about what it can address and what others need to address, and that a key to managing this issue would be awareness of and developing links with other activities and initiatives.

8.3 Stage 2 Research

A Stage 2 Work Plan (Appendix 3) was endorsed by the SC on 1 December 2005. The Work Plan included the key research areas: (i) understanding the context for irrigation in northern Australia; (ii) understanding the concept of irrigation mosaics; (iii) understanding tropical water systems; and (iv) developing an overall framework to support irrigation decision making, which became known as a 'sustainability framework'. The work plan highlighted the importance of establishing case study areas to ground the research. The NAIF project structure, key research areas and major inputs are shown in Figure 1.

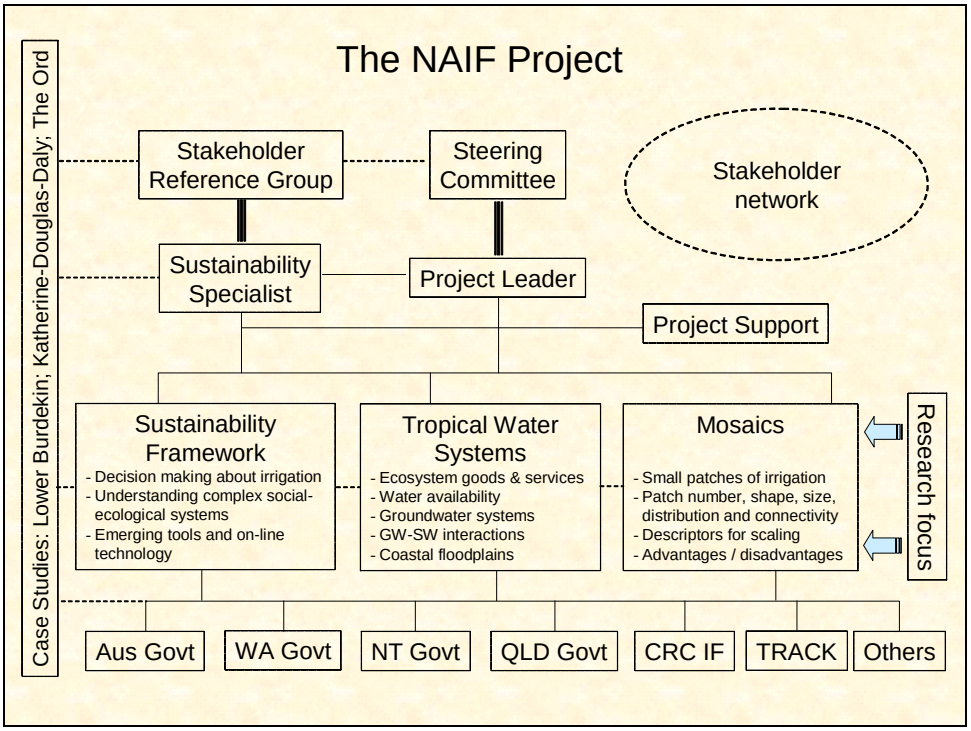

Figure 1: NAIF project structure, key research areas and major inputs

In accordance with the Stage 2 Work Plan, a Monitoring and Evaluation (M&E) Plan (Appendix 4) and Stakeholder Engagement and Communication (SE&C) Strategy (Appendix 5) were finalised in March 2006.

8.4 Changes to Project Goal, Objectives and Activities

Guided by the SC, NAIF has adapted in response to research results, improved understanding of the external environment (particularly in relation to changes in the

national water agenda), client needs and strategic opportunities. All significant changes have been reported and approved through the NPSI Milestone Reporting process. A comparison of the original project proposal, the Stage 2 Work Plan and later NAIF documents shows several significant changes during the project. It is instructive to review the origins of NAIF and its transition over time as there were several important shifts during the course of the project.

Project Goal

The original project goal was *"Building a basis for developing sustainable irrigation across tropical Australia".* On 14/2/2006 the SC endorsed a new project goal: *"To provide new knowledge, tools and processes to support debate and decision making regarding irrigation in northern Australia'.* This change reflects a subtle but important shift endorsed by the SC away from a focus on developing sustainable irrigation to a focus on supporting irrigation decision making to help achieve sustainable outcomes.

Project Objectives

Changes to the project objectives shown in Section 7 also reflect subtle but important shifts in NAIF thinking endorsed by the SC. The changes indicate increased focus on ecologically sustainable irrigation, consistent with the 1992 National Strategy for Ecologically Sustainable Development (Commonwealth of Australia, 1992). The changes also reflect more focus on supporting decision making to help ensure any irrigation in the north is sustainable, recognising that that no one research activity or framework can ensure irrigation is sustainable. Lastly, the changes to project objectives also emphasise the role of stakeholder input in developing and testing the proposed framework.

Research Activities

The Milestone 2 Report noted that in developing the Stage 2 Work Plan *"…activities will need to be detailed and allowance made for changing these activities through time as the project evolves. This is deemed necessary in such a complex project and to ensure that the project is continually building on new knowledge and learning's. It also demonstrates the need for peer review on some specific aspects of the project to ensure there is strong justification for any new direction or to reinforce that the current approach is the most appropriate."*

The SC and project team consequently took a very adaptive approach to research activities, continually monitoring whether activities will deliver useful outcomes and adjusting those activities to maximise the anticipated benefits. Significant shifts were:

- a shift from trying to identify a suite of biophysical indicators of sustainable irrigation in northern Australia to greater focus on the social process of decision making
- emergence of the QLD, NT and WA Governments as primary stakeholders and significant funders of NAIF
- increased focus on improving the accessibility of existing and new knowledge, tools and processes
- a shift from trying to deliver a single "sustainability framework" to delivering 'frameworks to support irrigation decision-making'.

9 Research Activities, Results, Interpretation and Practical Significance

This section deals with how the NAIF objectives have been achieved.

Objective 1 – Landscape attributes relevant to ESD [5]
The ecologically sustainable development factors relevant to irrigation in northern Australia have been identified and described in an ESD Component Tree System.

Objective 2 – Sustainability indicators for northern Australia
The ESD Component Tree system identifies the relevant factors at a range of scales from on-farm to local, catchment, regional, national and international and these are incorporated into a prototype knowledge platform. Sustainability indicators are seen as part of a more comprehensive approach to sustainability.

Objective 3 – An overall framework to support irrigation decision-making
An 'overall framework' consisting of the ESD component system, web-based catchment knowledge platforms and catchment communities working together to integrate science, policy and stakeholders has been conceptualised, developed as a prototype for the Lower Burdekin, supported by the NAIF SC and demonstrated.

Objective 4 – Case studies and stakeholders to inform and test the framework
Lower Burdekin, Ord and Daly River case studies have informed the conceptualisation, development and testing of the prototype framework. They have also made significant contributions to other NAIF research areas.

Objective 5 – Contribute new knowledge and tools through the framework
The prototype framework has been offered for consideration by policy makers, regulators, investors and managers. The utility of the framework for contributing tools and knowledge to support debate, decision-making and long-term strategic thinking has been demonstrated (Brisbane, Ayr, Darwin, Kununurra, Perth, Canberra, Katherine etc). To date, detailed testing has been focussed in the lower Burdekin.

The primary contribution of each research area towards achievement of the project objectives is shown (Table 1) and described further in this and following sections.

Table 1: Primary research contributions to project objectives

	Objective 1	Objective 2	Objective 3	Objective 4	Objective 5
Project management	X	X	X	X	X
Context for irrigation in northern Australia	X			X	X
Understanding northern Australian water systems	X			X	X
Understanding irrigation mosaics		X			X
Developing a sustainability framework	X	X	X	X	X
Case studies	X	X	X	X	X

[5] ESD is defined in the National Strategy for Ecologically Sustainable Development as "Using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the quality of life, now and in the future, can be increased". (Commonwealth of Australia, 1992)

9.1 Project Management

Activities, outputs and contribution to project objectives
The main activities in this research area were:

- Work planning, management and reporting
- Stakeholder engagement and communications
- Financial and human resource management.

The main outputs were:

- 7 NPSI Milestone Reports, Stage 2 Work Plan, SE&C Strategy, M&E Plan, Project Status Reports and other papers for 23 SC meetings
- 6 editions of NAIFNEWS, 5 NAIF media releases, 26 media items, 5 initial and 6 final NPSI workshops, and more than 160 major meetings, workshops, seminars and conferences featuring or coordinated by NAIF
- 4 Financial Reports to NPSI. The Final Financial Report is due 1/1/2008.

.
The main contribution to the project objectives was:

- support for the SC, and, guided by the SC, ensuring that research delivered against the project objectives.

Key findings
A report against the M&E Plan is attached (Appendix 6). The project has been highly successful in adapting and responding to new learnings and evolving needs. It has done this while maintaining focus on the original objectives, which have been slightly modified by the SC over time. An area of some concern has been the difficulty experienced in obtaining quality and timely reviews of the work, which has impacted on delivery times of some reports. A contributing factor to this has no doubt been the "busyness" of everyone in the water sector.

A report against the SE&C Strategy is attached (Appendix 7). Thirty seven (37) of the 42 actions identified in the Strategy due for completion by 31 October 2007 have been completed. Successful stakeholder engagement and collaboration has been a strong feature and the NAIF project received the 2006 CRC IF Award for Teamwork and Collaboration.

All Milestone and Financial Reports have been submitted and approved.

Interpretation and practical significance
It was always intended that the original NPSI funding would be the catalyst for further research and collaboration relating to irrigation in northern Australia. This has occurred and NAIF is now viewed as broader than and continuing beyond the original NPSI project. A detailed but flexible work plan, SE&C Strategy and M&E Plan will be important in relation to future NAIF activities.

The willingness and commitment to engage in conversations with a wide range of stakeholders has built trust between the NAIF project team and other individuals and organisations. This has resulted in numerous opportunities for the research to influence broader discussions, such as invitations to brief the Australian Government's Northern Australia Land and Water Taskforce. The trust that has developed provides a strong foundation to support current and future activities.

The human and financial resources required for a project of this scope and magnitude were significantly underestimated.

Key messages

- Research processes which effectively contribute to the integration of science, policy and stakeholders are valued highly by a wide range of stakeholders.

9.2 Understanding the Context for Irrigation in Northern Australia

Activities, outputs and contribution to project objectives

The main activities in this research area were:

- documenting the policy, legislation and institutional arrangements relevant to water and irrigation management in northern Australia
- reviewing past and present irrigation in northern Australia, focussing on key bio-physical information and sustainability issues
- analysing the Lower Burdekin, Ord and Daly irrigation areas to identify the implications to future design and management of tropical irrigation.

The main outputs were:

- reports on the policy, legislation and institutional arrangements relevant to irrigation in northern Australia
- a template to enable each northern jurisdiction to provide a report towards an overview of irrigation has been distributed to the northern governments
- a report drawing lessons from existing irrigation for future design and management of irrigation in northern Australia.

The main contributions to the project objectives were:

- identification of irrigation 'control structures[6] and influences' for incorporation into frameworks for decision making (Objectives 3 and 5)
- lessons from irrigation in the case study areas informing development of the decision making frameworks (Objective 4).

Key findings

There are several major challenges faced by those charged with the responsibility of making decisions about irrigation in northern Australia, including:

- Geographic scale. Approximately 40% of Australia's land mass occurs above the Tropic of Capricorn
- Limited water and other information. Limited research, monitoring and history of use in many areas is a constraint to scientific and practical understanding of northern systems. Water monitoring systems, for example, have decreased in recent years and data that does exist has not been well analysed and synthesised
- Availability of skills. Securing adequate human resources with the right skills is a challenge for all northern jurisdictions. In the case of QLD and WA, the available skills are largely being applied to more urgent priorities in the south
- High complexity and uncertainty. There is increasing pressure for the development and use of northern water resources but, despite the inherent complexity and uncertainty, government decision makers are often required to make decisions within timeframes set by legislation, policy or political need.

[6] 'Control structures' in this context are defined as laws, policies, plans etc that impact on decisions regarding irrigation, as opposed to the physical structures used to control water level and flows in irrigation delivery systems

National water policy debates are largely focussed on southern systems and especially those which are over-allocated. There is limited focus on the development of water policy that is appropriate for northern systems as opposed to adapting southern approaches to the north.

The land and water resources of northern Australia are already being used to maintain ecological systems, indigenous and other cultural values, and economic activity. These existing uses make a major contribution to the values that make northern Australia a place of national significance.

Generating localised short term benefits from irrigation is relatively 'easy'; delivering catchment scale long term sustainability is the challenge.

Interpretation and practical significance

Despite the research already carried out on northern Australia, particularly during the latter half of last century, there is a need to be realistic about the level of current understanding of northern systems and the limit to human resources likely to be available in northern Australia to address this. Even with current increases in effort through the Tropical Rivers and Coastal Knowledge (TRaCK), NAIF and other initiatives, it will take a long time to build knowledge about the north. This may require cautious decision making and judicious application of the precautionary principle. Utilising all forms of available knowledge and sharing of knowledge, skills and experiences across the jurisdictions of northern Australia are two ways of fast tracking improved understanding to support decision making.

Learning from the history of irrigation in southern Australia and elsewhere around the world is important but not sufficient. Lessons from previous experience may be misleading if applied incorrectly to northern Australia. Northern Australia has the opportunity to avoid some of the challenges now facing southern Australia but this may require significantly different approaches to those now being used to fix existing problems in the south. In addition to understanding what can and cannot be learnt from previous experiences, we need to develop the capacity to view, understand and manage northern Australia through a 'northern lens' which takes account of the national and international context. This includes building understanding of the pros and cons of applying current national water policy and approaches to the north.

If the proposition is accepted that the water resources of northern Australia are already being used, we need to develop our ability to understand the likely positive and negative consequences of changing those uses.

Key messages from the research

- The land and water resources of northern Australia are already being used and decisions are about redirecting water to different uses
- We need to develop the capacity to view, understand and manage northern Australia through a 'northern lens' which takes account of the national and international context
- Generating localised short term benefits from irrigation are 'easy'; delivering catchment scale long term sustainability is the challenge

"NAIF has highlighted the importance of having a long term view when considering irrigation across northern Australia. The long term research focus is extremely important and balances short term research being done through other projects." Ian Lancaster - NAIF SC Chair.

9.3 Understanding Water Systems of Northern Australia

Activities, outputs and contribution to project objectives
The main activities in this research area were:

- synthesising existing geological, geomorphological and hydrogeological studies of northern Australia
- assessing the practicality of developing a groundwater flow classification system for northern Australia.

The main outputs were:

- a report on current understanding of the hydrological constraints and opportunities for irrigation in northern Australia
- a report to the SC on the practicality and benefits of developing a groundwater flow classification system for northern Australia.

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The main contributions to the project objectives were:

- identification and description of hydrological issues relevant to sustainable irrigation in northern Australia (Objective 1)
- incorporation of relevant hydrological issues into frameworks for decision making (Objectives 3 and 5).
- the introduction of new ideas, knowledge and tools into public debates about the water systems of northern Australia (Objective 1 and 4).

Key findings
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. The antiquity of the landscape is often cited as the reason for the relative infertility of Australian soils.

Soils
Australian soils have been exposed to a variety of climates over geological time scales, which have resulted in a complex pattern of highly weathered soils that are generally low in nutrients. While it is difficult therefore 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.

Interpretation and practical significance

The flatness of the landscape has implications to streamflow and options for water storage and high rainfall intensities can severely constrain agricultural activities. Furthermore, across most of northern Australia, the scarcity of rainfall and streamflow during the dry winter months necessitates either the extraction of groundwater of sufficient quantity and quality for irrigation or large above ground storages.

In the wet tropics most major rivers are perennial. Few rivers are perennial in the wet-dry tropics but those that are have strong connection to underlying groundwater systems that supply groundwater baseflow. This connection supports unique natural ecosystems that are dependent upon the quantity and quality of flow in the dry season.

In the semi-arid and arid zones of northern Australia, average annual recharge and discharge rates are very low. This imposes considerable constraints to development of groundwater based resources in those regions, particularly when ecological values are applied. The use of groundwater for irrigation presents substantial management challenges because of the uncertainties associated with recharge, discharge and lateral flow, and the time lags associated with these processes. Such detailed information exists in few areas of northern Australia.

High flow events have important ecological implications for in-stream, estuarine, near-shore and marine environments. Some ecosystems are also dependent upon groundwater in sub-surface saturated zones and some deep rooted vegetation types have been found to depend upon groundwater (to varying extents) during the dry season.

We need to understand and manage connected systems of the north. For example, we need to understand the relationships between surface and groundwater, and the importance of both water quality and quantity, in systems that are spatially and temporally highly variable.

We need to understand how much of the water in northern Australia is available for use and whether the concept of ‘sustainable yield’ works in highly event driven systems. If it does, we need to develop a better understanding of what the sustainable yields are. In addressing water availability, we need to understand the unique ecosystems and the services they provide. We also need to understand the implications of policy decisions on surface water and alternative storage options such as groundwater on water availability.

We need to develop an understanding of what ecologically sustainable development means in northern Australia. Rather than traditional irrigation and/or dryland agricultural developments, new forms of development that are uniquely northern Australian in character, and hence different to what we currently understand and are comfortable with, may need to be developed.

Most current data indicates a wetting trend in the central north and north-west of Australia. However, global climate change models suggest this wetting trend may be short term (15 years or so) and rainfall may then revert to the overall drying trend predicted for all of Australia. We need to better understand the potential impacts of climate change on the water resources as well as the current and potential ecological, social and economic values associated with them.

Key messages from the research

- Groundwater can be critical to base flow and maintenance of ecological function
- Water quality is as important as quantity, especially in meeting ecological needs
- Irrigated systems are complex systems and we need to accept, understand and manage that complexity
- Water availability and storage needs for irrigation in event driven tropical systems are poorly understood
- We need to ensure policies and management strategies make sense for event driven tropical systems
- Irrigation must be preceded by catchment scale salt and nutrient management plans to deliver on long term sustainability objectives
- We must set and meet groundwater quantity (level) and quality targets in irrigated systems and adjust management practices to meet those targets
- 'Efficiency' is not the answer to everything; the aim is to understand the resilience of the natural system and to retain or rebuild resilience in irrigated systems
- Irrigation and water management is an individual and collective responsibility.

"While each of the take home messages are important, it is important not to lose the connectivity between them. Probably the biggest take home message is the complexity of the system and the need to manage that complexity". Doug Hall, Irrigation Australia.

9.4 Understanding Irrigation Mosaics

Activities, outputs and contribution to project objectives

The main activities in this research area were:

- a review of research into mosaics relating to ecology, forestry, meteorology and saline basins to aid understanding of the concept of irrigation mosaics and whether it may be an appropriate style of irrigation for northern Australia
- a review and application of existing and new modelling and analysis tools to explore potential advantages and disadvantages of irrigation mosaics.

The main outputs were:

- a report on the current understanding of irrigation mosaics drawing lessons from irrigation and other fields
- a report on the biophysical advantages and disadvantages of irrigation mosaics.

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The main contributions to the project objectives were:

- new understanding of the biophysical implications of irrigation mosaics (Objective 2)
- the introduction of new ideas, knowledge and tools into public debates about the potential role of alternative approaches to irrigation in the future of northern Australia (Objective 2 and 5).

Key findings

Making informed decisions about the future of irrigation in the north will require greater understanding of tropical systems and whether irrigation can be designed

and managed in a way that is more in harmony with the natural ecosystems. 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 ecologically 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.

To estimate the effect of irrigation area size and impact, a scaling method was developed which calculates the marginal impact of having mosaics compared to one large contiguous area. Numerical solutions for irrigation mosaics were also used as they offer more flexibility in reflecting actual field conditions, such as variable soils, rainfall and recharge rates.

From this research 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. The actual benefit will depend on a range of factors including the size of the individual patches, spacing between patches, and assimilative capacity of surrounding areas.

Interpretation and practical significance

There is growing interest in the potential for irrigation mosaics to deliver improved social and economic opportunities for rural and remote (commonly Indigenous) communities in northern Australia. The NAIF research shows that there are likely to be both advantages and disadvantages of irrigation mosaics with respect to several biophysical factors compared to more traditional forms of irrigation. Depending on the circumstances, this may result in a net benefit on biophysical grounds; however the longer-term environmental impacts of irrigation mosaics in space and time are still largely unknown. We have provided an overview of existing knowledge and current biophysical understanding of systems with natural spatial patterns in the landscape. This establishes a framework for further study on irrigation mosaics and their environmental impacts.

The potential impacts need to be studied carefully, and design criteria (size, shape, density, connectivity and spatial arrangement in harmony with the landscape) need to be established because environmental benefits may be short lived if space and time lags just delay any unwanted consequences of irrigation. Improved understanding of the potential for irrigation mosaics in northern Australia, and suitable designs, requires biophysical research and model development on:

- analytical solutions for periodic recharge of groundwater
- solute transport using particle tracing methods
- finite arrays of mosaics
- the effect of advection on evaporation rate as effected by size and number of irrigated patches
- the water and solute balance and irrigation requirements of sites throughout Northern Australia.

Studies into the ecological, social and economic performance of irrigation mosaics, and into the policy and governance frameworks required for them, are also needed to improve understanding of their potential advantages and disadvantages. Studies

could focus initially on the performance of existing irrigation areas that demonstrate irrigation mosaic characteristics, such as the Daly River. Understanding the likely performance of irrigation mosaics can help determine the potential future for planned irrigation mosaics and help identify how existing irrigation systems could be reconfigured for improved harmonisation with natural systems.

Key messages from the research

- There is growing interest in irrigation mosaics as an alternative approach to traditional large-scale contiguous irrigation systems
- Irrigation mosaics may have both negative and positive biophysical effects compared with more traditional systems, with a possible net positive impact
- Further research is required on the biophysical, ecological, social and economic advantages and disadvantages of irrigation mosaics.

"Mosaics are exactly what we have in mind for the centre. There is a need to fill knowledge gaps to achieve good decisions." Vincent Lang, NT Centrefarms.

9.5 An Overall (Sustainability) Framework for Irrigation Decision-Making

Activities, outputs and contribution to project objectives

The main activities in this research area were:

- examining the role and use of biophysical indicators of sustainability
- understanding irrigation decision making processes
- understanding social-ecological systems, sustainability and resilience[7] concepts
- reviewing the use of 'ESD Component Trees' in fisheries, agriculture and irrigation
- understanding learning models and the potential role of new and emerging web-based technology in resolving complex problems.

The main outputs were:

- an ESD Component Tree system for irrigation in northern Australia
- a prototype web-based Lower Burdekin Knowledge Platform (LBKP)
- establishment of a Lower Burdekin Water Futures (LBWF) Group to promote integration of policy, science and stakeholders in irrigation and water resources management in the catchment
- reports summarising the journey of the research and development of frameworks to support irrigation decision making in northern Australia
- a suite of other reports relating to irrigation decision making processes, including sustainability indicators, ecological risk assessment and Bayesian Belief Networks.

The main contributions to the project objectives were:

- identification of factors potentially relevant to decisions about sustainable irrigation in northern Australia (Objectives 1 and 2)
- the ESD Component Tree system, catchment knowledge platform and integration of science, policy and stakeholders through the LBWF is a

[7] Resilience is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker et al. 2004).

prototype framework supported by that group, the NAIF SC and sub-committee (Objective 3)
- support for the concept and prototype was tested in relation to the Lower Burdekin, Daly and Ord catchments through the NAIF Steering Committee and sub-committee and stakeholder workshops across northern Australia (Objectives 4 and 5).
- the introduction of new ideas, knowledge and tools into public debates about irrigation decision making in northern Australia (Objective 5).

Key findings

Initially NAIF aimed to *"…deliver a framework based on sustainability indicators and management criteria at a range of scales (field, farm, district, scheme, and catchment) to support planning, development, implementation and management of new schemes, and if necessary, modification of existing schemes across northern Australia."* While much of the initial aim remained, thinking about the framework shifted substantially as the research progressed. As issues of resilience, complexity, uncertainty, managing risk and adaptive management emerged through the research, the focus shifted away from developing a sustainability framework based on a set of biophysical indicators. As the social process of irrigation decision making became more prominent, the focus shifted towards a framework or suite of simple tools that could support communities and decision makers deal with complexity and uncertainty in a comprehensive, transparent and inclusive way that addresses the important environmental, social, economic and external issues relevant to a particular location or irrigation decision. The research also examined the potential use of new and emerging web-based environments to enhance the ability to manage irrigation within a catchment context. The following key messages emerged from the research.

Measuring sustainability with indicator frameworks implies that what constitutes sustainability (ie which indicators) is known. Getting to this stage in a transparent and equitable way requires a systems approach. A systems approach ensures the following: relationships are not separated from system components; a full range of stakeholders' perspectives are accepted and used to negotiate understanding; observers (eg users of indicator frameworks) are part of the system; and that scientific understanding is important, but so too is traditional knowledge and experiences and learnings of local people.

Ecological Risk Assessment (ERA) can appear or be biased by values and beliefs of the individuals involved in conducting an ERA, which can reduce some stakeholders' support for the process. There is a need therefore to inform participants early about how ERA will contribute towards an overall process that deals with the social, economic and ecological issues.

Models (such as Bayesian Belief Networks) can be viewed as tools for advising, educating and/or mutual learning. Modelling with existing communities of practice (a group of people who come together for the purpose of learning, for example grower groups) with a mutual learning approach, can build transparency, trust and cooperation, which facilitates the integration and adaptation of management practices.

Visioning that involves the development of alternative future scenarios can help communities prepare for change in several ways, including: (i) it can result in the development of plans that set out responses to possible futures; and (ii) it can build community capacity by strengthening social networks, trust, cooperative relationships, and knowledge integration. However, to develop outputs useful to and supported by community and planners, visioning must be undertaken as part of

existing processes, not as an activity isolated from regional / catchment planning. Computerised visualisation tools can support the development of visions and development scenarios by aiding discussion on the consequences of different scenarios.

An understanding of the control structures and influences relevant to a particular location is important to those proposing irrigation developments, to stakeholders and to decision makers. Mechanisms to support proponent, stakeholder and community understanding of the contemporary control structures and influences relevant to their area of interest are important components of any overall framework.

Economic activity (for example irrigation) is part of and takes place within the social system, which in turn is part of and takes place within the ecological system. The key question is not whether an industry or individual development is sustainable or not but rather what positive and negative contributions that industry or development makes across the full range of ESD Component Tree systems, which identify the ESD factors relevant to a particular industry, proposal, or location, have been successfully developed and applied in fisheries, aquaculture, agriculture, and irrigation triple bottom line reporting.

There is rapid growth in the development of on-line technology that recognises new approaches to learning and supports communities of practice in the resolution of complex problems and such approaches could be applied to irrigation decision making.

Interpretation and practical significance

Decisions about irrigation in northern Australia (and elsewhere) are extremely complex and there are many uncertainties. Recent experiences in the Murray Darling Basin and elsewhere have increased awareness of the risks and potential consequences of water use decisions. At the same time, the community now expects that decisions about proposals for developments will not only deliver economic benefits to proponents but will also deliver social and economic benefits to the broader community, with acceptable environmental impacts. Non-government organisations and community individuals are better trained, better connected and generally better equipped to play a 'watchdog' role on government and other decision making, and decision makers, than ever before. There is increasing pressure for the allocation of northern water resources but, despite the inherent complexity and uncertainty, government decision makers are often required to make decisions within timeframes set by legislation, policy or political needs. The sum of all these pressures is an environment that, quite naturally, encourages cautious or risk-averse decision-making. There is a widespread perception that this is a cause of increasing regulation, viewed by some as "red tape".

Dealing with the complexity and uncertainty related to decisions about irrigation in northern Australia emerges as a shared need and responsibility for catchment communities, proponents and decision makers.

In complex systems we need to understand and deal with the difference between uncertainty and risk to increase confidence in decision making. The matrix created by considering at the on-site, local, catchment, regional, state, national and international scale, all of the potential environmental, social, economic and external factors that are relevant to an irrigation proposal, is large. However, not all of these potential factors are relevant to a particular decision and not all of those that are relevant are of equal importance. What is required are tools that aid understanding of the difference between uncertainty and risk so that management effort can be focused

on the most important issues and decisions can continue to be made. ESD Component Tree systems are one such tool.

It is clear that we can do better at using the knowledge, tools and processes for irrigation decision making that already exist. Better utilisation of knowledge that already exists within catchments, coupled with improved methods for transferring experience across catchments may be a significant step forward. New understandings about learning models and about how and when individuals search for and share their knowledge can be utilised to develop catchment based knowledge platforms that help catchment communities and governments progressively build and tell the story about how the catchment operates in a biophysical, social and economic sense. The prototype LBKP demonstrates one way to achieve this.

The NAIF research has demonstrated opportunities to help communities and decision-makers deal with the inherent complexity and uncertainty of decisions about irrigation in northern Australia, including how to improve existing irrigation areas. The resulting framework of an ESD Component Tree system, catchment based knowledge platform and science, policy and stakeholders operating in an integrated way, is demonstrated through the Lower Burdekin prototype. The concept and prototype has received strong support in the Lower Burdekin, through the SC and at the NAIF Final Workshops.

Above all else, decisions about the future of irrigation in northern Australia are about people and relationships, and no single framework can hope to ensure sustainability. It is possible, however, to help catchment communities and governments on the journey towards sustainability by developing knowledge, tools and processes that reflect this reality and support those charged with making decisions about these complex issues.

Dealing successfully with the complexity of irrigation in northern Australia to achieve long term ecologically sustainable development will require decision-making and irrigation management systems that better utilise existing and emerging technologies and approaches.

Key messages from the research

- Dealing with complexity, uncertainty and risk in irrigation decision making emerges as a shared need and responsibility for catchment communities, proponents and governments
- Maintaining resilience and achieving ecologically sustainable development will require more sophisticated approaches to irrigation and water resource planning, decision making and management than currently exist
- Developing catchment knowledge platforms and ecologically sustainable development component tree systems with science, policy and stakeholders operating in an integrated way can help deliver more comprehensive, transparent and consistent decision making
- Above all else, decisions about the future of irrigation in northern Australia are about people and relationships

"If NAIF captures the imagination of stakeholders it will be through the sustainability frameworks". Kevin Devlin, SC member.

"The NAIF thinking, particularly the Ecological Sustainable Development component trees, has helped us evaluate the risks of a full irrigation scheme compared to a mosaic style system and helped guide the preparation of our briefings. Being able to

look at major component trees and compare multiple scenarios helped in terms of risk assessment, and influenced the thinking behind our water allocation planning." Tom Crothers, General Manager Water Allocation and Planning, NRW, QLD.

10 Reflections on the Research Process

10.1 Overall Reflections on the NAIF Project

On 19 August 2007 the SC and project team reflected on their NAIF experiences. Most of the key reflections in this section are informed by quotes from SC members during that session.

A project coming into its time
The level of focus on the future of northern Australia and the role that irrigation may play in that future has increased markedly since NAIF project inception. Ongoing water resource challenges in southern Australia have increased the community, political and scientific focus on the land and water resources of the north. There have been several major new initiatives relevant to irrigation in northern Australia launched since NAIF commenced in 2003. The National Plan for Water Security (NPWS), released by the Prime Minister in January 2007 notes that *"Future and ongoing development of northern Australia's land and water resources must take place in a strategic framework that is ecologically, culturally and economically sustainable…".* The NPWS included the establishment of a Northern Australia Land and Water Taskforce, chaired by Senator Bill Heffernan, and funding for Northern Australia Land and Water Assessments. The TRaCK research hub was also launched in 2007. NAIF was well positioned when these initiatives commenced and strong connections have developed.

"NAIF is a project coming into its time through the vision of Keith Bristow. We did not appreciate in 2004 that the issues NAIF is covering would be so relevant now and that we would be in a position of influence (eg briefing Senators)." Kevin Devlin, NAIF SC member.

"From Land and Water Australia's perspective, one of the terrific things about the NAIF Project is that it is recording and delivering its findings at a time when the community is discussing these issues." Anwen Lovett, NAIF SC Member.

Process is as important as products and outputs
There is a tendency to underplay the importance of the processes that have supported and been an important part of NAIF. Although the process has been extremely demanding, especially in time and travel costs, it is clear from the SC reflections that while the project outputs are valued, the research process itself is valued at least as highly.

"Making networks, especially interstate, which provide opportunity for discussion of issues, forming relationships and the verbal communication between stakeholders have all been an extremely beneficial outcome of the NAIF project. The inter-state networks are very valuable and are helping with day to day management. This project will facilitate better relationships between NRW and CSIRO and with the Burdekin stakeholders, and this is the catalyst of what this project has driven." Tom Crothers, NAIF SC Member.

10.2 Reflections on the Work Plan

Evolution of project objectives
Project objectives have been modified by the SC as the research and thinking progressed. The following is from the NAIF SC minutes, August 2007:

Kevin Devlin gave credit to Keith Bristow on casting the original objectives, which still stand, and leading the project to its current research themes. *"The original project was about satisfying objectives but these have evolved into major research themes with the influence of the SC, SRG and project team. The management of the project has been undertaken by an external and internal structure and we need to capture feedback on how effective each element has been".* Kevin Devlin, NAIF SC Member.

Managing expectations
Managing expectations has been difficult and no-one was aware of the size of the task when it first commenced. The initial announcement regarding the project gave a false impression about the level of funding available. In reality, the resources available for the scale of the task have been extremely limited and it has been a challenge managing the expectations with such a resource mismatch.

"The community was ready for these issues to be tackled and when NAIF came on board the project was asked to do more than it was capable of. The demand on the project increased as it was asked to become all things to all people and moving forward was difficult". Anwen Lovett, NAIF SC Member.

Accessing in-kind support
Despite increasing levels of commitment over time, it has not been possible to capture in-kind support from the various jurisdictions as effectively as was hoped and needed. All jurisdictions are struggling to meet their human resource needs for internal projects and have little or no spare capacity to provide as in-kind support.

Areas for improvement
While the case studies proved effective, work plans for each case study were not finalised until the second half of the NAIF project (although some activity was already taking place) and, consequently, what could be achieved through the case studies was overestimated. Establishing aims and activities for any case studies in future NAIF activities should be an early priority to maximise the benefits from them.

Changes to the Stage 2 Work Plan were agreed by the SC and recorded through the NPSI Milestone reporting process. Due to higher operational priorities, these changes were not subsequently reflected in updates to the Work Plan and tracking the changes is, therefore, not as easy as would be preferred.

10.3 Reflections on the Case Studies

Case study work plans
Three case study areas were established. The Lower Burdekin is a mature irrigation area, the Ord River is a semi-developed irrigation area for which there are further development intentions, and in the Daly there is some irrigation with considerable debate about irrigation expansion. The case studies were expected to:

- Allow the NAIF project to link closely with and draw from other activities taking place in the case study areas

- Help ensure that the overall framework can provide for the incorporation of ecological, social, economic and cultural values by those wishing to use it
- Help ensure that the risks and limitations of irrigation are clearly identified
- Help ensure that the SRG has the opportunity to understand the direct relevance of decisions about irrigation in northern Australia to the future of those individuals and communities.

For each case study a work plan was developed and agreed with the relevant state/territory representative on the SC. Each work plan detailed the proposed activities, expected benefits, stakeholders and the approach to stakeholder engagement, resourcing, and the achievement criteria, performance indicators and data sources to assess performance. A report on the NAIF case studies is included in Appendix 8.

Aims and activities
It was expected that the case studies would:

- Provide an overview of the history of irrigation in each location and lessons from it
- Assist the transfer of lessons across northern Australia
- Secure base data / knowledge for use in the sustainability framework, building on any knowledge platforms available through this or other projects
- Assist the identification of characteristics that increase a community's capacity to adapt to change
- Provide insights that will assist the consideration of development proposals
- Improve the understanding of understanding of groundwater systems, particularly surface water groundwater interactions and Karstic aquifer systems
- Improve the understanding of the concept of irrigation mosaics
- Help provide insights into the changes required, if any, to improve existing irrigation, regional natural resource planning and management
- Link with other CRC IF research in the region, especially triple bottom line reporting for sustainability and transformational change pathways that move the irrigation community and its stakeholders to a more sustainable future
- Provide lessons from existing irrigation which can be applied to new areas.

In reality, the Case Studies provided an important 'reason for being' for NAIF in specific locations. NAIF has been able to develop strong links with key stakeholders, including the relevant governments and other researchers, through each of these case studies. The case studies also provided an opportunity to profile the NAIF project locally and test ideas against local circumstances. This was particularly the case for the lower Burdekin where, following support for a conceptual framework, the SC endorsed development of a prototype for the lower Burdekin.

Assessment of case studies

Achievement Criteria	Performance Indicator	Statement	Contribution to Objectives
A comprehensive, practical and usable framework for supporting debate and decisions about irrigation in NA	Acceptance of framework by key stakeholders	Final NAIF NPSI workshops (Sep – Nov 2007) indicate interest & support in prototype framework	Objectives 3, 4 and 5
Wider knowledge	Comprehensive	Captured in various	Objectives 1

of key biophysical features relevant to irrigation in NA	collation and interpretation of key knowledge and understandings of NA landscapes	NAIF reports	and 2
Successful project communications	Case study stakeholders are part of NAIF Stakeholder Network and receiving quarterly project updates	Stakeholder network exceeding 300 members has received 6 editions of NAIFnews	Objectives 3 and 4
Effective implementation and coordination	Project partners maintain investment for project duration	All investments maintained	Objectives 1 to 5

A sounding board for ideas, concepts and products
Perhaps the most significant contribution of the NAIF case study sites has been to provide a sounding board for ideas, concepts and products being generated through the NAIF research.

"It was a fundamental underpinning of the project to have the three key example areas across northern Australia (lower Burdekin, Katherine-Douglas-Daly and the Ord). The advantage of having concentrated effort in those three areas has been the involvement from the three communities and the stakeholders has been enormous". Kevin Devlin, NAIF *SC Member*.

10.4 Reflections on and of the Steering Committee

The SC met 23 times during the course of the NPSI project, of which five were face-to-face meetings and 18 were tele-meetings. A sub-committee of the QLD, NT and WA Government representatives on the SC was established in mid 2006 to provide for greater interaction with the project team. The sub-committee met on two occasions outside of the regular SC meetings. Key reflections on the SC process are:

The Steering Committee has been an outstanding success
While it has not been without its challenges (outlined below) the SC and project team consider the SC to have been one of the strengths of NAIF. The willingness of members to remain engaged under pressure from other priorities has built the trust and commitment. Through the SC, NAIF has delivered a forum where the three states and Australian government are focussed on irrigation and water management. There is no other forum where this is occurring so effectively.

The importance of good communication
"Initially the project team provided a lot of support and assurance to SC members regarding the project's direction. The project encountered a lot of brick walls and confusion. Initially no-one realised how big the project was, but it had so much potential that we had to keep going... It was a struggle as a SC member in the early days but the internal management (project team) helped with their communication through one on one conversations and phone calls, to keep the project moving in the right direction". Andrew Kelly, NAIF *SC Member*.

People, not positions, are important
SC members value the breadth of skills brought to the SC and the relationships that have been built through it highly. They recognised that this is about individuals and not positions. *"The SC needs to capture and maintain a continuity of the skills of people instead of selecting a particular government position to hold the role".* Kevin Devlin, NAIF SC Member.

Maintaining continuity is a common challenge
"SC members came from different professions and it was a shame at times when SC members resigned from their post as expertise was lost". Andrew Kelly, NAIF SC Member. *"The challenge of keeping a continuity of membership is common to most R&D projects. There is a huge churn in this environment which is a negative for all projects".* Anwen Lovett, NAIF SC Member.

Trust is critical
Trust is critical to the operation of the SC. *"There is clear evidence of a very healthy level of trust within the SC and a willingness to share good and bad experiences. Keith and Jeff have good diplomacy skills. Building this trust takes time and it is very clear that the face-to-face interaction has played an extremely important role in the success of the project".* Ian Atkinson, NAIF SC Member.

Areas for improvement
The gap between meetings and communication with SC members was sometimes too long, requiring relearning concepts at each meeting. Additionally, at times some SC members felt a bit out of synchronisation with the sub-committee which met separately to advance the thinking. The sub-committee was seen as very useful, there just needed to be better reporting back to the main SC to help ensure all members were on the same part of the journey. As several SC members reflected, it is important that the project team put more effort into bringing new members up to speed.

10.5 Reflections on and of the Project Team

Fragmentation and flexibility of resources
The project team has been too small and fragmented given the expectations on the project. Until October 2005 there was nobody working on NAIF for greater than 50% of their time. In addition, while PhD students can make significant contributions to projects, and have done so in the case of NAIF, there are limitations on the ability to direct their research, which needs to meet PhD requirements and deadlines, compared with staff researchers.

Appointment of Sustainability Specialist
The 2005 decision by the SC and subsequent funding from the WA, NT, QLD and Australian Governments to fund the Sustainability Specialist position identified and recommended by Keith Bristow was critical. This appointment had the following benefits:

- A senior officer was focussed on NAIF full-time
- Important new skills, experience and networks were added to the project
- The appointment created a team capable of bringing together understandings of science, policy/management and stakeholder perspectives.

"There was early difficulty in engaging the state representatives and Jeff Camkin's background helped in this regard."…"Following any heavy science discussions within the SC meetings, I have always been able to get clarity of issues through follow up phone calls from Keith or Jeff". Andrew Kelly, NAIF *SC Member*.

Collaborative approach
"*The NAIF project has been driving and creating cross-collaboration and this has been led by the internal management of NAIF (project team). Not only inter-jurisdictional collaboration, but also the inter-project collaboration has been vital."* Ian Lancaster, Chair NAIF *SC*.

Areas for improvement
The project team does not yet fully encompass the skills needed for future NAIF work. A greater breadth of skills including in groundwater hydrology and geochemistry, irrigation systems, social sciences, ecosystem services and economics will all be required. The degree to which these need to be held within the core project team, as opposed to accessible to the project team, will depend on the breadth and depth of future activities.

Moving from recognition of the need to create the new Sustainability Specialist position to appointment took a long time due to the need to: (i) reach agreement on funding for the position with four jurisdictions and CSIRO; (ii) reach agreement on the role and position statement across multiple core NAIF funding organisations; and (iii) obtain internal (CSIRO) clearance for recruitment and appointment processes. Much of this complexity was caused by the multiplicity of funding partners. This is an issue not restricted to recruitment, and more streamlined processes and trust will improve efficiency and effectiveness of these sorts of collaborative projects.

10.6 Reflections on Stakeholder Engagement and Communications

General Stakeholder Engagement
Engaging stakeholders in a project which spans northern Australia has been challenging but, guided by the SC endorsed SE&C Strategy, this has been a highly successful feature of the NAIF project. A communications risk assessment undertaken in late 2005 provided important guidance for the SE&C Strategy and ongoing communications, and the main project risks identified through that process were successfully managed. Willingness to deal individually and directly with key stakeholders contributed significantly to this success. Subtle shifts in focus indicated through changes to the project objectives and to the language and key messages from the project team and SC were also very important in helping to reduce concerns, particularly from environmental groups, about the intent of NAIF.

"NAIF has highlighted irrigation and engaged with the community to develop relationships. The project has highlighted the importance of relationships and has achieved that – it has learnt from the mistakes of previous initiatives. The long term engagement has been valued by stakeholders who disparage the fly in fly out style that often occurs". John Ruprecht, NAIF *SC Member*.

Stakeholder Reference Group
In August 2005 a media release invited expressions of interested from *"people passionate about the future of northern Australia"* to join the NAIF SRG. Nine nominations were received, ranging from individuals to representatives of

organisations. The process did not attract the representative SRG membership that was intended, but all nominations were subsequently endorsed by the SC. An additional member with experience in local government was later added to fill an identified gap. The 10 member SRG, consisting of three members from each of WA, NT and QLD and one from NSW, provided a point of reference for the project team and SC. This was largely through one-on-one conversations between the project team and individual SRG members. In October 2006 the SRG met face to face with the SC and project team in Darwin. Key reflections on the SRG are:

- The call for EOIs NAIF did not attract some key stakeholders. This may have been because NAIF did not have a sufficiently high profile at that time
- A fully representative SRG for this project would greatly exceed the 10 members originally envisaged and may not be possible or workable
- Some stakeholders did not wish to be part of the SRG because of perceptions about the intent of the project and preferred one-on-one consultation
- Operating the SRG through one-on-one conversations was extremely time consuming and was largely abandoned in favour of other approaches focused on direct contact with key stakeholder organisations
- SC members consider that the one meeting with the SRG was a valuable experience, particularly in highlighting the range and strength of stakeholder views about irrigation in northern Australia
- Cost effective approaches to engaging stakeholders over such a broad issue and area need to be considered for future NAIF activity.

"The SC and SRG meeting held in Darwin last October was excellent - quite enlightening and educational to see the difference of opinions across the broad stakeholder group". John Ruprecht, NAIF *SC Member*.

Areas for improvement
Despite the successes, it seems that there can never be enough consultation, and some weaknesses in engagement internally (CSIRO, CRC IF and LWA/NPSI) and with some external stakeholders occurred at different times through the project. At times, some stakeholder groups were not effectively engaged, while others were engaged in the later part of the project. The key reflection is that this style of personal engagement is critical to projects of this nature but the level of effort required for a project of this scale was not fully recognised nor fully incorporated into project planning and funding. This is an important lesson for future projects.

10.7 Reflections on Project Monitoring and Evaluation

NAIF has, like other projects, experienced difficulty in securing good quality and timely reviews of its work, which at times has delayed progress and delivery of various components of work. In many cases this simply reflects how busy staff of all water organisations are at present. There is a need to reflect this reality in project planning by allowing sufficient time for reviews and locking in review commitments as early as possible.

More time could have been spent early in the NAIF project benchmarking and documenting the prevailing state of knowledge and understanding across northern Australia so that it was easier to demonstrate the real impact the project has had.

NAIF could have captured better, in an ongoing way, detail about the success or otherwise of the various processes being used. Nevertheless, the net outcome has

been well captured through the report on the NPSI Final Workshops through September-November 2007.

"We are really very positive about NAIF. A great example of research arriving at a time when it can inform policy" Anwen Lovett, Manager Sustainable Primary Industries, Land and Water Australia. LWA/NAIF teleconference, 21/9/07.

11 Adoption of Outputs - Communication & Adoption Activities

The NAIF project has been continually guided by the SC and the sub-committee of the NT, QLD and WA representatives. They have provided direct feedback and testing of the ideas, emerging understanding and frameworks being developed, and have helped ensure that the project outputs are practical, suitable and likely to be adopted. Given the importance of the WA, NT, QLD and Australian Governments in determining the future of irrigation in northern Australia, the views expressed by the NAIF sub-committee are important in gauging the likelihood of adoption. A draft, in October 2007, sub-committee communiqué (Appendix 9) includes:

"The project has already had a significant positive impact on inter-jurisdictional cooperation between the 3 governments in the North but also with community and industry stakeholders and other research programs." and *"This work has been lauded by an extensive range of interested parties including the North Australian Task force, community groups, industry and academia. The challenge now is to ensure that the work is utilised and that the project concepts are extended into new areas or the development and implementation of existing research".*

A series of invited workshops, chaired by the relevant state or territory SC member, was held around Australia during September and November 2007 as part of the NPSI final reporting process (Table 2). The aim of the workshops was to meet with a broad range of stakeholders across northern Australia, share learning's and experiences of the NAIF project over the last four years with a broad range of stakeholders across northern Australia, and to seek their feedback on progress to date and views on future directions and priorities. The presentation for each workshop was modified to suit the audience and time available, and workshops were deliberately interactive.

Table 2. Attendance at NAIF NPSI Final Workshops

Date	Location	Number of Participants
7 September 2007	Brisbane	22
14 September 2007	Ayr	24
24 September 2007	Darwin	21
25 September 2007	Kununurra	20
28 September 2007	Perth	19
28 November 2007	Canberra	35

Feedback from the workshops was very positive and supportive of the activities, ideas and outputs being generated through NAIF. A report on the NPSI Final Workshops, including a consolidated workshop presentation and feedback from attendees, is attached (Appendix 10). A few comments which relate to the likelihood of adoption of NAIF outputs drawn from those workshops and other sources include:

- *"A recurring theme in discussions was the opportunities available for mosaic-style smaller scale developments".* Northern Australia Task Force Communiqué (28-9-07)

- *"The NAIF Knowledge Platform is a fascinating way to go. A particularly useful mechanism to get awareness of available knowledge".* Gary Jensen, Manager Water Services, QLD DNRW

- *"This Lower Burdekin Knowledge Platform is a very, very useful path that will deliver best practice environmental management".* Michael Hoey, Chairman, North Burdekin Water Board

- *"I have had further thought on the knowledge platform concept and believe that this will be 'the' most valuable resource for knowledge dissemination for future Agriculture in the NT. Primarily due to the separation (tyranny of distance) of production areas, and the fact that the vast majority of our producers are on-line and computer literate it is logical to utilise this system to engage them and facilitate knowledge brokering."* Tim West, Environmental Development Officer, NT Horticultural Association / NT Agricultural Association.

- *"There is a requirement for capacity building in a fully transparent and engaged way. Irrigation is quite new to the NT. There is a need to have good and simple knowledge platforms to attract all stakeholders and provide answers to questions."* Ian Lancaster, NAIF SC Member.

12 Future Directions for NAIF

12.1 General Comments

The context in which NAIF takes place has changed significantly since 2003 and the project has, guided by the SC, adapted to the changing environment. The NAIF project has been highly collaborative, as evidenced by its success in taking out the 2006 CRC IF Award for Teamwork and Collaboration. In NAIF there is now a 'brand' with a shared vision and processes to transfer experiences across jurisdictional boundaries that would take years to rebuild from scratch. The following is drawn from the draft sub-committee communiqué (October 2007):

"The sub-committee agrees that the continuation of this project model would contribute greatly to help to ensure that any expansion of irrigation in the north of Australia is done in a sustainable manner."

NAIF is already well connected with TRaCK and a draft paper summarising the relationship between TRaCK and NAIF is attached (Appendix 11). NAIF is in a good position to evolve and grow in synergy with TRaCK, to harness different funding sources and tackle different but related issues.

There is a need to determine what form future NAIF activity should take. Issues and opportunities that arise from NAIF experiences to date are:

- The need for a new approach to at least some research efforts based on collaborative approaches built on trust and long term core funding (as opposed to short term, competitive funding)

- The need for these sorts of projects to bring teams together with understandings of science, policy/management and stakeholder perspectives

- The need to work across disciplines and scales simultaneously. This means working within a catchment context and feeding into larger visions and objectives while also connecting with local landholders

- The need to recognise that research products and research processes are both important and need to be properly resourced to match expectations

- The need to deliver tools that aid understanding of the difference between uncertainty and risk so that communities and governments can make decisions with reasonable confidence while knowledge gaps are progressively addressed

- The need to help development of environmental managers who are tuned to northern Australia's unique needs

- The need to develop fundamental understandings about how northern Australia functions ecologically, socially and economically.

"I am pleased to see how NAIF has matured over time. My only concern is short term funding and to ensure NAIF is supported well in the future". Lindsay Delzoppo, Director Planning Services, Queensland EPA.

"NAIF has highlighted the importance of having a long term view when considering irrigation across northern Australia. The long term research focus is extremely important and balances short term research being done through other projects." Ian Lancaster, NAIF SC Chair.

12.2 Ongoing NAIF Activities

It was expected that the original NPSI project would be the catalyst for further research and collaboration relating to irrigation in northern Australia under the NAIF umbrella. This has been successful and ongoing commitments at this time are:

CSIRO Sustainability Specialist Position
The WA, NT, QLD and Australian Governments have committed a total of $200k p.a. for three years to October 2008. This effort will continue to focus on frameworks to support decision making in northern Australia and bridging the gap between science, policy and stakeholders. Discussions to build on this effort are underway.

Geochemist Position
The CRC IF and Water for a Healthy Country Flagship are funding a new geochemist position from the 17 December 2007 for three years. The work will develop improved understanding of the geochemistry of groundwater systems and their role as a key link between land and water management practices and downstream ecosystems. This is a high priority identified through NAIF.

PhD Students
Four CRC IF PhD Students are currently associated with NAIF with target completion dates in 2008 (one), 2009 (one) and 2010 (two).

12.3 Future Research Directions

This section lists the research needs identified through NAIF, some of which fall outside of NAIF areas of focus. Additional details are included in Appendix 12.

Research Needs

Research priorities for northern Australia identified through NAIF (not in any particular order) are:

- Supporting the development of long-term visions for northern Australia
- Understanding northern Australia water systems including surface water-groundwater interactions
- Understanding irrigation mosaics, their long-term impacts and potential to contribute to ecologically sustainable development (social, economic & ecological impacts)
- Catchment scale salt and nutrient planning and management in northern irrigation systems
- Development and application of frameworks to support irrigation decision-making
- Potential for sustainable development linking mine water and irrigation in remote rural communities of northern Australia
- Water storage needs and the use of alternative or supplementary water sources (overland flow, flood harvesting, aquifer recharge etc) to support sustainable development in northern Australia
- Understanding the potential impacts of climate change in northern Australia, including on water resources
- A critical review of past irrigation and a concise summary of the obstacles to success (environmental, technical, social, economic, institutional etc)
- Improved understanding of ecosystem water needs
- Improved understanding of indigenous and other cultural values of water
- Identification of key policy issues relating to irrigation in northern Australia
- Carbon sequestration and carbon trading in northern irrigation systems.

Priorities for NAIF

Future research priorities for NAIF are:

1. Supporting implementation of the National Water Initiative by:
    - Cross-jurisdictional integration, knowledge transfer and capacity building in irrigation and water management
    - Delivering on the National Groundwater Action Plan
    - Supporting sophisticated, transparent and comprehensive irrigation and water planning
    - Supporting sophisticated, high tech irrigation and water management systems
    - Improving knowledge management and building community capacity.

2. Supporting implementation of the National Plan for Water Security by:
    - Developing long-term visions for northern Australia
    - Providing strategic frameworks to support sustainable development
    - Understanding the potential role of irrigation mosaics in northern Australia
    - Encouraging and supporting systems approaches to managing northern catchments.

13 Assessment of Commercial Potential

There is commercial potential in relation to the NAIF catchment knowledge platforms and further development of the knowledge space concepts. However, it is expected that the greatest benefit from this project will arise from making outputs publicly available through a range of mechanisms, including the world-wide-web.

14 List of Project Publication Titles

A list of NAIF publications is at Appendix 13.

15 References

Commonwealth of Australia. 1992. *National Strategy for ecologically sustainable development.* Australian Government Publishing Service, Canberra. 128 pp.

Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzig. 2004. Resilience, adaptability and transformability in social–ecological systems. Ecology and Society 9(2): 5. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art5/

16 Sources of Additional Information for the Reader

A complete list of references is provided within each NAIF report. The Final Technical Report provides a two page summary of each of the technical reports and includes a short-list of recommended references in relation to each report. Additional detail is also included on the NAIF web site: http://www.clw.csiro.au/naif/.

17 Acknowledgments

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
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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.

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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.

18 Appendices

SEE ATTACHED FILE FOR APPENDICES

Appendix 1: NPSI CDS23 Final Report Structure (Also attached below)

Appendix 2: Steering Committee Terms of Reference and Membership

Appendix 3: Stage 2 Work Plan

Appendix 4: Monitoring and Evaluation Plan

Appendix 5: Stakeholder Engagement and Communication Strategy

Appendix 6: Report on Monitoring and Evaluation Plan

Appendix 7: Report on Stakeholder Engagement and Communication Strategy

Appendix 8: Report on NAIF Case Studies

Appendix 9: Steering Committee Draft Communiqué

Appendix 10: Northern Australia Irrigation Futures: Sharing the learning's- NAIF Workshops (September to November 2007)

Appendix 11: Delivering on northern Australia's needs: Synergies between TRaCK and NAIF

Appendix 12: Future Research Directions

Appendix 13: Publications List (Also attached below)

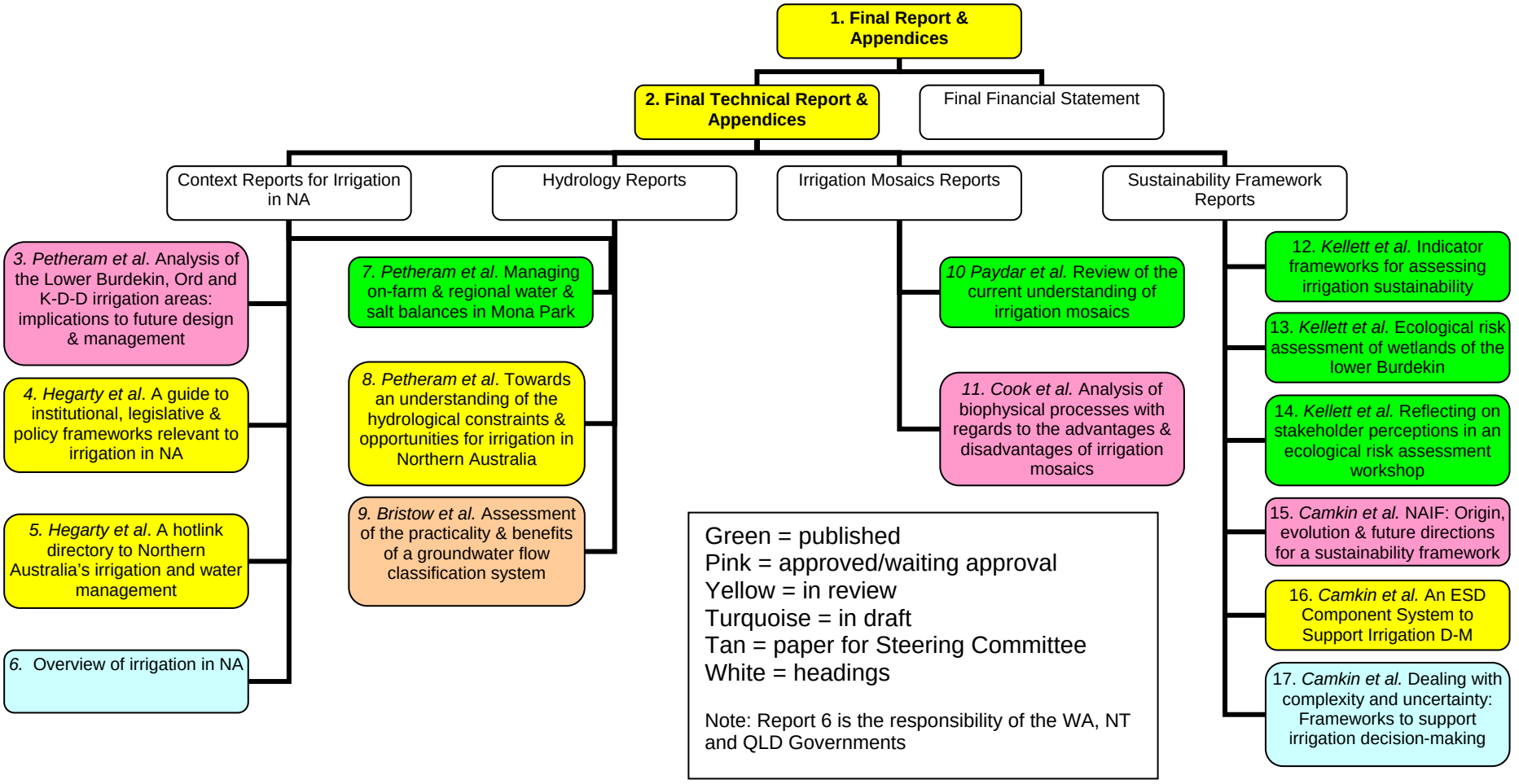
Appendix 1

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 not a commitment under the NPSI contract. (Outline prepared).*

END OF REPORT