CSIRO Land and Water

SUSTAINABLE MANAGEMENT OF THE BURDEKIN DELTA GROUNDWATER SYSTEMS

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SUSTAINABLE MANAGEMENT OF THE BURDEKIN DELTA GROUNDWATER SYSTEMS

1.0 BACKGROUND

The Burdekin delta is a major irrigation area with approximately 38,000 ha of irrigated sugarcane and other crops that fall within the North Burdekin Water Board (NBWB) and South Burdekin Water Board (SBWB) jurisdiction. Irrigation in the region relies heavily on underlying shallow major groundwater supplies.

The Delta Water Boards have a charter that requires that they manage replenishment of the groundwaters. At a scheme scale several techniques are used to artificially recharge the aquifer. At farm-scale, water practices such as 'recycling' and 'water spreading', and more recently direct pumping from recharge channels to farms in some distal aquifer zones have evolved to play an integral role in the management of the groundwater systems. 'Recycling' refers to the practice where irrigation water that is not used by the plants (excess irrigation) cycles through the soil back to the groundwater. This seems at odds with current practice and expectations in other irrigation areas and especially with the current drive for improved 'water use efficiency'. 'Water spreading' refers to the practice where water that is too turbid to be used for recharge via recharge pits is made available across the scheme as surface water for irrigation. Figure 1 provides a schematic of key factors of importance in the Burdekin delta irrigation area.

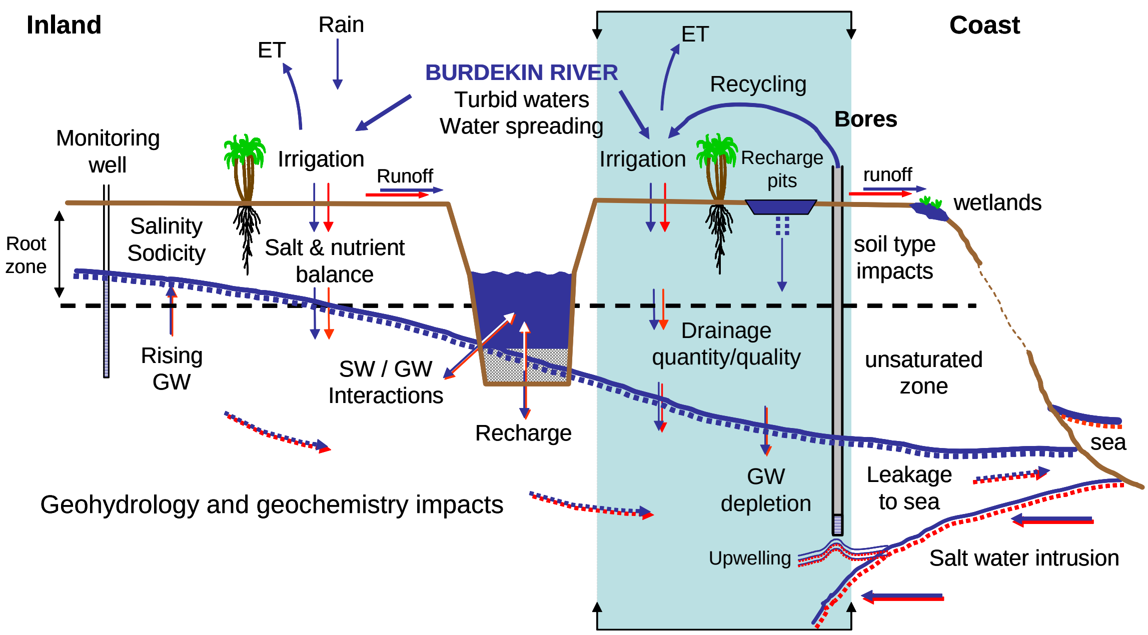

Figure 1: Framework showing water balance components and key issues to be addressed when assessing water resources and water management in the lower Burdekin. The shading indicates the major area of focus for this project

Increasing pressure from the community, environmentalists and regulatory bodies has raised questions about some of the current practices and their long-term impacts on water management and subsequent sustainability of the Burdekin delta aquifers. Of particular importance are questions relating to the impacts of current and improved irrigation efficiency on nutrient, salt and chemical loading of the groundwaters. Hence the focus of this work was on quantification of the drainage quantity and quality leaving the rootzone with potential of entering the groundwater system (Figure 1).

The project was closely coordinated with the Queensland Rural Water Use Efficiency Initiative Project "Management of furrow irrigation to improve water use efficiency and sustain the groundwater resource: A case study in the Burdekin region". The cooperation allowed investigation of improved management practices and also enabled more field sites to be established and maintained.

2.0 PROJECT DETAILS

Title: Sustainable management of the Burdekin delta groundwater systems

Duration: 1/10/2000 – 1/11/2003 modified to 1/3/2004

Contracted Research Organisation: CSIRO Land and Water

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Objectives:
The overall aim is to provide a basis for the development of sustainable management strategies for the Burdekin delta groundwater systems. This will be achieved by:

1. gaining a better understanding on how irrigation waters are stored and transported through the unsaturated zone
2. gaining an understanding of the impacts of current and improved irrigation efficiency on "recycling" and "water spreading" and subsequent interactions (if any) with nutrient, salt and chemical loading of the groundwaters
3. developing a conceptual framework and guidelines for improved and more sustainable management of the delta groundwater systems
4. providing some insights into the management of similar groundwater irrigation systems throughout Australia

Milestone number:
4a – Final report
Report on individual milestones for Milestone Report 4a is included in APPENDIX 1

Due date:
1 October 2003 modified to 1 March 2004

Funding:
This project was funded in part by the Land and Water National Program for Sustainable Irrigation, CSIRO, Queensland RWUEI, CRC Sugar, North and South Burdekin Water Boards, and collaborating farmers

Acknowledgements:
The project profited greatly from the input of many people and we thank in particular Gary Ham, Jessica Klok, Chris Chinn, Bob Brandon (BSES, Brandon), Peter Fitch, Aaron Hawdon, David Fanning, Joseph Kemei, Gary Swan, Lachlan Stewart (CLW, Townsville). We also thank Brett Tucker for his support in setting up the project.

Special thanks also to those who served on the Lower Burdekin Initiative Reference Group over the years and helped maintain communications between the project and other districts around the country. They included:

- Mr Bill Lowis, Manager, South Burdekin Water Board, Home Hill
- Mr Graham Laidlow, Manager, North Burdekin Water Board, Ayr
- Mr George Nielson, Chairman Burdekin CANEGROWERS, Ayr
- Mr Andrew Kelly, Manager, Ord Irrigation Cooperative, Kununurra
- Mr Noel Merrick, National Centre for Groundwater Management, University of Technology, Sydney
- Mr Bruce Teede, Carnarvon Water Advisory Committee, Carnarvon
- Mr Murray Chapman, Program Coordinator, Land and Water Australia National Program for Sustainable Irrigation, Benalla
- Mr Brett Tucker, Program Coordinator, NPIRD, Canberra
- Mr Tim Cummins, Consultant, Rosebank, NSW
- Mr Ted Gardner, Department of Natural Resources, Mines and Energy, Brisbane
- Dr Don Yule, Department of Natural Resources, Mines and Energy, Brisbane

We benefited greatly from interactions and meetings with the Reference Group and recommend that efforts are made to maintain a Reference Group for the lower Burdekin with members from across Australia.

3.0 ABSTRACT

The Burdekin delta is a major irrigation area in north Queensland with approximately 38,000 ha of sugarcane and other crops irrigated from shallow groundwater supplies.

Since the mid-1960's, water levels in the Burdekin Delta aquifer have been successfully managed by the North and South Burdekin Water Boards. Aquifer management methods developed locally include *artificial recharge* (diverting river water directly into the aquifer, mainly through recharge pits), *water spreading* (water too turbid for artificial recharge is made available for surface irrigation), and *recycling* (irrigation water that is not used by the crop drains through the soil back to the groundwater).

The Water Board Managers were seeking input on the likely effects of their practices on the long term sustainability of the aquifers as the community, environmentalists and regulatory bodies started to raise questions about the longer term sustainability of water and irrigation management practices around the country. This project therefore focussed on quantification of the drainage quantity and quality leaving the rootzone with potential of entering the groundwater system.

The project selected 10 sites representing major soil types. Water balance methods combined with solution sampling were used to determine deep drainage amount and quality over three seasons (2000 – 2003).

The project produced the first longer term measurements of irrigation application (= aquifer extraction) in the delta. Over the 3 seasons, 10 – 70 ML/ha (1000 – 7000 mm) were applied per season. Between 1 and 50 ML/ha (or 10-60% of irrigation + rainfall) drained beneath the crop root zone. Only weak correlation was found between irrigation, drainage and soil type, indicating that individual farmer management played a large role.

Nitrate-nitrogen levels of 1 – 12 mg/L were found in the irrigation water. When combined with fertilizer dissolution this led to nitrate leaching measurements of 10-200 kg NO_3-N / ha. This indicates that growing a crop without using supplementary fertilizer should be possible in at least some situations.

APSIM-Sugarcane modeling enabled us to run different water/fertilizer management scenarios and suggested that nutrient leaching could be reduced substantially by changing water and/or fertiliser management practices. Of particular benefit was applying fertilizer in the irrigation water (fertigation) which reduced leaching by up to 50%.

Data from the field sites were also "upscaled" using the newly developed Burdekin Delta Soils Map. This method indicated that some 236,000 – 723,000 ML of water and 1,300 – 4,000 t of nitrogen leached annually beneath cane crops in the Delta. These results agreed well with independent estimates provided by the Queensland Natural Resources, Mines and Energy Burdekin Delta Groundwater Model, and the initial desktop study of this project.

The main recommendations suggested by the research are:

i. Increased monitoring of aquifer extraction would enable higher resolution management of the groundwater resource and lessen the threat of salt water intrusion

ii. The nitrate content of irrigation water from bores should be included in fertilizer recommendations, in the same way as soil tests are used. The broader community who use groundwater for drinking purposes also need to be aware of the nitrate levels and have their water tested on a regular basis to ensure it is fit for consumption
iii. More effort is needed to promote the benefits of matching irrigation application with crop water use

The research findings have provided important data that have helped improve our understanding of the Burdekin delta groundwater systems and shown that excess pumping is causing problems for some parts of the delta. Lower pumping rates will decrease fertilizer (and other agrochemical) leaching rates, allow better management of groundwater levels, slow sea water intrusion, help assuage environmental criticism, and reduce expenditure on fertilizer and electricity.

4.0 REPORT AGAINST OBJECTIVES

The broad project objectives were to:

1. gain a better understanding on how irrigation waters are stored and transported through the unsaturated zone

Achieved through a range of experiments and modeling studies which have provided estimates of the various water balance components in clays, sandy loams and sands of the lower Burdekin. Despite the progress that has been made, obtaining accurate measurements of deep drainage at a practical field scale remains a difficult and costly challenge. This needs further work, particularly given the increasing need to monitor and demonstrate that applied land use management practices are not having adverse on- or off-site impacts. It is important to have practical and reliable field methodologies for measuring the quantity and quality of deep drainage to achieve this.

2. gain an understanding of the impacts of current and improved irrigation efficiency on "recycling" and "water spreading" and subsequent interactions (if any) with nutrient, salt and chemical loading of the groundwaters

Achieved through the various measurements carried out at the 10 field sites established as part of this study and assisted with modeling to analyse and extrapolate the field data. The tendency to extract more water from the aquifer than required by the crop is affecting groundwater quality, with the 'excess irrigation' able to leach salts and nitrogen to deeper depths below the root zone. Artificial recharge from river water also adds considerable quantities of salt to the aquifer each year, and lowering of groundwater levels near the coast through excessive pumping can result in seawater intrusion and further decline in groundwater quality. The simple change of applying less water to more adequately meet crop needs would result in less need for aquifer recharge using river water and a reduction in the amount of deep drainage and hence less salt and nitrogen entering the groundwater. The increasing occurrence of rising salinity and nitrogen levels above the ANZECC environmental guidelines standard at various points around the delta are evidence of limitations with some of the current water management practices

3. develop a conceptual framework and guidelines for improved and more sustainable management of the delta groundwater systems

Achieved through development of the framework encapsulated in Figure 1. Development and application of this framework has highlighted the importance of the interconnectedness between the water and solute fluxes and the need to use a systems approach to manage this interconnectedness. To achieve this successfully will require both an individual (farm enterprise) and collective (irrigation scheme) commitment and responsibility. Results of this work have also indicated that setting and meeting local and regional water table targets (both quantity and quality) could provide the key driver needed to ensure implementation of appropriate water and solute management strategies. These findings are now being used in setting targets for the Burdekin Dry Tropics Regional NRM plan

4. provide some insights into the management of similar groundwater irrigation systems throughout Australia

Achieved by i) including Bruce Teede (Carnarvon, WA), Andrew Kelly (Kununurra, NT), and Noel Merrick (University of Technology, Sydney) from around Australia on the Reference Group, to disseminate project results and outcomes through their interactions beyond the Burdekin, and ii) disseminating project results through a wide range of national forums including conference papers, seminar and workshop presentations, trade journal and newspaper articles, and radio. Results of this study will also become more important as future irrigation systems are developed in areas reliant on groundwater systems

5.0 SUMMARY OF METHODS

Site Selection

The primary objective of the experimental sites was to measure variability in irrigation application and deep drainage using water balance methods. Ten sites were selected to cover the major soil groups of the Burdekin delta with reference to the existing rudimentary Burdekin soils map (Figure 2).

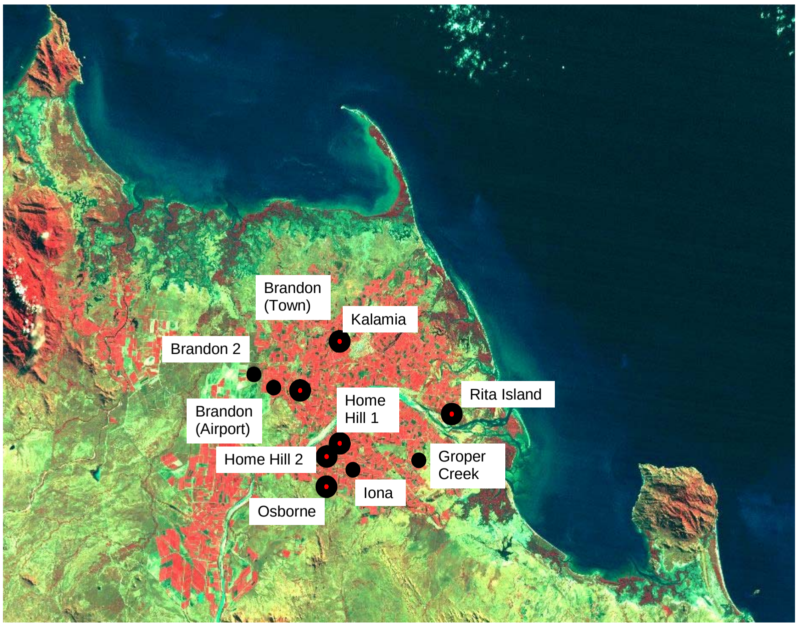

Figure 2. Location of the experimental field sites in the Burdekin delta. Red dots represent comprehensively instrumented sites

Measurements

Irrigation application was measured as a minimum at all sites. Six sites were instrumented to provide more comprehensive information on deep drainage rates and quality. Key instruments were suction samplers which extracted samples of soil water from beneath the crop root zone. All water samples were analysed in the BSES and CSIRO laboratories. Farmers were called upon to record paddock operations such as fertiliser and pesticide applications and flowmeter readings with most other information being logged automatically.

At end of season, yields on all fields were gathered from the mill records and water use efficiencies were calculated using the total irrigation applied.

All fields were sampled for texture/layering and chemistry, and several deep soil cores were taken to the top of the water table to measure the likelihood of the soil to retain nitrogen.

Modeling

The APSIM-Sugarcane model was used to impose different management scenarios on the study sites to identify methods of reducing the amount of nutrient potentially returning to the groundwater.

Upscaling From Field Sites to Whole Of Region

The project used output from the Qld RWUEI funded “Soils Mapping in the Burdekin Delta” project to identify the area of land represented by each field site. Data collected from the research sites over three years were used to put upper and lower bounds on the deep drainage potential of each soil type and these were aggregated to give whole of region ranges.

6.0 SUMMARY OF RESULTS

Irrigation Application and Deep Drainage

The project has been the first to measure irrigation application over a range of soil types in the Burdekin Delta, in the longer term. Applications were generally in the range 10-35 ML/ha over a season (1000-3500 mm) with one outlier at 70 ML/ha (7000 mm). Crop water requirement lies in the 10-15 ML/ha range, depending on length of time between harvests.

Deep drainage ranged from 1 – 50 ML/ha, or 10 – 60 % of applied irrigation plus rain. There was little correlation between soil type and deep drainage amounts pointing to the important variable of management as a major contributor. These irrigation and deep drainage amounts show the process of “recycling” in action.

Water Quality

The amount of nitrogen leaching beneath the cane rootzone varied widely from 12 to 200 kg/ha. One of the reasons for the high loads was the background nitrate content in the irrigation water which varied from 2 – 15 mg/L NO_3-N. Apart from exceeding the ANZECC environmental threshold of 5 mg/L on occasions, this represents an under-utilised resource and an opportunity to help bioremediate the aquifer. *This means that many crops could* *potentially obtain their total nitrogen requirement from the irrigation water*. Farmer trials by BSES are currently underway to demonstrate this finding.

The deep soil cores showed there was little capacity for the soil to retain N on its way through the profile to the groundwater.

Modeling of Field Sites

The modelling showed there was good opportunity for uncoupling the nutrient movement from the water movement. For instance, making a large change from the current practice of applying all fertiliser in one application at the start of the season to applying the fertiliser with the irrigation water (fertigation) reduced the amount of leaching by 50%. The simpler change of applying less water also had significant benefits in reducing nitrate leaching.

Regional Impacts

Upscaling the field site data using the new Burdekin Soils Map indicated a range of 236,000 – 723,000 ML of annual deep drainage (groundwater recharge). The range agrees with that derived from the Burdekin Delta Groundwater Model of 330,000 – 650,000 ML. However, great limitations exist when upscaling from one point in one paddock managed by one grower, to a whole soil type and then a region. The lack of measurements over a broader range of conditions is a severe restriction in obtaining improved estimates of deep drainage.

Using a similar method for nitrogen gives an annual leaching load of 1300 – 4000 t N across the delta. Given the limitations of this method, it is encouraging that the estimate gained by the desktop study in the first part of this project was 2300 t N, well within the upscaled range.

Effects of Excessive Pumping on Groundwater Quality

The data collected by this project and used in conjunction with other issues being investigated by the North and South Burdekin Water Boards would indicate that there are regions in the delta where the combination of high groundwater pumping rates and pump density is affecting the quality of the groundwater.

High nitrate levels (greater than the ANZECC trigger value for long term environmental risk) were found in the irrigation water at five of the six trial sites where these measurements were made. In a similarly distributed sampling trial, Thorburn et al (2003) found that 14% of bores sampled contained nitrate concentrations high enough to cause environmental risk. At least 50% of the nitrate found in Thorburn’s study could be traced back to inorganic sources eg fertiliser.

Eight of the ten trial sites measured were pumping far greater amounts of water than required by the crop. This process involves removing water from depth and moving it to the surface. Previous assumptions have been that water not used by the crop returns to the groundwater to be re-pumped (recycling in Figure 1). With our knowledge of the heterogeneous nature of the aquifer, comprising various clay and sand layers and lenses, this assumption will not hold in many situations. It is possible that intervening layers could divert the excess irrigation water away from the point of extraction, leaving an area of low potential which will be filled by water from elsewhere in the aquifer. In areas closer to the coast, the infilling water may contain higher salt levels, causing increased salinity of the groundwater being pumped for irrigation.

In addition to the diversion of return flows, greater pumping of groundwater will also increase direct losses from the system through both evaporation and runoff to the surface drainage system.

The artificial recharge scheme is aimed at replacing these two losses. The scheme has been very efficient at maintaining adequate head in the aquifer to resist sea water intrusion and provide irrigation water. However, although river water is regarded as good quality, it is still adding around 1 tonne of salt per hectare per year on average. Surface water supply is not distributed evenly across the delta and so the salt additions are concentrated in areas where demand is greatest ie where there is already water supply or water quality limitations.

The water quality problems now being experienced in small, well defined areas may be due to the combined effects of the artificial recharge scheme bringing salts to the delta for nearly 40 years, combined with the 200 % increase in number of pumps removing water from the aquifer. The effect of salts on the Burdekin aquifer may well be moderated by the climate which provides the potential for large flushing events, although this too needs further investigation. While flushing events may be a positive for salinity mitigation, they may increase the risk of moving more nutrients from the aquifer into marine and freshwater environments.

7.0 POLICY IMPLICATIONS

COAG is requiring communities to change to volumetric charging for all water consumed. Many irrigation areas have already gone through this transition while others are at various stages of making the required changes.

In respect to volumetric use and metering, the Burdekin Delta will find its operations are increasingly misaligned with other irrigation areas and current COAG requirements. The region will need to meet these requirements or negotiate an acceptable alternative with COAG.

Options for decreasing water use involve all or a combination of the following:

i) greater monitoring (soil moisture, crop growth, ET rates, flow metering) and control (timed pump switching) of water use
ii) better matching of field configuration (eg row length) to soil type and condition
iii) changing to more efficient irrigation systems eg sprinkler or drip

All of these options involve capital expenditure. Analyses have shown that under current economic conditions and with current sugar prices, changing to other irrigation systems is not a viable alternative. Also, the demographic of sugarcane growers is not conducive to rapid transition (Greiner et al, 2003).

Due to these factors, we strongly recommend that two instruments be put in place to accompany any major changes to water price or allocation, these being significant Incentive and Education programs. Both initiatives are being used to help other irrigation areas with the transition eg. the Coleambally Land and Water Management Planning Education Program, and Incentives for Catchment Works in the Shepparton Irrigation Region.

Coleambally Irrigation Limited (CIL) has developed a 12 unit education program covering subjects in the areas of agronomic, environmental and business management. To date 70 % of the landholders in the Coleambally Irrigation Area have completed the course and a total of some 12,000 landholder hours have been invested in the program (CIL, 2004).

As part of the incentives in the Shepparton Irrigation Region, whole farm plans have been prepared on 2,800 properties and these cover over 60% of the irrigated area in the region. In the most recent review conducted in 2000, over ninety percent of the landowners reported that they were satisfied with their plans and the majority indicated that if they purchased another property, one of the first activities would be to prepare a whole farm plan. In 2003 more than $2.5M of incentives were allocated on a cost share basis with farmers (Sampson and Lawler, 2004)

Development of various incentives (regulated and unregulated (market based instruments)) likely to support change and implementation of more sustainable irrigation and water management strategies that support profitable farming enterprises in the lower Burdekin will be explored further through the new CRC for Irrigation Futures.

8.0 RECOMMENDATIONS

Key recommendations arising from this project include:

- Far more widespread, if not universal, monitoring of groundwater pumping and groundwater quality would allow higher resolution management of the aquifer water levels and quality
- The nitrate content of groundwater used for irrigation needs to be incorporated in fertiliser recommendations, in addition to currently employed soil testing. Growers should therefore have their bore water tested for NO_3 at least annually, and BSES are now offering this service for growers. The broader community who use groundwater for drinking purposes also need to be aware of the nitrate levels and have their water tested on a regular basis to ensure it is fit for consumption
- A greater connection is needed between crop water use and irrigation application. This can only have economic, environmental and lifestyle (time) benefits to the growers and larger community

9.0 COMMUNICATION ACTIVITIES

The findings of this project have been widely publicised (see APPENDIX 2), including:

1. Regular 4-8 weekly Lower Burdekin Initiative (LBI) meetings
2. The LBI web site (http://www.clw.csiro.au/lbi/)
3. Conference Papers (>15)
4. Seminar and workshop presentations (>10)
5. Trade Journal and newspaper articles (>15)
6. Radio (>5)
7. Farmer letters (2)
8. Field days (3)
9. Project summary brochure (will be provided to Burdekin stakeholders and made available on the LBI website by mid 2004)

Key project publications are included in full in APPENDIX 3.

The Lower Burdekin Initiative (LBI)

In addition to the biophysical investigation carried out through this project, considerable additional effort was invested in building partnerships with the local community and resource managers through the LBI.

The need for the LBI was originally suggested by the locals as a way to ensure the research efforts of a range of agencies were well coordinated and collaborations well informed, and the time demands on the locals minimised wherever possible.

The LBI evolved into a dynamic forum for discussion of the research process, research results, communication strategies, and implications to management and policy, meeting every 4-8 weeks. The water managers and collaborating farmers became very involved in questioning data collection and interpretation, experimental design, and information dissemination. Ultimately, the capacity of both the researchers and collaborators has been raised immeasurably through the process, benefiting present and future research.

The LBI also conducted larger annual workshops and forums, with details of the 2002 and 2003 events available via the LBI website (http://www.clw.csiro.au/lbi/)

The LBI has resulted in greater understanding of the need for a systems approach to water and irrigation management in the lower Burdekin, and improved collaboration in identifying gaps and priorities and submission of proposals to address the gaps. There are currently several groundwater studies building on the knowledge generated through this project. A new set of research projects covering a broad range of issues relating to irrigation and water management in the lower Burdekin is also being coordinated through the LBI process for commencement in July 2004.

10.0 REFERENCES

CIL (Coleambally Irrigation Limited) (2004) Coleambally Annual Environmental Report 2003. Coleambally Irrigation Limited, Coleambally, NSW

Greiner, R., Stoeckl, N., Stokes, C., Herr, A. & J. Bachmaier (2003) Natural resource management in the Burdekin Dry Tropics: social and economic issues. Report for the Burdekin Dry Tropics NRM Board. Northern Futures, CSIRO Townsville

Sampson, K. & D. Lawler (2004) The role of whole farm planning in increasing the adoption of improved irrigation management in the Shepparton irrigation region. In Irrigation 2004 : Coming of Age. Conference of the Irrigation Association of Australia, Adelaide, 11-13 May 2004

Thorburn, P.J., Biggs, J.S., Weier, K.L. & B.A. Keating (2003) Nitrate in groundwaters of intensive agricultural areas in coastal Northeastern Australia. Agric Ecosyst Environ 94:49–58

APPENDICES

APPENDIX 1

Report on individual milestones for Milestone Report 4a

1. Steering committee meetings as required

Achieved. The Lower Burdekin Initiative Reference Group met as scheduled 1 May 2003. Lower Burdekin Initiative technical meetings were also held on a 4-8 weekly basis at CANEGROWERS, Ayr, which enabled good research coordination, ongoing discussion of results with stakeholders, and if need be modification of work plans and priorities.

2. Communication/ promotion activities as per strategy

Achieved. Key communications over the past year are summarised below:

- Posters were presented at the Giru Show (10/03) and BSES Field Days (03/03)
- Two papers were presented at the 2003 Australian Society of Sugarcane Technologists Conference (ASSCT) in Townsville (04/03)
- The project activities were discussed with a broad range of people through a project site visit as part of the 2003 ASSCT post conference tour (04/03)
- Two papers were presented at the MODSIM 2003 conference in Townsville on modelling and simulation (07/03)
- A summary of all project findings were presented to participating farmers in conjunction with BSES (03/04)
- Project results have been presented and discussed at a number of international forums over the last 2 years, including
  - HortResearch, Palmerston North, New Zealand
  - American Society of Agronomy, USA
  - University of Pretoria and Water Research Commission, South Africa
  - Challenge Program, IRRI, Philipines
- Project field sites have been visited on numerous occasions by a broad range of visitors to the region, including visitors from the USA, the UNESCO HELP program, Germany etc
- Project findings and results have been presented and discussed on a regular basis through the 4-8 weekly Lower Burdekin Initiative (LBI) meetings held mainly at the Canegrowers offices in Ayr. More detail about the LBI and access to some of the key reports and papers can be obtained via the LBI web page at: http://www.clw.csiro.au/lbi/

3. Compare field / modelled data with original mass balance estimates

Achieved. Details are included in the next section, which shows that the field and modeled data obtained through the course of the project are consistent with the original estimates provided in the Milestone 2 report.

4. Link field/modelling data with NR&M groundwater model and work with NR&M on scenario analyses of the long term impacts of groundwater loading on sustainability of the delta aquifer (Outputs will depend on quality of the DNR groundwater model).

Achieved within the limitations of the groundwater model not been completed by NRM&E, and therefore an inability to obtain results of various scenario analyses. It is envisaged that scenarios will focus on possible hydrological consequences of changes to resource allocation, which may include:

i. changes in ground and surface water allocation
ii. allocations to a variety of other (than agricultural) users
iii. impacts of potential new area developments
iv. major changes to whole of region extraction patterns brought about by changing the mix of crops, extension programs or regulation

Development of the NR&M groundwater model has not proceeded to plan as discussed at the beginning of the project and this has proved a real difficulty for this and other associated projects. Development of the model in place at the time of project commencement has now ceased and a new 'supermodel' has been started which will encompass both the Delta and Burdekin Haughton Water Supply System areas. The current knowledge from both models is being incorporated into the new model which is based on a smaller (higher resolution) grid. As always, a more detailed cut down version of the model will be needed to address locally specific issues. We have been advised that the new 'supermodel' is due for release to address the Burdekin Water Resource Plan by late 2004.

The Burdekin Delta Soils Mapping project was due for delivery in August 2003 and is currently being finalised. While some data from the map has been made available and used in this project to estimate data needed for the final report as discussed below, the actual map needed by this project has not been released, as it still needs internal review by NRM&E. Once finalised the soils map will allow visualisation of areas at risk of leaching, better understanding of the link between soil type and groundwater response, and ultimately, delineation of hydrological response units and hence land areas with specific management requirements.

Despite these limitations, considerable progress was made in addressing key sustainability issues as discussed below. The Soils Mapping Project calculated a "Leaching Fraction" for each soil unit using the SALF model and used this to combine units into broad "Water Management Groups" (Table 1), which we were able to use to extrapolate our site specific project data.

Table 1. Information from the Burdekin Delta Soils Mapping project

Water Management Group	Leaching Fraction Range (fraction of Irrigation + Rain)	NBWB (ha)	NBWB (%)	SBWB (ha)	SBWB (%)	Total (%)	Total (ha)	Cane Area
Not applicable eg urban areas/swamps		10683	26	2513	12	21	13195	
Negligible	0.01 - 0.06	10152	24	7513	35	28	17666	14080
Slight	0.12 - 0.26	8598	21	3548	17	19	12146	9650
Moderate	0.29 - 0.4	7461	18	5506	26	21	12967	10310
Marginal	0.49 - 0.52	665	2	568	3	2	1233	990
Severe	> 0.6	4173	10	1644	8	9	5817	4570
Totals		41732	100	21291	100	100	63024	39600

The 10 field sites were allocated to a Water Management Group and the data collected from the sites over three years were used to set upper and lower bounds on the deep drainage potential of each soil type. We are very conscious of the limitations of upscaling from one point, in one paddock, managed by one farmer, to a region, and great care is needed in handling and drawing conclusions from these data. Bounding the estimates at least gives an indication of the likely variability.

Results of these analyses show a large range from 236,000 – 723,000 ML deep drainage over the whole delta region (Table 2). Again, it is important to note that the bounds are probably unrealistic extremes, as actual on-farm practice will result in a mixture of lower and higher deep drainage rates, and it is unlikely that there will be many cases of low-low or high-high combinations. However, the absence of better spatial data restricts a more precise estimate. Despite these limitations, the range is similar to that derived from the Burdekin Delta Groundwater Model (330,000 – 650,000 ML; Arunakumaren 2000) which is encouraging given the very different methods employed with each estimate. The quality of these data could be improved if better pumping information was available. Various options for gaining improved data are available through calibrating pump power consumption so that this can be used to provide better estimates of the amount of water being pumped, or directly by installing meters.

The data in Table 2 shows that up to 30% of the total deep drainage could be coming from just 9% of the total area (given a **severe** rating in Table 1). This gives a clear target for focusing initial effort to decrease deep drainage.

Table 2. Upscaled regional deep drainage estimates

Water Management Group	Measured Deep Drainage (ML/ha)		Soil unit Drainage Volumes (ML)	
	Low	High	Low	High
Non cane area	1	1	13195	13195
Negligible	1	5	14180	70900
Slight	5	12	48750	117000
Moderate	5	23	52050	239430
Marginal	15	50	14853	49509
Severe	20	50	93399	233497
Whole region Deep Drainage Volume			236427	723532

Carrying the data through to tonnes of nitrate leached across the region introduces another variable – the local groundwater nitrate concentration which may not be correlated with the soil type. Also, the source of the nitrate may be distant from the point at which the bore water is pumped. With these further limitations in mind, the same procedure as described above was adopted to gain a regional view of the potential for nitrate leaching from the rootzone (Table 3).

The upscaling procedure suggests 1300 - 4000 t N are leaching below the root zone annually in the Burdekin Delta. However, as previously stated, due to the large disparity between the number of samples and scale of sampling, and the upscaled area, great care is needed when handling and interpreting this information. Despite the large limitations associated with these data it is again worth noting that the N excess calculated in the initial, desktop part of this study (2300 t N) is within the estimated range. Again, two unrelated methods have provided similar estimates.

Clearly, better water and fertiliser management are key aspects in further improving the sustainability of irrigation in the Burdekin Delta.

Table 3. Upscaled regional estimates of nitrate-nitrogen leaching

	Measured/interpolated Nitrate Leaching (kg/ha)		Soil unit nitrate leaching (t)	
Water Management Group	Low	High	Low	High
Negligible	8	13	113	184
Slight	15	86	146	839
Moderate	49	125	510	1562
Marginal	42	150	42	198
Severe	100	200	467	1167
Whole region nitrogen leaching			1278	3950

5. Identify and disseminate critical outcomes that can assist with policy directions/decisions

Achieved within the limitations of not having access to a range of scenarios (examples given under dot point 4 above) that were to be generated by the groundwater model.

Effect of Excessive Pumping on Groundwater Quality

The data collected by this project and used in conjunction with other issues being investigated by the North and South Burdekin Water Boards would indicate that there are regions in the delta where the combination of high groundwater pumping rates and pump density is affecting the quality of the groundwater.

High nitrate levels (greater than the ANZECC trigger value for long term environmental risk) were found in the irrigation water at five of the six trial sites where these measurements were made. In a similarly distributed sampling trial, Thorburn et al (2003) found that 14% of bores sampled in the lower Burdekin contained nitrate concentrations high enough to cause environmental risk. At least 50% of the nitrate found in Thorburn's study could be traced back to inorganic sources eg fertiliser.

Eight of the ten trial sites measured were pumping far greater amounts of water than required by the crop. This process involves removing water from depth and moving it to the surface. Previous assumptions were that water not used by the crop returns to the groundwater to be re-pumped (recycling in Figure 1). With our knowledge of the heterogeneous nature of the aquifer, comprising various clay and sand layers and lenses, this assumption will not hold in many situations. It is possible that intervening layers could divert the excess irrigation water away from the point of extraction, leaving an area of low potential which will be filled by water from elsewhere in the aquifer. In areas closer to the coast, the infilling water may contain higher salt levels, causing increased salinity of the groundwater being pumped for irrigation.

In addition to the diversion of return flows, greater pumping of groundwater will also increase direct losses from the system through both evaporation and runoff to the surface drainage system.

The artificial recharge scheme is aimed at replacing these two losses. The scheme has been very efficient at maintaining adequate head in the aquifer to resist sea water intrusion and provide irrigation water. However, although river water is regarded as good quality, it is still adding around 1 tonne of salt per hectare per year on average. Surface water supply is not distributed evenly across the delta and so the salt additions are concentrated in areas where demand is greatest ie where there is already water supply or water quality limitations.

Water quality problems now being experienced in small, well defined areas may be due to the combined effects of the artificial recharge scheme bringing salts to the delta for nearly 40 years combined with the 200% increase in number of pumps removing water from the aquifer. The effect of salts on the Burdekin aquifer may well be moderated by the climate which provides the potential for large flushing events, although this too would need further investigation. While flushing events may be a positive for salinity mitigation, they may increase the risk of moving more nutrients from the aquifer into marine and freshwater environments.

Lack of pumping data is a severe limitation to the ability to monitor and manage water movement through the aquifer. Good data would enable optimisation of pumping density, rates and installation depth to protect the aquifer water quality. Where optimisation required a decrease in the volume of water available to the crop then other water sources may be required eg surface water.

Policy Implications

COAG is requiring communities to change to volumetric charging for all water consumed. Many irrigation areas have already gone through this transition while others are at various stages of making the required changes.

In respect to volumetric use and metering, the Burdekin Delta will find its operations are increasingly misaligned with other irrigation areas and current COAG requirements. The region will need to meet these requirements or negotiate an acceptable alternative with COAG.

Options for decreasing water use involve all or a combination of the following:

i) greater monitoring (soil moisture, crop growth, ET rates, flow metering) and control (timed pump switching) of water use
ii) better matching of field configuration (eg row length) to soil type and condition
iii) changing to more efficient irrigation systems eg sprinkler or drip

All of these options involve capital expenditure. Analyses have shown that under current economic conditions and with current sugar prices, changing to other irrigation systems is not a viable alternative. Also, the demographic of sugarcane growers is not conducive to rapid transition.

Due to these factors, we strongly recommend that two instruments be put in place to accompany any major changes to water price or allocation, these being significant Incentives and Education programs. Both initiatives are being used to help other irrigation areas with the transition eg. the Coleambally Land and Water Management Planning Education Program, and Incentives for Catchment Works in the Shepparton Irrigation Region.

A number of these issues will be explored further through the CRC for Irrigation Futures.

6. Prepare draft final report for steering committee

Achieved. Early draft sections of the final report were provided to various members of the steering committee (Murray Chapman, George Nielson, Bill Lowis, Graham Laidlow, Andrew Kelly) for discussion/comment, especially regarding communicating the key messages

7. Prepare final report to LWA including steering committee amendments

Achieved. Feedback from the Steering Committee has been addressed and incorporated in delivering the final report.

APPENDIX 2

Project publications

Conference Papers:

1. Klok, J.A., Charlesworth, P.B., Ham, G.J. & K.L. Bristow. 2004. Effects of irrigation on deep drainage and nitrate leaching in the Burdekin delta. Irrigation Association of Australia (IAA) National Conference, 11-15 May 2004, Adelaide

2. Bristow, K.L., Charlesworth, P. B., Narayan, K., Stewart, L. & J.W. Hopmans. 2003. Improving water and nutrient management in the lower Burdekin, north Queensland. ASA-SSSA National Conference, 2-6 November, Denver, Colorado, USA. (Agron. Abstr. 2003 CD-ROM)

3. Bristow, K.L., Charlesworth, P. B., Narayan, K., Stewart, L., Cook, F.J. & J.W. Hopmans. 2003. A framework for improving water management in the lower Burdekin, north Queensland. In: Post, D.A. (Ed), MODSIM 2003 International Congress on Modelling and Simulation. Volume 1: 206-211. Modelling and Simulation Society of Australia and New Zealand, July 2003

4. Stewart, L., Charlesworth, P.B. & K.L. Bristow, 2003. Estimating nitrate leaching under a sugarcane crop using APSIM-SWIM. In: Post, D.A. (Ed), MODSIM 2003 International Congress on Modelling and Simulation. Volume 1: 218-223. Modelling and Simulation Society of Australia and New Zealand, July 2003

5. Klok, J.A., Charlesworth, P.B., Ham, G.J. & K.L. Bristow. 2003. Management of furrow irrigation to improve water use efficiency and sustain the groundwater resource: Preliminary results from a case study in the Burdekin delta. In: Proc. Aust. Soc. Sugar Cane Technol. Vol 25, 7 pp.

6. Charlesworth, P.B., Bristow, K.L., Stewart, L.M., Narayan, K. A. & R. Greiner. 2003. The Lower Burdekin Initiative – water management practices to support regionally sustainable communities. In: Proc. Aust. Soc. Sugar Cane Technol. Vol 25, 8 pp.

7. Charlesworth, P.B., Narayan, K.A., Bristow, K.L., Carthew, M., Lowis, B., Laidlow, G. & R. McGowan. 2002. The Burdekin delta – Australia's oldest artificial recharge scheme. ISAR-4, 4th International Symposium on Artificial Recharge, 22-26 September 2002, Adelaide

8. Bristow, K.L. & P.B. Charlesworth. 2002. Effective water management vital to the long-term economic viability of the lower Burdekin. In: Proceedings of the ANCID Conference, 1-4 September 2002, Griffith, NSW, Australia (Proceedings on CD)

9. Charlesworth, P.B., Chinn, C., Bristow, K.L. & G. Ham. 2002. Healthy crop and healthy groundwater: Sugarcane in the Burdekin delta. Irrigation Association of Australia (IAA) National Conference, 22-24 May 2002, Sydney

10. Qureshi, M.E., Harrison, S.R., Wegener, M.K. & K.L. Bristow. 2002. Irrigation water

pricing and farm profitability in the Burdekin delta sugarcane area. Irrigation Association of Australia (IAA) National Conference, 22-24 May, Sydney

11. Qureshi, M.E., Charlesworth, P.B., Bristow, K.L. & M.K. Wegener. 2002. Profitability of growing sugarcane under alternative irrigation systems in the Burdekin delta. Proc. Aust. Sugar Cane Technol. Soc. 24:107-112.

12. Qureshi, M.E., Wegener, M.K., Harrison, S.R. & K.L. Bristow. 2001. Economic evaluation of alternative irrigation systems for sugarcane in the Burdekin delta in north Queensland, Australia. In: Brebbia, C.A., Anagnostopoulos, P., Katsifarakis, K. & A.H-D. Cheng (Eds.).Water Resources Management, WIT Press, UK (ISBN 1-85312-880-5), pp. 47-57.

13. Qureshi, M.E., Wegener, M.K., Harrison, S.R. & K.L. Bristow. 2001. Economic evaluation of alternative irrigation systems for sugarcane in the Burdekin delta in north Queensland, Australia. In: Brebbia, C.A., Anagnostopoulos, P., Katsifarakis, K. & A.H-D. Cheng (Eds.).Water Resources Management, WIT Press, UK (ISBN 1-85312-880-5), pp. 47-57.

14. Bristow, K.L., Charlesworth, P.B., Lowis, Laidlow, G., & P. Gilbey. 2001. The Lower Burdekin Initiative: An industry/science partnership to facilitate improved water management. In: Proceedings of the ANCID Conference, 29th July – 1 August, Bunbury, Western Australia, Australia. 11 pages.

15. Qureshi, M.E., Mallawaarachichi, T., Wegener, M.K., Bristow, K.L., P.B. Charlesworth & S. Lisson. 2001. Economic evaluation of alternative irrigation practices for sugarcane production in the Burdekin delta. Australian Agricultural and Resource Economics Society 45th Annual Conference, 23-25 January 2001, Adelaide, Australia

16. Bristow, K.L., Charlesworth, P.B., McMahon, G.A., Arunakumaren, J., Bajracharya, K., Ham, G., Sutherland P., Laidlow, G., Lowis, B., Nielson, G., Qureshi, E., Christianos, N., Enderlin, N. & S. Eldridge. 2000. Towards a more integrated approach to water management in the Burdekin delta irrigation area. ANCID Conference, 10-13 September 2000, Toowoomba, Australia. 12 pages.

Seminar and Workshop Presentations:

1. Bristow, K.L. 2004. The Lower Burdekin Initiative. Burdekin Dry Tropics Board Public Meeting, 4th February 2004, Ayr

2. Bristow, K.L. 2003. Improving access to and management of limited water supplies through on-farm water storages. 5 December 2003, University of Pretoria, Pretoria, South Africa

3. Bristow, K.L. 2003. Irrigation within a broader regional water management framework. CGIAR Challenge Program on Water for Food, Theme I Crop-Water Productivity Improvement Workshop on "Improving water and food productivity at different scales in drought-prone and saline areas", 18-20 November 2003, IRRI, Los Baños, Philippines

4. Bristow, K.L. 2003. Northern Australia Irrigation Futures: Building a basis for developing sustainable irrigation across northern Australia. Land and Water Australia Sustainable Irrigation Program Investors Forum, 19 October, Shepparton, Victoria, Australia

5. Bristow, K.L. 2003. Improving water and solute management in the lower Burdekin. 1 September 2003, University of Pretoria, Pretoria, South Africa

6. Bristow, K.L. 2003. Salinity within an integrated water management framework. Water Industry Workshop, Organised by the Water Industry Training Association, 30th July 2003, Townsville, Queensland.

7. Bristow, K.L. 2003. The Lower Burdekin Initiative. BBIFMAC Reunion, 22 July 2003, Ayr, Queensland.

8. Bristow, K.L. 2002. Water issues in the lower Burdekin. Workshop on "Developing a framework to help guide sugar industry response to external demands for water reform in the Lower Burdekin", CRC Sugar, 6th December 2002, Ayr, Queensland

9. Bristow, K.L. 2002. Understanding the biophysical issues – the lower Burdekin. CSR-CSIRO Workshop on 'Underpinning a productive cane industry with sound environmental practices', 9 September 2002, Townsville

10. Bristow, K.L. 2001. The Lower Burdekin Initiative. Lower Burdekin Landcare AGM, Brandon (2 October 2001)

11. Bristow, K.L. 2001. The Lower Burdekin Initiative – towards a more integrated approach to water management. Australian Water Association (AWA) Meeting. Townsville (11 April 2001).

Trade Journals and Newspaper Articles:

1. Bristow, K.L. 2002. Burdekin healthy but under scrutiny. Townsville Bulletin (27 August 2002)

2. Bristow, K.L. 2001. Partnership makes progress in the lower Burdekin. Land and Water Link Number 11, CSIRO Land and Water, Adelaide, Australia. ISSN No. ISSN No.1329–3389. pp.11-12

3. Bristow, K.L. 2001. New Initiative in the Burdekin. Farming Ahead, No. 109. page 36.

4. Bristow, K.L. 2001. A waste not and want not attitude – managing wastewater. Townsville Bulletin (25 August 2001)

5. Bristow, K.L. 2001. Water the lifeblood of the lower Burdekin area. Townsville Rural Bulletin, Townsville (11 April 2001)

6. Bristow, K.L. 2001. Locals show off Initiative. Ayr Advocate, Ayr (1 April 2001)

7. Bristow, K.L. 2001. Burdekin groundwater sustainability initiative. Water Wheel (May 2001) pp. 4.

8. Bristow, K.L. 2001. New initiative in the Burdekin. Farming Ahead No. 109 (January 2001) pp. 36.

9. Bristow, K.L. 2000. Burdekin groundwater sustainability initiative. Land and Water Link Number 7, CSIRO Land and Water, Adelaide, Australia. ISSN No. 1329-3389. pp.4-5.

10. Charlesworth, P.B. 2000. New drainage meter for burdekin initiative. Australian Sugarcane. 4(4):13-14

11. Bristow, K.L. & J. Crough. 2000. Managing the Burdekin aquifer. Australian Sugarcane. 4(4):10-12.

12. Bristow, K.L. 2000. Growers help with Burdekin Delta probe. Australian Canegrower, July 2000, Vol. 22, No.15, p.17.

13. Bristow, K.L. 2000. New Initiatives in the Burdekin Delta Irrigation Area. Australian Canegrower May 2000.

14. Charlesworth, P. May 2001. Rural Bulletin Townsville. Computers fine-tuning water usage on farms. p18.

15. Bristow, K.L. April 2001. Rural Bulletin Townsville. Water the lifeblood of lower Burdekin area.

16. Mann, Kevin. April 2001. Ayr Advocate. Locals show off initiative.

Radio:

1. Bristow, K.L. 2002. Expert urges recharging of aquifers. ABC QLD Country Hour (8 October 2002)

2. Bristow, K.L. 2002. Water efficiency important. ABC QLD Country Hour (10 October 2002)

3. Bristow, K.L. 2001. Water management in the lower Burdekin – Irrigation / Salinity. ABC Radio Townsville (20 June 2001)

4. Bristow, K.L. 2001. The Lower Burdekin Initiative. ABC Radio Townsville (9 May 2001)

5. Bristow, K.L. 2000. The Burdekin Initiative: Understanding Water Related Issues. ABC Radio Karratha (WA Country Hour) (20 December 2000)

APPENDIX 3

Key project publications (listed chronologically) included as part of the report

Klok, J.A., Charlesworth, P.B., Ham, G.J. & K.L. Bristow. 2004. Effects of irrigation on deep drainage and nitrate leaching in the Burdekin delta. Irrigation Association of Australia (IAA) National Conference, 11-15 May 2004, Adelaide

Bristow, K.L., Charlesworth, P. B., Narayan, K., Stewart, L., Cook, F.J. & J.W. Hopmans. 2003. A framework for improving water management in the lower Burdekin, north Queensland. In: Post, D.A. (Ed), MODSIM 2003 International Congress on Modelling and Simulation. Volume 1: 206-211. Modelling and Simulation Society of Australia and New Zealand, July 2003

Stewart, L., Charlesworth, P.B. & K.L. Bristow, 2003. Estimating nitrate leaching under a sugarcane crop using APSIM-SWIM. In: Post, D.A. (Ed), MODSIM 2003 International Congress on Modelling and Simulation. Volume 1: 218-223. Modelling and Simulation Society of Australia and New Zealand, July 2003

Klok, J.A., Charlesworth, P.B., Ham, G.J. & K.L. Bristow. 2003. Management of furrow irrigation to improve water use efficiency and sustain the groundwater resource: Preliminary results from a case study in the Burdekin delta. In: Proc. Aust. Soc. Sugar Cane Technol. Vol 25, 7 pp.

Charlesworth, P.B., Bristow, K.L., Stewart, L.M., Narayan, K. A. & R. Greiner. 2003. The Lower Burdekin Initiative – water management practices to support regionally sustainable communities. In: Proc. Aust. Soc. Sugar Cane Technol. Vol 25, 8 pp.

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Bristow, K.L., Charlesworth, P.B., McMahon, G.A., Arunakumaren, J., Bajracharya, K., Ham, G., Sutherland P., Laidlow, G., Lowis, B., Nielson, G., Qureshi, E., Christianos, N., Enderlin, N. & S. Eldridge. 2000. Towards a more integrated approach to water management in the Burdekin delta irrigation area. ANCID Conference, 10-13 September 2000, Toowoomba, Australia. 12 pages.