A Framework for Improving Water Management in the Lower Burdekin

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Abstract: The lower Burdekin in tropical north Queensland is one of Australia's premier irrigation districts with a reputation for producing some of the highest yields and highest quality sugarcane. Its success to date has been based on favorable climatic and soil conditions and easy access to unlimited water. There is now increasing pressure within society to change the way water is valued, allocated, and managed, and within the lower Burdekin there are emerging questions about the long-term implications of current or changed management practices. 'Internal' drivers for change include salinity associated with rising water tables, concern about surface and groundwater quality, and threats of seawater intrusion. 'External' drivers for change include the Commonwealth of Australian Governments Water Reform Agenda and development and implementation of a) the Queensland Water Resource Plans and local Land and Water Management Plans and b) the Great Barrier Reef Protection Plan involving setting and meeting water quality targets. Addressing these issues and positioning the lower Burdekin for a viable and profitable future requires an integrated approach to water management. In this paper we discuss progress in developing a "framework" to help integrate various research activities aimed at improving understanding and management of water and solute (salt, nutrient, agro-chemical) in the lower Burdekin. We highlight the key biophysical processes involved and various modeling activities being undertaken to address surface and groundwater quality and salinisation processes associated with irrigation and seawater intrusion. We suggest 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. Our paper also sets the scene for more detailed discussions of specific areas of work being carried out in the lower Burdekin.

Keywords: *Irrigation, water quality, targets, sugarcane, lower Burdekin*

1. INTRODUCTION

The lower Burdekin (Figure 1), one of Queensland's premier irrigation areas, has a reputation for producing some of the highest yields and highest quality sugarcane in Australia. It is situated in the dry tropics on the northeast coast of Queensland, Australia, approximately 90 kilometres southeast of Townsville (Figure 1). It has some 80,000 ha of irrigated sugarcane and other crops and is dependent on access to large quantities of good quality water.

There are currently three different 'management zones' in the lower Burdekin (Figure 1). The Burdekin-Haughton Water Supply Scheme (BHWSS) lies mainly to the north and west of the Burdekin River. It is underlain to a significant extent by relatively shallow groundwater systems, and is managed by SunWater, a government owned corporation. Nearly all of the remaining irrigated area falls within the Burdekin delta system, which lies closer to the coast on both the north and south side of the Burdekin River. These areas are managed by the North and South Burdekin Water Boards, respectively, which are autonomous Boards independently funded by industry. The Burdekin delta is unique in that (1) it overlies shallow major groundwater supplies which are used for irrigation, (2) it is situated in close proximity to environmentally sensitive wetlands, waterways, estuaries, and the Great Barrier Reef, and (3) water pricing and water management practices have evolved in response to local needs. Details of the Burdekin delta system and operations of the two Water Boards are described by Bristow et al. (2000) and McMahon et al. (2000). While the Delta groundwater systems are connected to the BHWSS aquifers the strength of the link has not yet been ascertained.

As in other parts of the world irrigation in the lower Burdekin is facing increasing scrutiny by governments, environmentalists and other community groups who are questioning the way water is allocated and managed. They are demanding changes to ensure that water is well managed and that the potential impacts of excess solutes (salts, nutrients, agro-chemicals) that enter the river and groundwater systems and near shore marine environments are minimised. A recent

GBRMPA working group defined 10-year water quality targets (2011) for the entire Great Barrier Reef catchment, which include a 38% reduction in sediment, 39% reduction in nitrogen, 47% reduction in phosphorus, a 30-60% reduction in chlorophyll, and a reduction in detectable levels of heavy metals and pesticides (GBRMPA 2001). There is currently debate about the need for targets and the actual values, but based on what is happening internationally, water quality targets for all receiving waters (surface and groundwaters) are inevitable. It is important therefore that the lower Burdekin community plays a lead role in helping develop appropriate targets and associated monitoring systems to ensure compliance with agreed targets.

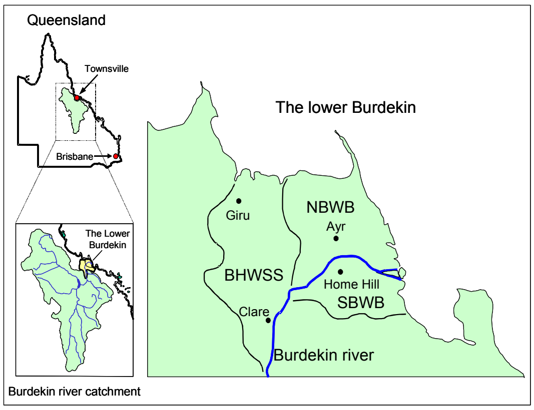

Figure 1 Locality map showing the lower Burdekin and indicative areas associated with the Burdekin Haughton Water Supply Scheme (BHWSS), North Burdekin Water Board (NBWB) and South Burdekin Water Board (SBWB)

Addressing water quality targets and other water and natural resource management requirements will require ongoing assessment and improvement of all land, water, and irrigation practices, which must be optimised to meet both production and environmental goals. The task is multi-faceted, complex, and beyond the capability of one individual, or discipline, or organisation. It will require new strategies and partnerships, and in some cases new science to address current and emerging issues. The Lower Burdekin Initiative (LBI) (Bristow et al. 2001) started this process by bringing a range of organisations together in an industry / science partnership, and while good progress has been made, much remains to be done (Charlesworth et al., 2003). In this paper we review some of the key issues and drivers. We highlight in particular the need for adoption of a more holistic, systems approach involving both modeling and measurement to improve understanding of the overall system, and where necessary, support development and implementation of changed land and water management practices. In doing this we also help set the framework for more detailed discussions of specific areas of work (eg Narayan et al. 2003; Stewart et al. 2003; Cook et al. 2003; Greiner et al. 2003).

2. WATER AND IRRIGATION MANAGEMENT

The rivers, groundwater systems (aquifers) and wetlands of the lower Burdekin are key assets that serve as critical water storage and supply systems for the region. Excess withdrawals from the delta groundwater systems led to establishment of the North and South Burdekin Water Boards in the mid 1960's to manage their replenishment (Charlesworth et al. 2002). The Boards use a number of strategies to achieve this, including the use of sand dams in the Burdekin River and a series of distribution channels and natural waterways together with a large number of recharge pits. The sand dams are used to help maintain practical operating levels at river pump stations by containing releases from upstream storages. Farm water practices such as 'recycling' (where excess irrigation returns through the soil back to the groundwater), and 'water spreading' (where water too turbid for the recharge pits is made available as surface water for irrigation) or direct pumping from recharge channels to farms in some distal aquifer zones have also evolved to play an integral role in the management of the groundwater systems (Bristow et al. 2000).

A major concern in recent years has been the realisation that there is insufficient data, knowledge and understanding of the interactions between current scheme and farm activities and groundwater quantity and quality and other potential offsite impacts. It is therefore difficult to assess whether current practices and continued use, or increased use, of the groundwaters are sustainable in the long-term.

When addressing these issues and contemplating making changes to the way water and irrigation is managed, it is essential that we take a systems approach and be fully aware of the interconnectedness of the various water and solute balance components (flows and storages) (Figure 2). Considerable effort has and is going into developing this understanding, not just of the interconnectedness, but also of how the interconnectedness should be managed. Depending on which part of the lower Burdekin one is dealing with, issues that need addressing include water quality, rising groundwater levels, salinity, nutrient leaching, groundwater pollution, falling water tables (groundwater depletion), and salt-water intrusion, amongst others (Figure 2).

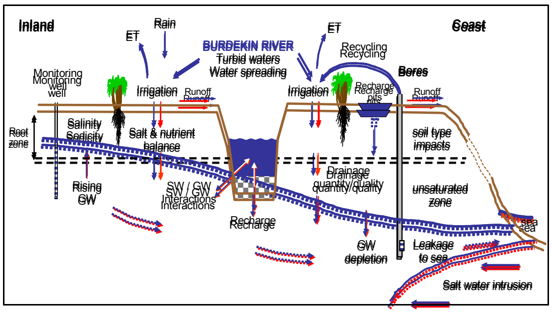

Figure 2 Schematic showing interconnectedness of water and solute balance terms and key issues involving water resources and water management in the lower Burdekin (ET = evapotranspiration; SW = surface water; GW = groundwater)

As with most irrigation schemes worldwide, effective management of solutes (salts, nutrients, agro-chemicals) remains a challenge. In the lower Burdekin, all three forms of salinity need attention: 1) dryland salinity in the upper catchment, because it impacts on the quality of water entering the lower Burdekin which is used for irrigation and/or to recharge the aquifers, 2) salinity associated with irrigation and rising groundwaters, which is already causing problems in some localised areas, and 3) salinity associated with salt-water intrusion at the land-ocean interface. Salt water intrusion is particularly important in the lower Burdekin because of its dependence on groundwater supplies for irrigation, and the very small change in elevation across the delta. This could make it difficult to establish and maintain adequate groundwater levels to ensure the salt-water wedge is subjected to a sufficient pressure head to push the seawater back once it has penetrated inland.

The role of the Burdekin river and other floodplain river and creek systems on the spatial and temporal dynamics of the groundwater systems also need attention. River flows have changed since completion of the Burdekin falls dam in 1987, and the impact of these changes on the surface water – groundwater interactions are not yet fully understood or accounted for. Maintaining more stable river flows could reduce the ‘pumping’ action of the rivers thereby limiting their potential to export salts from the region.

There are also questions as to whether the vast quantities of water associated with wet season events facilitate ‘flushing’ of solutes from the rootzone, and indeed from the groundwater systems, and if so over what time periods. The location of this irrigation scheme adjacent to the ocean suggests that it should be possible to at least manage the salts by flushing the drainage water containing salts into the ocean. If, however, the drainage waters also contain nutrients and agro-chemicals, then strategies to deal with these poor quality waters will be needed to prevent or minimise unwanted off-site impacts.

What has become clear from our work is the need to set and meet local and regional water table targets, in terms of quantity (water table depths) and quality. While these will need to be spatially specific, it is not yet clear whether a temporal component will be needed. Providing both farm and scheme managers with water table targets will help guide development of management strategies to achieve these targets. This will no doubt involve a focus on recharge strategies in some parts of the system, and surface and deep drainage management strategies in other parts of the system. Maintaining water table heights and required hydraulic heads near the land-ocean interface will be particularly important in terms of minimising threats of salt water intrusion. This may require rethinking the number and location of current production bores, and if need be their removal along the coastal fringe. If this were to happen, it would require a change in irrigation practice involving greater reliance on surface water supplies to these parts of the system. Given current understanding based on 2-D cross sectional modeling of saltwater intrusion (Narayan et al. 2003), it is essential that the saltwater wedge not be allowed to migrate inland as it may be difficult or even impossible to push back once it has penetrated inland. A three dimensional density induced flow model is now needed to assess impacts of the large number of pumps (≈ 2000) currently employed in the delta which affect stability of the saltwater interface.

Although progress is being made there is a need for much stronger links between measurement and modeling efforts. Application of inverse modeling is one way to ensure good connection between experiment and modeling and warrants additional effort. We also feel that implementation of improved real time monitoring systems with web based delivery of various forms of data to the managers desktop computer systems will play an vital role in facilitating improvement in overall irrigation and water management.

3. WATER QUALITY – THE FATE OF NITROGEN

In terms of addressing water quality, it is important to understand the N balance and to be able to determine the fate of N applied as part of farming (Figure 3). There are several sources of N, the main source being fertiliser N, which is typically 160 – 220 kg N ha^{-1} yr^{-1} on sugarcane farms in the lower Burdekin. Small amounts of N are also added via rainfall, some could be applied via irrigation water drawn from the river, and large amounts of N are potentially available via irrigation water drawn from bores. Measurements show that nitrate-nitrogen concentrations of bore water used for irrigation can vary from very small amounts to more than 10 mg L^{-1} (Figure 4) (Klok et al. 2003). Applying 20 ML ha^{-1} yr^{-1} irrigation with this quality water would add a further 200 kg N ha^{-1} yr^{-1} on top of whatever fertiliser N is applied. Although these are seemingly large quantities of N, we see from Figure 3 that, depending on soil type, they could be relatively small compared with the total N that can be held by the soil and organic matter in and above the rootzone. This can add to the difficulty in ascertaining what happens to the applied N.

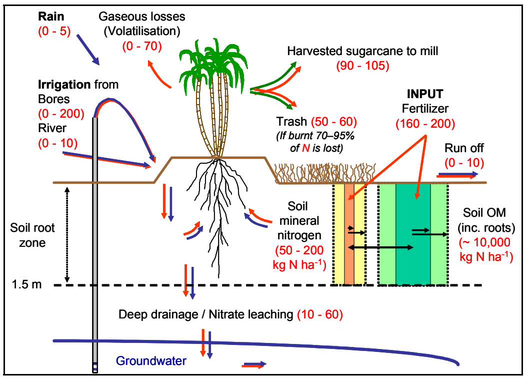

Figure 3 Schematic showing likely ranges in nitrogen balance components in kg N ha^{-1} yr^{-1} for sugarcane. Fertiliser inputs range between 160 and 220 kg N ha^{-1} yr^{-1} for target crop yields of 100 - 150 t ha^{-1} (OM=organic matter)

Ideally, we need as much of the applied N as possible to be used by the crop and removed from the field when the crop is harvested. It is clear from Figure 3 however that we are only removing a fraction, probably somewhere between 30-70% of the fertiliser N applied each year to sugarcane. Given that there can be as much or more N applied via irrigation as applied via fertiliser, there are potentially large amounts of N unaccounted for that will either build up in the system or leave the system through volatilisation, denitrification, surface runoff, or deep drainage. The N retained in the system will build up in the organic matter (above and below ground) and soil mineral N pools. Once the upper limit of these pools has been reached, large amounts of N could then relocate within or leave the system with potentially unwanted impacts on downstream rivers, groundwaters, wetlands, and near shore marine environments. While there is concern about these issues, our ability to accurately quantify the fate of applied N is lacking. One reason is that it is difficult and expensive to measure the various components of the N balance, and there are no long term field sites where efforts have been or are being made to measure each of the N balance components independently. The data on various N balance components that are available tend to come from different field sites, with different soils, climates, and histories, leaving uncertainty about the relationship between the various components and uncertainty about our ability to accurately close the N balance at particular sites.

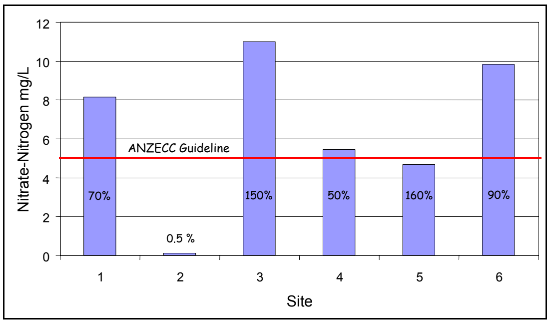

Figure 4 Nitrate-nitrogen levels of irrigation water drawn from bores at selected sites across the Burdekin delta. The numbers in each column indicate the amount of nitrogen added via irrigation during an irrigation season (2000/2001) as a percentage of the recommended nitrogen fertiliser rate of 200 kg N ha^{-1}. The 5 mg L^{-1} is the ANZECC long term environmental trigger value

Of particular interest is the amount and fate of N that leaves the root zone as deep drainage. We need to know if it is held in the unsaturated zone above the water table, and if so, for how long before it enters the groundwater systems. Determining the fate of N once it enters the groundwater systems needs particular attention, as we need to know whether it goes back into the river systems, wetlands, or out into the near shore marine environment. This is important in terms of setting and meeting within and end of catchment water quality targets. ‘Fluctuating’ water tables and their role in ‘stripping’ N and other solutes from the root zone is also not fully understood. This could be important in terms of the overall N balance given that water tables in the region can rise and fall by several meters in relatively short periods of time in response to wet season rainfall and drawdown through bore extraction for irrigation. We need to understand these processes to improve our modeling capability, and hence analysis of the longer term fate of applied N.

There are also concerns given current measurement techniques that we are underestimating the amount of N entering the groundwater systems. Many of the bores tend to be relatively deep, drawing groundwater from near the basement of the aquifer. When making measurements of bore water quality it is also fairly common for large quantities of bore water to be extracted until some measure such as EC stabilises, before samples are removed for N analysis. This could enhance mixing of the deeper groundwater resulting in a lower average concentration of a particular constituent. Sampling water from near the top of the aquifer is likely to provide a more accurate assessment of the N entering the groundwater system. If N is entering the groundwater system in this way, it could be beneficial to extract water for irrigation from the upper parts of the aquifer. This would enable better recycling of N, and by accounting for N applied in this way, could lead to associated reductions in the amount of N applied as fertiliser and hence improvement in groundwater quality.

It is clear from the above that there are many important issues regarding water and N balances that need to be addressed. This will require both field measurement and modeling approaches in order to make progress. Klok et al. (2003) through their measurement program and Stewart et al. (2003) through their modeling efforts have already made some progress, but much more effort is needed, particularly in linking the land and water management practices with the groundwater systems, to accurately determine the actual fate of applied N. Perhaps of higher priority in fostering short and long term economic and environmental benefits is to cut back on N applications through a N replacement strategy as suggested by Thorburn et al. (2003).

4. MAKING BETTER USE OF EXPERIMENTS AND MODELING

Experimentation alone will never be sufficient to address the various issues raised above. Experiments are about the past, and because they can only provide exposure to a subset of the wide range of possibilities of climate, soil and management conditions, are inherently limited in their predictive capability. While field and/or laboratory experiments are essential and are being used to help address knowledge gaps on specific issues, models allow us to capture our current best understanding of how a system, or parts of a system, works. They can be used to help analyse complex systems at a range of spatial and temporal scales, multiple interactions, competing demands, spatial and temporal variability, and extrapolation of experimental data and findings in both space and time (Dent 2000). Models provide the predictive capability that allows us to carry out scenario analyses and explore ‘what if’ type questions. They are essential for helping us ‘look into the future’ in an attempt to assess likely long term impacts of current (the ‘do nothing’ approach) or changed management practices.

While modeling at these systems levels is still relatively ‘immature’, it is essential that we take a more proactive approach to improve integration of our measurement and modeling activities. We need to continually improve our modeling capability across a range of spatial and temporal scales to ensure we capture the critical feedback and time lags in the system that govern the ultimate behavior of the system. In our case, this requires appropriate linkage of the crop-soil and groundwater models to account for the storage and transport of water and solutes in the unsaturated zone between the rootzone and groundwater. We also need to recognize that true ‘validation’ of these types of complex systems models is unlikely, and that a range of strategies will be needed to monitor and evaluate their progress and reliability so that they undergo continual improvement through a structured iterative process. Making progress with these efforts is crucial to delivering on ground strategies that address the current and emerging pressures in the lower Burdekin.

5. CONCLUSIONS

There has clearly been progress in the lower Burdekin over the last few years, with greater appreciation of the complexity and multi-dimensional nature of water management issues and their link to solute management, and improved benefits from better linkages between experimentation and modeling. This has resulted in an appreciation of the need to set and meet water table targets, and to tighten N management in order to capture both economic and environmental benefits. The progress that has been and is being made has required new ways of working, with a greater focus on systems analysis and understanding and managing the interconnectedness of systems, greater focus on partnerships between community, industry, government and research organisations, and implementation of participatory action research with farmers and other land and water managers. While increasing the efficiency of on ground projects, such activities can have high liaison overheads which are not always recognised or easily resourced.

Adopting these approaches has also required new ways of measuring progress and impacts, as the process of engagement and partnership is often as important, or more important, than the ‘products’ themselves that result from the work. A challenge that remains, however, is how best to nurture and build the required scientific capacity so that it can continue to make a difference well into the future. This is particularly challenging given that the majority of current funding is largely short term in nature, and likely to stay this way for some time to come. Care will therefore be needed to ensure that there is a capability to take a longer term more strategic view in dealing with the more difficult and complex issues, especially those that cut across scales and disciplines.

Perhaps the real success to date is that the process that has been initiated in the lower Burdekin, no matter how imperfect, is forcing the region to seek out new ways of addressing the various internal and external pressures, and is helping build improved understanding and confidence in better managing the regions water and irrigation resources. The long term economic viability of the lower Burdekin will undoubtedly be decided by how well the region succeeds with this.

6. ACKNOWLEDGEMENTS

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