IMPROVING THE QUALITY OF DRAINAGE WATER FROM NSW CANELANDS

By

RICK BEATTIE[1,3], GEORGE RAYMENT[2,3] and BRYAN GREEN[4]

[1]*NSW Sugar Milling Co-operative Limited, Broadwater*
[2]*Department of Natural Resources and Mines, Indooroopilly*
[3]*former CRC for Sustainable Sugar Production*
[4]*formerly BSES Limited/CRC Sugar, Broadwater*

rbeattie@nswsugar.com.au, George.Rayment@nrm.qld.gov.au

KEYWORDS: Awareness, DO, Drains, Nutrients, Pesticides, pH, Water Quality.

Abstract

THE NSW sugar industry after a 3.5 year SRDC/CRC Sugar funded study of surface water quality adjacent to canelands in north-east coastal NSW has emerged from having little direct awareness of physiochemical, nutrient and pesticide water quality in major drains adjacent to cane lands to a position of knowledge. The project targeted six of the many natural and constructed drains in the region, two in each of three mill areas (Condong; Tweed/Brunswick Catchments: Broadwater; Richmond Catchment: Harwood; Clarence Catchment). Automated water quality 'stations' were installed and maintained at the discharge end of the six main drains to continuously measure pH, electrical conductivity (EC), dissolved oxygen (DO), temperature, stream height and velocity. In addition, monthly water samples were collected close by and analysed on-site for DO and in a laboratory for suspended solids, pH, EC, chloride, nutrients (N and P) and pesticides (atrazine, diuron, 2,4-D, glyphosate, chlorpyrifos). Growers with farms adjacent to the drains operated as focus groups to discuss and respond progressively to the results from their respective drains, while a range of strategies were used during the study to inform other canegrowers and the wider community of the project's findings. The interactive nature of the study helped to raise awareness and change practices that subsequently led to measurable improvements in water quality, particularly for pesticide residues. There are sound reasons to establish locally relevant water quality criteria rather than to rely on generic guidelines that are different across the nearby state border with coastal south-east Queensland.

Introduction

About 35 000 ha of good agricultural land are used for sugar cane production by 600 growers in Australia's most southerly cane growing region, located at downstream ends of the Tweed, Brunswick, Richmond and Clarence River Catchments. Expansions of the area under cane and in milling capacity were features of the local industry since the formation of the NSW Sugar Milling Co-operative Ltd in 1978. Even with this expansion, the 'footprint' of the industry in the catchments is highly visible yet minor, comprising a little over one percent of the combined area of the four catchments (total catchment area of 3.095 million ha).

Water quality was rated among the highest of the environmental issues confronting the NSW sugar industry at a needs' workshop in August 1998. It also attracted attention during the 1998 strategic planning process of the Cooperative Research Centre for Sustainable Sugar Production (CRC Sugar).

To participate from a position of strength in environmental debates, the NSW sugar industry needed to be aware of its impacts on water quality. It also needed to know how changes to on-farm management might impact on water quality in adjacent drainage canals, which are unique and valuable features of the NSW sugar industry.

The CRC Sugar audit of fertiliser (Bloesch and Rayment, 1999) and pesticide (Hamilton and Haydon, 1997) use in northern NSW cane lands had provided an important foundation for a water quality-monitoring program.

On a local basis, it was recognised that a water quality monitoring program needed to involve growers on a similar basis that the acid sulfate soil (ASS) problem was addressed via the interactive farm-scale survey of ASS in NSW canelands in which every grower participated (Beattie *et al*., 2001).

The wide network of natural and constructed waterways in the region provided an opportunity to undertake water quality monitoring in micro-catchments surrounded almost exclusively by cane farms.

This paper describes briefly a 3.5 year project '*Improving the quality of drainage water from NSW canelands*' jointly funded by the Sugar Research and Development Corporation (SRDC) and the former CRC Sugar, the latter through the NSW Sugar Milling Co-operative Limited, (Sunshine Sugar), the Qld Department of Natural Resources and Mines (NR&M), and the Bureau of Sugar Experiment Stations (now BSES Limited).

Methods

The project commenced in July 1999 with the major objectives being to create awareness among NSW cane growers of relationships between cane growing practices and water quality; to progressively enhance water quality by modifying any practices identified by monitoring to be unsustainable; to inform growers on other drainage systems in NSW of management practices that have improved water quality, and to inform the regional community of findings and actions by cane growers to enhance water quality. Water quality monitoring commenced in November 1999 after appointment of a Project Officer and continued through to September 2002.

Drains and instrumentation

Six of the many natural and constructed drains in the region were targeted, two in each of three mill areas (Condong; Tweed/Brunswick Catchments: Broadwater; Richmond Catchment: Harwood; Clarence Catchment). The drains were numbered 1 to 6, with summary details in Table 1, inclusive of the number of cane growers in focus groups for each drain.

Table 1—Summary details of the six drainage systems/creeks.

Drain No.	Drainage systems	Location*	Catchment	Mill aea
1	Bartlett's Ck	Condong (20)	Tweed	Condong
2	Mooball Ck	Wooyung (14)	Brunswick	Condong
3	Empire Vale Ck	South Ballina (10)	Richmond	Broadwater
4	Dungarubba Drain	Dungarubba (17)	Richmond	Broadwater
5	Marsh's Drain No. 2	South Bank Rd., Palmers Channel (11)	Clarence	Harwood
6	Strange's Drain	Chatsworth Island East (9)	Clarence	Harwood

*The number of participants in each focus group is shown in brackets.

All drains were under tidal influence and all except Drain 2 were 'gated' to restrict the ingress of estuarine water, except that part-way through the study, the floodgates of Drains 5 and Drain 6 were regularly opened to encourage tidal water exchange. Chloride (Cl) and electrical conductivity (EC) analyses confirmed that all drains were influenced by estuarine water to variable extents. Drain 4 had the lowest (least saline) median EC and Drain 5 the highest (most saline). A region and site location map is shown as Figure 1.

Fig. 1—Region and site location map showing the approximate location in northern NSW of the drains, water quality monitoring sites, canelands and other local features.

Automated water quality 'stations' were installed and maintained at the discharge end of the six main drains to continuously measure pH, EC, dissolved oxygen (DO), temperature, stream height and velocity, the latter involving doppler technology. In addition, monthly water samples were collected close by and analysed by standard methods on-site for DO and in the National Association of Testing Authorities (NATA) accredited laboratory of the Queensland Department of Natural Resources and Mines, Indooroopilly, for suspended solids, pH, EC, Cl, nutrients [totals and components of nitrogen and phosphorus (N and P)] and pesticides (atrazine, diuron, 2,4-D, glyphosate, chlorpyrifos). The laboratory has details of the methods used, while summary details of what was monitored and when are provided in Table 2.

Table 2—Summary details of the main water quality monitoring program.

Category	Parameter	When
Physicochemical.		
	DO	Continuous and monthly
	pH	Continuous and monthly
	Temperature	Continuous and monthly
	Electrical conductivity (EC)	Continuous and monthly
	Chloride	Monthly
	Turbidity	Monthly
	Suspended Solids	Monthly
Nutrients		
	Total nitrogen (plus all major components, including mineral N)	Monthly at monitoring station; occasional at up-drain locations
	Total phosphorus (plus all major components, including reactive P)	Monthly at monitoring station; occasional at up-drain locations
Pesticides		
	Selected herbicides (atrazine, diuron, 2,4-D, glyphosate) and the insecticide chlorpyrifos	Monthly at monitoring stations; occasional at up-drain locations; glyphosate and chlorpyrifos only for the first 15 months.

Results and discussion

Drain physiochemical properties

pH

Water pH data added to the awareness of acidity and alkalinity in NSW main cane drains. The average monthly-monitored pH was 7.03 ± 0.86. The maximum pH recorded was 8.6, the minimum 3.74, and the median 7.2. Continuous monitoring of pH at the water monitoring stations has provided intensive data on pH. Examples of the continuously monitored pH data are shown in Figure 2.

Pulses of strong acidity were similarly detected by monthly and continuous monitoring, particularly in Drains 2 and 4. This suggests the entry of acidic drainage, probably from ASS known to occur in the area. Around 53% of cane lands in NSW are underlain by acid sulfate soils (Rayment *et al.,* 2001). Up-drain from the monitoring site on Drain 4 are natural wetlands known to produce acidic discharge and, despite the efforts of local growers to manage acidity in their own drains, this is the likely source of the strong acidic drainage detected at Drain 4.

For monthly water samples, the pH was >6.0 for 90.6% of the samples from all drains. Drains 1, 3 and 5 were the least acidic with samples from drains 1 and 5 exceeding pH 6.0 for 97% and drain 3 for 100% of the samples taken from these drains. The most acidic samples occurred in drains 2 and 4 but even in these drains 84.8% and 66.7% of the samples had pHs >6.0. This and the continuously monitored pH indicated that these drains were only periodically acidic. Measures to control acidity from these drains will be required throughout their catchment area not just the cane growing areas.

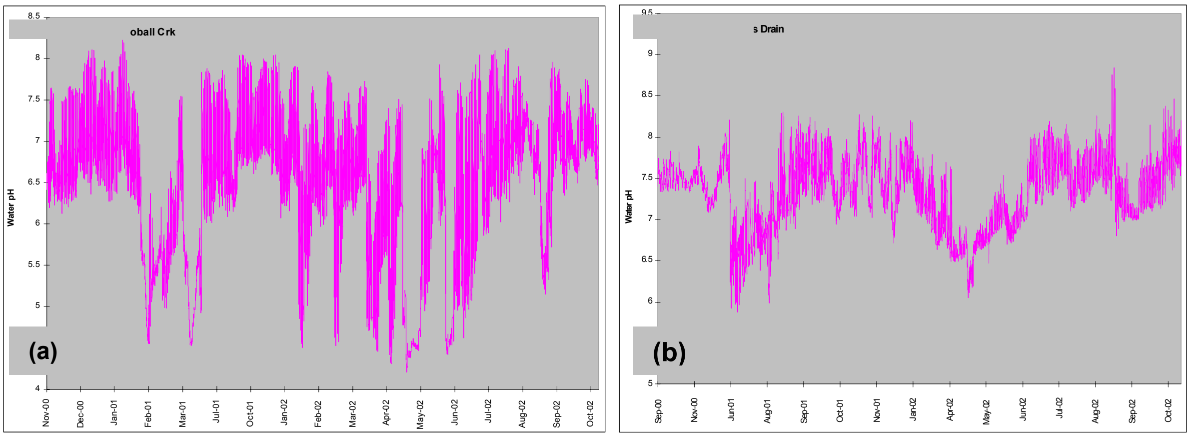

Fig. 2—Continuously monitored pH data from (a) Site 2 at Mooball creek and (b) Site 5 at Marsh's drain.

Dissolved oxygen (DO)

Waterways provide critical habitat in the life cycles of many fish and other important aquatic species. All need DO in the water to remain healthy and productive. Low DO concentrations have adverse effects on many aquatic organisms (e.g. fish, invertebrates, and micro-organisms) that rely on DO for efficient functioning and survival.

Data from monthly sampling covered the range 0–13.2 mg O_2/L, with a population median of 6.7, a 10th percentile of 3.9, and a 90th percentile of 9.9 mg O_2/L. That is, most of the monthly DO readings were within or close to the present generic ANZECC water guidelines for lowland rivers in NSW [(lower limit of 85% DO saturation, approximately 7.5–8 mg O_2/L; upper DO saturation of 110%, approximately 9–10 mg O_2/L); ANZECC, 2000]. Median DO values for Drains 1 to 6 were 7.7, 6.1, 6.7, 8.5, 6.0 and 7.1 mg/L, respectively.

Turbidity and temperature

Turbidity is a measurement used to quantify the degree to which light is scattered by suspended particles when travelling through the water column. Increased turbidity reduces the ability of light to penetrate the water column, limiting the ability of plants to photosynthesise.

With the exception of the 2001 floods in northern NSW, turbidity in the drains was within ANZECC (2000) guidelines, with medians for the drains ≤12 Nephelometric Turbidity Units

(NTU). Turbidity data indicated that there is minimal off site movement of suspended solids in these catchments; this was expected given the low slopes on most NSW cane lands. Suspended solids, which typically increase as turbidity levels increase, ranged from 1 to 77 mg/L in water samples monitored monthly (194 samples), with a median concentration at an acceptable concentration of 8.0 mg/L.

Water temperatures ranged from summer maximums of 29.3–31.9^{o}C and winter minimums of 8.7–13.1^{o}C.

Nutrients

Nitrogen (N)

In all there were about 195 monthly samples on which a suite of N determinations was made in the laboratory, with 31 to 33 samples from each main drain. Summary data from all drains combined are presented in Table 3.

Table 3—Summary statistics for monthly sampling for nitrogen concentrations (mg N/L).

Statistic	Total N	Total N Insoluble	Total N Soluble	Total Organic N	NH_4-N	NH_4-N as % of total N	Oxidised (NO_3-N)	NO_3-N as % of total N
All drains combined								
Count	195	195	195	195	194		195	
Maximum	3.35	1.65	2.43	1.90	1.60		1.69	
Minimum	0.01	ND	0.01	0.01	ND		ND	
Median	0.50	0.12	0.38	0.28	0.03	6.90	0.01	2.40

ND = not detected

Median concentrations of total N in individual drains ranged from 0.33 mg N/L through to 0.94 mg N/L, with a grand median (calculated from the combined raw data) of 0.50 mg N/L. This value would conform to year 2000 ANZECC generic guideline concentration for coastal rivers in south Queensland and is lower than the guideline for lowland rivers in non-coastal NSW. However, it exceeds by 0.15 mg N/L the generic guideline concentration for lowland rivers in coastal NSW. We do not understand why guidelines differ between regions.

Dissolved inorganic nitrogen (DIN) and its components (oxidised-N and ammonium/ammonia-N) attracted close attention due to their connection with land management practices. Across all drains, DIN was less than 10% of the total N concentration. Close to 80% of the total N in the drains was water-soluble and around 55% of the total N was present as organic N. In addition, ammonium-N consistently contributed more to DIN across all drains than did oxidised-N for reasons thought to be associated with the suppression of nitrification from strong acidity in soils and some drainwaters.

To enhance local confidence in the water quality guidelines for nutrients and ecosystem protection, it is clear that a review of these water quality criteria is a matter of priority with the aim of replacing them with more realistic criteria for waterways within the fertile, alluvial, sub-tropical coastal plains of NSW.

Phosphorus

As with N, there were about 195 monthly samples on which a suite of P determinations were made in the laboratory, with 31 to 33 monthly samples from each main drain. Summary data for the combined data are presented in Table 4, including the median percentages of DIP relative to total P.

Table 4—Summary statistics for monthly sampling on around 33 continuous occasions for phosphorus concentrations (totals and fractions; mg P/L).

Statistic	Total P	TP soluble	TP insoluble	Organic phosphorus as P	DIP	DIP as percent of total P
All drains combined data						
Count	195	195	195	195	194	
Maximum	0.68	0.56	0.47	0.23	0.43	
Minimum	ND	ND	ND	ND	ND	
Median	0.07	0.05	0.02	0.04	0.01	10.0

ND = not detected

Across the sampling period, median concentrations of total P in individual drains ranged from 0.04 mg P/L (Drain 2) through to 0.13 mg P/L (Drain 5), with a grand median calculated from the combined raw data of 0.07 mg P/L. This value exceeds the year 2000 ANZECC generic guideline concentration for coastal rivers in NSW of 0.025 mg P/L, and also exceeds the guideline for lowland rivers in non-coastal NSW and southeast Queensland. Most drains had one or more monthly concentrations below the relevant guideline concentration, which appears to be a 'tough' water quality criterion to apply to drains in fertile alluvial landscapes in northern NSW.

Across all drains, 50% of the total P (median percentage) was organic, while the corresponding median total inorganic P was 33% of total P. With the exceptions of Drain 5 and Drain 6 that had higher levels, median concentrations of DIP were within the range found in most natural waters (0.005–0.02 mg P/L; Chapman and Kimstach, 1997) and always below the ANZECC guideline of 0.008 mg P/L for lowland rivers in coastal NSW. These correspond to 5.0–8.3% of the total P in the same drains (median concentrations), whereas DIP expressed as a percentage of total P in Drains 5 and 6 were 24.6% and 28.7%, respectively. That is, waters in the two drainage systems in the Clarence River Catchment are clearly behaving differently to waters in the drains of the Richmond and Tweed.

Non-cane sources of water soluble P, probably from the estuary (e.g. sewage/septic and domestic/industrial discharges) could explain the findings of higher DIP from the Clarence Catchment. Another possibility is that the P reported as DIP was present as micro-particulates, able to pass through the filter papers used during sample preparation. Indeed, the mostly-alkaline waters of the two drains (5 and 6) plus the presence of calcium ions from the estuary would favour the formation of basic forms of calcium phosphate, which have very low water solubility. A third possibility is that cane growing soils of the Clarence may have lower P sorption capacities than those further north and/or significant preferential flow of P due to macroporosity. Cane farming practices in northern NSW are not sufficiently different to suggest these were the cause.

Pesticides

The six key points to emerge from the monitoring of pesticides in the drainwaters were:

- First, the failure to detect during 15 months of monthly monitoring any residues of the herbicide glyphosate and the insecticide chlorpyrifos.

- Second, median concentrations of atrazine, diuron and 2,4-D were mostly low or non-detectable and, with the exception of diuron on 6.6% of all (198) sampling occasions, were always within Australian water quality guideline values for moderately disturbed systems and within levels that assures the survival of 90% of aquatic organisms (ANZECC, 2000).

- Third, the patterns of off-site pesticide movement differed from drain to drain, despite similar sugar cane cultural practices, indicating that low-density water quality monitoring could lead to erroneous conclusions on pesticide environmental risk.

- Fourth, the levels of residues in Drain 6 declined to inconsequential levels following initiatives of the local agricultural advisor and growers to replace problem formulations with alternative products.

- Fifth, at no time did any pesticide residue exceed Australian Drinking Water Guidelines (1996) or recreational use guidelines (ANZECC, 2000).

- Sixth, the concentrations of the pesticide residues studied were unrelated to the concentrations of anions in the water at the same time, indicating that anion concentrations (nitrate, chloride, phosphate) cannot be used to predict pesticide movement or concentrations in NSW cane drains.

Drain flows

Another important finding was the small volumes of water (0.006% to 0.04%) discharged from the drains relative to mean annual flows in the river systems. For example, for the 68 drains in lower reaches of the Richmond River, the volume discharged from Drain 4 would scale up to approximately 2.7% of the total annual average river discharge, if equal volumes of water were regularly discharged from all other cane drains in that catchments. The flow data for Drains 1, 4 and 5 allowed estimates to be made of nutrient and pesticide fluxes from cane drains for the first time.

Raising awareness

Across the three mill areas, the total number of cane growers on the drain systems monitored was 81, representing approximately 12% of all NSW growers. Prior to the commencement of the project in 1999, growers on each drain system were contacted, the aims of the project explained and unanimous agreement to participate was obtained. These growers then received regular updates of water quality data via shed meetings on the drain system. The results were discussed in relation to current management practices and how management practices could be altered. Regular contact with the growers on the drains also occurred when collecting water sampling and when maintaining equipment at the sites.

An obvious improvement in controlling unwanted pesticide residues occurred as a consequence of the participation. Specifically, the occurrence of elevated levels of atrazine were brought to the attention of growers at Drains 1, 5 and 6 during shed meetings during the first 14 months of monitoring. This information generated considerable discussion and a concerted effort to investigate and use alternatives to atrazine. The efficacy of these changes can be seen in the marked reduction in atrazine concentrations in these drains for the remainder of the project (Figure 3).

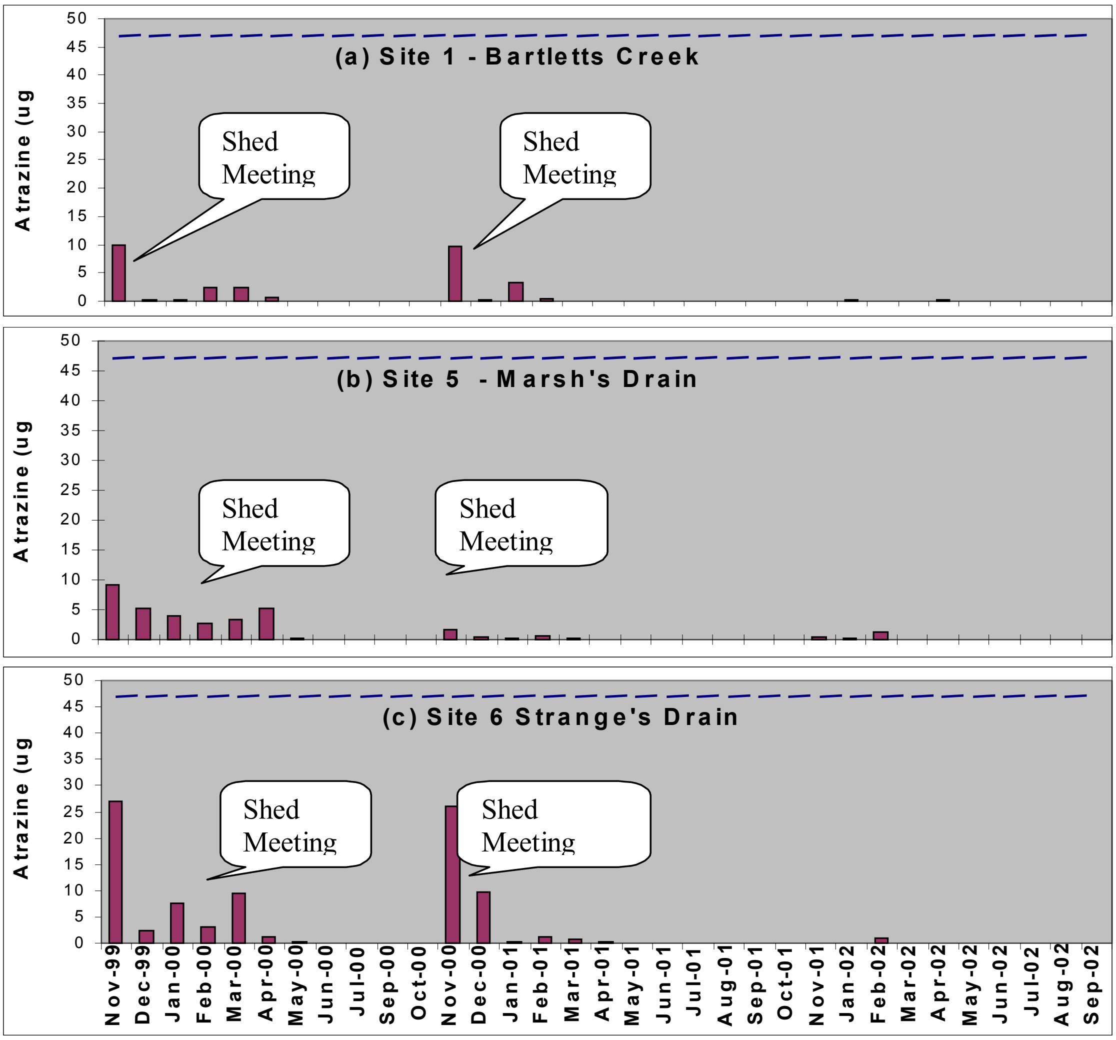

Fig. 3—Graphs illustrating the use of grower shed meetings as an important tool in either reducing the use of the water-mobile pesticide atrazine or using alternative pesticide. The relevant ANZECC guideline is shown as a dashed line.

Attitudinal surveys

Pre-project attitudinal surveys revealed cane growers adjacent to the selected main drainage systems were interested in water quality and its links to land use practices. A follow-up attitudinal survey revealed that grower understanding and knowledge of water quality was enhanced by the project. All of the growers responded that they had become more aware of the impact pesticides and fertilisers can have on water quality. Similarly, 90% of respondents indicated they had gained a better understanding and knowledge of water quality within their drainage system over the past 3 years due to their association with the study.

Other canegrowers were kept informed as was the local community and scientists associated with CRC Sugar. The initiative and some of the findings were also presented and discussed at national and international conferences on sugar and natural resource management.

The NSW sugar industry is committed to continue with water quality monitoring, using the equipment already in place and by equipping and training growers on other drains. The study has served as a model that others might adopt.

Acknowledgements

The authors acknowledge the integral involvement of Peter McGuire and Bob Aitken, Senior Extension Officers from Condong and Harwood respectively, in the project, particularly with local extension activities and data collation and analysis. The authors also gratefully acknowledge the support and funding provided by the Sugar Research and Development Corporation and the former CRC for Sustainable Sugar Production.

REFERENCES

ANZECC (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000). (ANZECC and ARMCANZ, Canberra.)

Australian Drinking Water Guidelines (1996). National Water Quality Management Strategy. NHMRC and ARMCANZ, Canberra. (http://www.nhmrc.gov.au/publications/pdf/eh19.pdf).

Beattie, R.N., Nielsen, P.J., Rayment, G.E., Aitken, R.L., McGuire, P.J. and Quirk, R.G. (2001). Achieving self-regulation for drain maintenance in the NSW sugar industry. Proc. Aust. Soc. Sugar Cane Technol., 23: 51–57.

Bloesch, P.M. and Rayment, G.E. (1999). Fertilisers in the NSW sugar industry - estimates of usage and likely environmental fate. In: Lawn, R.L. ed. Posters '99–A Collection of Poster Papers from the CRC Sugar Annual Review and Planning Meeting, 1999. 1 p. (CRC Sugar Occasional Publication, CRC Sugar, Townsville).

Chapman, D. and Kimstach, V. (1997) Selection of Water quality variables. In: Chapman, D. Spon, E. & F.N. ed. Water Quality Assessments, 2nd edition, London.

Hamilton, D. and Haydon, G. (1997). Final Report. Pesticides and Fertilisers in the New South Wales Sugar Industry—Estimates of Usage and Likely Environmental Fate. Vol. 1. Pesticides. (Dept. Natural Resources and CRC for Sustainable Sugar Production, Brisbane).

Rayment, G.E., Raymond, M. and Balakrishnan, T. (2001). Quick field test for lime rates of pyritic drain-spoil in NSW canelands. Proc. Aust. Soc. Sugar Cane Technol., 23: 58–63.