BUREAU OF SUGAR EXPERIMENT STATIONS
QUEENSLAND, AUSTRALIA

FINAL REPORT
NATURAL HERITAGE PROJECT 972471
Beneficial use irrigation strategies with treated urban effluent

by
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1.0 BACKGROUND

The cane growing area of the North Albert region adjoins rapidly developing urban areas between Beenleigh and the Gold Coast. The sugar industry is well placed to assist community desire for non-stream/non-marine discharge of the projected increase in volume of treated urban effluent by beneficial use on canelands. The beneficial use will be twofold; caneland acts as an environmental kidney, and the effluent water provides added value to the community and sugar industry through improved yield by covering deficits in effective rainfall. The irrigation strategy is designed to complement a wet lands strategy proposed by the Gold Coast City Council.

The beneficial use strategy must be validated by demonstration to the community and sugar industry that irrigation techniques are adequate to obtain economic benefits from irrigation while minimising any adverse environmental effects.

A significant portion of the caneland in the catchment between the Albert and Pimpama Rivers has potential for acid sulfate generation in the surface metre of soil. This project links with a project funded by Sugar Research and Development Corporation (SRDC), Gold Coast City Council and DNR to examine the impact of irrigation on acid sulfate export from local soils.

BSES and the DNR in consultation with the North East Albert Landcare Group, the Gold Coast City Council and the local sugar industry proposed to improve understanding of the impact of irrigation in the region by conducting an applied research/demonstration project to develop techniques for sustainable use of treated urban effluent on selected soils in the Rocky Point Mill area. The joint BSES/DNR proposal covered agronomic, environmental and public health aspects of irrigation development.

2.0 OBJECTIVES

1. To identify the demand for effluent water by comparing three levels of water application to assess economics of crop response to water, and the impact on balancing storage capacity;
2. To select irrigation strategies which (a) minimise impact on deep drainage and watertable elevation, (b) which sustain or improve water quality of adjoining streams and (c) which allay any concerns with community health issues;
3. To develop a soil management system to optimise capacity of the crop to take effluent waters, while maximising productivity under wet conditions. This will allow future adoption of the green cane production system and its large environmental and community benefits;
4. To monitor changes in soil salinity and sodicity associated with irrigation;
5. To use historic weather records and a water balance model to place project results in an historic perspective and determine long-term probability for water use and storage needs;
6. To ensure community and industry ownership of the project, and its outputs, through a participative extension process.

3.0 METHODOLOGY

3.1 Experimental

Two irrigation trial sites were chosen to reflect major soil types within the proposed irrigation area. Both were large-scale trials to allow assessment of irrigation impact on factors such as watertable levels, soil salinity and potential acid export.

The first site on a fine textured humic gley soil was set up to compare three irrigation strategies: nil irrigation, limited irrigation at planting/ratooning, and unlimited irrigation to satisfy crop water demand. The site is laser levelled and two irrigation methods were compared: furrow irrigation and subsurface drip irrigation. Plot size was six rows (9 m) by 300 m long with four replicates of each treatment. Irrigation was scheduled using a combination of tensiometers and Class A pan evaporation. Crop canopy development was assessed by periodic measurement of radiation interception by the crop canopy. This allowed adjustment of Class A pan data for estimated crop water use. Regular measurement of watertable depth was carried out in irrigated and unirrigated plots to assess the impact of irrigation on watertable levels. Prior to the commencement of irrigation detailed soil sampling of each treatment was carried out to a depth of 1 metre to allow later assessment of the impact of irrigation on soil properties.

The trial was commenced using irrigation water collected in an on farm dam adjacent to the trial site. Water in the dam is derived from surface runoff water and seepage water, and is similar in composition to water from the Beenleigh sewage treatment works. It was proposed that sewage water would be piped into the dam at a later stage when the Gold Coast City Council installed suitable delivery mains, and the dam water would be used only as an interim measure. Comparative analyses for the dam water and typical Beenleigh plant sewage effluent are given in Table 1.

Table 1: Comparative water analyses for dam and Beenleigh sewage effluent water

Analysis	Dam water	Beenleigh sewage effluent
Cl mg/l	192	100
TSS mg/l	723	650
Ca me/l	1.76	1.55
Mg me/l	3.04	5.42
Na me/l	6.14	4.78
K me/l	0.5	0.5
EC mS/cm	1.14	0.91
SAR	4.0	2.6
PH	6.2	7.5

The waters are similar in composition and would be expected to produce similar effects in the field.

It was planned that yield data from this trial would be used to validate long-term model predictions of response to irrigation in the Rocky Point mill area. In addition experience gained in managing furrow and drip irrigation would be used to guide irrigation development in the area.

The second trial was located on a humic gley soil type with acid sulfate potential layers within 1 m from the soil surface. This site was set up with subsurface drip irrigation and subsurface drainage pipe to allow assessment of the impact of irrigation on potential acid export from high acid sulfate potential soils. In this whole block scale trial measurements were planned on water quality of surface and subsurface runoff, groundwater discharge, redox potential of the soil profile and groundwater contributions to cane water use by capillary rise. A second block was set up for similar detailed measurements of watertable variation, generation and export of acid sulfate material under unirrigated conditions.

3.2 Extension

The trial sites were planned to be the focus for field days, open to the cane farming community and other interested community members. These days would discuss the impact of irrigation on cane production and any potential off-site environmental effects.

4.0 RESULTS

4.1 Yield response trial

4.1.1 Irrigation

This trial was planted in March 1998 with the cane variety Q151 and irrigation was commenced in Spring 1998. Limited irrigation was carried OUT late in 1998 and early in 1999 due to abnormally wet seasonal conditions, with a total of 2,370 mm of rainfall over a 21 month period. Furrow irrigated plots received a total of 244 mm in three applications, and drip irrigated plots a total of 83 mm in eight applications. These total applications are below the required amounts predicted using the water balance component of the model APSIM of 550 mm. This discrepancy is in part due to the difficulty in deciding when to recommence irrigation after rainfall. Tensiometers were located at 300 mm and 600 mm depths, and it was realised late in the irrigation season that the main soil zone of water use was very shallow, with tensiometers preferably being located at 200 mm and 450 mm to indicate when to recommence irrigation. Irrigation applications for drip and furrow irrigation are compared with model predictions in Table 2.

Table 2: Comparison of trial irrigation applications with model predictions

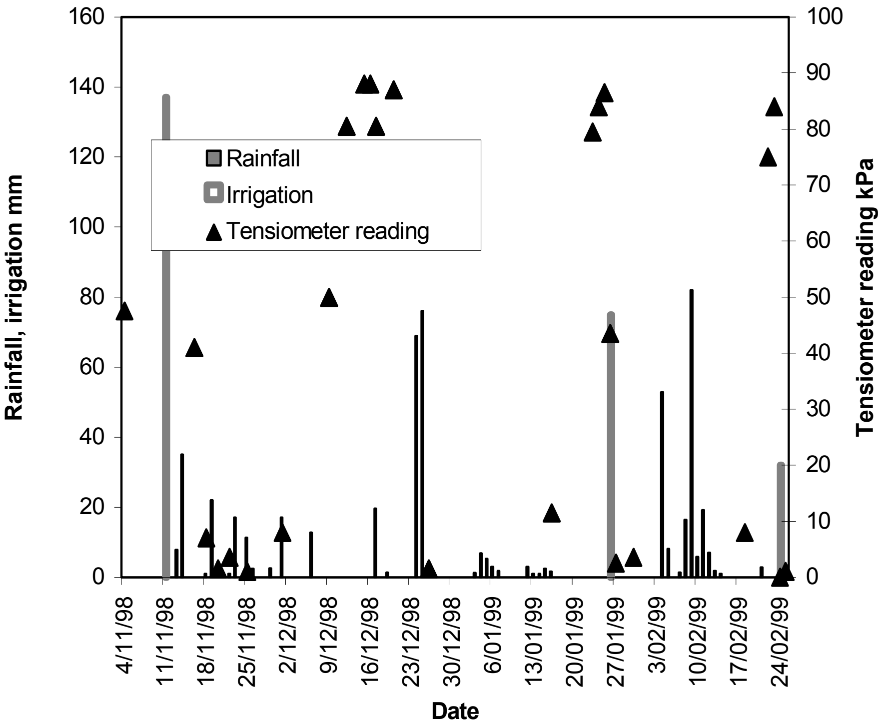
Drip irrigation		Furrow irrigation		Model prediction *	
Date	**Irrigation mm**	**Date**	**Irrigation mm**	**Date**	**Irrigation mm**
				2/9/98	50
				10/10/98	50
27/10/98	7.5			23/10/98	50
4/11/98	9.8	12/11/98	137	5/11/98	50
18/11/98	12.7				
12/12/98	11.4			5/12/98	50
16/12/98	12.2			20/12/99	50
20/12/98	13.4				
23/1/99	0.3			12/1/99	50
26/1/99	15.5	26/1/99	75	25/1/99	50
		24/2/99	32	26/2/99	50
				18/3/99	50
				1/5/99	50
Total	**82.8**		**244**		**550**

* Based on irrigation at a soil moisture deficit of 50 mm

Table 2 indicates that irrigation should have been commenced earlier in 1998 and carried through later in the 1999 season. There were also some apparent stress periods during the irrigation period.

Tensiometer readings in the furrow irrigated plots indicate some periods of stress between irrigations (Figure 1). A tensiometer reading of 60 cbar is considered to result in a 50% reduction in stalk elongation rates.

Fig. 1 Furrow irrigation tensiometer readings at 300 mm



4.1.2 Watertable measurements

Limited watertable measurements during 1998 and 1999 showed that watertable levels fluctuated between 0.7 and 1.0 m from the soil surface during the main irrigation period, and were close to the soil surface for short periods following heavy rain. There was no apparent effect of irrigation treatments on watertable levels, and this may have been due to lateral water flow from irrigated to unirrigated plots. No conclusions could be drawn about the impact of irrigation on watertable levels.

4.1.3 Yields

The plant crop was harvested in January 2000 at 22 months of age in very wet conditions. The harvest was delayed from the expected harvest date in September 1999 due to the wet conditions throughout the 1999 harvest season. Yields were measured by cutting each plot into containers and weighing at the mill. Two, six stalk samples were taken from each plot for ccs measurements.

The APSIM model was also used to compare effective rainfall, effective rainfall plus irrigation and predicted cane yield between the dryland, irrigated treatments and the model full irrigation treatment. It was assumed that the cane yield increased by 7 t/ha per 100 mm of effective rainfall and irrigation. Comparative data and actual cane yields are given in Table 3.

Table 3: Effective rainfall, irrigation, predicted yields and actual yields for the different trial treatments

Character	Dryland	Drip irrig.	Furrow irrig.	Pred. irrig.
Effective rain mm	1880	1848	1790	1613
Irrigation mm		83	244	550
Eff. Rain+irrig.		1930	2034	2163
Predicted yield t/ha	131.5	135.1	142.4	151.4
Measured yield t/ha	138.5	143	139.3	
Pred. Irrig. Resp t/ha		3.6	10.9	19.9
Meas.Irrig. Resp t/ha		4.5	0.8	
Meas. ccs	12.78	13.50	13.34	
Meas. Sugar t/ha	17.70	19.31	18.58	

The data in Table 3 shows no apparent cane yield response to irrigation, but a ccs response of approximately 0.6 unit, and a sugar yield response of approximately 7%. The cane yield response is smaller than expected from model studies, and this reflects the low precision of the trial due to site variability, plus some overlap of furrow irrigation into unirrigated plots. The similarity of model yields to actual trial yields suggests that a Cane Water Index of 7 t cane/Ml of water was appropriate for the Rocky Point area in 1998-1999.

It was intended that the trial would continue to a minimum of first and second ratoon crops to assess longer-term impacts of irrigation on productivity and soil properties. However, the connection of sewage water to the trial site by the Gold Coast City Council was delayed, and it was decided by the NHT management committee that the trial work should not be supported further. It was therefore not possible to assess longer term impacts of irrigation.

4.1.4 Soil/plant analysis

Soil analyses to a depth of 1 m, with results averaged over treatments are given in Table 4. There were no significant differences between treatments at the commencement of the trial for any of the analyses in Table 4.

The main items of interest in Table 4 are the relatively high exchangeable sodium levels and electrical conductivity, particularly at depth. Care will be required in irrigating this soil type, due to the potential for increasing soil salinity if watertables are raised by increased deep drainage. Exchangeable aluminium levels are also relatively high, and this is reflected in the low pH, particularly at depth. This site is considered to have some acid sulfate characteristics, and this is reflected in the high sulfur levels, particularly at depth.

Again it was not possible to assess the long term effects of irrigation on soil properties due to the premature ending of this project.

Table 4: Soil analyses to a depth of 1 m, prior to commencement of irrigation

Depth	P mg/kg	Ca me%	Mg me%	K me%	Na me%	Al me%	C%	S mg/kg	NO_3-N mg/kg
0-250	44	6.66	5.52	0.52	2.12	2.91	3.77	351	56
250-500	13	4.66	6.15	0.20	3.28	4.15	1.74	617	8
500-750	13	3.39	5.72	0.18	4.58	3.96	0.65	629	1
750-1000	27	3.30	5.74	0.21	5.31	3.75	0.48	644	1
	Fe mg/kg	**Mn mg/kg**	**Cu mg/kg**	**Zn mg/kg**	**pH**	**SEC mS/cm**	**ESP**	**Al %sat**	**Sum cations**
0-250	256	70	0.33	6.0	4.73	0.48	12.0	16.4	17.7
250-500	117	31	0.59	2.1	4.64	0.52	17.8	22.5	18.4
500-750	114	14	1.13	1.2	4.52	0.69	25.7	22.2	17.8
750-1000	82	14	1.48	1.4	4.46	0.85	29.0	20.5	18.3

Plant uptake of nutrients as indicated by third leaf analysis is summarised in Table 5.

Both calcium and Cu levels in third leaf are marginal, K levels are high. The low Ca levels are probably due to the high soil K, Na and Mg levels, despite high soil calcium levels. The low Cu levels reflect the low Cu in the surface soil, and the shallow rooting depth in this soil type. It appears unlikely that the low calcium and copper levels have influenced cane yield, but potassium fertiliser applications should be restricted to minimise any effect on calcium uptake.

Table 5: Third leaf plant analysis in March 1999

N %dm	Ca %dm	Mg %dm	P %dm	K %dm	S %dm
1.81	0.13	0.16	0.20	1.75	0.15
Cu mg/kg	**Zn mg/kg**	**Fe mg/kg**	**Mn mg/kg**	**Al mg/kg**	
2.9	18	47	117	19	

4.2 Long term irrigation requirements/yield response

Climatic records for the Rocky Point/Beenleigh area show an average rainfall of 1,225 mm over the last 37 years, Class A pan evaporation of 1,650 mm, and a sugarcane crop water demand of approximately 1,200 mm. Effective rainfall was estimated using the APSIM model to be approximately 900 mm, or 73% of total rainfall under dryland conditions, and 800 mm, or 65% of rainfall, under irrigated conditions. Average irrigation requirement was estimated to be between 350 and 400 mm. Allowing for the reduction in effective rainfall under irrigation the average effective irrigation would be approximately 300 mm. The variation in irrigation demand from year to year is indicated in Table 6.

Table 6: Variation in annual irrigation demand

Irrigation demand mm	0-150	150-300	300-450	450-600
% of years	5	18	34	42

The predicted distribution of irrigation demand throughout the year is given in Table 7. The main irrigation period is December to April, with limited irrigation for crop establishment in the August-October period in 16 of 37 years, or 43% of years.

Table 7: Predicted percentage distribution of irrigation demand throughout the year over the 37 year period

Month	A-O	Nov	Dec	Jan	Feb	Mar	Apr	May
% of annual irrigation	6.4	3.5	13.1	16.6	17.3	15.2	16.3	11.3

Data from existing irrigation districts with similar wetness problems to Rocky Point indicates that the yield response to irrigation is likely to be around 7 tonnes cane per 100 mm of effective irrigation. If effective irrigation is 300 mm per year on average, the average response to irrigation would be approximately 20 tonnes cane per hectare. The distribution of expected responses to irrigation based on the 37 years of data is given in Table 8. These figures are derived from water balance calculations carried out with the APSIM model and assume that irrigation is applied to meet crop water demand. There is some uncertainty about these figures due to possible watertable contributions to the crop water balance, and they should be treated with caution until local data is available on irrigation responses. The first year's data from the irrigation trial provide some backing for the assumption of a cane yield response of 7 tonnes of cane per 100 mm of effective rainfall plus irrigation. The lower yield response to irrigation than expected is likely to be partly due to furrow irrigation spreading laterally into control plots at the initial irrigation.

Table 8: Distribution of predicted cane yield responses to irrigation in the 37 years to 1998

Response t/ha	0	0-10	10-20	20-30	30-40	40-50
% of years	5	10	35	19	27	3
Yield gain t/ha		>0	>10	>20	>30	>40
% of years		95	85	50	31	3

4.3 Irrigation management

In assessing suitable irrigation methods for the soil type in the trial area, it is important that water applications can be matched to the soil readily available water capacity (RAW) in order to minimise adverse effects from salinity, waterlogging or acid sulfate export. While drip irrigation and low-pressure spray irrigation are ideal for this purpose, they are expensive relative to furrow irrigation. There is limited experience with furrow irrigation in the Rocky Point mill area, and the program SIRMOD was used to simulate generalised behaviour of the soil types available for irrigation development. Some data was obtained during irrigation of the trial on the humic gley soil type indicating a high infiltration rate in dry soil, and the need for high furrow inflow rates to minimise water applications. The spread of water laterally during irrigation also indicated the feasibility of irrigating every second row. Furrow advance data from the irrigation trial was used to assess the infiltration characteristics of the humic gley soil type. For other soil types generalised soil types were used in SIRMOD model runs.

Furrow design inflow rates, furrow shape and cutoff times to give minimal deep drainage during irrigation, and match the RAW in the major soil types, are given in Table 9 below. Alternate furrow irrigation is recommended for the humic gley soils to facilitate the high furrow inflow rates required to obtain rapid water advance down furrows, and minimise deep drainage of irrigation water. The figures in Table 9 are a guide only, and need to be confirmed by further irrigation experience.

Table 9: Furrow irrigation design guidelines for the major soil types in the Rocky Point mill area

Soil Group	Target application mm	Furrow flow l/s	Irrigation technique	Cutoff time h	Furrow width m
Humic gley, peaty gley	70	4-5	AF	2.5-3.5	0.8*0.6*0.4
Gilgaied acid clay	50	0.5-0.75	EF	5-9	0.6*0.5*0.3
Alluvial	70	1-1.25	EF	6	0.6*0.5*0.3

* AF= alternate furrow irrigation, EF= every furrow irrigation

** Furrow widths are for top, middle and base of furrows

4.4 Acid sulfate/irrigation trial

The dryland and irrigation trials, designed to assess potential acid sulfate export from cane farm sites in the area between the Albert and Pimpama rivers, were set up during 1998 and limited irrigation took place in the 1999 season.

Intensive monitoring of drainage water quality was carried out at the dryland sites during 1998 and 1999. This indicated that a recently drained site with predominantly pyrite in the profile produced high levels of aluminium in drainage water. A more mature site, that had been developed for 30 years, had mainly jarosite in the soil profile, and produced high levels of dissolved iron in the drainage water. Both types of acid sulfate affected soil present risks to the environment when drainage water is discharged into streams, and measures should be taken to limit the amount of drainage from these sites under irrigated conditions.

However, it was noted that typical drains in the area had a potential zone of influence extending only approximately 10 m from the drains, and this zone would be narrower if there was limited head available for drainage due to lack of free-board to the standing water level in the drains. It would be preferable to limit subsurface drainage on these soils and use shallower drains to encourage increased surface runoff where possible.

4.5 Extension

Both trial sites were utilised for field days attended by growers and other interested parties. The objectives of the project and preliminary results were presented at the field days. In addition weather station data from the acid sulfate sites was made available for community use through telephone assess to the datalogger records.

5.0 MEETING PROJECT OBJECTIVES

Objective 1 - *To identify the demand for effluent water by comparing three levels of water application to assess economics of crop response to water and the impact on balancing storage capacity.*

The trial to evaluate irrigation water requirements, and determine yield response to irrigation was established, and yield results were obtained for the plant crop. These indicated an apparent response in cane growth of 7 tonnes cane per 100 mm of effective irrigation and rainfall. It was not possible to establish a pattern of yield response and water requirement in different years due to the decision of the management committee to cease support for the trial program. The trial work is continuing with alternative funding due to the importance of trial work in deciding the economics of irrigation in the area, and in establishing suitable irrigation management practices.

Objective 2 - *To select irrigation strategies which (a) minimise deep drainage and watertable elevation, (b) which sustain or improve water quality of adjoining streams and (c) which allay any concerns with community health issues.*

The preliminary evaluation of furrow irrigation at this site, which has relatively high water intake rates, indicated that excessive water infiltration can be minimised by suitable water application techniques. The model SIRMOD was used to determine furrow inflow rates and irrigation set times for applying water to match the waterholding capacity of the major soil types in the area. Alternate furrow irrigation with high flow rates was identified as the most suitable technique for high infiltration rate organic soils in the study area. These results need to be confirmed by further experimentation.

Objective 3 - *To develop a soil management system to optimise capacity of the crop to take effluent waters, while optimising productivity under wet conditions.*

The irrigation trial site was set up on a laser levelled site with hilling up of the cane rows, both measures being designed to minimise any waterlogging effects on cane growth. The trial was trash blanketed at harvest of the plant crop. These measures are expected to give a reliable indication of the success of irrigation under wet conditions in future years.

Objective 4 - *To monitor changes in soil salinity and sodicity associated with irrigation.*

Individual trial plots were sampled at establishment of the trial to establish a baseline for soil sodicity and salinity. The site is moderately saline and sodic and should provide a good index of potential detrimental effects from irrigation. The base data will provide a reference for future assessment of trends following irrigation.

Objective 5 - *To use historic weather records and a water balance model to place project results in an historic perspective, and to determine long-term probability for water use and storage needs.*

Studies were carried out with 37 years of weather data using the model APSIM to determine long term irrigation requirements and responses to irrigation. While the model results need to be further confirmed by trial experience they provide a useful guide to irrigation responses and requirements. The predicted average irrigation requirement of 350 to 400 mm is slightly higher than earlier studies based on a shorter irrigation season.

Objective 6 - *To ensure community and industry ownership of the project, and its outputs, through a participative extension approach.*

The project was initiated with strong community support and several field days have been conducted to maintain community awareness and support. Project officers have also participated in irrigation planning committee meetings, and community meetings to discuss the implications of irrigation with effluent water.

6.0 OUTCOMES

Expected outcomes from the project in relation to the above objectives are as follows:

1. *Water use strategies that can be assessed by the industry for economics and social impact and which can be sustained by the effluent delivery system.*

One measure of success in achieving this outcome is sugar industry interest in adopting irrigation, and the ability of Gold Coast City Council to supply water to meet economic irrigation production requirements. There is strong interest in irrigation by local growers based on cane yield, ccs and other projected benefits, and the estimated water requirement of 3.5-4 Ml annually is being used in the planning process.

2. *Contemporary trial data will be used to seed a long-term investigation on watertables using hydologic models, while water quality and health data will result in community and industry confidence in the environmental aspects of beneficial use of irrigation.*

Limited information was obtained to achieve this outcome due to the curtailing of the project, but an understanding of issues related to acid sulfate effects on water quality was obtained. This will assist in management of sub-surface drainage to minimise acid sulfate export from irrigated sites.

3. *Improved productivity during wet weather, and wider adoption of the green cane trash production system, without adverse impact on production in cooler and wetter conditions.*

The production of cane in the plant crop of the irrigation trial was satisfactory in a wet year with laser levelling and hilling up. Trash blanketing in subsequent crops will determine the long-term success of these strategies. It is too early to decide on a successful outcome of management strategies, but laser levelling is being used as a component of proposed irrigation development.

4. *Establishing confidence that deep drainage losses from irrigation will have minimal impact on soil salinity and sodicity.*

While a benchmark has been established in the irrigation trial, insufficient time was available to establish confidence that irrigation will not impact on soil salinity and sodicity.

5. *To develop industry confidence in the yield and water use data from the trial as an indicator of long term effects of irrigation.*

Limited trial data was available to validate model predictions of long term irrigation benefits, but growers have shown confidence that irrigation is a viable proposition.

6. *Adoption of irrigation with confidence by growers, and minimal concern from the community about impacts on the environment.*

Growers have accepted early indications that irrigation is a viable option and are planning accordingly. There is some community concern about impacts on the environment, and a conservative development approach will be required until further assessment of potential impacts can be made. A monitoring system is to be set up to assess the impact of irrigation on water quality and watertable levels as irrigation development proceeds.