"Dripping with success"

THE CHALLENGES OF AN IRRIGATION REDEVELOPMENT PROJECT

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Abstract

Irrigation is vital to sugarcane production at Simunye sugar estate in Swaziland. When full commercial production commenced in 1982 the estate had two main irrigation systems; dragline sprinkler and surface furrow but in later expansions surface drip irrigation was used. By the mid-1990s there was increasing demand on water resources for further sugarcane expansion and with the infield sprinkler equipment showing signs of wear and tear, Simunye estate looked into irrigation redevelopment. A cost analysis of seven different irrigation options was undertaken and the one that offered the best return was conversion of the dragline sprinkler system to subsurface drip. The redevelopment project commenced in 1998 and so far 4 000 ha have been converted from sprinkler to drip. The system design uses a novel cluster house concept for controlling irrigation water and fertigation to cane blocks of about 100 ha. Radio controllers are used to provide automatic operation of pumps, valves and irrigation schedules. A post investment audit conducted in 1999 confirmed a sucrose increase of 15% and water saving of 22% compared to the sprinkler system, better than originally expected. Further analysis undertaken in 2001 revealed even better figures.

Key Words: sugarcane, subsurface drip, cluster house, post-investment audit

Introduction

The Royal Swaziland Sugar Corporation (RSSC), a joint Government and private sector company, was formed in the late 1970s to develop the Simunye sugarcane estate and mill in the northern lowveld of Swaziland. Simunye (meaning "we are one" in SiSwati) started full commercial operations in 1982 and some 20 years on has grown into one of Swaziland's most respected businesses with annual production of 170 000 tonnes raw sugar (98.5° pol) and 14 million litres of potable alcohol. RSSC shares are now quoted on the Swaziland stock exchange and regular dividends have been paid since 1992.

Simunye estate initially comprised 9 025 ha but various expansions on pockets of land within the estate boundary have boosted the cane area to 11 167 ha in 2001. Outgrowers at Umbuluzi, Malkerns, Lilanda and Inhlanyelo deliver cane to Simunye mill from a further 2 700 ha and plans are advanced for small grower schemes on the periphery of Simunye's boundary to develop a further 920 ha over the next two years.

In an average year the sugarcane crop receives 440 mm effective rainfall and requires an additional 750 mm irrigation (net) for optimum growth (see Figure 1). The Umbuluzi and Malkerns outgrowers have separate water rights but the Simunye small growers require water from the estate. This demand, coupled with the additional irrigation demand from Simunye's own expansion, will place further strain on the water supply infrastructure as exposed during a series of drought years in the early 1990s.

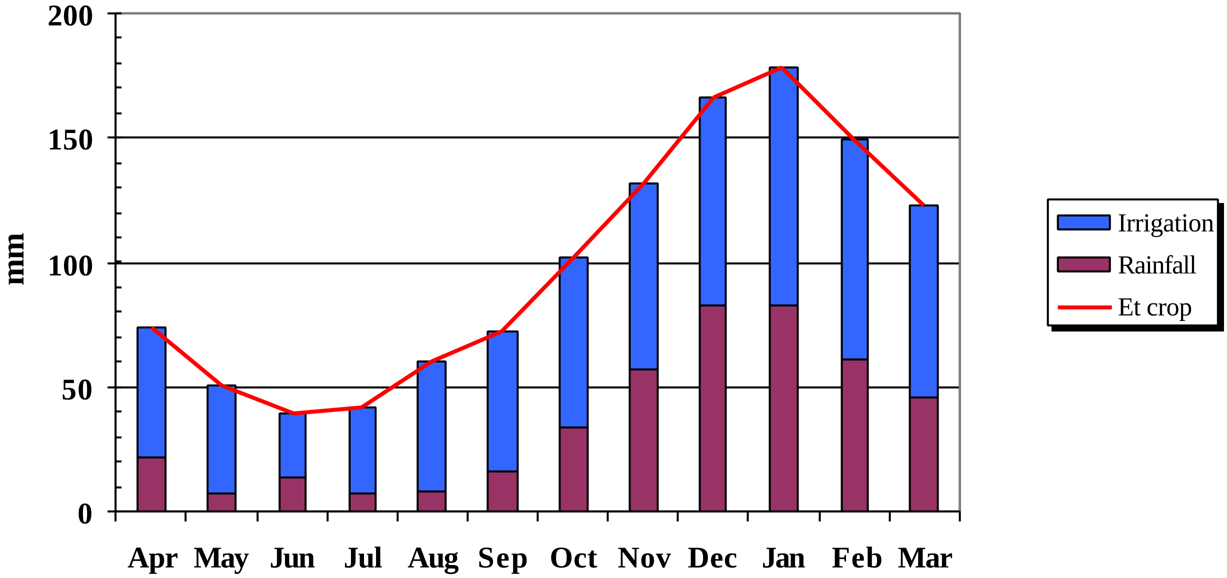

Figure 1: Monthly irrigation water requirement (average for 1980-97)

As a consequence of the drought RSSC examined its irrigation systems to identify ways of improving efficiency and cane yield per unit of water thereby releasing water for supporting additional areas of cane. This paper describes the irrigation redevelopment programme that ensued from the initial review process in 1994-97 through to the phased implementation in 1998-2000 and the first post-investment audit.

Irrigation systems at Simunye estate

The primary water supply for Simunye is the Mnjoli dam on the Black Mbuluzi river with a capacity of 130 Mm^3. A network of lined canals, pump stations, balancing dams and gravity offtakes distribute the irrigation water to the fields. The Ngomane portion of the estate obtains its water supply via a gravity canal directly linked to Mnjoli dam while the Mlaula portion obtains its water via a diversion weir and pump station on the Mbuluzi river downstream of Mnjoli dam (see Map 1).

At initial development Simunye utilised two irrigation systems, overhead sprinkler on 77% of the area and surface furrow on the remainder. Sprinkler was generally selected for the steeper undulating land with thin stony soils and furrow for the flatter land with deeper soils below the canal system.

The sprinkler system is a semi-solid set dragline system with the sprinklers mounted on tripod riser pipes. The sprinklers move around a 12 position module on a grid spacing of 18 m x 20 m and operate at a flow rate of 0.44 l/s @ 3.4 bar which delivers an application rate of 4.4 mm/hr. The sprinkler module covers an area of 72 m x 60 m (0.432 ha). Irrigation set times are only 6 or 8 hours because of the shallow nature of the soils and low water holding capacity. At peak demand irrigation cycles are three or four days.

Surface drip irrigation was initially installed in one trial field of 41 ha in 1982 to test the suitability of this relatively new form of irrigation for sugarcane. Thereafter, a large expansion of 560 ha surface drip was undertaken in 1985 (Pollok and Bosua, 1986), initially for growing cotton and beans, but later converted to sugarcane. Then from 1991-2001 other expansions have occurred under a mixture of surface and subsurface drip that have added a further 1 500 ha. The design of drip systems has changed markedly over the years as operating experience has been gained and new equipment has become available. Initial systems used surface drip laterals but following successful commercial trials in the late 1990 subsurface drip laterals have been used in all but the stoniest ground. Figure 2 illustrates the growth in cane area and drip irrigation at Simunye from 1982 to 2001 from the 2 100 ha of expansion and 4 000 ha of redevelopment that has occurred.

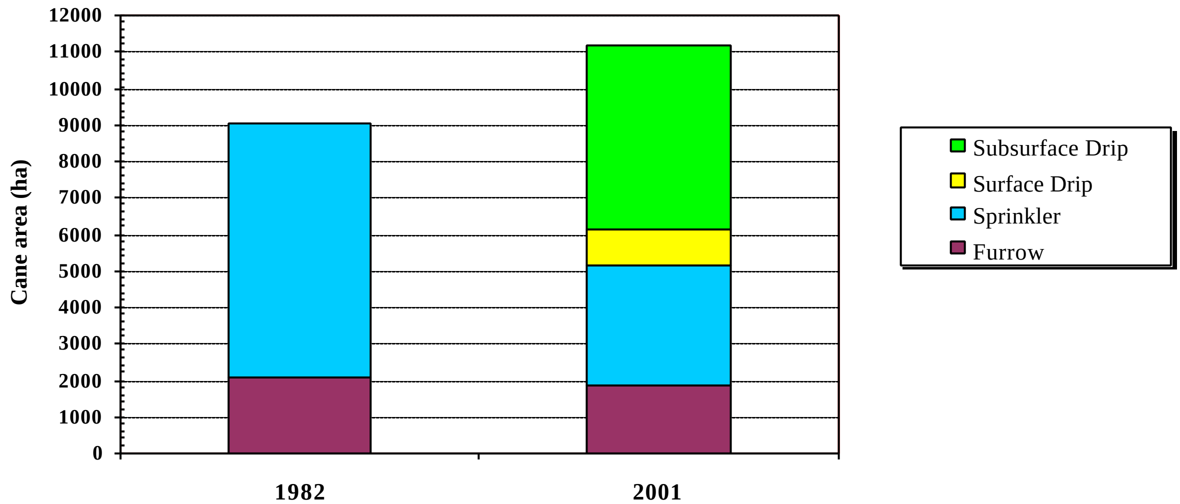

Figure 2: Growth in cane area and drip irrigation over last 20 years

Why change?

The dragline sprinkler system provided very good service during its initial 15 years of operation; it was low in capital cost, it fitted well to the topography, minimal land levelling was required, it is a simple system to operate and it is highly visible making faults easy to spot and remedy. However, by the 1990s the shortcomings of the dragline sprinkler system were becoming evident. Also, the sprinkler equipment was nearing the end of its serviceable life and if a change were to be made then this was the time to do it.

The motivation for change was to: -

- Provide a more even wetting pattern
- Improve water use efficiency
- Make water available for future expansions
- Improve soil water drainage
- Increase sucrose yield
- Reduce labour inputs
- Reduce the level of night shift operations
- Increase the level of automation
- Provide an irrigation system that can be operated by management if an industrial dispute were to occur

- Provide a more even power demand
- Reduce the cost of cane production
- Reduce maintenance costs
- Maximise cane production

Irrigation options considered and final selection

The options open to RSSC fell into three categories: -

a) **Retain** the existing sprinkler system as originally designed and replace worn-out hydrants, aluminium laterals, hoses, tripods and sprinklers. This is the "without project" option and used in the financial appraisal for comparing alternatives on an incremental cost/benefit basis.

b) **Upgrade** the existing sprinkler system by changing materials, burying laterals, altering grid spacing, etc. Such options may provide lower operating and maintenance costs but do not improve water use efficiency or productivity, which are held back by the inherent design of the dragline sprinkler system.

c) **Convert** the existing "semi-solid" set system to a "solid" set system such as centre pivot, solid-set sprinklers or drip. These options provide the opportunity for meeting all the objectives listed above.

Seven different irrigation systems were evaluated and compared to the "without project" option (Merry, 1997). This was done by undertaking sample designs, estimating capital and operating costs and conducting a discounted net present value analysis of incremental costs and benefits. The evaluation ranked "conversion to drip" highest, followed by "conversion to centre pivot (+sprinkler solid set in corners) and the "without project" base case third. Other options such as solid set sprinkler and upgraded dragline systems were ranked lower than the "without project" option.

One of the primary benefits underpinning the drip option was its historical sucrose yield performance compared to sprinkler which showed an average increment of 1.6 tonnes pol per hectare up to 1997 when the redevelopment decision was being made (see Figure 3).

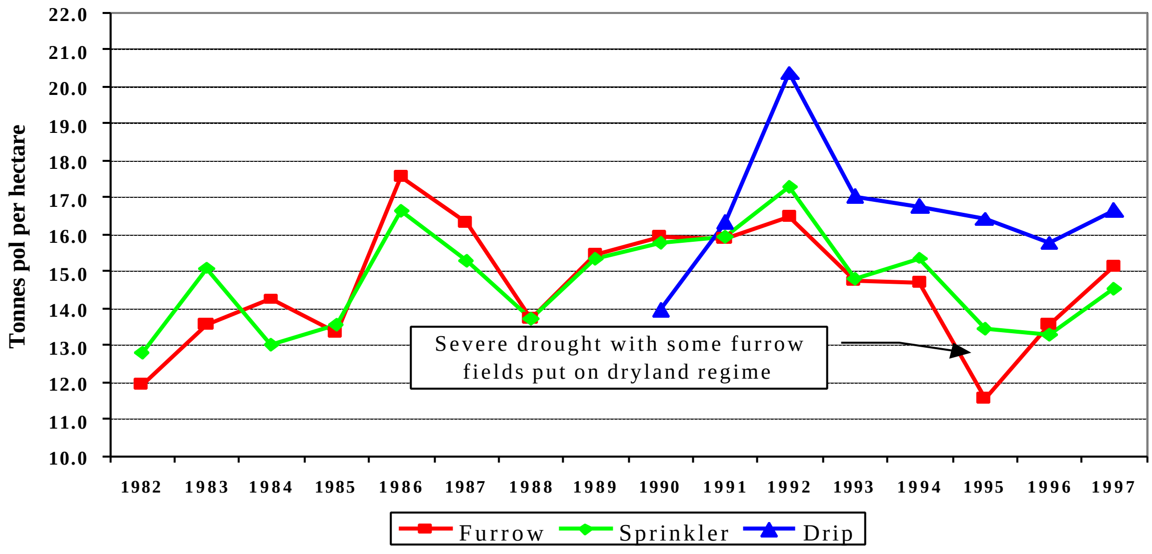

Figure 3: Sucrose productivity by irrigation type

Other measured benefits of drip were labour, water and power savings but in the case of water this does not provide a significant monetary saving as there is no bulk water charge and the main supply is gravity fed by canal from Mnjoli dam. However, the "opportunity value" of this water is very significant indeed as it supports the estate expansion development and the proposed small grower schemes.

Change management and challenges

The decision to proceed with the redevelopment project was made by the RSSC Board in 1997 with the Ngomane sprinkler area (4 763 ha) to be implemented first. Water quality in the Mlaula sprinkler area (2 274 ha) is much poorer and the decision was made to defer irrigation redevelopment there in the short term but upgrade replant fields to solid set using spare sprinkler equipment from the Ngomane redevelopment. Phased implementation in the Ngomane area was undertaken as detailed in Table 1 below: -

Table 1 Irrigation redevelopment phases

Phase/Year	Pump station command areas	Area (ha)
1 – 1998	PS9, PS10, PS12(part), PS16	1 344
2 – 1999	PS10, PS11, PS12(part), PS14 (part), PS15, PS20, PS21	1 996
3 - 2000	PS14(part), PS18	597
4 - deferred	PS13, PS17	826
Total area in Ngomane redevelopment plan		**4 763**

Phase 4 was originally to be completed in 2001 but was deferred in favour of developing the Riverside expansion area.

Irrigation redevelopment raises a host of fresh problems and challenges that never existed with the original greenfield development. The chief of these being how to install thousands of kilometres of drip laterals and pipelines while maintaining cane field productivity and how to change the 'mind set' of operators from a basic sprinkler system to a technologically advanced drip system.

Fortunately, RSSC had many years' experience of installing and operating drip systems and recognised early on that detailed forward planning was necessary and that a specialist implementation team had to be formed with the core of this team comprising estate staff having a solid technical background and many years experience in cane production operations. The key factors in meeting the challenges and achieving successful implementation were: -

- To set clear targets on water savings, yield increments and costs on which the project could be controlled and judged in a post-investment audit.
- To establish formal design, supply and installation contracts for drip systems.
- To involve Section Managers and other field staff in the whole project cycle of design, implementation and commissioning so that they contribute, influence and feel part of the change process rather than having an alien system suddenly thrust upon them only after commissioning.

- To focus attention and time on optimising the design to ensure the drip system will integrate properly with estate operations (land preparation, harvesting, ratoon maintenance, in-field drainage etc).
- To plan the redevelopment and replanting in blocks so as to provide the best utilisation of equipment and to minimise the interval between ploughout and replant. In certain fields with young, productive ratoons within a redevelopment block, surface dripperline was laid as an interim measure.
- To draw in the technical expertise of the drip system manufacturers for design advice, troubleshooting, system testing and staff training.
- To compile appropriate operating manuals and guidelines and conduct regular field seminars. Section Managers in the Phase 1 redevelopment became 'champions' for training and knowledge transfer in the later phases.

Design features and project implementation

One of the early decisions made was to tender for a turnkey contractor to undertake detailed design, supply of equipment, civil and building works, mechanical and electrical installation and commissioning. Previous experience had shown to RSSC that small drip developments could be handled in-house but that a project on the scale envisaged required external contractors. Tenders comprised a work scope, programme, performance specification, general specification, price schedule and contractual conditions based on MF/1, published jointly by the Institution of Electrical Engineers and the Institution of Mechanical Engineers. MF/1 is very appropriate for turnkey projects where the equipment component is larger than the civils component.

Tenderers had to submit a sample design and technical proposal together with their price schedules. The response to this was very good and the winning bid was submitted by a joint venture, MBB/Nyman, linking a consulting engineer specialising in agriculture/irrigation development and an irrigation equipment supply/installation company. The joint venture combined with a trenching and civils subcontractor, Walda Construction, and a drip equipment manufacturer, Netafim, to provide a complete turnkey service.

It was always RSSC's intention to negotiate Phases 2 to 4 with the Phase 1 contractor providing the contract was undertaken satisfactorily and the price escalation was within published indices. Happily this was the case and no further tendering was necessary on the redevelopment project.

The system design contained many new and novel features not previously used in drip developments at Simunye and four of these are highlighted.

1. The "cluster" concept was used to group irrigation control valves together in a secure building commanding some 100 ha rather than locating the valves within the fields. Slightly longer pipe runs were necessary but this was more than offset by the benefits of having centralised irrigation control, secondary filtration, fertigation and chemigation all at one secure location. Photos 1 and 2 show a cluster house arrangement and Map 2 is a typical redevelopment plan defining cluster groups and irrigation panels. Cluster houses can be operated automatically or manually.

2. The Arkal Spin-Klin Star 18 disc filters were used for primary filtration (see Photo 3) instead of traditional sand media filters. The throughput of the Star 18 filter is 500 m^3/hr and it has the same footprint as a sand media filter with a capacity of only 60 m^3/hr.

3. Dual row planting was adopted with drip lateral spacing at 1.8 m and cane rows 0.2 m either side of the drip lateral (see Figure 4 and Photo 4). This configuration provided better protection for the drip tape, a more appropriate spacing for mechanical harvesting, less compaction of cane stools and a 17% saving on drip tape over the conventional 1.5 m cane row spacing.

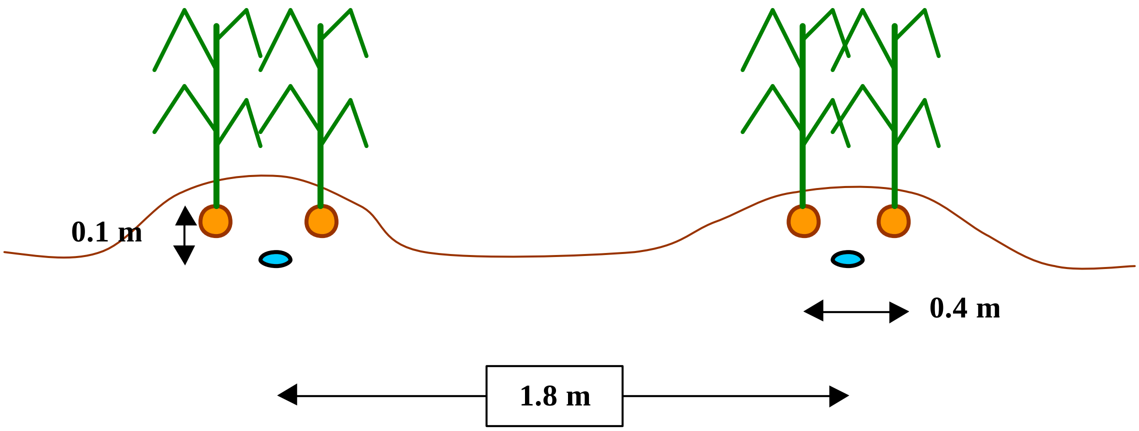

Figure 4: Schematic diagram of dripperline/cane row profile

4. The IRRInet system was used for automatic control of pumps, valves and fertigation from a central computer using Motorola radio control equipment. In previous generation drip systems RSSC had tried automatic control via hydraulic tubes and electric cables but without sustained success and had reverted to manual control. The IRRInet system currently covers a trial 780 ha area but will be extended in the future.

The drip system specification is: -

Design peak demand	7.7 mm/day
Design flow rate	3.3 m^3/hr/ha
Drip tape	Netafim Ram SL, 0.40 mm wall, 15.7 mm ID
Drip emitters	1.6 litres/hr @ 0.92 m spacing
Drip lateral spacing	1.8 m
Cluster house	9 irrigation panels at 9-12 ha each (valves grouped in 3's)
Irrigation phases	x 8 hours at peak demand

The cluster house is equipped with an intake manifold, secondary disc filters, hydrometer, control valves, venturi injector for fertigation, backwash valves and injector point for chemigation. The water from Mnjoli dam has few impurities and so only treflan (root inhibitor) and chlorine are injected via a portable dosing unit just a couple of times per year. The ends of subsurface drip laterals are connected to buried flushing mains with manually operated flush valves at ground level.

The pump stations and asbestos cement mainlines were retained from the original sprinkler system and the new primary filter stations and cluster houses connected into existing pipework. The drip system operates at slightly lower pressure than the sprinkler and so no change to motor ratings was necessary.

Many of the system components such as primary filter station and cluster house could be constructed without disturbing the cane fields. The turnaround from when RSSC handed over a ploughout field to the Contractor for system installation/commissioning and it was handed back to RSSC for planting was just three weeks.

Post investment audit

During the initial project evaluation a rigorous financial appraisal was undertaken to assess whether the benefits accruing from the cost of converting sprinkler to subsurface drip provided an acceptable rate of return. This financial appraisal was an incremental cost-benefit analysis against the "without project" option of retaining the original sprinkler design but replacing in-field equipment.

There were four major benefits from the redevelopment: -

1. **Increased sucrose** 1.6 tpol/ha based on historical comparison of irrigation types
2. **Power levelling** 4.6 kVA/ha/yr saving based on improved load factors
3. **O & M saving** US$ 140/ha/yr (labour, power consumption and maintenance)
4. **Water saving** 1.5 Ml/ha/yr saving has an opportunity value of US$ 160/ha/yr

The opportunity value of the water saving is calculated on its potential to grow cane on expansion land at 11.5 tc/Ml, 13.8% pol, 89% recovery and gross margin US$ 75/ts. The average sucrose for the period 1990-96 was 15.1 tpol/ha (sprinkler) and 16.7 tpol/ha (drip).

In 1999 when Phase 1 of the redevelopment was completed and Phase 2 was in progress a post-investment audit was undertaken on the project (Merry, 1999). The financial analysis has always been done on the whole redevelopment area and in the Swaziland currency (Emalangeni) but for the purpose of this paper the comparison between pre-investment and post-investment has been converted to unit area and US dollars (see Table 2 below): -

Table 2 Comparison of pre-investment forecasts and post-investment results

Cost	Pre-investment (1997) US$/ha	Post-investment (1999) US$/ha
"Without project" cost	860	868
Convert to subsurface drip	2 642	2 542
Incremental cost	1 782	1 674

Benefits	Pre-investment (1997)		Post-investment (1999)	
	Parameter	US$/ha	Parameter	US$/ha
Increased sucrose	1.6 tpol/ha	107	1.5 tpol/ha	91
Power levelling	4.6 kVA/ha	39	1.56 kVA/ha	15
O & M saving		142		219
Water saving/opportunity value	1.5 Ml/ha	160	1.45 Ml/ha	162
Total benefits		448		487
IRR calculation on cashflow	**26.5%**		**29.1%**	

The post-investment audit revealed movements in most parameters but the overall effect was a slightly better rate of return. The audit took a prudent approach and although early indications of sucrose yield and water savings were better than pre-investment estimates the long term averages were adopted. As a consequence sucrose dropped slightly due to poor result in 1998 from some of the older surface drip ratoons but was still 15% higher than sprinkler. Also, 1998 was a wet year with effective rainfall well above average and this resulted in less opportunity to save irrigation water. However, the competitive tender process resulted in a conversion cost lower than originally estimated and operations and maintenance savings were better than expected primarily through higher labour productivity. With the cluster house design one irrigator (cluster house attendant) can manage 96 ha whereas under the sprinkler system one irrigator can only cover 17 ha. Figure 5 shows in pie chart form the relative value of benefits as measured at post-investment.

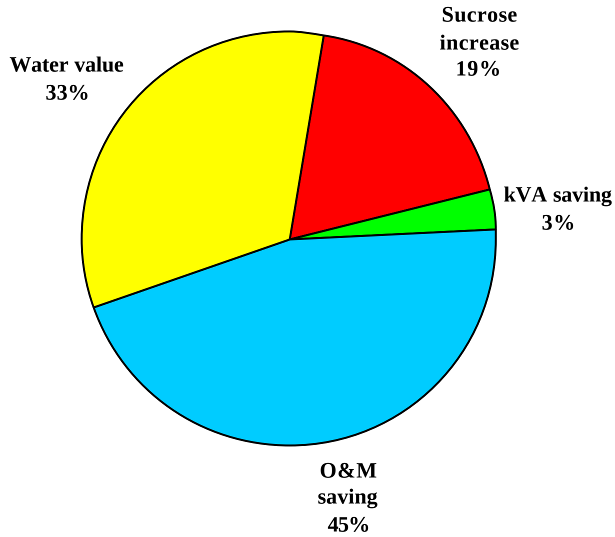

Figure 5: Relative value of project benefits

Further monitoring and analysis has been carried out by RSSC (Ndlovu et al, 2001) on 46 fields converted to subsurface drip in 1998 and compared to 13 sprinkler fields of equivalent age and ratoon class distributed throughout the estate. The findings were that average sucrose increment was 23% for plant cane and 24% for the 1st ratoon and the water use efficiency was 29% better for plant cane and 18% for the 1st ratoon. These results are superior to the parameters used in the 1999 post-investment audit and further confirm that the redevelopment project has met and exceeded its original targets.

Conclusions

The irrigation redevelopment project for the conversion of dragline sprinkler to subsurface drip at Simunye has been successfully implemented with the benefits achieved exceeding initial expectations. The key success factors in this project are considered to be: -

- The definition of clear project targets underpinned by detailed evaluation
- The adoption of the cluster house principle for irrigation operations
- The involvement of field staff in all aspects of design and implementation
- The partnership between the project implementation team, the turnkey contractor and the equipment manufacturer in working towards common goals

- The continuous monitoring and dissemination of data from redeveloped fields to further optimise and refine designs in later phases of redevelopment.

Acknowledgements

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Ndlovu L S, Ellis R D and Street W H. (2001) Conversion from sprinkler to subsurface drip irrigation in Swaziland. The International Society of Sugar Cane Technologists XXIV Congress, Brisbane, Australia, September 2001.

Photo 1: Cluster house external view with fertiliser tanks

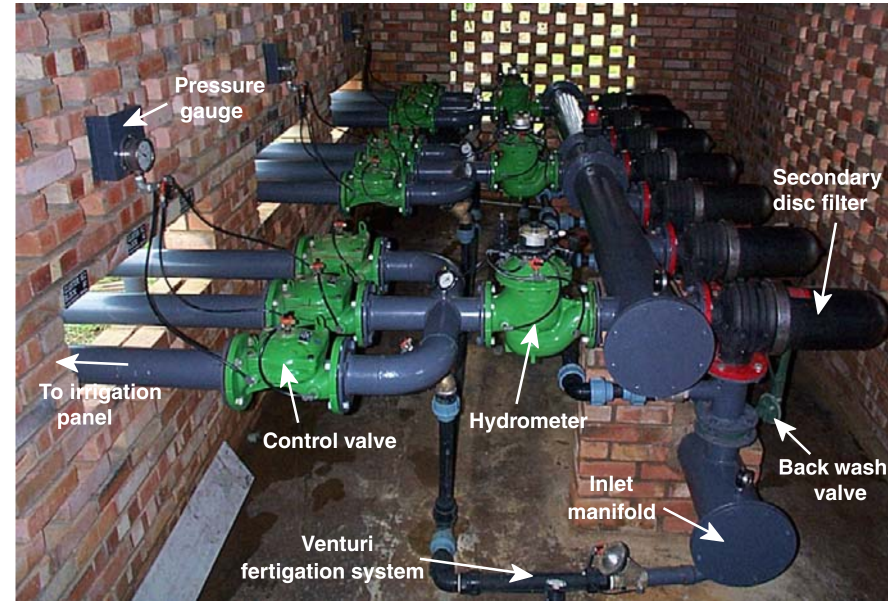
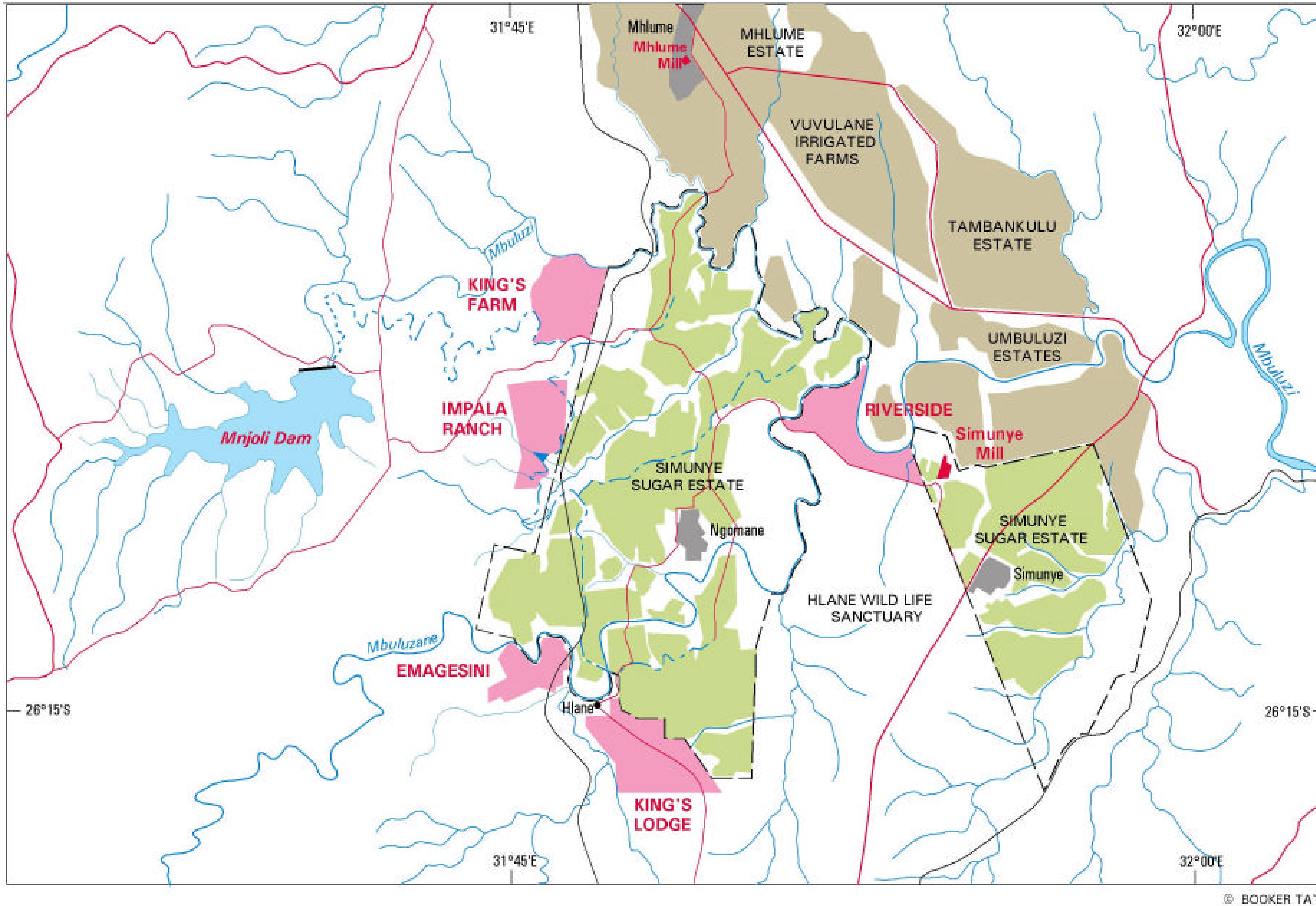


Photo 2: Cluster house internal view - valves set up for manual operation

Photo 3: Primary filters - Arkal Star 18

Photo 4: Dual row first ratoon cane with drip lateral exposed

Map 1 General plan of Simunye sugar estate



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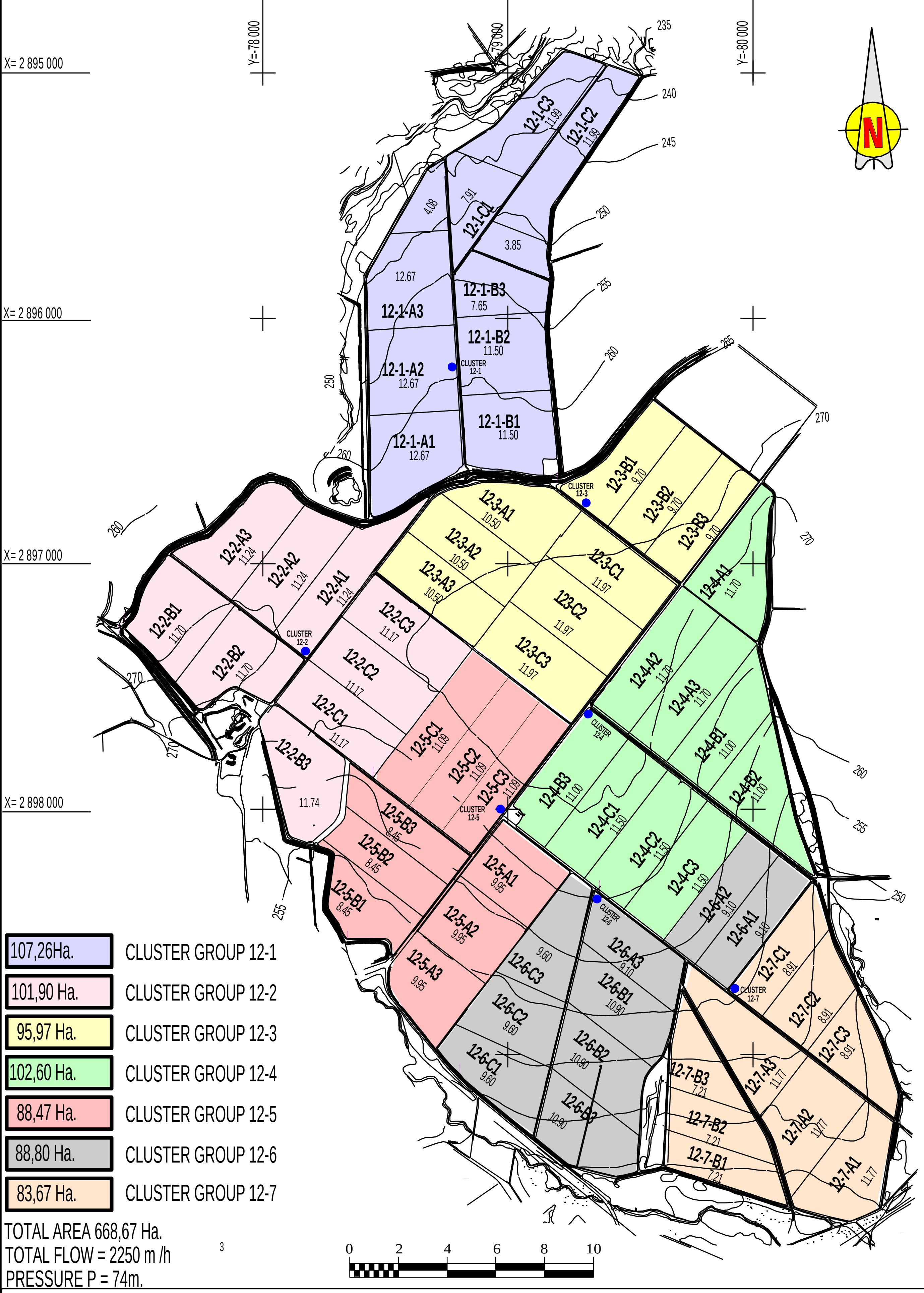

Note: Map 2 is produced from an irrigation layout drawing by the MBB/Nyman joint venture