TECHNICAL ASPECTS AND COST ESTIMATING PROCEDURES OF SURFACE AND SUBSURFACE DRIP IRRIGATION SYSTEMS

Volume 1 of 3

MAIN REPORT

by

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This report forms part of a series of three reports. The reports are:
Technical Aspects and Cost Estimating Procedures of Surface and Subsurface Drip Irrigation Systems Volume 1: Main Report **(WRC Report No. TT 524/12)**
Technical Aspects and Cost Estimating Procedures of Surface and Subsurface Drip Irrigation Systems Volume 2: A Manual for irrigation designers **(WRC Report No. TT 525/12)**
Technical Aspects and Cost Estimating Procedures of Surface and Subsurface Drip Irrigation Systems Volume 3: A Manual for irrigation farmers **(WRC Report No. TT 526/12)**

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Executive Summary

Drip irrigation is considered to be the most efficient irrigation system if it is correctly selected, planned, designed, managed and properly maintained.

Research funded by the Water Research Commission (WRC) and projects completed by the Agricultural Research Council's Institute for Agricultural Engineering (ARC-IAE) on the performance of surface and sub-surface drip irrigation found that the emission uniformity as measured in the field declined over time for all dripper types. This indicates a decline in efficiency due to clogging or lack of maintenance. Correct planning, design, installation and maintenance is essential and it is recommended that regular water quality analysis be carried out to identify potential clogging problems.

The information generated also assists in the selection of emitter and filter type and with the development of preventative measures against clogging, such as use of root growth inhibitors against root intrusion, indicating that proper maintenance schedules and their implementation are thus of utmost importance for the long-term efficient operation of drip irrigation systems.

The results of all these projects created useful information on costing, choice, operation and maintenance of drippers and filters. It was concluded that this knowledge must be disseminated by means of technology transfer and training sessions for designers and farmers.

Through this project, a manual for designers and a manual for farmers have been developed, the former providing guidance for the selection, planning and design of drip systems for designers, and the latter enabling irrigators with sub-surface drip irrigation systems to apply good management and maintenance schedules to enable them to adhere to the objectives of the National Water Resources Strategy (2004) regarding the efficient and beneficial use of water.

In the framework on Water for Growth and Development (Department of Water Affairs and Forestry (DWAF), 2008: 4, 18 & 39) it is stated that inefficient water use in commercial irrigation must be urgently addressed. Recommended actions include measurement of the quantity of water distributed and applied at specific times; preparation of water use efficiency and risk management plans; and a reduction of the quantity of water used for irrigation by existing farmers through investment in appropriate technology. Furthermore, reference is made to proposals by the Department of Agriculture (DoA) (2007: 37-39) contained in the Irrigation Strategy for South Africa, for establishing new farmers and development of an estimated additional 600 000 ha of suitable land. It is argued that most of this potential expansion can be achieved as a result of savings through water loss control and improved irrigation efficiency through application of better irrigation methods such as drip irrigation.

In previous WRC projects on technology transfer, it was shown that adoption of new information is a complex process. In general, end users of information and technology have to be aware and convinced of the technology before it will be accepted and implemented. Specific attention must therefore be given regarding technical information and economic justification of technology. This requires purposeful technology transfer and training of end-users such as designers and farmers. A common understanding of the design principles and practical use of technology by designers, water users and water managers is therefore necessary.

The aim of the project was to facilitate technology transfer in the field of surface and surface drip irrigation with the objectives to facilitate a process towards effective implementation and usage of surface- and subsurface drip irrigation systems in terms of technical and economic principles.

To achieve this, the following tasks were carried out:

- User-friendly guidelines in the form of manuals were compiled for designers and farmers on cost-estimating procedures, the selection, implementation and maintenance of surface and subsurface drip irrigation systems.
- The purpose of the manuals is to provide a comprehensive information document for irrigation designers and farmers operating in South Africa and other SADC countries. It should be read and used in conjunction with the KBase, (a database developed as part of the WRC project by NB Systems) which contains technical information on drippers and filters, and the IRRICOST spreadsheet model, a cost estimating tool that was adapted specifically for the purposes of the WRC project by the University of the Free State.

  The manuals cover technical aspects and cost estimating procedures of designing surface and subsurface drip irrigation systems. The manuals furthermore include recommendations and guidelines regarding the suitability and management of soil and water for drip irrigation, and the selection, costing, design, operation and maintenance of drip irrigation and filtration equipment. It is aimed specifically at drip irrigation in field and permanent crop applications, and does not apply to greenhouse or specialized fertigation units.
- A total of 77 filters and 144 drippers available on the South African market were identified. Performance testing was carried out in the ARC-IAE laboratory on those not been reported on yet in WRC reports, in order to update the performance characteristics list.
- The technical aspects of drippers and filters that are covered in the manual provide background information on different types of equipment, and the factors to be taken into consideration when selecting system components. It also provides details on the methods and calculations used to estimate the cost of drip irrigation systems.
- Continuous Professional Development (CPD) courses were organised to train designers on the selection and usage of surface and subsurface drip irrigation systems with reference to technical and economic principles. The CPD courses have been presented in various areas of South Africa. Over 100, mainly designers and technical personnel, attended the courses. It was 6 hour training sessions and presentations on the technical, cost and product (Agriplas, Conns and Netafim) were presented.
- Field and information days were organised, to present and practically demonstrate the principles of economics, operation and maintenance of drip and filtration systems to farmers and irrigation managers (commercial as well as small scale). It has been presented in 6 hour information sessions and presentations and demonstrations were done on the practical aspects of drip irrigation, cost and products. Presentations by technical personnel from Agriplas, Conns, Netafim and Naan-Dan-Jane were also made.

- Scientific papers were published and presented at an International and National level.
- Popular articles were published in relevant magazines, and radio talks were delivered on the costing, selection, operation and maintenance of surface- and subsurface drip irrigation systems

The project team succeeded in collating the information from various (mainly WRC) research reports and developed two manuals, one for designers and one for farmers, on the latest approaches and technology to assist with the choice, design, cost analysis, operation and maintenance of drippers and filtration equipment. The information was further disseminated by means of technology transfer and training sessions to designers and farmers.

Acknowledgements

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The members of the Reference Group are thanked for their contributions. The Reference Group comprised of the following members:

Dr G R Backeberg	:	Water Research Commission (Chairman)
Dr A J Sanewe	:	Water Research Commission
Mr N M P Opperman	:	Agri SA
Mr I Schooling	:	Agriplas
Mr G Johnstone	:	Agriplas
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Mr T Masike	:	Department of Water Affairs
Mr A S Roux	:	Department of Agriculture, Western Cape
Mr F J du Plessis	:	MBB Consulting
Mr E Erasmus	:	Netafim SA
Mr C M Stimie	:	Rural Integrated Engineering

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- The drip irrigation companies: Agriplas, Conns and Netafim for their support and supplying of data.

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List of Acronyms and Abbreviations

ARC-IAE	Agricultural Research Council's Institute for Agricultural Engineering
CPD	Continuous Professional Development
DI	Dirt index
DoA	Department of Agriculture
GDARD	Gauteng Department of Agriculture and Rural Development
ICID	International Commission on Irrigation and Drainage
IRRICOST	A computer program to estimate both the annual fixed and variable irrigation costs
KBase	Knowledge Base System
MALCID	Malawian Committee on Irrigation and Drainage
NWRS	National Water Resource Strategy
RDBMS	relational database management system
SABI	South African Irrigation Institute
SDI	Subsurface drip irrigation
WRC	Water Research Commission
WUE	Water Use Efficiency

1 INTRODUCTION

1.1 Drip irrigation today

Drip irrigation is considered to be the most efficient irrigation system if it is correctly selected, planned, designed, managed and properly maintained.

Irrigated agriculture plays a major role in the livelihoods of nations all over the world and although irrigation is one of the oldest known agricultural techniques, improvements are still being made in irrigation methods and practices. During the last three decades, major technology advances have taken place in the development drip irrigation systems: the global uptake of drip irrigation increased from 3 Mha in 2000 to more than 9 Mha in 2012.

Drip irrigation is an irrigation method that applies water slowly to the roots of plants, by depositing the water either on the soil surface or directly to the root zone, through a network of valves, pipes, tubing, and emitters (Figure 1).

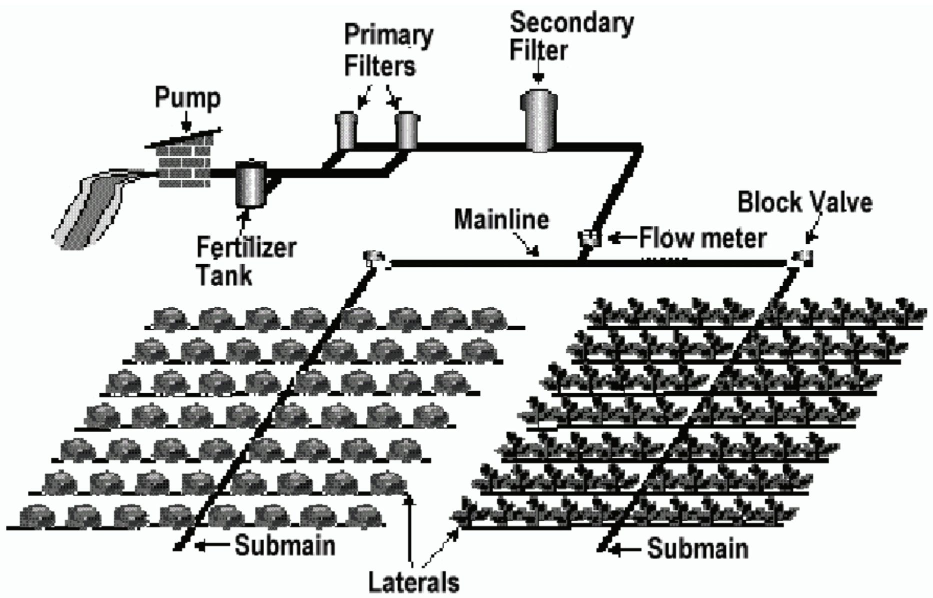


Figure 1: Schematic diagram of a typical drip irrigation system

A manuals for designers and an manual for farmers have been developed through this project, to provide guidance in the selection, planning and design of drip systems for designers and to enable irrigators with sub-surface drip irrigation systems to apply good management and maintenance schedules, allowing them to adhere to the conditions of the National Water Act (NWA), Act No. 36 of 1998, regarding the efficient and beneficial use of water in the public interest. The NWA makes provision the protection, use, development, conservation, management and control of water in a sustainable and equitable manner for the benefit of all people in South Africa.

Currently, surface and sub-surface drip systems account for 160 000 hectares of drip irrigation in South Africa (Van der Stoep, 2011). In the framework on Water for Growth and Development (Department of Water Affairs and Forestry (DWAF), 2008: 4, 18 & 39) it is stated that inefficient water use in commercial irrigation must be urgently addressed. Recommended actions include measurement of the quantity of water distributed and applied at specific times; preparation of water use efficiency (WUE) and risk management plans; and a reduction of the quantity of water used for irrigation by existing farmers through investment in appropriate technology. Furthermore, reference is made to proposals by the Department of Agriculture (DoA) (2007: 37-39) contained in the Irrigation Strategy for South Africa, for establishing new farmers and development of an estimated additional 600 000 ha of suitable land. It is argued that most of this potential expansion can be achieved as a result of savings through water loss control and improved irrigation efficiency through application of better irrigation methods such as drip irrigation.

1.2 The development of drip irrigation

Drip irrigation was used in ancient times by filling buried clay pots with water and allowing the water to gradually seep into the soil. Modern drip irrigation began its development in Germany in 1860 when researchers began experimenting with sub irrigation using clay pipes to create combination irrigation and drainage systems.

In 1913, E.B. House at Colorado State University succeeded in applying water to the root zone of plants without raising the water table. Perforated pipe was introduced in Germany in the 1920s and in 1934, O.E. Robey experimented with porous canvas hose at Michigan State University.

With the advent of modern plastics during and after World War II, major improvements in drip irrigation became possible. Plastic micro tubing and various types of emitters began to be used in the greenhouses of Europe and the United States.

A new technology of drip irrigation was then introduced in Israel by Simcha Blass and his son Yeshayahu. Instead of releasing water through tiny holes, blocked easily by tiny particles, water was released through larger and longer passageways by using friction to slow the water flow rate inside a plastic emitter. The first experimental system of this type was established in 1959 in Israel by Blass, where he developed and patented the first practical surface drip irrigation emitter.

1.3 Advantages of drip irrigation

The advantages of drip irrigation are:

- Sophisticated technology
- Maximum production per mega-litre of water
- Increased crop yields and profits
- Improved quality of production
- Less fertiliser and weed control costs
- Environmentally responsible, with reduced leaching and run-off
- Labour saving
- Application of small amounts of water more frequent

1.4 Disadvantages of drip irrigation

The disadvantages of micro-irrigation are:

- Expensive
- Requires managerial skills

- Waste: The plastic tubing and "tapes" generally last 3-8 seasons before needing replacement
- Clogging
- Plant performance: Studies indicate that many plants grow better when leaves are wetted as well

During 1990 the most important methods of irrigation used were flood irrigation on 32.8% of the 1 290 132 ha total area, sprinkler irrigation on 54.4% of the area and micro/drip irrigation on 11.8% of the area (Backeberg & Reinders, 2009). Over recent years, however, gradual shifts have taken place away from less efficient flood or surface irrigation to more efficient micro and drip irrigation methods (see Table 1).

Preliminary analysis of data for 2007 provided by DWA shows that for the registered area of 1 675 882 ha under irrigation, 14,4% is now under flood, 54,9% is under sprinkler, and 21,8% is under micro/drip, while 8,9% is unknown. (Backeberg & Reinders, 2009). If the 8,9% is regarded as flood irrigation, the total amount will then be 23,3%. Over a period of 18 years therefore, the area under micro and drip irrigation has more than doubled from 152 235 ha to 365 342 ha.

Table 1: Changes in areas and methods of irrigation in South Africa 1990-2007 (Source: Backeberg & Reinders, 2009)

Year	**Area (ha)**	**Method of irrigation (%)**		
		Flood	**Sprinkler**	**Micro/drip**
1990	1 290 132	32,8	54,4	11,8
2007	1 675 882	14,4 (23,3)	54,9	21,8

2 PROJECT BACKGROUND

2.1 Overview

In the 2004 National Water Resource Strategy (NWRS), the strategy for irrigated agriculture provides a framework of regulatory support and incentives to improve efficiency, with a plan of action towards the following:

- Implement measures that reduce wastage.
- Convince users to progressively modernise their water conveyance infrastructure and irrigation equipment.
- Put in place preventative maintenance programmes.
- Follow water allocation processes which promote the equitable and optimal utilisation of water.

Research funded by the WRC, and projects completed by the ARC-AEI on the performance of surface and sub-surface drip irrigation have found that emission uniformity as measured in the field declines over time for all dripper types, indicating a decline in efficiency due to clogging or lack of maintenance. Correct planning, design, installation and maintenance of drip irrigation systems is essential and it is recommended that regular water quality analysis be carried out to identify potential clogging problems. The information generated also assists in emitter type and filter selection and for developing preventative measures, such as use of root growth inhibitors against root intrusion. Proper maintenance schedules and their implementation are thus of utmost importance for the long-term efficient operation of drip irrigation systems.

The results of all these projects created useful information on costing, choice, operation and maintenance of drippers and filters. It was concluded that this knowledge must be disseminated by means of technology transfer and training sessions for designers and farmers.

In previous WRC projects on technology transfer, it was shown that adoption of new information and technology is a complex process. In general, end users of information and technology have to be aware and convinced of the technology before it will be accepted and implemented. Specific attention must therefore be given regarding technical information and economic justification of technology. This requires purposeful technology transfer and training of end-users such as designers and farmers. A common understanding of the design principles and practical use of technology by designers, water users and water managers is therefore necessary.

2.2 Project aims

The aim of the project was to facilitate technology transfer in the field of surface and surface drip irrigation with the following objectives. The focus of the technology exchange was in those areas in South Africa where there is a concentration of drip irrigation system, to enable the improvement of practices and management of drip irrigation in these areas. The expansion of drip irrigation to new areas and/or enterprises was encouraged through information days, TV inserts and radio talks, thus enhancing and supporting the vision of the WRC to transfer published information to the end user in order to make a difference in water use patterns.

The general objective of the project was thus to facilitate a process towards effective implementation and usage of surface and subsurface drip irrigation systems in terms of technical and economic principles. The specific objectives of the project were to:

1) Analyse the following published WRC reports:

- "*Performance of surface drip irrigation systems under field conditions*." FH Koegelenberg; FB Reinders; AS van Niekerk et al. WRC Report 1036/1/02
- "*Sub-surface drip irrigation: Factors affecting the efficiency and maintenance*." FB Reinders; HS Smal; AS van Niekerk et al. WRC Report 1189/1/05
- "*Guidelines for the selection and use of various micro-irrigation filters with regards to filtering and backwashing efficiency."* AS van Niekerk; FH Koegelenberg; FB Reinders et al. WRC Report 1356/1/06
- "*Cost estimating procedures for micro- drip- and furrow irrigation systems as well as economic analysis of the relevant irrigation systems for large- and small scale farmers in the Onderberg/Nkomazi region*." LK Oosthuizen; PW Botha; B Grové et al. WRC Report 974/1/05;

and to compile user-friendly guidelines for the cost-estimating procedures, selection, implementation and maintenance of surface and subsurface drip irrigation systems.

2) Identify all the different types of drippers and filtration equipment available on the South African market and undertake performance testing in the ARC-IAE laboratory on those that had not yet been described in WRC reports, in order to update the list of performance characteristics.

3) Compile a Knowledge Base System (KBase) on all the different types of drippers and filtration equipment with their technical performance characteristics and design information.

4) Organise Continuous Professional Development (CPD) courses to train designers with respect to the technical and economic principles involved with the selection and usage of surface and subsurface drip irrigation systems. (The manual and KBase will be used as training material.)

5) Organise field days to present and to practically demonstrate the principles of economics, operation and maintenance of drip and filtration systems to farmers and irrigation managers.

6) To publish popular articles in relevant magazines, and to give radio talks on the costing, selection, operation and maintenance of surface and subsurface drip irrigation systems.

2.3 Project deliverables

Table 2 summarises the deliverables that were identified and addressed in the project.

Table 2: Summary of deliverables

No.	Deliverable	Description
1	Preparatory phase report	Report on the gathered information from the WRC reports, Companies information and other relevant information
2	Testing and analysis phase report	Test results of newly identified drippers and filters
4	Interim 1 compilation phase report (Manual)	Manual with user-friendly guidelines with cost estimating procedures, selection, implementation and maintenance of surface and subsurface drip irrigation systems including filters for designers
5	Interim 2 compilation phase report (Manual)	Manual with user-friendly guidelines with cost estimating procedures, selection, implementation and maintenance of surface and subsurface drip irrigation systems including filters for commercial and small scale farmers.
6.	Compilation phase report (KBase)	KBase on all the different types of drippers and filtration equipment with their technical performance characteristics and design information on a CD
7.	Interim 1 technology transfer phase to designers	Organising and presenting of information to designers
9.	Interim 2 technology transfer phase to farmers	Organising and presenting of information to commercial and small scale farmers
10.	Interim 3 technology transfer phase report	a) Report on CPD courses for designers. b) Report on field days for farmers and irrigation managers
11.	Knowledge dissemination phase report	Report on papers, articles, radio talks and DVD

2.4 Project outcomes

2.4.1 Preparatory phase

The reports on drippers and filters (technical information and cost analysis techniques) published by the WRC provided excellent information, forming the basis of the manuals that were developed for designers and farmers. A comprehensive list of technical information for available drippers and filtration equipment was also obtained from major companies.

The following reports and publications were studied:

1. Burger, JH; Heyns, PJ; Hoffman, E; Kleynhans, EPJ; Koegelenberg, FH; Lategan, MT; Mulder DJ; Smal, HS; Stimie, CM; Uys, WJ; Van der Merwe, FPJ; Van der Stoep, I; Viljoen, P. 2003. *Irrigation Design Manual.* Agricultural Research Council – Institute for Agricultural Engineering. RSA.

2. Du Plessis, FJ; Van Averbeke, W; Van der Stoep, I. 2002. *Micro-Irrigation for smallholders, guidelines for funders, planners, designers and support staff in South Africa.* Report No. TT 164/01. WRC, Pretoria, RSA.

3. Koegelenberg, FH; Reinders, FB; Van Niekerk, AS; Van Niekerk R; Uys WJ. 2002. *Performance of Surface Drip Irrigation Systems Under Field Conditions*. Report No. 1036/1/02. WRC, Pretoria, RSA.

4. Netafim. 2008. *Product guide.* Netafim South Africa.

5. Oosthuizen, LK; Botha, PW; Grovè, B; Meiring, JA; Monkhei, MM; Pretorius, IG. 2005. *Cost estimating procedures for micro-, drip- and furrow irrigation systems as well as economic analysis of the relevant irrigation systems for large- and small scale farmers in the Onderberg/Nkomazi region*. Report 974/1/05. WRC, RSA.

6. Reinders, FB; Smal, HS; Van Niekerk, AS; Bunton, S; Mdaka, B; 2005. *Sub-Surface Drip Irrigation: Factors Affecting the Efficiency and Maintenance*. Report No. 1189/1/05. WRC, Pretoria, RSA.

7. Sne, M. 2006. Micro irrigation in arid and semi-arid regions: Guidelines for planning and design. International Commission on Irrigation and Drainage (ICID). New Delhi, India.

8. Van Niekerk, AS; Koegelenberg, FH; Reinders, FB; Ascough, GW. 2006. *Guidelines for the Selection and Use of Various Micro-Irrigation Filters with Regards to Filtering and Backwashing Efficiency*. Report No. 1356/1/06. WRC, Pretoria, RSA.

The following detailed information was extracted from the filtration publication:

- Matching the filter type with the water quality and the irrigation system
- Choice of equipment
- Upstream side of the filter station
- Design principles with respect to:
    - Commissioning of the filters
        - Filtration
        - Backwashing
        - Sizing of a filter
    - Filters operation, and
    - Maintenance of filters

Regarding the dripper reports and publications, detailed information was extracted with respect to:

- Water analysis and sampling
- Water evaluation scale for dripper clogging hazard
- Water treatment
- Choice of equipment with respect to:
    - Pump intake
    - Filters
    - Air valves

    - Pressure control valves
    - Flushing manifolds and laterals, and
    - Emitter type
- Design principles with respect to:
    - Filters
    - Dripper emission infirmity
    - Flushing velocity of laterals
    - Design report
- Installation
- Maintenance with respect to:
    - Filter operation
    - Lateral flushing
    - Use of chemicals
    - Use of growth inhibitors
    - General aspects
- Management of soil water levels
- Lateral spacing and wetted area

The cost estimating procedure and economic analysis of drip irrigation systems cannot be done by simply comparing different price quotations; Therefore, information was collated in terms of the technical, economic and financial considerations that would need to be made by farmers when choosing or evaluating different irrigation systems.

The first step in the analysis of the economics of irrigation is a technically and economically sound estimate of the irrigation system cost. The cost estimating procedure illustrates how the total annual costs of the system are estimated after calculating the irrigation costs. The profitability and financial feasibility of converting an existing irrigation system to a more efficient system such as a drip system can then be evaluated. For this purpose the results of the cost estimating procedures can then be fed into a capital budgeting procedure. The importance of risk was also acknowledged: risk simulation procedures were used to evaluate the risk efficiency of alternatives.

Cost estimating worksheets for drip irrigation that can be used for the evaluation process were developed.

2.4.2 Testing and analysis phase

Filtration and drip irrigation equipment available on the South African market was identified, and technical data was collected from the companies concerned. Agriplas and Netafim drippers and Agriplas, Netafim and Conns filters were evaluated. Performance testing on a selection of drippers and filters was undertaken in the Hydrolab of the ARC-IAE.

2.4.2.1 Filters

A wide variety of filtration equipment is available on the South African market. Working from the published reports and information from the companies, all the filters were coded in order to assist with identification. Figure 2 shows the coding hierarchy which was adopted for filters.

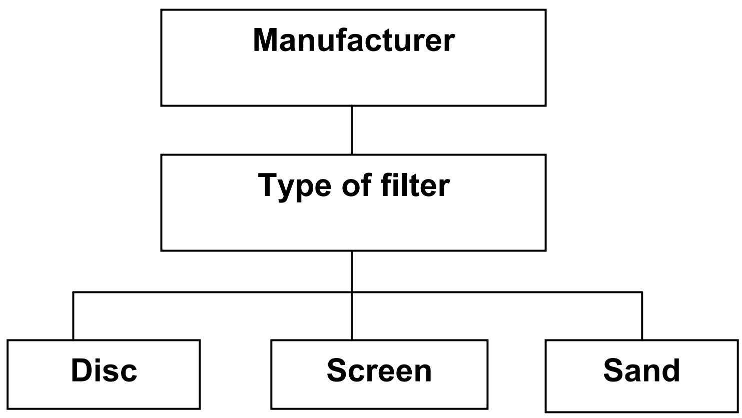


Figure 2: Hierarchy for coding filters

The following coding sequence was followed:

- The first letter of the code is the first letter of the manufacture name (e.g. N for Netafim)
- The second letter of the code is the first letter of the filter type (e.g. D for disc filters, C for screen filters and S for sand filters), and
- The digits represent the filter number (e.g. 01, 02, 03…n)

Agriplas, Conns and Netafim supplied data for all their filtration equipment in raw format. This was analysed, consolidated and tabulated, and circulated back to the companies for confirmation.

Agriplas filters are shown in Table 3, Netafim filters are shown in Table 4, whilst Conns filters are shown in Table 5. In most cases technical data for the products is available from the companies.

Table 3: Agriplas filter names and assigned codes

Type	Name of Filter	Code
Disc	Amiad 3 disc filter (80 mm)	**AD01**
Disc	Amiad 3 disc filter (Tagline series) (80 mm)	**AD02**
Disc	Amiad 2S disc filter (Tagline series) (50 mm)	**AD03**
Disc	Amiad 2 disc filter (Tagline series) (50 mm)	**AD04**
Disc	Amiad 1.5 disc filter (Tagline series) (40 mm)	**AD05**
Disc	Amiad 1 disc filter (Tagline series) (25 mm)	**AD06**
Disc	Amiad 3/4 disc filter (Tagline series) (20 mm)	**AD07**
Disc	Amiad 1-C disc filter (25 mm)	**AD08**
Disc	Amiad 1-S disc filter (25 mm)	**AD09**
Disc	Amiad 11/2-C disc filter (40 mm)	**AD10**
Disc	Amiad 11/2-S disc filter (40 mm)	**AD11**
Disc	Amiad 2-T disc filter (50 mm)	**AD12**
Disc	Amiad 2-T-S disc filter (50 mm)	**AD13**
Disc	Amiad 3TL disc filter (80 mm)	**AD14**
Disc	Amiad 3LT-S disc filter (80 mm)	**AD15**
Screen	Amiad 3 disc filter (Tagline series) (80 mm)	**AC01.1**
Screen	Amiad 2S screen filter (Tagline series) (50 mm)	**AC01.2**
Screen	Amiad 2 screen filter (Tagline series) (50 mm)	**AC01.3**
Screen	Amiad 1.5 screen filter (Tagline series) (40 mm)	**AC01.4**
Screen	Amiad 1 screen filter (Tagline series) (25 mm)	**AC01.5**
Screen	Amiad 3/4 disc filter (Tagline series) (20 mm)	**AC01.6**
Screen	Amiad self-cleaning screen filter (Taf 3) (80 mm)	**AC02.1**
Screen	Amiad self-cleaning screen filter (Taf 2) (50 mm)	**AC02.2**
Screen	Amiad 3 screen filter (Taf series) (80 mm)	**AC02.3**
Screen	Amiad 2 supr screen filter (Taf series) (50 mm)	**AC02.4**
Screen	Amiad 2 screen filter (Taf series) (50 mm)	**AC02.5**
Screen	Amiad self-cleaning screen filter (Saf 3000) (150 mm)	**AC03.1**
Screen	Amiad self-cleaning screen filter (Saf 6000) (150, 200, 250 mm)	**AC03.2**
Screen	Amiad self-cleaning screen filter (Saf 4500) (100, 150, 200 mm)	**AC03.3**

Screen	Amiad self-cleaning screen filter new (Saf 3000) (80, 100, 150 mm)	**AC03.4**
Screen	Amiad self-cleaning screen filter (Saf 1500)(50, 80, 100 mm)	**AC03.5**
Screen	Amiad 1-C screen filter (25 mm)	**AC04**
Screen	Amiad 1-S screen filter (25 mm)	**AC05**
Screen	Amiad 11/2-C screen filter (40 mm)	**AC06**
Screen	Amiad 11/2-S screen filter (40 mm)	**AC07**
Screen	Amiad 2 T screen filter (50 mm)	**AC08**
Screen	Amiad 2 T-S screen filter (50 mm)	**AC09**
Screen	Amiad 3 TL screen filter (80 mm)	**AC10**
Screen	Amiad 3 LT-S screen filter (80 mm)	**AC11**
Sand	Silicon II 41 sand filter (80 mm)	**AS01**
Sand	Silicon II 28 sand filter (80 mm)	**AS02**
Sand	Silicon II 18 sand filter (50 mm)	**AS03**
Sand	Combination sand and disc filter (41 mm)	**AS04**
Sand	Combination sand and disc filter (28 mm)	**AS05**
Sand	Combination sand and disc filter (28 mm)	**AS06**

Table 4: Netafim filter names and assigned codes

Type	**Name of Filter**	**Code**
Disc	Arkal Spin Klin disc filter (Three-Filter unit) (100 mm)	**ND01**
Disc	Arkal 3 disc filter (Arkal 3 Twin) (80 mm)	**ND02**
Disc	Disc (20 mm)	**ND04**
Disc	Short (25 mm)	**ND05**
Disc	Super (25 mm)	**ND06**
Disc	Short Chemical (40 mm)	**ND07**
Disc	Short (40 mm)	**ND08**
Disc	Super (40 mm)	**ND09**
Disc	Leader (50 mm)	**ND10**
Disc	Dual (50 mm)	**ND11**
Disc	Spin Klin (50 mm)	**ND12**
Disc	Sand Separator (50 mm)	**ND13**
Disc	Leader (80 mm)	**ND14**
Disc	Twin (80 mm)	**ND15**
Disc	Spin Klin (80 mm)	**ND16**
Disc	Super Angle (80 mm)	**ND17**
Disc	Super Angle (100 mm)	**ND18**

Disc	Super (100 mm)	**ND19**
Disc	Super (150 mm)	**ND20**
Screen	B-Series Screen	**NC01**
Disc	Arkal Spin klin spine model II(auto)	**ND21**
Disc	Arkal 2 Spin klin compact filter	**ND22**
Disc	Arkal 3/4 manual disc filter with differential tightening	**ND23**
Disc	Arkal 1 manual disc Filter with differential tightening	**ND25**
Disc	Arkal 1 Super manual disc Filter with differential tightening	**ND26**
Disc	Arkal 1.5 manual disc filter with differential tightening	**ND27**
Disc	Arkal 1.5 Super manual disc filter with differential tightening	**ND28**
Disc	Arkal 2 Dual manual disc filter with differential tightening	**ND30**
Disc	Arkal 3 Twin manual disc filter with differential tightening	**ND32**
Disc	Arkal Dual Lite 50 mm	**ND36**
Disc	Arkal Dual Lite 80 mm	**ND37**

Table 5: Conns filter names and assigned codes

Type	**Name of filter**	**Code**
Disc	Conn D40-65 Inline disc filter	**CD01**
Disc	Conn D40-80 Inline disc filter	**CD02**
Disc	Conn D80-80 Inline disc filter	**CD03**
Disc	Conn D80-100 Inline disc filter	**CD04**
Sand	Conn 12 Auto Sandfilter	**CS01**
Sand	Conn 20 Vertin Sandfilter	**CS02**
Sand	Conn 40 Vertin Sandfilter	**CS03**
Sand	Conn 40 Sandfilter (80 mm)	**CS04**

2.4.2.2 Drippers

A wide range of drippers is available on the South African market. Contact was made with Agriplas and Netafim who are the main suppliers of drippers in South Africa. The data was analysed and tabulated. Technical details of Agriplas dripper examples are shown in Table 6, whilst those for Netafim dripper examples are shown in Table 7.

Table 6: Technical details of Agriplas drippers

Button Dripper

Dripper name	Emitter Discharge (ℓ/h)
Agriplas PC Button Dripper	1
	2,2
	3,1
	3,8
	5,2
	7,8
	8,0
	12
Agriplas Regular Button Dripper	2,0
	4,0
	8,0

Regular Drip

Dripper name	Emitter Discharge (ℓ/h)
Agriplas Regular Drip 12 mm	0,9
	2,1
	2,8
	1,0
	2,2
	3,0
Agriplas Regular Drip 16 mm	1,0
	1,6
	2,1
	3,9
	1,2
	1,9
	2,2
	4,4
Agriplas Regular Drip 20 mm	1,2
	2,2
	3,0
	4,5
	1,2
	2,2
	3,1
	4,5

Drip Tape

Dripper name	Emitter Discharge (ℓ/h)
Agriplas Drip Tape 16 mm	0,65
	1,0
	0,65
	1,0
	0,65
	1,0

PC Drip

Dripper name	Emitter Discharge (ℓ/h)
Agriplas PC Drip 12 mm	1,15
Agriplas PC Drip 16 mm Agriplas PC Drip 17 mm	1,2
	1,6
	2,2
	3,6
Agriplas PC Drip 20 mm	1,2
	1,6
	2,2
	3,4

Table 7: Technical details of Netafim drippers and laterals

UniRam RC and UniRam CNL

Dripper	Emitter Discharge (ℓ/h)
Netafim UniRam 17010 Netafim UniRam 17012 Netafim UniRam 20010 Netafim UniRam 20012	0.7
	1.0
	1.6
	2.3
	3.5

DripNet PC

Dripper	Emitter Discharge (ℓ/h)
Netafim DNPC 16010 Netafim DNPC 20010 Netafim DNPC 17004	0.6
	1.0
	1.6
	2.0
	3.0
	3.8

Tiran

Dripper	Emitter Discharge (ℓ/h)
Netafim Tiran 16010 Netafim Tiran 16008 Netafim Tiran 20010 Netafim Tiran 12010	1.0
	1.5
	2.0
	4.0
	8.0

Super Typhoon

Dripper	Emitter Discharge (ℓ/h)
Netafim Super Typhoon 16125	0.80
	1.10
	1.60
	2.70
Netafim Super Typhoon 16150	1.05
	1.65

Streamline

Dripper	Emitter Discharge (ℓ/h) Nominal	Max Pressure
Netafim Streamline 16060	1.10	1.00
	1.60	1.45
Netafim Streamline 16080	1.05	1.05
	1.60	1.60

MicroDrip

Dripper	Emitter Discharge (ℓ/h) Nominal	At 1.2 m Pressure
Netafim MicroDrip 08008	2.0	0.71

Online Button Drippers – Non Pressure compensated

Dripper	Emitter Discharge (ℓ/h)
Netafim Woodpecker BD	2.0
	4.0
	8.0
Netafim Arrow Dripper	1.6
	2.3

Online Button Drippers – Pressure compensated

Dripper	Emitter Discharge (ℓ/h)
Netafim Woodpecker PC	2.0
	4.0
	8.5
Netafim Mataf	25.0
Netafim Woodpecker PCJ	2.0
	4.0
	8.0

Online Button Drippers – Pressure compensated CNL

Dripper	Emitter Discharge (ℓ/h)
Netafim CNL Low	2.0
	4.0
	8.5
Netafim CNL High	3.0
	6.0
	12.0
Netafim CNL PCJ	0.5
	1.2
	2.0
	4.0

A total of 77 filters and 144 drippers have been identified and a selected group most commonly used on the South African market has been tested.

2.4.2.3 Filter testing

The performance of the filters was evaluated under controlled conditions in a world class hydraulic laboratory at the ARC-IAE. The test bench (Figure 3) is a re-circulating system, consisting mainly of two reservoirs, a pump, pipes, valves, two Dirtiness Index (DI) meters, electric pressure and flow sensors, and instrumentation displaying all the signals and with two-way communication with the controlling computer.

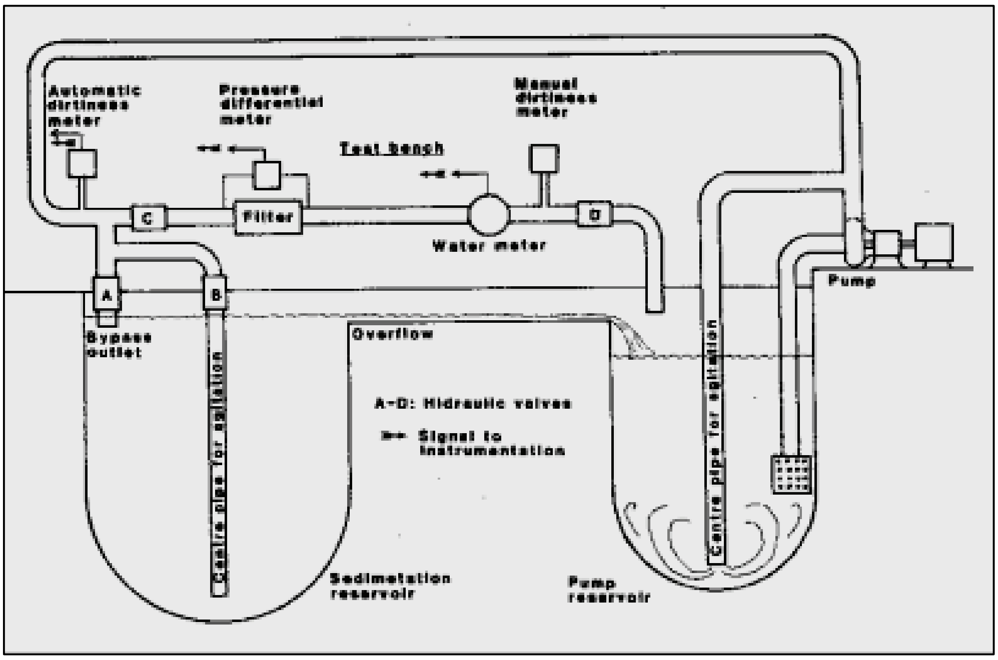


Figure 3: The irrigation filter test bench

The following parameters were closely monitored and recorded in response to changes in the dirtiness of the water circulating through the test bench:

- total volume that was filtered;
- the flow-rate through the filter;
- the pressure differential; and
- the dirtiness index (DI) before and after the test.

The filtration efficiencies were calculated from these measurements using the following equation:

$$\text{Filtration efficiency} = 100(1 - \frac{\text{DI } \textit{after filter}}{\text{DI } \textit{before filter}})\%$$

The tests were repeated after backwashing the filters, and the data used to determine the backwash efficiency.

$$\text{Backwash efficiency} = \frac{\text{Volume filtered at DI with backwashing}}{\text{Volume filtered at DI by clean filter}} \times 100$$

Where: DI_n = Dirtiness Index of a specific value.

2.4.2.4 Emitter testing

Discharge and coefficient of discharge variation (CV_q) tests were conducted on the selected emitters. New drip lines with emitters were obtained from the manufacturers, and tested in the laboratory for average discharge and for the manufacturing coefficient of discharge variation (CV_q), as shown in Figure 4.

Figure 4: Test bench for emitter discharge and CVq tests

Ten sections of a drip line, each containing ten emitters, were attached to the water supply manifolds of the test bench (Figure 4) on both sides to ensure that all emitters operate at equal pressure. The pressure in the water supply manifolds was adjustable and automatically controlled at pre-set values. Each emitter discharged into a separate calibrated and electronically monitored measuring cylinder, which were also equipped with an electronically controlled drain valve.

The test was started with the drain valves on the measuring cylinders in the open position. These valves were then simultaneously closed once the operating pressure had stabilised at a preset value. The pressure and flow rate of the water supply system, and the time it took for individual measuring cylinders to fill was continuously electronically monitored and recorded, and the water temperature recorded. This cycle was repeated for each pressure setting. Tests on regular emitters were carried out for operating pressures from 20 kPa with increments of 20 kPa up to 300 kPa, or a lesser pressure if so prescribed by the manufacturer. All tests were repeated three times.

In the case of pressure compensating emitters, the discharge rate was measured with the operating pressures increasing from 20 kPa with increments of 20 kPa up to 100 kPa, and from there at increments of 50 kPa up to 400 kPa. The discharge rate was also measured with similarly declining pressures. In accordance with ISO standards flow rate measurements were taken three minutes and CVq measurements one hour after pressure stabilisation. Since the discharge of pressure compensated emitters generally decreases slightly over time, the average discharge rates given in the discharge test might be slightly higher than the discharge given in the CVq test.

The average discharge of the emitters at each pressure was determined by dividing the supply flow rate by the number of emitters on test, and the test results were represented in the form of a table, a discharge curve and by the mathematical equation:

$$q_e = kP^x$$

where: q_e = emitter discharge (ℓ/h)

k = emitter constant

P = emitter operating pressure (kPa)

x = discharge exponent.

The discharge of individual emitters at a particular pressure was calculated by dividing the volume of each of the calibrated cylinders by the time taken for the particular cylinder to fill. CVq values, the minimum and maximum discharge and the variation in discharge were established for the total sample of 100 emitters, as well as for four groups of 25 emitters in accordance with ISO/TC 23/SC 18 N 89 standards. The CVq, expressed as a percentage of the average discharge, was calculated as follows:

$$\overline{q} = \frac{1}{n} \sum_{i=1}^{n} q_i$$

$$S_q = \left[\frac{1}{n-1} \sum_{i=1}^{n} \left(q_i - \overline{q}\right)^2 \right]^{1/2}$$

$$CV_q = \frac{S_q}{\overline{q}}$$

where:

q_i	=	emitter discharge rate (ℓ/h)
n	=	number of emitters of the sample
$\overline{q}$	=	mean of all the measured discharge rates (ℓ/h)
S_q	=	standard deviation of the discharge rate of the emitter
CV_q	=	coefficient of variation of discharge rate of the emitters.

2.4.2.5 Filter test results

Specifications as obtained from the Manufacturers and the performance tests that were carried out on the selected filters in the laboratory are given in Table 8 to Table 14.

The test reports are with ARC-IAE and selective data is shown in the tables.

Table 8: Agriplas: Manufacture's filter specifications

Filter	Filter descrip-tion	Maximum flow rate (m^3/h)	Maximum operating pressure (kPa)	Minimum operating pressure (kPa)	Filtration area (cm^2)	Filtration volume (cm^3)	Minimum backwash pressure (kPa)	Backwash flow rate (m^3/h)	Recom flush time (sec)	Waste flush volume (m^3)	Sand size (mm)	Automation		Information source	Tested	
												Electric	Hydraulic		Yes	No
AD01	Disc	50	1 000	NA	1 185	NA	NA	NA	NA	NA			Yes	File/Brochure	Yes	
AD02	Disc	50	800	NA	1185	NA	NA	NA	NA	NA				File/Brochure		No
AD03	Disc	25	800	NA	1185	NA	NA	NA	NA	NA				File/Brochure		No
AD04	Disc	25	800	NA	790	NA	NA	NA	NA	NA				File/Brochure		No
AD05	Disc	15	800	NA	460	NA	NA	NA	NA	NA				File/Brochure		No
AD06	Disc	5	800	NA	-	NA	NA	NA	NA	NA				File/Brochure		No
AD07	Disc	3	800	NA	-	NA	NA	NA	NA	NA				File/Brochure		No
AD08	Disc	5	1000	NA	-	NA	NA	NA	NA	NA				File/Brochure		No
AD09	Disc	7	1000	NA	200	NA	NA	NA	NA	NA				File/Brochure		No
AD10	Disc	15	1000	NA	200	NA	NA	NA	NA	NA				File/Brochure		No
AD11	Disc	15	1000	NA	460	NA	NA	NA	NA	NA				File/Brochure		No
AD12	Disc	25	1000	NA	790	NA	NA	NA	NA	NA				File/Brochure		No
AD13	Disc	25	1000	NA	1185	NA	NA	NA	NA	NA				File/Brochure		No
AD14	Disc	50	1000	NA	1185	NA	NA	NA	NA	NA				File/Brochure		No
AD15	Disc	50	1000	NA	1580	NA	NA	NA	NA	NA				File/Brochure		No
AC01.1	Screen	50	800	NA	700	NA	NA	NA	NA	NA				File/Brochure		No
AC01.2	Screen	25	800	NA	700	NA	NA	NA	NA	NA				File/Brochure		No
AC01.3	Screen	25	800	NA	465	NA	NA	NA	NA	NA				File/Brochure		No
AC01.4	Screen	15	800	NA	340	NA	NA	NA	NA	NA				File/Brochure		No
AC01.5	Screen	5	800	NA	110	NA	NA	NA	NA	NA				File/Brochure		No
AC01.6	Screen	3	800	NA	110	NA	NA	NA	NA	NA				File/Brochure		No
AC02.1	Screen	50	1000	250	465	NA	200	8 (min)	12	0,026			Yes	File/Brochure	Yes	
AC02.2	Screen	25	1000	250	465	NA		8 (min)	12	0.032			Yes	File/Brochure		No
AC02.3	Screen	50	800	150	700	NA		5.7 (min)	16	0.025		Yes		File/Brochure		No
AC02.4	Screen	25	800	150	700	NA		5.7 (min)	16	0.025		Yes		File/Brochure		No
AC02.5	Screen	25	800	150	465	NA		4 (min)	16	0.018		Yes		File/Brochure		No
AC03.1	Screen	150	1 000	150	3 000	NA	200	11 (min)	20	0,061				File/Brochure	Yes	
AC03.2	Screen	400	1000	200	6000	130 000 000		20(min)	40	0.28		Yes		File/Brochure		No

Table 8: Agriplas: Manufacture's filter specifications (cont.)

Filter	Filter description	Maximum flow rate (m^3/h)	Maximum operating pressure (kPa)	Minimum operating pressure (kPa)	Filtration area (cm^2)	Filtration volume (cm^3)	Minimum backwash pressure (kPa)	Backwash flow rate (m^3/h)	Recommended flush time (sec)	Waste flush volume (m^3)	Sand size (mm)	Automation		Information source	Tested	
												Electric	Hydraulic		Yes	No
AC03.3	Screen	250	1000	200	4500	80 000 000		15 (min)	20	0.083		Yes		File/Brochure		No
AC03.4	Screen	150	1000	200	3000	57 000 000		11 (min)	20	0.064		Yes		File/Brochure		No
AC03.5	Screen	80	1000	200	1500	35 000 000		6 (min)	15	0.025		Yes		File/Brochure		No
AC04	Screen	5	1000		110									File/Brochure		No
AC05	Screen	7	1000		170									File/Brochure		No
AC06	Screen	15	1000		170									File/Brochure		No
AC07	Screen	15	1000		340									File/Brochure		No
AC08	Screen	25	1000		465									File/Brochure		No
AC09	Screen	25	1000		700									File/Brochure		No
AC010	Screen	50	1000		700									File/Brochure		No
AC011	Screen	50	1000		930									File/Brochure		No
AS01	Sandfilter	41	1 000	100	6 648	332 380	200	50 (max)	180	2				File/Brochure	Yes	
AS02	Sandfilter													File/Brochure		No
AS03	Sandfilter													File/Brochure		No
AS04	Sandfilter													File/Brochure		No
AS05	Sandfilter													File/Brochure		No
AS06	Sandfilter													File/Brochure		No

Table 9: Agriplas laboratory test results

Filter	Filter description	Filtration test		Friction loss (kPa)	Backwash efficiency (%)	Test laboratory	Test report available
		Hand-cleaned (%)	Backwashed (%)				
AD01	Disc filter	85,1	76,4		20,1	IAE Hydrolab	Yes
AS01	Sandfilter	-	-			IAE Hydrolab	Yes
AC02.1	TAF 3	-	26,4			IAE Hydrolab	Yes
AC03.1	SAF 3000	-	69,4			IAE Hydrolab	Yes

Table 10: Netafim: Manufacture's filters specifications

Filter	Filter Description	Maximum flow rate (m^3/h)	Maximum operating pressure (kPa)	Minimum operating pressure (kPa)	Filtration area (cm^2)	Filtration volume (cm^3)	Minimum backwash pressure (kPa)	Backwash flow rate (m^3/h)	Recommended flush time (sec)	Waste flush volume (m^3)	Sand size (mm)	Automation		Information source	Tested	
												Electric	Hydraulic		Yes	No
ND01	Disc	30	1 000	NA	1 760	2 640	280	16 (min)	30	0,13				Brochure	Yes	
ND02	Disc	30	1 000	NA	1 900	2 450	250	40 (max)	60	0,67				Brochure	Yes	
ND04	Disc	4	1 000	N/A	160	95	N/A	N/A						Brochure		No
ND05	Disc	6	1 000	N/A	308	370	N/A	N/A						Brochure		No
ND06	Disc	8	1 000	N/A	500	592	N/A	N/A						Brochure		No
ND07	Disc	4	600	N/A	308	370	N/A	N/A						Brochure		No
ND08	Disc	8	1 000	N/A	308	370	N/A	N/A						Brochure		No
ND09	Disc	12	1 000	N/A	500	592	N/A	N/A						Brochure		No
ND10	Disc	25	1 000	N/A	950	1 425	N/A	N/A						Brochure		No
ND11	Disc	25	1 200	N/A	950	1 225	N/A	N/A						Brochure		No
ND12	Disc	25	1 000	280	880	1 320	N/A	N/A						Brochure		No
ND13	Disc	25	1 000	114	N/A	N/A	N/A	N/A						Brochure		No
ND14	Disc	40	1 000	N/A	1 900	2 850	N/A	N/A						Brochure		No
ND15	Disc	40	1 000	N/A	1 900	2 450	N/A	N/A						Brochure		No
ND16	Disc	40	1 000	280	1 760	2 640	N/A	N/A						Brochure		No
ND17	Disc	50	1 000	N/A	1 852	1 774	N/A	N/A						Brochure		No
ND18	Disc	60	1 000	N/A	1 852	1 774	N/A	N/A						Brochure		No
ND19	Disc	100	1 000	N/A	3 704	3 548	N/A	N/A						Brochure		No
ND20	Disc	120	1 000	N/A	3 704	3 548	N/A	N/A						Brochure		No
ND21	Disc		1 000	280				8		0.033				Brochure		No

Table 10: Netafim: Manufacture's filters specifications (cont.)

Filter	Filter Description	Maximum flow rate (m^3/h)	Maximum operating pressure (kPa)	Minimum operating pressure (kPa)	Filtration area (cm^2)	Filtration volume (cm^3)	Minimum backwash pressure (kPa)	Backwash flow rate (m^3/h)	Recommended flush time (sec)	Waste flush volume (m^3)	Sand size (mm)	Automation		Information source	Tested	
												Electric	Hydraulic		Yes	No
ND22	Disc	20	1 000		880	1 320	280					Yes		Brochure		No
ND23	Disc	4	1 000	N/A	N/A	95	N/A	N/A						Brochure		No
ND25	Disc	6	1 000	N/A	308	370	N/A	N/A						Brochure		No
ND26	Disc	8	1 000	N/A	500	592	N/A	N/A						Brochure		No
ND27	Disc	8	1 000	N/A	308	370	N/A	N/A						Brochure		No
ND28	Disc	12	1 000	N/A	500	592	N/A	N/A						Brochure		No
ND30	Disc	25	1 200	N/A	950	1 225	N/A	N/A						Brochure		No
ND32	Disc	40	1 000	N/A	1 900	2 450	N/A	N/A						Brochure		No
NS03	Sand	70	600											Brochure		No
ND36	Disc	20	800	N/A	950	1 225	N/A	N/A						Brochure		No
ND37	Disc	40	800	N/A	1 900	2 450	N/A	N/A						Brochure		No

Table 11: NETAFIM Filter laboratory test results

Filter	Filter description	Filtration test		Friction loss (kPa)	Backwash efficiency (%)	Test laboratory	Test report available
		Hand-cleaned (%)	Backwashed (%)				
ND01	Arkal Spin Kleen	-	71,4			IAE Hydrolab	Yes
ND02	Arkal 3, Disc Filter	35,8	26,6		41,9	IAE Hydrolab	Yes

Table 12: Conns Manufacture's Filters Specifications

Filter	Filter descrip-tion	Maximum flow rate (m^3/h)	Maximum operating pressure (kPa)	Minimum operating pressure (kPa)	Filtration area (cm^2)	Filtration volume (cm^3)	Minimum backwash pressure (kPa)	Backwash flow rate (m^3/h)	Recom flush time (min)	Flush volume (m^3)	Sand size (mm)	Automation		Information source	Tested	
												Electric	Hydraulic		Yes	No
CD01	Disc	40	1000	200	0,19		200	15	2	1,5		Yes	Yes	Brochure	X	
CD02	Disc	40	1000	200	0,19		200	15	2	1,5		Yes	Yes	Brochure	X	
CD03	Disc	60	1000	200	0,38		200	30	2	1,5		Yes	Yes	Brochure	X	
CD04	Disc	60	1000	200	0,38		200	30	2	1,5		Yes	Yes	Brochure	X	
CS01	Sand	10	1000	200	0,20 (m^2)		200	15	2	1,5	0,8-1,4	Yes	Yes	Brochure	X	
CS02	Sand	18	1000	200	0,35 (m^2)		200	20	3	2	0,8-1,4	Yes	Yes	Brochure	X	
CS03	Sand	40	1000	200	0,70 (m^2)		200	60	4	3	0,8-1,4	Yes	Yes	Brochure	X	
CS04	Sand	40	1 000	200	7 000	280 000	100	60 (max)	3-4	3	0,8-1,4	Yes	Yes	Report	X	

Table 13: Conns laboratory test results

Filter	Filter description	Filtration test		Friction loss (kPa)	Backwash efficiency (%)	Test laboratory	Test report available
		Hand-cleaned (%)	Backwashed (%)				
CS04	Sand filter		100%	0,25	92%	Yes	Yes

Table 14: Additional data from Agriplas

INDEX	Type	Model	In/Out ø (mm)	Filter. deg (micron)							Available Information			Max flow (m^3/h)	Pressure Max (bar)	Filter Area (cm^2)	Flushing time	Wasted H_20 (*l*)	min flushing flow (m^3/h)
				500	300	250	200	180	130	100	Technical	Selection	Maintenance						
Tagline screen filter	screen	c/w	20	√	√		√		√	√	Yes	Yes	Yes	3	8	110			
Tagline screen filter	screen	c/w	25	√	√		√		√	√	Yes	Yes	Yes	5	8	110			
Tagline screen filter	screen	c/w	40	√	√		√		√	√	Yes	Yes	Yes	15	8	340			
Tagline screen filter	screen	c/w	50	√	√		√		√	√	Yes	Yes	Yes	25	8	465			
Tagline screen filter	screen	super	50	√	√		√		√	√	Yes	Yes	Yes	25	8	700			
Tagline screen filter	screen	c/w	80	√	√		√		√	√	Yes	Yes	Yes	50	8	700			
Tagline screen filter	screen	flanged c/w	80	√	√		√		√	√	Yes	Yes	Yes	50	8	700			
Tagline disc filter	disc	c/w	40			√	√		√	√	Yes	Yes	Yes	15	8	460			
Tagline disc filter	disc	c/w	50			√	√	√	√	√	Yes	Yes	Yes	25	8	790			
Tagline disc filter	disc	super	50			√	√	√	√	√	Yes	Yes	Yes	25	8	790			
Tagline disc filter	disc	c/w	80			√	√	√	√	√	Yes	Yes	Yes	50	8	1150			
Tagline disc filter	disc	flanged c/w	80			√	√	√	√	√	Yes	Yes	Yes	50	8	1150			
Amiad screen filter	screen	black c/w	20	√	√		√		√	√	Yes	Yes	Yes	3	10	110			
Amiad screen filter	screen	blue chem c/w	20		√						Yes	Yes	Yes	3	10	110			
Amiad screen filter	screen	super c/w	25	√	√		√		√	√	Yes	Yes	Yes	7	10	170			
Amiad screen filter	screen	super c/w	40	√	√		√		√	√	Yes	Yes	Yes	15	10	340			
Amiad screen filter	screen	T c/w	50	√	√		√		√	√	Yes	Yes	Yes	25	10	465			
Amiad screen filter	screen	T flanged c/w	80	√	√		√		√	√	Yes	Yes	Yes	50	10	700			
Amiad screen filter	screen	Twin flanged c/w	80	√	√		√		√	√	Yes	Yes	Yes	50	10	930			
Amiad disc filter	disc	super c/w	25			√	√		√	√	Yes	Yes	Yes	7	10	200			
Amiad disc filter	disc	super c/w	40			√	√		√	√	Yes	Yes	Yes	15	10	460			
Amiad disc filter	disc	T c/w	50			√	√	√	√	√	Yes	Yes	Yes	25	10	790			
Amiad disc filter	disc	T flanged c/w	80			√	√	√	√	√	Yes	Yes	Yes	50	10	1185			
Amiad disc filter	disc	Twin flanged c/w	80			√	√	√	√	√	Yes	Yes	Yes	50	10	1580			
Amiad steel screen filter	screen	c/w	80	√	√		√		√	√	Yes	Yes	Yes	50	10	1430			
Amiad steel screen filter	screen	compact c/w	100	√	√		√		√	√	Yes	Yes	Yes	80	10	1430			

Amiad steel screen filter	screen	super c/w	100	√	√		√		√	√	Yes	Yes	Yes	80	10	2740			
Amiad steel screen filter	screen	compact c/w	150	√	√		√		√	√	Yes	Yes	Yes	160	10	2740			
Amiad steel screen filter	screen	super c/w	150	√	√		√		√	√	Yes	Yes	Yes	160	10	5720			
Amiad steel disc filter	disc	c/w	80			√	√	√	√	√	Yes	Yes	Yes	50	10	790			
Amiad steel disc filter	disc	compact c/w	100			√	√	√	√	√	Yes	Yes	Yes	80	10	2600			
Amiad Torpedo screen filter plastic	screen	S c/w	25	√	√		√		√	√	Yes	Yes	Yes	7	10	170			
Amiad Torpedo screen filter plastic	screen	S c/w	40	√	√		√		√	√	Yes	Yes	Yes	15	10	340			
Amiad Torpedo screen filter plastic	screen	T c/w	50	√	√		√		√	√	Yes	Yes	Yes	25	10	465			
Amiad Torpedo screen filter plastic	screen	T c/w	80	√	√		√		√	√	Yes	Yes	Yes	50	10	700			
Amiad Torpedo screen filter plastic	screen	flanged dbl c/w	80	√	√		√		√	√	Yes	Yes	Yes	50	10	930			
Amiad Torpedo screen filter plastic	screen	flanged c/w	80	√	√		√		√	√	Yes	Yes	Yes	50	10	1430			
Amiad Torpedo screen filter plastic	screen	compact fl. c/w	100	√	√		√		√	√	Yes	Yes	Yes	80	10	1430			
Amiad Torpedo screen filter plastic	screen	super fl c/w	100	√	√		√		√	√	Yes	Yes	Yes	80	10	2740			
Amiad Torpedo screen filter plastic	screen	compact fl. c/w	150	√	√		√		√	√	Yes	Yes	Yes	160	10	2740			
Amiad Torpedo screen filter plastic	screen	super fl c/w	150	√	√		√		√	√	Yes	Yes	Yes	160	10	5720			
Amiad Torpedo screen filter plastic	screen	flanged c/w	200	√	√		√		√	√	Yes	Yes	Yes	300	10	5720			
Amiad Scanaway screen filter plastic	screen	T c/w	50	√	√		√		√	√	Yes	Yes	Yes	25	10	465			
Amiad Scanaway screen filter plastic	screen	T c/w	80	√	√		√		√	√	Yes	Yes	Yes	50	10	700			
Amiad Scanaway screen filter plastic	screen	flanged c/w	80	√	√		√		√	√	Yes	Yes	Yes	50	10	930			
Amiad Scanaway screen filter plastic	screen	super fl c/w	100	√	√		√		√	√	Yes	Yes	Yes	80	10	2740			
Amiad Scanaway screen filter plastic	screen	compact fl. c/w	150	√	√		√		√	√	Yes	Yes	Yes	160	10	2740			
Amiad Scanaway screen filter plastic	screen	super fl c/w	150	√	√		√		√	√	Yes	Yes	Yes	150	10	5720			
Amiad Scanaway screen filter plastic	screen	flanged c/w	200	√	√		√		√	√	Yes	Yes	Yes	300	10	5720			
Amiad Brushaway screen filter plastic	screen	T c/w	50	√	√		√		√	√	Yes	Yes	Yes	25	10	465			
Amiad Brushaway screen filter plastic	screen	T c/w	80	√	√		√		√	√	Yes	Yes	Yes	50	10	700			
Amiad Brushaway screen filter plastic	screen	super fl c/w	80	√	√		√		√	√	Yes	Yes	Yes	50	10	930			
Amiad Brushaway screen filter plastic	screen	super fl c/w	100											80	10	2740			
Amiad Brushaway screen filter plastic	screen	compact fl. c/w	150	√	√		√		√	√	Yes	Yes	Yes	160	10	2740			
Amiad Brushaway screen filter plastic	screen	super fl c/w	150	√	√		√		√	√	Yes	Yes	Yes	160	10	5720			
Amiad Brushaway screen filter plastic	screen	flanged c/w	200	√	√		√		√	√	Yes	Yes	Yes	300	10	5720			
Filtomat aut. screen filter M102C	screen	threated c/e	50	√	√		√		√	√	Yes	Yes	Yes	40	max 8 min 2	750	10	15	15
Filtomat aut. screen filter M103C	screen	flanged c/w	80	√	√		√		√	√	Yes	Yes	Yes	80	max 8 min 2	1500	10	15	15
Filtomat aut. screen filter M103CL	screen	flanged c/w	80	√	√		√		√	√	Yes	Yes	Yes	80	max 8 min 2	1500	10	20	20

Filtomat aut. screen filter M104C	screen	flanged c/w	100	√	√		√		√	√	Yes	Yes	Yes	80	max 8 min 2	1500	10	20	20
Filtomat aut. screen filter M104LP	screen	flanged c/w	100	√	√		√		√	√	Yes	Yes	Yes	180	max 8 min 2	4500	15	125	26
Filtomat aut. screen filter M104XLP	screen	flanged c/w	100	√	√		√		√	√	Yes	Yes	Yes	400	max 8 min 2	6800	15	150	30
Filtomat aut. screen filter M106XLP	screen	flanged c/w	150	√	√		√		√	√	Yes	Yes	Yes	400	max 8 min 2	6800	15	150	30
Filtomat aut. screen filter M108LP	screen	flanged c/w	200	√	√		√		√	√	Yes	Yes	Yes	400	max 8 min 2	6800	15	150	30
Filtomat aut. screen filter M110LP	screen	flanged c/w	250	√	√		√		√	√	Yes	Yes	Yes	400	max 8 min 2	6800	15	150	30
Silicon II sandfilters	sand	18"									Yes	Yes	Yes	18	10				
Silicon II sandfilters	sand	28"									Yes	Yes	Yes	28	10				
Silicon II sandfilters	sand	41"									Yes	Yes	Yes	41	10				

2.4.2.6 *Dripper test results*

Performance tests were carried out on various drippers in the Hydrolab. Typical test results are given in Table 15 for regular drippers and in Table 16 for pressure compensated drippers.

The test reports are with ARC-IAE and selective data is shown in the tables.

Table 15: Typical Laboratory test results on Regular Drippers

Dripper	Emitter discharge (ℓ/h)	Discharge test				CV_q Test (P=100kPa nominal)				
		Discharge (ℓ/h)				Discharge (ℓ/h)				CV_q (%)
		100 kPa	200 kPa	300 kPa	400 kPa	Max	Min	Ave	Var (%)	
Regular 12 mm	2	2,23	3,19	3,93	Not tested	2,5	2,1	2,2	18,2	2,1
Regular 12 mm	4	2,26	3,25	4,01	Not tested	2,6	2,2	2,3	17,4	2,4
Regular 16 mm	2	4,07	5,77	7,07	Not tested	4,5	3,8	4,1	17,1	3,8
Regular 16 mm	4	4,25	6,07	7,46	Not tested	4,7	4,1	4,3	14,0	2,2

Table 16: Typical Laboratory test results on Pressure Compensated (PC) Drippers

Dripper name	Emitter discharge (ℓ/h)	Discharge test (Average P)				CV_q Test(P = 200 kPa nominal)				
		Discharge (ℓ/h)				Discharge (ℓ/h)				CV_q (%)
		100 kPa	200 kPa	300 kPa	400 kPa	Max	Min	Ave	Var (%)	
PC 17	2,3	2,47	2,41	2,45	2,51	2,4	2,1	2,3	13,0	2,6
PC 17	3,5	3,72	3,65	3,78	3,74	4,2	2,5	3,6	47,2	4,0
PC 20	2,3	2,53	2,40	2,46	2,45	2,5	2,0	2,3	21,7	3,9
PC 20	3,5	3,68	3,50	3,60	3,47	3,6	3,2	3,4	11,8	2,6

Additional technical data of Netafim's drippers is provided in Table 17.

Table 17: Particulars of the NETAFIM drippers and lateral dimensions (NSA Product guide – Drip)

UniRam RC and UniRam CNL

Dripper	Flow-Q (l/h)	K (A)	X (B)	Kd	ID (mm)	OD (mm)	Wall (mm)	Pressure (m)				Coils (m)
								Minimum		Maximum		
								RC	CNL	Work	Flush	
UniRam 17010	0.7	0.7	0	1.2	14.4	16.4	1.0	5	10	35	46	500
	1.0	1.0										
	1.6	1.6										
	2.3	2.3										
	3.5	3.5										
UniRam 17012	The same as UniRam 17010			1.1	14.6	17.0	1.2	5	10	40	52	400
UniRam 20010				0.4	17.5	19.5	1.0			35	46	300
UniRam 20012				0.4	17.5	19.9	1.2			40	52	300
NB	*UniRam CNL close below 1.4 meter and during negative pressure due to Anti-Siphon*											

DripNet PC

Dripper	Flow-Q (l/h)	K (A)	X (B)	Kd	ID (mm)	OD (mm)	Wall (mm)	Pressure (m) Minimum	Pressure (m) Maximum Work	Pressure (m) Maximum Flush	Coils (m)
DNPC 16010	0.6	0.6	0	0.72	14.2	16.2	1.0	4	25*	39	500
	1.0	1.0									
	1.6	1.6									
	2.0	2.0							30*		
	3.0	3.0									
	3.8	3.8									
DNPC 20010	The same as DNPC 16010			0.35	17.5	19.5	1.0	4	25/30*	39	300
DNPC 17004				0.40	16.2	17.0	0.4	4	22	25	**
NB	** The maximum working pressure is defined by the Dripper and not by the pipe wall thickness.* *** DripNet PC 17004 cassette length for 0.3 m = 900 meter, 0.4- 0.5 m = 1000 meter and 0.6-1.0 m = 1250 meter*										

Tiran

Dripper	Flow-Q (l/h)	K (A)	X (B)	Kd	ID (mm)	OD (mm)	Wall (mm)	Maximum Pressure (m) Work	Maximum Pressure (m) Flush	Coils (m)
Tiran 16010	1.0	0.348	0.46	0.4	14.2	16.2	1.0	35	46	500
	1.5	0.520								
	2.0	0.693								
	4.0	1.387								
	8.0	2.774								
Tiran 16008*	The same as Tiran 16010			0.4	14.2	15.8	0.8	27	35	500
Tiran 20010				0.1	17.5	19.5	1.0	35	46	300
Tiran 12010				0.7	10.2	12.2	1.0	35	52	500
** Can be coiled on a cassette*										

Super Typhoon

Dripper	Flow-Q (l/h)	K (A)	X (B)	Kd	ID (mm)	OD (mm)	Wall (mm)	Wall (mil)	Maximum Pressure (m) Work	Maximum Pressure (m) Flush	Coils (m)
Super Typhoon 16125	0.80	0.284	0.45	0.1	16.2	16.8	0.31	12.5	18	21	N1
	1.10	0.390									
	1.60	0.529	0.48								
	2.70	0.894									
Super Typhoon 16150	1.05	0.373	0.45	0.1	16.2	17.0	0.38	15.0	22	25	N2
	1.65	0.546	0.48								

NB

Mil = (mm÷0.025) Mil is an American standard for wall thickness.

N1 = Cassette length for 0.2 m = 1250 meter and 0.3- 0.6 =1500 meter.

N2 = Cassette length for 0.6 m = 1250 meter.

Streamline

Dripper	Flow-Q (l/h) Nominal	Flow-Q (l/h) Max Pressure	K (A)	X (B)	Kd	ID (mm)	OD (mm)	Wall (mm)	Wall (mil)	Maximum Pressure (m) Work	Maximum Pressure (m) Flush	Coils (m)
Streamline 16060	1.10	1.00	0.392	0.45	0.1	16.2	16.5	0.15	6.0	8	9	N3
	1.60	1.45	0.568									
Streamline 16080	1.05	1.05	0.373	0.45	0.1	16.2	16.6	0.20	8.0	10	12	N4
	1.60	1.60	0.568									

NB

Mil =(mm ÷0.025) Mil is an American standard for wall thickness

N3 = Cassette length for 0.2 m = 2600 meter and 0.3-0.4 = 3000 meter.

N4 = Cassette length for 0.2 m = 2200 meter and 0.3-04 = 2500 meter.

MicroDrip

Dripper	Flow-Q (l/h) Nominal	Flow-Q (l/h) At 1.2 m Pressure	K (A)	X (B)	Kd	ID (mm)	OD (mm)	Wall (mm)	Maximum Pressure (m)	Maximum Pressure (m) Flush	Coils (m)
MicroDrip 08008	2.0	0.71	0.647	0.49	2.0	6.4	8.0	0.8	20	26	600

Online Button Drippers – Non Pressure compensated

Dripper	Flow-Q (l/h)	K (A)	X (B)	Colour Top	Colour Bottom	Pressure (m) Min	Pressure (m) Max	Pressure (m) Close
Woodpecker BD	2.0	0.662	0.48	Black	Red	5	20	n/a
	4.0	1.325			Black			
	8.0	2.649			Green			
Arrow Dripper	1.6	0.551	0.48	Light Grey		5*	12	n/a
	2.3	0.761		Black				
NB	**If Arrow- and Button Drippers are combined the minimum pressure at button dripper must be 22 meters or calculate the actual minimum pressure as per tables below.*							

The minimum operation pressure of CNL button drippers combined with Arrow drippers:

Arrow drippers		
Pressure (m)	1.6 l/h Flow rate (l/h)	2.3 l/h
1	0.5	0.8
2	0.8	1.1
4	1.0	1.5
5	1.2	1.6
6	1.3	1.8
7	1.4	1.9
8	1.5	2.1
10	1.6	2.3
12	1.8	2.5

Dripper	Flow rate (l/h)	Min. Pressure
CNL Low	2.0, 4.0, 8.5	10 m
CNL High	3, 6, 12	14 m

Example 1: CNL High 12 l/h + 6 Arrow drippers (2.3 l/h)		
14 m	8 m	22 m
Example 2: CNL Low 8.5 l/h + 4 Arrow drippers (2.3 l/h)		
10 m	8 m	18 m
Example 3: CNL Low 4 l/h + 4 Arrow drippers (1.6 l/h)		
10 m	4 m	14 m
Example 4: CNL High 6 l/h + 4 Arrow drippers (1.6 l/h)		
14 m	8 m	22 m

NB	*Design system to have ≥ 4 m pressure at the Arrow dripper thus a minimum of 1.0 l/h or 1.5 l/h at the Arrow drippers to ensure a minimum velocity to reduce the clogging risk.*

Online Button Drippers – Pressure compensated

Dripper	Flow-Q (l/h)	K (A)	X (B)	Colour Top	Colour Bottom	Pressure (m) Min	Pressure (m) Max	Pressure (m) Close
Woodpecker PC	2.0	2.0	0	Black	Red	5	40	n/a
	4.0	4.0			Black			
	8.5	8.5			Green			
Mataf	25.0	25.0	0	Black	Purple	10	40	n/a
Woodpecker PCJ	2.0	2.0	0	Black	Red	5	40	n/a
	4.0	4.0			Black			
	8.0	8.0			Green			

Online Button Drippers – Pressure compensated CNL

Dripper	Flow-Q (l/h)	K (A)	X (B)	Colour		Pressure (m)		
				Top	Bottom	Min	Max	Close
CNL Low	2.0	2.0	0	Brown	Red	10	40	1.5
	4.0	4.0			Black			
	8.5	8.5			Green			
CNL High	3.0	3.0	0	Black	Black	14	40	3.0
	6.0	6.0						
	12.0	12.0						
CNL PCJ*	0.5	0.5	0	Black	Mustard	7	40	1.2
	1.2	1.2			Brown			
	2.0	2.0			Red			
	4.0	4.0			Grey			
NB	** CNL PCJ have rings at the bottom for identification*							

2.4.3 Manual compilation phase

Two comprehensive manuals were compiled, (one for designers and one for farmers) covering the technical aspects and cost estimating procedures of surface and subsurface drip irrigation systems.

Relevant information from the WRC reports and other publications and manuals was compiled into user-friendly guidelines dealing with cost estimating procedures, the selection, implementation and maintenance of surface and subsurface drip irrigation systems and the selection and use of filtration equipment. These manuals are described in more detail in section 3.1 and 3.2.

2.4.4 Knowledge Base System compilation phase

A CD-based Knowledge Base System (KBase) was compiled which captured information on the various types of drippers and filtration equipment, together with their technical performance characteristics and design information. The CD is at the back of the Main report.

The KBase is a versatile tool that can both capture and provide information. The information can be sorted and searched in a number of ways and all the information in the database (including pictures) can be printed. Information is available regarding dripper and filter manufacturers; long flow path or pressure compensation drippers; whether drippers or filters have been tested; the type of filter elements, and whether filters are manual or automatic, electric or hydraulic. The KBase is described in more detail in Section 3.3.

2.4.5 Cost spreadsheet compilation phase

The irrigation cost estimation procedure (IRRICOST-SPREADSHEET) was developed to do an economic analysis of drip irrigation systems. Therefore, information was collated in terms of the technical, economic and financial considerations that would need to be made by farmers when choosing or evaluating different irrigation systems. Variances in factors such as the area under irrigation, the type of soil irrigated and the pumping heights necessitate the estimation of the fixed and variable costs of each system. The Spreadsheet contains therefore a procedure to assist in evaluating the cost of a drip irrigation system. The Spreadsheet can be accessed on the KBase CD at the back of the Main report. This phase is described in more detail in section 3.4.

2.4.6 Technology transfer phase

The technology transfer phase involved training and technology exchange sessions throughout South Africa to facilitate the process of drip irrigation adoption. Participants included designers, commercial, large and small scale farmers and managers currently using micro irrigation, as well as farmers and managers who would like to adopt drip irrigation. Training and information was provided.

Continuous Professional Development (CPD) courses were organised to train designers on the technical and economic principles of the selection and usage of surface and subsurface drip irrigation systems. The manual and KBase were used as training material for these courses.

The sessions were organised in collaboration with various branches of the South African Irrigation Institute and the Institute of Agricultural Engineers, and carried out by means of PowerPoint presentations plus video clips of the operation of drippers and filters, as well as practical demonstrations of the maintenance schedules for filters and drippers. This phase is described in more detail in Section 3.5.

2.4.7 Knowledge dissemination phase

The research resulted in the dissemination of the compiled reports, providing an excellent opportunity to inform designers and farmers alike. The concepts of drip irrigation technology were published as popular articles and presented at workshops, seminars and conferences. Scientific papers were also prepared and presented at National and International Congresses. This Phase is described in more detail in Section 3.6

3 PRODUCTS

3.1 Drip Irrigation manual for designers

The purpose of the manual for designers is to provide a comprehensive information document for the designers of drip systems in South Africa and other SADC countries. It should be read and used in conjunction with the KBase, (a database developed as part of the WRC project by NB Systems) which contains technical information on drippers and filters, and the IRRICOST spreadsheet model, a cost estimating tool that was adapted specifically for the purposes of the WRC project by the University of the Free State.

The manual is aimed specifically at drip irrigation in field and permanent crop applications, and does not apply to greenhouses or specialised fertigation units. It covers the technical aspects and cost estimating procedures of designing surface and subsurface drip irrigation systems. It does not include the general aspects of irrigation planning and design and in this regard, other sources or the ARC-Institute for Agricultural Engineering's Irrigation Design Manual can be consulted. It includes recommendations and guidelines regarding the suitability and management of soil and water for drip irrigation, and the selection, costing, design, operation and maintenance of drip irrigation and filtration equipment.

The technical aspects of drippers and filters that are covered in the manual provide background information on different types of equipment, and the factors to be taken into consideration when selecting system components. It also provides details on the methods and calculations used to estimate the cost of drip irrigation systems.

The content is presented under the three broad headings of technical aspects, guidelines, and procedures. Figure 5 shows the structure of the manual.

With the technical aspects of drippers and filters, background information is provided on the different types of equipment and the factors to be taken into account with respect to characteristics, selection and products available.

The guidelines provide general guidelines for planning and design and then specific guidelines for drip irrigation systems. It is comprehensive information that can assist in planning a successful drip irrigation system.

The final part is the procedures that provide details on the methods and calculations used during planning, designing and costing of the drip system.

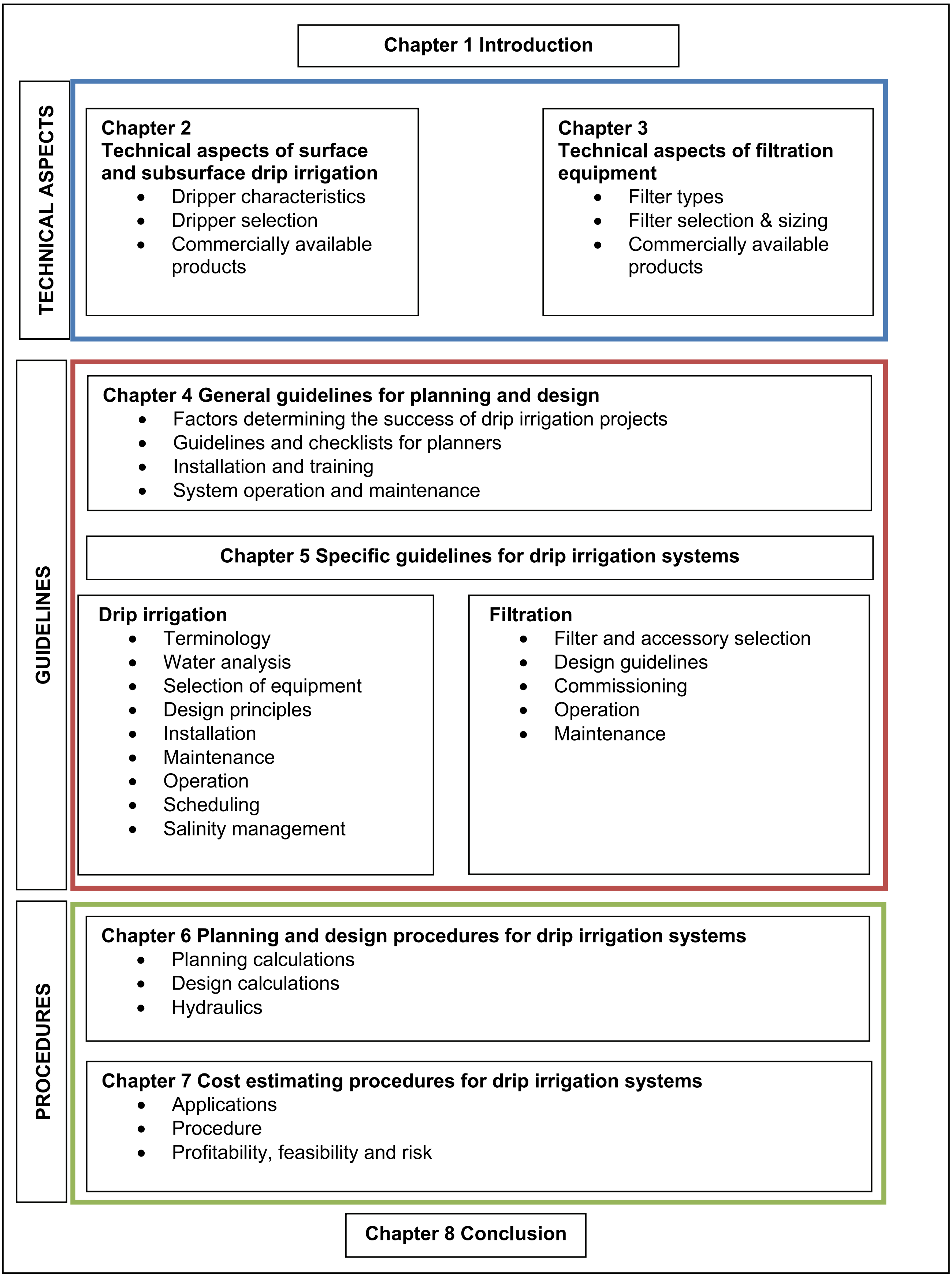


Figure 5: Structure of the Manual for Irrigation Designers

3.2 Drip Irrigation Manual for Farmers

The purpose of the manual for farmers is to provide a comprehensive information document for irrigation farmers in South Africa and other SADC countries. It can be read and used in conjunction with the KBase, (a database developed as part of the WRC project by NB Systems) which contains technical information on drippers and filters, and the IRRICOST spreadsheet model, a cost estimating tool that was adapted specifically for the purposes of the WRC project by the University of the Free State.

The manual covers the technical aspects of surface and subsurface drip irrigation systems; filtration equipment and cost estimating procedures. The manual includes recommendations and guidelines regarding the suitability and management of soil and water for drip irrigation, and the selection, costing, design, principles, operation and maintenance of drip irrigation and filtration equipment. It is aimed specifically at drip irrigation in field and permanent crop applications, and does not apply to greenhouses or specialised fertigation units.

The technical aspects of drippers and filters that are covered in the manual provide background information on different types of equipment, and the factors to be taken into consideration when selecting system components. Details on the methods and calculations used to estimate the cost of drip irrigation systems are also provided in the guidelines aspects that are addressed including water quality, installation, maintenance and operation, management of soil water levels and salinity management.

The procedures give guidelines regarding cost estimating calculations that include capital and operational costs.

The content is presented under the three broad headings of technical aspects, guidelines, and procedures. Figure 6 shows the structure of the manual.

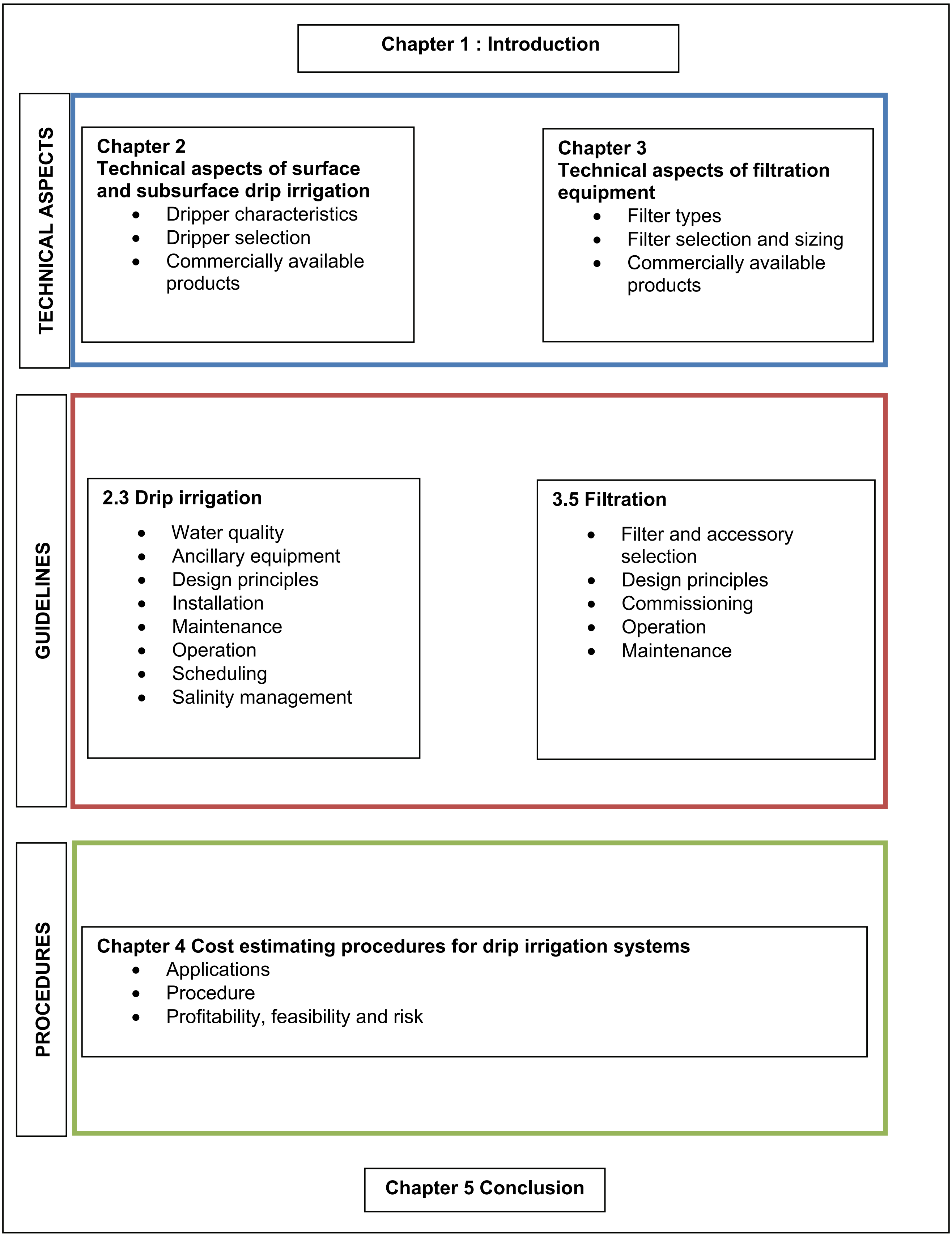


Figure 6: Structure of the Manual for Irrigation Farmers

3.3 Knowledge base system

The CD-based KBase is a versatile tool that comprises information on the various types of drippers and filtration equipment, together with their technical performance characteristics, design information, and pictures. The information can be sorted and searched in a number of ways and printed out if required, and includes details of manufacturers; the type and categories of drippers and filters available, and test details and results. Figure 7 shows the startup page of the KBase. This KBase is in the form of a CD at the back cover of the Main Report, Volume 1.

Figure 7: Knowledge Base System

3.3.1 Uses and benefits of KBase

The KBase has the following uses and benefits:

- Assists in obtaining information on a dripper, filter or general information (Figure 6)
- Provides a centralised database of drippers and filters with capturing functions (Figure 8 and 9)
- Links to manufacturers' web sites
- Links to an unlimited number of images (see Figure 10)
- Links to specific dripper or filter catalogues if available
- Links to the " Manual for Irrigation Designers"
- Links to the "Manual for Irrigation Farmers"
- Links to the "Cost estimating procedures"

3.3.2 KBase user requirements

KBase runs on any Windows platform and uses very little resources. KBase is written in Delphi using Firebird as the underlying database. Firebird is an open source SQL relational database management system (RDBMS) that provides rapid transaction processing and data sharing in a single or multi-user environment.

3.3.3 KBase installation

KBase is distributed on a CD. Two files are needed to install KBase:

- Firebird-1.0.3.972-Win32.exe
- SetupkBase.exe

Firebird for Windows must be installed before KBase can be run. However, if other applications are already using Firebird it does not need to be re-installed.

To install Firebird, run **Firebird-1.5.5.4926-3-Win32.exe** and follow the instructions (Use the default settings).

Install KBase, run the **SetupkBase.exe** file. The installation form shown in Figure 8 will open.

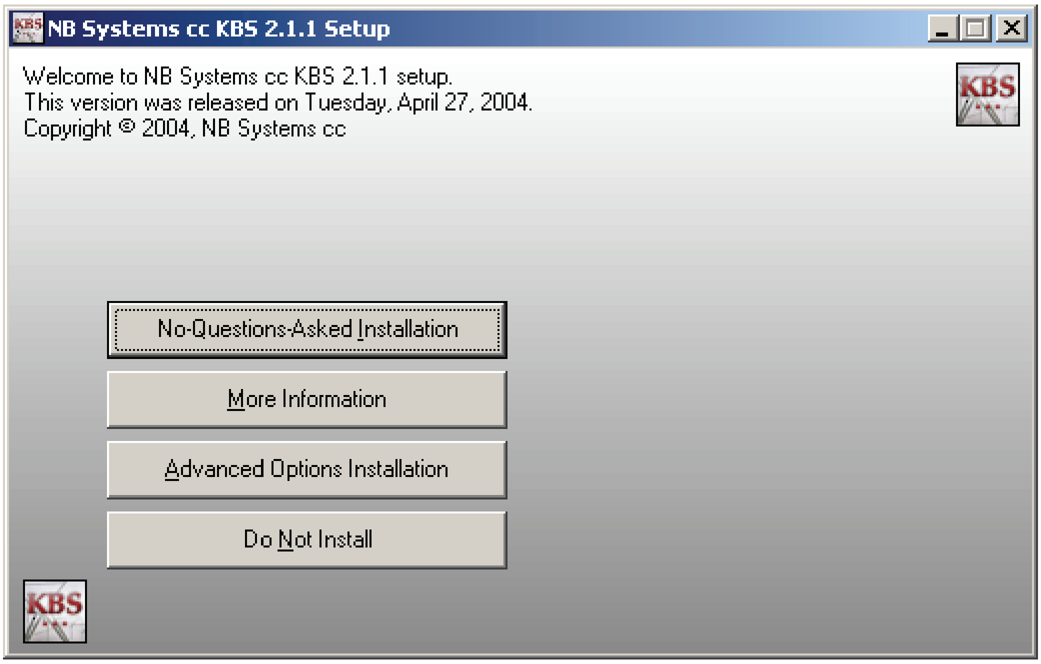


Figure 8: KBase installation form

The four buttons on the installation form provide the following options:

This button is used to install KBase to the default folder (c:\KBase) automatically (without asking any questions).

This button is used to open a document containing information that might be useful before installing KBase.

This button is used to change the default installation folder c:\KBase to another one.

This button is used to quit the installation without making any changes to the system.

3.3.4 *KBase main screen*

The KBase main screen shown in Figure 9 comprises a number of speed buttons at the top of the screen, and some dropdown boxes that are used to sort and filter the records in the database. The tabs displayed at the bottom of the screen are used to edit and display information about the selected record.

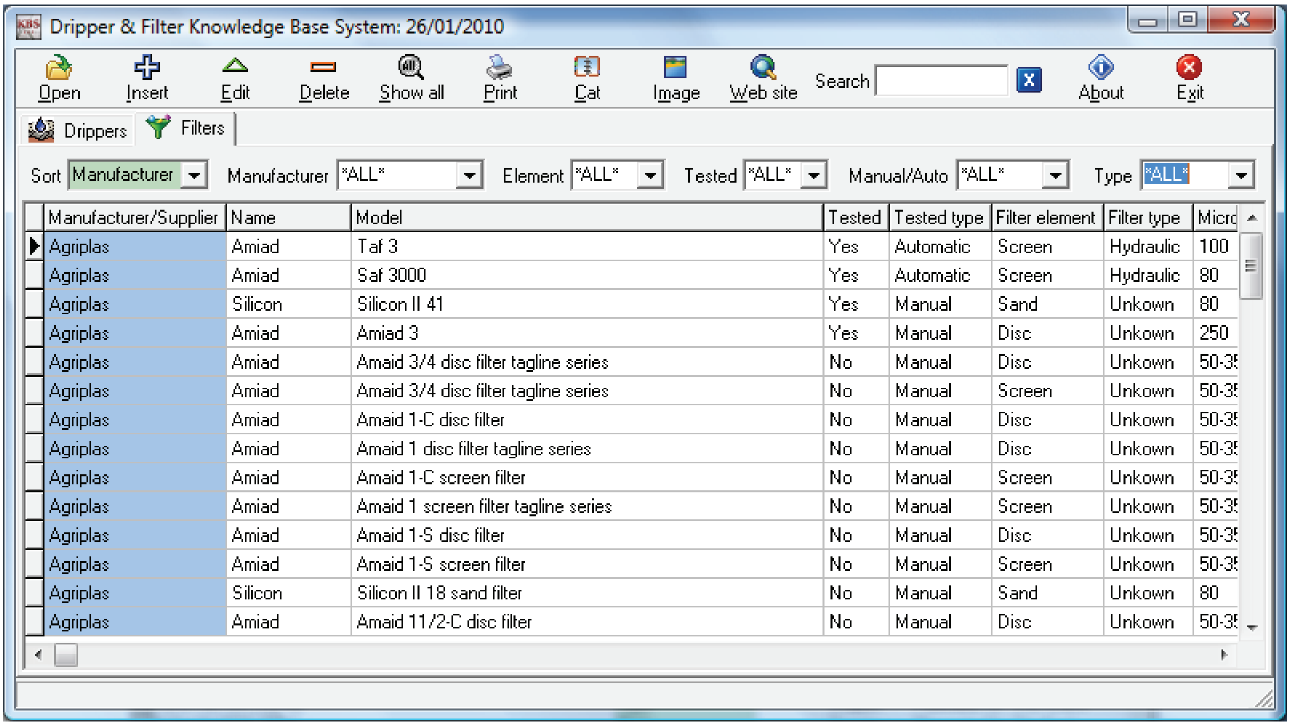
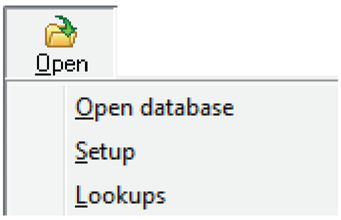


Figure 9: KBase main screen

This caption on the main screen indicates the last modification date.



Clicking the **Open** button results in a dropdown menu which provides options to open the KBase database. The default database is **c:\KBase\KBase.fdb**. KBase opens with the previous database selected.

The **Setup** option opens the **Setup** form (Figure 10) which is used to set the path to the Acrobat reader executable file and the default documents path.

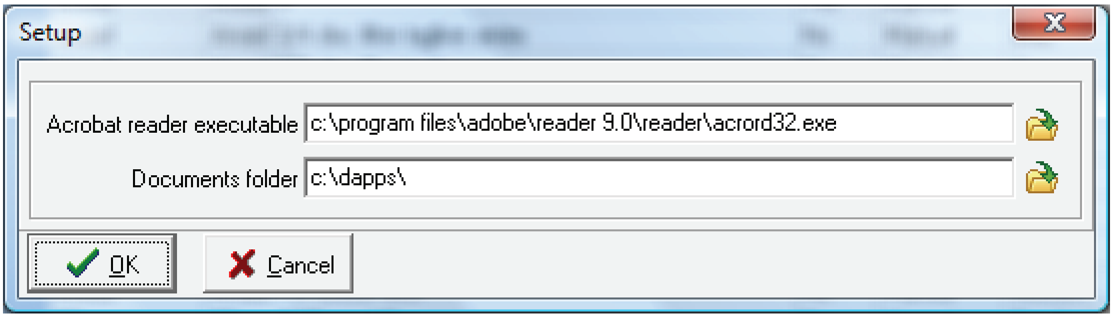
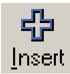


Figure 10: Setup input form

When new versions or updates are made available it might be necessary to update the KBase database. This is done with the **Run SQL database** button.



The **Insert** button opens the **dripper** or **filter Insert** forms (Figure 11 and Figure 12) which are used to capture a dripper or filter record. The following fields are captured on the **Dripper Insert** form:

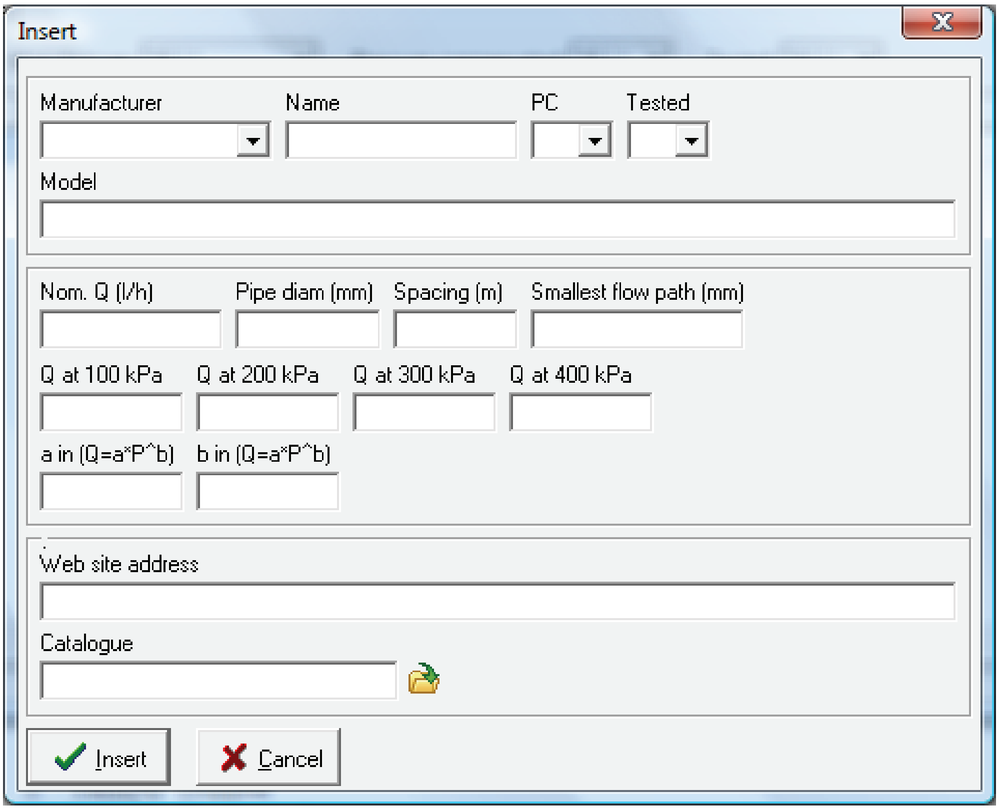


Figure 11: Dripper Insert form

The following fields are captured on the **Filter Insert** form:

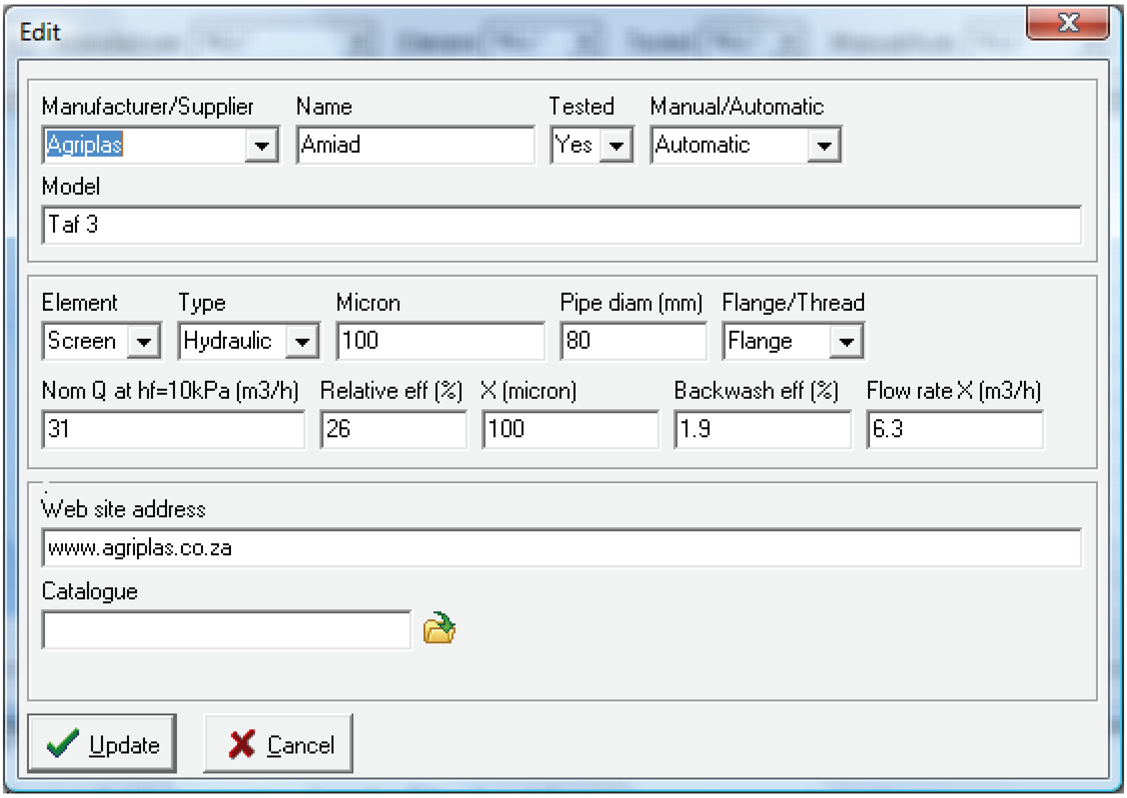


Figure 12: Filter Insert form

The **Edit** button is used to edit the information captured on the current dripper or filter record using the same fields as for the **Insert** button.

The **Delete** button is used to delete the current dripper or filter record. The user is prompted for a confirmation before the record is deleted.

The **Show all** button is used to reset all the filter options to *ALL* which will display all records.

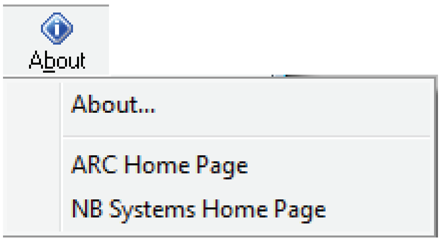
The **Print** button is used to print the dripper or filter report depending on the filter settings.

The **Catalogue** button opens the catalogue of the current dripper filter if it is available.

The **Image** button displays any images which are linked to the current dripper or filter record. This button is also used to link any number of images to the current record.

The **Web site** button is used to open the web site of the manufacturer or supplier of the current dripper or filter, if any.

The **Search** box is used to filter the dripper or filter records according to any sub string.



The **About** button opens a dropdown menu with options which are used to open the KBase About form and website links to the ARC and NB systems home pages.

The **Exit** button is used to exit/close KBase.

3.3.5 Capturing images

Images are captured using the **Insert, Edit** and **Delete** buttons on the **Images** form Figure 13. The following graphic formats are supported: *.jpeg, *.jpg, *.bmp, *.emf and *.wmf. An unlimited number of images can be linked to a specific device. The image can be stretched to fill the total image display area, and can be printed. If an image is too large for the image display area, it can be displayed in the **Full** view, which has scrollable sidebars.

It is important not to capture images at maximum resolution due the amount of file space an image can take up. It is recommended to keep the image size as small as possible without losing definition. Most of the images in KBase were captured at a size of 100 KB or smaller.

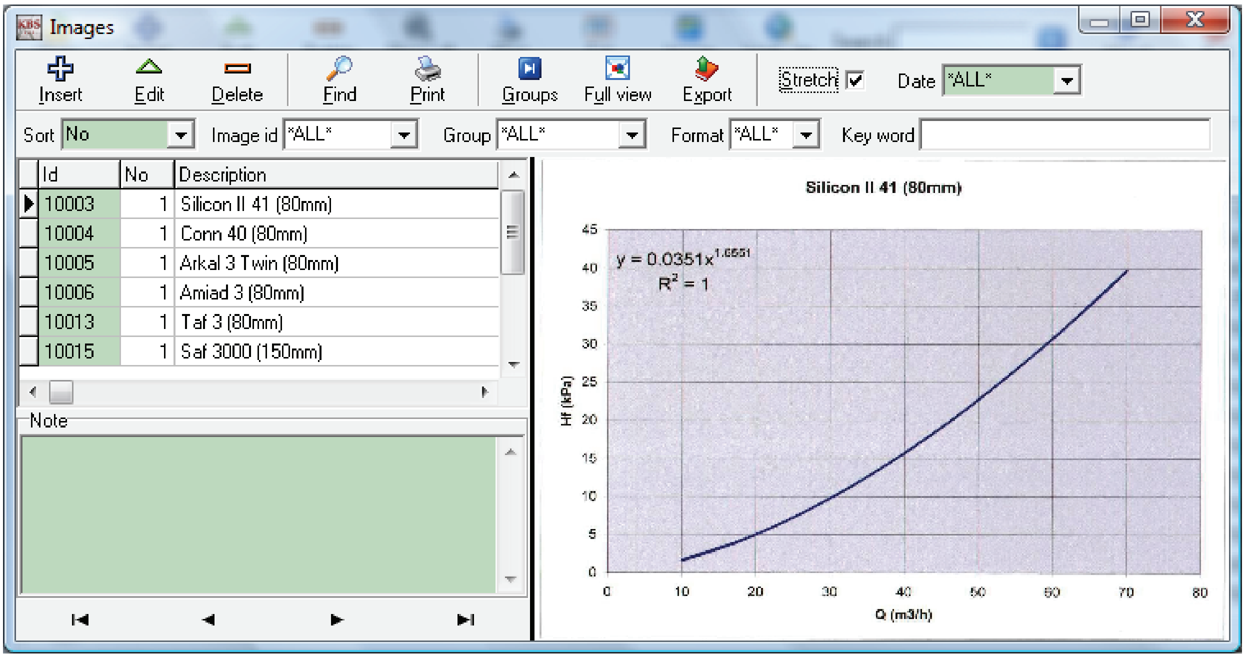
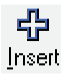


Figure 13: Images form

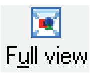


The **Insert** button opens the **image Insert form** which is used to load an image from a file and to add a note to the specific image. The following graphic formats are supported: *.jpeg, *.jpg, *.bmp, *.emf and *.wmf.

The **Edit** button opens the **Edit form** which is used to edit the current image and corresponding note.

The **Delete** button deletes the current image record.

The **Print** button is used to print the current image.



The **Full view** button is used to display the current image in the **Full view form** with scrollable borders if the current image is too big for the image display area.

Use the **Stretch** checkbox to stretch the current image to the full image display area. The image might however be warped, depending on the X and Y aspect ratios.

3.4 Cost spreadsheet using IRRICOST

3.4.1 Background

The irrigation cost estimation procedure (IRRICOST-SPREADSHEET) was developed as a Microsoft Excel© 2007 workbook/model. No installation other than Excel is required. The IRRICOST-SPREADSHEET contains macros to move from one sheet to another within the model, and the user should "enable macros" in Excel in order to be able to utilise this feature of the model.

IRRICOST is included on the KBase CD at the back of the Main Report, Volume 1.

3.4.2 Layout and use

The workbook/model contains nine spreadsheets. The Eskom sheet (Figure 14) captures the electricity tariff structures that need to be updated with the latest available information. Input to the model starts with the Mainline sheet. The Mainline is linked to seven alternative irrigation systems which are divided into pivot irrigation systems and a group of systems that represents sprinkler or drip irrigation.

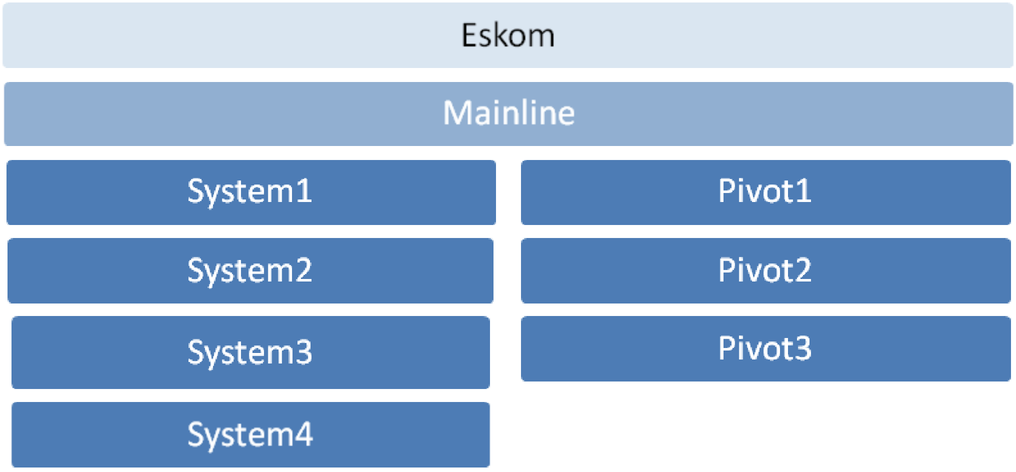


Figure 14: Eskom sheet

In order to link the different irrigation systems to the mainline configuration the user must specify the different irrigation systems that are linked to the mainline of the combination of irrigation systems. The spreadsheet is developed such that cells shaded in red are defined as input whereas green represents the answers to calculations. Light blue represent macro buttons. Clicking on a macro button links the appropriate irrigation system to the mainline. The different sheets can then be opened to populate the data (See fig. 15 and Fig. 16)

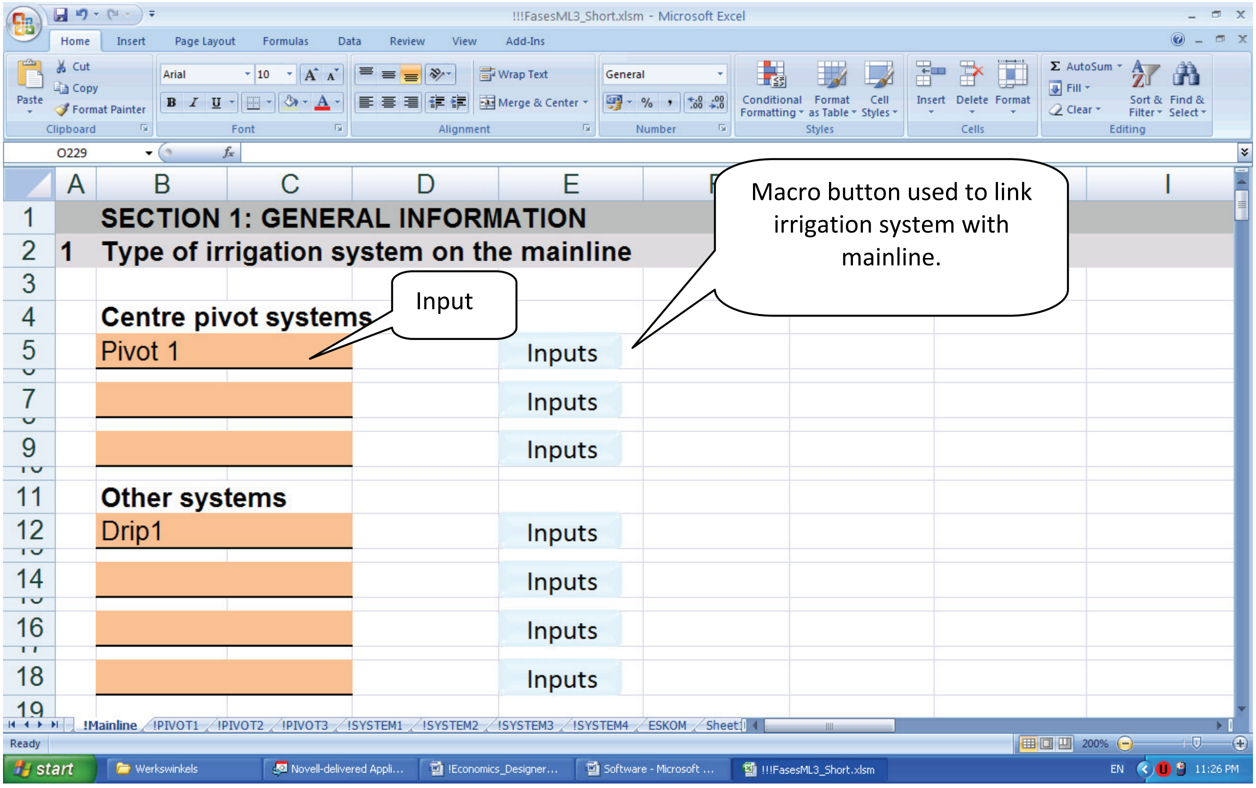


Figure 15: Type of Irrigation system sheet

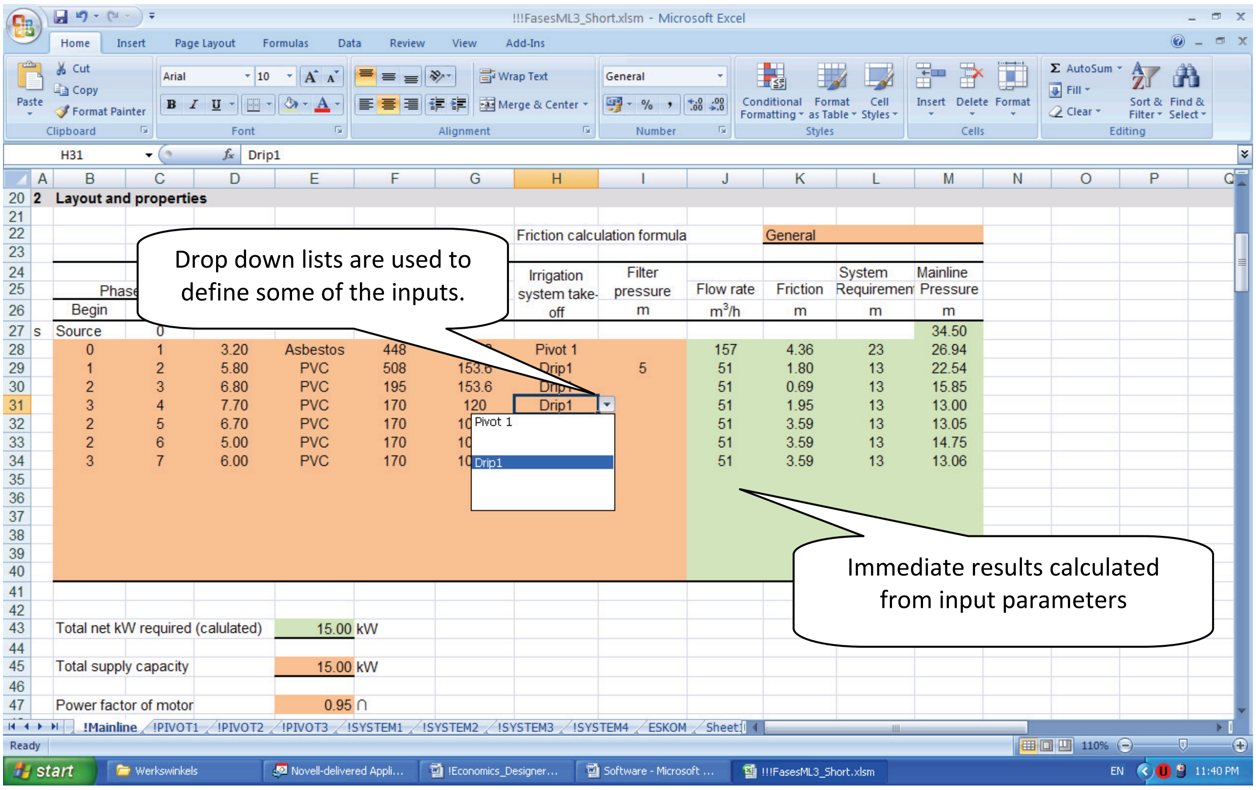


Figure 16: Irrigation layout and properties sheet

Three different types of data are necessary to use the spreadsheet model:

Irrigation system design parameters: these parameters are available from the irrigation system design provided by the service provider.

Economic parameters: the investment cost of the irrigation system is available from service providers. Default values that can be used to calculate depreciation, repair and maintenance, insurance cost, etc. is available from Oosthuizen et al., 2005

Electricity tariff structures: These are available from the Eskom website: http://www.eskom.co.za/

3.5 Technology transfer

Technology transfer to designers and farmers was done by means of:

3.5.1 Information days

Information days were held in Bloemfontein and Nelspruit where all aspects of Drip irrigation were presented and discussed. It was mainly attended by Designers but Farmers were also present.

The information days were preceded by an irrigation evaluation course with practicals to understand the working- and performance principles of irrigation systems. It included practical demonstrations on the maintenance of drip and filtration systems.

The following information was shared with the designers and delegates present in a more or lesser extent depending on the focus of the technology transfer:

- drip irrigation in history
- advantages of drip-irrigation
- disadvantages of drip-irrigation
- technical aspects of surface- and subsurface drip irrigation systems
- technical aspects of filtration equipment
- general guidelines for planning and design
- specific guidelines for drip irrigation systems
- planning and design principles with drip irrigation
- cost estimating procedures for drip irrigation systems

3.5.2 Formal training

The project leader was approached by UNESCO-IHE in Delft to lecture drip irrigation design to Master degree students that enroll for the Water Management programme. The students come from all over the world especially Africa and Asia and on average 15 students attend these classes. So far three groups have been trained. The first group was trained in 2009. What is excellent about this is that the technology with findings from the WRC funded research in South Africa is transferred into the international arena.

3.5.3 Continuous Professional Development (CPD) courses for designers

Continuous Professional Development (CPD) courses for designers have been presented in various areas in South Africa. Over 100, mainly SABI members attended the courses. It was 6 hour training sessions and presentations on the technical, cost and products (Agriplas, Conns and Netafim) were presented. The attendants were also asked to evaluate the courses and they gave a point of 75% for the information received and 78% for the presentations.

The following information was discussed with the designers during the CPD courses:

- Introduction to Drip Irrigation
- Technical Aspects of Surface- and Subsurface Drip Irrigation Systems
- Technical Aspects of Filtration Equipment
- General Guidelines for Planning and Design
- Specific Guidelines for Drip Irrigation Systems
- Cost Estimating Procedures for Drip Irrigation Systems
- Planning and Design Principals with Drip Irrigation

The planning and design procedure applicable to drip irrigation as presented is summarised in the following main points:

Planning:

1. Determine irrigation requirement (from SAPWAT or another reliable source of information)
2. Calculate the cycle length, gross irrigation requirement per cycle, standing time and emitter discharge for the peak irrigation period using the planning flow diagram
3. Select a suitable emitter from a manufacturer's catalogue based on required emitter discharge
4. Calculate the system discharge, number of groups/blocks and the group/block size
5. Undertake a preliminary block lay-out

Hydraulic design:

6. Decide on required EU for the design according to the relevant norms to calculate the allowable emitter discharge variation
7. Calculate the allowable pressure variation in a block and divide between laterals and branch line (Manifold: 0.5 m; Lateral: remaining part of Δp – use this division as starting point)

Lateral design:

8. Determine optimum lateral position along the length of the manifold
9. Determine the lateral pipe size(s) taking topographic slope into account
10. Calculate the required lateral inlet pressures and actual Δp (compare with allowable)
11. If the actual pressure variation is too big, choose larger diameter pipes or change block dimensions.
12. Repeat steps 8 to 11 for each block.

Manifold design:

13. Use remaining allowable pressure to determine suitable pipe sizes, taking topographic slope into account.
14. Check maximum discharge variation against allowable variation calculated in point 7.
15. Calculate the required inlet pressure and discharge to each block.
16. Select a suitable control valve (and secondary filter if applicable) for each block
17. Repeat for all blocks

Main line design (on critical path from pump to hydraulically most remote block inlet):

18. Calculate most economic diameter for main line.
19. Select practical pipe sizes, calculate the hydraulic gradient and select correct pipe classes.
20. Determine maximum pressure and discharge required at the source (pump duty point).

Non-critical path main line design:

21. Use up available pressure difference from critical path take-off point to point of application to size the sub-mainlines to the block inlets.

Water supply system and accessories:

22. Select, position and size suitable air valves for the whole system
23. Select a suitable primary filter or filter bank
24. Select suitable control and automation accessories for the pump station
25. Determine a suitable suction pipe size
26. Choose pump and motor to satisfy the peak system requirement
27. Calculate maximum static suction head for installation

3.5.4 Information days for farmers and irrigation managers

Information days for farmers (commercial as well as small scale) and irrigation managers have also been presented. It was a 6 hour information session and presentations on the practical aspects of drip irrigation, cost and products. Presentations from Agriplas, Conns, Netafim and Naan-Dan-Jain were presented. The evaluation by the attendants gave a point of 77% for the information received and 78% for the presentations.

3.6 Knowledge dissemination

The results of the research undertaken during this project were disseminated via a number of scientific papers, presentations, popular articles, radio talks and TV inserts in order to inform designers and farmers alike.

3.6.1 Scientific papers

A paper, "*Impact of Global Changes on Irrigation Development and Future Trends in Irrigation Practice in South Africa*" was prepared and presented by F B Reinders for the 20th International Congress on Irrigation and Drainage in Lahore, Pakistan from 13 to 19 October 2008. The principles of drip irrigation technology were included in the paper.

A paper: "*Institutional reform and modernisation of irrigation systems in SA*" pointing out the benefits of drip irrigation technology, was prepared and delivered in December 2009 by Dr Backeberg and Mr Reinders at the 60th meeting of the International Commission on Irrigation and Drainage (ICID) at their 5th Asian Regional Conference.

A paper prepared by Dr Backeberg and Mr Reinders, "*Institutional reform and modernisation of irrigation systems in SA*" was presented on the 23 March 2010 during National Water Week at a DWA Water Week conference in Mpumalanga. Drip irrigation formed a major focal point of the paper.

A peer reviewed paper: "*Drip and Filtration equipment's performance*" by Mr Reinders was presented by Mr Reinders at the ICID Congress in Tehran, Iran on the 20 October 2011 and published by ICID in October 2011 in their Congress Proceedings.

3.6.2 Presentations

Mr Reinders presented "*Sustainable Irrigation for optimal crop production*" at a Farmers Day at Cullinan, Gauteng Province in 2008. Principles and practices of drip irrigation were included as part of the presentation. The information was very well received by the approximately one hundred farmers in attendance.

Mr Reinders was invited by the Italian Irrigation and Drainage Committee (Ital-ICID) to participate in a technical study tour and a workshop on "*New Hose Reel Irrigation Machines*" held in Italy from 30 May to 3 June 2010. Mr Reinders presented a paper on "*Irrigation in South Africa within a global perspective*" where he addressed the principles of drip irrigation researched in South Africa.

Mr Reinders presented a one week introductory course on Irrigation Water Management to Extension Officials of the Department of Agriculture (DoA), Gauteng Province in 2008. In addition to a presentation on "*Agricultural Water Use Efficiency in Gauteng Province*" a presentation was made on "*Agricultural Water*

Management" that included the basics of drip irrigation technology and its correct application and management.

Mr Reinders made a presentation on the 17 March 2010 at an International Indaba: "*Engineering planet future*" and took part in an interactive panel discussion on "*Water, Crisis or Comfort*" organised by the SA Institute of Civil Engineers at the CSIR Conference Centre. The different irrigation technologies were discussed with specific reference to drip irrigation.

Mr Reinders delivered a paper at Agri SA's Conference on Food security on the 11 August 2010. The title of his paper was: "*Contribution Of Irrigation Towards Stable Agricultural Production*" and in addition to irrigation systems in general he also demonstrated the principles of drip irrigation.

At a successful CPD event from 28-30 September 2010 arranged by the South African Institute of Agricultural Engineers, Mr Reinders delivered a paper entitled "*Contribution of water and irrigation towards stable food production*" in which he outlined the principles of irrigation, including drip irrigation.

At the South African Irrigation Institute's (SABI) 100th Council meeting on the 15 April 2010, the irrigation industry was invited to the celebrations where Mr Felix Reinders was the guest speaker. He presented an overview of the development of Irrigation in South Africa and the role that SABI has played in the organised irrigation industry. The development of the different types of irrigation systems, including drip irrigation, was addressed.

At Agri-Cape's Water Summit in the Western Cape on the 16 April 2010. Mr Reinders delivered a presentation: "Water: Crisis or Comfort?" It was attended by representatives of several Water User Associations, DWA, DoA, commercial and small-scale farmers and other interested individuals. In the presentation the benefits of drip irrigation were highlighted. In total 120 delegates attended it. The same presentation was delivered in Pretoria for the South African Institute of Agricultural Engineers' meeting on 13 May 2010.

At the Gauteng Department of Agriculture and Rural Development (GDARD) seminar on the 5 May 2010, Mr Reinders presented the progress on the project "Research, develop and implement a program to improve and thereafter maintain standards for agricultural water use efficiency in Gauteng Province" by the ARC-IAE.

On an invitation of the Malawian Committee on Irrigation and Drainage (MALCID), Mr Reinders as a keynote speaker made a presentation on the *Role of the Commission on Irrigation and Drainage* with respect to irrigation, including drip irrigation technology.

Presentations were made on Drip Irrigation at Glen in the Free State on the 1 September 2010, and at Nelspruit (now Mbombela), Mpumalanga Province on the 22 September 2010. The presentations formed part of information days arranged by the South African Irrigation Institute. All the research and test results, approaches and design principles pertaining to drippers and filters were presented. The delegates attending included designers, departmental officials, companies and farmers. The presentations were well received, with in depth discussions taking place after the presentations.

On request of UNESCO in Delft, Netherlands, Mr Reinders has presented a drip irrigation design course to international Master Degree students every year in July. All the principles of drip and filters are discussed, design approaches explained together with management approaches.

Training was provided in the irrigation industry on *Evaluation of Irrigation Systems, with drip irrigation as one of the systems,* to:

- 32 designers from 30-31 August 2010 in Glen, Bloemfontein in the Free State.
- 18 designers from 21-22 September 2010 in Nelspruit, Mpumalanga Province
- 25 designers from 21-22 September 2011 in Malelane, Mpumalanga Province
- 15 designers from 4-5 October 2011 in Cedara, KwaZulu-Natal Province

Apart from the different irrigation systems, drip irrigation was discussed intensively, examples presented and a practical exercise undertaken in the field.

At the National Farming Convention and EXPO (NAFCO) on the 30 September 2010 in Groblersdal, Mpumalanga Province, farmers were trained on "*Maintenance and Management or irrigation systems with reference to drip irrigation*" This was repeated on the 1 and 2 September 2011.

A scientific presentation: "*Drip and Filtration equipment's performance*" was presented at the 8th International Micro Irrigation Congress in Tehran, Iran on the 21 October 2011. It was attended by 300 delegates from more than 35 countries.

Mr Reinders served on the Scientific Committee for the 8th International Micro Irrigation Congress with the theme "Innovation in Technology and Management of Micro Irrigation for Enhanced Crop and Water Productivity". A total of 96 papers were received from 9 Countries. Mr Reinders was therefor also the General Reporter of the Congress that was held in Tehran, Iran on the 14 October 2011 and presented a summary of the papers.

3.6.3 Popular articles

The following articles were published in various magazines:

- An article '*Irrigation: making every drop count'* was published in the Farmer's Weekly of 29 January 2010 by Mr Reinders together with Dr Backeberg of the WRC.
- A short write up '*More soil can be irrigated'* in the Landbouweekblad was published on the 29 January 2010 by Mr Reinders and Dr Backeberg of the WRC.
- An article '*Institutional reform and modernisation of irrigation systems in South Africa'* was published in the Feb/March 2010 SABI magazine by Dr Backeberg and Mr Reinders.
- An article was published by Mr Reinders in the journal of Fertiliser Society of South Africa: "*Irrigation Trilogy*", November 2009 with drip irrigation formed part of the article.
- Reinders, FB: *Elektrisiteitskostes: Impak op drupbesproeiing'*. Afgriland Sept/Okt 2010
- *Besproeiing stelselkeuse*, Reinders FB, Spilpunt tydskrif, Spilpunt, Jan/February 2010
- Reinders, FB: *'Riglyne vir die ontwikkeling van ' Besproeiingstelsel'*, Spilpunt Maart/April 2011
- Reinders, FB: '*Besproeiing: Kies stelsel van die eerste water'*. Landbouweekblad 11 March 2011
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- *Micro irrigation-Part 2,* Reinders FB, Ads and Agri Magazine, March 2011
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- *Kies die regte stelsel : Drupbesproeiing*, Botha W, Landbouweekblad, Augustus 2011
- *Drip irrigation technology for improved water productivity*, Reinders FB, AgrIng News, November 2011

3.6.4 Radio talks, Television and the web

The following radio talks were presented:

- Reinders, FB.: *Irrigation, RSG, 6 March 2009*
- Reinders, FB*: 'Impact of electricity costs on drip irrigation' RSG August 2010*

Television inserts

In an initiative from SABI and Media World a television series was created on irrigation technologies and systems. Mr Reinders facilitated this series and it was successfully broadcasted on SABC 2 on the programme Agriculture Today. Drip irrigation received special attention and the whole manufacturing process and the application of drip in practice together with the use and management principles were broadcasted during October 2010 and repeated on popular demand in January 2011.

Web pages

As part of an information campaign, the company AgriFarm launched a section on their website with irrigation information. Mr Reinders assisted in writing an information sheet on "Principles of management and maintenance of drip irrigation systems" that was posted on the website.

4 CONCLUSION

4.1 Reaching the project objectives

The purpose of this technology transfer project funded by the WRC was to facilitate a process towards effective implementation and usage of surface and subsurface drip irrigation systems in terms of technical and economical principles. The project team managed to disseminate the information of mainly WRC research reports by compiling two drip irrigation manuals, one for designers and one for farmers, on the latest approaches and technology to facilitate the choice, design, cost analysis, operation and maintenance of drippers and filtration equipment. The information was further introduced by means of technology transfer and training sessions on field days to designers and farmers.

The focus of the technology exchange was in those areas in South Africa where there is a concentration of drip irrigation. The technology transfer effort was further strengthened by TV and radio broadcasts as well as popular articles in relevant magazines and scientific papers at National and International Congresses and Symposiums.

The Manuals ("A manual for irrigation designers" and "A manual for irrigation farmers") on the technical aspects and cost estimating procedures of surface and subsurface drip irrigation systems, provide comprehensive information for irrigation designers and farmers operating in South Africa and other SADC countries.

The Manuals include recommendations and guidelines regarding the suitability and management of soil and water for drip irrigation. For the designers, information on the selection, costing, design, installation and commissioning forms an important part of the manual, while for the farmers, information on the selection, costing, operation and maintenance of drip irrigation and filtration equipment are emphasized.

The Manual is further complimented with a Knowledge Base System (KBase) on a CD that contains technical information on drippers and filters and the costing spreadsheet (IRRICOST) to calculate costs of drip irrigation. The two manuals are also in PDF format on the CD.

The key to the future, continued growth and success of drip irrigation, is the understanding of the principles, using of proper technology, applying good design practices, correctly costing of the system and managing the drip irrigation system according to best practices.

5 REFERENCES

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6 ANNEXURE

6.1 Drip Success Story

The paper: "Dripping with success: The Challenge of an irrigation redevelopment project" by R E Merry from Booker Tate Limited, Thame, Oxfordshire, UK, was presented by him in October 2001 at the British Society of Sugar Cane Autumn Technical Meeting. The paper is an analysis of the success with drip irrigation at Simunye Sugar Estate in Swaziland and the author, Bob Merry, gladly gave written permission that the paper can be reprinted in the WRC-Drip Irrigation Main Report, to serve as an example what can be achieved with drip irrigation. At that time in of the analysis in 2001, only 4000 ha were developed with drip irrigation. Ten years later in 2011, close to 12 000 ha has been developed with drip irrigation and a number of other estates followed their example.

The International Commission on Irrigation and Drainage (ICID) also awarded the WATSAVE Award to Mr Robert E Merry in 2002 with the "Technology Award" in recognition for outstanding contribution to water saving with drip irrigation.

"Dripping with success"

THE CHALLENGES OF AN IRRIGATION REDEVELOPMENT PROJECT

R E Merry
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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.

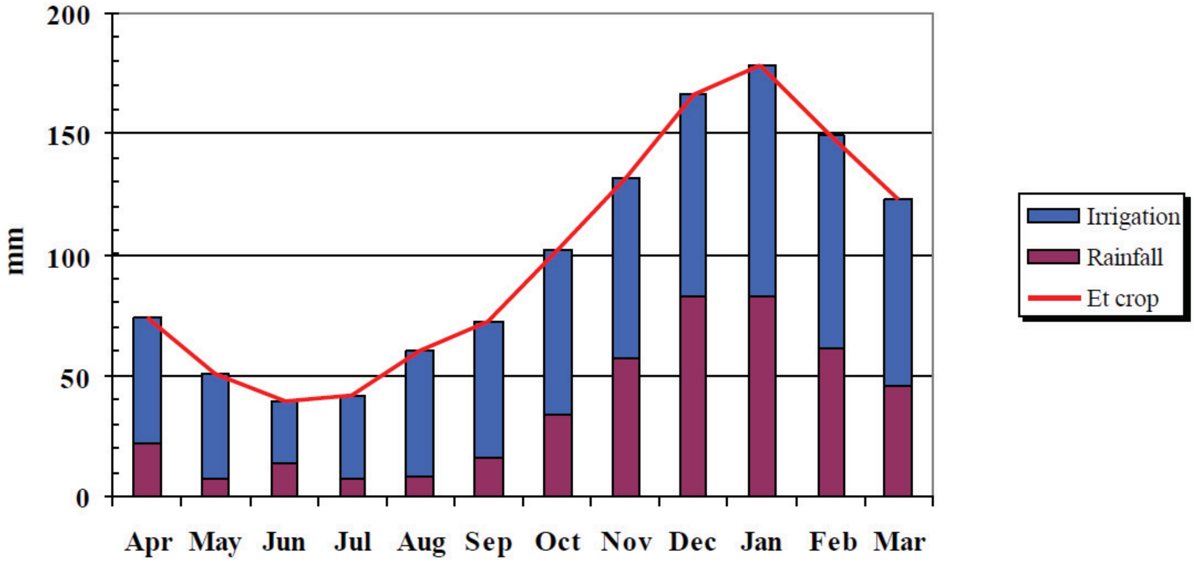

Figure 1: Monthly irrigation water requirement (average for 1980-97)

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.

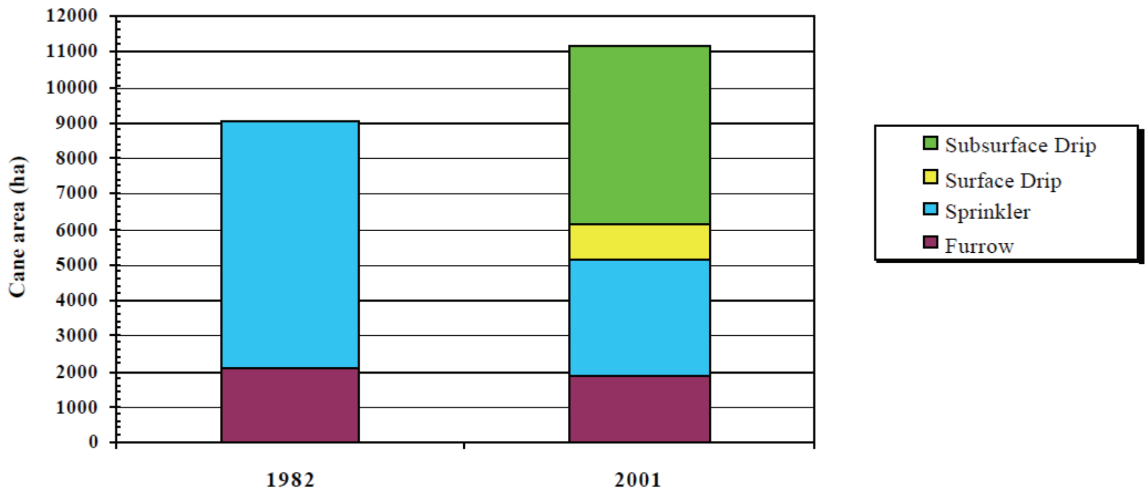

Figure 2: Growth in cane area and drip irrigation over last 20 years

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).

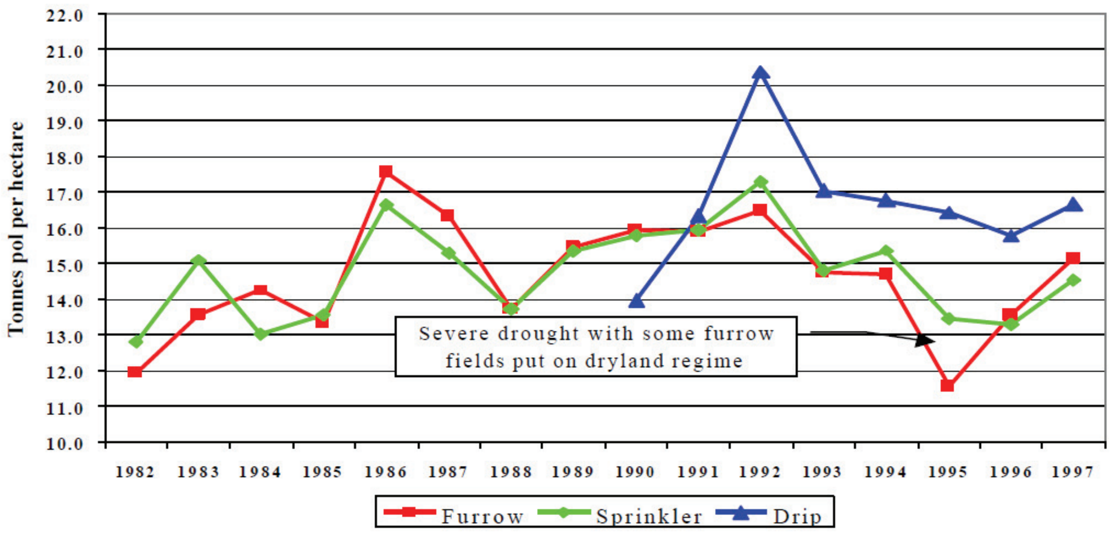

Figure 3: Sucrose productivity by irrigation type

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.

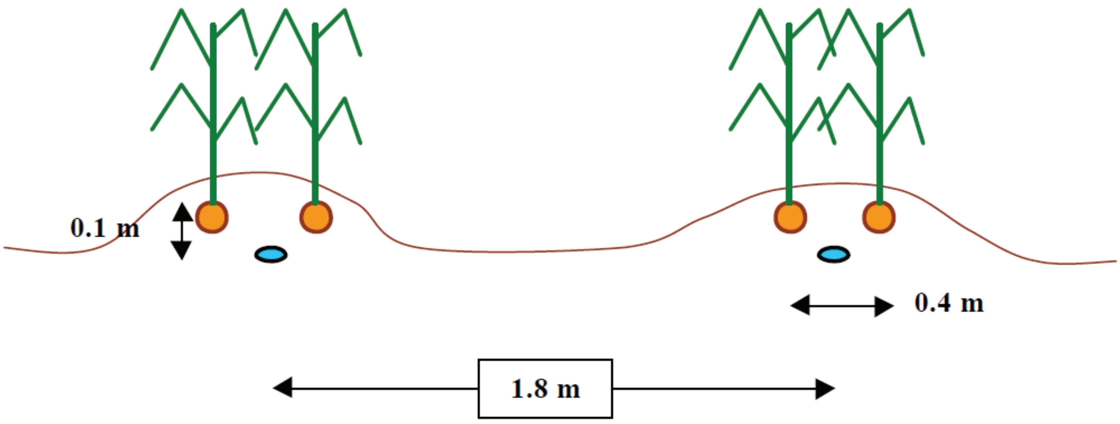

Figure 4: Schematic diagram of dripperline/cane row profile

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.

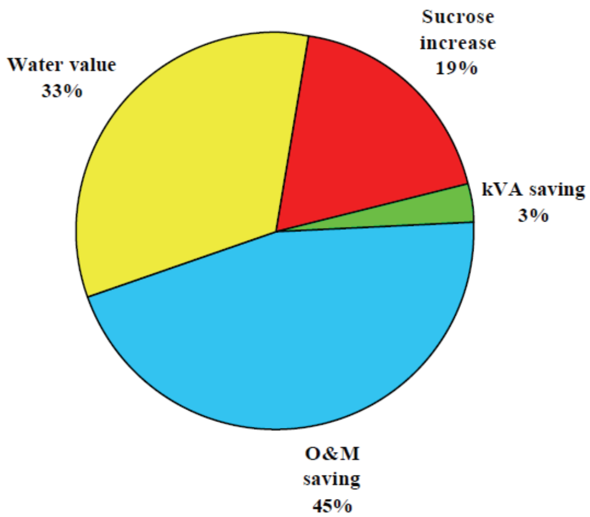

Figure 5: Relative value of project benefits

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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Photo 1: Cluster house external view with fertiliser tanks

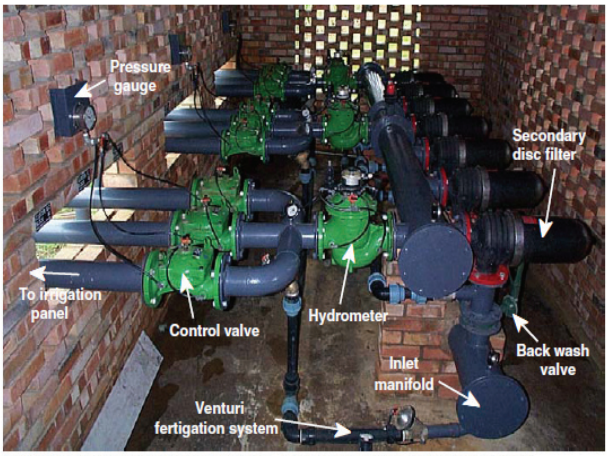
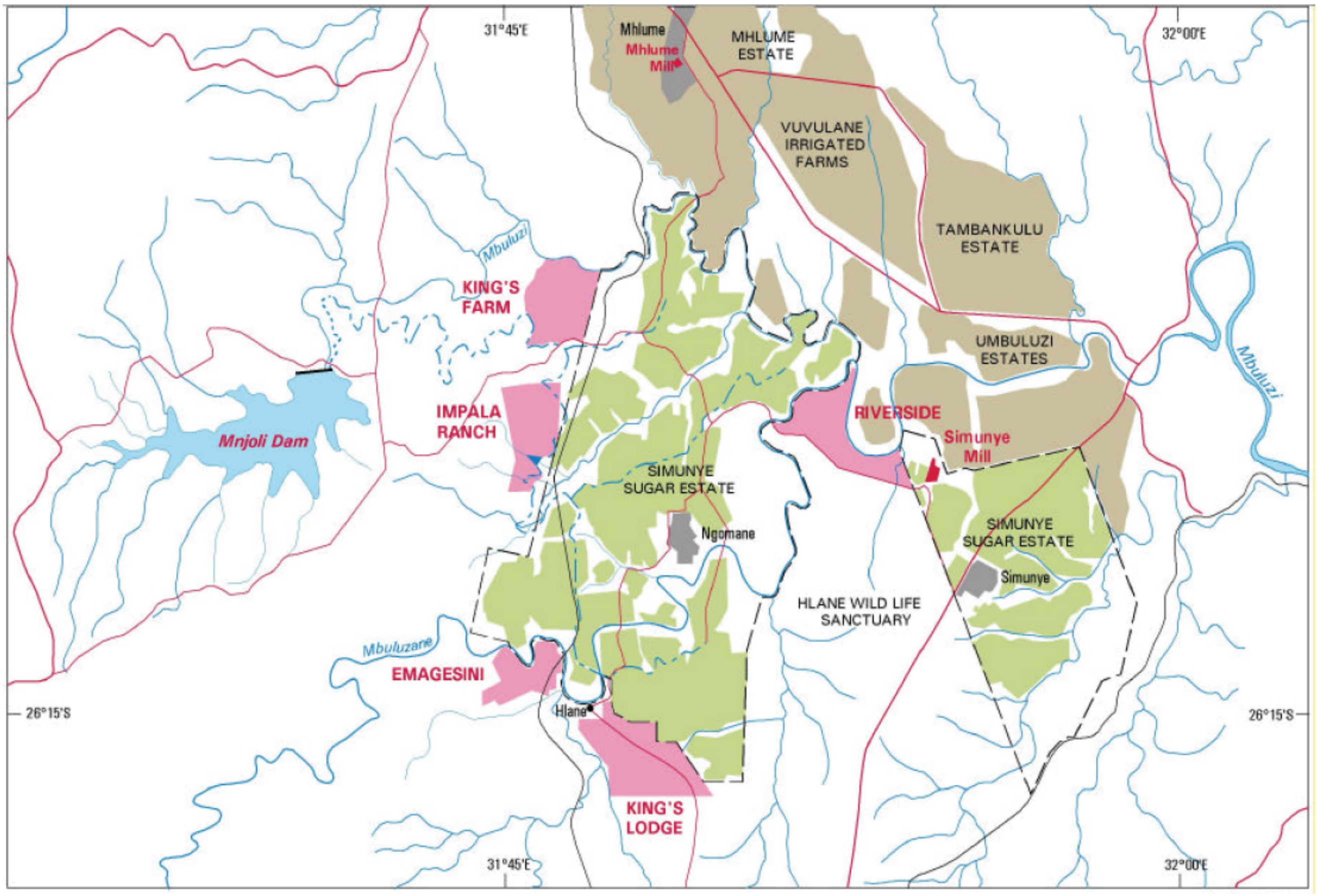


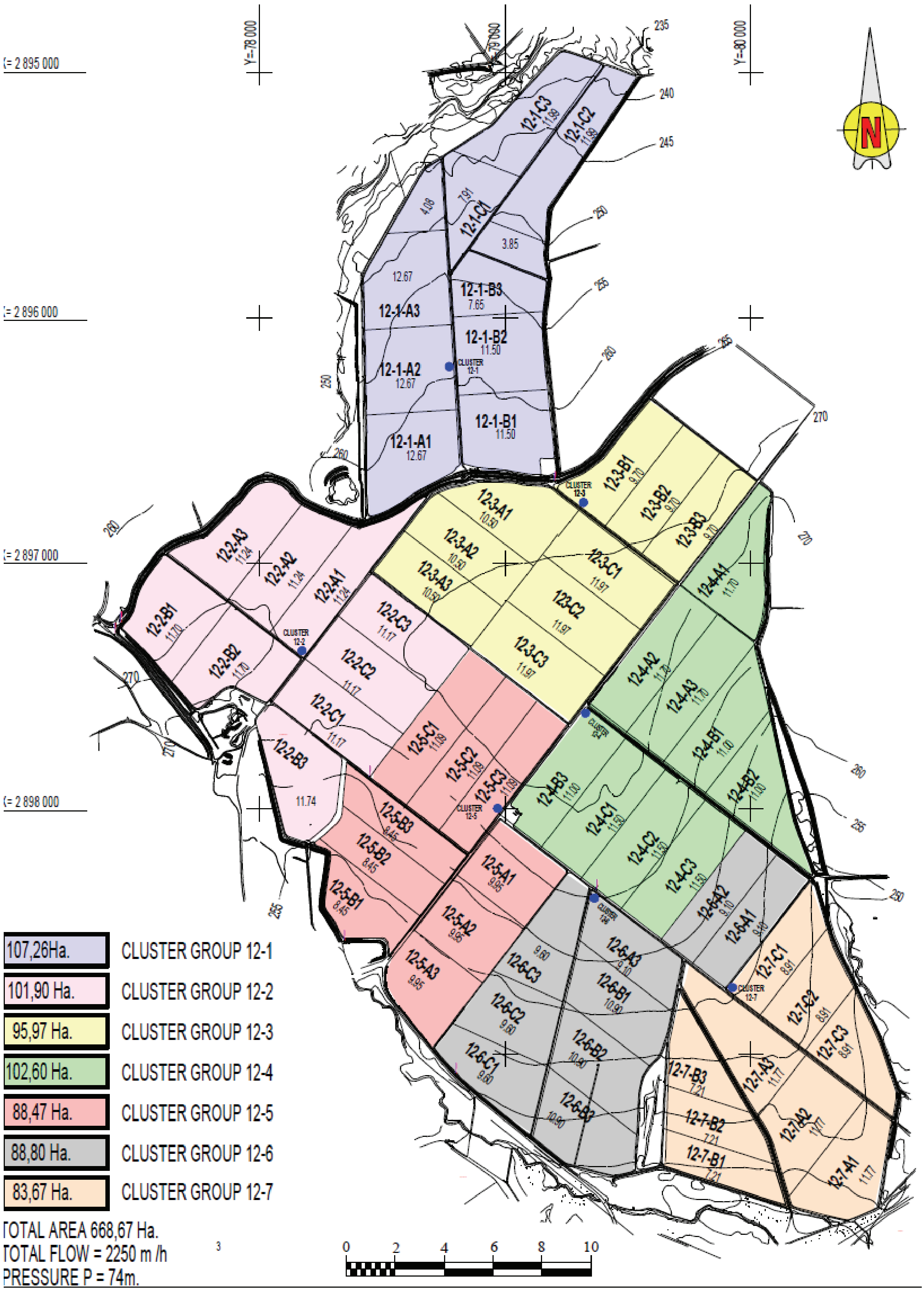
Photo 2: Cluster house internal view - valves set up for manual operation

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





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