DEVELOPMENT OF TECHNICAL AND FINANCIAL NORMS AND STANDARDS FOR DRAINAGE OF IRRIGATED LANDS

Volume 2

Supporting information relating to the updating of technical standards and economic feasibility of drainage projects in South Africa

Report to the
WATER RESEARCH COMMISSION

By
AGRICULTURAL RESEARCH COUNCIL
Institute for Agricultural Engineering

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This report forms part of a series of three reports. The reports are:
Volume 1: Research Report.
Volume 2: Supporting Information Relating to the Updating of Technical Standards and Economic Feasibility of Drainage Projects in South Africa.
Volume 3: Guidance for the Implementation of Surface and Sub-surface Drainage Projects in South Africa

EXECUTIVE SUMMARY

This report concludes the directed Water Research Commission (WRC) Project "Development of technical and financial norms and standards for drainage of irrigated lands", which was undertaken during the period April 2010 to March 2015.

The main objective of the Project was to develop technical and financial norms and standards for the drainage of irrigated lands in Southern Africa that resulted in a report and manual for the design, installation, operation and maintenance of drainage systems.

BACKGROUND

In South Africa an area of 1 399 221 ha was irrigated and 1 675 822 ha registered for irrigation during 2008 (Van der Stoep & Tycote 2014). It is estimated that 241 630 ha (Scotney et al. 1995) is affected by rising water tables and salinisation and problems appear to be expanding. There are many causes of drainage problems in South Africa. Some typical causes of drainage problems are:

- inefficient and badly managed irrigation systems, specifically in the case of very shallow soils and insufficient natural drainage. Salts then start to accumulate and the end result is that the land has to be withdrawn from production,
- leaking earthen dams and irrigation furrows,
- in some areas terraces are designed and established in order to obtain the right slopes for flood irrigation but, unfortunately, sooner or later drainage problems start to occur at the bottom of these terraces, and
- where natural waterways are being cultivated, wet conditions are expected and therefore drainage problems.

The main centres where there are drainage problems in the country include:

- the areas along the Orange River, especially at Vaalharts, Douglas and Upington,
- winter rainfall area at Robertson, Worcester, Swellendam, Ceres and Wellington with undulating topography,
- KwaZulu-Natal Region – Pongola and Nkwalini in the sugar producing areas with very heavy clay soils,
- Eastern Cape – Gamtoos valley, Sundays River valley and Great Fish River valley,
- Mpumalanga, Limpopo and North West region – Loskop and Hartbeespoort Irrigation schemes, and
- mainly where there is irrigated agriculture.

Planning and design of sub-surface drains was undertaken up to 1965 by members of the Soil and Irrigation Institute, and the staff of the Directorate of Agricultural Engineering. Various approaches were tested and at present designs are carried out according to

selected norms and formulas like the Borehole Method of “Van Beers” to determine the hydraulic permeability, the drain spacing formula of Hooghoudt, and the use of derived formulas from Manning for determining the pipe diameter. Various techniques are currently used to assist the engineering practitioners in the field to quickly determine the layout spacing, pipe diameter, drain slope, etc., from various inputs.

Good practices, approaches and design techniques do exist in soil conservation (surface drainage) and need to be revisited, upgraded and compiled in a comprehensive format.

With the extensive research internationally and locally, practical experience and testing of drainage techniques and materials by personnel of the Soil and Irrigation Research Institute, the Directorate of Agricultural Engineering and others, a sound foundation of knowledge has been established 25 years ago and the need to update knowledge in this regard is essential.

RATIONALE

The extent and severity of drainage problems in South Africa is estimated at 241 630 ha (Scotney et al. 1995) and the problem of rising water tables and salinisation appear to be expanding. There are indications that the costs of drainage installation have increase quite significantly.

Apart from isolated projects for specific reasons, there has been no comprehensive research on drainage in South Africa over the past 25 years. The existing drainage design, installation and maintenance norms and standards have been adjusted by means of ad hoc studies. Consequently there is a need to revise and publish up to date norms and standards for South Africa. The timing of these revisions is critical because there are only a handful of experts in the drainage field and there is an urgent need to train new practitioners. By extension, it is then expected that these revised standards should form the basis for training of students at tertiary level and guiding of practitioners. The demand for the design of drainage in the field by far exceeds the available capacity.

Research output and modelling approaches available internationally should be assessed for applicability in South Africa. Also new ways of managing drainage should be introduced instead of only a narrow focus on the current available solutions. Due to poor quality water, more water for leaching is required which increases the need for drainage under field condition. Leaching is required because yields are declining and economic returns are negatively affected. Old drainage systems are no longer functional or coping because of a lack of operation and maintenance. Unfortunately new drainage systems have not been introduced to cope with the excessive water. The technical lifespan of existing drainage systems has expired, and with new technology the systematic replacement of current drainage systems needs to take place.

It is essential (actually imperative) to assess the financial feasibility of replacing and installing new drainage systems and this requires decision making support.

For existing and new schemes surface runoff has to be realigned and aligned effectively with sub-surface drainage. In the case of revitalisation of irrigation schemes a big component of the funding is allocated to surface and sub-surface drainage. There is a need to justify financial incentives or grants and determine the financial feasibility of drainage at farm and scheme level. Reclamation of irrigation land through drainage will improve production on existing schemes and this will decrease the pressure or need to develop new areas.

Effective management of the operation and maintenance of drainage systems will increase water use efficiency and lead to water savings which will support food security in rural areas.

OBJECTIVES AND AIMS

Main Objective:

To develop technical and financial standards and guidelines for assessment of the feasibility of surface and sub-surface drainage systems under South African conditions.

Specific Aims:

1. To review internationally and nationally available norms and standards and to give an overview of current drainage systems, practices and technology;
2. To evaluate the interaction between irrigation, drainage practices and impact on the natural environment;
3. To describe technical/physical/biological/financial requirements for drainage;
4. To refine and develop technical standards for drainage with reference to soil types, crops, irrigation method, water tables, salinisation, water quality and management practices;
5. To refine and develop financial standards for drainage with reference to capital investment, financing methods, operation and maintenance expenditure and management practices;
6. To evaluate the technical and financial feasibility of drainage based on selected case studies;
7. To develop guidelines for design, installation, operation and maintenance of drainage systems.

METHOD

The research method followed in the research project was tailored to answer the specific aims. The specific method followed for the specific aims are summarised as follows:

Aims 1, 2 and 3

Literature reviews of local and international books, journal articles and internet publications were conducted, and from these sources the terminology, definitions, practices and technology of the various drainage approaches were identified and documented. The descriptions included engineering, soil science, environmental and economic approaches on drainage. The review of literature also provided an overview of current drainage systems, practices and technologies worldwide, and those suited to South African conditions.

Appropriate research study sites were identified based on available information, extent of drainage problems, and cropping enterprises being practiced where data collection, drainage system performance and modelling were undertaken. In the end three study sites were selected; Vaalharts (Northern Cape), Pongola (KwaZulu-Natal), and Breede River (Western Cape) irrigation schemes. The sites provided a range of climatic, soil and crop data variations that ensured that the results from the study would be widely applicable to South Africa. At these sites on-going drainage practices were monitored and evaluated for their adequacy (or otherwise) to deal with the drainage problems. Data was collected ranging from climate, soils, hydrology, crops, drainage system characteristics and layout and the drainage problems in existence. This information was applied in analysing and modelling the most appropriate engineering, environmental and economical approaches to drainage planning, design and development.

Aims 4 and 5

Water balance studies, international and local technical models applied in drainage design and management were reviewed. For the technical aspects, the following models were reviewed – Drainmod, WaSim and SaltMOD were reviewed. From this group the world renowned Drainmod model was selected for verification and validation for the Pongola (Impala) study site. For Breede River and Vaalharts study sites the Endrain model was applied.

For the determination of the financial feasibility of drainage at the farm level a suite of related financial models under the Armour et al. (2008) model were reviewed and applied. These are SMCEDs, BankMod, FinData and FinAnalysis and SMsim. The DRAINFRAME methodology was also reviewed.

Aim 6 and 7

Drainmod was applied to evaluate the technical feasibility of drainage in the Impala irrigation scheme case study. Endrain was applied in the case of Breede River and Vaalharts irrigation schemes. Evaluations were carried out on existing installed drainage systems focusing on the type of drainage system, soil type, irrigation method, operation and management practices. The main output of the technical aspects of the research was the development of the appropriate drainage design criteria.

The Armour et al. (2008) model was applied across all the three study areas for the financial feasibility assessments of drainage at the farm level. The financial evaluations focused on the capital management, financing methods, operation and maintenance expenditure, and financial parameters such as Net Present Value (NPV), Internal Rate of Return (IRR), Return on Capital Investment (RCI) and cost-benefit ratios (CBA) were used to select the best drainage alternatives.

MAIN FINDINGS AND CONCLUSIONS

The main objective of the Project was to develop technical and financial norms and standards for the drainage of irrigated lands in Southern Africa. Thus, through funding from the Water Research Commission, the project, "Development of technical and financial norms and standards for the drainage of irrigated lands", was initiated. As a result of thorough research, three comprehensive volumes were produced: Volume 1 consists of the research report; Volume 2 contains supporting information; while Volume 3 provides guidance on both the technical and financial aspects for the implementation of surface and sub-surface drainage.

Literature reviews of local and international books, journal articles and internet publications were conducted, and from these sources, the terminology, definitions, practices and technology of the various drainage approaches were identified and documented. The descriptions included engineering, soil science, environmental and economic approaches on drainage. The review of literature also provided an overview of current drainage systems, practices and technologies worldwide, and those suited to South African conditions.

Water balance studies, international and local technical models applied in drainage design and management were also reviewed. For the technical aspects, the following models were reviewed – Drainmod, WaSim, SaltMOD and Endrain. From this group the world renowned Drainmod model was selected for verification and validation for the Pongola (Impala) study site and for the Breede River and Vaalharts study sites, the Endrain model was applied. Evaluations were carried out on existing designed and installed drainage systems focusing on the type of drainage system, soil type, irrigation method, operation and management practices. Although Drainmod confirmed that present design approaches are correct, it is a cumbersome approach as the model need to be tested first for a specific area before it could be fully put into use as a design and evaluation technique. On the other hand the Endrain model was found to be a user-friendly model for design purposes. A spreadsheet with the basic formulas can also be utilised according to the input data that is obtained from the field and this report.

On the financial side the Armour and Viljoen, (2008) models were used as a starting point and from this the DrainFin model was developed and applied across all three the study areas for the financial feasibility assessments of drainage at the farm level. The DrainFin model and all its components are described and is on the CD included with Volume 3. It include a database, enterprise crop budgets, a drainage plan and capital budget, projected financial statements and scenario analysis that can be done to determine the economic and financial viability of a drainage project. The accurate composition of the projected Cash flow-statement, Income statement and Balance sheet is essential for financial assessment and evaluation. The DrainFin model makes provision for the comparison of up to ten different scenarios. These scenarios can be evaluated and compared in terms of per-hectare analysis.

The effect of subsidies, grants, etc. can easily be accommodated in the model to discount the monetary effect of government intervention on the financial feasibility of sub-surface drainage.

In addition, examples are presented in the text which illustrate application of the underlying scientific and economic principles which are unique to the field of drainage.

Comprehensive guidance is provided on the subject for both the technical and financial aspects of surface and sub-surface drainage and will benefit the following persons in both the engineering and financial sectors:

- Engineering technicians in the country’s provincial agricultural departments
- Financial and technical advisors at co-operatives and agri-businesses who offer financial and technical advice to farmers
- Banks who offer financial assistance to farmers
- Technical personnel at engineering consultancies
- Students in the field of agricultural or bio-resources engineering

The project focused on acquiring, synthesizing and transferring contemporary knowledge on drainage (surface and subsurface) in South Africa, as described in the specific objectives. The project was managed by a core team who was responsible for collating data and report-writing, backed up by a team of specialist consultants and Departments from the collaborating organisations that provided inputs. The gap in knowledge on drainage (surface and subsurface) has now been filled and efforts should be made that the guidelines are widely implemented.

ACKNOWLEDGEMENTS

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Volume 2:

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LIST OF ABBREVIATIONS

ARC-IAE	Agricultural Research Council-Institute of Agricultural Engineering
ASAE	American Society of Agricultural Engineering
BankMod	Bank model for financial analysis (of drainage)
BCR	Benefit cost ratio
B/C	Benefit/cost
BS	Base saturation
CAN-CS	Canistero fine loamy soil
CARA	Conservation of Agricultural Resources Act (Act 43 of 1983)
CEC	Cation exchange capacity
CLIMWAT	Climatic database for use with CROPWAT model
CMA	Catchment Management Area
CMS	Catchment Management System
CRM	Coefficient of residual mass
DAFF	Department of Agriculture , Fisheries and Forestry
Dil	Depth to impermeable layer
DP	Drainage porosity
DR	Drainage rate
DRAIN-FIN	Drainage Financial model
DRAINFRAME	Drainage Integrated Analytical Framework
DRAIMOD	Drainage Model
DS	Deep seepage
DUL	Drained upper limit
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical conductivity
ESP	Exchangeable sodium percentage
ET	Evapotranspiration
FAO	Food and Agricultural Organisation
FinData	Financial analysis model
FinAnalysis	Financial analysis model
GM	Gross margin
GNW	Growth in net worth
GPS	Geographical positioning system
GPV	Gross production value
HDPE	High density polyethylene (pipe)
HYDRUS	Modelling software for analysis of water flow, heat and solute transport

ICID	International Commission on Irrigation and Drainage
IRR	Internal rate of return
ISO	International Standardisation Office
ISRIC	International Soil Reference and Information Centre
LWSR	Layer water supply rate
MAE	Mean absolute error
NCSU	North Carolina State University
NFI	Net farm income
NFP	Net farm profit
NPV	Net present value
OM	Operation and maintenance
PET	Potential evapotranspiration
PMAD	Production, marketing, administration costs and depreciation
PVC	Polyvinyl chloride (pipe)
PWSR	Profile water supply rate
RETC	Retention curve (computer code)
SABS	South African Bureau of Standards
SaltMOD	Salinity (salt) .model
SAR	Sodium adsorption ratio
SCS	Soil Conservation Service
SEPAC	South-eastern Purdue Agricultural Centre
SEW30	Summation of the daily occurrences of excess water within 30 cm of the soil surface
SMCEB	Direct profitability analysis model
SMsim	Micro-economic simulation model
SWAMP	Soil Water Management Program model
USEPA	United States Environmental Protection Agency
USA	United States of America
WaSim	Water Balance Simulation model
WEBS-CC	Webster clay soil
WMA	Water Management Area
WRC	Water Research Commission
WTD	Water table depth

1. INTRODUCTION

Proper drainage helps to aerate the soil for improved plant performance, enables the leaching of salts from the soil profile to prevent harmful built-up, and produce soil conditions more favourable for conducting farm operations.

Planning and design of drainage systems have being undertaken since 1965 by members of the Soil and Irrigation Institute, and the staff of the Directorate of Agricultural Engineering. The main centres where there is a history of drainage problems in South Africa are:

- The areas along the Orange River, especially at Vaalharts, Douglas and Upington.
- Winter Rainfall area at Robertson, Worcester, Swellendam, Ceres and Wellington (undulating topography).
- KwaZulu-Natal Region – Pongola and Nkwalini in the sugar producing areas with very heavy clay soils.
- Eastern Cape Region – Gamtoos valley, Sundays River valley and Great Fish River valley.
- Mpumalanga, Limpopo and North West region – Loskop and Hartbeespoort Irrigation schemes

Following a desktop study of the areas as listed above, and taking into consideration the aspects discussed in Volume 1 of this report as well the location of project personnel, the following three schemes were selected for drainage evaluations during the WRC project:

- Vaalharts Irrigation Scheme (Jan Kempdorp/Hartswater)
- Breede River Irrigation Scheme (Robertson)
- Impala irrigation Scheme (Pongola)

The physical measurements, modelling of drainage system behaviour as well as financial feasibility assessments undertaken at case study sites within these areas are discussed in this volume.

2. IDENTIFICATION, MOTIVATION AND SELECTION OF APPROPRIATE SITES FOR DRAINAGE INVESTIGATIONS

In order to identify suitable irrigation areas for the drainage evaluations to take place, the factors contributing to excess water problems in agricultural soils are briefly presented here. These factors were taken into consideration during the selection of possible areas.

- Soil texture

Soil texture has a major effect on how soil absorbs and stores water. Fine textured soils (with a high clay content) generally hold water well but drain poorly. Coarse-textured soils (with a high sand fraction) drain well but have a poor water-holding capacity.

- Soil structure

This refers to the physical arrangement of the solid mineral particles. A granular structure usually helps to promote the movement of water through a soil while a structure that is massive (without any distinctive arrangement) usually limits water movement.

- Permeability

Permeability is a term to describe the ease with which water moves through a soil. It is influenced by the soil’s texture, structure, the effect of human activities (such as compaction) and other factors.

- Topography

The shape and the slope of the land surface can cause wet soil conditions, especially around local depressions without a natural outlet where water can accumulate.

- Geological formations

The underlying geology of a soil can influence drainage from the topsoil. If the arable soil is underlaid by dense clay or solid rock, it will restrict the downward movement of the water, causing the soil above to stay saturated if no other point of outflow exists.

- Compaction

Compaction is usually the result of human activities on a soil. Continuous soil preparation at the same depth, or during wet soil conditions, can compact the soil and destroy its structure. Compaction eliminates pores in the soil thereby destroying the structure, and water will then accumulate above the compacted layer as it is practically impermeable. If the compacted layer is very shallow, root development will be limited and run-off will occur much sooner during a wetting event.

- Precipitation

Rain and other forms of precipitation can occur at unwanted periods during the production cycle – heavy rain could follow a recent irrigation event, or the rain can fall in amounts or intensities greater than what the soil can absorb and/or store. Under these circumstances additional drainage will help improve the soil conditions for crop growth.

2.1 Vaalharts Irrigation Scheme

The Vaalharts Scheme is located in the Northern Cape on the border with the North West province as shown in Figure 2-1.

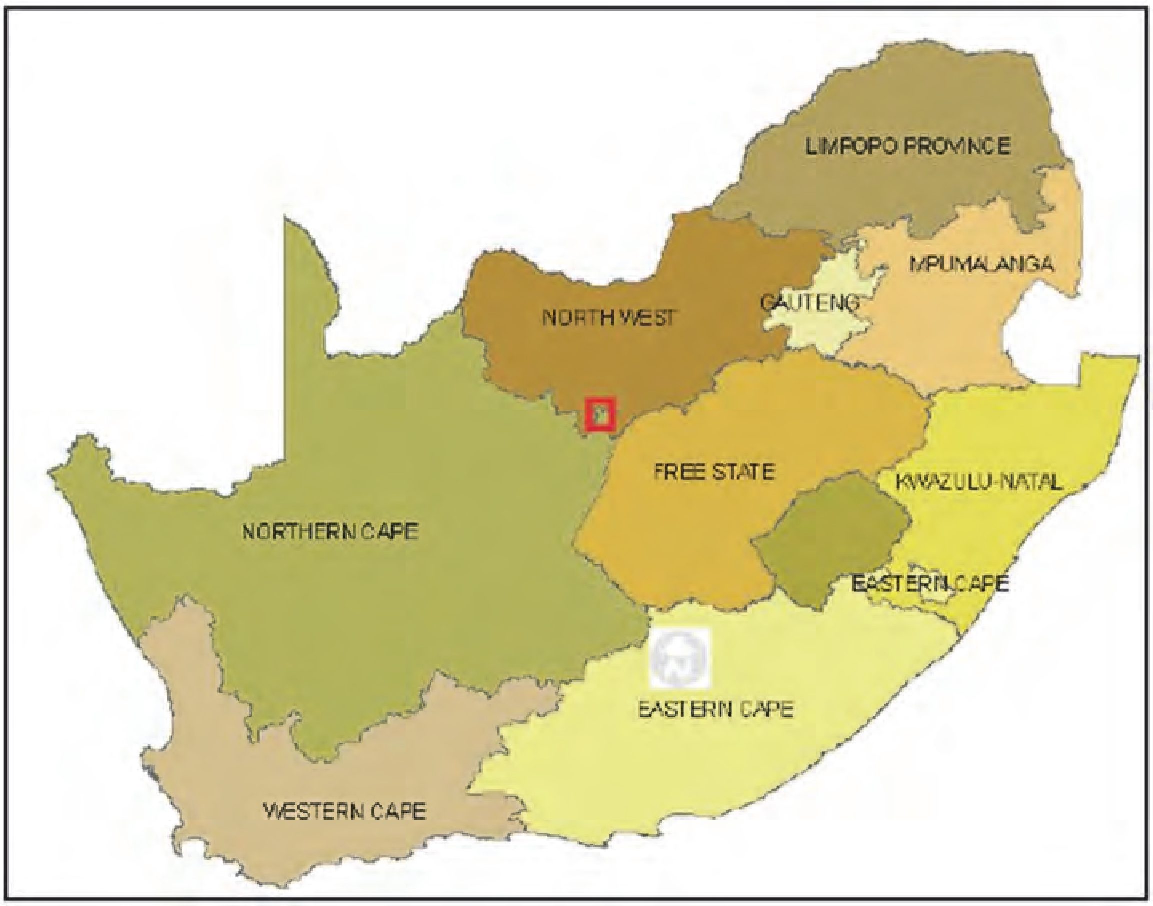


Figure 2-1 Location of the Vaalharts Irrigation Scheme (Verwey, Vermeulen and Van Tonder 2011)

The farms on the scheme stretches from Jan Kempdorp in the south to an area north of Hartswater, as shown in Figure 2-2.

The soil-climate-water quality combination as well as great distances to bigger fresh produce markets has limited the production pattern to mainly grain crops, lucerne, groundnuts, cotton and with potatoes, wine grapes and deciduous fruit on a smaller scale. Small areas with suitable microclimate conditions and where soils are suitable are used for farming with citrus fruit. Production of pecan nuts takes place on a small scale and olives have started coming in on a small scale as an alternative crop.

Figure 2-2 Aerial view of farm lay-out at Vaalharts scheme (Verwey et al. 2011)

2.1.1 **Scheme background**

This scheme of 34 704ha irrigated area is situated in South Africa at 24˚ 45’E and 27˚ 45’S and at an altitude of 1 100 m.

The soils are mainly sandy with calcium carbonate layers below which act as water traps resulting about 33% of the area experiencing serious water logging and salinity problems. Installing subterranean drains on farm which link up to main drainage channels and improvement in irrigation scheduling over time has contained this problem to some extent. However, the drainage water drains into the Harts River, from where it flows to the Spitskop dam and from where poor quality irrigation water is extracted for 1 663ha. Upstream of the Spitskop dam another 2 468ha are irrigated with drainage water pumped out of the Harts River. Irrigation scheduling services are provided and it is estimated that about 5% of the farmers make use of this service. Over time, different variants of evaporation pans have been used as a guide to irrigation scheduling.

When the scheme was developed in the late 1930s, it was developed as a flood irrigation scheme with 30 morgen (25.7ha) farms. The water distribution system was lined right through and designed to give water one day per week per farm on the community canals. Most farms had an overnight dam for short-term storage of water, the usual capacity being enough to store the water delivered during the night. A general tendency has developed where financially stronger farmers buy out weaker farmers, so that very few of the original “one-farm” enterprises exist, with the result that the average irrigation enterprise size is now about 68ha.

Flood irrigation has to some extent been replaced by mainly centre pivot irrigation. Vineyards and orchards are irrigated by micro spray and drip systems. The estimated extent of each is 60% flood, 35% centre pivot and 5% micro and drip systems. Difference of opinion of the extent of the irrigation systems is found, no formal survey has been conducted over the last number of years and some commentators estimate the extent of centre pivot irrigation to be as high as 60%. Farmers who make use of irrigation scheduling services and who have installed irrigation systems where better water control and a better distribution efficiency is easier to attain than with flood irrigation systems, report increases in crop yield of about 30%, however, these claims have not been confirmed through unbiased measurement.

At the northern end of the scheme and area that was previously part of a homeland area is also irrigated. This area, known as Taung, is 3 750ha in extent and is farmed by 400 emerging farmers as well as developing commercial farmers.

- Soils

The soils of the area are alluvial and are described as Kalahari Sand (Hough and Rudolph 2003). The soil consists mainly of sand, silt and clay (on average 75% sand, 15% clay and 10% silt). The irrigation area is situated in an old glazier valley that is drained by the Hartz

River. Underlying the red Kalahari Sand is the Dwyka shale and tillite, calcrete and Ventersdorp lava. There are areas where the calcrete is impermeable. The map in Figure 2-3 depicts the soil types.

According to Bennie (2008) in Verwey et al. (2011), the available water in the soils for crop production varies from 100 to 136 mm/m and infiltration rates vary from 12 to 30 mm/h.

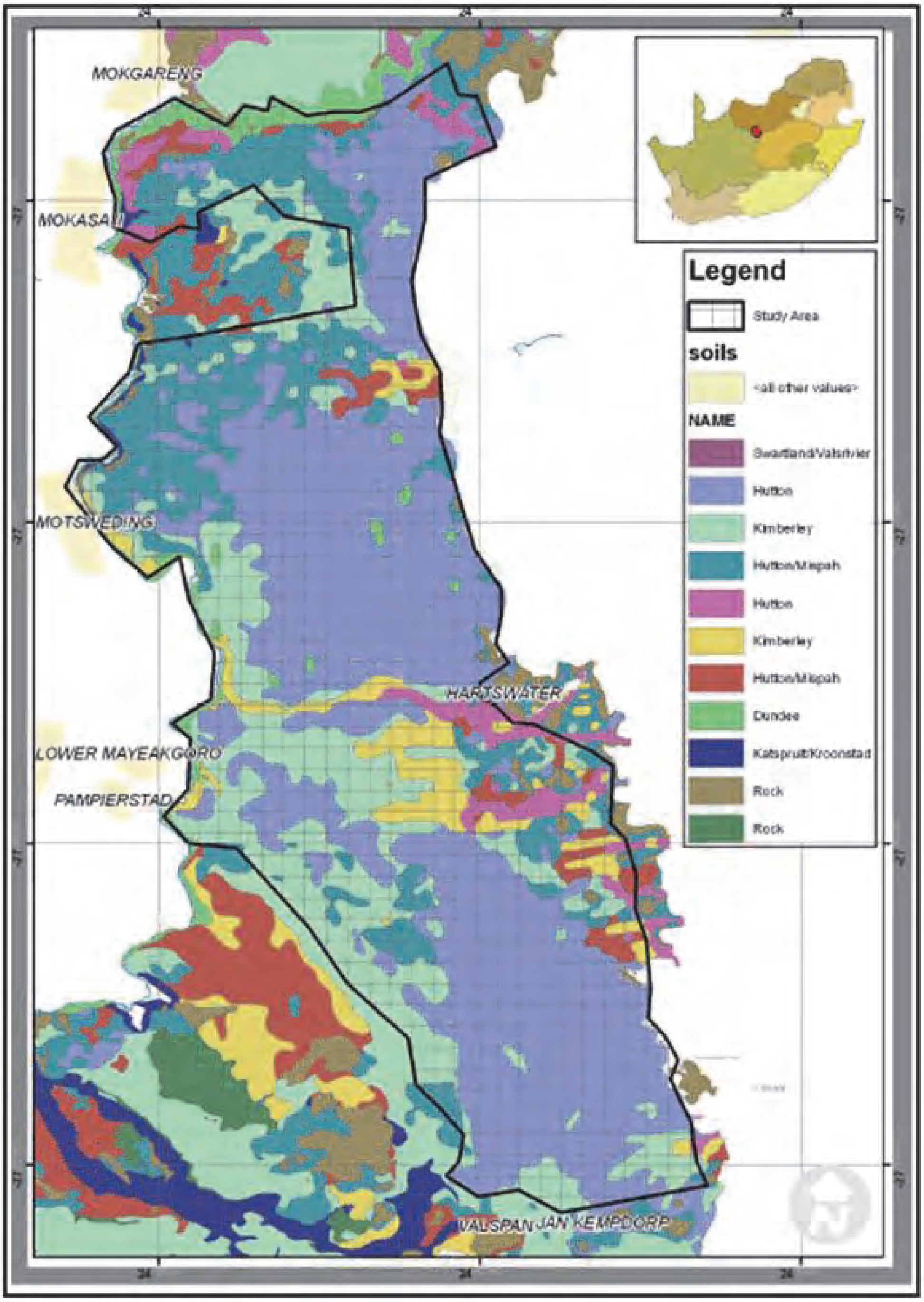


Figure 2-3 Soil map of the Vaalharts scheme (Barnard 2008, in Verwey et al. 2011)

- Topography

The irrigation scheme is situated on the flood plain of the Harts River, which was a glazier valley. The elevations in the study area vary between 1065 and 1170 mamsl. The gradients are in the order of 1:150 from east to west and 1:1030 from north to south. A topographic map was generated by Verwey et al. (2011) as shown in Figure 2-4.

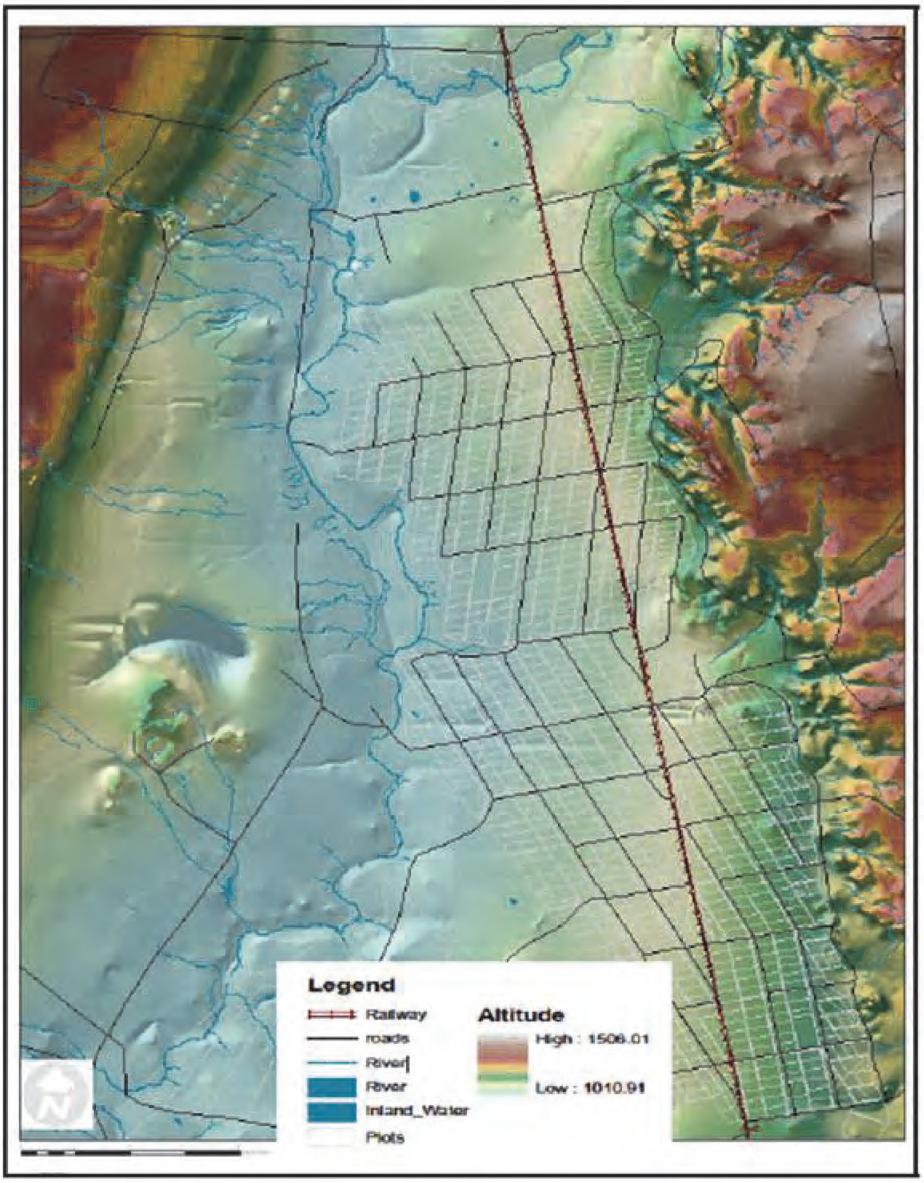


Figure 2-4 Topographic map of the Vaalharts scheme generated by Verwey et al. (2011)

- Geology

The irrigation scheme is predominantly flat as 70% of the area comprises of slopes less than 1% (Verwey et al. 2011). The geology in the area forms part of the Ventersdorp Supergroup. Lithostratigraphic classification of the area was done in 1965, 1976 and 1980, and the specific area of the study area was named the Bothaville formation. In 1975 it was classified again into the Rietgat sub formation (Schutte 1994, in Verwey et al. 2011).

The geology consists of the Bothaville Formation overlying the Hartswater Group (comprising of the lower Mhole Formation and the upper Phokwane Formation). The area comprises of a Harts-Dry Harts Valley (stratum of calcrete) that runs in a north-south direction (Schutte 1994, in Verwey et al. 2011).

The Rietgat formation in the Taung Jan Kempdorp area was known as the Phokwane Formation of the Hartswater group. The Phokwane formation consists mainly of porphyrite lava, volcanic tufa, tuffaceous sediments and chert (Schutte 1994 in Verwey et al. 2011).

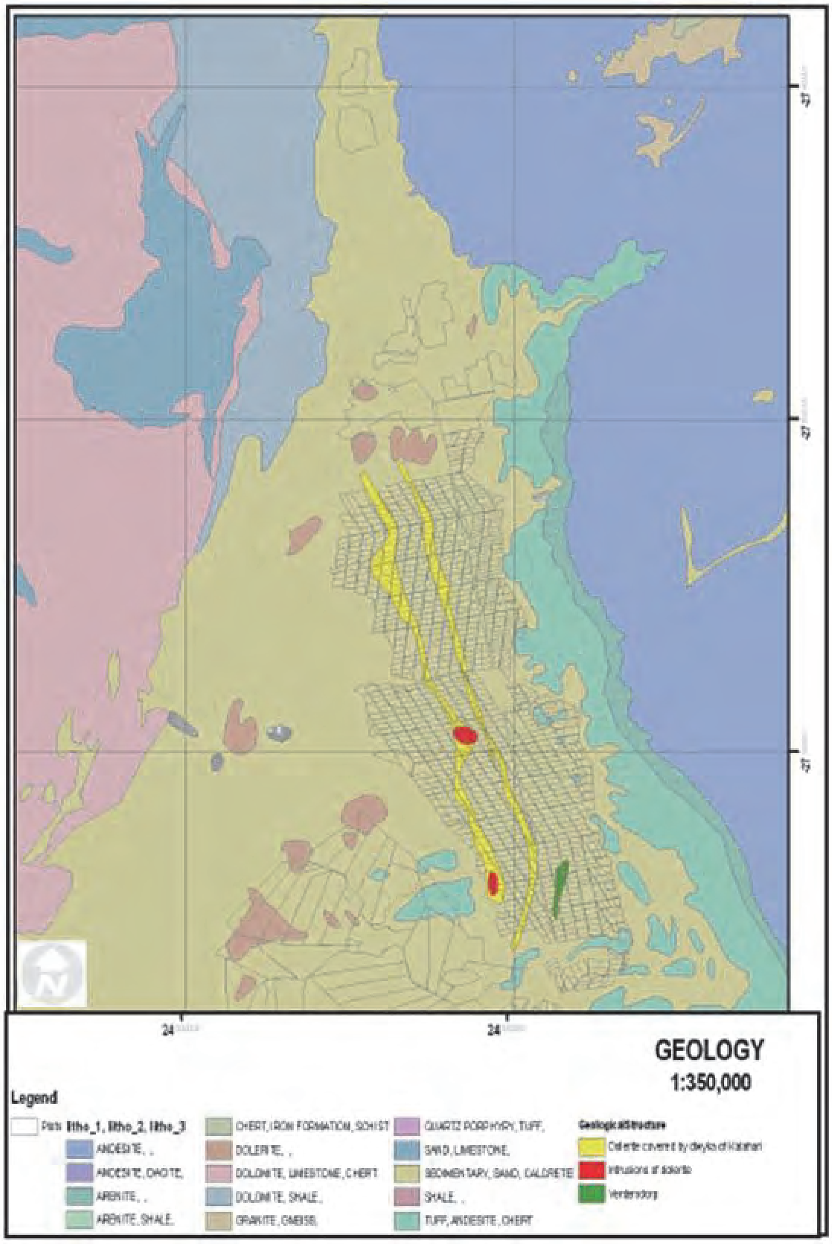


Figure 2-5 Geology of the Vaalharts scheme (Verwey et al. 2011)

- Precipitation

The climate is semi-arid, annual rainfall is 475 mm and frost occurs regularly in winter. Annual reference ET_0 amounts to 1 545 mm and average daily ET_0 for peak month requirement is 6.3 mm per day.

2.1.2 **Motivational factors**

The following factors were considered of importance when selecting this scheme for the drainage evaluations to be undertaken during this WRC project:

- Long history of drainage problems and solutions

Farmers experienced waterlogging and salinisation problems at the scheme within 15 years of it being established, and to remedy the problem the installation of a main sub-surface drainage system began in 1972. The feeder canals were also lined with concrete. However, in 2000 it was discovered that approximately 50% of the plots did not have proper discharge points for the drained water although roughly 80% have installed internal subsurface drains. Because of this on-going problem, expertise on the subject of drainage has developed in the area and can benefit this project.

- Recent work undertaken by Verwey et al. (2011)

A WRC funded project entitled 'The influence of irrigation on groundwater at the Vaalharts irrigation scheme' (WRC project KV 254/10) resulted in a report with up to date information and measured data from 247 piezometers that was installed and monitored by the Department of Agriculture. This is very valuable information and will provide the project team with solid information to evaluate the effectiveness of drainage systems against.

- Project team member resident on scheme

One of the project advisors, Chris van Niekerk, resided in the Vaalharts area at the beginning of the project, where he worked for the Department of Agriculture.

- Scheme earmarked for major upgrades via National Department of Agriculture , Fisheries and Forestry (DAFF) project.

A recent investigation into the condition of the Vaalharts scheme's infrastructure has shown that approximately R4 billion must be spent to ensure the sustainability of the scheme. There is therefore already an interest in improvement and other parallel processes going on to determine what management and infrastructural changes are needed to optimise water use at the scheme, which will be well supported by outcomes from the WRC project.

- Supportive scheme management/well-organised WUA

The WUA is well-organised and is in favour of the project, making it easier to undertake field work and have access the data that may be needed for the WRC reports.

2.2 Breede River Irrigation Scheme

The Breede River Conservation Board was the owner of the original Lake Marais or Brandvlei Dam. In 1974, control of the dam and water supply was taken over by DWAF. The Board oversees a number of boards in the Robertson and Bonnievale areas which all get water from the Brandvlei Scheme. It covers the area from the Brandvlei Dam (off channel) near Worcester to Goudmyn near Robertson, a distance of 55km. The location of the dam and the applicable stretch of the Breede River is shown in Figure 2-6.

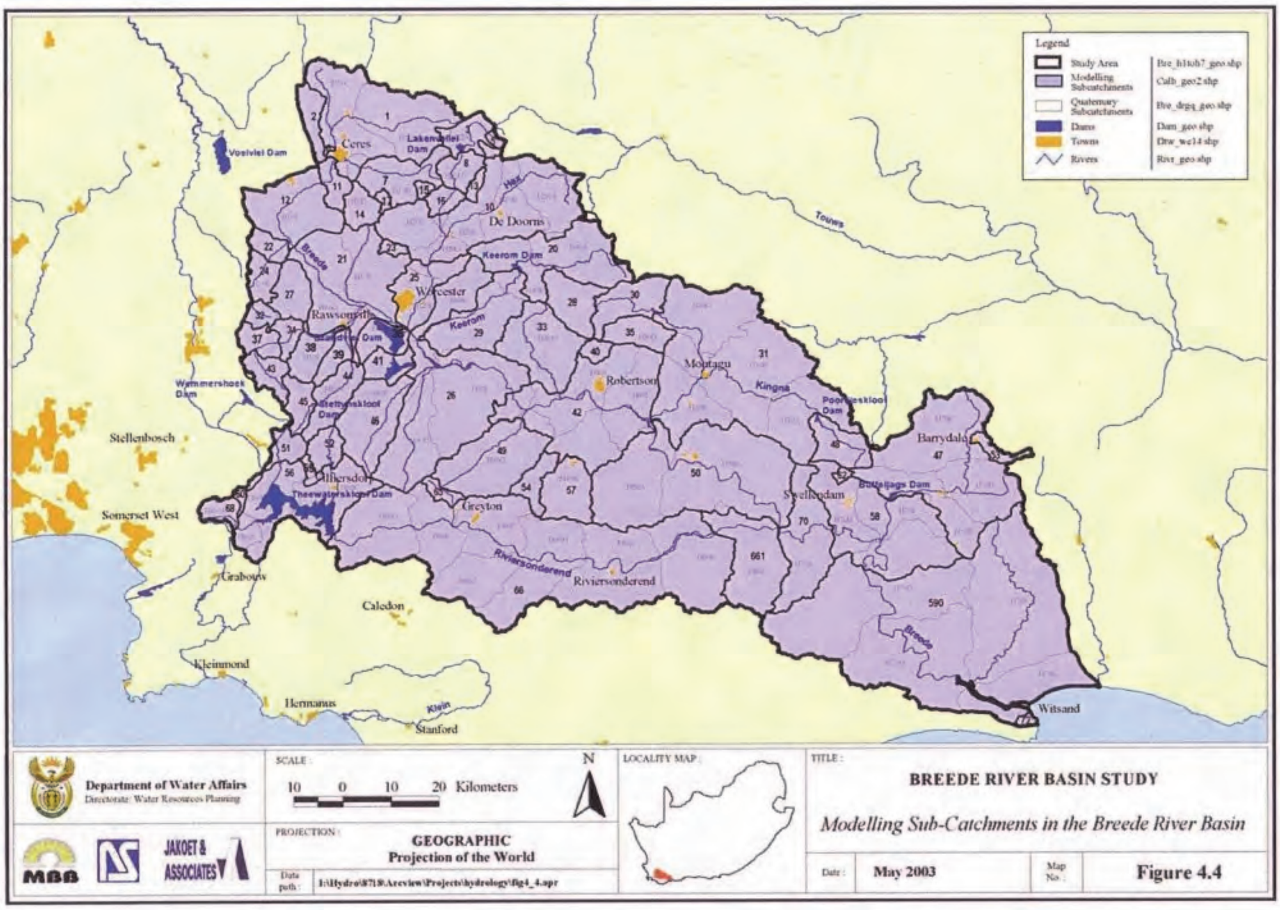


Figure 2-6 Location of the Breede River irrigation area

The name of the Board has since been changed to the Central Breede River Water User Association. The CEO of the scheme is Mr Louis Bruwer, a civil engineering consultant in Robertson.

The districts served by the Association can be summarised as follows:

Angora Irrigation Board	1751,8 ha
Robertson (Breede River) Irrigation Board	2748,9 ha
Le Chasseur and Goree Irrigation Board	4195,8 ha
Zanddrift Irrigation Board	3283,5 ha
Diverse River Pump Areas	1064,5 ha
Total:	13044,5 ha

The total scheduled area of the scheme is approximately 15 500ha. The mentioned districts include farms that abstract water directly from the Breede River by means of private pump stations. There are approximately 150 private pumps on the Breede River between the Greater Brandvlei Dam and the Zanddrift weir, with typical capacities of between 0,01 m^3/s and 0,139 m^3/s. A number of farmers scheduled under the irrigation boards receive water from a series of four canals which are fed from diversion weirs along the Breede River.

2.2.1 Scheme background

The scheme background can be described by means of the following aspects:

- Soils

Soils in the area vary from typical Karoo clay-loam intersticed with lime hardpan hills originating from Bokkeveld shales, to fine sandy silt deposits on the river bank – locally known as “island soils”. See Figure 2-7.

According to Van Rensburg, De Clercq, Barnard and Du Preez (2011), the capacity of soils to retain salts was indicated in a saline-water irrigation experiment carried out in the Breede River catchment by Moolman et al. (1999) and De Clercq et al. (2001a) in Van Rensburg et al. (2011). A Trawal soil (varying between a soil family 1100 and 1200, Soil Classification Working Group 1991) was irrigated with 6 qualities of irrigation water (30 mS·m-1, 75 mS·m-1, 150 mS·m-1, 250 mS·m-1, 230 mS·m-1 and 500 mS·m-1) over a period of 8 years. They found that the soil had a threshold salinity level of about 550 mS·m-1 (the threshold level refers to the maximum amount of salt that the soil could retain under the applied conditions) and that the soil irrigated with water with an EC of 150 mS·m-1 and higher, easily reached the threshold value and stayed there for the duration of the irrigation season. This was done using a 10% over-irrigation with each irrigation event and all extra salt in the system was leached. This response therefore indicated that different soil types had specific salinity threshold values and when irrigated agriculture is planned for a region, the specific salinity threshold values, which can also relate to the cation exchange capacity of the soils, need to be kept in mind.

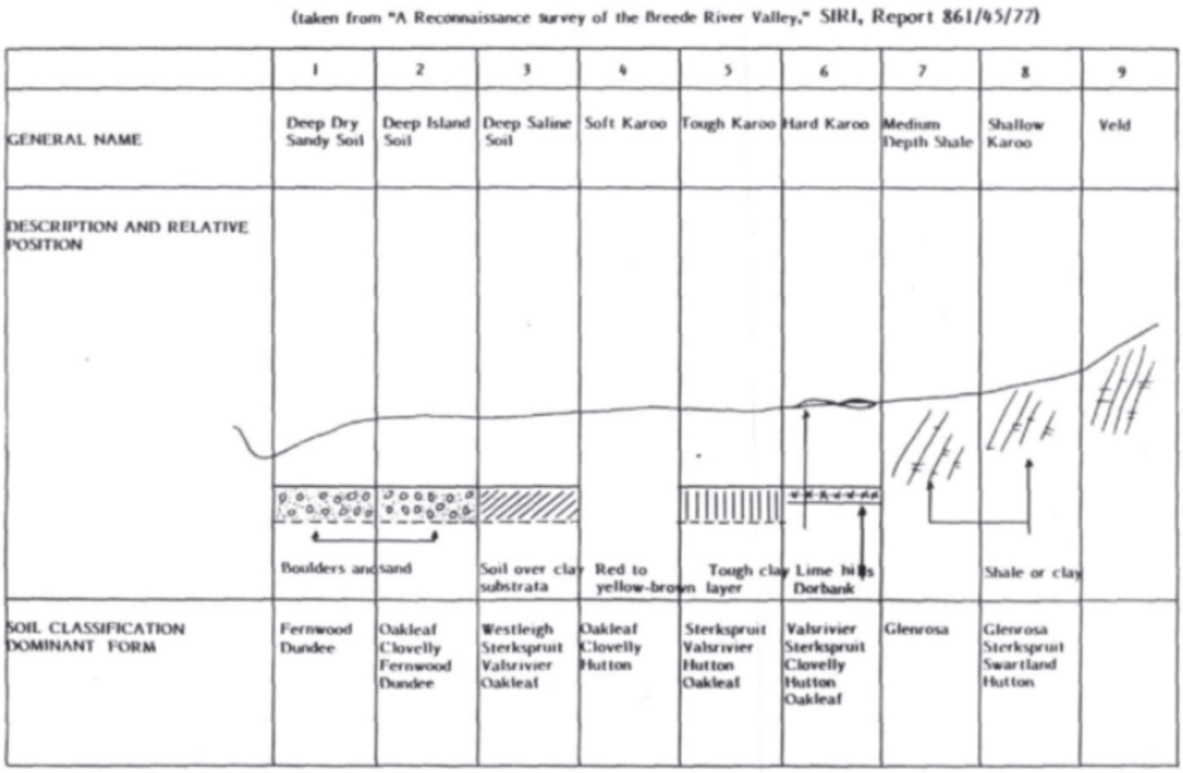


Figure 2-7 Typical soils in the Breede River valley (MBB Consulting Engineers 1989)

- Topography

Physically the area can be described as flat, undulating land extending over the lower parts of various subcatchments.

- Geology

Most of the lower parts of the Breede River valley is underlaid by Bokkeveld shales which are notorious for both their impermeability and high salt content. Groundwater is therefore not a significant supplementary source of water.

- Precipitation

The area falls in the winter rainfall region with an annual average of between 300 and 350 mm per year. The average annual A-pan evaporation is approximately 2400 mm per year. Irrigation takes place mostly in the summer months from September to April.

The chronic water shortages during the summer causes water quality problems in the rivers in this area. During this period (when irrigation takes place), water seeps from the fields into the tributaries, causing the water quality to deteriorate because of the nutrient load in the seepage. Monitoring undertaken during the 80s showed an increase in river salinity (Van Rensburg et al. 2011).

2.2.2 **Motivational factors**

The following factors were considered of importance when selecting this scheme for the drainage evaluations to be undertaken during this WRC project:

- Long history of drainage problems and solutions

From as early as the beginning of the 20th century (1900), shortly after the first unlined canals were dug, farmers experienced waterlogging problems in the irrigation fields, especially in the areas next to the canals, which were soon lined to alleviate these problems. Because of this on-going problem, expertise on the subject of drainage has developed in the area and can benefit this project.

- Project team member resident on scheme

One of the project team members, Hans King, works for the Department of Agriculture in Stellenbosch. His presence in the area will be valuable for effective field work.

- Economic considerations

The fact that high value salt sensitive permanent crops are grown in the area, together with the fact that the Western Cape is coming under increasing pressure from a domestic water supply perspective, increases the value of the water and therefore the importance of any work done to promote sustainable solutions. The western Cape was also identified as an area where rainfall could reduce because of the effects of climate changes, which will put further pressure on the resources.

- Supportive scheme management/well-organised WUA

The WUA is well-organised and is in favour of the project, making it easier to undertake field work and have access the data that may be needed for the WRC reports.

2.3 **Impala Irrigation Scheme**

Pongola is located in the north-eastern side of South Africa close to the South African and Swaziland boarder in the KwaZulu-Natal province, as shown in Figure 2-8.The scheduled irrigation area of the Impala Irrigation Scheme is 17012 ha which is farmed by approximately 170 irrigators. Water is supplied from the Bivane dam from where it is distributed via a network of canals. The main crop is sugar cane but citrus, maize and vegetables are also produced. The scheme use the WAS program to manage its water and good historical data on water use is available. The sugar industry also support the area well with extension services.

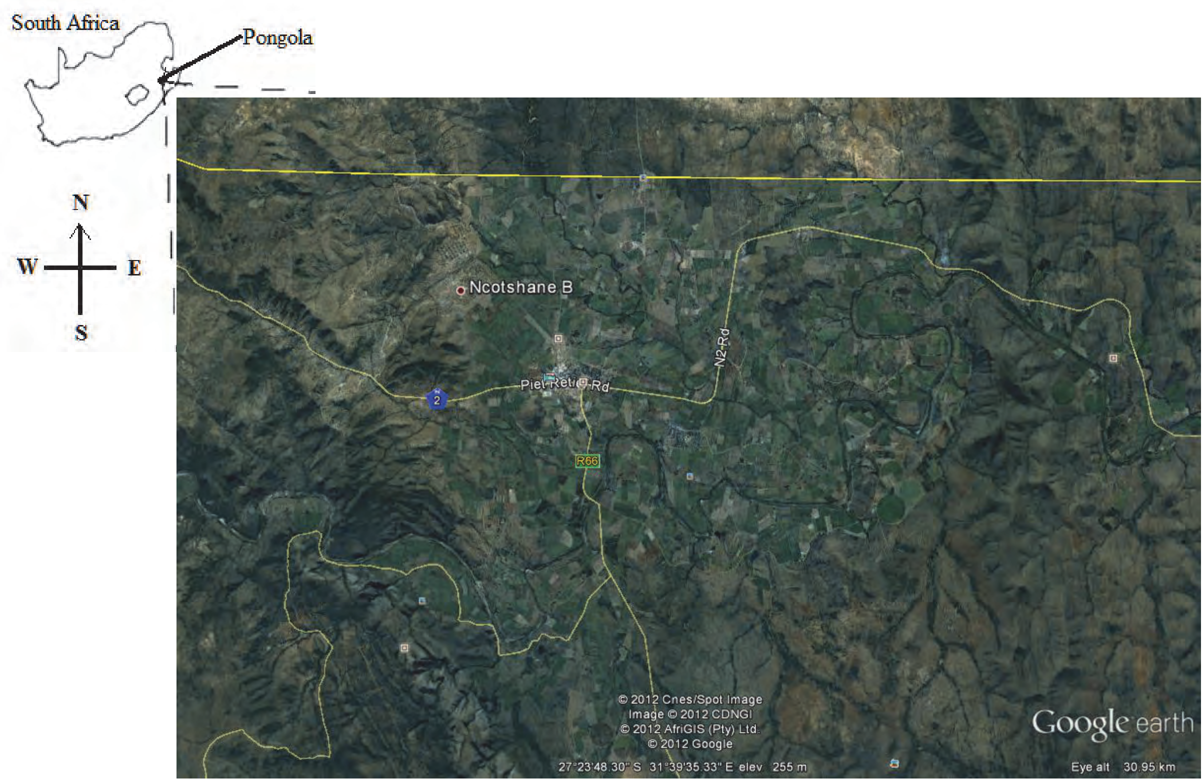


Figure 2-8 Location of the Impala irrigation scheme

The main crop is sugar cane but citrus, maize and vegetables are also produced. The scheme use the WAS program to manage its water and good historical data on water use is available. The sugar industry also support the area well with extension services.

2.3.1 **Scheme background**

The scheme background can be described by means of the following aspects:

- Soils and topography

The area is dominated by clay-loam and clay soils (Van der Merwe 2003) with fairly gentle slopes.

Sugarcane is the most dominant crop being grown in the area using sprinkler irrigation. Due to frequent irrigation during winter season and intense rainfall during the summer season, shallow water table problems have been reported in most irrigation fields. Additionally, soil salinisation problems have also been reported with some agricultural fields being deserted, e.g. in Makatini.

As a preventive measure to the shallow water table and soil salinisation problems, the sugarcane fields were first artificially drained using subsurface drainage systems in 1980s.

However, between 1995 and 2002, it was noticed that shallow groundwater tables were still affecting sugarcane growth in both fields. The subsurface drainage systems were, therefore, abandoned and all man-holes were filled up. This was followed by a recalculation of the drain depth and spacing using the steady state drain spacing approach (i.e. using the Hooghoudt (1940) steady state drain spacing equation), and the installation of the current subsurface drainage system in 2003. Details of the existing subsurface drainage systems are given below.

- Precipitation

The Aridity Index (AI) for the area for the past 13 years is 0.12, which according to UNESCO (1979) is the ratio of mean annual rainfall (P) (mm) to mean annual reference evapotranspiration (ETo) (mm). This Aridity Index characterises the area to be an arid region ($0.03<P/ETo<0.20$). Thus, during the months of April to October (winter season) crop production is mainly through irrigation, while in November to March (summer season) crop production is dependent on both rainfall and irrigation.

2.3.2 **Motivational factors**

The following factors were considered of importance when selecting this scheme for the drainage evaluations to be undertaken during this WRC project:

- Long history of drainage problems and solutions

In-field drainage problems have been occurring for more than 15 years at the scheme, resulting in wide-spread installation of drainage systems. Shallow water tables are being experienced even in areas where drainage systems were installed. Because of this on-going problem, expertise on the subject of drainage has developed in the area and can benefit this project.

- Installation of piezometers by the Department of Agriculture

The Department has installed piezometers across the scheme but no data is collected regularly. The piezometer are a valuable potential source of information and if data collection can be enabled, will provide the project team with solid information to evaluate the effectiveness of drainage systems against.

- Project team member resident on scheme

One of the project team advisors, Johan van der Merwe, resides in the Pongola area, where he works for the Department of Agriculture, KwaZulu-Natal. His presence in the area will be valuable for effective field work.

- Increased cane production wanted by the sugar mill

The Pongola mill was bought by TSB in 2012, and the millers would like to increase the tonnage of cane processed by the mill. As all the water allocations have been taken up by farmers on the scheme, the only option for increased tonnage is to increase the yield per hectare on the existing irrigation areas, Work being done to support this initiative will therefore be looked favourably on by the local stakeholders, which will provide support to the WRC project.

- Supportive scheme management/well-organised WUA

The WUA is well-organised and is in favour of the project, making it easier to undertake field work and have access the data that may be needed for the WRC reports.

3. TECHNICAL AND FINANCIAL REQUIREMENTS FOR MEASUREMENT AND MODELLING OF DRAINAGE

As discussed in Chapter 2, three case study sites were selected based on the variety of drainage problems encountered and the specific site conditions with respect to climate, dominant soils, key crops grown and irrigation systems used. The three case study sites selected are Pongola in KwaZulu-Natal, Vaalharts in Northern Cape and Breede River in Western Cape. Table 3-1 summarises the key site conditions at the three case study sites.

Table 3-1 Site conditions for the 3 case study sites for the project

Study Site	Soil Type(s)	Main Crops	Irrigation System(s)
Vaalharts (NC)	Sand and sandy loams	Lucerne, maize and wheat	Centre pivot, flood and sub-surface
Breede River (WC)	Karoo clay-loam	Grapes and stone fruit	Drip, micro-sprinkler and sub-surface
Impala (KZN)	Clay loam	Sugar cane	Centre pivot and dragline

Simulation models provide a better understanding of natural interrelated systems and help in making effective management decisions and planning of an agricultural production system. However, there is a need for calibration and validation of the models under site specific conditions before the model can be fully applied as a support decision making tool. During the project, sites were selected in the case study areas to collect data from to populate the simulation models.

3.1 Technical requirements

In order to cover a variety of situations that can require drainage, the typical inputs required for a drainage design were used to compile a list of technical requirements for the different sites. These inputs concern the following aspects of the drainage system, with details shown in Table 3-2:

- Weather
- Soil
- Structure affecting seepage
- Site aspects

Table 3-2 Technical inputs required for measurement and modelling

Data	Unit	Time step
Weather data inputs		
Precipitation	mm	daily
Maximum and minimum air temperature	°C	daily
Potential evapotranspiration	mm	daily
Soil property inputs		
Profile layer depths	mm	Once off
Hydraulic conductivity per layer	$cm.h^{-1}$	Once off
Soil-water characteristic per layer		Once off
Drainage volume	cm^3	daily
Infiltration rate	$cm.h^{-1}$	Once off for different soil types
Soil water content at saturation	$cm^3.cm^{-3}$	Once off for different soil types
Soil water content at permanent wilting point	$cm^3.cm^{-3}$	Once off for different soil types
Soil water holding capacity	% or mm/m	
Irrigation water salinity	$mS.m^{-1}$	Per irrigation event
Soil water salinity	$mS.m^{-1}$	Daily
Drained water salinity	$mS.m^{-1}$	Daily
Seepage inputs		
Thickness of restrictive layer	cm	Once off
Hydraulic conductivity of restrictive layer	$cm.h^{-1}$	Once off
Lateral hydraulic conductivity	$cm.h^{-1}$	Once off
Site and drainage system inputs		
Drain depth	m	Site/system specific
Drain spacing	m	Site/system specific
Depth to restrictive layer	m	Once off
Crops cultivated	type	Site specific

3.2 Financial requirements

The financial model was developed to improve the financial sustainability of irrigated agriculture while at the same time ensuring social and environmental sustainability. The model requires the financial inputs as shown in Table 3-3.

Table 3-3 Financial inputs required for measurement and modelling

Data	Unit
Case study data	
Farm size	ha
Current irrigation systems (per system)	ha
Land use (crops) – Crop and the AREA	ha
Land use (crops) – Crop, area and yield per well drained, poorly drained oil	ha and ton/ha
Rotation crops % of year (Monthly land occupation) per crop	% or months
Currently drained	ha
Current drainage system and ha	ha/system
Additional drainage required	ha
Time required to install draining per drainage type	Weeks
Average clay % of area to be drained	%
Current liabilities (Short/Medium and Long-term)	Rand
Current Assets (Short/Medium/Long-term)	Rand
Gross farm income	Rand
Total direct allocatable production costs	Rand
Total fixed costs	Rand
Non-farm income	Rand
Income tax	Rand
Private and household expenses	Rand
Capital costs	
Macro infrastructure	R/ha
On farm infrastructure	R/ha
Loose capital	R/ha
Soil and Drainage system inputs	
Soil water depth (meter)	Meter
Soil water holding capacity (%)	%
Quota (m^3/ha/year)	m^3/ha/year
Irrigation water salinity (mg/litre)	mg/litre
Soil water salinity TDS – Salt (mg/litre)	mg/litre
Soil water salinity ECe (mg/l)	mg/litre
Soil water salinity ECe (mS/m)	mS/m
TDS(if water salinity is not available)	Parts/million

Data	Unit
Saturated soil water volume (m^3)	m^3
Irrigation water salinity threshold (mg/litre) specified per crop	mg/litre
ECe Threshold (mS/m) specified per crop	mS/m
ECe Gradient %/mS/m specified per crop	%/mS/m
Max Physiological yield (ton per ha) specified per crop	ton/ha
Current Yield (waterlogging + salinity)	ton/ha
Yield curve with draining (reduced or no water logging and salinity)	ton/ha/year
Crop price (Rand per ton)	Rand/ton
Total variable costs (Rand per ha) – leaching excluded	Rand/ha
Water and electricity cost	R/mm
Crop water requirement	mm/ha
Water and Electricity cost	R/ha
Leaching	%
Drainage costs (capital)	R/ha
Term	Years
Interest Rate	%
Repayment	R/yr
Drainage Maintenance	% of cost
Drainage Maintenance cost	R/ha

4. PHYSICAL MEASUREMENTS OF THE INTERACTION BETWEEN IRRIGATION, DRAINAGE PRACTICES AND THE NATURAL ENVIRONMENT

During the project, measurements were undertaken in the three case study areas to collect the data required for the tools that are to be employed to assess, measure, simulate, model and evaluate the various factors that influences drainage design. The correct design of efficient drainage systems requires information on soil types, crops, irrigation methods, water tables, salinization, water quality and soil water management practices. This information was used to develop and/or refine the technical and financial standards for drainage systems reported in in Volume 3 of this report.

4.1 Vaalharts Irrigation Scheme

At Vaalharts Irrigation Scheme four case study sites were selected:

- Case study 1 (site 1) represents a situation where flood irrigation is replaced with centre pivot irrigation system. This will provide insight into how the drainage needs changes from flood (two seasons) to centre pivot systems (two seasons).
- Case study 2 (site 2) offers the prospect to study drainage over four growing seasons. The effluent was pumped back to the neighbour's storage dam where it was blended with Vaal River water and re-used to irrigate the same field. This practice was stopped during the first season on realising that the salts are recycled, but re-installed in the last season due to a shortage of water. Nevertheless, disposal of drainage effluent was impossible because there was no drainage canal installed at this site. The major question that needs to be answered is: What is the fate of salts and water under poor artificial drainage and disposal facilities.
- Case study 3 (site 3) was a waterlogged area and the farmer also replaced the flood irrigation (two seasons) with centre pivot irrigation (one season). This case study provides *in situ* evidence on how the soil was reclaimed by switching from flood to centre pivot irrigation.
- Case study 4 (site 4) represents a situation where different artificial drain-spacings were used in a sandy soil irrigated with a centre pivot. The research question here is if the drain spacing will affect the soil and crops on the long run and how should it be managed?

4.1.1 Location of case study sites

The four sites used for this study is demarked on the map of the Vaalharts Irrigation Scheme depicted in Figure 4-1. Three of the sites are from Block K and one from Block F. The general features of the sites with respect to irrigation and drainage systems and the presence/absence of a water table are summarised in Table 4-1.

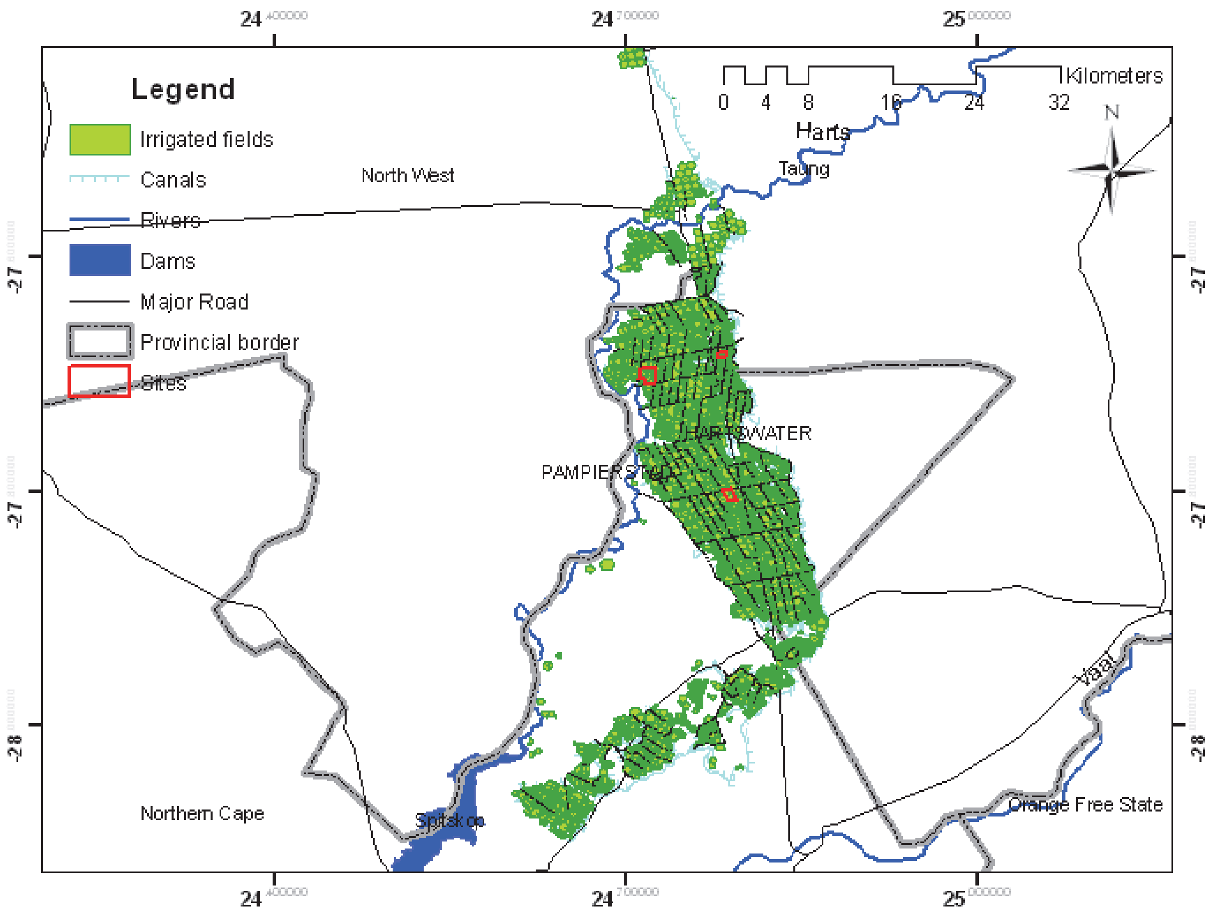


Figure 4-1 Geographical position of the four sites selected for the drainage studies at the Vaalharts Irrigation Scheme. The sites are located in the North Canal section in Block K and Block F.

Table 4-1 Selected case study sites at the Vaalharts Irrigation Scheme

Site	Measuring points	Irrigation system	Water table	Drainage system
1	v1	Flood/Centre pivot	Yes	Yes
2	V4	Linear	Yes	No
3	v8	Flood/Centre pivot	Yes	Yes
4	v12	Centre pivot	Yes	Yes

4.1.2 **Data available at selected sites**

The measurement data originates from a previous WRC project (Van Rensburg et al. 2012) contracted by the University of the Free State (Department of Soil, Crop and Climate Sciences). However, the data from site 1, 2 and 3 were never used in the Van Rensburg et al. report. The data from site 4, which were presented in Van Rensburg et al. report, were re-analysed to answer the specific research question set in the aims.

The measurements at these sites mostly concerned the soils' baseline data such as profile descriptions, texture, bulk density, saturated hydraulic conductivity (Ksat), cation exchange capacity (CEC), electrical conductivity of the saturated extract at the start of the project (EC_e) and sodium adsorption ratio (SAR_e) of the saturated extract at the start of the project.

Irrigation and rain were measured with rain gauges installed in the 4 m x 4 m site. Soil water contents were measured with the neutron water meter on a weekly basis when possible. The depth of water table was also monitored weekly with the aid of piezometers. Discharge rates of the in-field artificial drains were manually measured.

It is impossible to measure all the components of the soil water balance under water table conditions and therefore the SWAMP model was used to facilitate the study. Evaporation from the soil (E), transpiration from crops, water table uptake and drainage were simulated from soil water content, irrigation, rain, water table heights and crop yield (seed and biomass) measured in the crop fields.

- Site 1 (K Block- plot 4K5)

General information with respect to the location (Figure 4-2) and owner of the farm are summarised in Table 4-2 Infrastructure such as irrigation and drainage system are also given. This case study represents a situation where the irrigation method was changed from flood to centre pivot. The change occurred at the end of the second growing season. The soil was classified to be of the Bloemdal form and Roodeplaat family and the pedological properties of the diagnostic horizons are summarised in Table 4-3. Briefly, it is wind-blown sands on a deep lime layer. In this case the sand was enriched with clay that probably came from the Ventersdorp lava-koppie located east of the site. The clay and silt contents increase over depth from 17% in the A horizon) to 35% in the B3 horizon (1200 mm). There are signs of wetness present in the C horizon which indicates that the subsoil becomes periodically saturated or forms a water table as indicated in Table 4-3. This is the reason why an artificial drainage system was installed. Relevant physical and chemical properties of the 300 mm soil layers are summarised in Table 4-4 and Table 4-5. The hydraulic properties of the centre pivot are summarised in Table 4-6. From the results it is clear that the system is in a good condition.

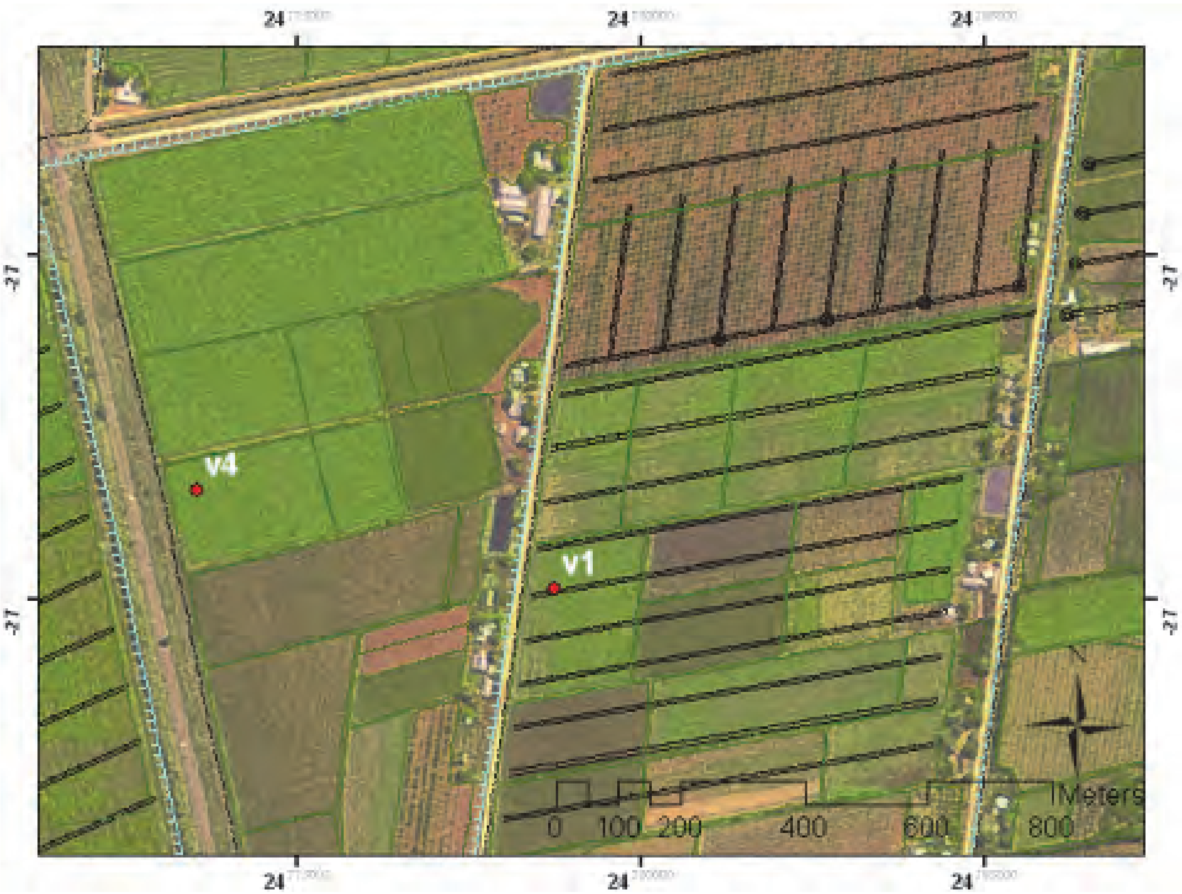


Figure 4-2 Location of the internal drainage system at site 1 (measuring point v1 where (flood irrigation was converted to centre pivot) and site 2 (measuring point v4 under a linear irrigation system). The layout of the drainage system in site 2 was not available at the writing of this report). Both sites are located in the K-block

The agronomic practices applied over the four seasons are summarised in Table 4-7. It is important to note that lucerne was cultivated over the first two seasons under flood irrigation, where after wheat and maize was planted in the last two seasons.

Table 4-2 General information on Site 1

General information				
Location	X-coordinate	24.778722	**Soil form**	Bloemdal
	Y-coordinate	-27.684528	**Soil family**	Roodeplaat
Farmer's name			**Water source**	Vaal river
Farm	4K5		**Irrigation system**	1st and 2nd season – Flood/3rd and 4th season – Centre pivot
Water table	Yes		**Drainage system**	Yes

Table 4-3 Soil profile description

Profile no:	V1	**Soil form and family:**	Bloemdal *Roodeplaat*
Map/photo:	2724DB Taung	**Surface rockiness:**	None
Latitude and longitude:	27° 41' 4.1"/25° 13' 15.8"	**Occurrence of flooding:**	None
Surface stoniness:	None	**Wind erosion:**	None
Altitude:	1128.3 m	**Water erosion:**	None
Terrain unit:	Upper footslope	**Erosion stability:**	Stabilized
Slope:	1 %	**Vegetation/Land use:**	Agronomic field crops
Slope shape:	Concave	**Water table:**	1700 mm
Aspect:	West	**Described by:**	Dr PAL le Roux, Prof LD van Rensburg, Mr JH Barnard and Mr JB Sparrow
Microrelief:	None		
Parent material solum:	Unknown	**Date described:**	30/10/07
Underlying material:	Sandstone siliceous	**Weathering of underlying material:**	Moderate
Geological group:	Ventersdorp	**Alteration of underling material:**	Ferruginised

Horizon	**Depth (mm)**	**Description**	**Diagnostic horizon**
A	0-350	**Moisture status:** moist; **dry colour:** yellowish red (5YR 4/6); **moist colour:** dark reddish brown (2.5YR 3/3); 11 % clay; fine loamy sand; no mottles; apedal massive; slightly hard, slightly firm, sticky, slightly plastic; common normal fine pores; no cracks; no slickensides; no cutans; no coarse fragments; no depositional stratification; water absorption: 2 second; many roots; abrupt smooth transition.	Orthic
B1	350-700	**Moisture status:** moist; **dry colour:** reddish yellow (5YR 6/8); **moist colour:** yellowish red (5YR 4/6); 15 % clay; fine sandy loam; no mottles; apedal massive; soft, friable, slightly sticky, non-plastic; common fine normal pores; no cracks; no slickensides; no cutans; no coarse fragments; no depositional stratification; water absorption: 2 second; common roots, diffuse smooth transition.	Red apedal
B2	700-1100	**Moisture status:** moist; **dry colour:** yellowish red (5YR 5/8); **moist colour:** dark reddish brown (5YR 3/4); 17 % clay; fine sandy loam; no mottles; apedal massive; soft, friable, slightly sticky, non-plastic; few fine normal pores; no cracks; no slickensides; no cutans; no coarse fragments; no depositional stratification; water absorption: 2 second; common roots, diffuse smooth transition.	Red apedal
B3	1100-1300	**Moisture status:** moist; **dry colour:** Strong brown (7.5YR 5/8); **moist colour:** brown (7.5YR 4/4); 20 % clay; fine sandy clay loam; common fine distinct red, yellow, black, brown and grey mottles; weak fine crumb; slightly hard, slightly firm, sticky, slightly plastic; few fine normal pores; no cracks; no slickensides; no cutans; no coarse fragments; no depositional stratification; water absorption: 2 second; few roots, clear smooth transition.	Red apedal
C	1300-1800+	**Moisture status:** wet; **dry colour:** brownish yellow (10YR 6/8); **moist colour:** yellow (10YR 7/6); 20 % clay; fine sandy clay loam; many medium prominent red, yellow, black, brown and grey mottles; weak fine crumb; slightly hard, firm, sticky, plastic; few fine bleached pores; no cracks; no slickensides; no cutans; no coarse fragments; no depositional stratification; water absorption: 2 second; no roots, transition not reached.	Unspecified material with signs of wetness

Table 4-4 Physical properties of the 300 mm soil layer intervals

Soil physical properties						
Particle size distribution (%)	**Soil depth (mm)**					
	0-300	**300-600**	**600-900**	**900-1200**	**1200-1500**	**1500-1800**
Course sand	9.4	9.5	12.0	9.5	6.8	8.0
Medium sand	13.8	14.3	15.1	13.9	10.6	11.7
Fine sand	46.0	41.3	37.3	37.2	33.0	34.1
Very fine sand	14.3	13.3	12.6	13.5	12.9	14.2
Total sand	83.5	78.5	77.0	74.2	63.3	68.0
Course silt	2.7	2.7	4.7	4.8	6.2	5.2
Fine silt	3.0	3.0	2.0	4.0	9.0	7.0
Total silt	5.7	5.7	6.7	8.8	15.2	12.2
Clay	11.0	15.0	17.0	16.0	20.0	20.0
Silt + Clay	16.7	20.7	23.7	24.8	35.2	32.2
Bulk density (kg m^{-3})	1679	1652	1630	1658	1706	1714
Saturated hydraulic conductivity (mm h^{-1})	9.35	15.55	-	-	-	5.54

Table 4-5 Chemical properties of the soil layers

Soil chemical properties						
Depth (mm)	**0-300**	**300-600**	**600-900**	**900-1200**	**1200-1500**	**1500-1800**
pH (H_2O)	6.8	7.0	7.7	8.4	8.2	8.1
CEC ($cmol_c\ kg^{-1}$)	8.6	10.2	7.9	8.0	12.0	11.3
Saturated extractable cations ($mg\ \ell^{-1}$)						
Start of season 1						
Ca	67.0	66.6	83.4	102.1	247.0	79.8
Mg	38.7	29.1	25.4	5.0	6.6	9.9
K	36.0	36.0	40.0	50.0	135.0	70.0
Na	50.0	68.0	98.0	174.0	410.0	210.0
End of season 1						
Ca	47.2	44.0	39.5	78.4	96.1	58.3
Mg	12.4	10.2	11.9	4.7	4.4	4.5
K	21.0	13.0	11.0	31.0	50.0	34.0
Na	37.0	30.0	32.0	99.0	132.0	83.0
End of season 2						
Ca	34.0	48.8	45.1	126.1	152.4	71.6
Mg	18.4	19.9	6.5	6.3	5.3	5.0
K	14.4	21.0	16.4	57.0	78.0	54.0
Na	23.0	50.0	41.0	118.0	233.0	108.0
End of season 3						
Ca	53.0	75.2	65.8	60.3	45.2	-
Mg	27.8	15.5	17.0	17.4	7.8	-
K	24.0	32.0	27.0	22.0	19.0	-
Na	68.0	57.0	42.0	40.0	52.0	-
End of season 4						
Ca	-	-	-	-	-	-
Mg	-	-	-	-	-	-
K	-	-	-	-	-	-
Na	-	-	-	-	-	-

Table 4-6 Information on the evaluation on the performance of the centre pivot

Centre pivot evaluation				
Centre pivot speed	**Uniformity coefficient (%)**	**Distribution uniformity (%)**	**Application coefficiency (%)**	**System efficiency (%)**
50 %	88.5	84.6	95.5	80.8
20%	86.9	83.8	99.5	83.4
Mean	87.7	84.2	97.5	82.1

Table 4-7 Specific agronomical practices applied during the measuring period which stretched over four growing seasons

Agronomic practices			
Season	**1** **2**	**3**	**4**
Crop rotation	**Lucerne**	**Wheat**	**Maize**
Cultivar	-	SST 835	Seed maize
Planting date	-	15/07/2008	22/12/2008
Harvesting date	-	02/12/2008	02/06/2009
Planting density	-	140 kg ha^{-1}	100 000 plant ha^{-1}
Farmers yield	-	6 t ha^{-1}	-
Type of fertilizer applied (kg ha^{-1})	-	400 kg 7:3:2 (46) 200 kg Ureum (46)	200 kg 6:3:4 (40) 300 kg Ureum (46)
Total kg N ha^{-1}	-	200	175
Total kg P ha^{-1}	-	46	19
Total kg K ha^{-1}	-	31	25
Pest management	-	Grandstar	Callisto – 250 mℓ/ha Gasiprim – 1 ℓ/ha Dual – 0.5 ℓ/ha
Cultivation practices	Plough, rip, wonder till and plant	Rip, wonder till and plant	Bale, burn, wonder till (2x) and plant – After harvest – Land is burned

- Site 2 (K Block- plot 1K6)

General information with respect to the location and owner of the farm are summarised in Table 4-8. Infrastructure such as irrigation and drainage system are also given. This case study represents a condition where the drainage water from the field is pumped back to the storage dam of the neighbour's. The drainage water is then blended with Vaal River water and re-used to irrigate the same field. The farmer had stopped the practice during the first season on realising the potential danger of re-cycling the salts that might harm the soil and the crop. However, he continued with the blending in the last (fourth) season.

The soil was officially classified to be of the Hutton form and Ventersdorp family it has similar properties as the soil at site 1. The pedological properties of the diagnostic horizons are summarised in Table 4-9 and are mainly similar to that of the soil at site 1. The main difference is the texture class; clay content varied between 4 and 10% in this site compared to 11- 22% at site 1. As in the case of site 1 the C-horizon has signs of wetness and a fluctuating water table was present. Unfortunately the layout of the artificial drainage system is not available (Figure 4-2 also provides detail on this site).

The relevant physical and chemical properties of the 300 mm soil layers are summarised in Table 4-10 and Table 4-11. The hydraulic properties of the linear irrigation system are summarised in Table 4-12. From the results it is clear that the system is in a good condition.

The agronomic practices for lucerne are summarised in Table 4-13.

Table 4-8 General information on Site 2

General information					
Location	X-coordinate	24.773556	**Soil form**	Hutton
	Y-coordinate	-27.683417	**Soil family**	Ventersdorp
Farmer's name			**Water source**	Vaal river
Farm	1K6		**Irrigation system**	Linear system
Water table	Yes		**Drainage system**	Yes

Table 4-9 Soil profile description of site 2

Profile no:	V3	**Soil form and family:**	Hutton *Ventersdorp*
Map/photo:	2724DB Taung	**Surface rockiness:**	None
Latitude and longitude:	27° 40' 48.8"/25° 13' 37.4"	**Occurrence of flooding:**	None
Surface stoniness:	None	**Wind erosion:**	Slight
Altitude:	1125.5 m	**Water erosion:**	None
Terrain unit:	Upper footslope	**Erosion stability:**	Stabilized
Slope:	1 %	**Vegetation/Land use:**	Agronomic field crops
Slope shape:	Concave	**Water table:**	2100 mm
Aspect:	West	**Described by:**	Dr. P.A.L. le Roux, Prof L. D. van Rensburg, Mr. J. H. Barnard and Mr. J. B. Sparrow
Microrelief:	None		
Parent material solum:	Single; aeolian	**Date described:**	30/10/07
Underlying material:	Unknown	**Weathering of underlying material:**	Unknown
Geological group:	Ventersdorp	**Alteration of underling material:**	Generalized

Horizon	Depth (mm)	Description	Diagnostic horizon
A	0400	**Moisture status:** moist; **moist colour:** dark brown (7.5YR 3/4); 6 % clay; fine sandy; no mottles; apedal massive; soft, loose, non-sticky, non-plastic; many normal fine and medium pores; no cracks; no slickensides; no cutans; no coarse fragments; aeolian depositional stratification; water absorption: 1 second; many roots; diffuse smooth transition.	Orthic
B1	400-1200	**Moisture status:** moist; **moist colour:** red (10R 4/8); 8 % clay; fine sandy; no mottles; apedal massive; soft, loose, non-sticky, non-plastic; common normal fine and medium pores; no cracks; no slickensides; no cutans; no coarse fragments; aeolian depositional stratification; water absorption: 1 second; common roots, diffuse smooth transition.	Red apedal
B2	1200-1500	**Moisture status:** moist; **moist colour:** red (2.5YR 4/8); 8 % clay; fine sandy; very few fine faint grey, yellow and olive mottles; apedal massive; soft, loose, non-sticky, non-plastic; common normal fine and medium pores; no cracks; no slickensides; no cutans; no coarse fragments; aeolian depositional stratification; water absorption: 1 second; few roots, diffuse smooth transition.	Red apedal
C	1500+	**Moisture status:** moist; **moist colour:** yellow (10YR 7/6); 8 % clay; fine sandy; common fine prominent grey, yellow and olive mottles; apedal massive; soft, loose, non-sticky, non-plastic; few normal fine pores; no cracks; no slickensides; no cutans; no coarse fragments; aeolian depositional stratification; water absorption: 1 second; no roots, transition not reached.	Unspecified
	Remarks:	This soil has an underlying water table that fluctuates between 1750 mm and 2100 mm, therefore soil could be classified as a Bloemdal due to the signs of wetness in the C horizon. Soil was instead classified as a Hutton due to the classification depth limitation of 1500 mm, according to the Taxonomical System of South Africa (Soil Classification Working Group 1991)	

Table 4-10 Physical properties of the 300 mm soil layer intervals at site 2

Soil physical properties						
Particle size distribution (%)	**Soil depth (mm)**					
	0-300	**300-600**	**600-900**	**900-1200**	**1200-1500**	**1500-1800**
Course sand	15.8	15.4	16.2	18.6	15.5	20.3
Medium sand	17.1	16.2	15.3	15.7	17.2	16.1
Fine sand	41.4	43.2	42.5	38.9	40.7	37.9
Very fine sand	12.4	12.5	12.9	12.4	13.0	13.5
Total sand	86.7	87.2	86.8	85.6	86.5	87.9
Course silt	2.8	2.8	8.5	2.5	2.6	2.5
Fine silt	2.0	2.0	2.0	2.0	4.0	2.0
Total silt	4.8	4.8	10.5	4.5	6.6	4.5
Clay	10.0	10.0	4.0	8.0	8.0	8.0
Silt + Clay	14.8	14.8	14.5	12.5	14.6	12.5
Bulk density ($kg\ m^{-3}$)	-	-	-	-	-	-
Saturated hydraulic conductivity ($mm\ h^{-1}$)	-	-	-	-	-	-

Table 4-11 Chemical properties of the soil layers at site 2

Soil chemical properties						
Depth (mm)	**0-300**	**300-600**	**600-900**	**900-1200**	**1200-1500**	**1500-1800**
pH (H_2O)	7.4	7.5	7.7	8.2	7.9	8.0
CEC ($cmol_c\ kg^{-1}$)	5.0	5.5	4.0	4.5	3.9	3.3
Saturated extractable cations (mg ℓ $^{-1}$)						
Start of season 1	**0-300**	**300-600**	**600-900**	**900-1200**	**1200-1500**	**1500-1800**
Ca	28.1	348.0	156.0	204.0	179.0	157.6
Mg	2.7	6.6	2.3	4.3	13.0	54.4
K	7.8	104.0	77.0	89.0	72.0	55.0
Na	45.0	270.0	330.0	360.0	220.0	150.0
End of season 1						
Ca	184.0	27.4	50.4	208.0	352.0	49.8
Mg	12.8	1.3	2.9	11.3	16.9	2.4
K	47.0	7.0	16.0	89.0	125.0	20.0
Na	164.0	44.0	261.0	460.0	580.0	45.0
End of season 2						
Ca	23.9	183.0	251.0	239.0	179.0	212.0
Mg	2.1	2.7	3.4	2.2	5.2	12.8
K	10.1	25.0	106.0	81.0	56.0	68.0
Na	35.0	88.0	200.0	240.0	195.0	240.0
End of season 3						
Ca	57.8	61.5	86.0	172.0	178.0	134.8
Mg	3.7	2.7	2.1	2.3	4.1	6.7
K	25.0	21.0	37.0	42.0	39.0	38.0
Na	61.0	67.0	97.0	161.0	178.0	147.0
End of season 4						
Ca	80.0	198.0	150.0	137.0	222.0	93.3
Mg	2.5	3.6	2.5	1.6	16.2	8.6
K	23.0	34.0	46.0	40.0	45.0	24.0
Na	100.0	191.0	273.0	198.0	244.0	120.0

Table 4-12 Information on the evaluation on the performance of the linear irrigation system at site 2

Centre pivot speed	Uniformity coefficient (%)	Distribution uniformity (%)	Application efficiency (%)	System efficiency (%)
100 %	92.9	94.7	99.7	94.4
20%	90.8	86.3	89	76.8
Mean	91.8	90.5	94.4	85.6

Table 4-13 Specific agronomical practices applied during the measuring period which stretched over four growing seasons at site 2

Agronomic practices				
Season	**1**	**2**	**3**	**4**
Crop rotation	**Lucerne**			
Cultivar	WL 612			
Planting date	July 2004			
Harvesting date	-			
Planting density	25 kg ha^{-1}			
Farmers yield	-			
Type of fertilizer applied (kg ha^{-1})	400 kg 2:3:4 (30) 5 000 kg Cattle manure			
Total kg N ha^{-1}	256			
Total kg P ha^{-1}	115			
Total kg K ha^{-1}	218			
Pest management	Harnas – 1.5 ℓ ha^{-1}			
Cultivation practices	Rip, disk, wonder till and plant			

- Site 3 (K Block-3K13)

General information with respect to the location and owner of the farm are summarised in Table 4-14. This case study presents a unique condition where the field was waterlogged due to a very wet pre-season and flood irrigation method used. However, the two neighbouring farmers combined there resources and installed a centre pivot that was shared by them during the last two of the four seasons measured. The layout of the drainage system is presented in Figure 4-3.

The soil was classified to be of the Hutton form and Ventersdorp family and the pedological properties of the diagnostic horizons are summarised in Table 4-15. The soil is pedologically similar to that find in site 2. The physical and chemical supportive data are summarised in Table 4-16 and Table 4-17.

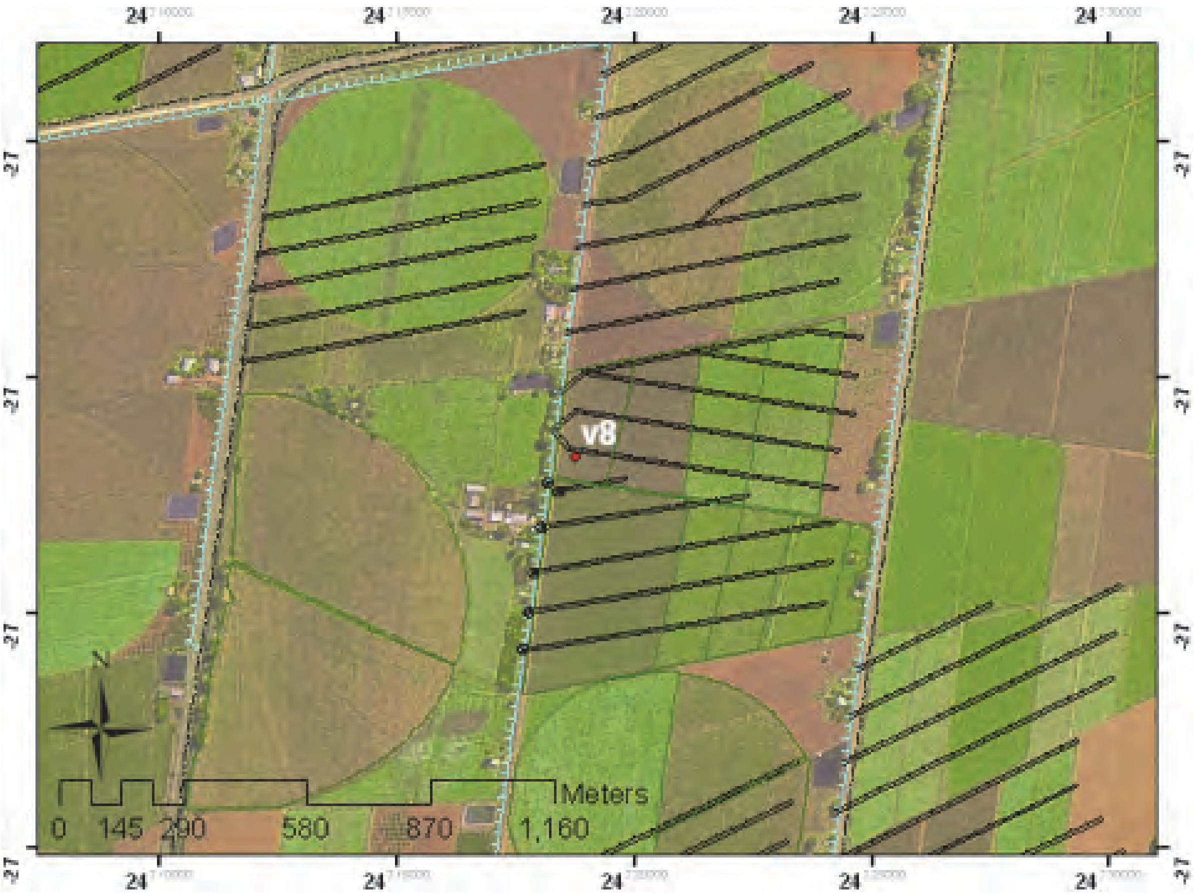


Figure 4-3 Location of the internal drainage system at site 3 (measuring point v8 where flood irrigation was replaced by a centre pivot) within K-block.

The hydraulic properties of the centre pivot are summarised in Table 4-18. From the results it is clear that the system is in a good condition.

The agronomic practices of the field crops planted in a double crop sequence (wheat-maize in the first year and then wheat-groundnuts in the second year) are summarised in Table 4-19.

Table 4-14 General information on Site 3

General information				
Location	X-coordinate	24.719056	**Soil form**	Hutton
	Y-coordinate	-27.696528	**Soil family**	Ventersdorp
Farmer's name			**Water source**	Vaal river
Farm	3K13		**Irrigation system**	Flood/Centre Pivot
Water table	Yes		**Drainage system**	Yes

Table 4-15 Soil profile description of site 3

Profile no:	V 6	**Soil form and family:**	Hutton *Ventersdorp*
Map/photo:	2724DA Norlim	**Surface rockiness:**	None
Latitude and longitude:	27° 42' 20.9"/25° 16' 52.9"	**Occurrence of flooding:**	None
Surface stoniness:	None	**Wind erosion:**	Slight
Altitude:	1085.9 m	**Water erosion:**	None
Terrain unit:	Lower footslope	**Erosion stability:**	Stabilized
Slope:	0.5 %	**Vegetation/Land use:**	Agronomic field crops
Slope shape:	Concave	**Water table:**	1800 mm
Aspect:	West	**Described by:**	Dr. P.A.L. le Roux, Prof L. D. van Rensburg, Mr. J. H. Barnard and Mr. J. B. Sparrow
Microrelief:	None	**Date described:**	30/10/07
Parent material solum:	Origin single, aeolian	**Weathering of underlying material:**	Unknown
Underlying material:	Unknown	**Alteration of underling material:**	Generalized
Geological group:	Ventersdorp		

Horizon	Depth (mm)	Description	Diagnostic horizon
A	0-350	**Moisture status:** moist; **moist colour:** dusky red (10R 3/3); 6 % clay; fine sandy; no mottles; apedal massive; loose, loose, non-sticky, non-plastic; many normal fine and medium pores; no cracks; no slickensides; no cutans; no coarse fragments; aeolian depositional stratification; water absorption: 1 second; many roots; clear smooth transition.	Orthic
B1	350-900	**Moisture status:** moist; **moist colour:** red (10R 4/6); 6 % clay; fine sandy; no mottles; apedal massive; soft, friable, non-sticky, non-plastic; common normal fine and medium pores; no cracks; no slickensides; no cutans; no coarse fragments; aeolian depositional stratification; water absorption: 1 second; common roots; gradual smooth transition.	Red apedal
B2	900-1500	**Moisture status:** moist; **moist colour:** red (2.5YR 4/6); 8 % clay; fine sandy; no mottles; apedal massive; soft, friable, non-sticky, non-plastic; few normal fine and medium pores; no cracks; no slickensides; no cutans; no coarse fragments; aeolian depositional stratification; water absorption: 1 second; common roots; gradual smooth transition.	Red apedal
C	1500+	**Moisture status:** wet; **moist colour:** light red (2.5YR 7/6); 10 % clay; fine loamy sand; common medium distinct grey, yellow and olive mottles; apedal massive; soft, friable, non-sticky, non-plastic; few normal fine pores; no cracks; no slickensides; no cutans; no coarse fragments; water absorption: 1 second; no roots.; transition not reached.	Unspecified
	Remarks:	This soil has an underlying water table that fluctuates between 1600 mm and 1900 mm, therefore soil could be classified as a Bloemdal due to the signs of wetness in the C horizon. Soil was instead classified as a Hutton due to the classification depth limitation of 1500 mm, according to the Taxonomical System of South Africa (Soil Classification Working Group 1991)	

Table 4-16 Physical properties of the 300 mm soil layer intervals at site 3

Soil physical properties						
Particle size distribution (%)	**Soil depth (mm)**					
	0-300	**300-600**	**600-900**	**900-1200**	**1200-1500**	**1500-1800**
Course sand	14.8	15.2	14.3	15.9	15.6	-
Medium sand	16.4	16.1	14.2	14.5	13.7	-
Fine sand	42.8	42.0	43.6	42.8	41.2	-
Very fine sand	14.1	14.8	14.9	14.3	16.0	-
Total sand	88.1	88.1	87.0	87.5	86.6	-
Course silt	2.8	3.0	3.1	3.1	1.3	-
Fine silt	2.0	2.0	6.0	2.0	4.0	-
Total silt	4.8	5.0	9.1	5.1	5.3	-
Clay	6.0	6.0	6.0	6.0	8.0	-
Silt + Clay	10.8	11.0	15.1	11.1	13.3	-
Bulk density (kg m^{-3})	-	-	-	-	-	-
Saturated hydraulic conductivity (mm h^{-1})	-	-	-	-	-	-

Table 4-17 Chemical properties of the soil layers at site 3

Soil chemical properties						
Depth (mm)	**0-300**	**300-600**	**600-900**	**900-1200**	**1200-1500**	**1500-1800**
pH (H_2O)	6.9	7.4	7.9	7.9	7.9	-
CEC ($cmol_c$ kg^{-1})	3.5	3.2	2.6	2.4	2.6	-
Saturated extractable cations (mg ℓ $^{-1}$)						
Start of season 1						
Ca	73.1	96.5	45.4	22.3	67.1	35.4
Mg	16.8	11.7	2.1	1.9	2.3	2.2
K	33.0	50.0	30.0	7.7	8.3	12.8
Na	43.0	45.0	67.0	37.0	58.0	107.0
End of season 1						
Ca	102.7	56.2	34.8	51.8	46.8	36.0
Mg	18.6	4.5	2.5	3.0	3.2	3.0
K	58.0	24.0	14.0	22.0	18.0	12.0
Na	56.0	49.0	42.0	50.0	51.0	57.0
End of season 2						
Ca	61.6	64.2	54.0	59.0	56.0	40.0
Mg	7.4	2.5	1.0	1.2	1.9	1.4
K	30.0	29.0	15.6	16.4	15.2	14.0
Na	38.0	47.0	48.0	50.0	60.0	69.0
End of season 3						
Ca	42.0	93.7	66.8	53.8	75.5	61.8
Mg	11.0	5.2	3.1	3.6	7.3	4.8
K	14.9	47.0	32.0	24.0	29.0	26.0
Na	57.0	107.0	114.0	83.0	83.0	100.0
End of season 4						
Ca	39.3	121.7	98.5	89.0	50.8	61.9
Mg	7.6	7.9	2.9	2.6	2.2	2.3
K	12.8	34.0	30.0	26.0	13.0	16.4
Na	43.0	157.0	103.0	93.0	56.0	92.0

Table 4-18 Information on the evaluation on the performance of the centre pivot

Centre pivot evaluation				
Centre pivot speed	**Uniformity coefficient (%)**	**Distribution uniformity (%)**	**Application efficiency (%)**	**System efficiency (%)**
100 %	91.5	85.4	99	84.6
20%	84.5	76.5	85.1	65.1
Mean	88	81	92.1	74.9

Table 4-19 Specific agronomical practices applied during the measuring period which stretched over four growing seasons at site 3

Agronomic practices				
Season	**1**	**2**	**3**	**4**
Crop rotation	**Wheat**	**Maize**	**Wheat**	**Groundnuts**
Cultivar	Carnia 826	Pioneer 33A14	Krokodil	Aqua
Planting date	12/06/2007	04/12/2007	16/06/2008	25/11/2008
Harvesting date	25/11/2007	21/05/2008	20/11/2008	18/04/2009
Planting density	140 kg ha^{-1}	85 000 plants ha^{-1}	125 kg ha^{-1}	156 kg ha^{-1}
Farmers yield	7.5 t ha^{-1}	9.8 t ha^{-1}	4.5 t ha^{-1}	3 t ha^{-1}
Type of fertilizer applied (kg ha^{-1})	400 kg 6:2:1 (32) 300 kg 5:0:1 (47) 300 kg UAN (32)	300 kg 4:3:4 (33) 550 kg Ureum (46)	2000 kg Chicken manure 200 kg 6:3:4 (32) 406 kg UAN (32)	200 kg 2:3:4 (30) 300 kg Ureum (46)
Total kg N ha^{-1}	300	289	230	152
Total kg P ha^{-1}	29	27	59	20
Total kg K ha^{-1}	38	36	66	27
Pest management	MCPA	Diamond Armadillo	-	Hammer Harnas Basigrin – 4 ℓ ha^{-1} Punch – 0.4 ℓ ha^{-1}
Cultivation practices	Till cultivator, wonder till and plant	Bale, burn, plough, wonder till (2x) and plant	Burn, plough, wonder till (2x) and plant	Bale, burn, plough, wonder till (2x) and plant – After harvest – Bale

- Site 4 (F Block- 4-6F7)

General information with respect to the location and owner of the farm are summarised in Table 4-20. The layout of the artificial drainage system located under the centre pivot is presented in Figure 4-4. From this it is clear that the drain spacing at measuring point v11 differs widely from that at v12.

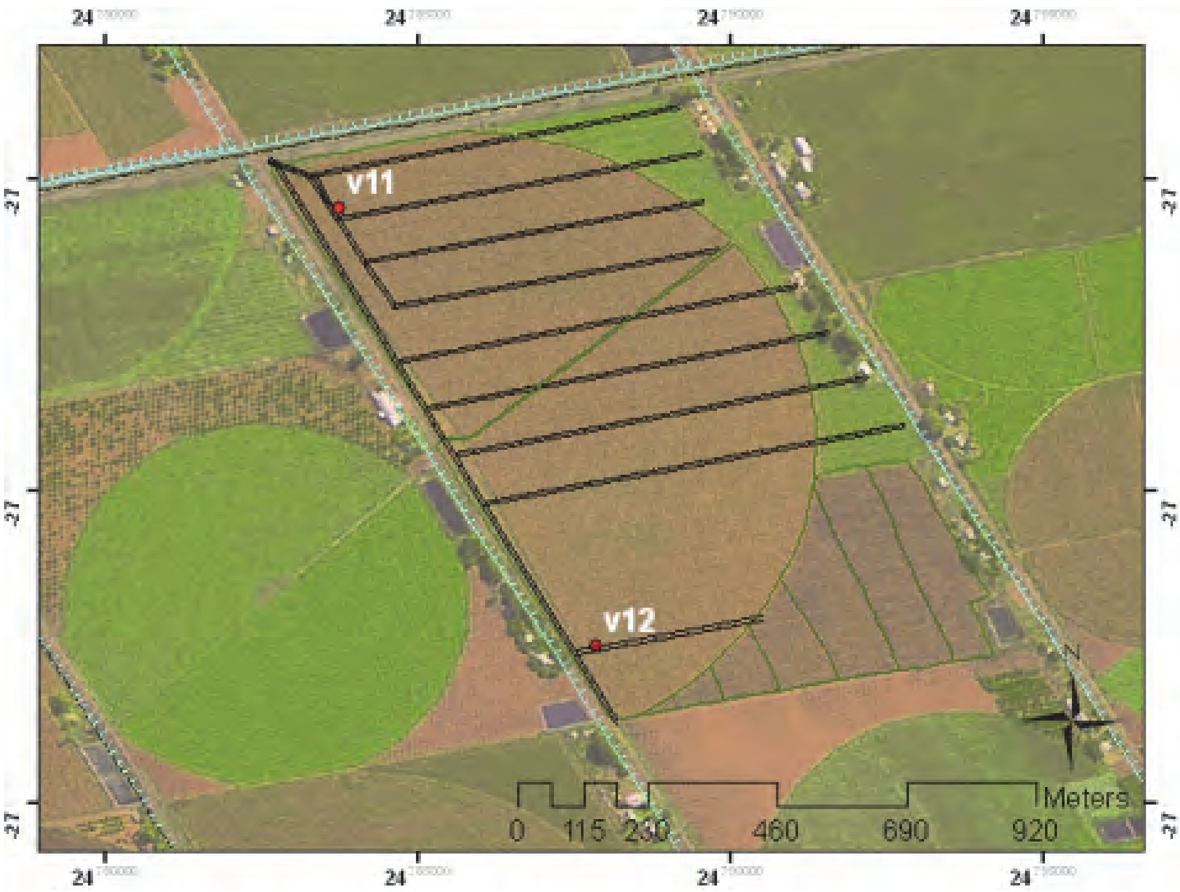


Figure 4-4 Location of the internal drainage system at site 4 (measuring point v11 and v12 under the centre pivot) within F-block.

The soil was classified to be of the Bloemdal form and Roodeplaat family. Details on the pedological properties (basic similar to that of site 2 and site 3) are available in Table 4-21. The relevant physical and chemical properties of the 300 mm soil layers are summarised in Table 4-22 and Table 4-23.

The hydraulic properties of the centre pivot are summarised in Table 4-24. From the results it is clear that the system is in a good condition.

The agronomic practices applied over the four seasons are summarised in Table 4-25. The farmer used a double cropping sequence with a very popular wheat-maize combination in the first year and a barley-maize combination in the second year.

Table 4-20 General information on site 4

General information				
Location	X-coordinate	24.783389	**Soil form**	Bloemdal
	Y-coordinate	-27.800500	**Soil family**	Roodeplaat
Farmer's name			**Water source**	Vaal river
Farm	4-6F7		**Irrigation system**	Centre Pivot
Water table	Yes		**Drainage system**	Yes

Table 4-21 Soil profile description of site 4

Profile no:	V 12	**Soil form and family:**	Bloemdal *Roodeplaat*
Map/photo:	2724 DD Jan Kempdorp	**Surface rockiness:**	None
Latitude and longitude:	27° 28' 26.9"/25° 12' 43.5"	**Occurrence of flooding:**	None
Surface stoniness:	None	**Wind erosion:**	Moderate
Altitude:	1108.7 m	**Water erosion:**	None
Terrain unit:	Upper footslope	**Erosion stability:**	Stabilized
Slope:	1 %	**Vegetation/Land use:**	Agronomic field crops
Slope shape:	Concave	**Water table:**	1500 mm
Aspect:	West	**Described by:**	Dr. P.A.L. le Roux, Prof L. D. van Rensburg, Mr. J. H. Barnard and Mr. J. B. Sparrow
Microrelief:	None	**Date described:**	30/10/07
Parent material solum:	Origin single, aeolian	**Weathering of underlying material:**	Unknown
Underlying material:	Sandstone siliceous	**Alteration of underling material:**	Generalized
Geological group:	Ventersdorp		

Horizon	**Depth (mm)**	**Description**	**Diagnostic horizon**
A	0-400	**Moisture status:** moist; **moist colour:** dark yellowish brown (10YR 4/4); 4 % clay; fine sandy; no mottles; apedal massive; loose, loose, non-sticky, non-plastic; many normal fine and medium pores; no cracks; no slickensides; no cutans; no coarse fragments; aeolian depositional stratification; water absorption: 1 second; many roots; clear smooth transition.	Orthic
B1	400-1100	**Moisture status:** moist; **moist colour:** red (2.5YR 4/8); 6 % clay; fine sandy; no mottles; apedal massive; soft, friable, non-sticky, non-plastic; common normal fine and medium pores; no cracks; no slickensides; no cutans; no coarse fragments; aeolian depositional stratification; water absorption: 1 second; common roots, clear smooth transition.	Red apedal
B2	1100-1500	**Moisture status:** moist; **moist colour:** yellowish red (5YR 5/8); 8 % clay; fine sandy; common coarse distinct grey, yellow, olive and black mottles; apedal massive; soft, friable, non-sticky, non-plastic; common normal fine and medium pores; no cracks; no slickensides; no cutans; no coarse fragments; aeolian depositional stratification; water absorption: 1 second; few roots, gradual smooth transition.	Red apedal
C	1500+	**Moisture status:** wet; **moist colour:** reddish yellow (7.5YR 6/6); 10 % clay; fine loamy sand; many coarse prominent grey, yellow, olive and black mottles; apedal massive; soft, friable, slightly sticky, non-plastic; few fine normal fine pores; no cracks; no slickensides; no cutans; no coarse fragments; aeolian depositional stratification; water absorption: 1 second; no roots, transition not reached.	Unspecified material with signs of wetness
	Remarks:	There are enough signs of wetness from a depth of 1100 mm to qualify this soil as a Bloemdal. The signs of wetness are formed as a result of a water table that fluctuates between 1100 mm and 1600 mm.	

Table 4-22 Physical properties of the 300 mm soil layer intervals at site 4

Soil physical properties						
Particle size distribution (%)	**Soil depth (mm)**					
	0-300	**300-600**	**600-900**	**900-1200**	**1200-1500**	**1500-1800**
Course sand	5.9	5.6	8.1	7.7	7.6	8.5
Medium sand	17.2	16.9	21.2	24.0	24.9	22.0
Fine sand	52.9	52.4	47.6	47.0	45.3	46.9
Very fine sand	14.1	13.4	12.2	10.2	9.7	11.0
Total sand	90.1	88.4	89.0	88.8	87.5	88.5
Course silt	2.8	2.4	2.8	2.7	2.5	0.7
Fine silt	2.0	2.0	2.0	2.0	2.0	2.0
Total silt	4.8	4.4	4.8	4.7	4.5	2.7
Clay	6.0	8.0	8.0	8.0	10.0	10.0
Silt + Clay	10.8	12.4	12.8	12.7	14.5	12.7
Bulk density (kg m^{-3})	1605	1653	1626	1627	1654	1656
Saturated hydraulic conductivity (mm h^{-1})	39.80	34.55	-	-	-	24.34

Table 4-23 Chemical properties of the soil layers at site 4

Soil chemical properties						
Depth (mm)	**0-300**	**300-600**	**600-900**	**900-1200**	**1200-1500**	**1500-1800**
pH (H_2O)	6.9	7.3	7.5	8.0	8.2	8.2
CEC ($cmol_c$ kg^{-1})	3.2	3.5	2.3	2.1	2.2	2.3
Saturated extractable cations (mg ℓ $^{-1}$)						
Start of season 1						
Ca	28.4	34.8	43.3	36.5	29.4	23.5
Mg	12.6	12.2	10.7	6.3	2.8	3.4
K	20.0	26.0	26.0	20.0	16.0	14.0
Na	19.6	44.0	66.0	63.0	82.0	62.0
End of season 1						
Ca	63.6	49.1	35.0	41.7	58.5	30.0
Mg	10.3	10.9	5.1	8.0	6.1	2.5
K	21.0	16.2	10.0	10.8	18.0	8.0
Na	24.0	33.0	28.0	29.0	48.0	36.0
End of season 2						
Ca	52.6	37.9	28.2	76.1	64.4	57.6
Mg	7.9	5.9	3.7	3.3	2.5	5.2
K	15.7	8.1	10.1	14.1	14.3	12.2
Na	36.0	30.0	36.0	45.0	50.0	44.0
End of season 3						
Ca	57.6	58.6	52.4	122.0	53.4	52.1
Mg	14.9	11.0	18.3	4.7	6.1	6.9
K	22.0	16.0	13.5	50.0	13.4	14.6
Na	60.0	68.0	127.0	115.0	41.0	40.0
End of season 4						
Ca	48.6	42.5	38.5	47.2	122.1	120.1
Mg	11.7	3.8	4.8	6.7	6.5	5.3
K	14.5	10.3	9.7	11.7	27.0	33.0
Na	33.0	46.0	48.0	69.0	93.0	90.0

Table 4-24 Information on the performance evaluation of the centre pivot at site 4

Centre pivot evaluation				
Centre pivot speed	**Uniformity coefficient (%)**	**Distribution uniformity (%)**	**Application efficiency (%)**	**System efficiency (%)**
80 %	91.1	80.6	78	62.9
20%	94.9	87.4	70.3	61.4
Mean	93	84	74.2	62.2

Table 4-25 Specific agronomical practices applied during the measuring period which stretched over four growing seasons at site 4

Agronomic practices				
Season	**1**	**2**	**3**	**4**
Crop rotation	**Wheat**	**Maize**	**Barley**	**Maize**
Cultivar	Carnia 826	Pannar 6236 B	Cocktail	Pannar 6236 B
Planting date	29/06/2007	03/12/2007	16/06/2008	03/12/2008
Harvesting date	27/11/2007	18/05/2008	10/11/2008	07/05/2009
Planting density	100 kg ha^{-1}	85 000 plants ha^{-1}	75 kg ha^{-1}	90 000 plants ha^{-1}
Farmers yield	4.5 t ha^{-1}	13.3 t ha^{-1}	7.6 t ha^{-1}	12.3 t ha^{-1}
Type of fertilizer applied (kg ha^{-1})	500 kg 7:2:3 (31) 500 kg ANO_3 (21) 100 kg Ureum (46)	300 kg 4:3:4 (33) 400 kg 10:1:6 (20) 400 kg UAN (32)	250 kg 2:3:4 (30) 500 kg ANO_3 (21)	350 kg 4:3:4 (33) 600 kg UAN (32)
Total kg N ha^{-1}	242	211	122	239
Total kg P ha^{-1}	26	30	25	35
Total kg K ha^{-1}	39	50	33	47
Pest management	Buctril	Curater – 20 kg ha^{-1} Armadillo – 1.2 ℓ ha^{-1} Diamond – 1.4 ℓ ha^{-1}	Buctril MCPA	Deusis – 60 mℓ ha^{-1} Armadillo – 1.3 ℓ ha^{-1} Gardiun – 1.3 ℓ ha^{-1}
Cultivation practices	Burn, plough, wonder till and plant	Bale, burn, rip and plant	Burn, wonder till and plant	Bale, burn, rip and plant – After harvest – Burn

4.1.3 Measurement results

Only data collected by Van Rensburg et al. was used during this project, and only for modelling purposes, which is discussed in Chapter 5 below.

4.2 Breede River Irrigation Scheme

Drainage is implemented for two possible reasons in this catchment – either to control shallow groundwater tables, especially in winter, or to control salinity, especially in summer. Drainage design services have been provided by the Department of Agriculture (Western Cape) for more than 20 years but subsidies on drainage works are no longer available.

Because of the long history of coordinated drainage system implementation, a significant amount of capacity has been built within the department. Software have been developed for the design of the subsurface drainage systems and technicians have a good understanding of the maintenance requirements of the systems, and how the lack thereof will reduce the effectiveness of the systems.

4.2.1 Location of the case study sites

Four sites have been selected for measurements to be undertaken. The sites are located in the Worcester, De Doorns and Wolseley areas, and the ages of the systems range from 12 years old to newly installed.

4.2.2 Data available at selected sites

Information presented here was obtained with the assistance of the Department of Agriculture Western Cape, and specifically the following reports, which is gratefully acknowledged: 715/000 840/1, 715/000 726/9, 715/000 174/1, 715/005 760/6

- Site 1 (De Doorns)

This farm is located south-west of De Doorns, between the railway line and Hex River, and is bordered by a steep slope above it which introduces run-off (due to the natural drainage patterns towards the Hex River) onto the identified area from the south eastern side (Figure 4-5). The surface of the terrain is undulating, leading so inconsistency in the required subsurface drain depth. The slope of the field is approximately 4.5% at the top before flattening out to about 3.2%. The farmer wanted to develop the area with vineyard.

Figure 4-5 Aerial view of Breede River site 1 (De Doorns)

The topsoil at the site is mostly fine sand with some areas of loamy sand, underlain by medium to coarse sand, resulting in a soil of which the second layer is more permeable than the top layer. Large round pebbles occur in the profile. Permeability decreases towards the lower (northern) part of the field, and the natural subsurface drainage of the soil was further inhibited by the farm road that runs north-east to south-west, which will have compacted soil below it. Drainage problems could be observed on the soil surface in the middle of the field.

A subsurface drainage system was designed in 2002 to address the problem (Figure 4-6). The system consists of a herringbone system (double sided entry) of field drains leading into a collector drain, with the main drain taking the drainage water down to the Hex River. Although the drained area is only 9.3ha, the main drain (indicated as section 1-1 in Figure 4-6) was designed to handle drainage for 42ha, in case of future expansion of the drainage system.

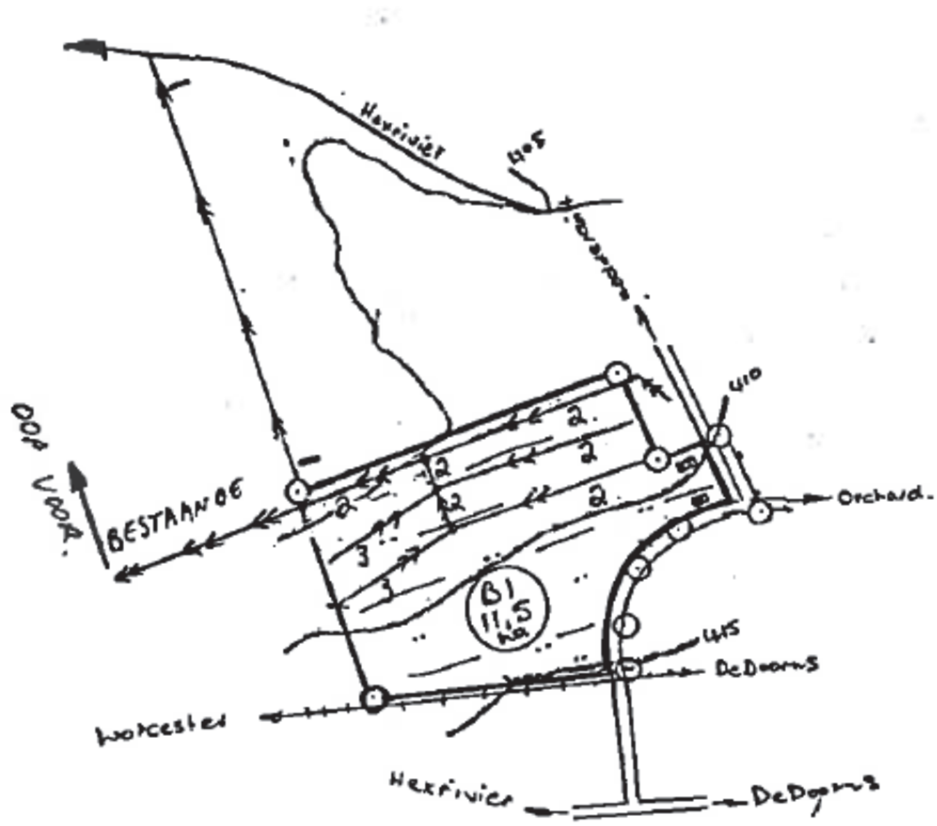


Figure 4-6 Lay-out of drainage system at Breede River site no 1

The system planning process included the site being visited and the soil profile being inspected by means of 6 profile holes that were dug in the field. The data was analysed and the soil profile descriptions are shown graphically in Figure 4-7. The results show the different types of soil, their depths and hydraulic conductivities (K values), and the profiles are categorised according to porosity classes 1 (impermeable) to 4 (highly permeable). The location of the impermeable layer, where the drains should be installed ideally, is also shown for each profile hole – these occur mostly at a depth of just below 2 m.

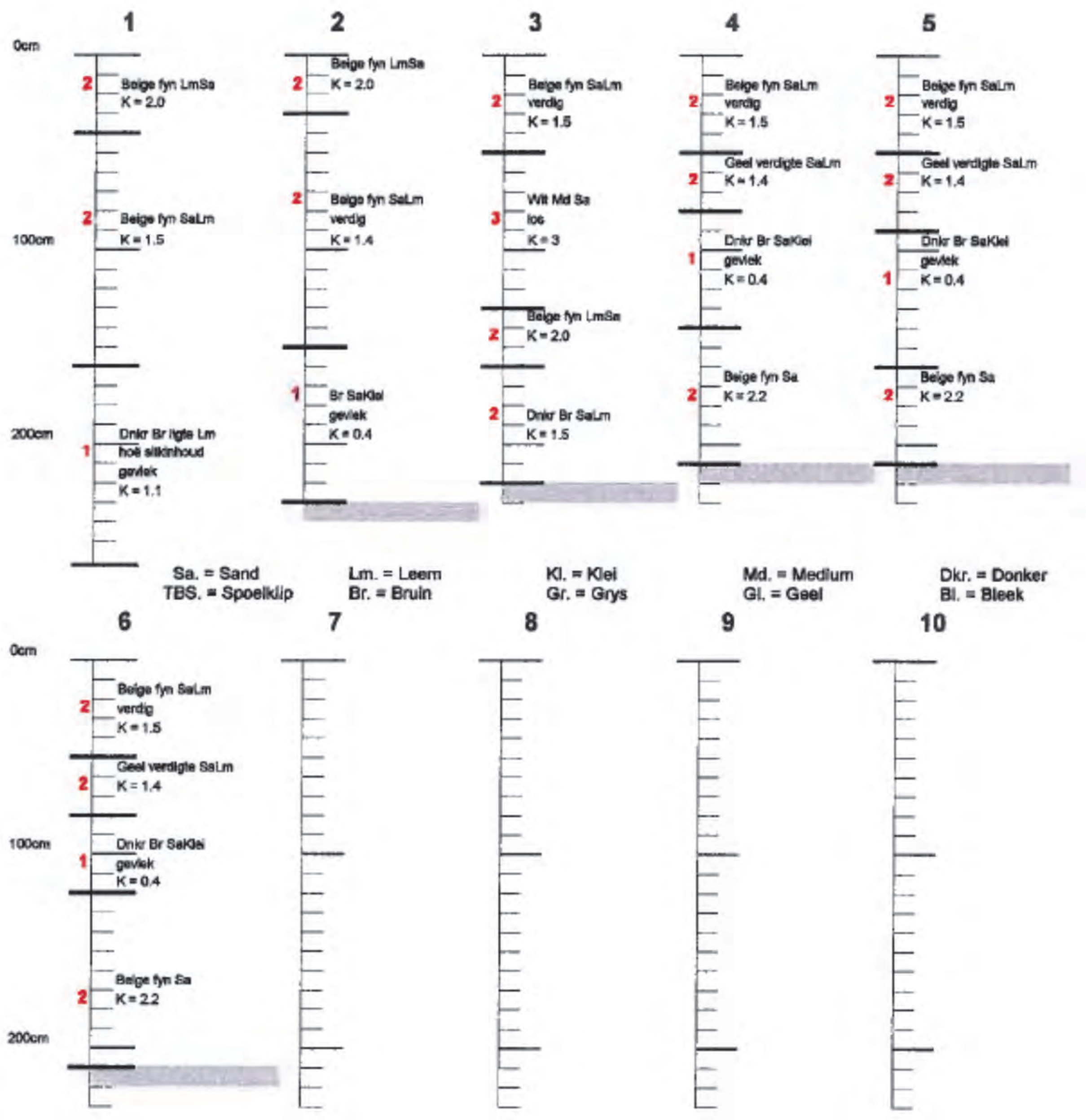


Figure 4-7 Soil profile descriptions at Breede River site no 1

The profile hole data was used to calculate theoretical drain spacing using the Hooghoudt formula . The results showed a required drain spacing of between 17.4 m and 41.8 m, with an average of about 32.3 m.

A summary of the design data is shown in Table 4-27. Analysis of the profile data resulted in a suggested drain depth of 1.8 m at a spacing of 60 m, which is approximately double the theoretical calculated value of 32.3 m. It is standard design practice to propose an actual installation spacing which is double the design spacing. The total cost of the system to drain 9.3ha was R36 393.56 (in 2002).

Table 4-26 Drain design calculations for Breede River site no 1

Aspect		**Hole 1**	**Hole 2**	**Hole 3**	**Hole 4**	**Hole 5**	**Hole 6**
Drain discharge (mm/day)	q	5					
Hydraulic conductivity, (m/day)	K_1	1.5	1.5	2.2	1.4	1.2	1.5
Hydraulic conductivity, (m/day)	K_2	1.1	0.4	1.5	2.2	2.2	2.2
Proposed drain depth (m)	b	2	1.5	2	2	2	2
Minimum drained soil depth between drains (m)	a	1	1	1	1	1	1
Water depth above the drain, between drains (m)	h	1	0.5	1	1	1	1
Depth of the impermeable layer below the drain (m)	D	0	0	0	0	0	0
Drain spacing (m)	L	34.9	17.4	41.8	33.1	31.4	35.3

Table 4-27 Drainage design data for Breede River site no 1

Item	**Value**
Average depth to impermeable layer	2 m
F factor	0.8 x 0.001
Maximum average monthly rainfall	65 mm (Orchard weather station) (31 days/month)
Hydraulic conductivity of soil layer above drain (K1)	4.5 mm/day
Hydraulic conductivity of soil layer below drain (K2)	5.25 mm/day
Design drain discharge	= f x rainfall per day x 2 x 1 = 3.355 mm/day Practical: 5 mm/day
Proposed drain depth to pipe bottom (b)	1.8 m
Minimum drained soil depth between drains (a)	1 m
Water depth above the drain, between drains (h)	0.8 m
Depth of the impermeable layer below the drain (D)	0.2 m
Design drain spacing	60.4 m
Selected practical drain spacing (L)	60 m
Total cost of system	R36 393.56

- Site 2 (Breërivier)

The site is located between Worcester and Wolseley with the Breede River flowing through the farm (Figure 4-8). The field where drainage was installed in 2000, is located north-east of the railway line with an even slope of approximately 2.5%, and is located at the lower end of a substantial natural catchment (the area drains south-west, towards the Breede River). The field is also surrounded by other irrigated fields, which increases the water content of the soil in the surrounding area, and the railway line restricts some of the natural subsurface drainage towards the river.

Figure 4-8 Aerial view of Breede River site 2 (Breërivier)

The top soil in generally sandy and yellow to brown in colour, overlaying loamy sand to sandy loam soils that are gritty with a high stone (pebble) content. The farmer wanted the area of 30 ha drained to establish vineyards.

The drainage system that was designed, has a herringbone lay-out as shown in Figure 4-9 and was designed for drainage discharge of 6.1 mm/day. The system has 2 collector drains that delivers the water into an open drainage channel that crosses neighbouring farms until it reaches the Breede River.

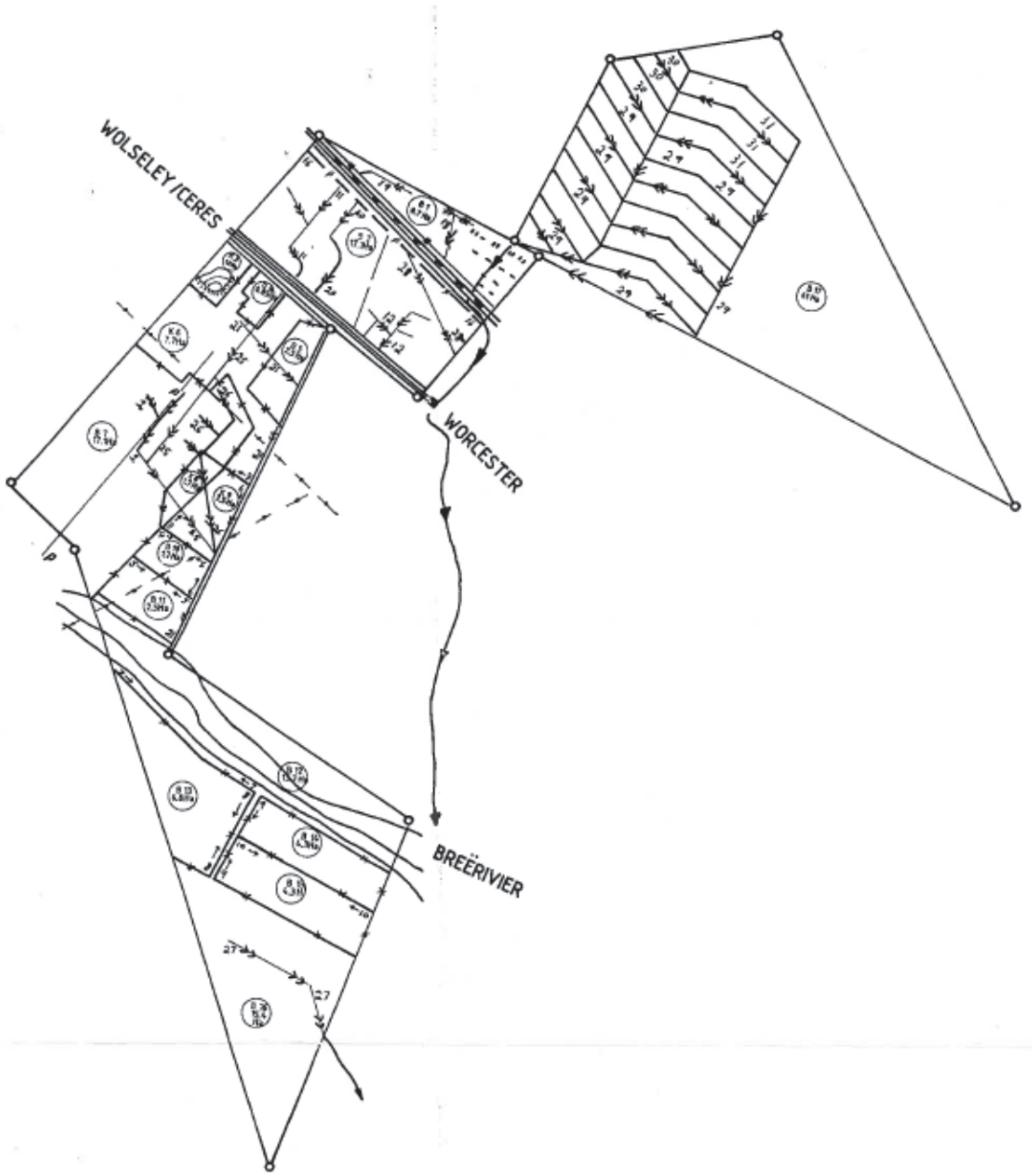


Figure 4-9 Lay-out of drainage system at Breede River site no 2

The system planning process included the site being visited and the soil profile being inspected by means of 50 profile holes that were dug in the field. The data was analysed and the soil profile descriptions are shown graphically in Figure 4-10. The results show the different types of soil, their depths and hydraulic conductivities (K values), and the profiles are categorised according to porosity classes 1 (impermeable) to 4 (highly permeable). The location of the impermeable layer, where the drains should be installed ideally, is also shown for each profile hole – these occur mostly at a depth of between 1.7 m and 2.2 m.

The profile hole data was used to calculate theoretical drain spacing using the Hooghoudt formula. The results showed a required drain spacing of 30 m.

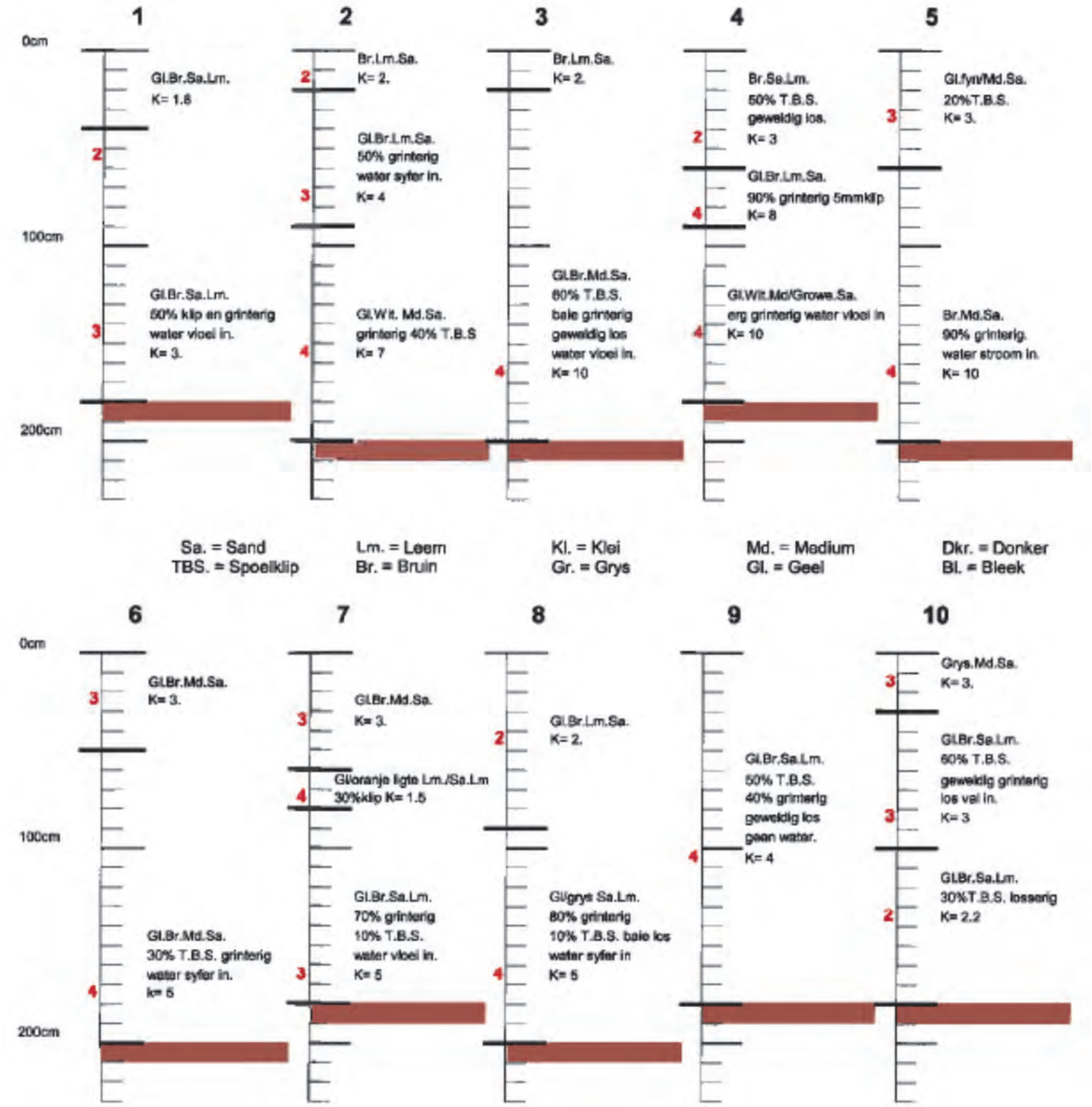


Figure 4-10 Soil profile descriptions at Breede River site no 2

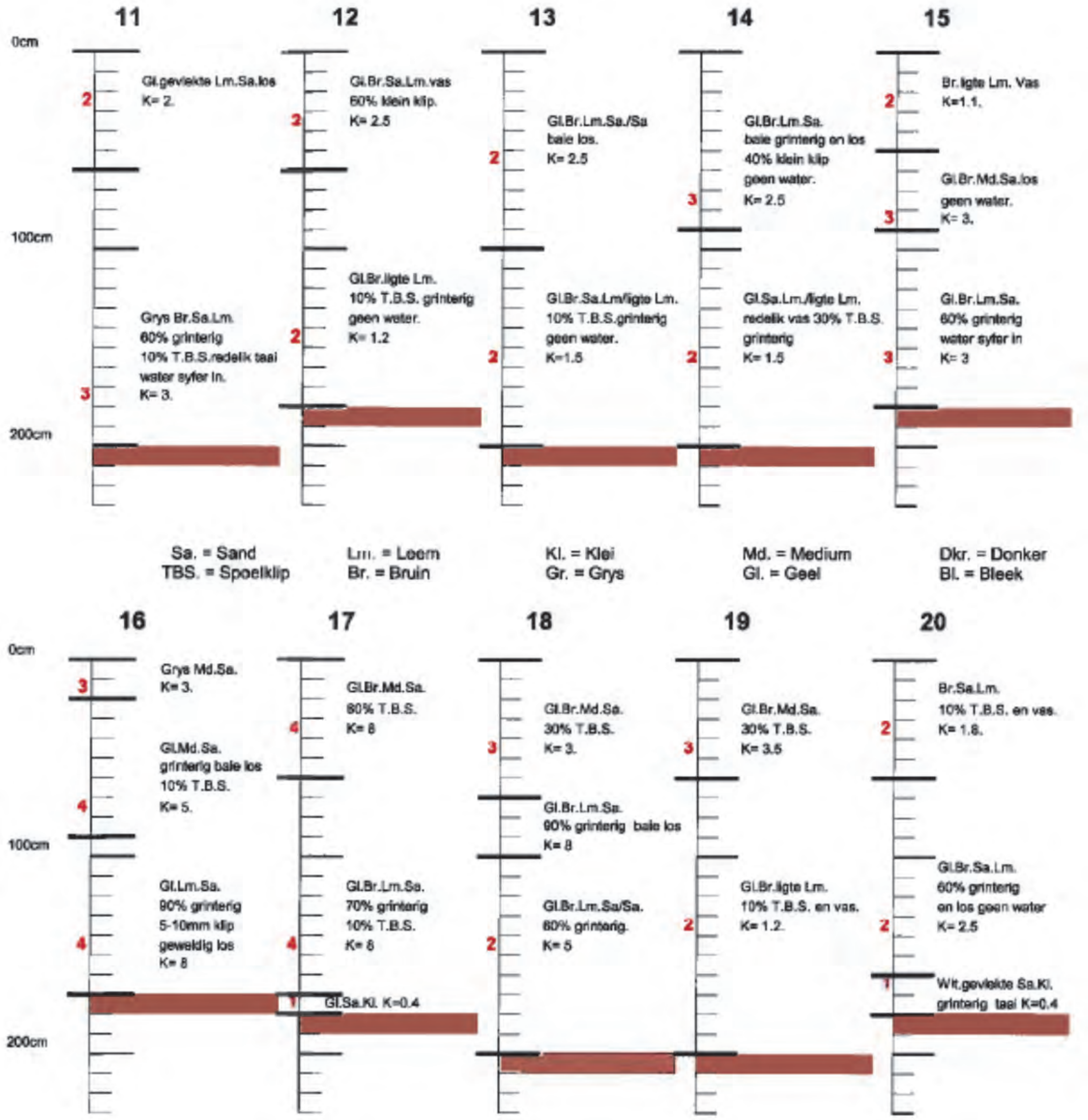


Figure 4-10 Soil profile descriptions at Breede River site no 2 (continued)

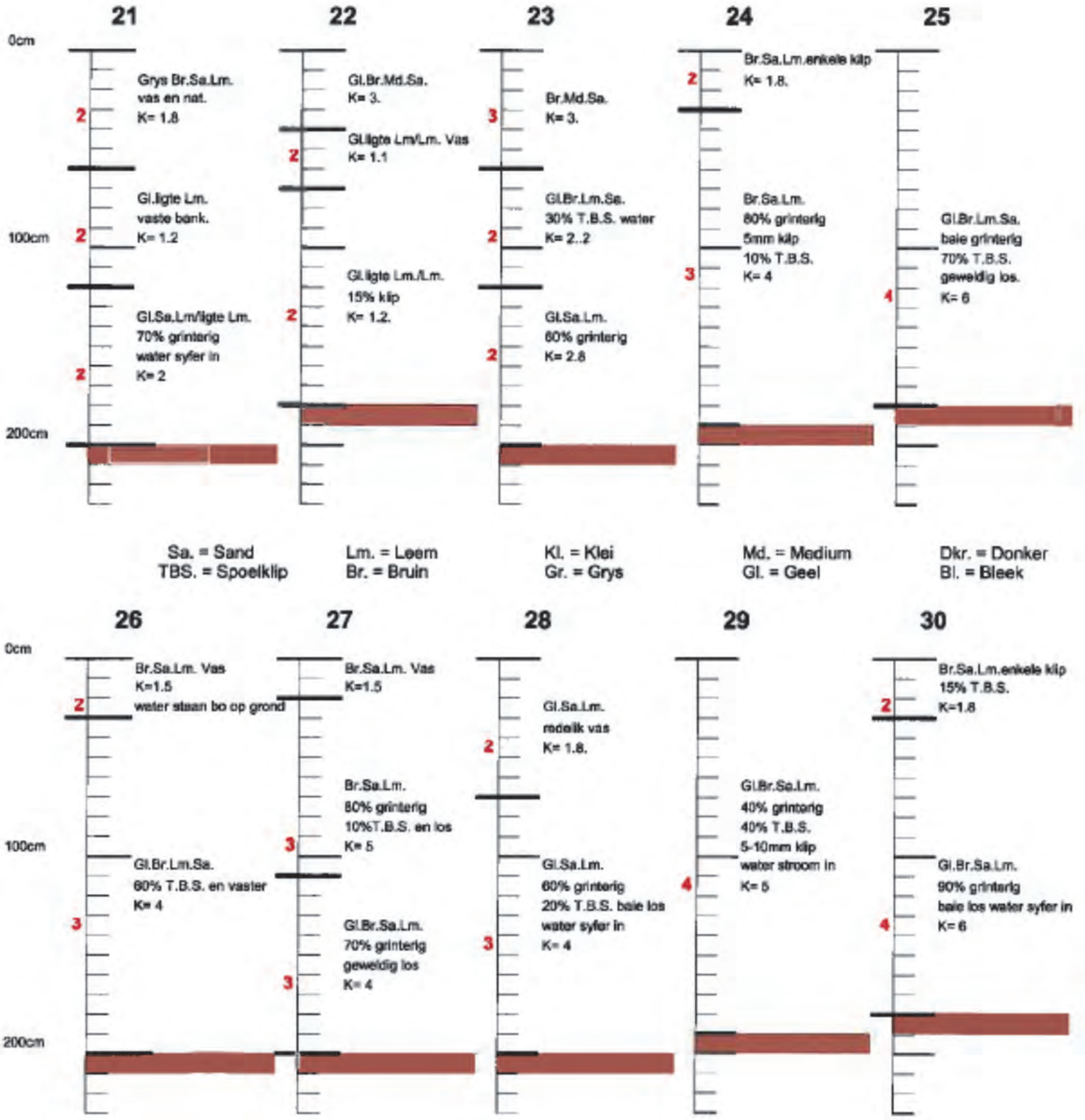


Figure 4-10 Soil profile descriptions at Breede River site no 2 (continued)

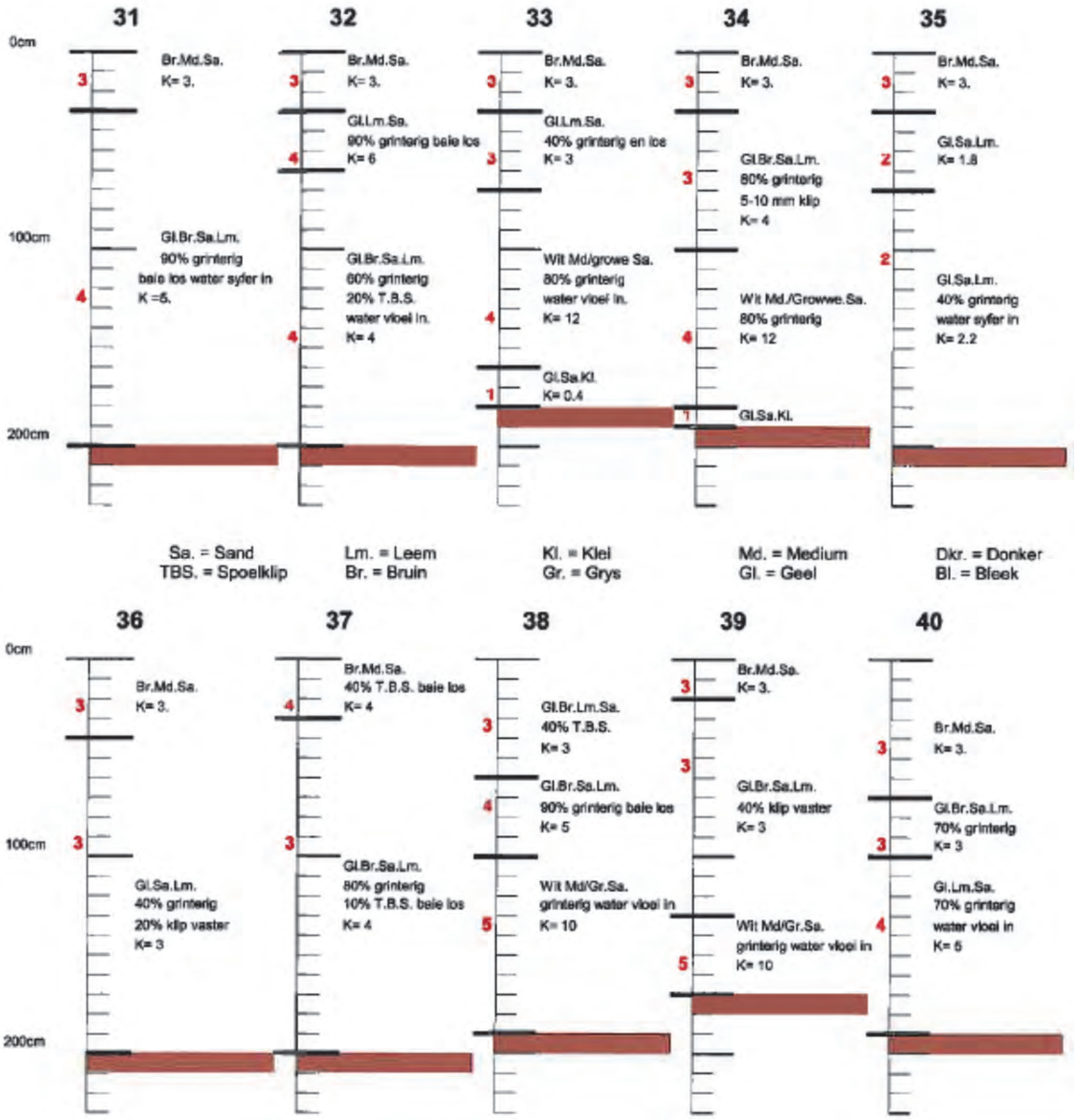


Figure 4-10 Soil profile descriptions at Breede River site no 2 (continued)

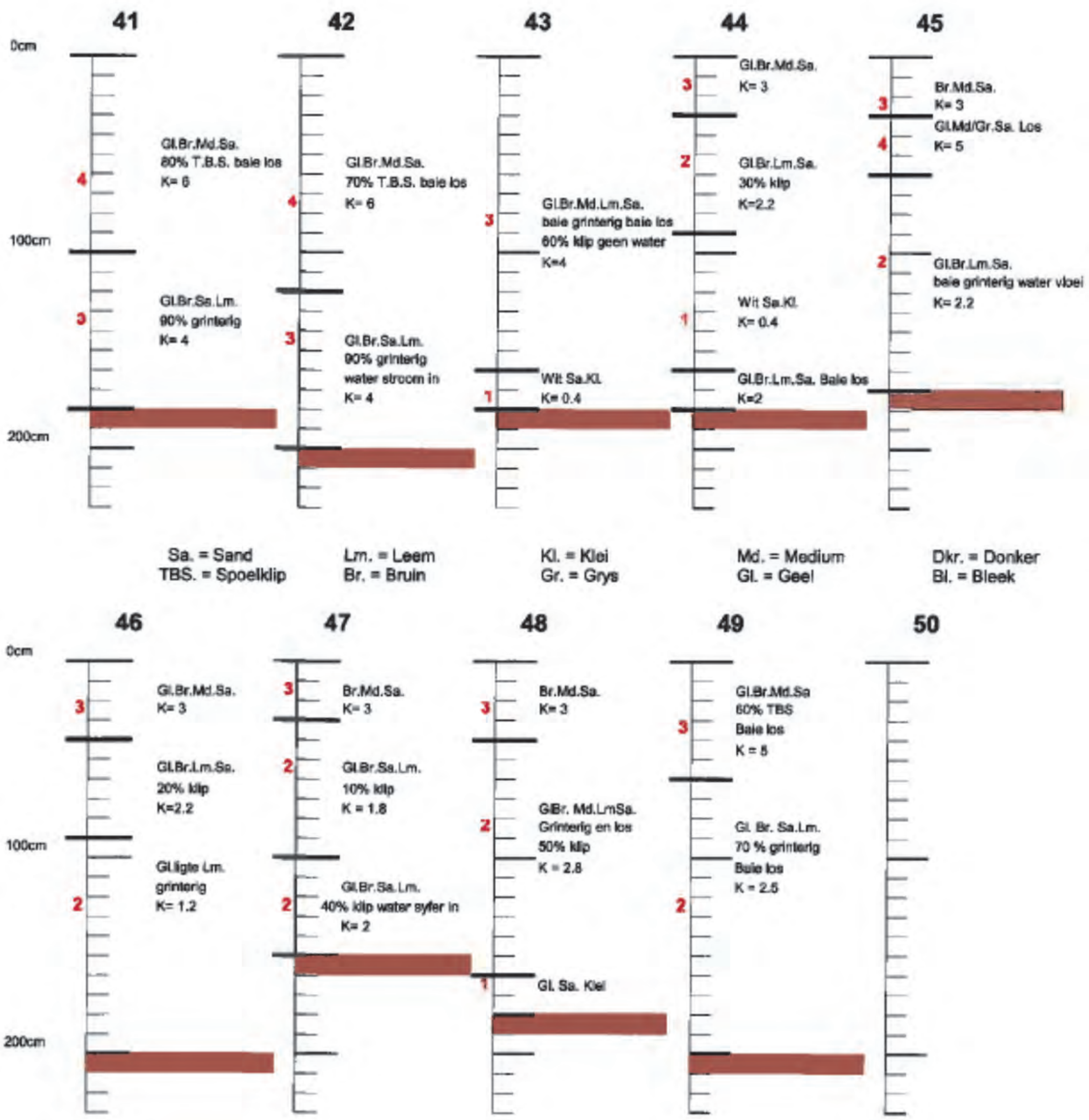


Figure 4-10 Soil profile descriptions at Breede River site no 2 (continued)

A summary of the design data is shown in Table 4-28. Analysis of the profile data resulted in a suggested drain depth of 2 m at a spacing of 60 m, which is approximately double the theoretical calculated value. The final design consisted of field drains with a diameter of 75 mm leading into collector drains ranging in size from 75 mm to 200 mm. The total cost of the system to drain 30 ha was R109 917.34 (in 2000).

Table 4-28 Drainage design data for Breede River site no 2

Item	Value
Average depth to impermeable layer	2 m
F factor	0.8 x 0.001
Maximum average monthly rainfall	118 mm (Bothashalt weather station) (31 days/month)
Hydraulic conductivity of soil layer above drain (K1)	4.1 mm/day
Hydraulic conductivity of soil layer below drain (K2)	3.9 mm/day
Design drain discharge	= f x rainfall per day x 2 x 1 = 6.090 mm/day Practical: 6.1 mm/day
Proposed drain depth to pipe bottom (b)	2 m
Minimum drained soil depth between drains (a)	1 m
Water depth above the drain, between drains (h)	1 m
Depth of the impermeable layer below the drain (D)	0.2 m
Design drain spacing	60.9 m
Selected practical drain spacing (L)	60 m
Total cost of system	R109 917.34

The final lay-out of the system is shown in Figure 4-11.

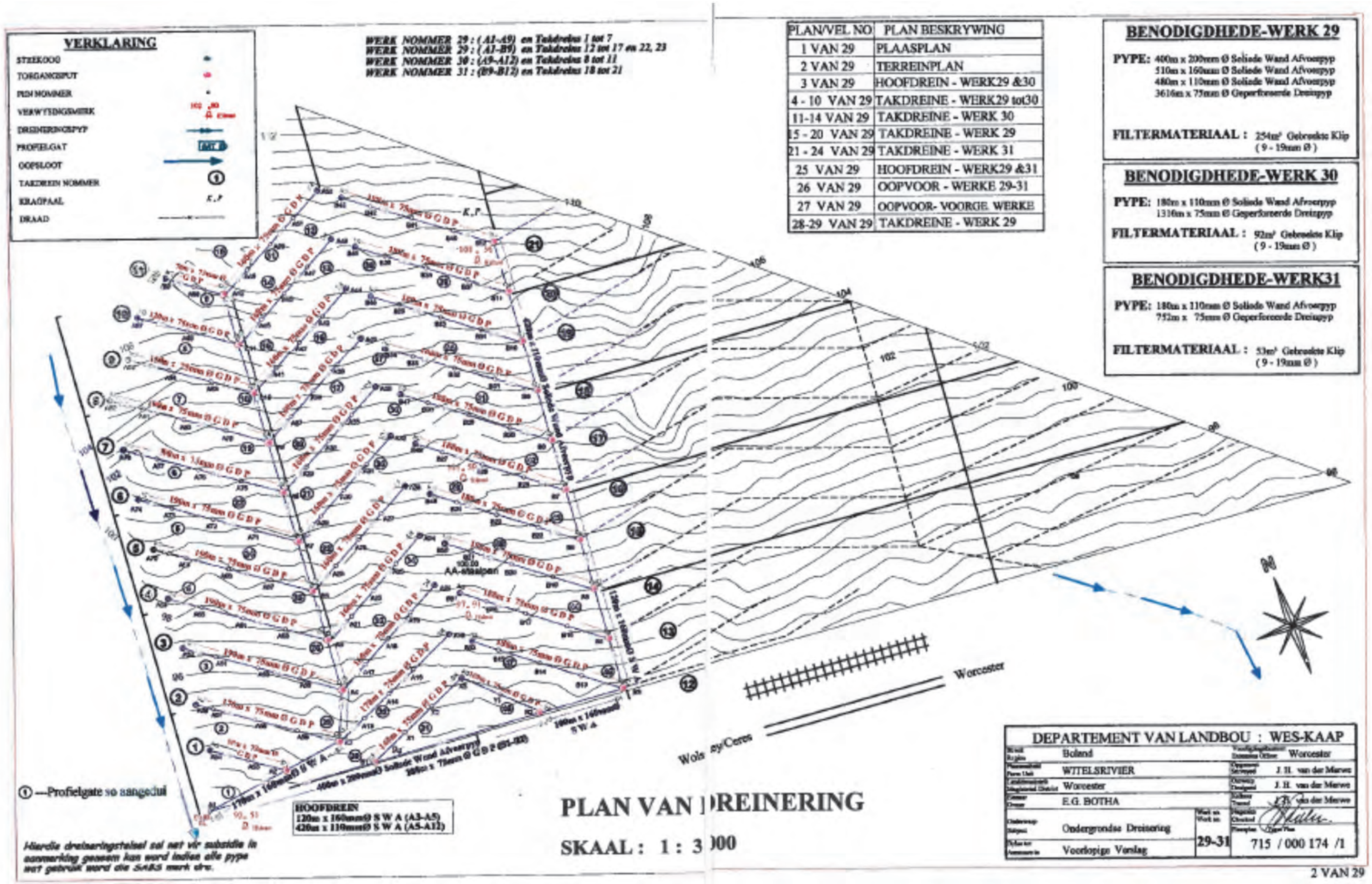


Figure 4-11 Detail of drainage system design for Breede River site no 2

- Site 3 (Scherpenheuwel)

This site is located south east of Worcester, below the Brandvlei Dam, in a very arid area where salinity problems commonly occur where permanent crops are established under irrigation. The area was previously planted with lucerne and irrigated by centre pivot, as can be seen in Figure 4-12a, taken in 2008 before the drainage system was installed. On the (b) of the same figure, the locations of field drains can be clearly seen as they run across the newly developed vineyard blocks.

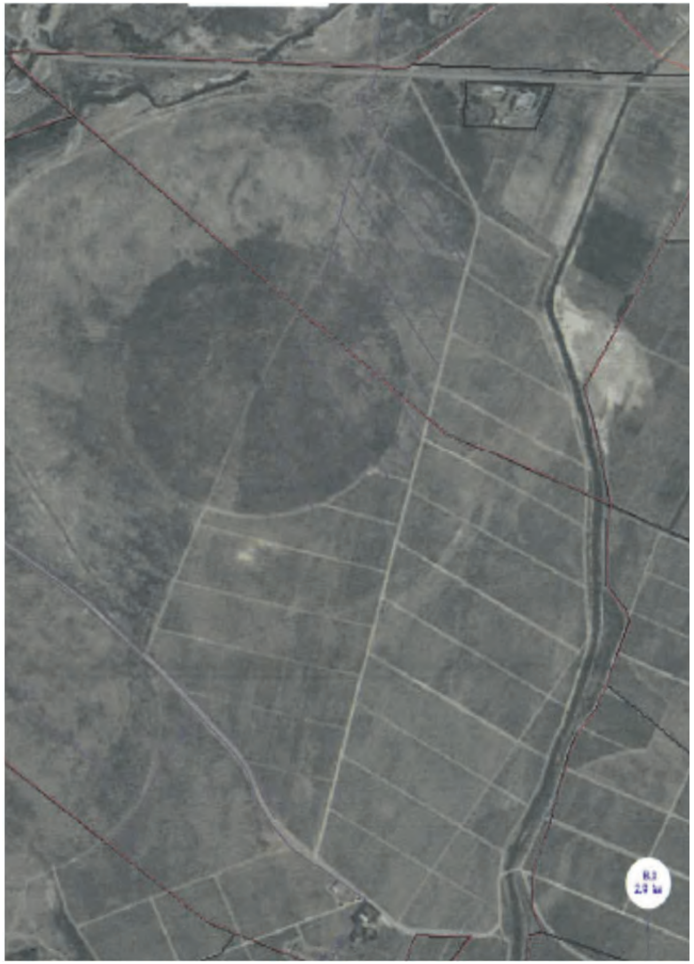
The site is located in the Doring River catchment, a tributary to the Breede River and is very flat, with an average slope of 0.5% towards the north. The soils in this area is more suitable to extensive agriculture but irrigation development leads to salinisation with salt accumulation typically occurring in the lower lying areas. The previous cultivation practices of lucerne under centre pivot, lead to salinity problems and when the farmer decided to change to vineyard, a drainage system became necessary.

A soil survey showed that the topsoil which is about 50 cm deep, is typically a fine grey sandy loam with low permeability due to dispersion that could be reduced by applying gypsum, but this would only be effective when done in conjunction with drainage. The underlying soils are dark brown fine loamy sand to sandy loam which was more permeable than the top soil. Many profile holes had water in them within 24 hours of being opened up.

Due to the lack of slope, the drainage system had to be carefully planned to ensure the effective removal of the drainage water at 2.5 mm/day on the 24.5 ha area. A herringbone lay-out was used as shown in Figure 4-13 and the field drains positioned so as to obtain the maximum drop due to the natural slope. The main drain was designed for 49 ha, as to make provision for possible future expansion of the drainage system.

The system planning process included the site being visited and the soil profile being inspected by means of 50 profile holes that were dug in the field. The data was analysed and the soil profile descriptions are shown graphically in Figure 4-14. The results show the different types of soil, their depths and hydraulic conductivities (K values), and the profiles are categorised according to porosity classes 1 (impermeable) to 4 (highly permeable). The location of the impermeable layer, where the drains should be installed ideally, is also shown for each profile hole – these occur mostly at a depth of between 1.9 m and 2.2 m.

The profile hole data was used to calculate theoretical drain spacing using the Hooghoudt formula. The results showed a required drain spacing of between 43 m and 113 m. A spacing of 58 m would satisfy the requirements of 70% of the profile holes, and a practical spacing of 60 m was decided on.



(a) 2008

(b) 2011

Figure 4-12 Aerial view of Breede River site 3 (Breërivier)

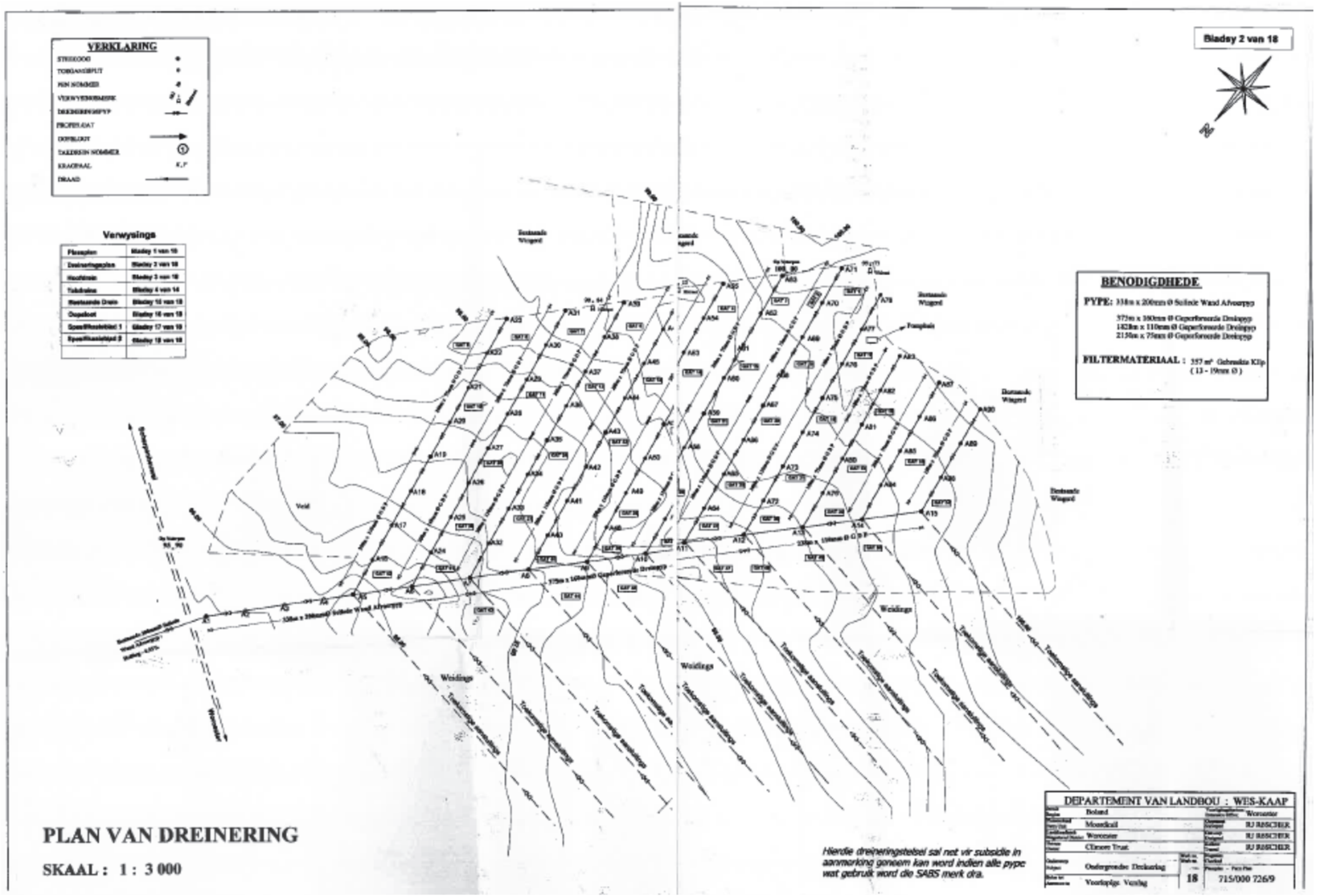


Figure 4-13 Lay-out of drainage system at Breede River site no 3

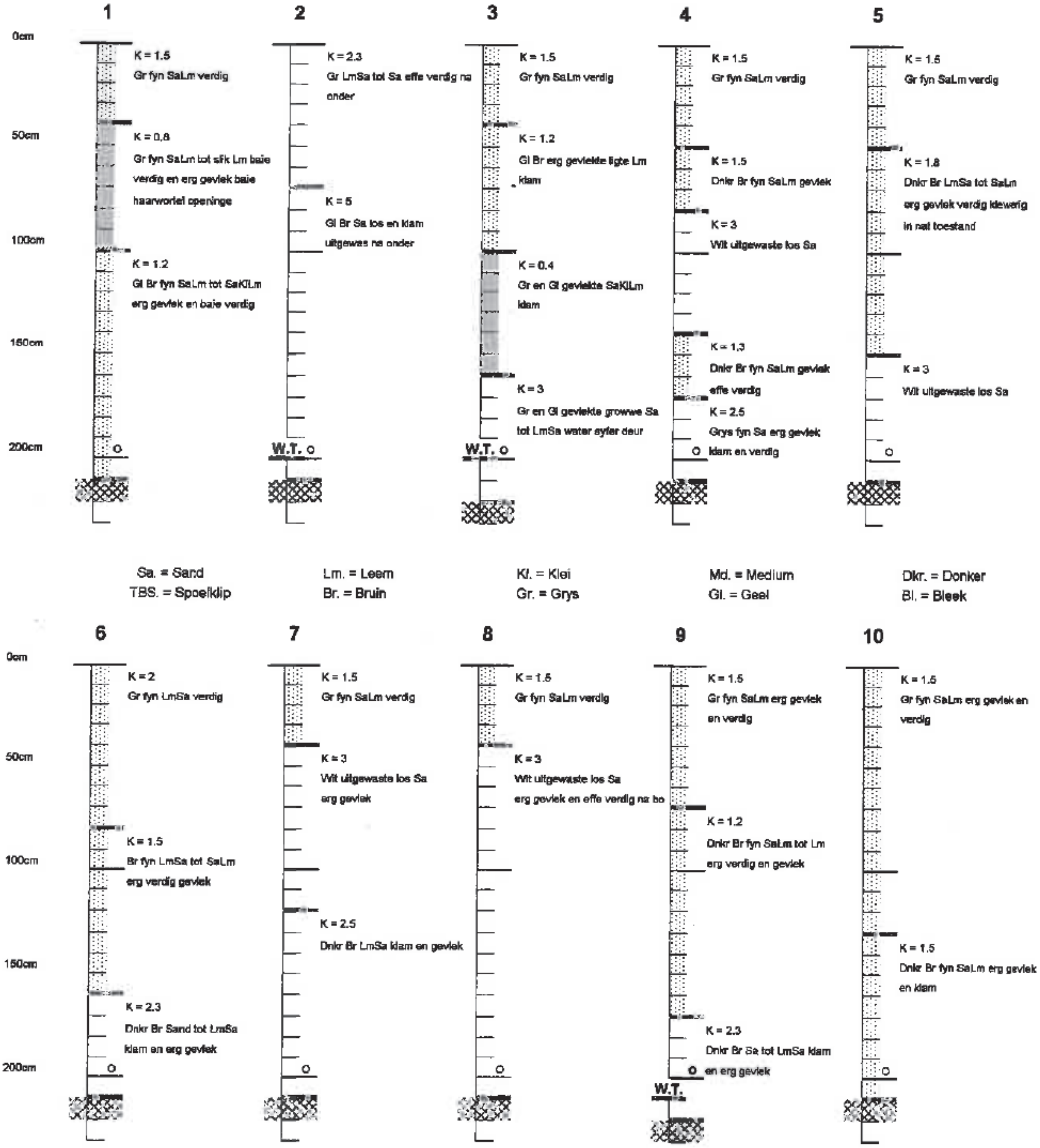


Figure 4-14 Soil profile descriptions at Breede River site no 3

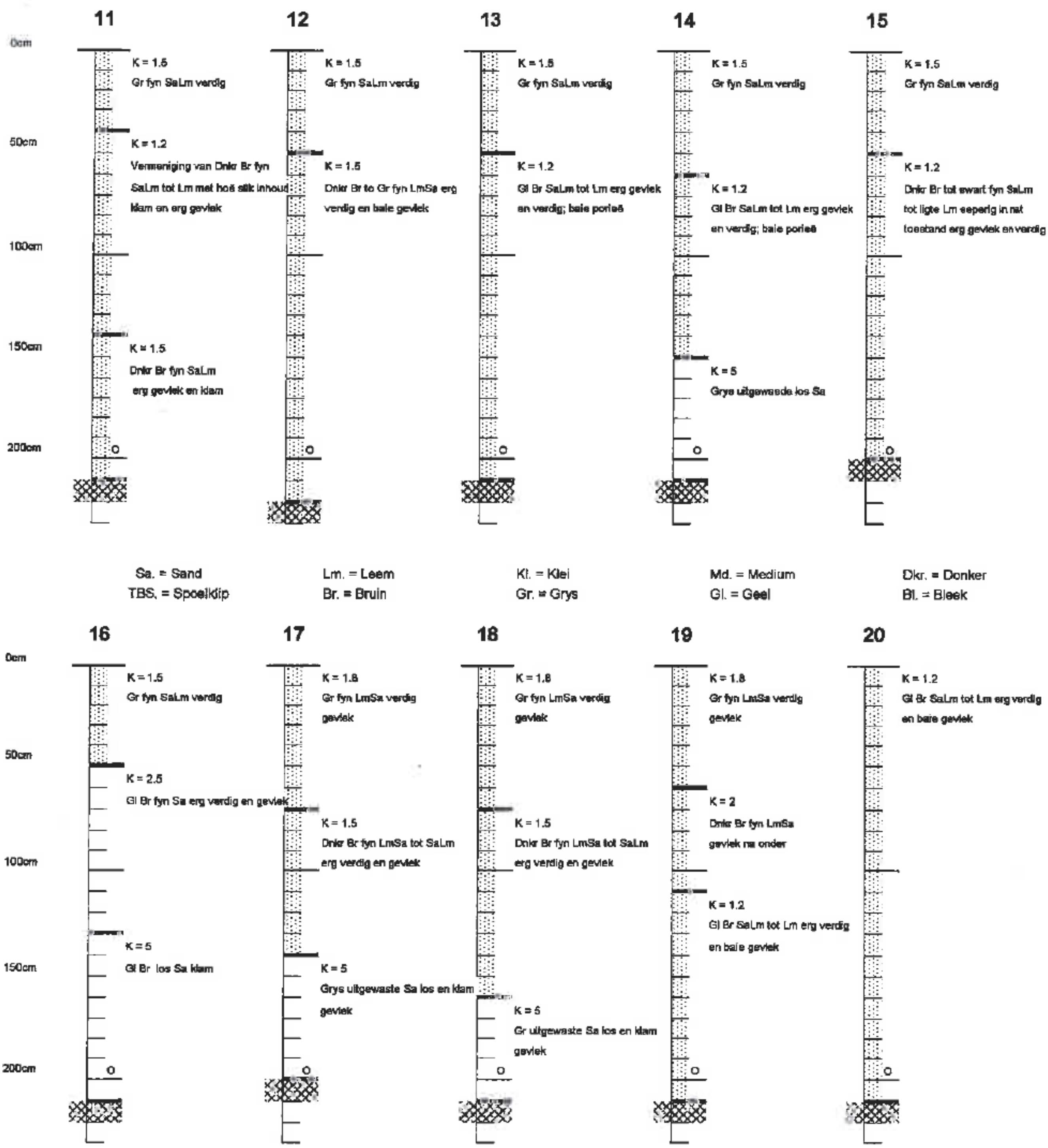


Figure 4-14 Soil profile descriptions at Breede River site no 3 (continued)

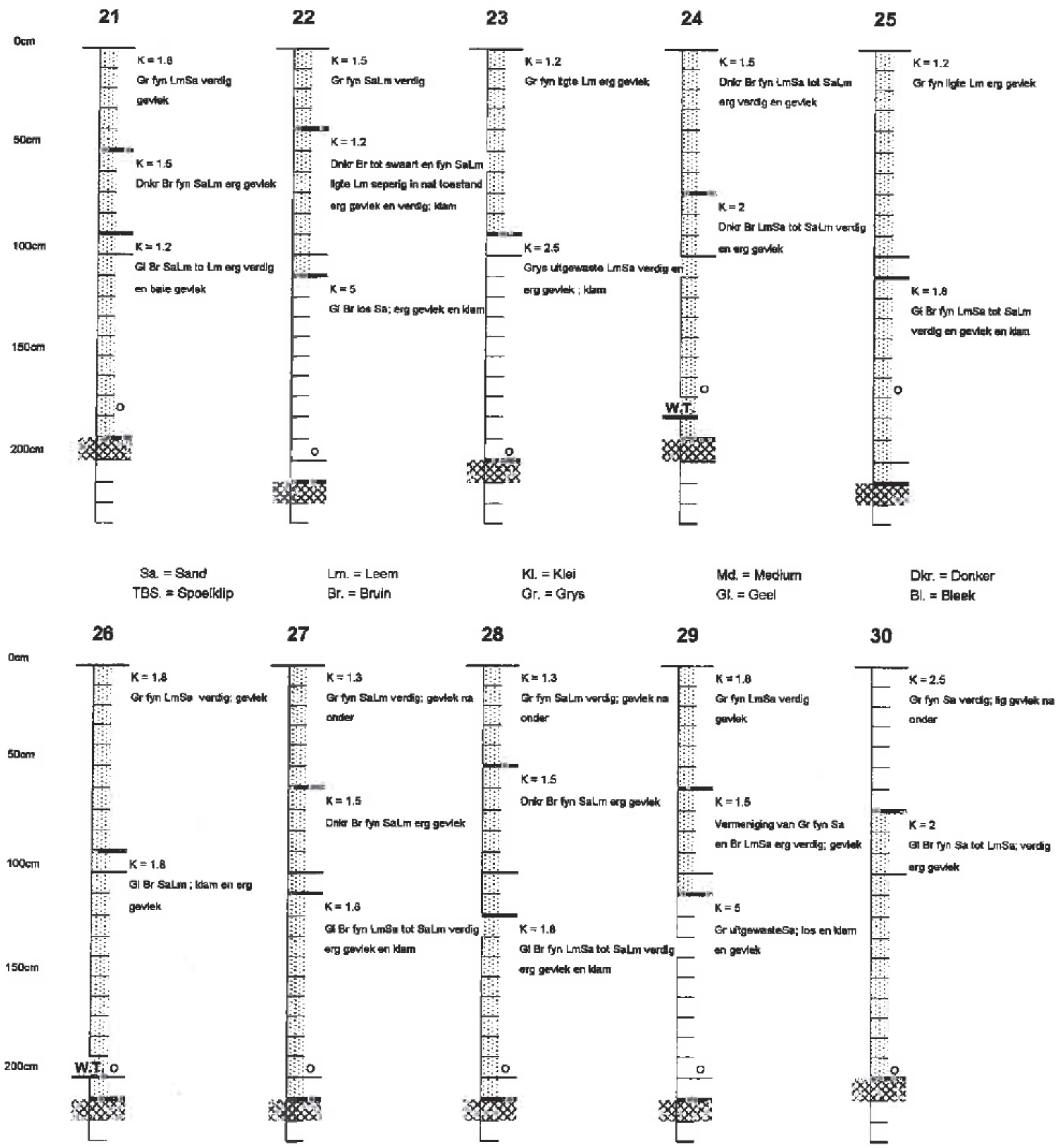


Figure 4-14 Soil profile descriptions at Breede River site no 3 (continued)

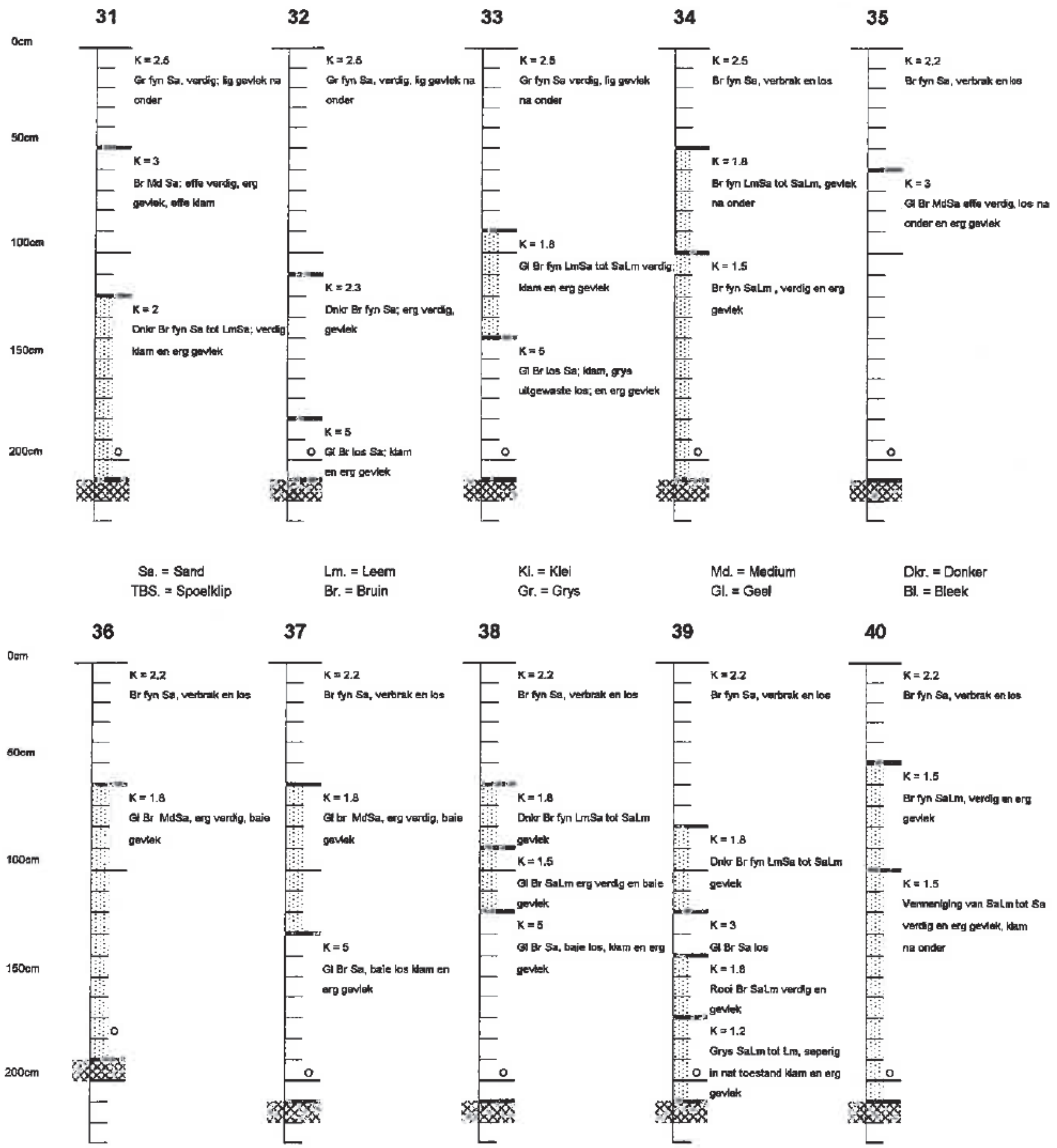


Figure 4-14 Soil profile descriptions at Breede River site no 3 (continued)

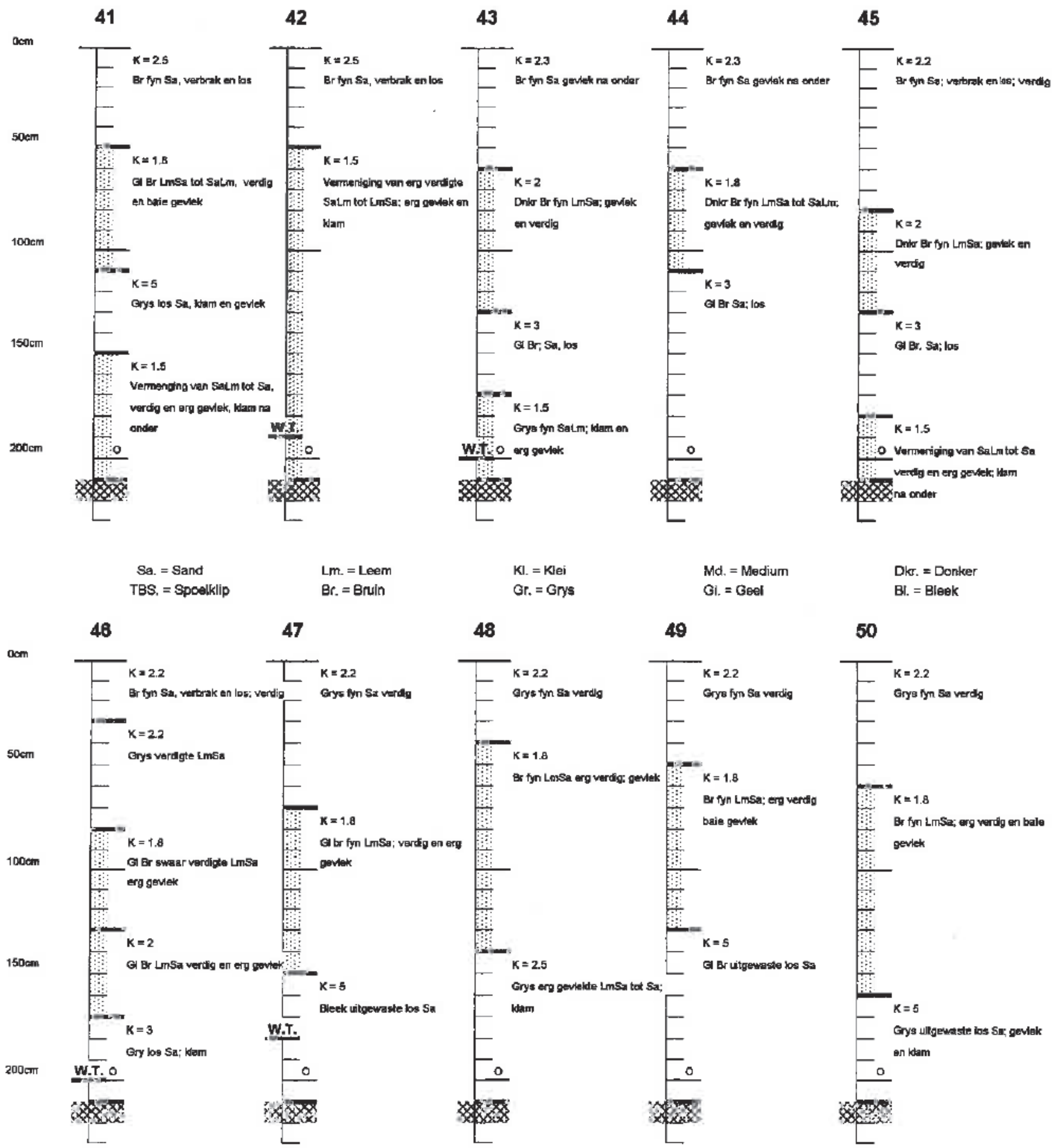


Figure 4-14 Soil profile descriptions at Breede River site no 3 (continued)

A summary of the design data for the 24.5 ha area is shown in Table 4-29. Analysis of the profile data resulted in a suggested drain depth of 2 m at a spacing of 60 m. The final design consisted of field drains with a diameter of 75 mm leading into collector drains ranging in size from 75 mm to 200 mm. The total cost of the system to drain 24.5 ha was R84 358.97 (in 2008).

Table 4-29 Drainage design data for Breede River site no 3

Item	Value
Average depth to impermeable layer	2.2 m
F factor	0.8 x 0.001
Maximum average monthly rainfall	33 mm (Alfalfa weather station) (31 days/month)
Hydraulic conductivity of soil layer above drain (K1)	2.1 mm/day
Hydraulic conductivity of soil layer below drain (K2)	1.8 mm/day
Design drain discharge	= f x rainfall per day x 2 x 1 = 1.884 mm/day Practical: 2.5 mm/day
Proposed drain depth to pipe bottom (b)	2 m
Minimum drained soil depth between drains (a)	1 m
Water depth above the drain, between drains (h)	1 m
Depth of the impermeable layer below the drain (D)	0.2 m
Design drain spacing	58.6 m
Selected practical drain spacing (L)	60 m
Total cost of system	R84 358.97

- Site 4 (Brandvlei)

The fourth site selected for the Breede River case study area (see Figure 4-15), is located south east of Worcester on the bank of the Breede River, immediately below the Brandvlei Dam, which provides off-channel storage the lower Breede River area.

The area of about 100 ha was previously flood irrigated and drainage is needed to control groundwater levels as well as manage salinity. The drainage system design is currently being finalised by the Department and preparation for the installation has already commenced. Unfortunately the installation took too long for this site to be used during the project for data collection.

Figure 4-15 Aerial view of Breede River site 4 (Brandvlei)

- Site 5 (Wolseley)

This is a new site that was added when it became evident that the system at Site no 3 was not going to become operational during the first season of monitoring.

The farm is located south-west of Wolseley, immediately below the Waterval nature reserve and next to a forestry area, bordered by a steep slope on the west which introduces run-off (due to the natural drainage patterns towards the Breede River) (Figure 4-16). The surface of the terrain is sloping, and there is a farm dam at the highest point of the farm that leads to seepage water in the area below, leading to wet areas in the fields. The slope of the field is approximately 1%. The farmer grows vegetables and pears.

Figure 4-16 Aerial view of Breede River site 5 (Wolseley)

The topsoil at the site is mostly fine grey or light brown sand, underlain by a multi-layered soil consisting of sandy to sandy loam textures, resulting in a soil of which the top layer is more permeable than the deeper layers. The impermeable layers occur at depths varying from 0.2 m to 0.7 m.

The whole farm has drainage systems installed, which was done over a period of 20 years mostly through subsidy schemes (Figure 4-17).

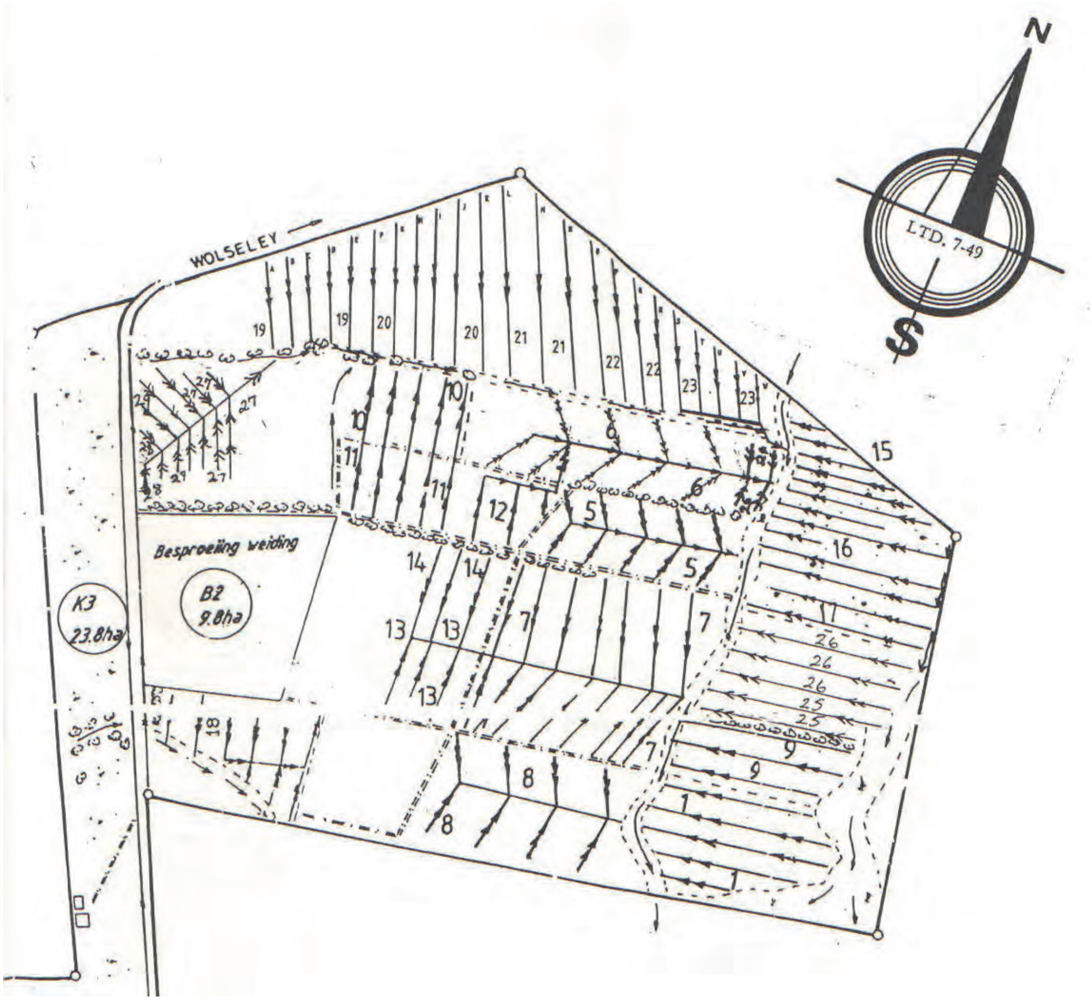


Figure 4-17 Lay-out of drainage system at Breede River site no 5

The system planning process included the site being visited and the soil profile being inspected by means of 15 profile holes that were dug in the field. The data was analysed and the soil profile descriptions are shown graphically in Figure 4-18. The results show the different types of soil, their depths and hydraulic conductivities (K values), and the profiles are categorised according to porosity classes 1 (impermeable) to 4 (highly permeable). The location of the impermeable layer, where the drains should be installed ideally, is also shown for each profile hole – these occur mostly at a depth of just below 2 m.

The profile whole data was used to calculate theoretical drain spacing using the Hooghoudt formula. A summary of the design data for one of the systems where monitoring is to take place, is shown in Table 4-30. Analysis of the profile data resulted in a suggested drain depth of 1.6 m at a spacing of 34 m.

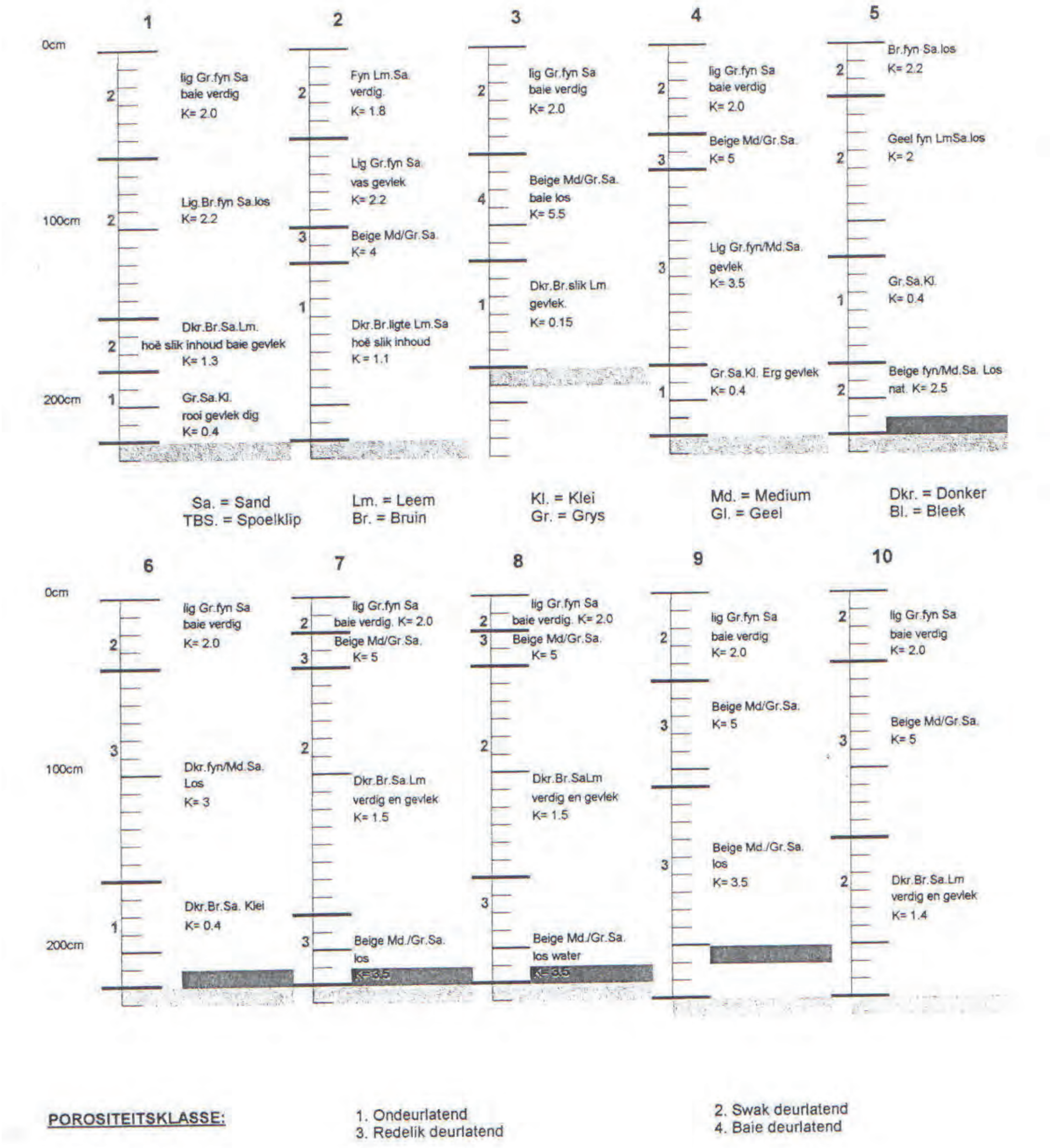


Figure 4-18 Soil profile descriptions at Breede River site no 5

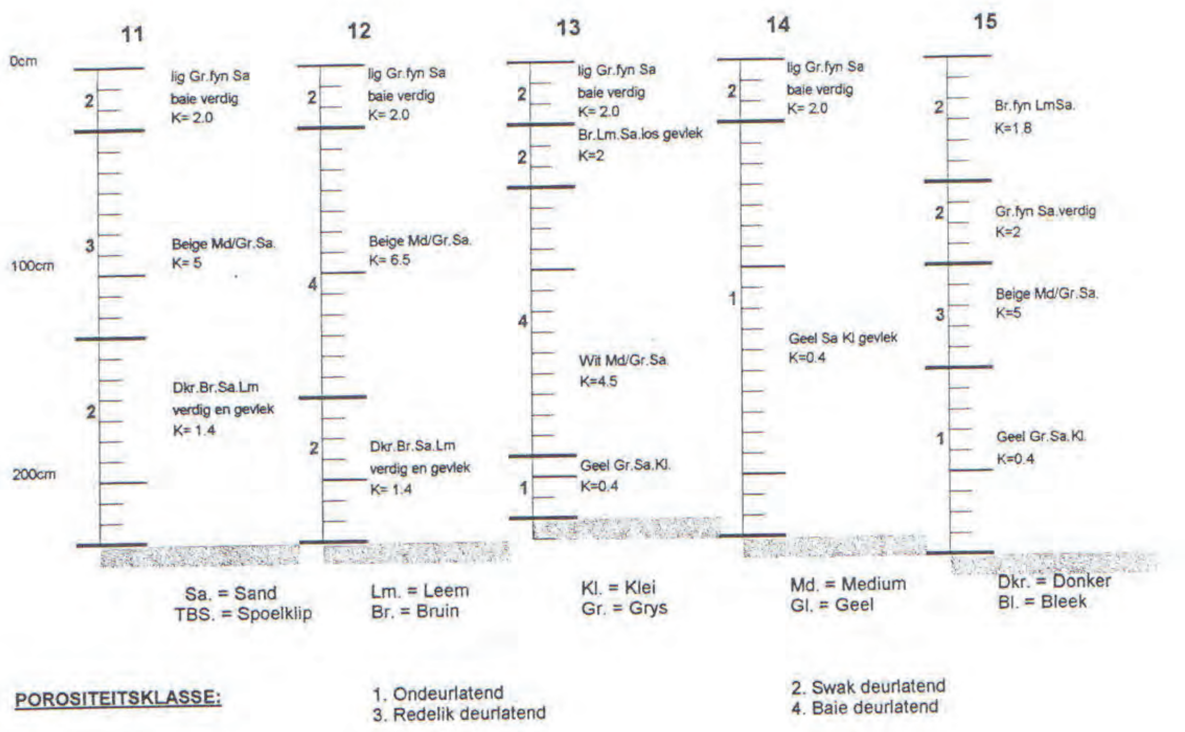


Figure 4-18 Soil profile descriptions at Breede River site no 5 (continued)

Table 4-30 Drainage design data for Breede River site no 5

Item	Value
Average depth to impermeable layer	1.6 m
F factor	0.8 x 0.001
Maximum average monthly rainfall	95 mm (La Plaisante station) (31 days/month)
Hydraulic conductivity of soil layer above drain (K1)	3.42 m/day
Hydraulic conductivity of soil layer below drain (K2)	1.46 m/day
Design drain discharge	= f x rainfall per day x 2 x 1 = 4.903 mm/day Practical: 5 mm/day
Proposed drain depth to pipe bottom (b)	1.6 m
Minimum drained soil depth between drains (a)	1 m
Water depth above the drain, between drains (h)	0.6 m
Depth of the impermeable layer below the drain (D)	0.1 m
Design drain spacing	33.6 m
Selected practical drain spacing (L)	34 m

4.2.3 **Measurement results**

- Saturated hydraulic conductivity

The saturated hydraulic conductivity values were calculated from the profile hole data collected during the drainage system design. The values for the different study sites are shown in Table 4-31.

Table 4-31 Saturated hydraulic conductivity values for Breede River sites (m/day)

	Site 1	Site 2	Site 3	Site 4	Site 5
Hydraulic conductivity of soil layer above drain (K1)	4.5	4.1	-	2.1	3.4
Hydraulic conductivity of soil layer below drain (K2)	5.25	3.9	-	1.8	1.5

- Measurement of soil water characteristics

Capacitance probes commonly used for irrigation scheduling are used to monitor the soil water content, up to a depth of 1.5 m. These probes were selected as they offer continuous logging results and also record the movement of water at different depths in the profile. Two types of probes are used for soil water movement – the continuous logging probe from DFM Software solutions (DFM 2012) and the 10HS Moisture sensor from Decagon Devices (Decagon 2010). Furthermore the Decagon CTD sensor is used to measure electrical conductivity at Site 3 where the drainage system is used to control salinity (Decagon 2012).

- Weather data acquisition

Weather data is used from an automatic station at Wolseley, managed by the Department of Plant Production and Soil Science of the University of Pretoria and providing hourly data.

- Continuous logging probe data

The probe software provides various options to output the soil water content, rainfall, evapotranspiration and irrigation data. The most useful format is the summary graphs the presents line graphs for soil water content in the rootzone overall (0-50 cm), in the top roots (0-30 cm), and in the buffer zone (50-80 cm), together with bar charts of the rainfall events (pink bars) and irrigation events (blue bars), and also the daily ET_o values (green line graph).

- Site 1 (De Doorns)

The crop grown at this site is table grapes (Crimson seedless variety) and irrigation takes place with 32 l/h micro sprayers. The soil water content was monitored up to a depth of 0.8 m using selected capacitance probes, which form part of the farmer's existing irrigation scheduling system. There is a total of 20 probes installed on the 25 ha farm, and 5 probes were selected for monitoring of the drainage system's performance. One probe is located in a block above the drained area (B10.5), two probes are located in the drained area (B10.1 and B10.3), and a further two probes are located below the drained area (B3.4 and B9.4). The locations of the selected probes, and their orientation relative to the farm boundaries (red lines) and drainage system (dotted lines), are shown in Figure 4-19 by the yellow crosses. The farm is bordered in the south by the railway line and in the north by the Hex River.

The probes are all installed in irrigation blocks with similar soils, but it is important to note that on most of the farm, there is a compacted sand layer at approximately 0.5 m depth in addition to the impermeable layer at approximately 2.1 m depth (where the drainage system is installed). From the data that have been recorded, it looks like the water removed from the field by the drainage system, enters the farm horizontally (as natural subsurface water that is draining towards the Hex River) during the rainy season. However, the monitoring probes showed that the compacted sand layer at 0.5 m contributes to drainage problems in the root zone during the irrigation season. To summarise therefore: the source of water in the profile during winter, is not only the rainfall on the farm but also the subsurface water which is draining through the farm to the river and leads to continuous saturation of the soil at depths below 0.5 m; once the rain stops, these deeper soil layers are drained, and the source of water in the profile is the irrigation applied, which remains in the top 0.5 m of the profile and only moves marginally through the compacted sand layer.

The total amounts of irrigation given to each block during the monitoring period are shown in Table 4-32. The amounts varied by block and had an influence on the soil water content as discussed further below. It was observed that the farmer applied less water to the 2 blocks where the drainage system is installed. The total irrigation requirement for the 3 month period was calculated as 174 mm.

Table 4-32 Irrigation applied to the monitored blocks at the De Doorns site (Sept-Nov 2012)

Block number	Irrigation applied, mm	Possible contribution to ET_c from water in profile, mm
B10.5	146	30
B10.3	109	65
B10.1	106	68
B3.4	129	45
B9.4	161	13

The data for the 5 probes are shown in Figure 4-20 to Figure 4-24 and discussed below.

Figure 4-19 Locations of monitoring probes relative to the drainage system at Breede River Site 1 (De Doorns)

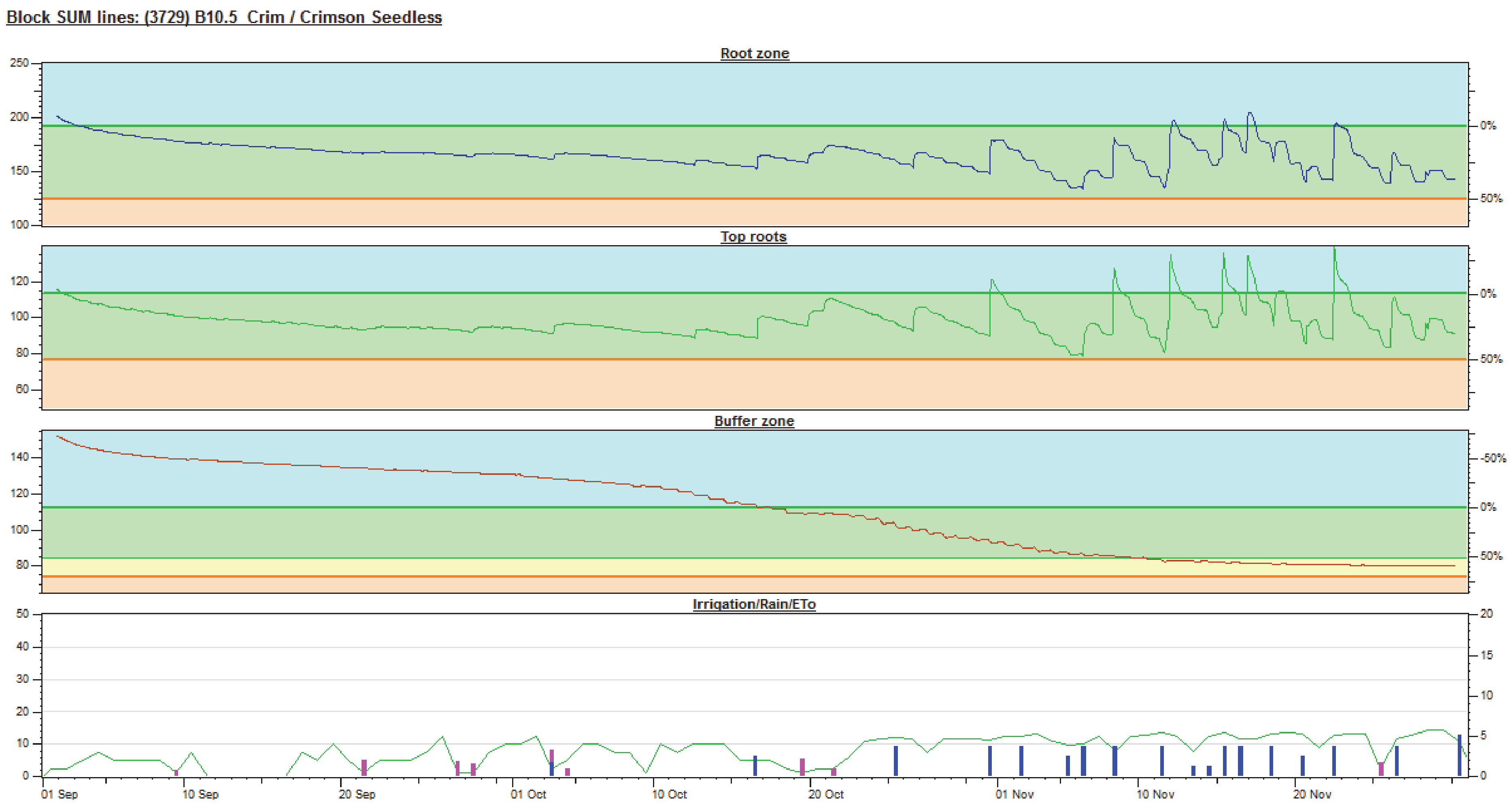


Figure 4-20 Monitoring results at location B10.5 of the De Doorns site

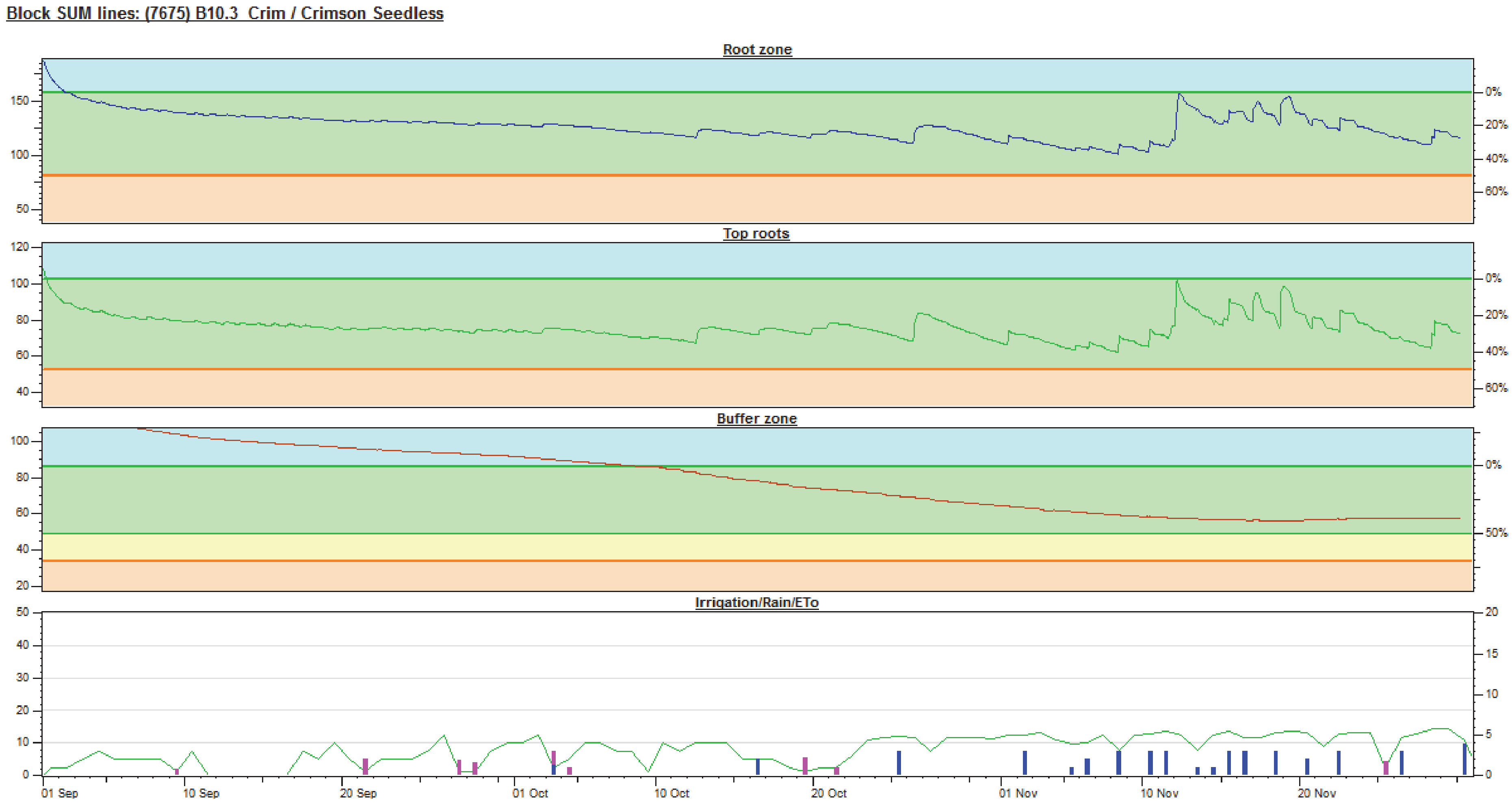


Figure 4-21 Monitoring results at location B10.3 of the De Doorns site

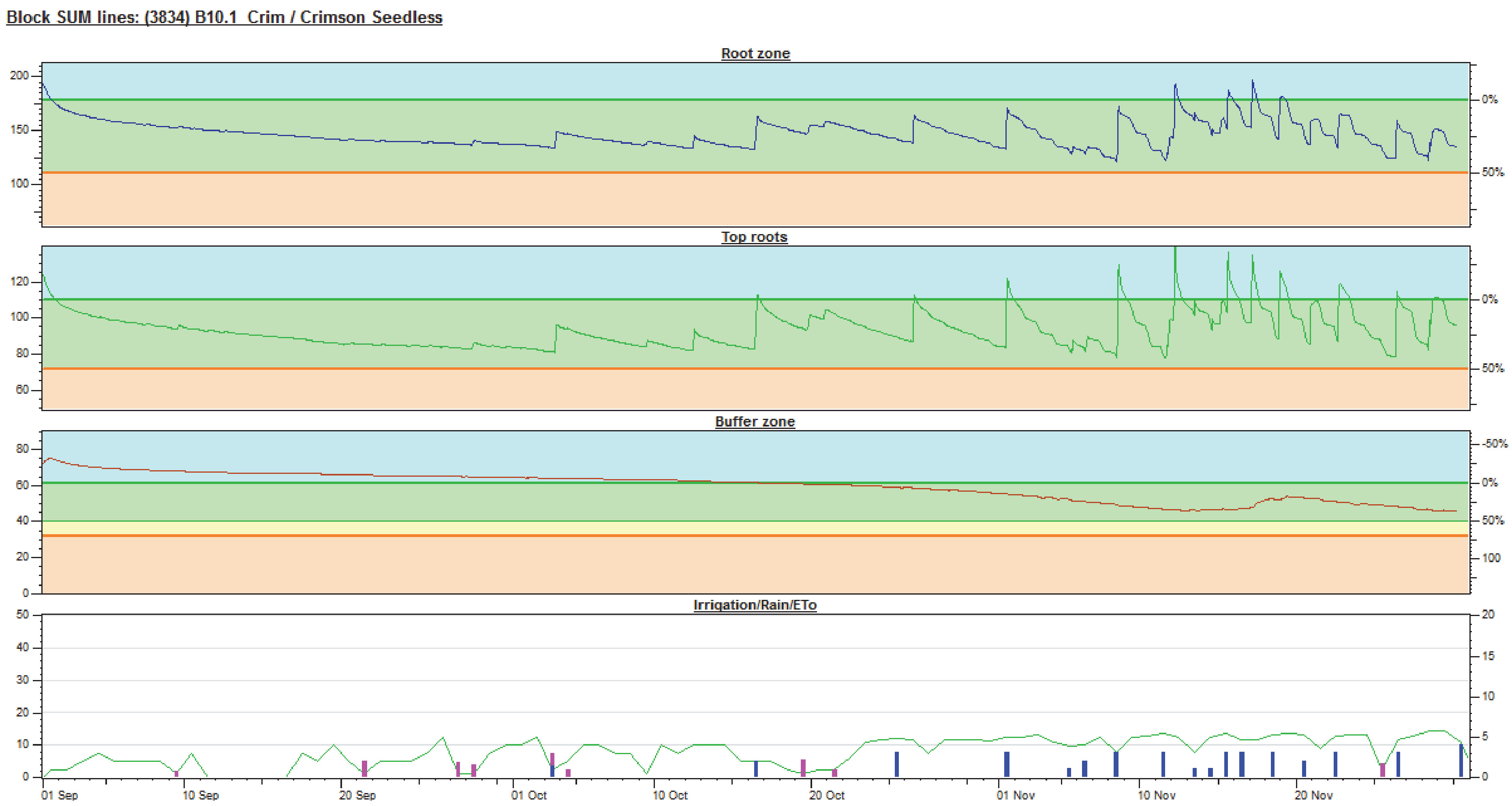


Figure 4-22 Monitoring results at location B10.1 of the De Doorns site

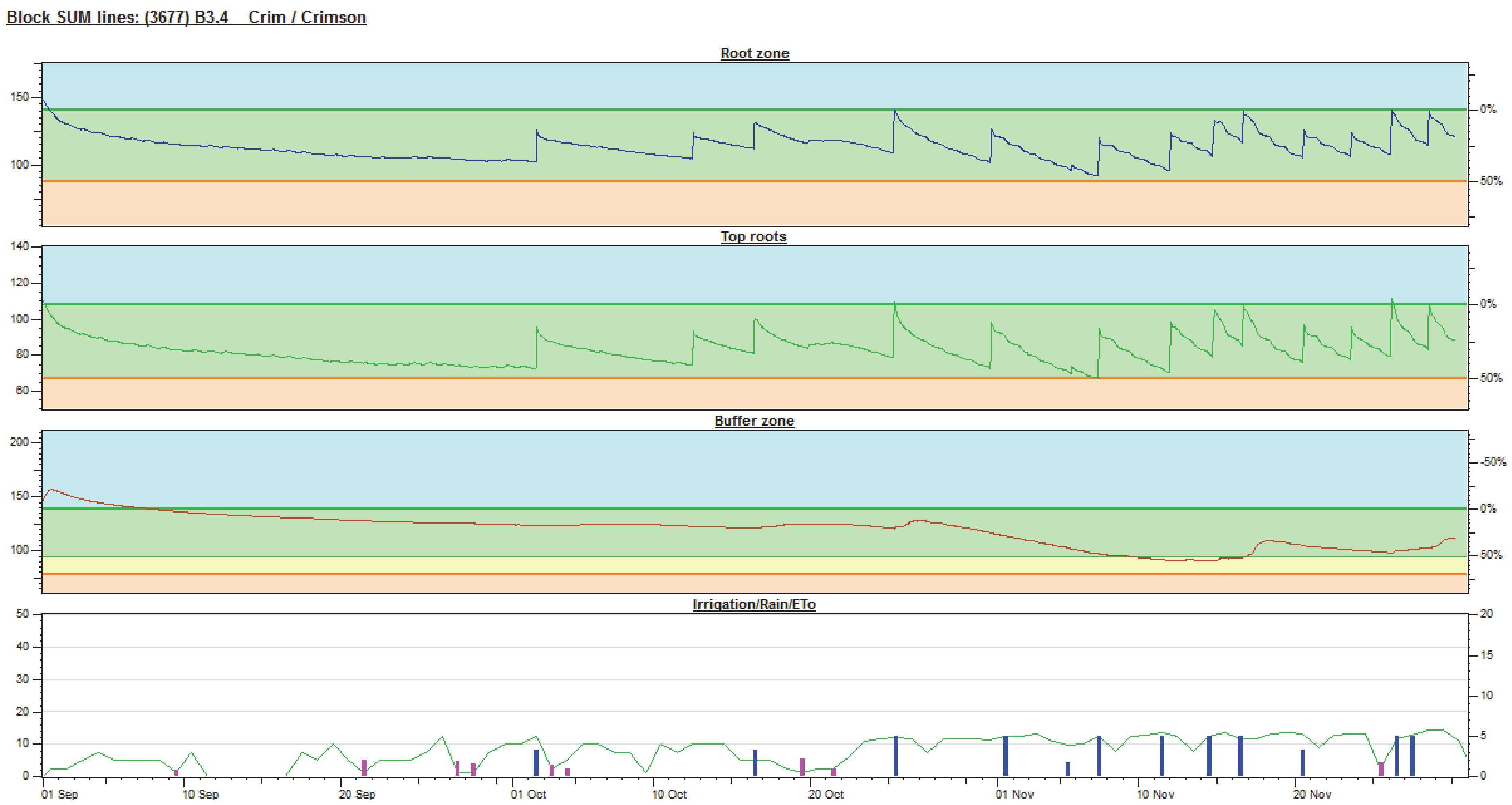


Figure 4-23 Monitoring results at location B3.4 of the De Doorns site

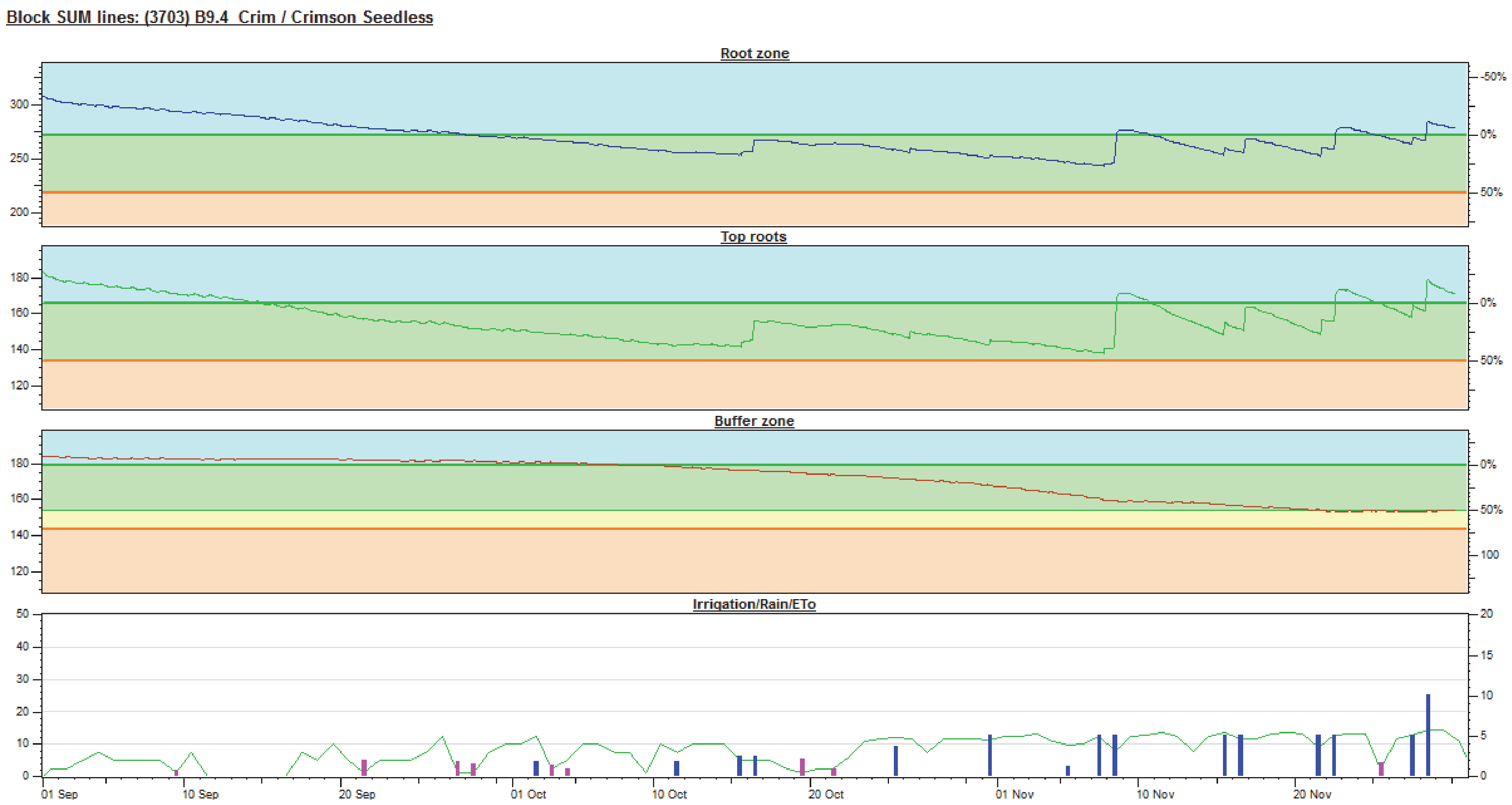


Figure 4-24 Monitoring results at location B9.4 of the De Doorns site

Block B10.5 is located at the highest point of the farm and is better drained than the other blocks. In Figure 4-19 it can be seen that the deeper soil ("buffer zone") started draining due to gravity at the beginning of September, but from 1 October until 23 November the reduction in water content was due to crop water use – this can be seen if the separate line graphs for the sensors at different depths are drawn (in Figure 4-20 for block B10.5). The water content measured in the topsoil (0.1 m depth) and the root zone (0.3 m) reflects the irrigation events clearly but this water evidently don't reach the deeper part of the profile below the root zone, as the line graphs of the sensors at 0.6 m and 0.8 m shows no increase in water content after the irrigation events.

Figure 4-25 to Figure 4-29 shows the separate line graphs for the other 4 probes. When comparing the line graphs of the sensors at different depths, of the different probes, it can be seen that more water drained from the deeper part of the profile in blocks B10.5 and B10.3, than in blocks B10.1, B3.4 and B9.4.

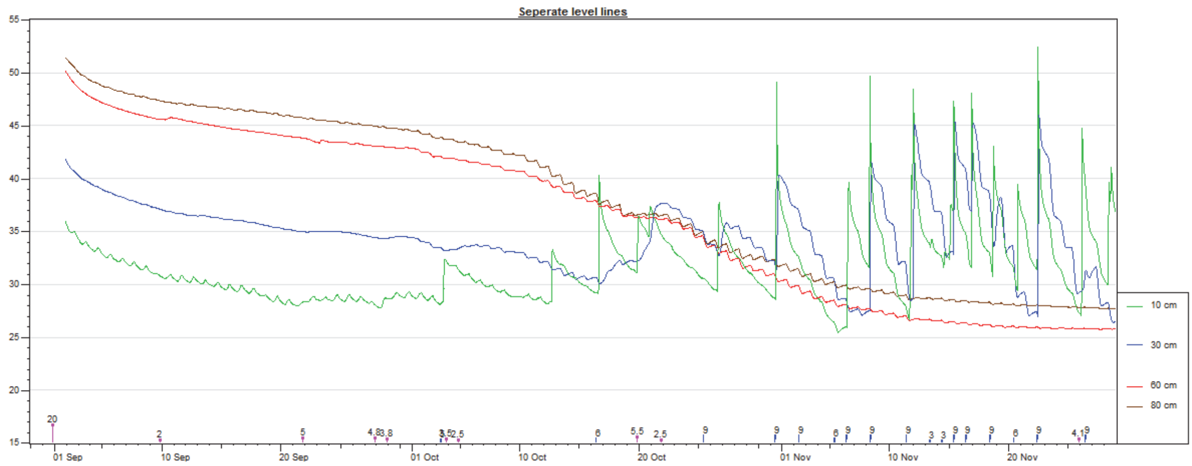


Figure 4-25 Separate line graphs of sensors of the probe in Block B10.5 at Site 1

In the case of blocks B10.3 and B10.1 (Figure 4-21 and Figure 4-22), where the drainage system is installed, it can be seen that there was an increase in water content at 0.5 m depth around the 16th of November but the content decreased or stabilized again thereafter (due to the effect of the drainage system). The data from blocks B3.4 and B9.4 (Figure 4-23 and Figure 4-24) showed similar increases in water content at 0.5 m from 16 November but without the recovery seen in block B10.1 (and block B10.3 but to a lesser extent), as no drainage systems are installed in the first two blocks.

It is however important to keep the effect of the compacted layer at 0.5 m in mind when analysing all of the data as this will have an effect on the water content. This effect can be clearly seen at blocks B10.1 and B9.4 (Figure 4-22 and Figure 4-23), where the farmer is struggling to keep the water content in the root zone within the green band – the irrigated amounts are less than the calculated crop water requirement but still the water contents are very high.

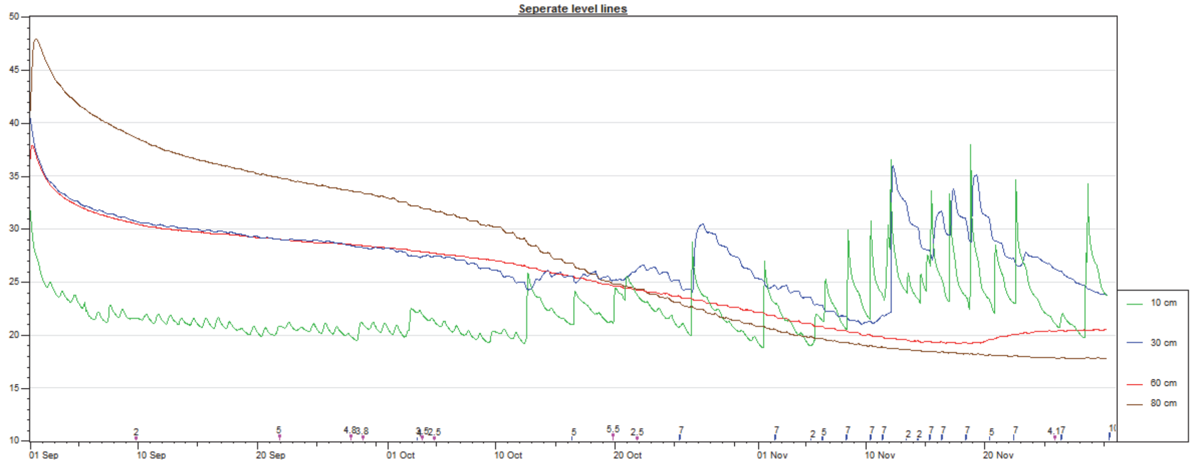


Figure 4-26   Separate line graphs of sensors of the probe in Block B10.3 at Site 1

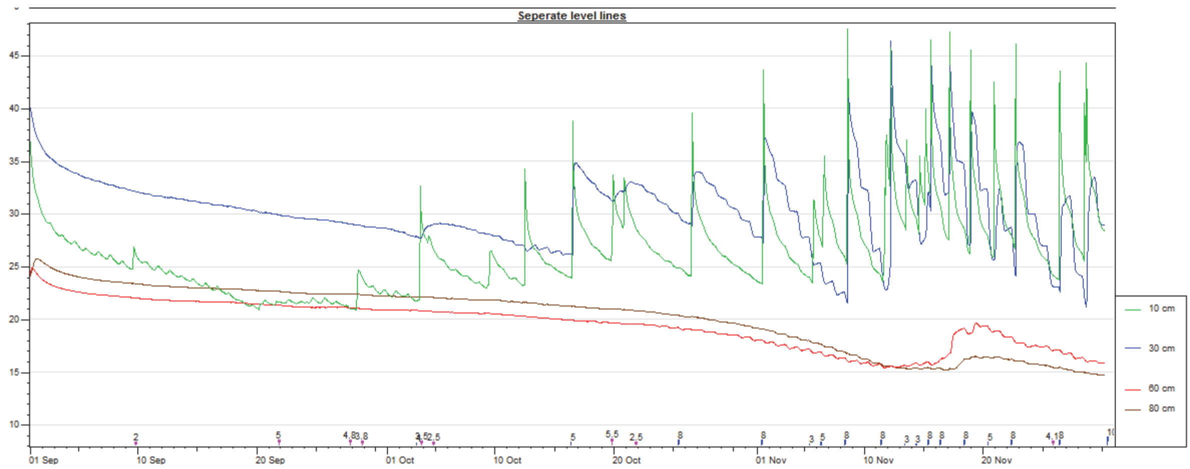


Figure 4-27   Separate line graphs of sensors of the probe in Block B10.1 at Site 1

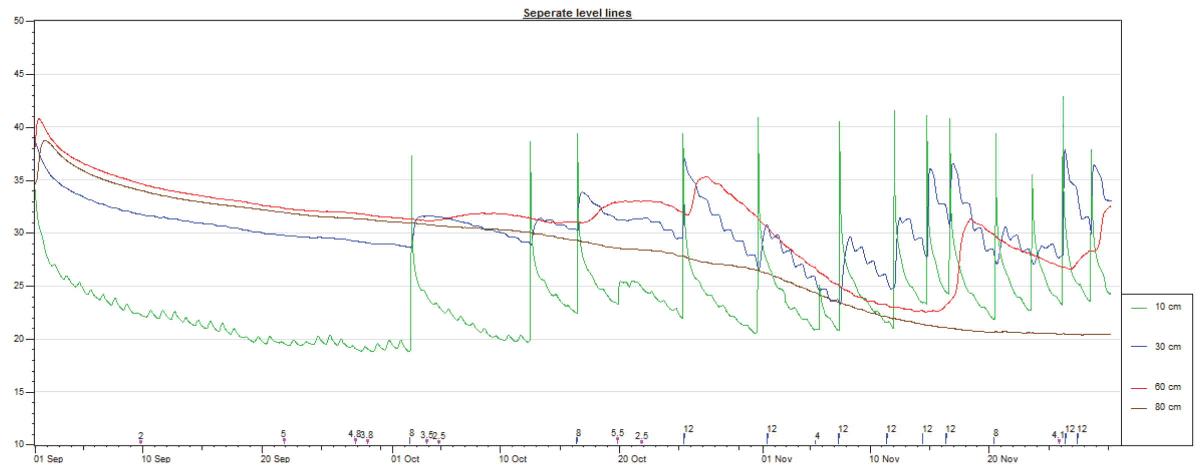


Figure 4-28 Separate line graphs of sensors of the probe in Block B3.4 at Site 1

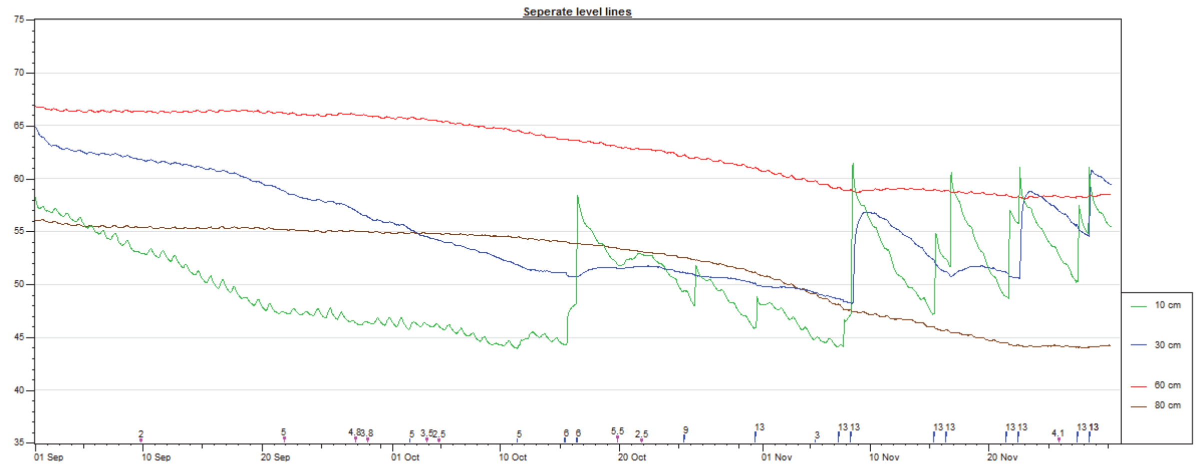


Figure 4-29 Separate line graphs of sensors of the probe in Block B9.4 at Site 1

In order to improve the monitoring of soil water levels at this site, it is recommended that monitoring takes place at depths deeper than what the currently installed probes can produce – ideally up to a depth of at least 1.5 m, as the drainage system is installed at a depth of 1.9 m and is supposed to lower the water table to a depth of 1 m. It will be especially useful to be able to monitor this during the winter months when it rains.

- Site 2 (Breërivier)

The same approach as with Site 1 was taken in the case of Site 2 – data from the soil water content probes used by the farmer for irrigation scheduling was used to assess the drainage of water in the soil profile. Unfortunately the farmer had not kept accurate record of the irrigation events so limited results could be obtained. The farmer grows different varieties of peaches.

Four probes on the drained area were selected for monitoring. During the field visit to establish the locations of the probes, it was found that the drainage system had not been installed by the previous owner of the farm according to the design of the Department of Agriculture. Instead of the herringbone lay-out designed by the technicians from the Department of Agriculture, a much simplified subsurface system at nearly double the design spacing was installed, disposing water into an existing surface drain (see Figure 4-30).

The locations of the probes are also shown in Figure 4-30. Orchards have been developed on the areas where probes G6 and G8 are located since the time that the aerial photograph used as background in the figure was taken. Blocks F1 and F2 are irrigated with micro sprinklers and block G6 and G8 with drip irrigation.

The orchard at probe G6 was planted only in 2012 and no probe data was available yet for this reporting period. For the other 3 probes, soil water content and climate (ETo and rainfall) data was collected over the 3 month period (September to November 2012).The data for all 3 probes are shown in Figure 4-31 to Figure 4-33 (summary graphs) and Figure 4-34 to Figure 4-36 (separate line graphs). The lack of irrigation data complicates the interpretation but the data is discussed below.

The soil at this site differs from the soil at Site 1, with a much larger fraction of stone ("spoelklip") occurring in the profile. Infiltration rates are high and the soil water content changes rapidly after irrigation events. The original soil investigations showed free water occurring in profile holes at a depth as shallow as 0.8 m, enforcing the necessity of the drainage system at the correctly designed spacing.

The data from blocks F1 and F2 showed that the farmer is managing the root zone well, with the water content staying within the green band (Figure 4-31 and Figure 4-32); however, in block F1 there has been a steady increase in water content of the deeper soil layers (0.8 m depth) which could be due to the inadequacy of the incorrectly installed drainage system. Block G8 is being over-irrigated, with the farmer's strategy of frequent small applications (especially since 1 November) leading to high water content in the root zone and also in the buffer zone (Figure 4-33). The data also clearly shows how the micro sprinklers used in blocks F1 and F2 are vastly more suited to the soil than the drip irrigation used in block G. The micro sprinklers spread the water on the soil surface while the drip irrigation leads to highly concentrated point applications that infiltrates rapidly to the deeper layers of the soil profile.

Figure 4-30 Locations of monitoring probes relative to the drainage system at Breede River Site 2 (Breerivier)

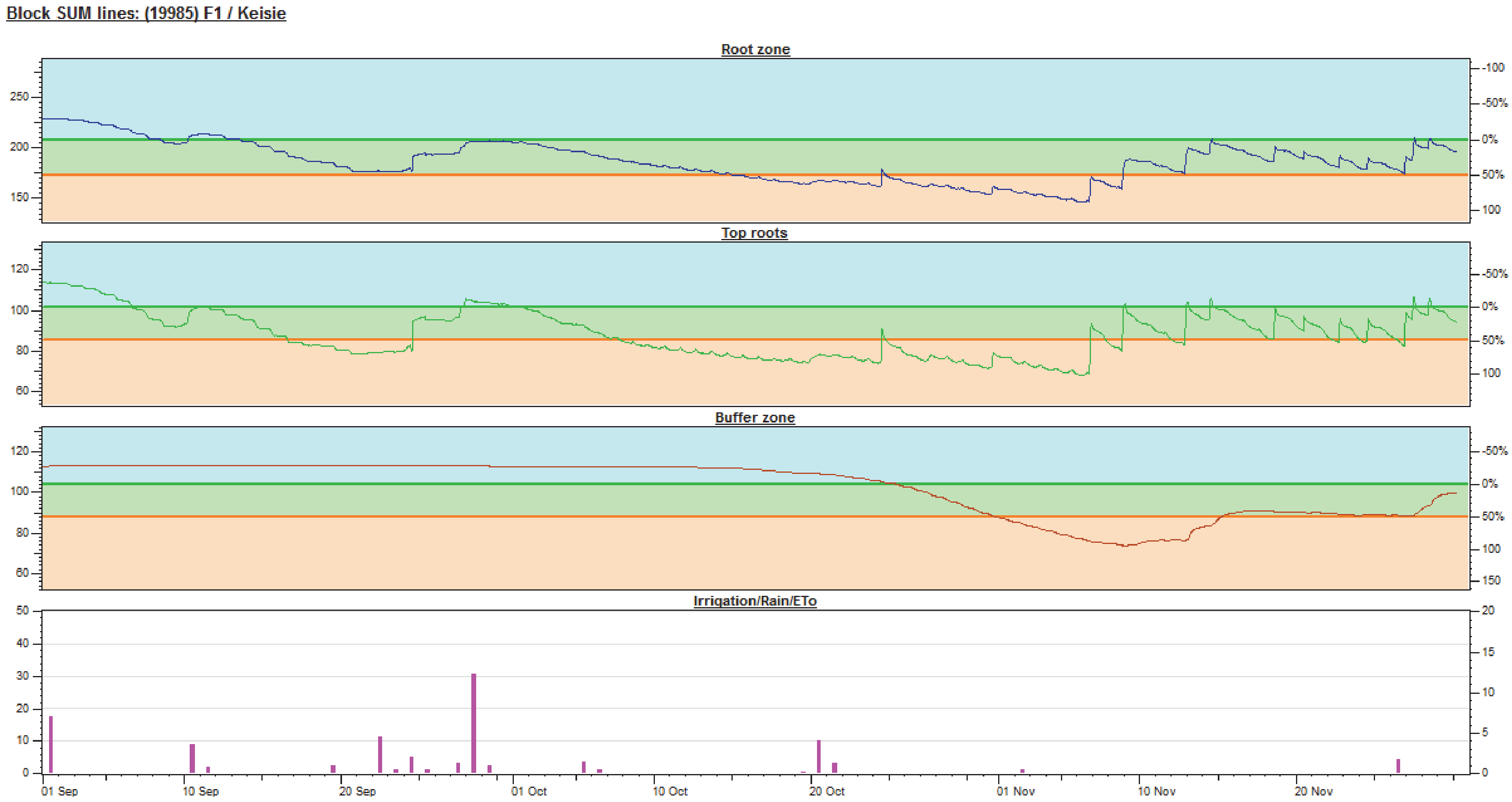


Figure 4-31 Monitoring results at location F1 of the Breerivier site

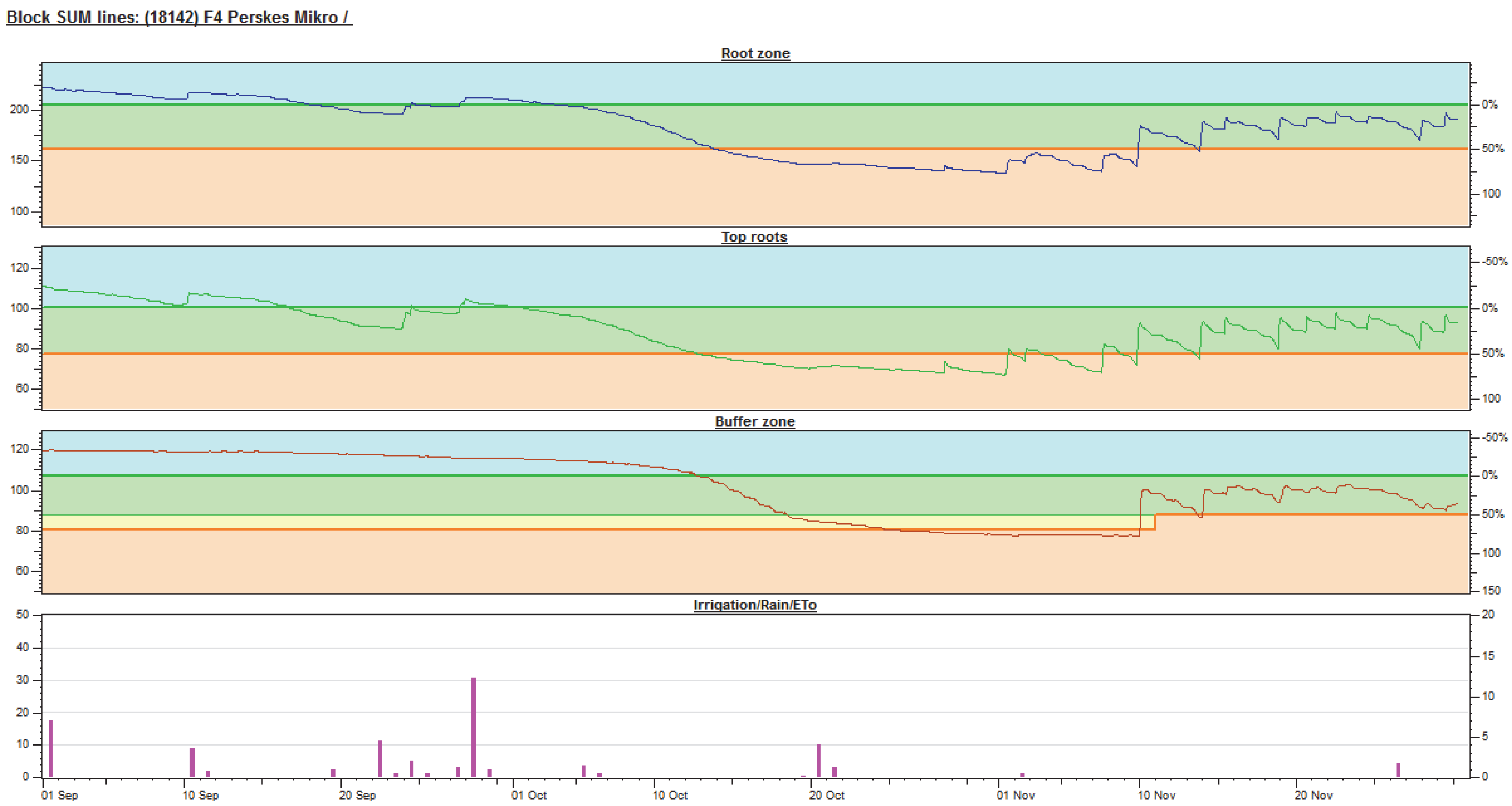


Figure 4-32 Monitoring results at location F2 of the Breerivier site

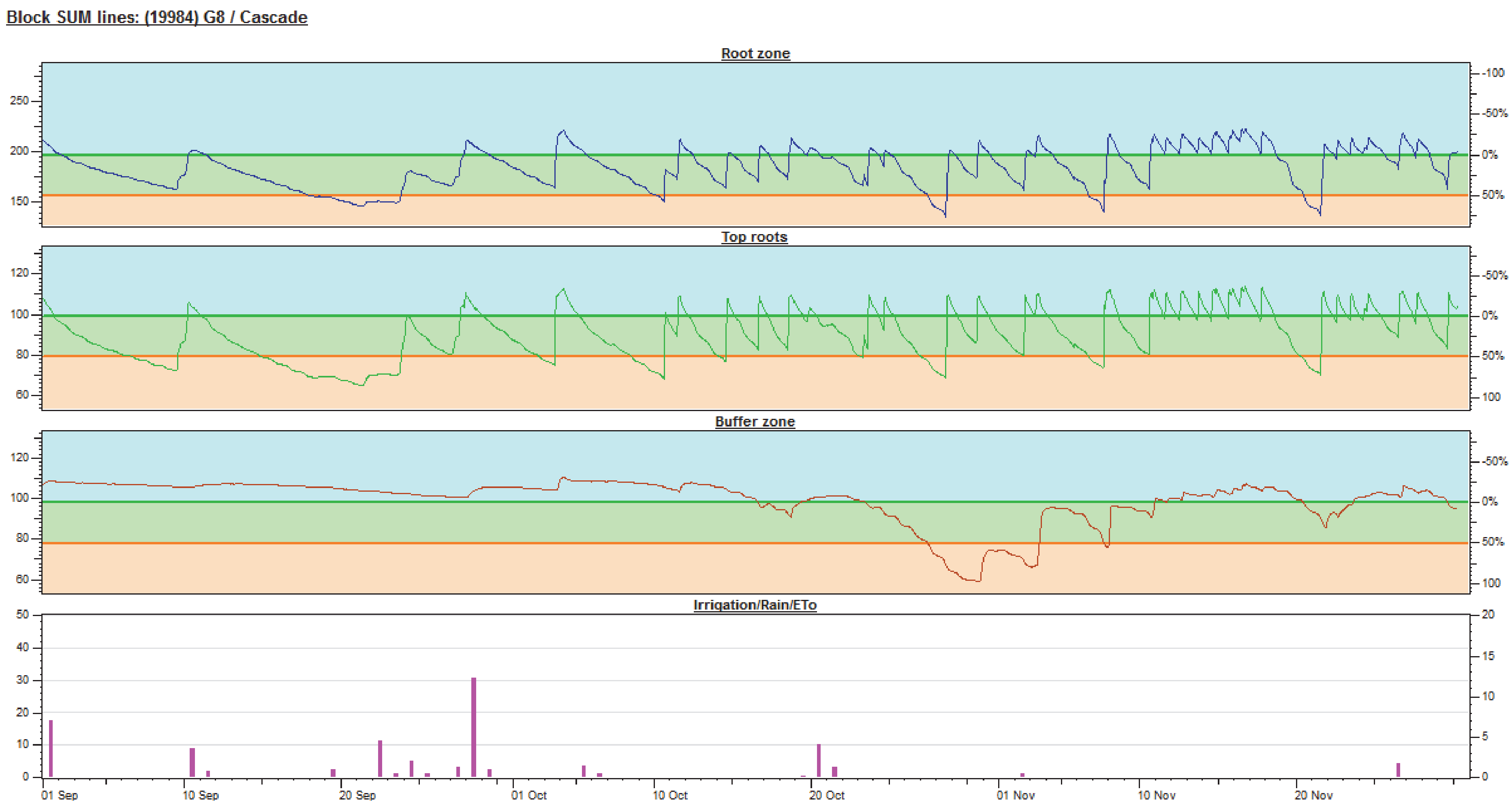


Figure 4-33 Monitoring results at location G8 of the Breerivier site

If the separate line graphs are considered, the increase in water content in the buffer zone can be seen from the graphs of the sensors located at a depth of 0.8 m, and even in the root zone at 0.3 m. The water content in the deep layers has been increasing steadily at all 3 probes since irrigation commenced in October, with in the case of block G8, reaching similar levels than those measured during winter when rainfall occurs.

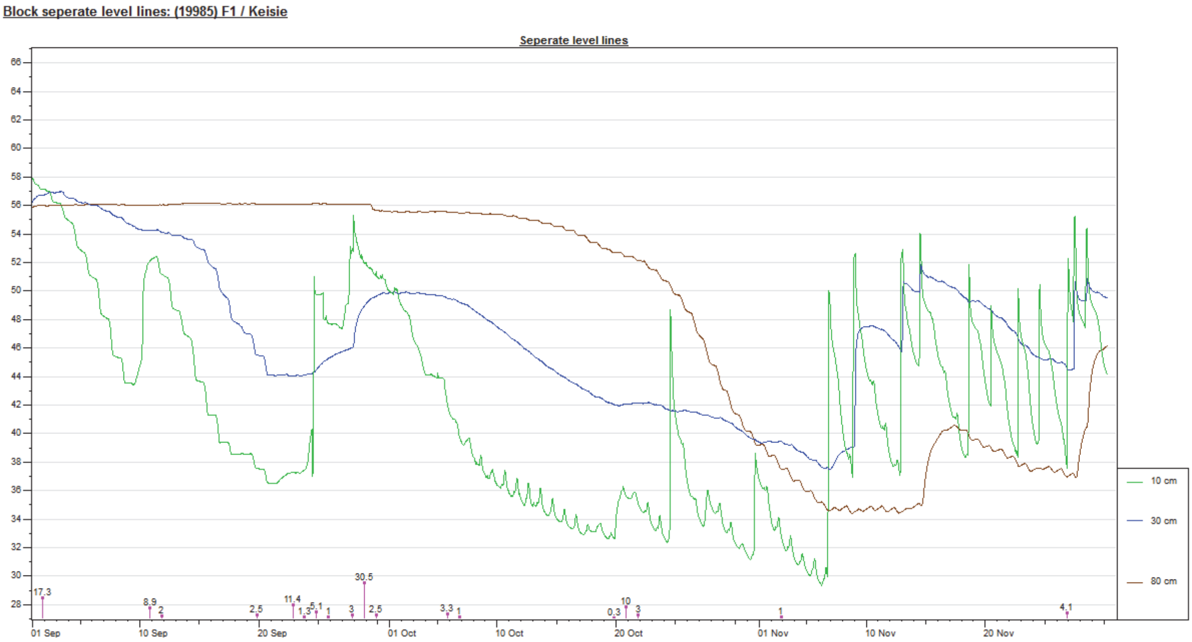


Figure 4-34 Separate line graphs of sensors of the probe in Block F1 at the Breerivier site

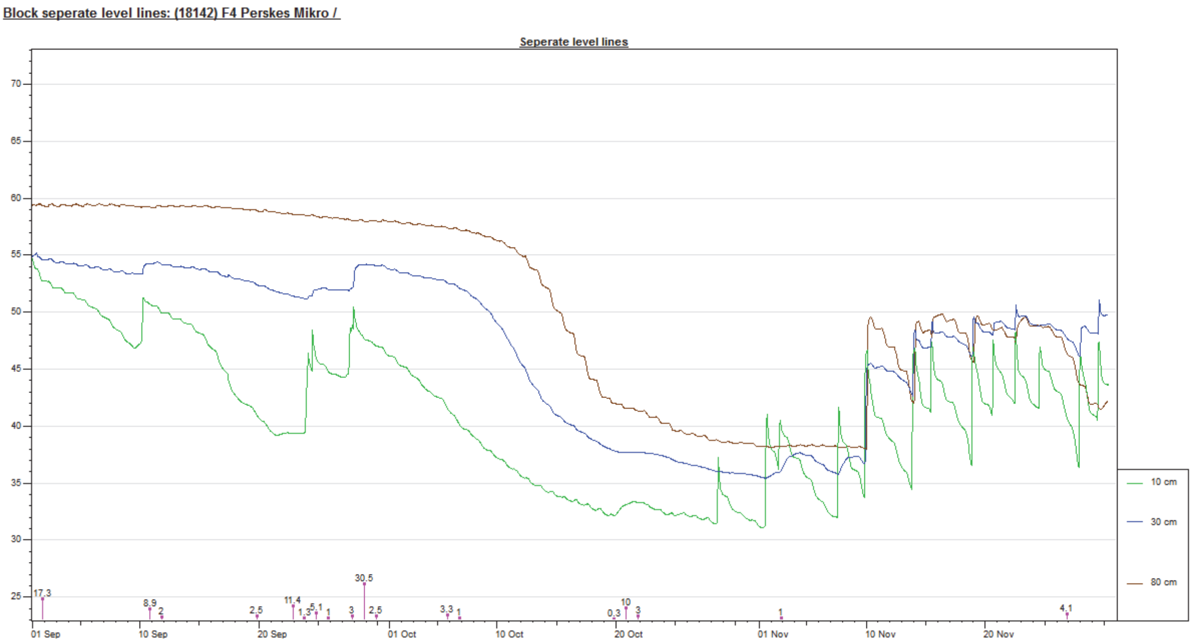


Figure 4-35 Separate line graphs of sensors of the probe in Block F2 at the Breerivier site

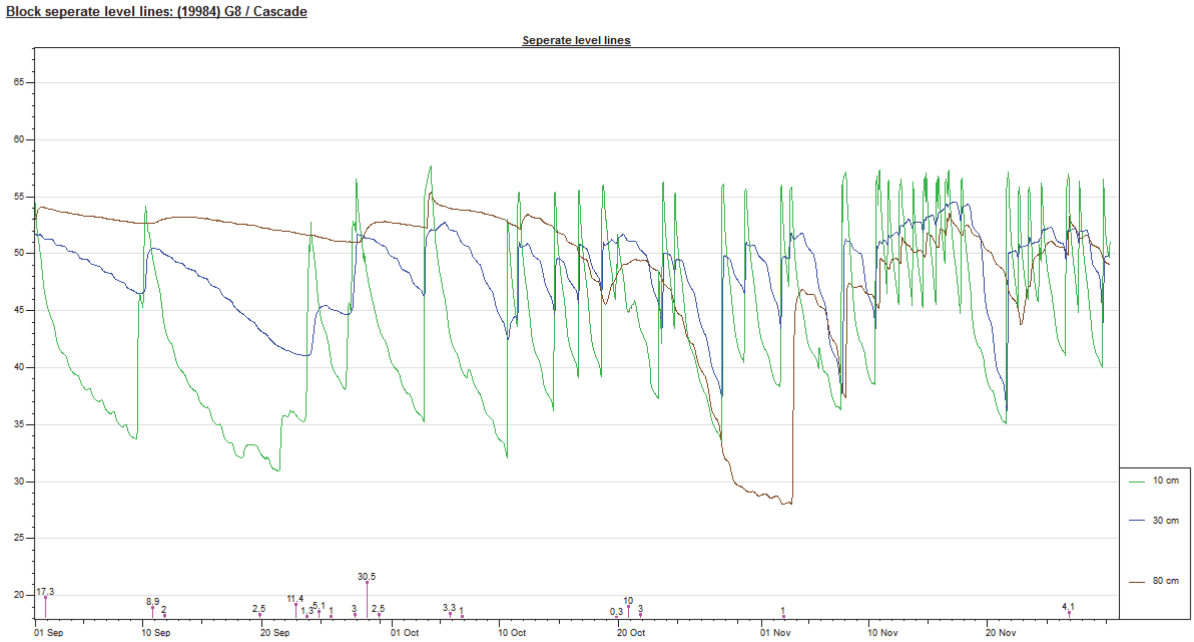


Figure 4-36 Separate line graphs of sensors of the probe in Block G8 at the Breerivier site

- Site 4 (Scherpenheuwel)

This site was selected as the purpose of the drainage system is to control salinity (rather than high water tables) and special equipment had to be purchased for monitoring. A salinity sensor was installed in March 2013 at a depth of 1.4 m, which should have been well within the water table according to the measuring results from the survey team from the Department of Agriculture but no free water was found at this depth and the sensor never responded during monitoring in the rain season of 2013.

Figure 4-37 Mottled appearance of soil taken from hole drilled for salinity

Figure 4-38 Salinity probe installed at Site 4 (Scherpenheuwel)

- o Site 5 (Wolseley)

This is a new site that was added when it became evident that the system at Site no 3 was not going to become operational during the first season of monitoring.

As planned, two 1.5 m continuous logging probes were installed on the farm (Figure 4-39) to monitor the water table in the pear orchards on the farm. The installed drainage system was supposed to drain the water level to a minimum depth of 1 m, with the impermeable layer of the soil being at 1.6 m.

Figure 4-39 Installation of soil water probe at Breede River site 5

The summed graphs for the two probes for the 2013/2014 season is shown in Figure 4-40 and Figure 4-41. At both probes, the buffer zone of the soil (set as 150cm to 180cm below the soil surface) remained saturated throughout the winter (rainfall season). The water content in the soil at this level only started to reduce from the middle of December, which is well into the growing season.

If the individual line graphs are considered (Figure 4-42 and Figure 4-43), it can be seen that the soil was saturated up to a depth of 0.6 m from the soil surface until December – it would therefore seem that the drainage system was not effectively reducing the water table to the required 1 m depth.

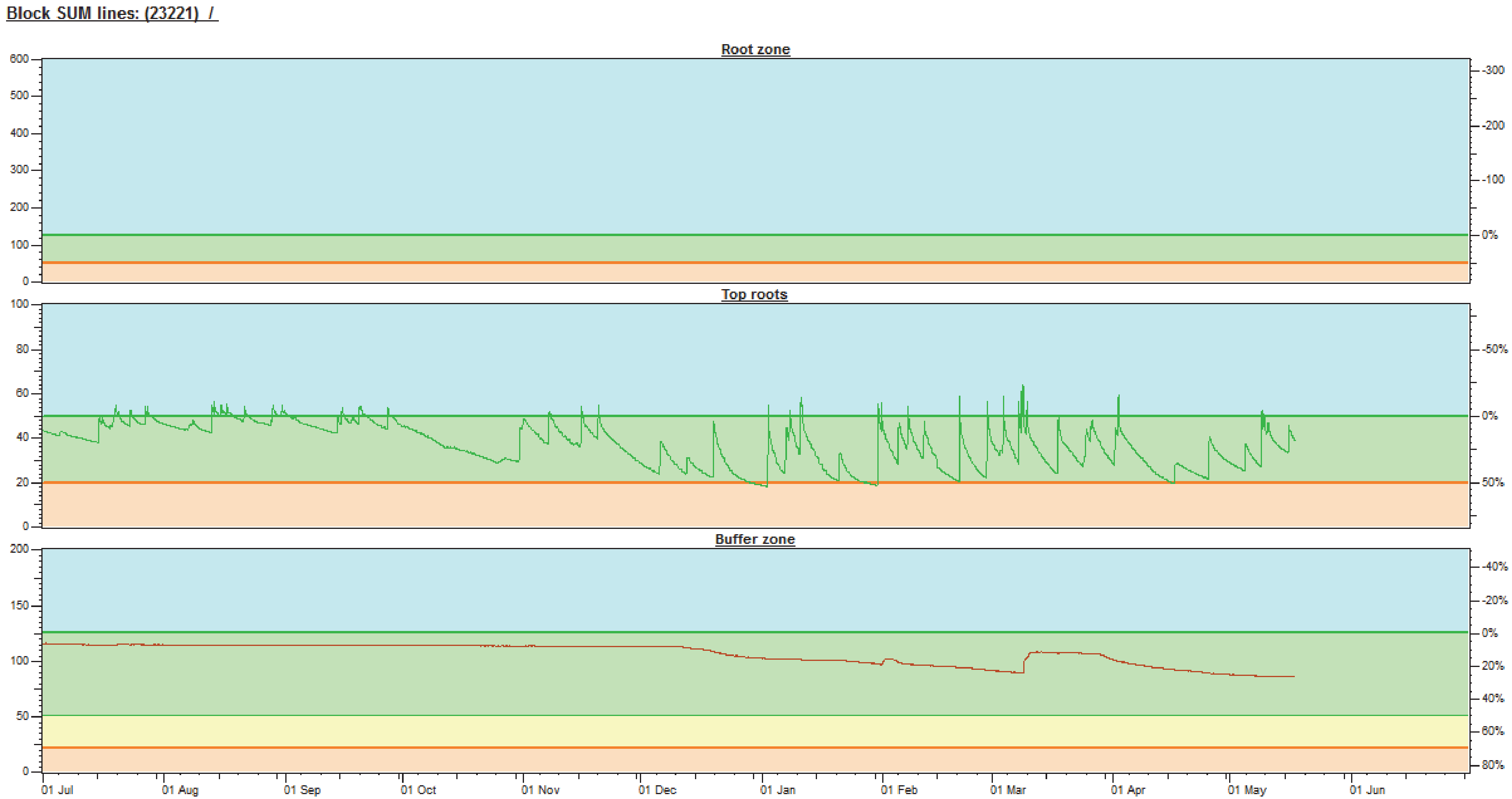


Figure 4-40 Monitoring results at probe 1 of the Wolseley site

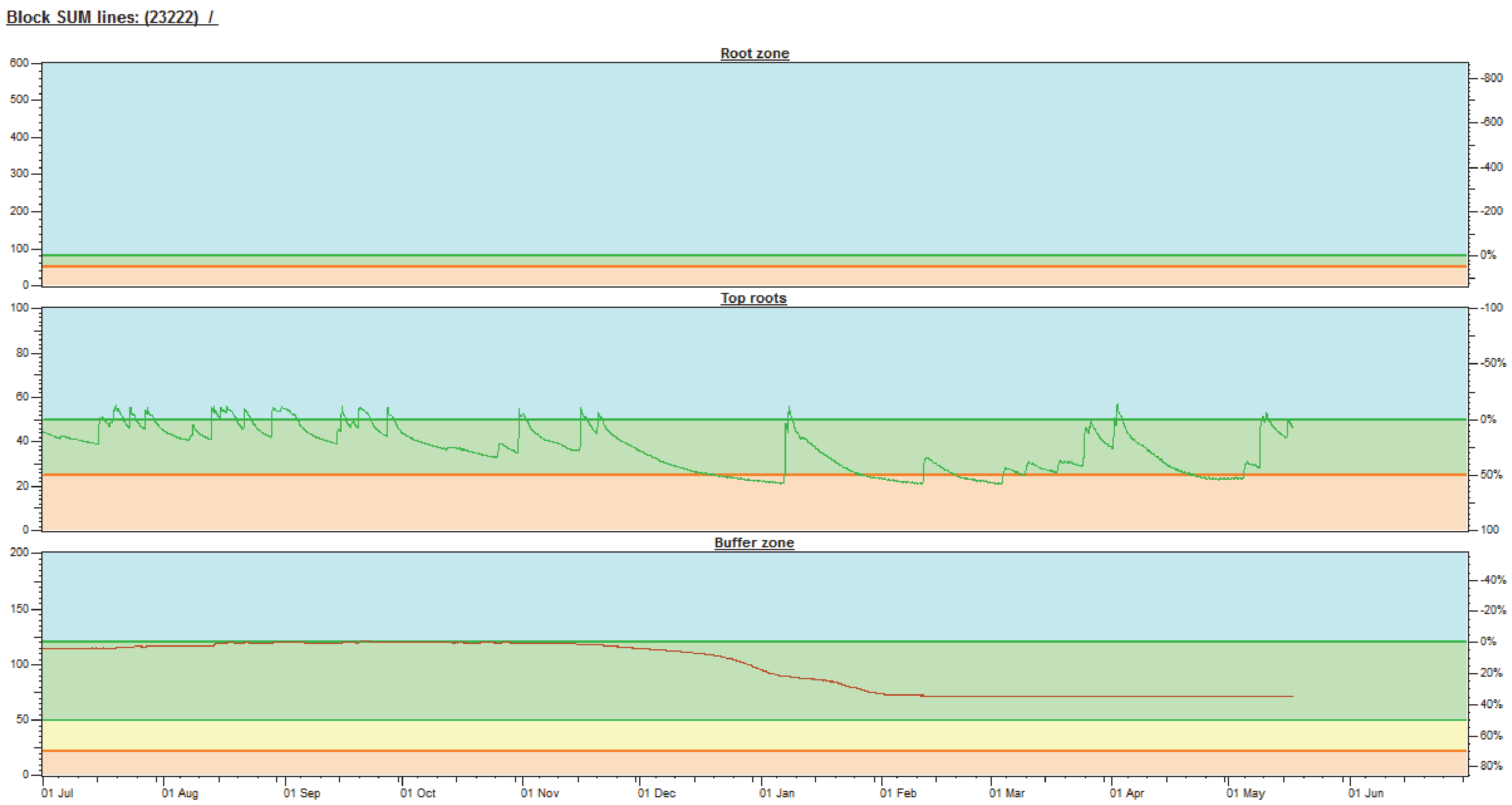


Figure 4-41 Monitoring results at probe 2 of the Wolseley site

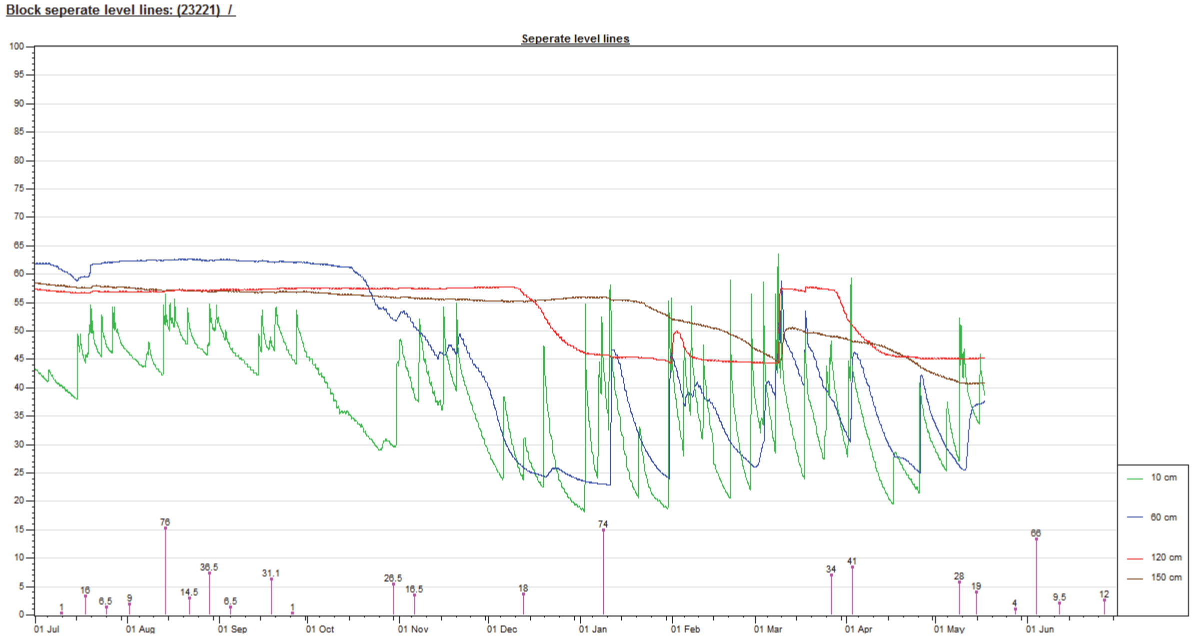


Figure 4-42 Separate line graphs of sensors of probe 1 at the Wolseley site

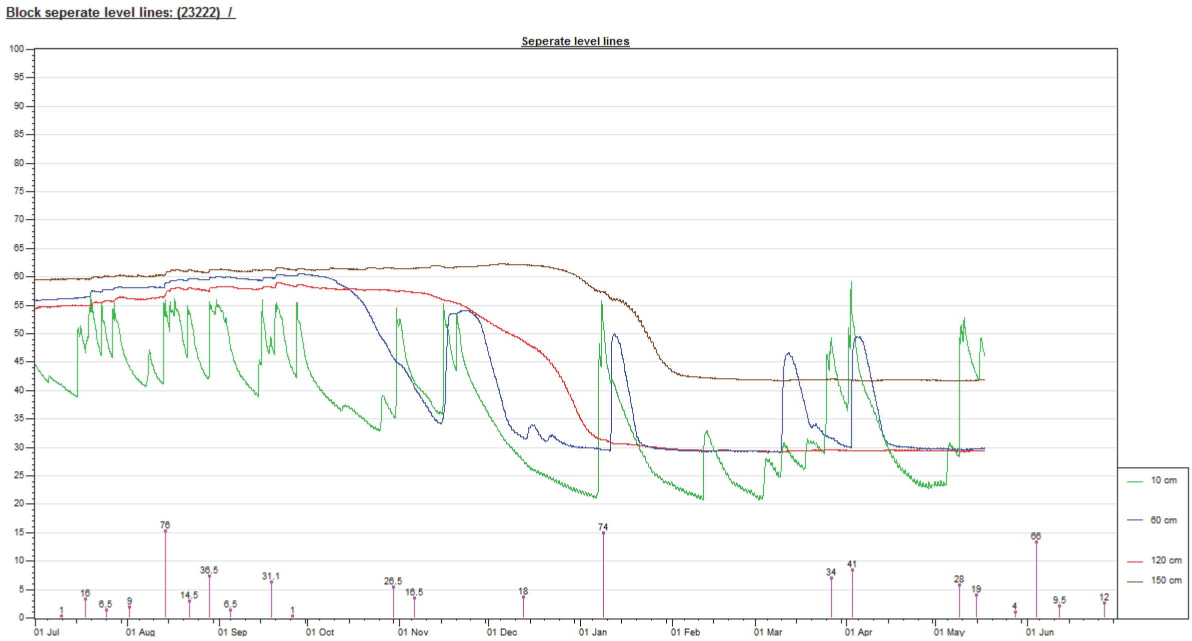


Figure 4-43 Separate line graphs of sensors of probe 2 at the Wolseley site

4.3 **Impala Irrigation Scheme**

Drainage is mostly installed at the Impala Irrigation Scheme to lower water tables and improve growing conditions in the root zone.

4.3.1 **Location of case study site**

As part of a research initiative, sugarcane fields with Well Maintained Subsurface Drainage System (WMDS) on 32 ha and Poorly Maintained Subsurface Drainage System (PMDS) on 20 ha (Figure 4-44), were first artificially drained using subsurface drainage systems in 1987. However, between 1995 and 2002, it was noticed that shallow groundwater tables were still affecting sugarcane growth in both fields. The subsurface drainage systems were, therefore, abandoned and all the man-holes were filled up. This was followed by a recalculation of the drain depth and spacing, using the steady state drain spacing approach (i.e. using the Hooghoudt (1940) steady state drain spacing equation), and the installation of the current subsurface drainage system in 2003.

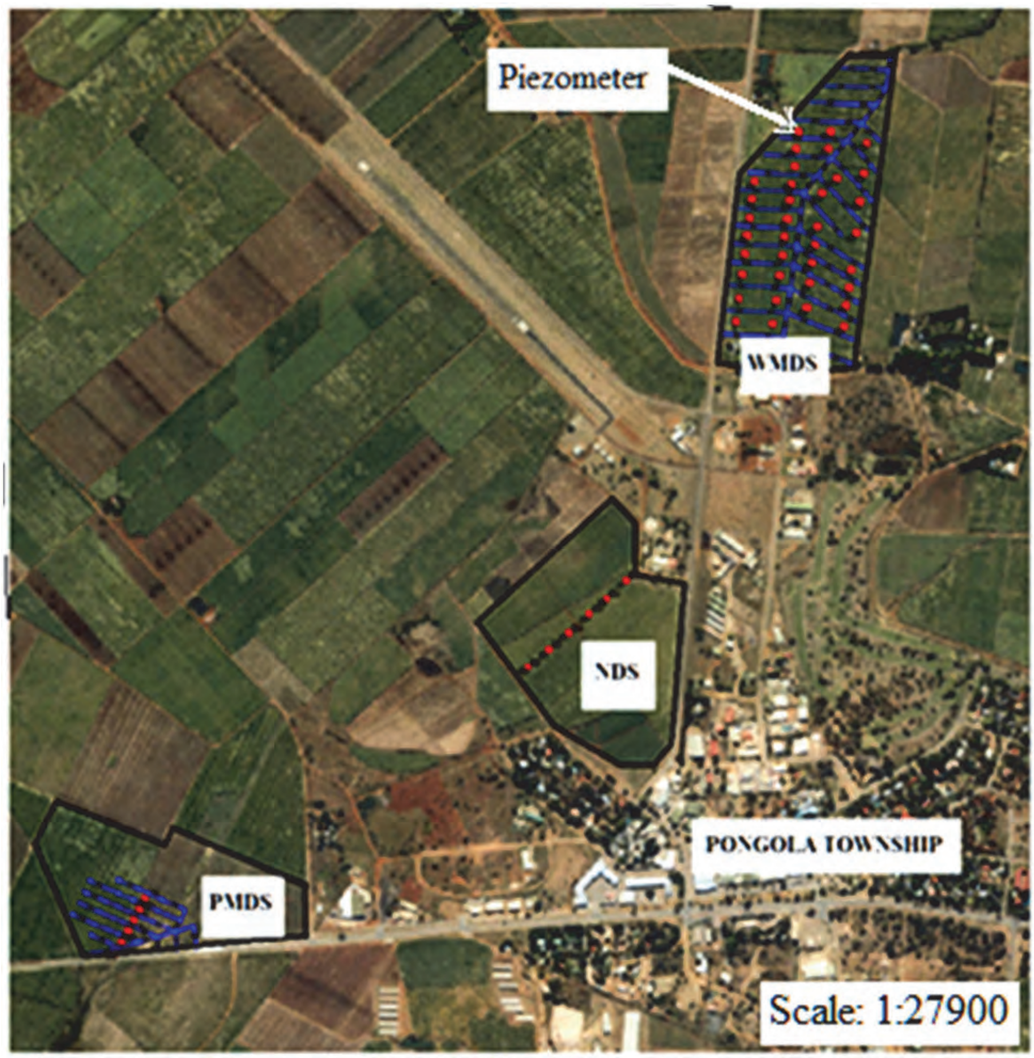


Figure 4-44 Location of the three study sites (WMDS = Well Maintained Subsurface Drainage System, NDS = No Subsurface Drainage System, PMDS = Poorly Maintained Subsurface Drainage System) and distribution of piezometers on each site

4.3.2 **Data available at the selected site**

Details of the existing subsurface drainage systems are given in Table 4-33 while the suggested maintenance requirements are shown in Table 4-34.

Table 4-33 Drainage system design parameters for the subsurface drainage systems at the two study sites (WMDS and PMDS) (Van der Merwe 2003)

Design Parameter	**Symbol**	**Value**	**Units**
Drain depth	W	1.8	m
Drain spacing	L	54 and 72	m
Design drain discharge	q	5	$mm.day^{-1}$
Design water table depth	z	1	m
Depth to impermeable layer	D_{il}	9	m
Drain pipe radius	r	55	mm

On the area indicated as “NDS” in Figure 4-44 (28 ha), no subsurface drainage system has ever been installed and as in the case of WMDS and PMDS, it is currently not known whether the natural drainage system at the site is effectively controlling the shallow water table depth and soil salinization within the root zone depth or not.

Table 4-34 Recommended subsurface drain maintenance (Van der Merwe 2003)

Age of the drainage system (Yrs)	**Maintenance frequency**
< 1	Once every 3 months
1 ≤ 2	Once every 6 months
> 2	Once every year

The selection of the three sugarcane fields (WMDS, PMDS, and NDS) was based on them having certain similarities, e.g. type of crop, crop stage, depth to impermeable layer, soil type and irrigation method as shown in Table 4-35

Table 4-35 Details of similar physical characteristics considered in the selection of the three study sites (WMDS, PMDS and NDS)

Physical characteristic	**Description**
Slope	<3%
Soil type	Clay and clay-loam soil
Depth to impermeable layer	9 m below the soil surface
Crops grown	Sugarcane
Type of irrigation	WMDS = Quick coupling sprinkler irrigation
	PMDS = Quick coupling sprinkler irrigation
	NDS = Centre pivot sprinkler irrigation

A total of 36 piezometers, most of them installed at 54 x 54 m grid nodes on the whole 32 ha field were used after a thorough reconnaissance survey of the whole study area. This translated to 55 piezometers per 50 ha, which was far more than the minimum sampling density suggested by FAO (2007).

The piezometers were manually augured (Figure 4-45a), using a 70 mm outside diameter auger to a depth of 1.7 m from the soil surface. A 50 mm internal diameter, class 4 PVC pipe with perforations, was then lowered in each piezometer to a depth of 1.7 m, while ensuring that a 30 cm length was above the ground level to prevent runoff water from flowing in. End caps were fitted to both ends of the pipe to prevent the intrusion of materials into the piezometer (Figure 4-45b). To prevent clogging of the perforations, coarse sand was back filled throughout the whole perforated section of pipe.

WTDs at each piezometer were located by gradually lowering an electronic dip meter in the piezometer until a sound was heard. Under laboratory conditions, the measurement error of the electronic dip meter was determined to be ±0.5 cm, which, according to Van Beers (1983), is within the acceptable range. Figure 4-45 (c) and (d) are demonstrations of how WTDs were measured.

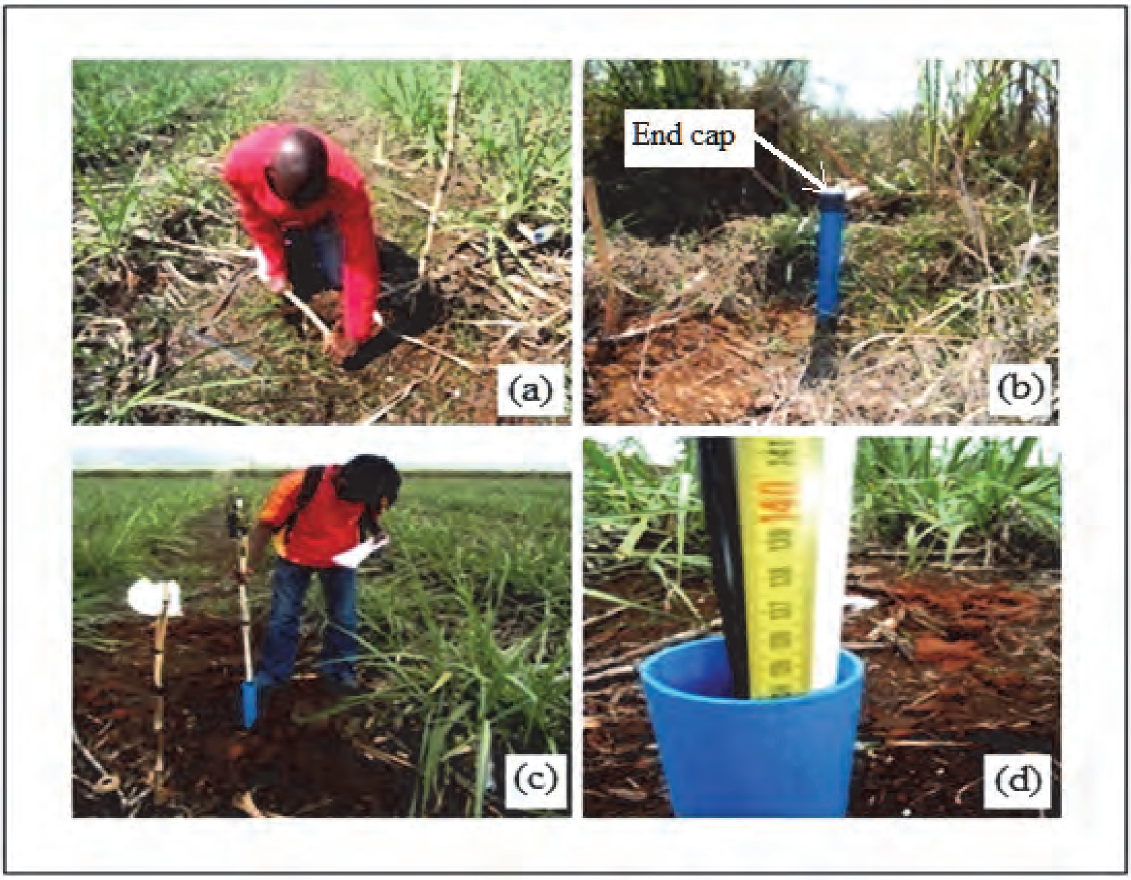


Figure 4-45 Installation of the piezometers and the measurement of groundwater table depth, using an electronic dip meter

For the first three weeks of the study (September 09 to 30, 2011), WTDs were monitored every day, after which (October 01 to November 30, 2011) a monitoring frequency of once in two days was found to be appropriate. However, during the summer months of December 2011 to February 2012, the water table monitoring frequency was reduced again to once per day due to frequent rainfall events.

The latitudes and longitudes of all the locations of the piezometers were taken using a GPS. Average WTDs at each piezometer for both the summer and winter seasons were calculated and recorded. This was followed by the preparation of an XYZ file using the Microsoft Excel, where X, Y and Z are latitude (m), longitude (m) and average WTD (m), respectively. The XYZ file was processed, using Surfer8 software to generate a water table map for the site. The classification of shallow water table affected areas was based on the 1.0 m WTD that the subsurface drainage system at the site was designed to maintain. Using this design water table depth, areas with WTD shallower than 1.0 m were considered to be affected, while those with WTD≥ 1.0 m from the soil surface were considered not to be affected.

To determine the effect of drainage conditions on WTD (i.e. subsurface drainage system maintenance level and presence and absence of artificial subsurface drainage systems), out of the 36 piezometers installed in WMDS, six were installed mid-way between drainage laterals. Similarly, in field PMDS, six piezometers were also installed mid-way between drainage laterals, while the same was done with six piezometers installed in NDS, since there was no subsurface drainage system on it.

Water table depths at each of the six piezometers in each field were averaged, as suggested by Manjunatha et al. (2004) and statistically compared for any significant differences, using the Analysis of Variance (ANOVA). In addition, cumulative frequencies (CF) of WTDs above the 1.0 m design water table depth were calculated.

4.3.3 **Measurement results**

- Saturated hydraulic conductivity

Soil hydraulic conductivity (K_{sat}) values were measured using the in situ method, i.e. the auger-hole method (Van Beers 1983), which according to Oosterbaan and Nijland (1994), is the most accurate and yet the simplest method, as opposed to laboratory methods. Prior to carrying out K_{sat} tests, five trenches were dug in the field (north, south, east, west and center) to a depth of 2.3 m from the soil surface. This was done to characterize any heterogeneities in soil layer boundaries and to determine the number and thicknesses of the soil profile layers from the soil surface. The field was then divided into three sections (upper, middle and lower sections). Three 70 mm diameter auger-holes were drilled in each of the upper and middle sections, while four auger-holes were drilled in the lower section. This made a total of 10 auger-holes drilled in the whole field and was done to determine the best possible mean K_{sat} value that could represent the whole field during model calibration, as recommended by Sobieraj et al. (2001).

The measurement procedure followed during the K_{sat} test is given by Van Beers (1983). It was observed that the auger smeared the surface of the auger-hole during the drilling process. The water level in the auger-hole was therefore left to stabilize for one day, in order to allow for a true water table to be established. On the following day, the water table depth in the auger-hole was determined and was followed by the bailing out of about one quarter of the water depth in the auger-hole. After which, water level readings in the hole were then taken every 10 seconds, using a Laser meter (HANNA Instruments) that was mounted on top of the access tube, as demonstrated in Figure 4-46.

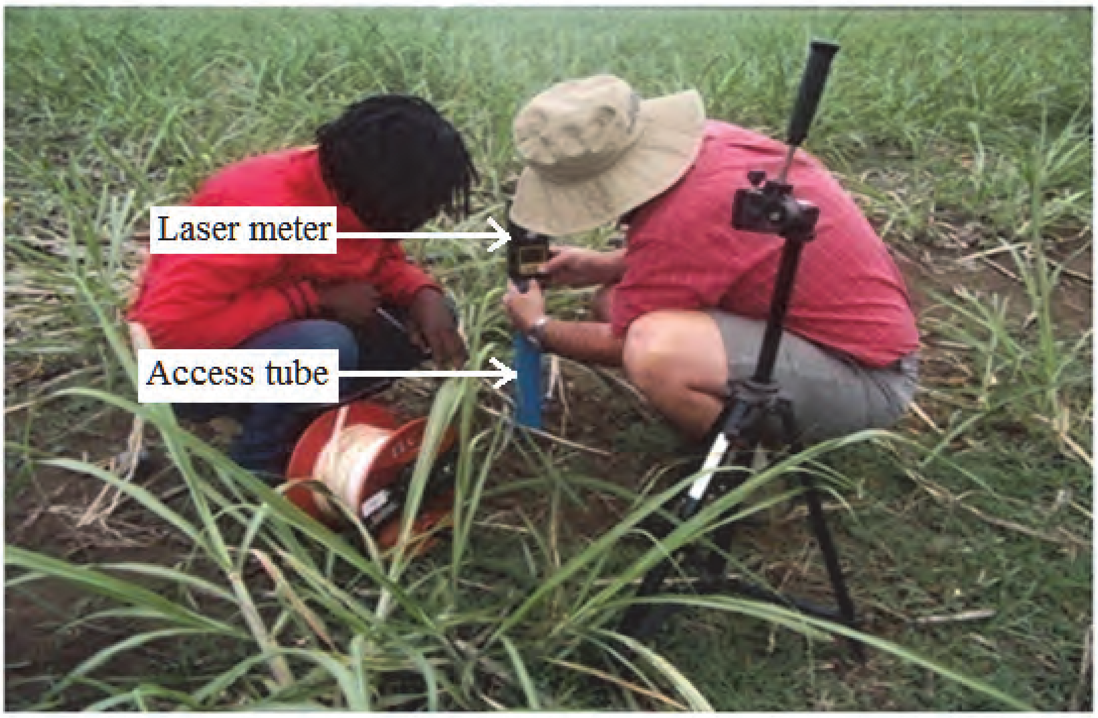


Figure 4-46 Measurement of K_{sat} using the auger-hole method

About five readings were taken successively at each auger-hole and average changes in water table depths (cm) per unit time (sec) were then calculated and recorded. Saturated hydraulic conductivity values in $m.day^{-1}$ were computed as (Ernest 1950):

$$K_{sat} = \frac{400a}{(20 + h/a)(2 - y/h)y}\frac{\Delta y}{\Delta t} \tag{4.1}$$

Where Δy is the rise in water level during the test (cm); Δt is the time taken for rise in water level measurement (sec); *a* is the radius of the auger-hole (cm); *h* is the depth of the water table to the bottom of the auger-hole (cm); *y* is the depth of water table to the beginning of the test reading (cm). Figure 4-47 is a section of one of the auger-holes, during the K_{sat} measurement, using the auger-hole method.

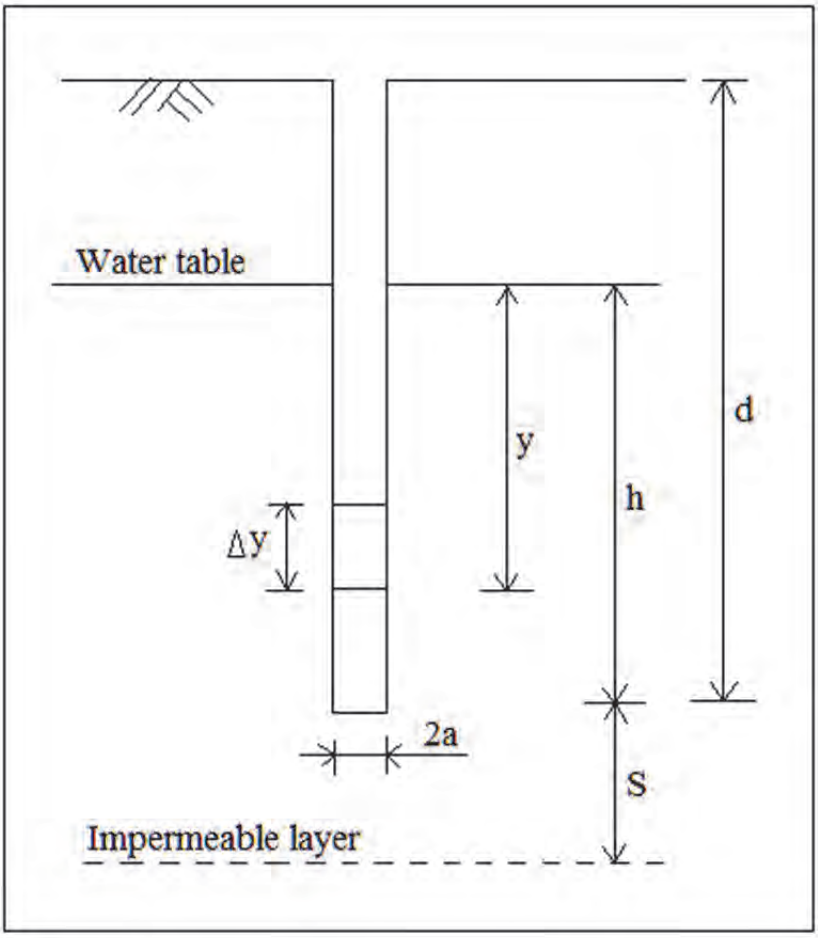


Figure 4-47 A section of one of the auger-holes where K_{sat} was measured, using the auger- hole method (after Van Beers 1983)

- Measurement of soil water characteristics

The DRAINMOD model requires the following relationships in order for it to establish a soil water balance: (i) water table depth and volume of water drained (ii) water table depth and upward flux and (iii) Green Ampt infiltration parameters and recharge (Singh et al. 2006). According to Skaggs (1978), the model calculates these parameters from the soil water characteristic data of the top soil layer, i.e. residual moisture content (θ) versus soil water pressure heads (*h*).

Soil water pressure heads (m) and their respective soil moisture contents ($cm^3.cm^{-3}$) were measured using a pressure plate at the University of KwaZulu-Natal School of Engineering laboratory. Richards (1948) and Klute (1986) found out that the pressure plate laboratory method can reliably measure soil water characteristics, when undisturbed soil samples are used.

Undisturbed soil samples were collected from the upper soil layer (0-40 cm) using 50 mm internal diameter and 50 mm long stainless steel rings. Refer to Figure 4-48 for the description of the laboratory set up.

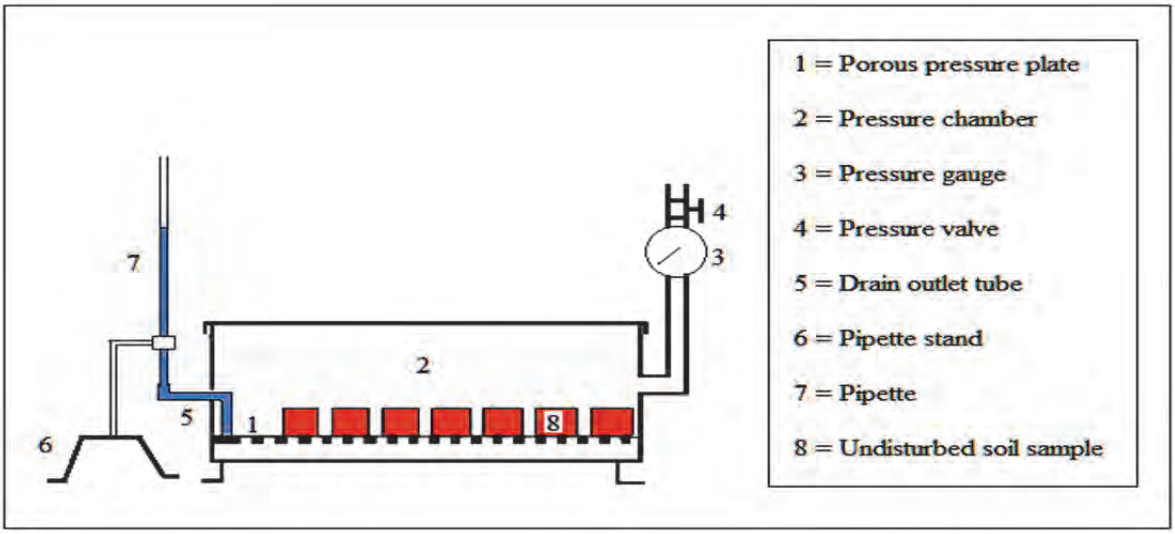


Figure 4-48 A schematic of the pressure plate used to measure soil water characteristics (after Warrick 2000)

Firstly, the soil cores and the porous pressure plate were fully saturated in a vacuum chamber for three days, after which, the soil cores were carefully weighed without subjecting them to any pressure. The soil cores were then placed on the porous plate in the pressure chamber and tightly closed. A 10 m pressure was set by loosening the pressure valve to increase the pressure in the pressure chamber to the set pressure, so that water could drain out of the soil sample, as a result of the applied pressure. The rise in water level draining from the soil samples through the pipette was left to stabilize, after which, the soil cores were then removed from the pressure chamber, weighed and placed back in the pressure chamber. The applied pressure was then increased and the same procedure was followed for increased pressures of 20, 40, 110 and 150 m. The 0 to 150 m pressure range was chosen because Skaggs (1978) highlights that the DRAINMOD model requires the very last soil moisture content ($cm^3.cm^{-3}$) to be calculated, after subjecting a soil sample to a pressure of ≥10 m, while the rest of the soil water contents can be calculated after subjecting the soil samples to smaller pressures.

The soil cores were then oven-dried at 105^{o}C for 24 hours and the soil water contents at each respective pressure setting were calculated as:

$$\theta_v = W_i \frac{\rho_{soil}}{\rho_{water}} \qquad (4.2)$$

Where θ_v is the volumetric soil water content ($cm^3.cm^{-3}$); W_i is the soil water content by mass ($g.g^{-1}$) (wet basis); ρ_{soil} is the bulk density of the soil sample ($g.cm^{-3}$); ρ_{water} is the density of water ($1g.cm^{-3}$) (Warrick 2002).

The Van Genuchten soil water retention model was fitted to the measured $\theta(h)$ data, using the RETC program (Van Genuchten et al. 1992) – a HYDRUS-2D soil water retention optimization program. In addition, mean moisture contents ($cm^3.cm^{-3}$) and their respective pressure heads (0-150 m) were calculated and imputed in DRAINMOD 6.1.

- Weather data acquisition

A fourteen year weather data (daily rainfall, potential evapotranspiration (PET) and minimum and maximum temperature) from 1998 to 2012 were obtained from the Pongola SASRI weather database, located about three kilometers from the study site. Weather data records for the previous years were incomplete for some days, hence they could not be used because the DRAINMOD model requires completed daily weather data records. The DRAINMOD weather file also requires the inclusion of the irrigation component ($mm.day^{-1}$) in the rainfall input file to account for any recharge to the soil system through irrigation. Hence, depths of irrigation water per irrigation day ($mm.day^{-1}$) were measured using a rain gauge installed at the study site. This was followed by the modification of the rainfall file to include irrigation depths for each irrigation day throughout the whole study period. The PET, rainfall and temperature data files prepared in the Microsoft Excel spreadsheet were then converted to the DRAINMOD model data input format, using the DRAINMOD model weather data utility program.

5. MODELLING FOR EXTRAPOLATION OF THE INTERACTION BETWEEN IRRIGATION, DRAINAGE PRACTICES AND THE NATURAL ENVIRONMENT

This chapter describes mainly the work on modelling of drainage behaviour using the DRAINMOD model and a sensitivity analysis that were carried out on the Drain spacing formula of the well-known and used formula of Hooghoudt. In the Vaalharts case study the SWAMP model was also used to facilitate the study as it is impossible to measure all the components of the soil water balance under water table conditions. How the models were used to obtain the water balance was explained in the Volume 1 of this report and hence will not be discussed further. Briefly, evaporation from the soil (E), transpiration from crops, water table uptake and drainage were simulated from soil water content, irrigation, rain, water table heights and crop yield (seed and biomass) measured in the crop fields.

As already alluded to in previous reports, DRAINMOD is a widely applied drainage research, design and management model. DRAINMOD has been under development and in use for more than three decades now (Skaggs 1978, Skaggs 1991) and has found worldwide application (Jin and Sands 2003; Wang et al. 2006; Luo et al. 2001). Compared to many hydrologic models, DRAINMOD is easy to use, requires relatively few inputs, and yet provides quite accurate predictions. In the last two decades, many researchers have extensively tested the model for different climatic conditions, soil types, and farming practices (e.g. Skaggs et al. 1981; Fouss et al. 1987; Sabbagh et al. 1993.). In these evaluations, the model is calibrated and validated against field measured water table and subsurface drain flow data. There are versions of DRAINMOD applicable to cropped lands, forestry areas, agricultural catchments, and even under snowbound conditions. Its structure allows for the simulation of drainage behaviour under a variety of conditions, especially cropped lands. DRAINMOD can be applied either for design purposes as in deciding on the spacing and depth of placement of tube drains, or for monitoring water table behaviour, under a given set of climate, soil and cropping scenarios. It must be emphasised that, just like any model, the DRAINMOD model needs to be calibrated and then validated before use or application. DRAINMOD simulations are particularly sensitive to the (lateral) saturated hydraulic conductivity (Ksat) of the soil, thus extra care must be exercised in determining this at the field level.

Calibration is the process where-by default model input parameters are systematically adjusted to attain the best possible agreement between simulated and observed data sets, whereas validation is the process of testing the model's reliability in making appropriate predictions based on the calibrated parameters (Singh et al*.* 06). It is recommended that two independent data sets be used during the calibration and validation periods, in order to avoid ambiguities when making recommendations concerning the model's dependability (Schaap et al. 2001; Dayyani et al. 2009; Dayyani et al. 2010). Therefore, the October 1998 to September 1999 water table depth (WTD) and drainage discharge (DD) data were chosen to be used for calibration, while the data set from September 2011 to February 2012 was used for validation purposes. The calibration procedure adopted in this study was similar to that of Dayyani et al. (2010) and Dayyani et al. (2009). It should be pointed out that the K_{sat} values were assumed not to have gone through significant changes during the 1998-2012 period. This was because the cropping system and cultivation practices at the site had not changed.

Literature shows that the DRAINMOD model can be calibrated on a trial-and-error basis (Dayyani et al. 2010), by adjusting any or a set of input parameters presented in Table 5-1, until an optimal agreement between observed and simulated data sets is attained.

Table 5-1 DRAINMOD model calibration parameters based on literature

Calibration parameter(s)	Source(s)
Lateral hydraulic conductivity, maximum soil surface storage depth, crop root depth	Zhao et al. (2000)
Monthly ET factors	Jin and Sands (2003)
Drainage coefficient, saturation soil water content, residual soil water content, lateral saturated hydraulic conductivity of soil layers	Haan and Skaggs (2003) Singh et al. (2006)
Vertical hydraulic conductivity of the bottom soil layers	Wang et al. (2006)

The lateral saturated hydraulic conductivity ($K_{L\text{-}sat}$) for the bottom soil layer was set at twice the vertical saturated hydraulic conductivity (K_{sat}), while $K_{L\text{-}sat}$ for the top soil layer was set equal to the K_{sat}, as suggested by Skaggs (1978). In addition, considering that crop residues were observed on the soil surface at the study site and that crop residues increase soil surface water storage depth (Gilley 1994), the soil surface water storage depth was set at 2 cm, contrary to the default 0.5 cm depth.

Time series simulations of WTDs and DDs were run, using the DRAINMOD model after every alteration of an input parameter or set of parameters. Simulated WTDs and DDs were then compared to observed WTDs and DDs. Initially, the agreement between the two data sets were assessed by mere visual judgments from WTD and DD hydrographs (Moraisi et al. 2007; Dayyani et al. 2009), and later on, quantitative statistical model performance parameters, Mean Absolute Error (MAE), Pearson's product-moment correlation (R^2), and

Coefficient of Residual Mass (CRM), were employed, as suggested by Legates and McCabe (1999) and Vazquez et al. (2002). Statistical parameters in both the calibration and validation periods for both WTD and DD data sets were calculated and tabulated.

5.1 Vaalharts irrigation scheme

In order to carry out investigations the computer simulation model DRAINMOD was selected. DRAINMOD is based on a water balance in the soil profile and uses climatological records to simulate the performance of drainage and water table control systems. The model was developed specifically for shallow water table soils and approximate methods are used to quantify the hydrologic components: subsurface drainage, sub irrigation, infiltration, evapotranspiration (ET) and surface runoff. Soil property inputs include the saturated hydraulic conductivity (by layers), the relationships between drainage volume and water table depth, and information concerning upward flux from the water table. The effective root zone depth as a function of time is also an input. Hourly precipitation and daily maximum and minimum temperatures are read from weather records and the water balance is conducted on an hour by hour basis. Summaries of the model predictions for hydrologic components such as rainfall, infiltration, drainage, ET, etc., are available on a daily, monthly or annual basis. The effects of water management system design on yields can also be investigated.

Of the four sites, Site 4 (F Block- 4-6F7) was selected to set up and calibrate the DRAINMOD model. Setting up DRAINMOD model requires setting up modules for soils and weather. The soils data was collected during a previous WRC project (Van Rensburg et al. 2012) while the weather data was collected from nearby weather station.

The soils at the site were described by referring to baseline data such as texture, bulk density, saturated hydraulic conductivity (Ksat), cation exchange capacity (CEC), electrical conductivity of the saturated extract at the start of the project (ECe) and sodium adsorption ratio (SARe) of the saturated extract at the start of the project.

In order to obtain some of the inputs required for the soil water balance the SWAMP and EnDrain models were used to supplement the measured inputs with data such as evaporation from the soil (E), transpiration from crops, water table uptake and drainage simulated from soil water content, irrigation, rain, and water table heights.

5.1.1 **DRAINMOD model calibration, evaluation and statistical analysis for Site 4**

In order for DRAINMOD to be used effectively it needs to be calibrated. Calibration is the process where-by default model input parameters are systematically adjusted to attain the best possible agreement between simulated and observed data sets, whereas validation is the process of testing the model's reliability in making appropriate predictions based on the calibrated parameters (Singh et al. 2006). It is also stated that literature shows that the DRAINMOD model can be calibrated on a trial-and-error basis (Dayyani et al. 2010), by adjusting any or a set of input parameters, until an optimal agreement between observed and simulated data sets is attained.

The parameters which can be adjusted according to literature are lateral hydraulic conductivity, maximum soil surface depth, crop root depth (Zhao et al.,2000), Monthly ET factors (Jin and Sands 2003), drainage coefficient, saturation soil water content, residual soil water content, lateral saturated hydraulic conductivity of soil layers (Haan and Skaggs 2003; Singh et al. (2006)) and vertical hydraulic conductivity of the bottom layers, (Wang et al. 2006)

In addition the lateral saturated hydraulic conductivity (KL-sat) for the bottom soil layer needs to be set at twice the vertical saturated hydraulic conductivity (Ksat), while KL-sat for the top soil layer was set equal to the Ksat, as suggested by Skaggs (1978).

The process involved in calibrating DRAINMOD involves running time simulations of water table depths and drainage discharges. Simulated water table depths (WTDs) and drain discharges (DDs) are then compared to observed water table depths and drain discharges. The DRAINMOD model needs to be run after every alteration of an input parameter or set of parameters and after each run simulated WTDs and DDs need to compared to observed WTDs and DDs.

Initially, the agreement between the two data sets are to be assessed by mere visual judgments from WTD and DD hydrographs (Moraisi et al. 2007; Dayyani et al. 2009), and later on, quantitative statistical model performance parameters, Mean Absolute Error (MAE), Pearson's product-moment correlation (R2), and Coefficient of Residual Mass (CRM), were employed, as suggested by Legates and McCabe (1999) and Vazquez et al. (2002).

The period for which the model is to be run is for the period 29/06/2007 to 7/05/2009.

5.1.2 **SWAMP**

Site 8: Irrigation and drainage results are presented in Figure 5-1 on an event basis stretching over four continuous crop growing seasons, viz. peas, groundnut, wheat and cotton. Irrigation events were scheduled using a subjective method. These methods are based on the farmer's own intuitive (tacit knowledge), and is not based on scientific methodologies supported by atmospheric, soil water or crop measurements (Montagu and Stirzaker 2008). Soil water content results in Figure 5-1 showed that the intuitive method worked very well in the first season, except when the first large rain event occurred in the latter part of the season. Rainfall was relative high during the groundnut-season and the farmer was unable to synchronise it with the irrigation applications. This caused a sudden rise of the water table during the middle of growing season. Rainfall was very low in the following wheat season, and the corresponding irrigations caused a slight decline in the soil water contents compared to the end of the previous seasons. The water table heights showed a sharp increase during the last third of the wheat season, indicating over-irrigation during this period. Unfortunately the water table height was not measured near the end of the wheat season and the beginning of the cotton season. The water table heights oscillated between 1620 mm and 1270 mm from the surface during the cotton season. Soil water contents fluctuated between 450 mm and 550 mm during the corresponding period.

Results of the seasonal soil water balance computed with the aid of the SWAMP model are summarised in Table 5-2. As expected from semi-arid climate, rainfall varied considerably amongst the winter and summer seasons. Wetter conditions prevailed in the first winter season (202 mm) compared to the second winter season (29 mm). Both summer seasons were relative wet with groundnuts that received 61 mm more than cotton. Irrigations varied between 334 mm and 752 mm. Adding rainfall and irrigation give a perspective on the water supply conditions; 546, 877, 781 for peas, groundnuts, wheat and cotton, respectively. ET simulated with the SWAMP model varied between 432 mm and 537 mm. This is considerably lower than the total water supply by rain and irrigation. Conditions like this support high drainage, but this is not evident from the artificial drainage results which was zero. Inspection of the drainage lateral showed that it was completely blocked. This explains the rise of the water table depths discussed earlier.

The results of the salt balance components, derived from the SWAMP model, are presented in Table 5-2. From this it is clear that rainfall is insignificant salt source when compared to the other sources; it contributes only to about 1% of the total salt additions that amounted to of 11 516 kg ha-1 over the two years. This is understandable because the site is far from industries and the sea that can increase salt load of rain. Fertilizers, on the other hand, are a significant source of salt as indicated by its contribution of 13% (153 kg ha-1) during the study. Irrigation water application was the greatest salt contributor; a total of 10 364 kg ha-1 was transported via irrigations, i.e. 90% of the total salt added to the site. Fortunately 95% of the total salts gained during the study period were removed through natural drainage and zero by the artificial drains due to its poor maintenance. The model does not concern precipitation as a salt-removal mechanism.

From the overall water and salt balance results it is clear that the farmer adopted an over-irrigation strategy, hoping intuitively for a water-stress free environment. Obtaining insurances this way poses fundamental questions on the utilization of scares water sources through irrigation and drainage and its impact on the environment.

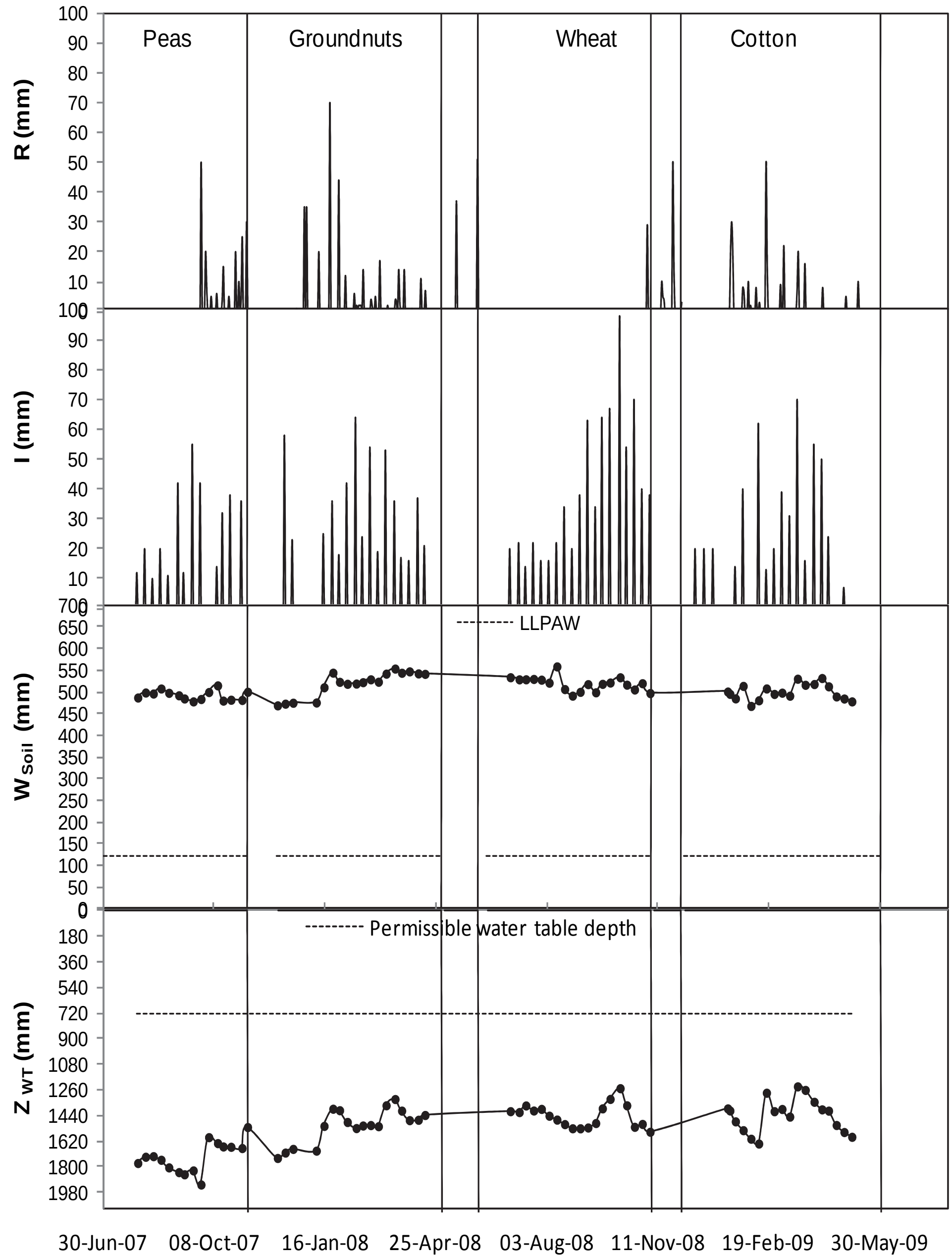


Figure 5-1 Rainfall (R), irrigation (I), soil water content of a 2000 mm profile (W_{Soil}), water table depth (Z_{WT}), lower limit of plant available water (LLPAW) and permissible water table depth for measuring point v6 (Van Rensburg et al. 2012)

Table 5-2 Soil water and salt balance of measuring point v6 for the four growing seasons (Data from Van Rensburg et al. 2012).

Crop	Soil water balance (mm)											
	ΔW	Gains				Losses					Internal drainage	
		R	I	+D	Total	E	T	-D	Total	ET	WT_{Uptake}	P
Peas	13	202	344	4	563	41	496	4	541	537	169	-165
Groundnut	72	334	543	0	949	34	436	335	805	470	222	-557
Fallow	-8	91	0	0	91	24	0	74	98	24	0	-74
Wheat	-36	29	752	0	872	68	435	315	818	503	278	-594
Fallow	3	94	0	0	94	29	0	61	90	29	0	-61
Cotton	-23	273	501	0	774	70	362	365	797	432	233	-597
Salt balance (kg ha^{-1})												
	ΔS_{Soil}	Gains					Losses				Internal movement	
		S_R	S_I	S_D	S_F	Total	S_T	S_{AD}	$\pm S_D$	Total	S_{WTU}	S_P
Peas	899	30	1574	0	214	1818	0	0	-919	-919	2293	3212
Groundnut	99	50	2606	0	237	2893	0	0	-2794	-2794	2434	5228
Fallow	-456	14	0	0	0	14	0	0	-470	-470	0	470
Wheat	477	4	3779	0	267	4050	0	0	-3573	-3573	3340	6913
Fallow	-345	14	0	0	0	14	0	0	-359	-359	0	359
Cotton	-90	41	2405	0	281	2727	0	0	-2817	-2817	2792	5607

Water balance components: ΔW_{Soil} = change in soil water content; R = rainfall; I = irrigation; E= evaporation; T = transpiration; D = simulated natural drainage with a net gain indicated with (+D) or loss by (-D); WTU = water table uptake (WTU); P = percolation into the water table. Salt balance components: ΔS_{Soil} = salt changes in the soil; salt additions through S_F = fertilizers, S_R = rainfall, S_I = irrigation and $+S_D$ natural drainage through capillary rise; salt removal through S_{AD} = artificial drainage system and $-S_D$ = natural drainage from the potential root zone (2000 mm). S_P is the movement of salt into the water table through percolation and S_{WTU} = simulated capillary rise.

Site 12: In contrast to the previous case study, this farmer made use of an objective scheduling method. Capacitance probes were installed to a soil depth of 800 mm, which allows for the monitoring of the water regime over six positions along the probe. Probes were installed near both the measuring points (v11 and v12). However, the project team did not interfere with the scheduling of the crops and the farmer was allowed to make its own scheduling decisions. The resulting soil water regimes at the two measuring points, measured independently by the project team, are presented in Figure 5-2. Results of the seasonal soil water balance, computed with the aid of the SWAMP model, are summarised in Table 5-3 for v11 and Table 5-4 for v12. The water regime results confirmed that the rainfall was similar at both measuring points (v11 and v12), but the irrigation amounts were slightly higher in v11 compared to v12. Despite the higher irrigations, the water table of v11 remained deeper than in the case of v12. This trend was consistent over the entire two years of the study. The phenomenon can be explained by the design of the in-field drainage system. In the case of v12 the laterals were spaced at intervals of 50 m, compared to the single line at v12. Water accumulated in v12 due to the poor drainage design.

The slightly higher irrigations in v11 can be explained by the scheduling method used. The capacitance probes measures the top 800 mm soil depth and the soil dry at a faster rate at v11 due to the lower water table depth. Thus, more water is applied to recharge the apparent greater deficit in the topsoil of v11 compared to v12. However, the model estimated that the water table supplied between 93 and 263 mm to the crops over the four seasons. Longer probes will give a better understanding of the water regime over the entire rooting zone and more water could be saved by reducing the irrigation amounts. Several studies showed that water tables can contribute up to 50% of the total crop water requirements.

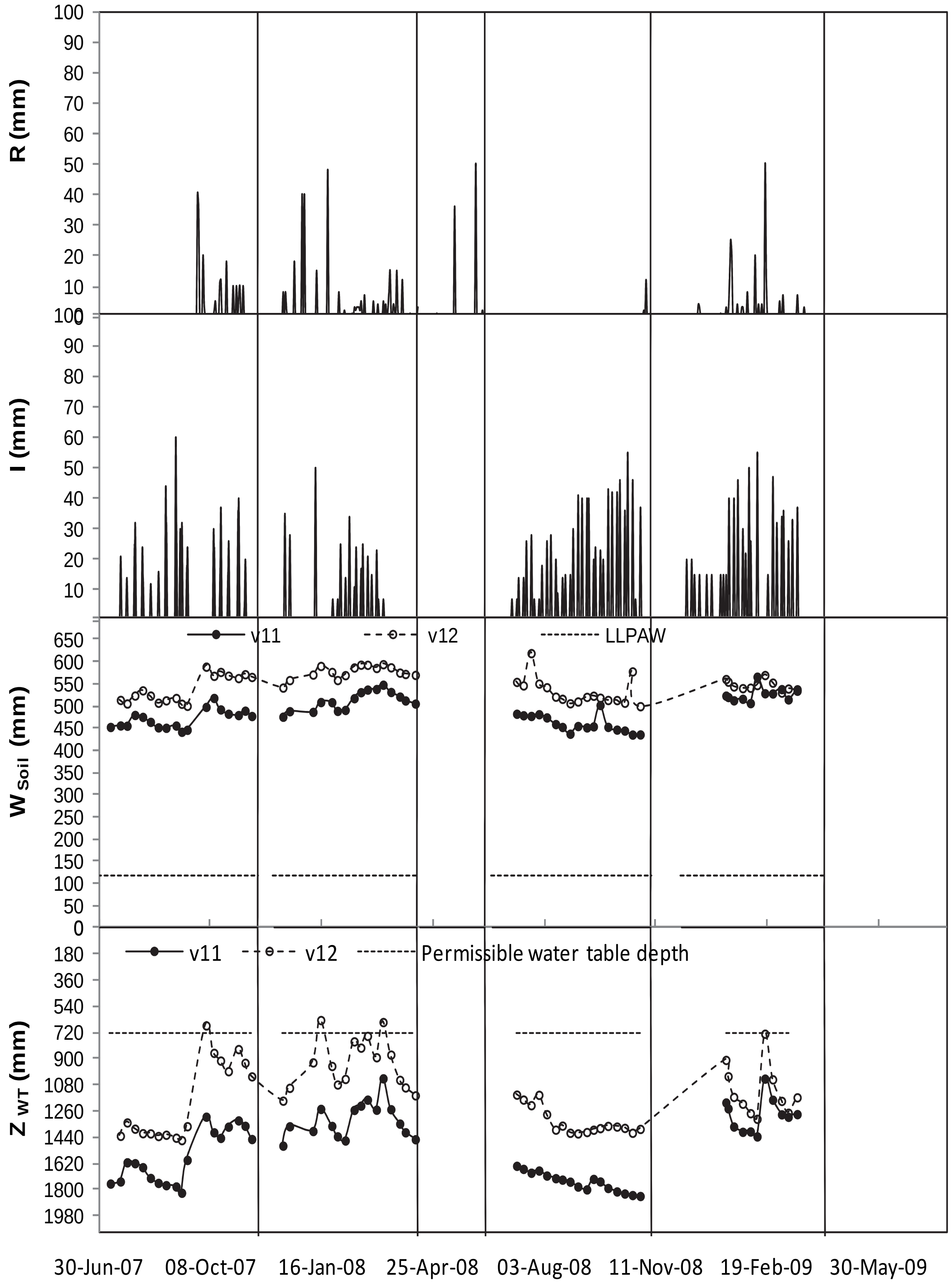


Figure 5-2 Rainfall (R), irrigation (I), soil water content of a 2000 mm profile (W_{Soil}), water table depth (Z_{WT}), lower limit of plant available water (LLPAW) and permissible water table depth for measuring points v11 and v12 (Van Rensburg et al. 2012).

Table 5-3 Soil water and salt balance of measuring point v11 for the four growing seasons (Data from Van Rensburg et al*.* 2012).

Crop	**Soil water balance (mm)**												
	ΔW	**Gains**				**Losses**						**Internal drainage**	
		R	**I**	**+D**	**Tota**	**E**	**T**	**-D**	**AD**	**Tota**	**ET**	**WT_{Uptake}**	**P**
Wheat	25	19	362	16	718	53	57	0	68	694	62	229	66
1^{st} Maize	30	31	178	29	783	48	56	0	141	755	61	357	65
1^{st} Maize dry	-23	90	0	0	90	31	0	48	34	113	31	0	48
Barley	-47	14	459	15	625	57	52	0	90	671	58	290	138
2^{nd} Maize	14	20	375	93	673	37	48	0	132	657	52	315	222
Salt balance (kg ha^{-1})													
	ΔS_{So}	**Gains**					**Losses**					**Internal moveme**	
		S_R	**S_I**	**+S**	**S_F**	**Tota**	**S_T**	**$-S_D$**	**S_{AD}**	**Tota**	**-**	**S_{WTU}**	**S_P**
Wheat	1437	29	165	60	419	216	0	0	728	729	-	2147	2087
1^{st} Maize	-121	47	868	10	419	134	0	0	146	146	-	3534	3524
1^{st} Maize dry	-220	14	0	0	0	14	0	175	461	221	-	0	1758
Barley	2442	2	216	93	286	339	0	0	947	947	-	2918	1985
2^{nd} Maize	216	30	199	0	362	229	0	786	138	217	-	3304	4090

Water balance components: ΔW_{Soil} = change in soil water content; R = rainfall; I = irrigation; E= evaporation; T = transpiration; D = simulated natural drainage with a net gain indicated with (+D) or loss by (-D); WTU = water table uptake (WTU); P = percolation into the water table. Salt balance components: ΔS_{Soil} = salt changes in the soil; salt additions through S_F = fertilizers, S_R = rainfall, S_I = irrigation and $+S_D$ natural drainage through capillary rise; salt removal through S_{AD} = artificial drainage system and $-S_D$ = natural drainage from the potential root zone (2000 mm). S_P is the movement of salt into the water table through percolation and S_{WTU} = simulated capillary rise.

Table 5-4 Soil water and salt balance of measuring point v12 for the four growing seasons (Data from Van Rensburg et al. 2012)

Crop	Soil water balance (mm)												
	ΔW	Gains				Losses						Internal drainage	
		R	I	+D	Tot	E	T	-D	AD	Tot	ET	WT_{Uptake}	P
Wheat	52	19	321	22	734	51	56	0	67	683	61	355	135
1st Maize	29	31	172	31	803	49	58	0	141	771	63	451	134
1st Maize dry	-15	90	0	0	90	30	0	41	34	105	30	0	41
Barley	-55	14	428	65	507	63	40	0	90	561	47	318	253
2nd Maize	-26	20	339	25	569	36	42	0	132	597	46	334	309
Salt balance (kg ha^{-1})													
	ΔS_{Soil}	Gains					Losses					Internal moveme	
		S_R	S_I	$+S_D$	S_F	Tot	S_T	$-S_D$	S_{AD}	Tot	-	S_{WTU}	S_P
Wheat	1168	29	146	0	419	191	0	34	715	749	-	4850	4884
1st Maize	-125	47	839	0	419	130	0	109	146	256	-	5517	6615
1st Maize dry	-198	14	0	0	0	14	0	154	461	200	-	0	1540
Barley	1965	2	215	50	286	294	0	0	947	947	-	3774	3270
2nd Maize	-844	30	180	0	362	219	0	165	138	304	-	2853	4508

Water balance components: ΔW_{Soil} = change in soil water content; R = rainfall; I = irrigation; E= evaporation; T = transpiration; D = simulated natural drainage with a net gain indicated with (+D) or loss by (-D); WTU = water table uptake (WTU); P = percolation into the water table. Salt balance components: ΔS_{Soil} = salt changes in the soil; salt additions through S_F = fertilizers, S_R = rainfall, S_I = irrigation and $+S_D$ natural drainage through capillary rise; salt removal through S_{AD} = artificial drainage system and $-S_D$ = natural drainage from the potential root zone (2000 mm). S_P is the movement of salt into the water table through percolation and S_{WTU} = simulated capillary rise.

5.2 **Breede River Irrigation Scheme**

Four farms were originally selected for investigation but production data was only received from one farmer and this site was selected for the case study. . The farmer wanted the area of 30 ha drained to establish vineyards.

The drainage system that was designed has a herringbone lay-out as shown in

Figure 4-9 and was designed for drainage discharge of 6.1 mm/day. The system has 2 collector drains that deliver the water into an open drainage channel that crosses neighbouring farms until it reaches the Breede River.

A summary of the design data is shown in Table 4-28. Analysis of the profile data resulted in a suggested drain depth of 2 m at a spacing of 60 m, which is approximately double the theoretical calculated value. The final design consisted of field drains with a diameter of 75 mm leading into collector drains ranging in size from 75 mm to 200 mm. The total cost of the system to drain 30 ha was R109 917.34 (in 2000). The cost of the system in present day terms, is R618594 (2014), which is more than R20000 per ha.

Four continuous logging water content probes installed on the drained area were selected for monitoring. During the field visit to establish the locations of the probes, it was found that the drainage system had not been installed by the previous owner of the farm according to the design of the Department of Agriculture. Instead of the herringbone lay-out of the design done by the technicians from the Department of Agriculture, a much simplified subsurface system at nearly double the design spacing was installed, disposing water into an existing surface drain (see Figure 5-3 Locations of monitoring probes relative to the drainage system at the Breede River Site).

The locations of the probes are also shown in Figure 5-3 Orchards have been developed on the areas where probes G6 and G8 are located since the time that the aerial photograph used as background in the figure was taken. Blocks F1 and F2 are irrigated with micro sprinklers and block G6 and G8 with drip irrigation.

Table 5-5 Drainage design data for the Breede River site

Item	Value
Average depth to impermeable layer	2 m
F factor	0.8 x 0.001
Maximum average monthly rainfall	118 mm (Bothashalt weather station) (31 days/month)
Hydraulic conductivity of soil layer above drain (K1)	4.1 mm/day
Hydraulic conductivity of soil layer below drain (K2)	3.9 mm/day
Design drain discharge	= f x rainfall per day x 2 x 1 = 6.090 mm/day Practical: 6.1 mm/day
Proposed drain depth to pipe bottom (b)	2 m
Minimum drained soil depth between drains (a)	1 m
Water depth above the drain, between drains (h)	1 m
Depth of the impermeable layer below the drain (D)	0.2 m
Design drain spacing	60.9 m
Selected practical drain spacing (L)	60 m
Total cost of system (2000)	R109 917.34

The orchard at probe G6 was planted only in 2012 and no probe data was available yet for this reporting period. For the other 3 probes, soil water content and climate (ETo and rainfall) data was collected over the 3 month period (September to November 2012).

Figure 5-3 Locations of monitoring probes relative to the drainage system at the Breede River Site

The soil at this site has a much larger fraction of stone ("spoelklip") occurring in the profile. Infiltration rates are high and the soil water content changes rapidly after irrigation events. The original soil investigations showed free water occurring in profile holes at a depth as shallow as 0.8 m, enforcing the necessity of the drainage system at the correctly designed spacing.

The probe data from blocks F1 and F2 had shown that the farmer is managing the root zone well,; however, in block F1 there has been a steady increase in water content of the deeper soil layers (0.8 m depth) which could be due to the inadequacy of the incorrectly installed drainage system. Block G8 is being over-irrigated, with the farmer's strategy of frequent small applications (especially since 1 November) leading to high water content in the root zone and also in the buffer zone. The data also showed how the micro sprinklers used in blocks F1 and F2 are vastly more suited to the soil than the drip irrigation used in block G. The micro sprinklers spread the water on the soil surface while the drip irrigation leads to highly concentrated point applications that infiltrates rapidly to the deeper layers of the soil profile.

5.2.1 **Technical modelling**

In order to assess the feasibility of the drainage system installation, a number of scenarios were modelled. From an engineering perspective, the following 2 scenarios were modelled:

- The performance of the drainage system as originally designed (60 m spacing), in terms of the discharge and water table draw down, and
- The performance of the drainage system as installed by the farmer (100 m spacing), in terms of the discharge and the water table draw down.

From a financial perspective, both these scenarios were compared with the whole farm situation should the drainage system not be installed at all.

The performance of the drainage systems was evaluated by using the EnDrain model (Oosterbaan 1996). The computer program calculates the discharge, hydraulic head or spacing between parallel subsurface drains: pipe drains or open ditches, with or without entrance resistance.

The calculations are based on the concept of the energy balance of groundwater flow as published by Oosterbaan et al. (www.waterlog.info/Articles). However, the traditional concepts based on the Darcy and waterbalance (continuity) equations are also used.

The program allows for the presence of three different soil layers with different hydraulic permeabilities: one layer above and two below drain level. The last two layers can also have different horizontal and vertical permeabilities. The variables used in the program are defined in Figure 5-4.

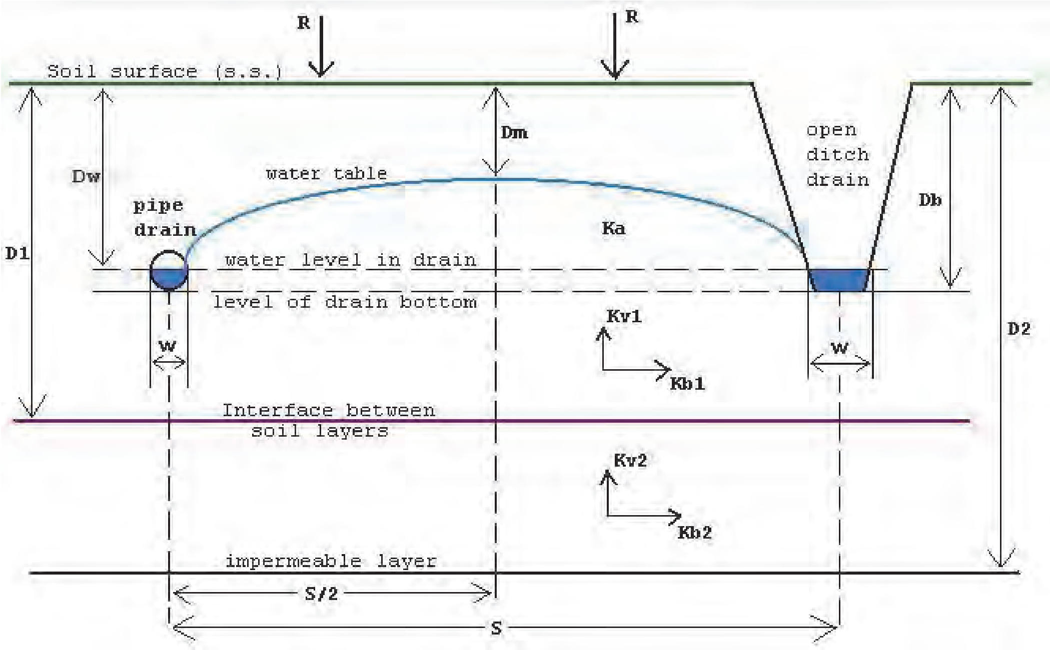


Figure 5-4 Definition of inputs for the Endrain model

The inputs for the first scenario (designed drain spacing of 60 m) are shown in Figure 5-5. The scenario was modelled for the 75 mm perforated drainage pipes as specified in the design of the Department of Agriculture.

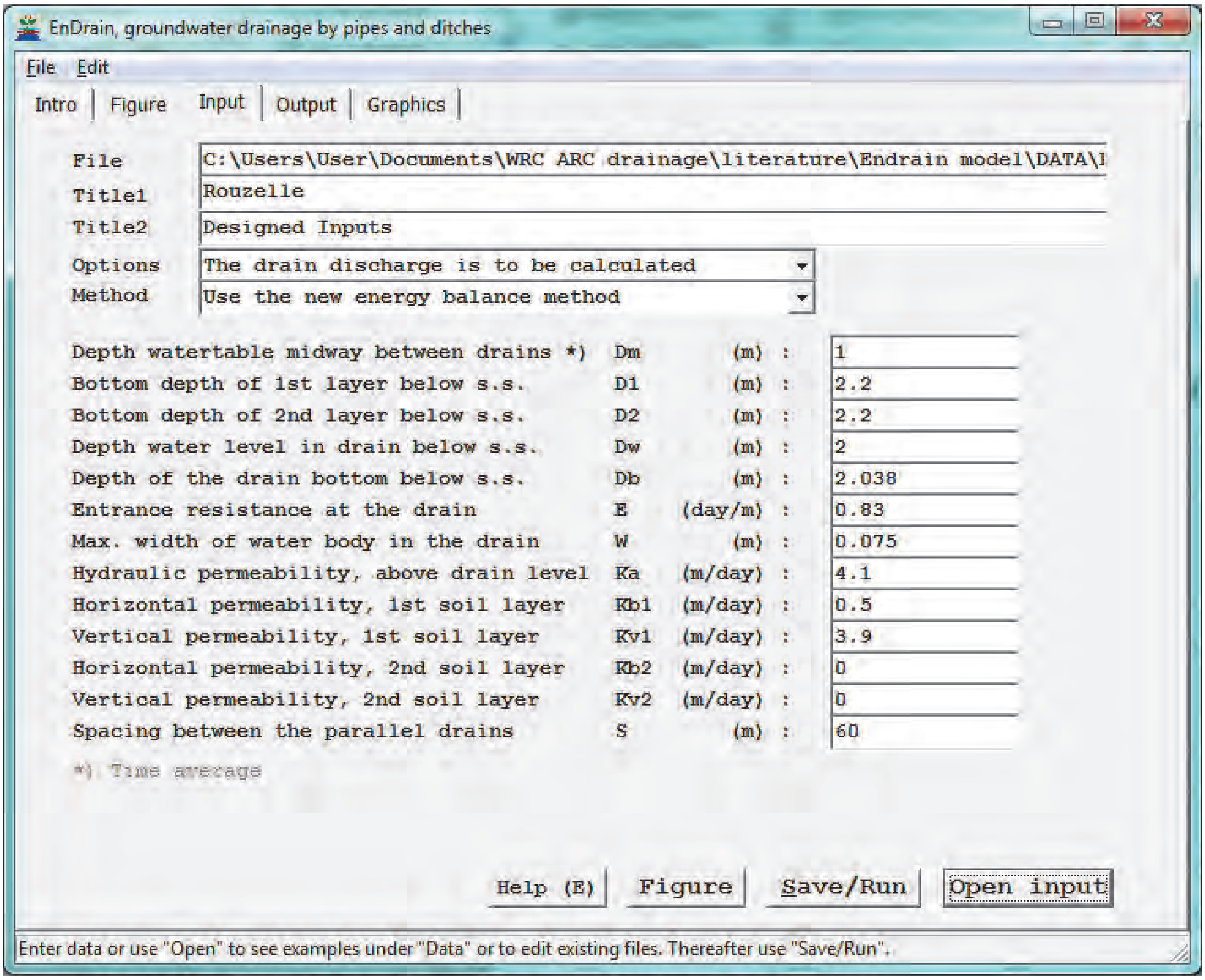


Figure 5-5 Endrain model inputs for Breede case study scenario 1

The results confirmed that the design was correctly done and that the system would be able to discharge 6.19 mm per day (compared to the design requirement of 6.09 mm/day used by the Department) and it would draw the water table depth down to 1 m below the soil surface according to the energy balance method. The more conservative Darcy equation showed that the water level would only be drawn down to 0.829 m below the soil surface.

The inputs to run the Endrain model for the situation as found in the field, where the farmer installed a much simplified system of pipes 160 mm in diameter (scenario 2), are shown in Figure 5-6. In this case the drain spacing was set to 100 m.

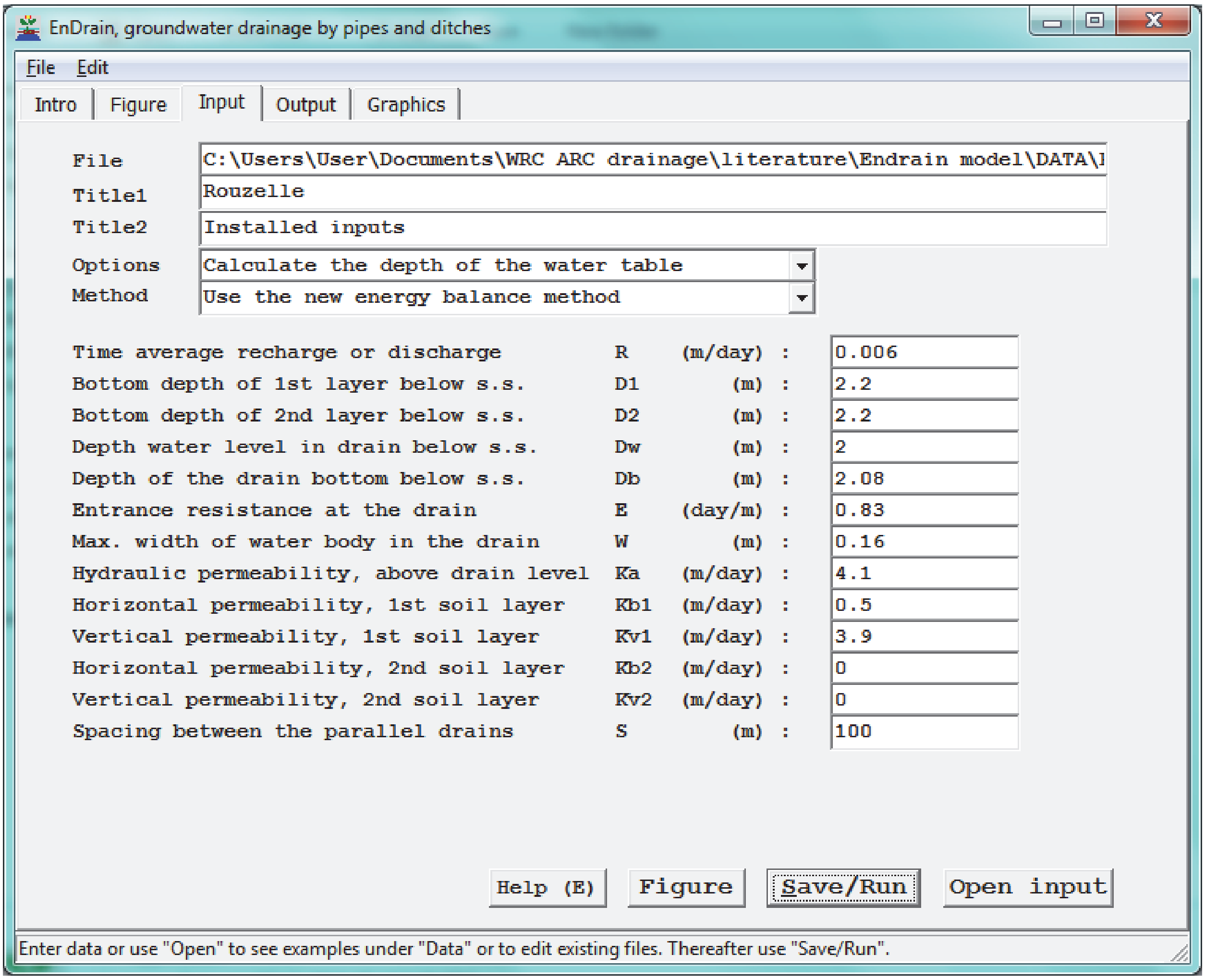


Figure 5-6 Endrain model inputs for Breede case study scenario 2

The results of the simulation showed that the installed system will only be able to draw the water table depth midway between the drains down to 0.36 m using the energy balance equation (or possibly as little as 0.08 m using the Darcy equation). Furthermore, the discharge capacity of the system is reduced to 2.45 mm day (compared to the 6.09 mm/day design requirement).

The results of both scenarios are graphically presented in Figure 5-7 and Figure 5-8. Note that the installation depth of the drains was set at a depth of 2 m for both scenarios.

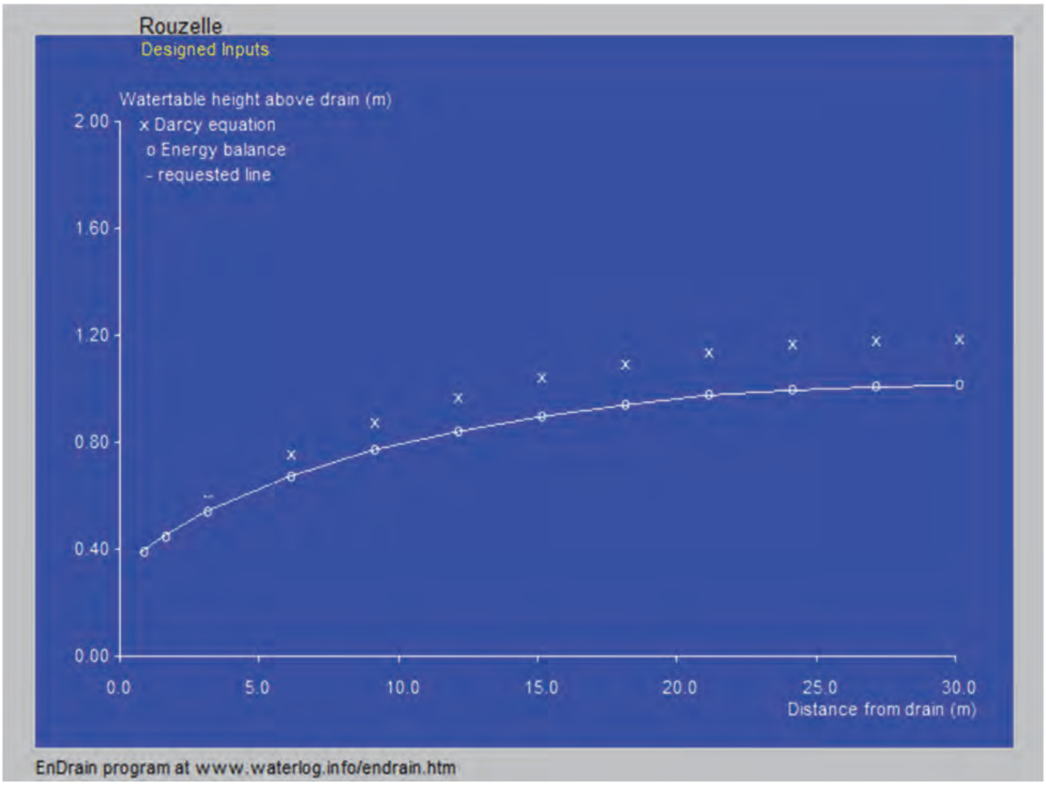


Figure 5-7 Breede River case study – modelled results for designed values (scenario 1)

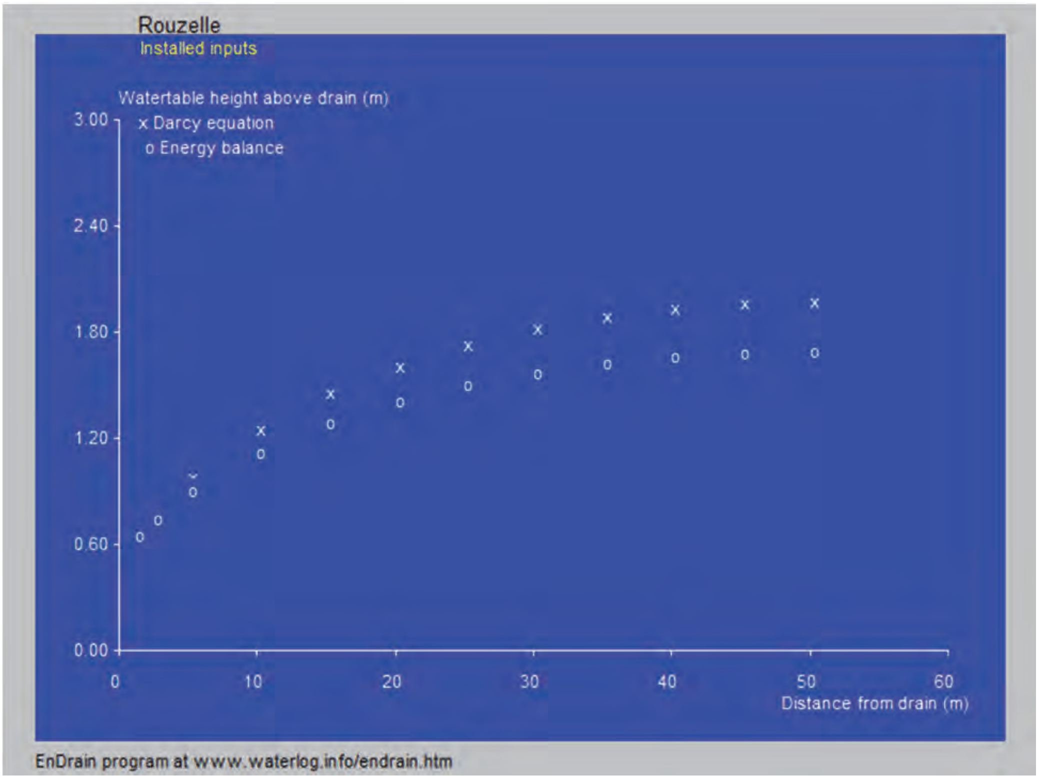


Figure 5-8 Breede River case study – modelled results for installed values (scenario 2)

5.3 Impala irrigation scheme

Simulation scenarios were run to represent two soil types, i.e. clay-loam and clay soil. These two soil types were chosen because they were the two soil textural classes found at the site. Input parameters such as the Ksat values, details of the soil profile layers and the soil water characteristics, were dependent on the type of soil, while input parameters such as type of crop, crop root elongation (m) with respect to time (days) and weather data, were kept constant in both the clay and clay-loam soils. For clay soil, simulation scenarios were run with drain depths ranging from 1.4 to 1.8 m and drain spacing from 25 to 40 m at 3 m intervals. On the other hand, for clay-loam soil, simulation scenarios were run at drain depths ranging from 1.4 to 1.8 m, with drain spacing from 55 to 70 m. The selection of this drain depth and spacing simulation range for both soil types was based on a drain depth and spacing guide for KwaZulu-Natal developed by Russell and Van der Merwe (1997). For every simulation scenario, the mean WTD and DD were computed and were presented graphically.

5.3.1 Performance characterization of the DRAINMOD model

The DRAINMOD model simulation for the October 1998 to September 1999 was considered for calibration. However, it was thought that during the calibration period the model could have performed very well because the DRAINMOD model system parameters were adjusted to obtain optimal agreements between pairs of observed WTD and DD. For that reason, the simulation for the September 2011 to February 2012 period was considered to validate the calibrated parameters. During the calibration period, the adopted drain depth and spacing were 1.8 m and 90 m, respectively, while a drain depth and spacing of 1.8 m and 54 m, respectively, were used during the validation period. This was because the drainage system in the 1998-1999 period was designed at a drain depth and spacing of 1.8 and 90 m, respectively, while in the 2003-2012 period, the system was designed at a drain depth and spacing of 1.8 and 54 m, respectively.

Details of the input parameters that were adjusted during the DRAINMOD model calibration are shown in Table 5-6.

Table 5-6 Details of the DRAINMOD model calibration parameters

Input parameter	**Description**	**Calibrated parameter**
Top soil layer lateral hydraulic conductivity ($K_{1L\text{-}sat}$)	Set at equal to measured vertical K_{sat}	0.96 $m.day^{-1}$
Bottom soil layer lateral hydraulic conductivity ($K_{2L\text{-}sat}$)	Set at twice the measured vertical K_{sat}	0.48 $m.day^{-1}$
Maximum soil surface storage depth (cm)	Set at four times the default 0.5 cm depth	2 cm

Considering that no significant differences were observed among mean WTD at three piezometers AP1, AP2 and AP3, the WTD data from one piezometer were selected to be used in validating the DRAINMOD model. To avoid bias in selecting data to use in validating the DRAINMOD model, random numbers were assigned to AP1, AP2 and AP3. Water table depth data from AP2 were then randomly selected to be compared to simulated WTD data during validation, while DD data from MH2, which corresponded to AP2, were compared to simulated DD.

- DRAINMOD model performance during calibration

The results of time series observed and simulated WTD and DD hydrographs during the calibration period are shown in Figure 5-9 and Figure 5-10, respectively. As expected of arid and semi-arid climatic conditions, both observed and simulated WTDs in Figure 65 show a fluctuating trend. Furthermore, it can be seen in Figure 5-9 that fluctuation of WTD continued, even on rain-free and non-irrigation days. According to Skaggs (1980) and Gupta and Yadav (1993), continual WTD or DD fluctuation during the zero recharge days depicts the presence of unsteady state WTD and DD. According to FAO (2007) unsteady state WTD and DD are not a strange phenomenon in arid and semi-arid climates. It can also be seen in Figure 5-9 that peak WTDs coincided with peak rainfall/irrigation days, indicating that the water table was indeed reacting to the recharge through rainfall and irrigation. A reaction factor (α), calculated from the observed water table fluctuation was found to be 0.12 day^{-1}, which according to Smedema and Rycroft (1983), indicates that the water table at the site reacts slowly to the recharge through rainfall or irrigation.

A study of the results in Figure 5-9 further indicate that the model predicted shallow WTDs of less than 100 cm better than the deeper WTDs of more than 100 cm. Besides this, the results show that generally the model predicted WTDs quite accurately, with a very strong R^2 value of 0.967 and a small MAE of 18.84 cm. A CRM of -0.117 gives an indication that the model has a general tendency of over-estimating WTDs.

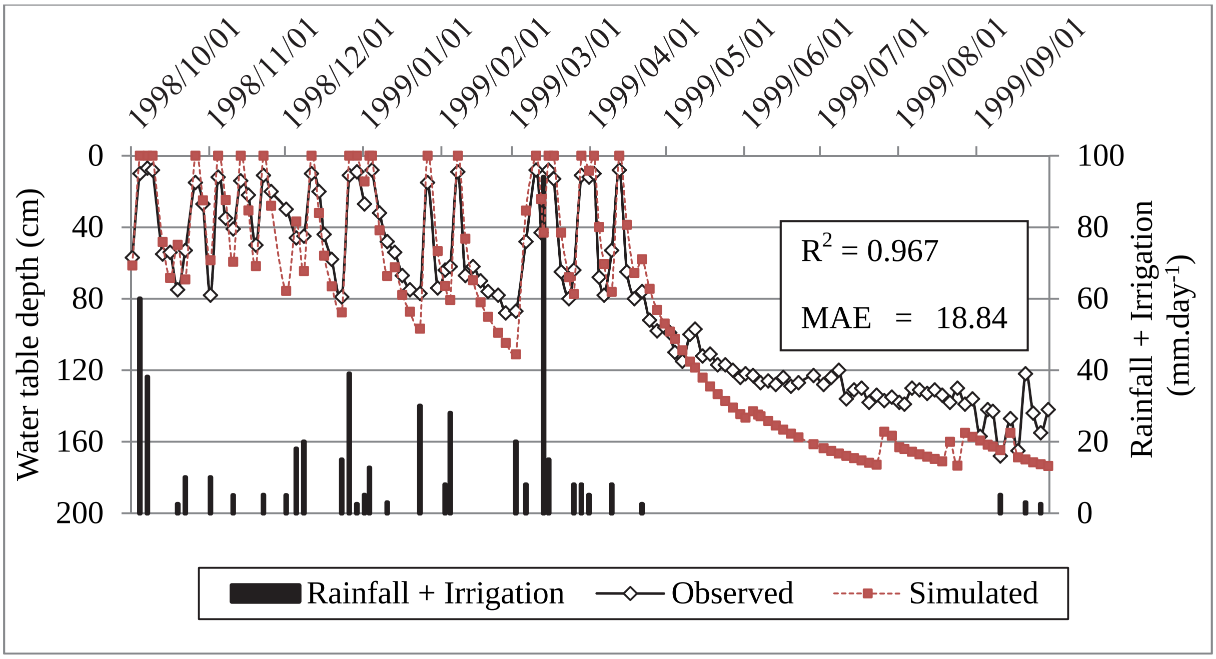


Figure 5-9 Observed and simulated water table fluctuation during the model calibration period (October 1998 to September 1999)

Results of time series observed and simulated DD hydrographs during the calibration period (September 1998 to October 1999) are shown in Figure 5-1. Just like the DRAINMOD model calibration results in simulating WTDs, both the observed and simulated DD hydrographs show a fluctuating trend, depicting the presence of unsteady state DD behavior. A study of the results in Figure 5-10 also shows that the model predicted DDs of greater than 2 mm.day^{-1} better than DDs of less than 2 mm.day^{-1}. Statistically, observed and simulated DD hydrographs show a strong agreement, with a high R^2 and a small MEA of 0.893 and 0.603 mm.day^{-1}, respectively.

A comparison of the R^2 values between pairs of observed and simulated WTD in Figure 5-11 and DD in Figure 5-12, shows that the model performed better in predicting WTD (R^2 =

0.967) than DD (R^2 = 0.893). Unlike the results of observed and simulated WTD (Figure 5-9) in which the model over-estimated DDs, contrary results were obtained in Figure 5-10 (CRM>0), giving an indication that the model also under-estimated DD during the calibration period.

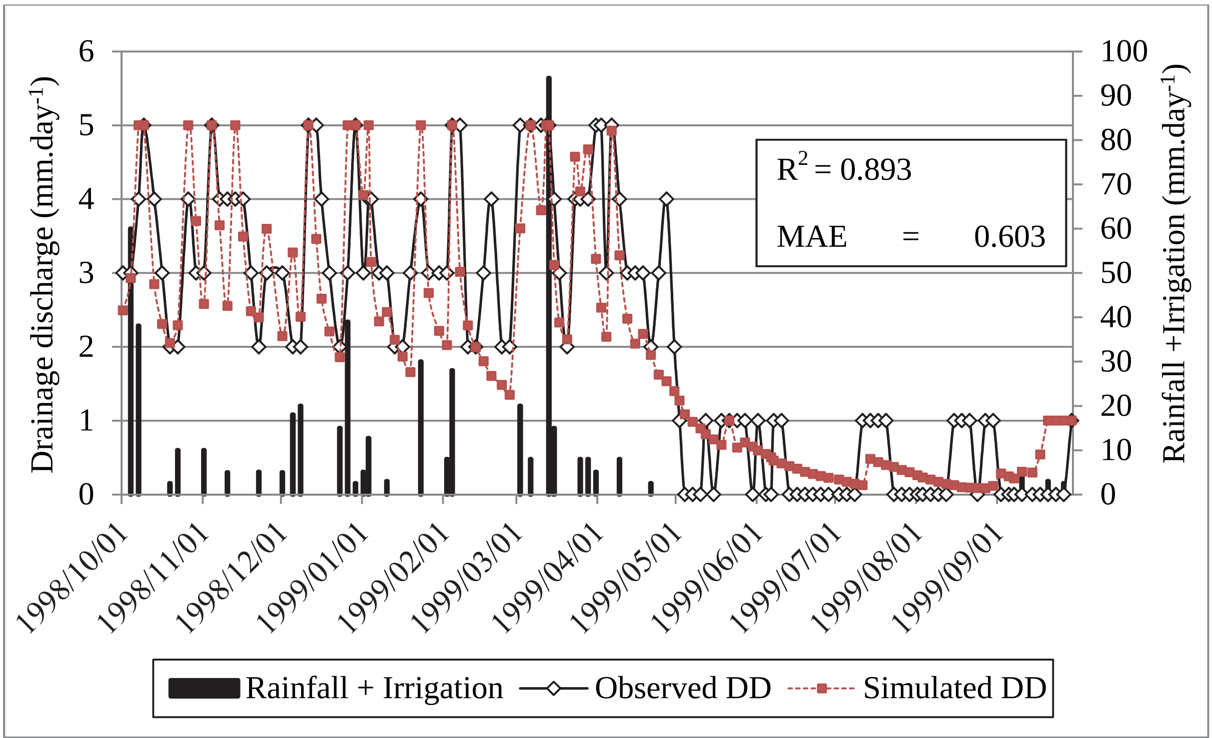


Figure 5-10 Observed and simulated drainage discharge hydrographs during the model calibration period (October 1998 to September 1999)

- DRAINMOD model performance during validation

Results of the DRAINMOD model performance in simulating WTD during the validation period are shown in Figure 5-11. A visual judgment of these results clearly shows that the observed and simulated WTD fluctuations correlated very well. This is statistically proven by a very strong R^2 value of 0.826 and a small MAE of 5.341 cm. The negative CRM value of -0.015 depicts that the model over-estimated WTD during the validation period. However, comparing the MAE of 18.84 cm obtained during the calibration period (Figure 5-9) and the MAE of 5.341 cm obtained during the validation period, as seen in Figure 5-11, gives an indication that there are small differences between individual pairs of observed and simulated WTD during the validation period than the calibration period.

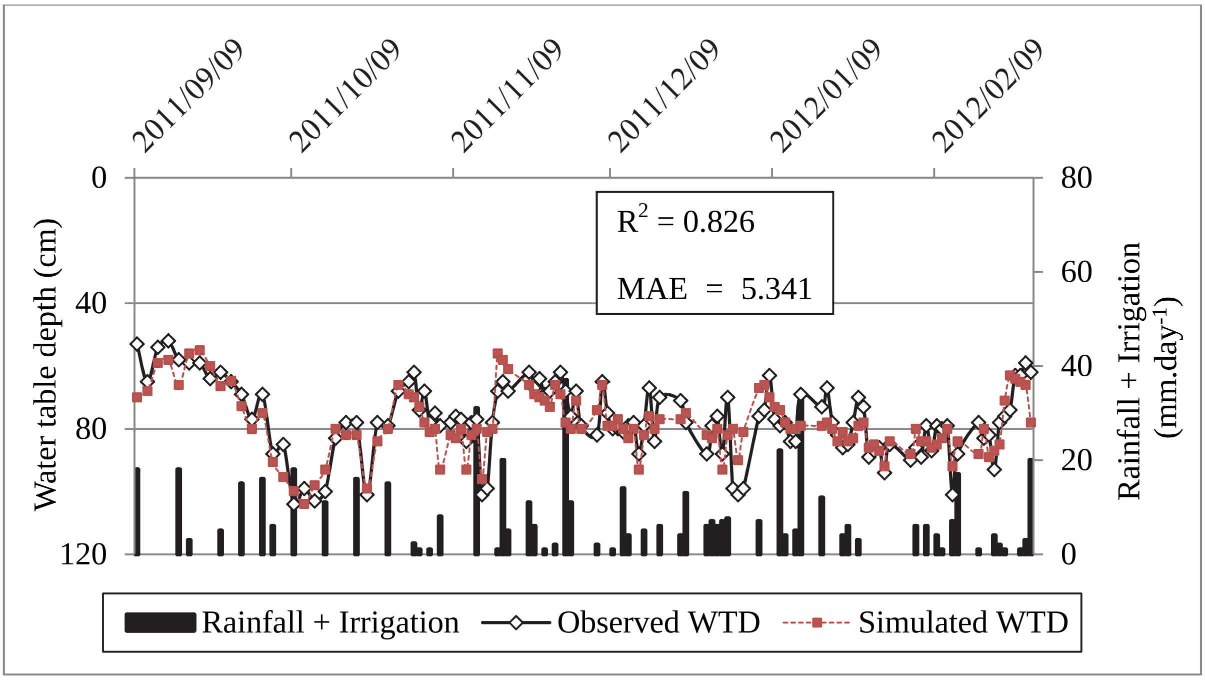


Figure 5-11 Observed and simulated water table fluctuation during the validation period (September 2011 to February 2012)

Results of the DRAINMOD model performance in predicting DDs during the validation period are shown in Figure 5-11. A very good correlation between the observed and simulated drainage discharge hydrographs can visually be deduced in Figure 5-13. Statistically, the correlation between the observed and simulated DDs is strong, with an R^2 value of 0.801 and a small MAE of 0.181 mm.day^{-1}. Unlike the calibration results of observed and simulated DD (Figure 5-12), where the model showed a general tendency of over-estimating WTDs, the results in Figure 5-10 show that the DRAINMOD model has a general tendency of neither under-estimating or over-estimating DDs with a CRM of 0.0004, which is very close to zero.

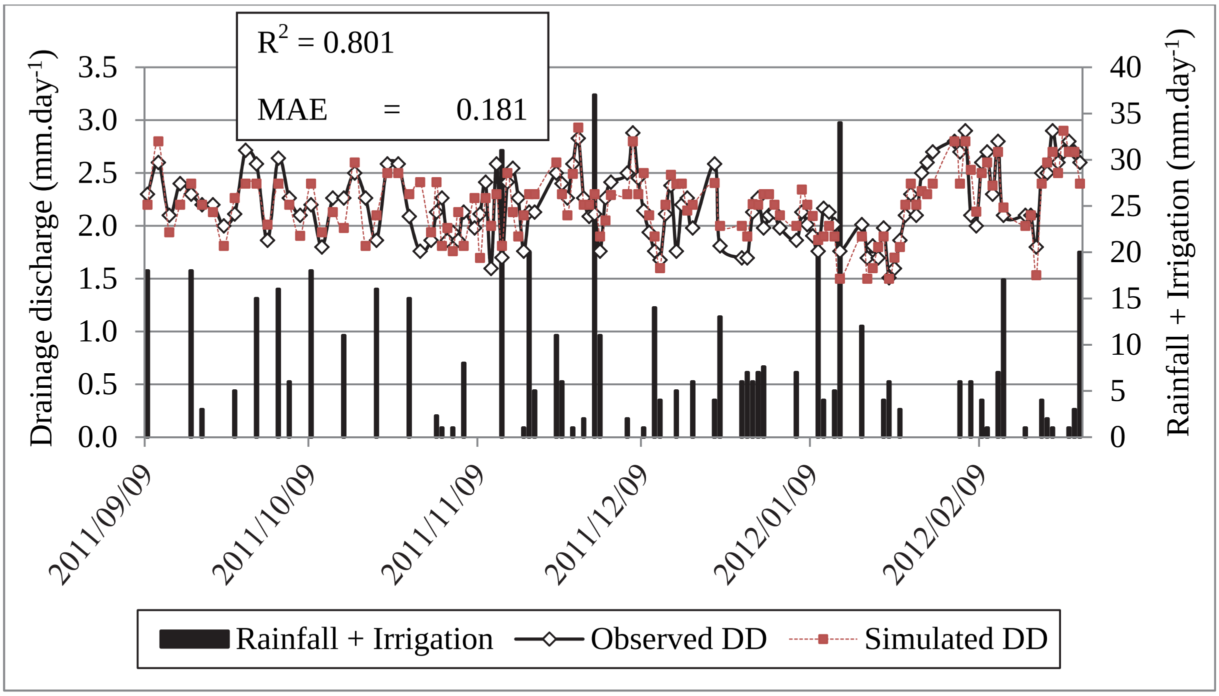


Figure 5-12 Observed and simulated drainage discharge hydrographs during the validation period (September 2011 to February 2012)

5.3.2 Simulation scenarios at various drain depths and spacing combinations for two different soils types

The calibrated DRAINMOD model was used to simulate WTDs and DDs for subsurface drainage systems installed in clay (K_{sat} = *0.24 m day*$^{-1}$) and clay-loam soils (K_{sat} = *0.6 m.day*$^{-1}$). The results of mean simulated WTDs and their respective mean DDs at various combinations of drain depth and spacing are shown in Figure 5-13 and Figure 5-14. It is evident from the results in Figure 5-13 that, when considering a constant drain depth, mean WTDs below the soil surface increase with decreasing drain spacing, and vice versa. For instance, in clay soil, it can be seen in Figure 5-13 that for a subsurface drainage system installed at a drain depth of 1.4 m and its corresponding drain spacing of 40 m, the system establishes a mean WTD of 1.0 m. However, at the same 1.4 m drain depth, the system establishes a mean WTD of 1.11 m, when the drain pipes are installed at a closer spacing of 25 m.

Furthermore, the results in Figure 5-13 show that considering drain pipes installed in clay soil at drain depth ranging from 1.4 to 1.8 m, mean WTDs between 1.0 and 1.5 m can be established, when the drain pipes are installed at a spacing ranging from 25 to 40 m. On the other hand, by installing drain pipes at the same 1.4 to 1.8 m drain depth, mean WTDs between 1.0 and 1.5 m can be established in clay-loam soil when drains are installed at a relatively wider spacing, ranging from 55 to 70 m.

Results of mean DDs at various combinations of drain depth and spacing in Figure 5-14, show that when keeping the drain depth constant in both clay and clay-loam soils, mean DDs increase with decreasing drain spacing and vice versa. Furthermore, it can be seen in Figure 16 that generally mean DDs are increasing with increasing drain depth when drain spacing and type of soil are kept constant.

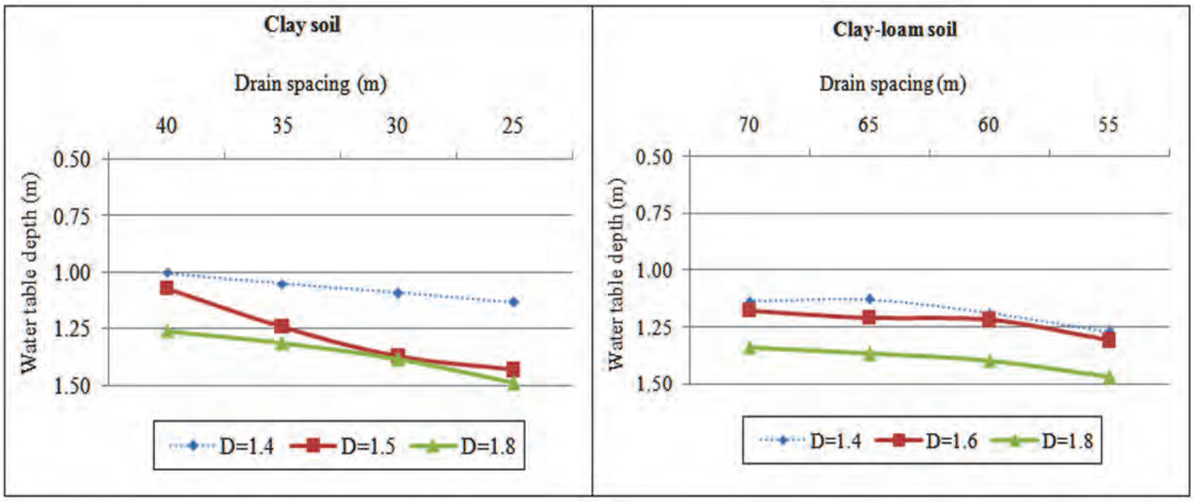


Figure 5-13 Mean water table depths in clay and clay-loam soils simulated at different drain depth (m) and spacing (m) combinations

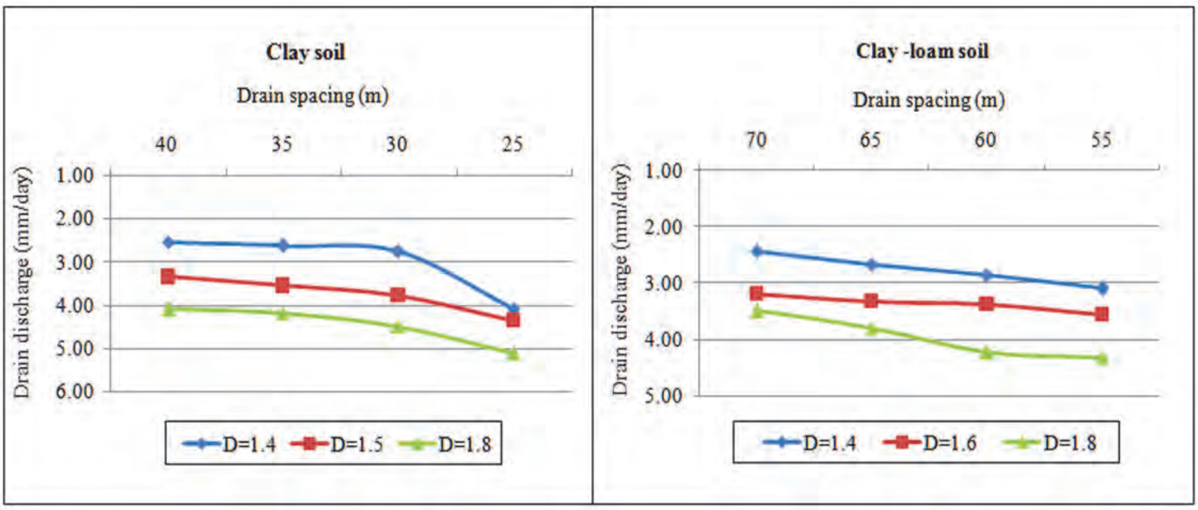


Figure 5-14 Mean drainage discharges in clay and clay-loam soils simulated at different drain depth (m) and spacing (m) combinations

5.3.3 **Discussion**

This section will discuss the results obtained in the previous sections, particularly by making comparisons with results reported by other authors.

- Description of soil hydraulic properties at the study site

The design of subsurface drainage systems for water table control in agricultural fields requires a thorough understanding of soil hydraulic properties governing the flow of groundwater both in the saturated and unsaturated zones. According to Cameira et al. (2000) and Manyame et al*.* (2007), K_{sat} and soil water characteristics are the two crucial soil hydraulic properties that are required when designing subsurface drainage systems.

- Saturated hydraulic conductivities (Ksat)

According to Twarakavi et al*.* (2008), K_{sat} values are significantly affected by soil textural class, in that this soil physical property is directly linked to K_{sat}. Results of K_{sat} of the top soil layer at the site reported by Van der Merwe (2003) were in the range of 0.9 to 1.05 m.day^{-1}, which were generally higher compared to K_{sat} values of the bottom soil layer, both in clay and clay-loam soils. The difference in K_{sat} values between the top and bottom soil layers were chiefly attributed to the differences in soil textural classes in the two soil layers.

These results were partly comparable to those of Kosgei et al*.* (2009). In their study, in the Thukela basin, South Africa, Kosgei et al*.* (2009) found that K_{sat} values were slightly higher in the top soil layer than those of the bottom soil layer. They attributed this phenomenon to frequent soil tillage operations in the top soil layer, which therefore increased the soil porosity and hence the higher K_{sat} values in the top soil layer. However, in this study, since soil bulk densities of the top soil layer were higher than those of the bottom soil layer, and since ploughing at the site is done after every four or so years, the high K_{sat} values in the top soil layer could not be attributed to tillage operations. Otherwise, if the ploughing operation was to be done annually at the site, the top layer K_{sat} values could possibly become even greater than what was observed. Thus, it made more sense to attribute the K_{sat} difference to the mere difference in the soil textural classes between the top and bottom soil layers.

- Soil water characteristic curves (SWCCs)

According to Millan and Gonzalez-Posada (2005), soil moisture content decreases with increasing soil water pressure heads until an equilibrium soil water pressure head is attained. This equilibrium soil water pressure head forms the permanent wilting point, beyond which plant roots cannot absorb any more water from the soil (Smedema and Rycroft 1983). The decreasing trends of fitted soil water characteristic curves (SWCCs) were in agreement with the author’s initial expectations. Similar trends of SWCCs have been widely reported by other authors (e.g. Vogel et al. 2001; Twarakavi et al. 2008 and Nasta et al. 2009).

- Performance evaluation of the DRAINMOD model

According to Skaggs (1978), the DRAINMOD model was initially developed to simulate WTDs and DDs under humid climatic conditions, where shallow water table depths are more prevalent (Sanai and Jain 2006). This could explain the reason why the model appeared not to simulate deep WTDs, as accurately as was the case with shallow WTDs, particularly during the calibration period. The results of the DRAINMOD model evaluation at a sugarcane field in north-eastern New South Wales, Australia, reported by Yang (2008) also showed that the model failed to simulate WTDs of more than 0.8 m as accurately as was case with WTD less than 0.8 m.

It was nevertheless encouraging that the general performance results of the DRAINMOD model in simulating WTDs and DDs, during the calibration period, were better than the results reported by Dayyani et al. (2009). In their DRAINMOD model simulation study in the Quenchbec region of Canada, Dayyani et al. (2009) reported that the model predicted WTDs and DDs with R^2 values of 0.77 and 0.73, respectively, during the calibration period. These R^2 values are relatively lower than R^2 values of 0.967 and 0.893 found in this study in the calibration period. However, besides these heartening results, Dayyani et al. (2009) model validation results improved substantially with R^2 values of 0.93 and 0.90 for WTD and DD, respectively, which were higher than R^2 values of 0.826 and 0.801 found in this study, during the validation period. Dayyani et al. (2009) used very precise and automated water level and drainage discharge data loggers to locate the depth of the water table and measure daily drainage discharges, respectively. This explained why Dayyani et al. (2009) model validation results were better than the validation results found in this study.

On another encouraging note, the DRAINMOD model in this study predicted better WTDs than the results reported by Singh et al. (2006). Singh et al. (2006) found that the model predicted the WTD with R^2 values of 0.89 and 0.88 during the calibration and validation periods, respectively, which were very close to the R^2 values of 0.967 and 0.826 found in this study during the calibration and validation periods. The MAE of 5.41 cm found between observed and simulated WTDs during the validation period was smaller than the 7.0 cm found by Yang (2008).

Yang (2008) reports that the accurate estimation of K_{sat} values to be used in the simulation of WTD and DD using the DRAINMOD model, enhances the adoptability of the model in an area, while the use of measured daily PET data, improves the accuracy of the model in making right predictions. Notably, during their drainage simulation studies, both Singh et al. (2006) and Dayyani et al. (2009) used estimated PET data, SWC and laboratory determined K_{sat} values as model inputs. The better performance of the DRAINMOD model in this study was to a large extent attributed to the use of measured PET data, SWC and in-situ determined K_{sat} values as input parameters. In addition, the use of an electronic dip meter in locating the position of WTD as opposed to other methods, e.g. float meters, might have improved the quality of observed WTD data quite significantly. This obviously reduced the differences between observed and simulated WTD values. Nonetheless, the use of WTD data loggers could have improved the quality of the results even more.

The slightly less agreement between the observed and the estimated DDs in both the calibration and validation periods could be explained by the use of a low accuracy drainage discharge measurement method when measuring DDs, both during the 1998-1999 and 2011-2012 periods. The bucket and clock method adopted in this study might have led to so many measurement errors. Possibly, such errors resulted in greater differences between observed and simulated DDs. However, this could have been improved by using DD measurement equipment with a data logging mechanism. Unfortunately, this could not be achieved because of inadequate funds allocated for research equipment.

- DRAINMOD simulation runs at varied drain depth and spacing combinations

The design of subsurface drainage systems for crop production systems involves appropriate determination of drain depth, spacing and drainage discharge in relation to a particular type of soil and crop (Hooghoudt 1940). Results of mean simulated WTDs and DDs upheld the general prevailing idea of installing drain pipes at shallow depths, in order to establish water WTDs near the soil surface and vice versa. The possible explanation to this water table behavior could be due to reduced hydraulic heads at mid-drain spacing, which according to Dagan (1964) has a direct effect on both WTD at mid-drain spacing and drain discharge at drain outlet points.

However, considering a constant drain depth and soil type, in as far as establishing deeper WTD is concerned, installing drain pipes at a closer spacing appeared to be a better option. This was attributed to an elliptical water table shape with a very steep cone of depression, which according to Rimidis and Dierickx (2003), increases the drain flux towards the drain pipe, hence the high water table draw down (Δh) at mid-drain spacing and the increased drainage discharges.

On the other hand, the analysis of mean WTDs at various combinations of drain depth and spacing in clay and clay-loam soils suggested that closer drain spacing in clay soil and a wider drain spacing in clay-loam soils are more likely to establish the same mean seasonal WTD when drain depth is kept constant in both soil types. This was explained by differences in K_{sat} values for the two soil types, corroborating the description behind the Hooghoudt drain spacing equation in Section 2.1.

In a study of the similar nature conducted in the Southern part of Louisiana, USA, Carter and Camp (1994) found out that by considering the same type of soil and a constant drain depth, shallow WTDs are established when drain pipes are installed at a wider spacing, while deeper WTDs are established when drain pipes are installed at a closer spacing. On the other hand, in Southeast Queensland, Australia, Cook and Rassan (2002) found that considering a subsurface drainage system with drain pipes installed at the same drain depth in two soil types with different K_{sat} values, the same WTD can be established in both soil types, but with drain pipes installed at a wider spacing in the soil with a higher K_{sat} value, and vice versa. This clearly indicates that the results found in this study corroborated well with study findings reported by Carter and Camp (1994) and Cook and Rassan (2002).

According to Oosterbaan (2002) and FAO (2007) the use Hooghoudt equation in arid and semi-arid conditions is based on a mean seasonal WTD and drainage discharge. Thus, it is apparent that under these climatic conditions the application of the Hooghoudt equation is not entirely based on a steady state criterion, but a dynamic equilibrium WTD and DD (Oosterbaan 2002). It therefore follows that based on the simulation results obtained in this study, respective drain depth, spacing and drainage discharge of 1.4 to 1.8 m, 55 to 70 m and 2.5 to 4.2 mm.day^{-1}, would be appropriate to ensure safe WTD between 1.0 and 1.5 m depth for sugarcane grown in clay-loam soil. On the other hand, for sugarcane grown in clay soil, respective drain depth, spacing and drainage discharge of 1.4 to 1.8 m, 25 to 40 m and 2.5 to 5.1 mm.day^{-1} appeared to be appropriate to ensure a WTD between 1.0 m and 1.5 m from the soil surface.

6. REFINEMENT OF FINANCIAL STANDARDS FOR DRAINAGE WITH REFERENCE TO CAPITAL INVESTMENT, FINANCING METHODS, OPERATION AND MAINTENANCE EXPENDITURE AND MANAGEMENT PRACTICES

One of the objectives of the project was to develop a user-friendly financial model that integrates:

- Whole-farm planning (20-year period)
- Crop yield curves (with and without drainage)
- Capital and maintenance expenditure (sub-surface drainage system)
- Financial analysis (Whole-farm and Per-hectare), and
- Comparison of different scenarios and measuring against norms

A model as described in Volume 1 Chapter 7 of this report was developed that makes provision for cash flow-, income statement and balance sheet projections. The model is designed in a user-friendly way with step-by-step instructions to ensure an accurate outcome.

6.1 Description of the case study – Pongola

Information from a case study farm in Pongola was used to verify and validate the model. Please note that the data used needs validation and merely serves for demonstrative purposes.

For the sake of brevity only a summarised description of the farm is reflected in Table 6-1. The reader is referred to APPENDIXES A to APPENDIX E for more detail of the case study farm.

Table 6-1 Brief Farm description – Pongola case study

Land use		
Total irrigation land		88
	High potential	*88*
	Medium potential	
	Low potential	
Irrigable land (not yet developed)		
Total dry land area		0
Veldt		0
Homestead and waste		6
Total area farmed		**94**
CROP COMPOSITION		**Year 1**
Permanent crops		
1	Sugarcane	88
Cash crops		
1	Maize	0
Total crops		**88**
ASSETS & LIABILITIES		
Assets		**16,360,000**
	Total current assets	*500,000*
	Total medium term assets	*1,450,000*
	Total fixed assets	*14,410,000*
Liabilities		**2,011,733**
	Total current liabilities	*711,733*
	Total medium term liabilities	*300,000*
	Total long term liabilities	*1,000,000*
Total net worth		**14,348,267**

In essence, the case study entails an 88 hectare sugarcane farm with an asset value of R16 360 000 and a net worth of R14 348 267.

6.2 **Crop enterprise budget – sugarcane**

Table 6-2 is a summary of sugar cane enterprise budget for Pongola. The complete enterprise budget is in Appendix E.

Table 6-2 Summary of crop enterprise budget – sugar cane

Year	Yield without drainage	Yield with drainage	Income per hectare (without drainage)	Income per hectare (with drainage)	Total production cost	Additional cost due to drainage	GM (without drainage)	Production cost %	GM (with drainage)	Production cost %
1	90	105	31,650	36,925	18,845	929	12,805	60%	17,151	54%
2	90	115	31,650	40,442	18,845	1,601	12,805	60%	19,996	51%
3	90	120	31,650	42,200	18,845	1,283	12,805	60%	22,072	48%
4	90	125	31,650	43,959	18,845	1,493	12,805	60%	23,621	46%
5	90	130	31,650	45,717	18,845	2,230	12,805	60%	24,642	46%
6	90	135	31,650	47,475	18,845	1,913	12,805	60%	26,718	44%
7	90	140	31,650	49,234	18,845	2,122	12,805	60%	28,267	43%
8	90	140	31,650	49,234	18,845	2,649	12,805	60%	27,740	44%
9	90	140	31,650	49,234	18,845	2,122	12,805	60%	28,267	43%
10	90	140	31,650	49,234	18,845	2,122	12,805	60%	28,267	43%
11	90	140	31,650	49,234	18,845	2,649	12,805	60%	27,740	44%

6.3 Capital budget for installing sub-surface drainage

Drainage is quite expensive and the layout depends on many factors. A heavy soil will require a spacing of 20-30 meters, a medium soil 40 -50 meters and a light soil 70-80 meters in the Pongola area (Van der Merwe 2013).

Table 6-3 serves as a guideline to estimate cost of sub-surface drainage installation for different spacing and soil conditions.

Table 6-3 Guideline estimate cost of sub-surface drainage

	Drain Spacing (meter)		
heavy Clay (>35%)	30	32.5	35
25-35% Clay	55	62.5	70
Sandy soils	70	90	110
	Meters pipe required per Ha		
heavy Clay (>35%)	333.3	307.7	285.7
25-35% Clay	181.8	160.0	142.9
Sandy soils	142.9	111.1	90.9
	Estimated cost per ha		
heavy Clay (>35%)	R 33,333.33	R 30,769.23	R 28,571.43
25-35% Clay	R 18,181.82	R 16,000.00	R 14,285.71
Sandy soils	R 14,285.71	R 11,111.11	R 9,090.91

(Source: Van der Merwe 2013)

The more detailed capital budget for sub-surface irrigation installation for 25.86ha can be viewed in Appendix F. It also contains the farm plan, field plan, irrigation plan, drainage plan, contour plan and water table depths.

6.4 **Modelling results**

For illustration purposes, six scenarios were modelled. These are:

- Without drainage – 10% starting debt ratio
- With drainage – 10% starting debt ratio
- Without drainage – 40% starting debt ratio
- With drainage – 40% starting debt ratio
- Without drainage – 30% starting debt ratio
- With drainage – 30% starting debt ratio

Table 6-4 shows the sugar cane yield that has been used in the modelling.

Table 6-4 Yield curve "with" and "without" drainage

Yield	1	2	3	4	5	6	7	8
Without drainage	90	90	90	90	90	90	90	90
With drainage	115	120	125	130	135	140	140	140

Table 6-5 reflects the production cost ratio, projected cash flow ratio, projected debt ratio and projected end bank balance of the different scenarios.

Table 6-5 Comparison of scenarios

Scenario nr & description		Production cost ratio *	Projected cash flow ratio *	Highest Projected Debt ratio	End Bank balance
1	Without drainage - 10% Starting debt ratio	82%	91%	53%	-5,573,185
2	With drainage - 10% Starting debt ratio	68%	116%	24%	10,625,454
3	Without drainage - 40% Starting debt ratio	82%	51%	621%	-65,018,528
4	With drainage - 40% Starting debt ratio	68%	83%	175%	-18,522,914
5	Without drainage - 30% Starting debt ratio	82%	60%	413%	-43,278,721
6	With drainage - 30% Starting debt ratio	68%	106%	42%	2,144,451
	* *20-year average*				

The modelling results can be interpreted as follows:

Without drainage – 10% starting debt ratio

- Not financially feasible – projected cash flow ratio is negative (<100%) and debt ratio exceeds the norm (<50%).
-

With drainage – 10% debt ratio

- Financially feasible – projected cash flow ratio > 115%,
- Highest projected debt ratio < 50%, and
- Positive bank balance

With the exception of the "With drainage – 30% debt ratio"-scenario, all other scenarios seems not to be financially viable. Although the "With drainage – 30% debt ratio"- scenario seems financially viable, it is still a question whether any financier will finance an entity with such a low projected cash flow ratio.

6.5 Financing decision support tool

The Financing decision support tool takes into account several critical financing norms and criteria to calculate if the case study/scenario will qualify for financing under normal circumstances. The module was designed in such a way that it combines per hectare Benefit cost analysis and Whole-farm planning (analysis) projected over a 20-year period. The reader/user must however be aware that the module merely serves as a rough indicator to determine the likelihood of getting finance.

Critical financing norms included in the Financing decision support tool are the five C''s of credit as defined by Wilson et al. (2006), namely:

- Capacity (cash flow ratio)
- Capital (debt ratio)
- Collateral (sufficient to cover the loan)
- Conditions (Benefit cost ratio, payback period, IRR and NPV)
- Character of the prospective client (trustworthy of not, history, etc.)

Capacity, capital and conditions are calculated by using modelling results. Collateral and character needs manual input from the user. Collateral can only be determined if the prospective lenders guidelines/criteria are available. Character, however, is a subjective decision by the Lender.

Table 6-6 illustrates the Financing decision support tool. The answers are measured against the norms and the module assign accordingly a “yes” or “no” (approval) towards each criteria element. If the answer is a positive “yes”, one (1) point is assigned to the specific criteria. A maximum of eight points can be accumulated if all criteria are positively met. The module will still approve financing if two of the eight criteria items are not met, provided that one of these two do not include “cash flow ratio” of “character”. These two criteria are non-negotiable and should be met to qualify for financing approval.

Table 6-6 Financing decision support tool

Capacity	Answer *		Norm	Approval	Scoring	Vital elements
Cash flow ratio	93%	>	115%	No	0	0
Capital						
Debt ratio	14%	<	50%	Yes	1	
Collateral						
Sufficient available "yes" or "no"	yes		yes	Yes	1	
Conditions						
Benefit Cost ratio (B/C) : 1	5.8	>	1	Yes	1	
Payback average	1.4	<	8	Yes	1	
Internal Rate of Return (IRR)	0%	>	8%	No	0	
Net Present value (NPV)	0			Yes	1	
Character						
Trustworthy "yes" or "no"	yes		yes	Yes	1	1
Economic & Financially feasible	**No**				6	1
					Total pts	**2**

** Average 1st 10 years*

Table 6-7 illustrates the different scenarios that were run for the Pongola case study. Not one of the scenarios qualified for finance on its own without subsidy. With 50% subsidy, the 10% debt scenario will qualify for finance according to the norms that were assigned to the different criteria and norms.

Table 6-7 Financing decision support tool summary for Pongola case study

Scenario Description	Norm	1 Without drainage - 10% Starting debt ratio	2 With drainage - 10% Starting debt ratio	3 Without drainage - 40% Starting debt ratio	4 With drainage - 40% Starting debt ratio	5 Without drainage - 30% Starting debt ratio	6 With drainage - 30% Starting debt ratio	7 With drainage - 10% Starting debt ratio (50% subsidy)
Capacity								
Cash flow ratio	> 115%	No	No	No	No	No	No	Yes
Capital								
Debt ratio	< 50%	Yes	Yes	No	No	No	Yes	Yes
Collateral								
Sufficient available "yes" or "no"	yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Conditions								
Benefit Cost ratio (B/C) : 1	> 1	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Payback average	< 8	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Internal Rate of Return (IRR)	> 8%	No	No	No	No	No	No	No
Net Present value (NPV)	0	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Character								
Trustworthy "yes" or "no"	yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Economic & Financially feasible		**No**	**No**	**No**	**No**	**No**	**No**	**Yes**

It should be iterated that these scenarios merely serves for illustration purposes and that the data for the Pongola study still needs to be validated. Please also take note that for financing purposes the average 1st 10-years figures are used for calculation purposes, compared to the average 20-year figures for comparison purposes (see Table 6-5).

6.6 **Summary**

This chapter summarises the preliminary results for the Pongola case study. It gave a brief description of the case study farm, sugar cane enterprise budget, the sub-surface drainage installation capital budget and the modelling results. Several scenarios were run including "with" and "without" drainage for a 10%, 30% and 40% debt ratio. A 10% debt "with drainage and 50% subsidy" scenario was also run to illustrate the impact of subsidies on the economic viability and financial feasibility of sub-surface drainage.

The Financing decision module takes into account the five C's of credit namely: capacity, capital, collateral, character and conditions. Where possible a value is assigned to the quantitative measured criteria. The qualitative criteria require input from the user. The Financing decision support tool then indicate the likelihood of the case study/scenario to get finance via the normal credit channels.

7. EVALUATION OF TECHNICAL AND FINANCIAL FEASIBILITY OF DRAINAGE BASED ON SELECTED CASE STUDIES

7.1 Technical feasibility

The technical feasibility of installing drainage at the case study sites was assessed according to the guidelines provided in chapter 7 of volume 1 of this report, which focuses on the following:

- Meteorology investigation
- Investigation of land conditions:
    - Topographic investigation
    - Soil and groundwater investigation
    - Investigation on land use and ownership
    - Water use investigation
    - Drainage water outflow
- Custom of drainage practices
- Investigation of regional/area agriculture

Technical inputs impacting on the performance, and capital and maintenance cost of drainage installation is derived from three other models namely DRAINMOD, SWAMP and EnDrain.

DRAINMOD is based on a water balance in the soil profile and uses climatological records to simulate the performance of drainage and water control systems. The SWAMP model simulates the movement of salts within the soil profile.

The EnDrain computer program (Oosterbaan 1996) calculates the discharge, hydraulic head or spacing between parallel subsurface drains: pipe drains or open ditches, with or without entrance resistance.

7.1.1 Vaalharts irrigation scheme site

The key reasons for installing a sub-surface drainage scheme are to combat rising water tables and the accumulation of salts in the soil profile, both of which have a detrimental effect on crop growth and ultimately crop yield. Both of these problems occur in the Vaalharts Irrigation Scheme.

Irrigation water is relayed to the plots on the Vaalharts and Taung Irrigation Schemes through an extensive network of open channels, siphons and pipes. The main canal is 18.4 km long; it splits into the northern canal, which is 82 km long and serves 33 400 ha, and the western canal, which is 22 km long, serving 4 800 ha. The water reaches the plots by means of feeder (45 km) and tertiary (580 km) canals. There are 5 balancing dams on the scheme. Farmers also make use of overnight dams to enable them to irrigate when the canal is dry and to assist with scheduling.

By 1976 it was estimated that approximately 3000 ha of soils on the scheme were saline or saline sodic to a depth of 0.3 m. Drainage systems, totaling 500 km of subsurface lateral drains at a depth of 1.5 m-1.7 m, were installed to control the water table and promote the leaching of salts. The system of open concrete storm water drains in some parts served as outlets for the new systems. Although the subsurface drains kept the ground water table below 0.7 m and leached salts from recently salinized patches, approximately 1500 ha of saline soils remained at the end of 1977. In 1980 it was estimated that there remained 1000ha of salt effected soils on the scheme.

The design and installation of drainage systems in the Vaalharts scheme centred on the application of the Hooghoudt drainage formula of 1940. The main inputs to the equation are illustrated in Figure 7-1. Originally drains (laterals) were installed at spaces of 50 m, 60 m and 80 m apart at depths ranging from 1.2 m to 2.4 m. The laterals had diameter of 50 mm while the main drains were typically 100 mm in diameter.

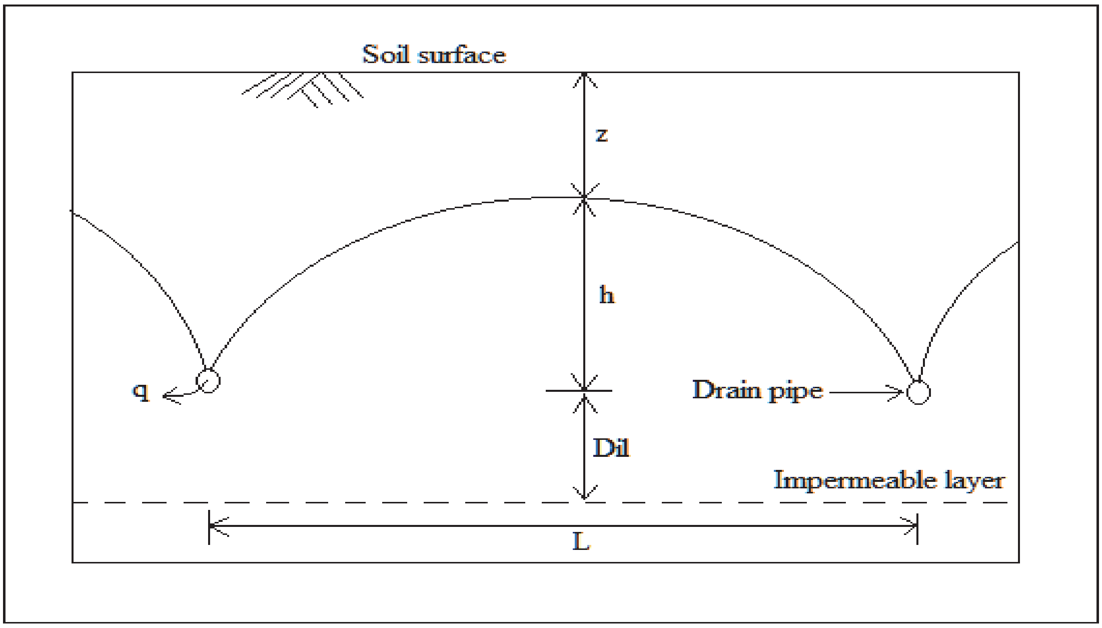


Figure 7-1 Main variables in groundwater drainage design

The cost of the drainage system is typically dependent on the spacing of the drains since the greater the number of drains the greater the capital costs and associated earthworks. It ultimately depends on the crops tolerance to waterlogging and/or salt accumulation in the soil profile as to the maximum spacings of drains within a drainage system.

7.1.2 **Breede River site**

- Meteorological investigation

Adequate historical weather data was available to use as background for determining the drainage factor (f). The Bothashalt weather station was used by the Department of Agriculture in 2000 and currently there is an ARC automatic weather station on the farm used for the case study.

- Topographic investigation

A topographical survey was done and a map with contour intervals of 0.5 m was produced, as required by the design guidelines. The slope of the field perpendicular to the contour is approximately 2.5% and fairly even, making it suitable for the installation of subsurface drainage.

- Soil and groundwater investigation

A detailed soil investigation was done, with 50 profile holes drilled up to a depth of 2 m and the soil profile described for each hole (see Figure 7-2). The depth at which the water table occurred was noted for each profile hole, which was as shallow as 20cm in some parts of the field. A large round stone fraction is found in the area and this should be kept in mind when pricing earth works for the construction of the drainage system. The origin of the water is the Winterhoek Mountains in the east, from which rain and snow drains at the end of the winter, with the subsurface component of the drainage surfacing in the fields below the mountain range. Furthermore, the Wabooms River and Breede River are each located about 1.8km to the north and the west of the case study farm respectively, resulting in high water tables. At the time of the initial investigation (2000) the part of the farm was not cultivated so irrigation inefficiency could not have contributed to the waterlogging problem. The permeability of the soil was not measured directly in the field but was estimated on the basis of the soil texture.

- Investigation on land use and ownership

The area to be drained was natural veld before the drainage system was installed. Subsequently, it was developed into fruit orchards for peach, plum and nectarine trees irrigated with micro sprinklers and drip irrigation.

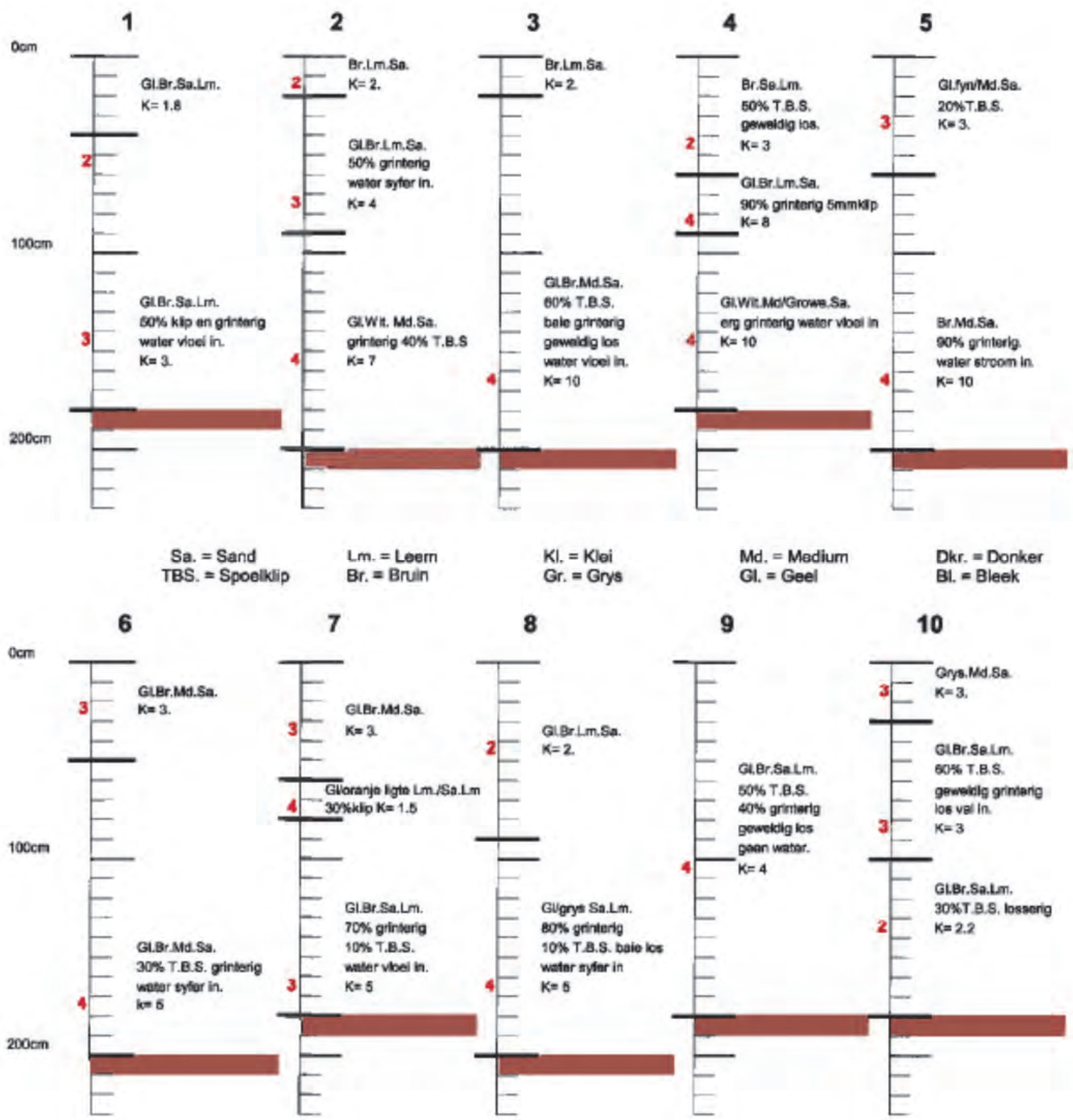


Figure 7-2 Soil profile descriptions at the Breede River site

- Water use investigation and drainage water outflow

Some of the surrounding fields on neighbouring farms are also fitted with drainage systems and many of the systems deposit their water into surface drainage ditches. The new system was also designed to discharge into a surface drain that leads to the Breede River, with the necessary permission obtained from the neighbour over whose property the ditch runs.

- Custom of drainage practices

A subsurface drainage system was selected as this had been found to be the most appropriate for the area and crop type. The original design was a herringbone type of lay-out with a spacing of 60 m between drains, resulting in a system discharge capacity of 6.1 mm/day.

7.1.3 **Impala irrigation scheme site**

- Profile depth

The profile depth was found to be more than 1.8 m indicating a fairly deep profile. Given the deep rooted system of sugar cane, the profile of the Pongola soils suit sugarcane cropping with installed drains. Such a deep profile allows drains to be at wider spacing as groundwater flow is not restricted resulting in high entry losses to subsurface drains. Wider spacings make drain design and installation less costly and therefore likely to be more viable.

- Saturated hydraulic conductivity (K)

The average K value for Pongola was 0.32 m/day (with a standard deviation of 0.16 m/day), although there was evidence of soil layering. On a comparative basis these results are typical of silty clay, silty clay loam and clay loam as found in Pongola. In terms of implications on drainage system design, such low values require drains to be closely spaced. Close spacing of drains result in high drain installation costs impacting on viability of the enterprise.

- Drainable porosity

Estimated from the hydraulic conductivity values, the drainable porosity was found to be in the range 3-8% implying a soil with a structure that fine to medium prismatic, angular blocky and platy. Here saturated hydraulic conductivity is much more important in drainage design that drainable porosity.

- Drainage coefficient

The drainage coefficient for the Pongola site was found to average about 3-5 mm/day. This is slightly low compared to, for example, the 7 mm/day found and used in drainage design in the Netherlands. In terms of drainage design, a low drainage coefficient implies drains have to remove less water thus the design could be for wider spacings making for a less costly drain system.

- Drainage criteria and drain design

The results from Pongola indicate technically feasible drain design but probably slightly costly installations because of the need for close spacings due to low hydraulic conductivity.

7.2 **Financial feasibility**

This section summarizes the economic and financial feasibility modelling results of the three selected case studies, viz. Vaalharts, Pongola and Breede River. The results include Crop-Drain modelling results that simulate estimated seed yields of crops grown in water table soils, as influenced by waterlogging and soil salinity under specific rainfall and soil conditions, in the presence or absence of artificial drainage, due to irrigation with a specific water quality. These modelling results feed into the Drain-Fin model to evaluate the economic and financial feasibility of the drainage investment decision.

The Drain-Fin model was developed as a user-friendly financial assessment model that integrates:

- Whole-farm planning (20-year period)
- Crop yield curves (with and without drainage)
- Capital and maintenance expenditure (sub-surface drainage system)
- Financial analysis (Whole-farm and Per-hectare), and
- Comparison of different scenarios and measuring against norms

The modelling framework consists of seven modules, i.e.:

- Enterprise crop budgets (yearly projected produce yield and prices and input costs for both “With drainage” and “Without drainage” scenarios for each crop, field or production block over a twenty year period).
- Projected Capital budget and maintenance cost per hectare for installation of sub-surface drainage.
- Whole-farm Cash flow projection over a twenty year period. The cash flow includes, amongst others, production income and costs, capital and non-farm income, non allocated and capital costs, debt redemption and payments and other costs, e.g. private expenses.
- Income statement projection over a twenty year period. The projected income statement makes provision for, inter alia, depreciation and tax provision.
- Projected balance sheet. Current, medium and long term assets and liabilities are projected over a twenty year period. Depreciation and growth in net worth are, amongst others, included the projection.
- Economic and financial analysis. The analysis includes Whole-farm projected production cost analysis, -cash flow ratio, -debt ratio, -bank balance. The analysis also includes a “Per-hectare” sub-surface drainage analysis, calculating the Benefit-cost Ratio, Payback period, Internal Rate of Return (IRR) and Net Present Value (NPV).
- The Financing decision support tool takes into account several critical financing norms and criteria to evaluate if the case study/scenario will qualify for financing under normal circumstances. The module was designed in such a way that it

combines per hectare Benefit cost analysis and Whole-farm planning (analysis) projected over a 20-year period. The reader/user must however be aware that the module merely serves as a rough indicator to determine the likelihood of getting finance.

Technical inputs impacting on the capital and maintenance cost of drainage installation is derived from two other models namely DRAINMOD and SWAMP. DRAINMOD is based on a water balance in the soil profile and uses climatological records to simulate the performance of drainage and water control systems. The SWAMP model simulates the movement of salts within the soil profile.

The modelling results for the case studies are presented in the sections below and described in two sections, viz. (a) Waterlogging and salinity modelling to determine potential yield, and (b) economic and financial modelling to determine the impact of waterlogging and salinity on financial vulnerability of farming systems.

The detailed financial modelling results for the case studies are attached in Appendix G (Vaalharts), Appendix H (Pongola) and Appendix I (Breede River).

7.3 Pongola case study

7.3.1 Waterlogging and salinity modelling results for Pongola case study

Figure 7-3 displays the assumptions on which the modelling to determine potential yield for sugar cane in the Pongola case study, was based.

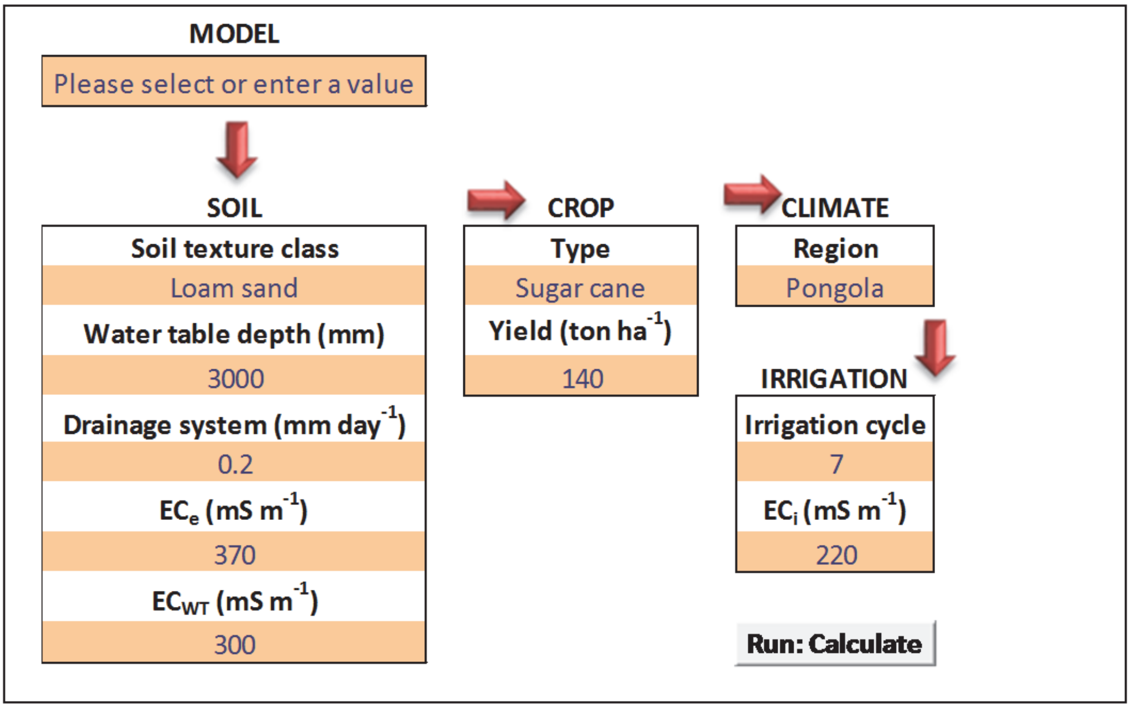


Figure 7-3 Modelling inputs to determine logging and salinity for Sugar cane

Figure 7-4 displays the measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (EC_e) and water table salinity (EC_{WT}) over a period of 20 years (approximately 7000 days) due to the inputs shown in Figure 7-4.

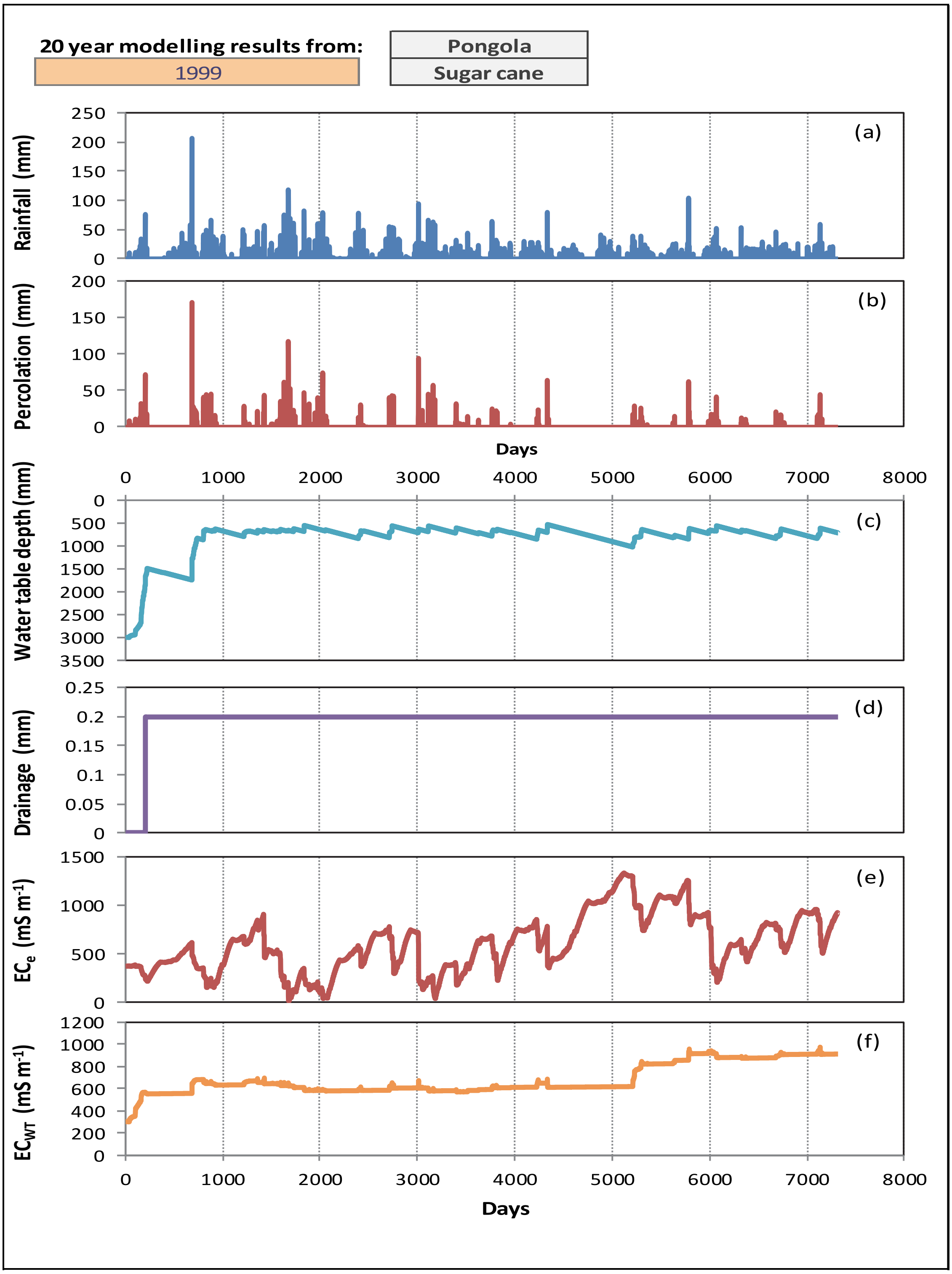


Figure 7-4 Measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (EC_e) and water table salinity (EC_{WT}) over a period of 20 years (approximately 7000 days)

Figure 7-5 shows the relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

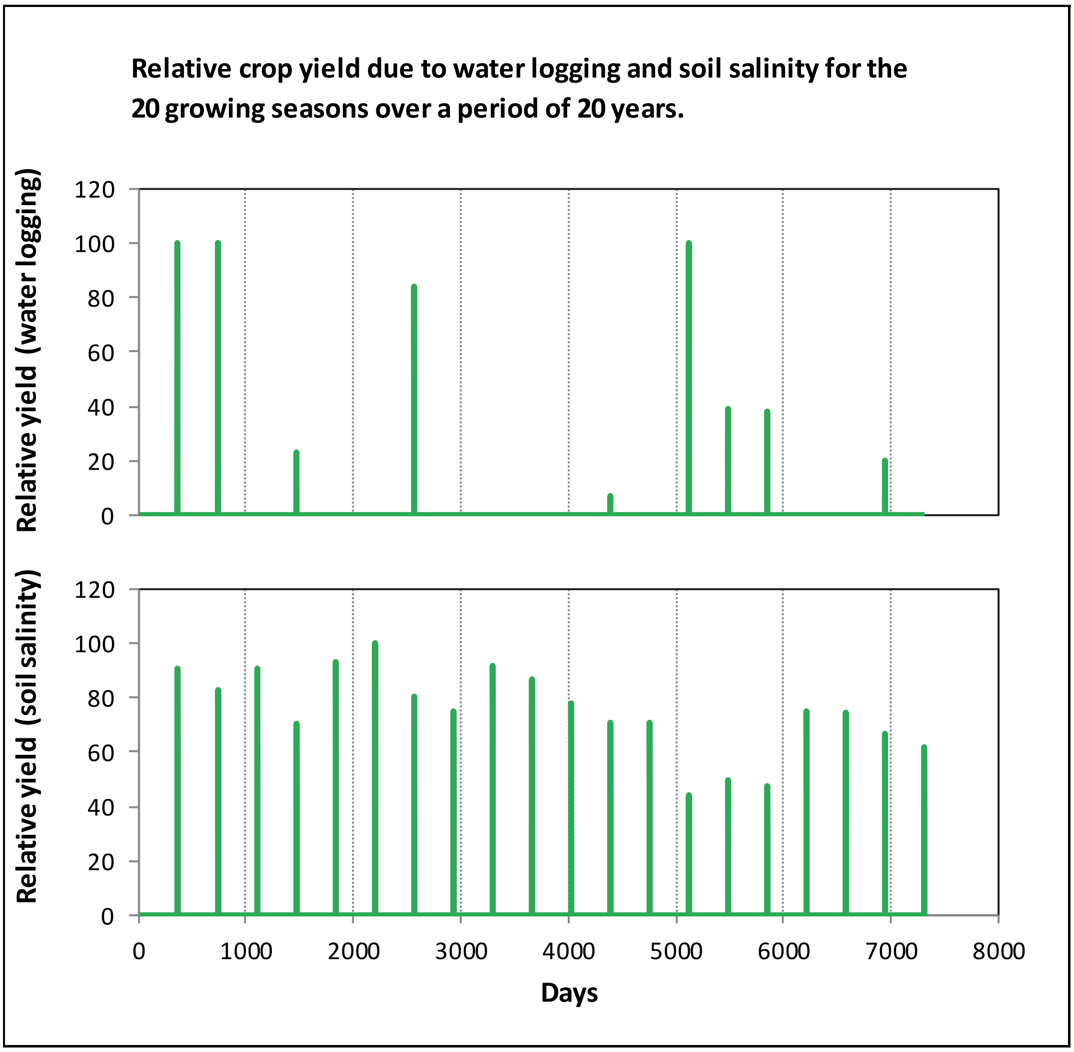


Figure 7-5 Relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

Figure 7-6 displays the mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

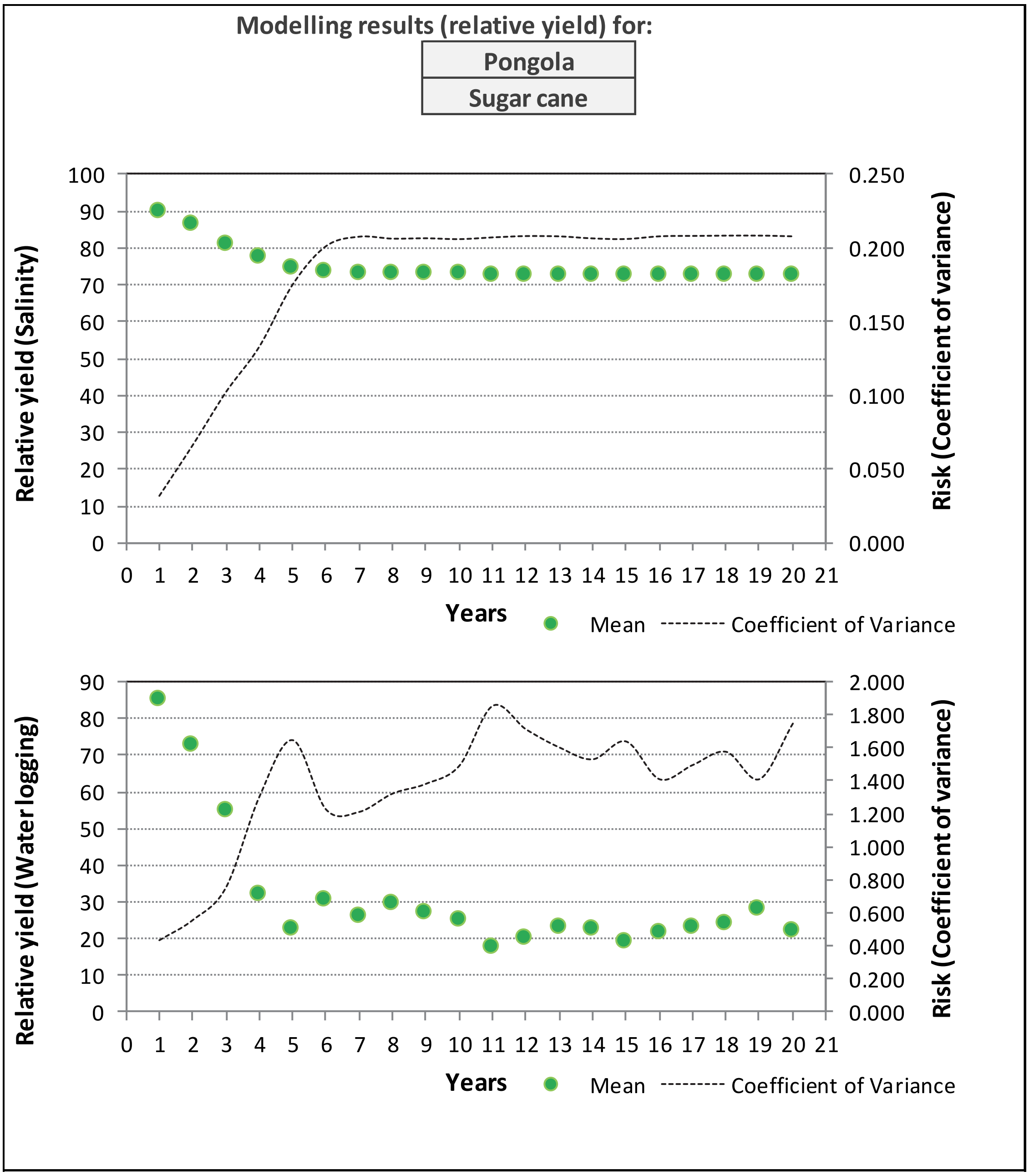


Figure 7-6 Mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

Table 7-1 displays the mean relative crop yield of the 20 repetitions in Figure 7-6 converted to ton ha^{-1} according to potential yield specified in Figure 7-5 together with the standard deviation and coefficient of variance.

Table 7-1 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance

Modelling results (ton ha^{-1}) for:	Pongola
0.2 (mm day-1) drain	Sugar cane

Year	Water logging			Salinity		
	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	119.00	51.289	43	125.81	3.926	3
2	101.85	56.314	55	120.82	7.934	7
3	76.51	57.500	75	113.28	11.524	10
4	44.80	58.243	130	108.43	14.384	13
5	31.71	52.103	164	104.55	18.275	17
6	42.98	52.549	122	102.92	20.667	20
7	36.61	44.259	121	102.15	21.164	21
8	41.30	54.488	132	102.04	21.010	21
9	37.94	52.300	138	102.10	21.049	21
10	34.79	51.810	149	102.02	20.973	21
11	24.50	45.350	185	101.91	21.066	21
12	28.35	48.431	171	101.74	21.127	21
13	32.06	51.262	160	101.71	21.097	21
14	31.78	48.525	153	101.81	20.982	21
15	27.02	44.176	163	101.78	20.927	21
16	30.38	42.719	141	101.77	21.115	21
17	32.55	48.593	149	101.80	21.151	21
18	33.95	53.380	157	101.74	21.151	21
19	38.99	54.875	141	101.90	21.194	21
20	30.59	53.371	174	101.78	21.112	21

The modelling results show that from a waterlogging and salinity point-of-view, waterlogging poses a bigger threat to potential yield than salinity. In the absence of subsurface drainage, sharp decreases in yield can be expected from year 1 as a result of waterlogging.

Table 7-2 shows the relative crop yield based on the same assumptions, but including a 5 mm day-1 drainage system.

Table 7-2 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance after introduction of 5 mm day-^{1} drainage system

Modelling results (ton ha^{-1}) for:	Pongola
5 (mm day-1) drain	Sugar cane

	Water logging			Salinity		
Year	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	140.00	0.000	0	126.17	4.542	4
2	140.00	0.000	0	122.73	8.199	7
3	140.00	0.000	0	118.61	10.312	9
4	140.00	0.000	0	115.71	12.733	11
5	140.00	0.000	0	113.73	14.417	13
6	140.00	0.000	0	112.54	15.240	14
7	140.00	0.000	0	111.90	15.549	14
8	140.00	0.000	0	111.44	15.741	14
9	140.00	0.000	0	111.15	15.906	14
10	140.00	0.000	0	111.03	15.991	14
11	140.00	0.000	0	110.95	16.045	14
12	140.00	0.000	0	110.90	16.065	14
13	140.00	0.000	0	110.92	16.042	14
14	140.00	0.000	0	110.90	16.031	14
15	140.00	0.000	0	110.90	16.056	14
16	140.00	0.000	0	110.86	16.061	14
17	140.00	0.000	0	110.86	16.051	14
18	140.00	0.000	0	110.89	16.074	14
19	140.00	0.000	0	110.89	16.026	14
20	140.00	0.000	0	110.87	16.046	14

The results show that the drainage system resolves the waterlogging problem and at the same time reduces salinity. The remaining salinity impact can be managed by means of flushing the field.

7.3.2 Economic and financial modelling results for the Pongola case study

The composition and functioning of the Drain-Fin model was discussed in previous submissions and therefore only the final modelling results are discussed in the sections below.

- Economic Benefit Cost analysis (per hectare)

Table 7-3 illustrates the Economic Benefit Cost analysis for sugarcane.

Table 7-3 Economic Benefit Cost analysis – Pongola crops

Sugarcane *(Per hectare drainage installation analysis)*	
Benefit-Cost Ratio	4.9 : 1
Payback period (average)	1.6 years
Internal Rate of Return (IRR)	52.2%
Net Present Value (NPV)	335 990

The Economic Benefit Cost analysis shows that installation of drainage for sugarcane is economically viable.

- Financial Whole-farm analysis

For the Whole-farm analysis, five scenarios were modelled. These are:

- o Without drainage – 0% start-up debt ratio
- o With drainage – 0% start-up debt
- o With drainage – 20% start-up debt ratio
- o With drainage – 30% start-up debt ratio
- o With drainage – 30% start-up debt ratio – 50% subsidy

Table 7-4 reflects the production cost ratio, projected cash flow ratio, projected debt ratio and projected end bank balance of the different scenarios.

Table 7-4 Comparison of Financial Whole-farm analysis scenarios – Pongola

Scenario nr & description		Production cost ratio *	Projected cash flow ratio *	Highest Projected Debt ratio	End Bank balance
1	Without drainage - 0% Debt ratio	137%	31%	1017%	-106 477 345
2	With drainage - 0% Debt ratio	62%	142%	19%	24 434 990
3	With drainage - 20% Debt ratio	62%	129%	40%	12 834 001
4	With drainage - 30% Debt ratio	62%	102%	59%	-4 533 908
5	With drainage - 30% Debt ratio - 50% subsidy	62%	131%	41%	12 568 586
	* *20-year average*				

The modelling results can be interpreted as follows:

Without drainage – 0% start-up debt ratio

- Not financially feasible – projected cash flow ratio <115% and debt ratio exceeds acceptable financing norm (<50%).

With drainage – 0% start-up debt ratio

- Financially feasible – projected cash flow ratio > 115%

- Highest projected debt ratio < 50%

With drainage – 20% start-up debt ratio

- Financially feasible – projected cash flow ratio > 115%
- Highest projected debt ratio < 50%

With drainage – 30% start-up debt ratio

- Not financially feasible – projected cash flow ratio < 115%
- Highest projected debt ratio > 50%

With drainage – 30% start-up debt ratio – 50% subsidy

- Financially feasible – projected cash flow ratio > 115%
- Highest projected debt ratio > 50%

Without drainage the case study farm will not be financially viable. The farm will be financially viable with 20% start-up debt ratio with drainage installed. However, chances are slim that the operation will succeed with a start-up debt ratio in excess of 30%, unless drainage installation costs are partially financed through “green box” grants.

- Financing decision support tool
- Table 7-5 summarises the financing decision support tool indicators for the different scenarios.

Table 7-5 Summarised financing decision support tool – Pongola

Scenario / Description	Norm	1 Without drainage - 0% Debt ratio	2 With drainage - 0% Debt ratio	3 With drainage - 20% Debt ratio	4 With drainage - 30% Debt ratio	5 With drainage - 30% Debt ratio - 50% subsidy
Capacity						
Cash flow ratio	> 115%	No	Yes	Yes	No	Yes
Capital						
Debt ratio	< 50%	No	Yes	Yes	No	Yes
Collateral						
Sufficient available "yes" or "no"	yes	Yes	Yes	Yes	Yes	Yes
Conditions						
Benefit Cost ratio (B/C) : 1	> 1	Yes	Yes	Yes	Yes	Yes
Payback average	< 8	Yes	Yes	Yes	Yes	Yes
Internal Rate of Return (IRR)	> 8%	Yes	Yes	Yes	Yes	Yes
Net Present value (NPV)	0	Yes	Yes	Yes	Yes	Yes
Character						
Trustworthy "yes" or "no"	yes	Yes	Yes	Yes	Yes	Yes
Economic & Financially feasible		**No**	**Yes**	**Yes**	**No**	**Yes**

** Average 1st 20 years*

In the economic and financially feasible row the scenarios with a "yes" will most probably attract finance from commercial banks in the normal run of business. Scenarios with a "no" will most probably not qualify for commercial finance. Please note that this tool serves as an indicator only.

- Summary

This section summarises the modelling results for the Pongola case study. Several scenarios were run including "with" and "without" drainage for 0%, 20% and 30% start-up debt ratios. The 30% start-up debt ratio "with drainage and 50% subsidy"-scenario illustrates the impact of green box grants/subsidies on the economic viability and financial feasibility of sub-surface drainage. The results show that it will not be financially viable for a farming operation with a debt ratio in excess of 30% to install subsurface drainage without subsidy. Subsidies will ultimately assist the farming operation to stay financially viable while installing drainage. However, it will not be financially viable for farming operations with debt levels in excess of 40% to install drainage, even with a 50% subsidy. In order for farming operations with debt ratios of more than 40% to stay financially viable, the subsidy on installation of drainage should exceed 50% of drainage installation cost.

7.4 Vaalharts case study

7.4.1 Waterlogging and salinity modelling results for Vaalharts case study

The waterlogging and salinity modelling for the Vaalharts case study include four crops, i.e. pecan nuts, lucerne, maize and barley. The modelling results are presented in the sections below.

- Pecan nuts

Figure 7-7 displays the assumptions on which the modelling to determine potential yield for pecan nuts in the Vaalharts case study, was based.

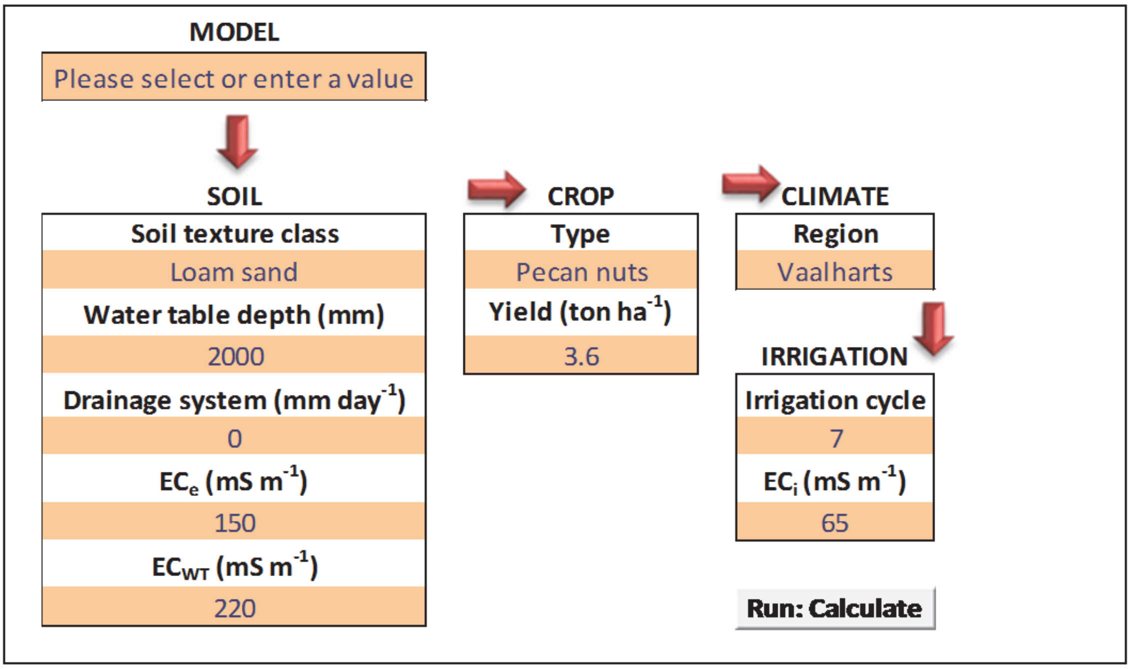


Figure 7-7 Modelling inputs to determine logging and salinity for pecan nuts

Figure 7-8 displays the measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (ECe) and water table salinity (ECWT) 20 years (approximately 7000 days) due to the inputs shown in Figure 7-7.

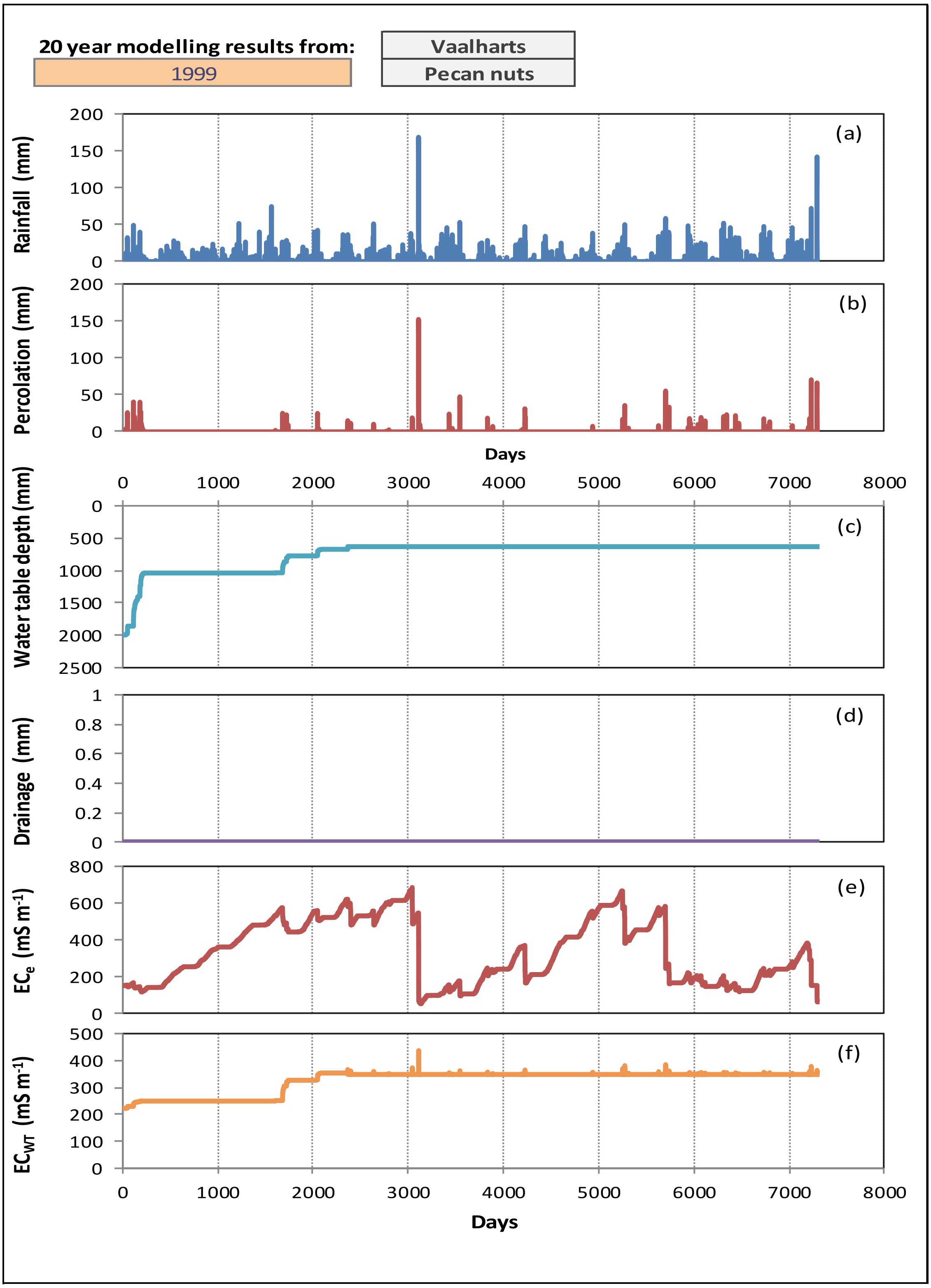


Figure 7-8 Measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (EC_e) and water table salinity (EC_{WT}) 20 years (approximately 7000 days).

Figure 7-9 shows the relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

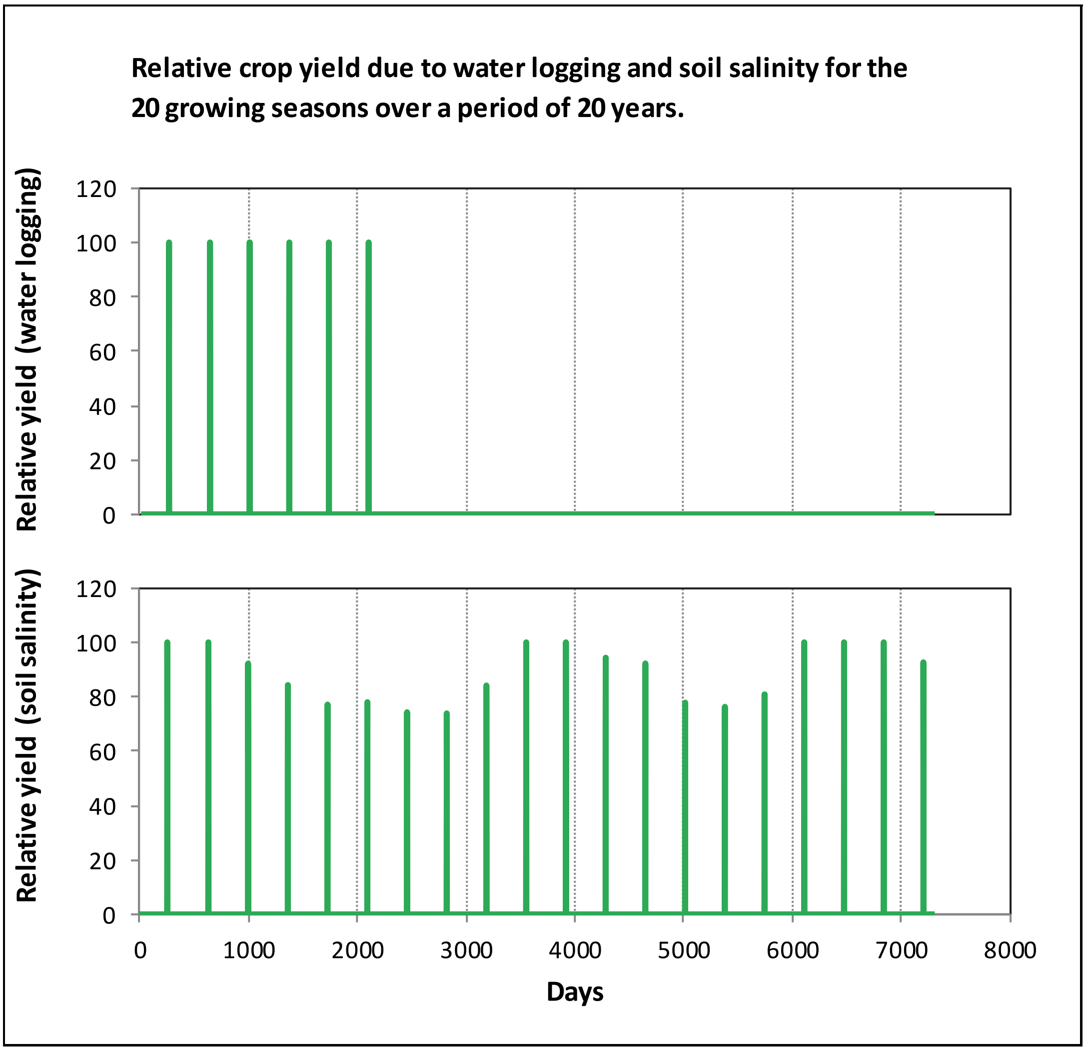


Figure 7-9 Relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

Figure 7-10 displays the mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

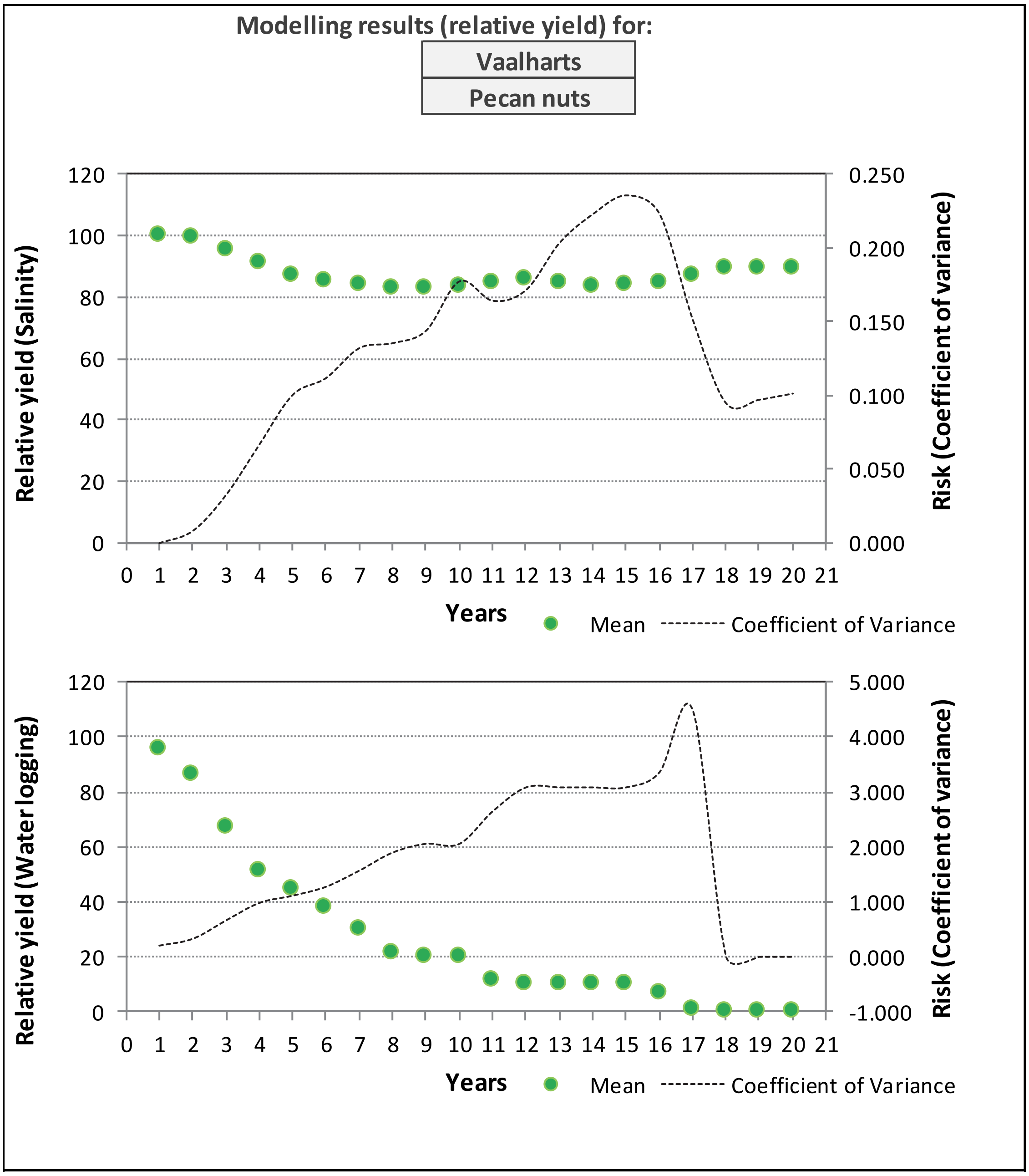


Figure 7-10 Mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

Table 7-6 displays the mean relative crop yield of the 20 repetitions in Figure 7-6 converted to ton ha-[1] according to potential yield specified in Figure 7-3 together with the standard deviation and coefficient of variance.

Table 7-6 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance

Modelling results (ton ha^{-1}) for:	Vaalharts
0 (mm day-1) drain	Pecan nuts

	Water logging			Salinity		
Year	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	3.44	0.700	20	3.60	0.000	0
2	3.11	1.018	33	3.58	0.030	1
3	2.41	1.590	66	3.43	0.112	3
4	1.85	1.810	98	3.28	0.219	7
5	1.62	1.795	111	3.14	0.316	10
6	1.37	1.749	127	3.08	0.345	11
7	1.08	1.693	157	3.02	0.400	13
8	0.78	1.470	189	2.99	0.406	14
9	0.72	1.477	205	2.99	0.431	14
10	0.72	1.477	205	3.00	0.533	18
11	0.42	1.104	264	3.05	0.501	16
12	0.36	1.108	308	3.09	0.530	17
13	0.36	1.108	308	3.04	0.619	20
14	0.36	1.108	308	3.02	0.673	22
15	0.36	1.108	308	3.02	0.712	24
16	0.26	0.857	335	3.04	0.679	22
17	0.03	0.113	447	3.13	0.474	15
18	0.00	0.000	0	3.22	0.305	9
19	0.00	0.000	0	3.22	0.313	10
20	0.00	0.000	0	3.21	0.326	10

The modelling results shows that from a waterlogging and salinity point-of-view, waterlogging poses a bigger threat to potential yield than salinity. In the absence of subsurface drainage, sharp decreases in yield can be expected from year 3 as a result of waterlogging.

Table 7-7 shows the relative crop yield based on the same assumptions, but including a 1 mm day^{-1} drainage system.

Table 7-7 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance after introduction of 1 mm day-^{1} drainage system

Modelling results (ton ha^{-1}) for:	Vaalharts
1 (mm day-1) drain	Pecan nuts

	Water logging			Salinity		
Year	**Mean**	**stdev**	**CV (%)**	**Mean**	**stdev**	**CV (%)**
1	**3.56**	0.169	5	**3.60**	0.000	0
2	**3.60**	0.000	0	**3.59**	0.023	1
3	**3.60**	0.000	0	**3.49**	0.086	2
4	**3.60**	0.000	0	**3.36**	0.142	4
5	**3.60**	0.000	0	**3.23**	0.191	6
6	**3.60**	0.000	0	**3.11**	0.239	8
7	**3.60**	0.000	0	**3.00**	0.288	10
8	**3.60**	0.000	0	**2.89**	0.335	12
9	**3.60**	0.000	0	**2.79**	0.382	14
10	**3.60**	0.000	0	**2.68**	0.435	16
11	**3.60**	0.000	0	**2.59**	0.482	19
12	**3.60**	0.000	0	**2.50**	0.525	21
13	**3.60**	0.000	0	**2.42**	0.570	24
14	**3.60**	0.000	0	**2.34**	0.618	26
15	**3.60**	0.000	0	**2.27**	0.661	29
16	**3.60**	0.000	0	**2.20**	0.687	31
17	**3.60**	0.000	0	**2.15**	0.699	33
18	**3.60**	0.000	0	**2.10**	0.709	34
19	**3.60**	0.000	0	**2.06**	0.712	35
20	**3.60**	0.000	0	**2.03**	0.703	35

The results show that the drainage system resolves the waterlogging problem and at the same time reduces salinity. The remaining salinity impact can be managed by means of flushing the field.

- Lucerne

Figure 7-11 displays the assumptions on which the modelling to determine potential yield for lucerne in the Vaalharts case study, was based.

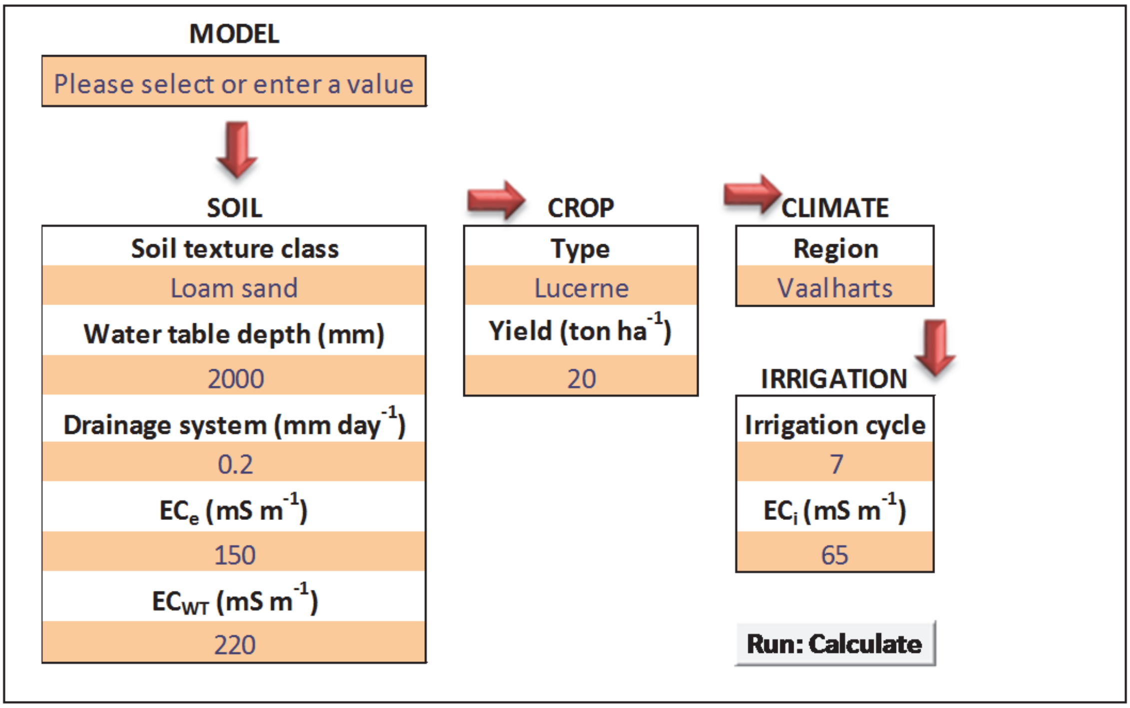


Figure 7-11 Modelling inputs to determine logging and salinity for lucerne

Figure 7-12 displays the measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (ECe) and water table salinity (ECWT) 20 years (approximately 7000 days) due to the inputs shown in Figure 7-11.

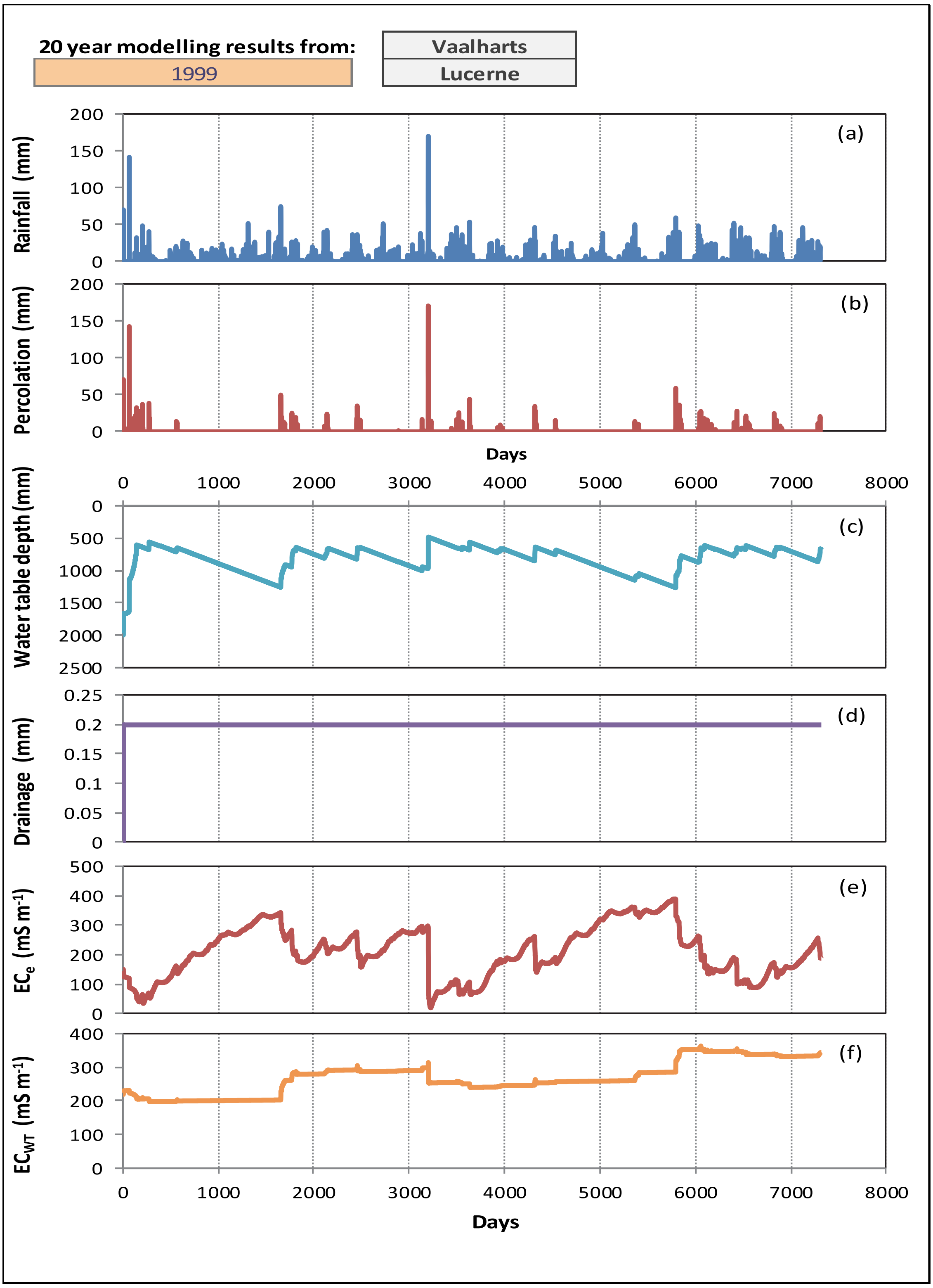


Figure 7-12 Measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (EC_e) and water table salinity (EC_{WT}) 20 years (approximately 7000 days).

Figure 7-13 shows the relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

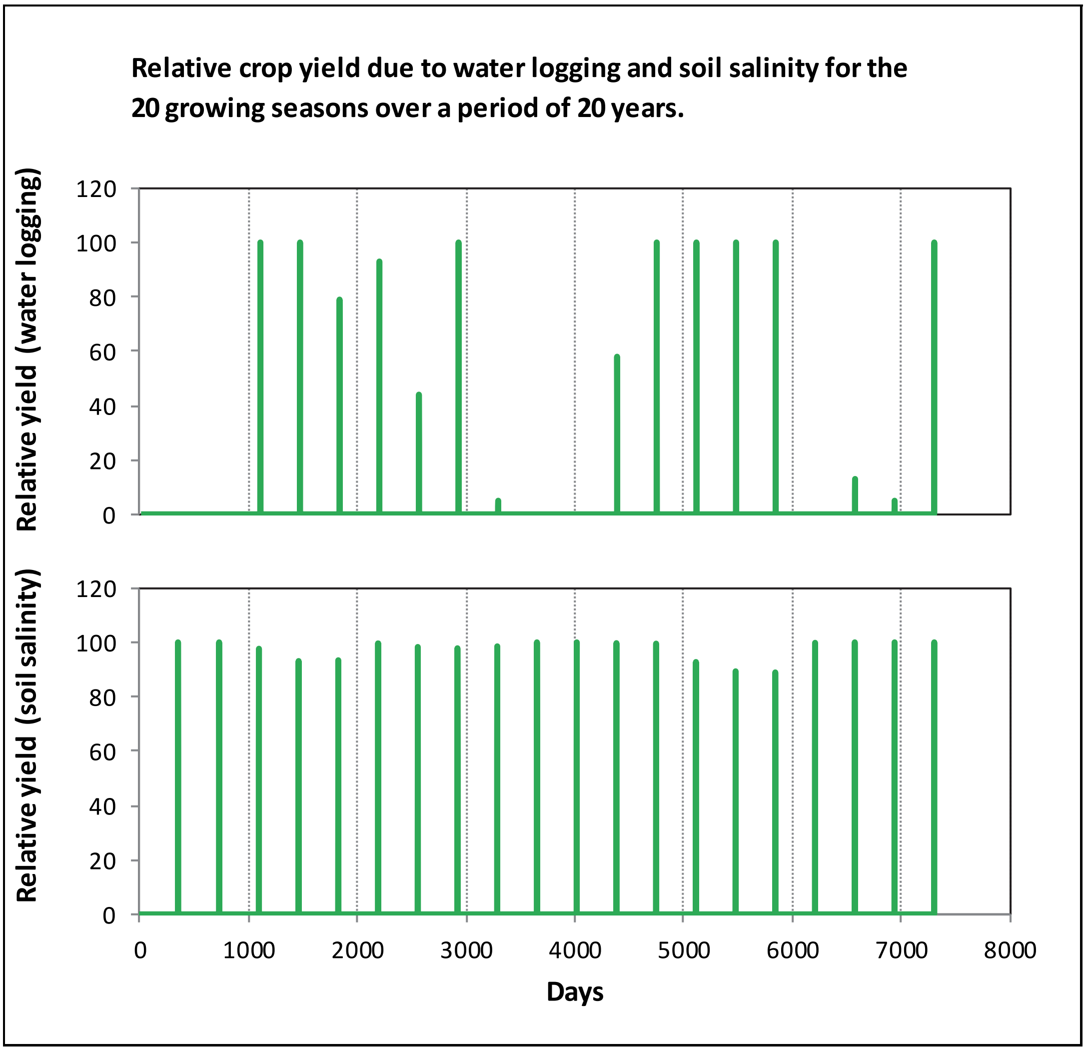


Figure 7-13 Relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

Figure 7-14 displays the mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

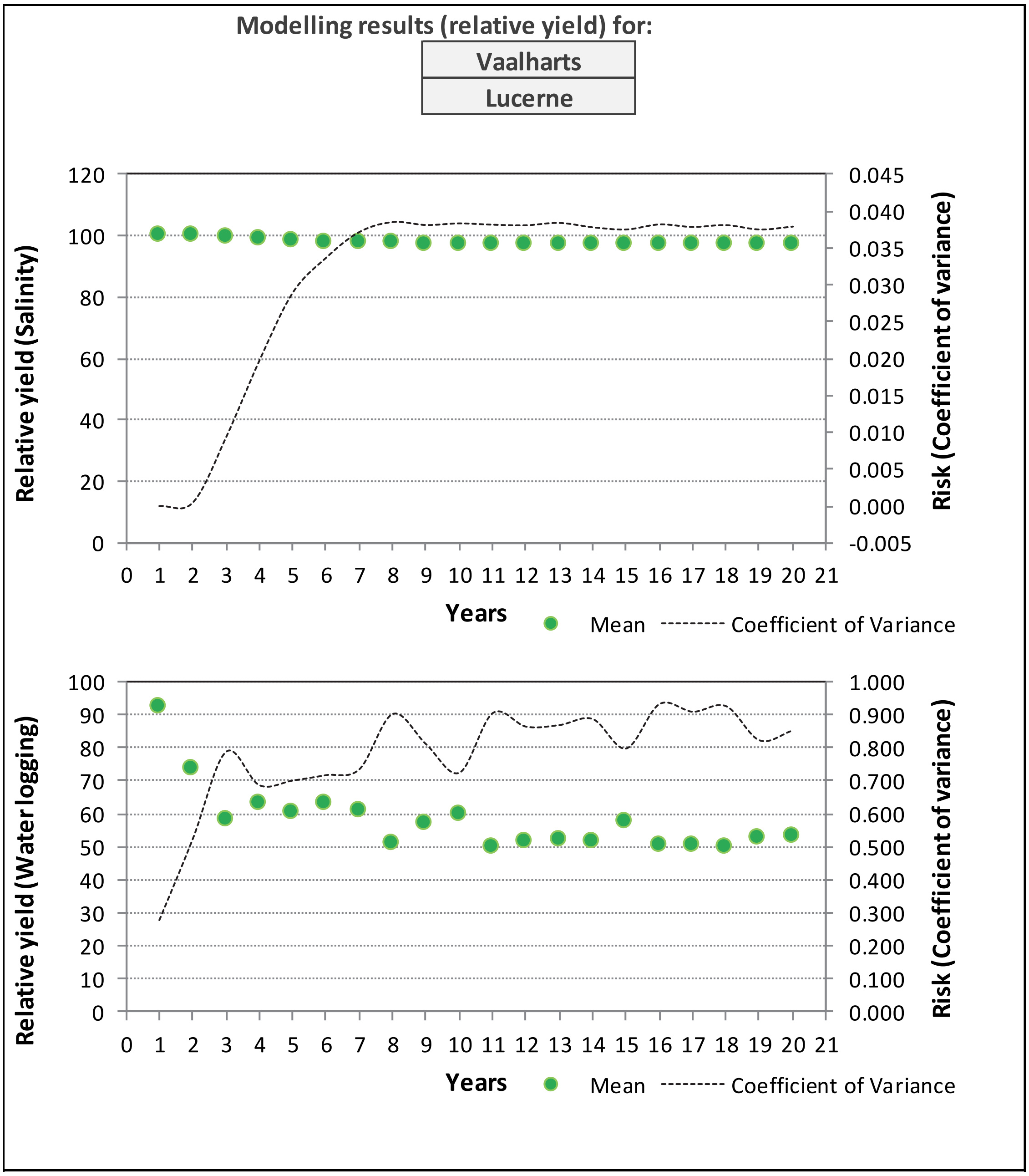


Figure 7-14 Mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

Table 7-8 displays the mean relative crop yield of the 20 repetitions in Figure 7-14 converted to ton ha-1 according to potential yield specified in Figure 7-11 together with the standard deviation and coefficient of variance.

Table 7-8 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance

Modelling results (ton ha^{-1}) for:	Vaalharts
0.2 (mm day-1) drain	Lucerne

Year	Water logging			Salinity		
	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	18.41	5.071	28	20.00	0.000	0
2	14.69	7.651	52	20.00	0.009	0
3	11.62	9.123	79	19.91	0.186	1
4	12.60	8.622	68	19.78	0.391	2
5	12.11	8.457	70	19.64	0.570	3
6	12.66	9.045	71	19.57	0.661	3
7	12.22	8.956	73	19.52	0.728	4
8	10.20	9.179	90	19.49	0.753	4
9	11.36	9.183	81	19.49	0.745	4
10	11.92	8.609	72	19.48	0.749	4
11	9.94	8.970	90	19.48	0.746	4
12	10.35	8.916	86	19.48	0.745	4
13	10.45	9.052	87	19.48	0.751	4
14	10.29	9.101	88	19.49	0.739	4
15	11.51	9.157	80	19.49	0.733	4
16	10.04	9.335	93	19.48	0.747	4
17	10.05	9.113	91	19.48	0.740	4
18	9.97	9.208	92	19.49	0.745	4
19	10.52	8.627	82	19.49	0.733	4
20	10.59	9.005	85	19.49	0.741	4

The modelling results shows that from a waterlogging and salinity point-of-view, waterlogging poses a bigger threat to potential yield than salinity. In the absence of subsurface drainage, sharp decreases in yield can be expected from year 2 as a result of waterlogging.

Table 7-9 shows the relative crop yield based on the same assumptions, but including a 1 mm day-^{1} drainage system.

Table 7-9 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance after introduction of 1 mm day^{-1} drainage system

Modelling results (ton ha^{-1}) for:	Vaalharts
1 (mm day-1) drain	Lucerne

Year	Water logging			Salinity		
	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	19.80	0.894	5	20.00	0.000	0
2	19.53	1.507	8	20.00	0.021	0
3	19.80	0.805	4	19.94	0.155	1
4	19.75	0.986	5	19.89	0.232	1
5	19.77	0.897	5	19.86	0.308	2
6	19.79	0.893	5	19.85	0.277	1
7	19.77	0.897	5	19.83	0.262	1
8	19.77	0.897	5	19.83	0.255	1
9	19.79	0.809	4	19.81	0.260	1
10	19.81	0.721	4	19.82	0.259	1
11	19.80	0.805	4	19.81	0.258	1
12	19.76	0.903	5	19.81	0.261	1
13	19.81	0.721	4	19.81	0.263	1
14	19.76	0.903	5	19.81	0.262	1
15	19.80	0.805	4	19.81	0.266	1
16	19.78	0.815	4	19.81	0.265	1
17	19.81	0.721	4	19.81	0.265	1
18	19.81	0.721	4	19.81	0.263	1
19	19.81	0.721	4	19.81	0.263	1
20	19.79	0.809	4	19.81	0.261	1

The results show that the drainage system resolves the waterlogging problem and at the same time reduces salinity.

- Maize

Figure 7-15 displays the assumptions on which the modelling to determine potential yield for maize in the Vaalharts case study, was based.

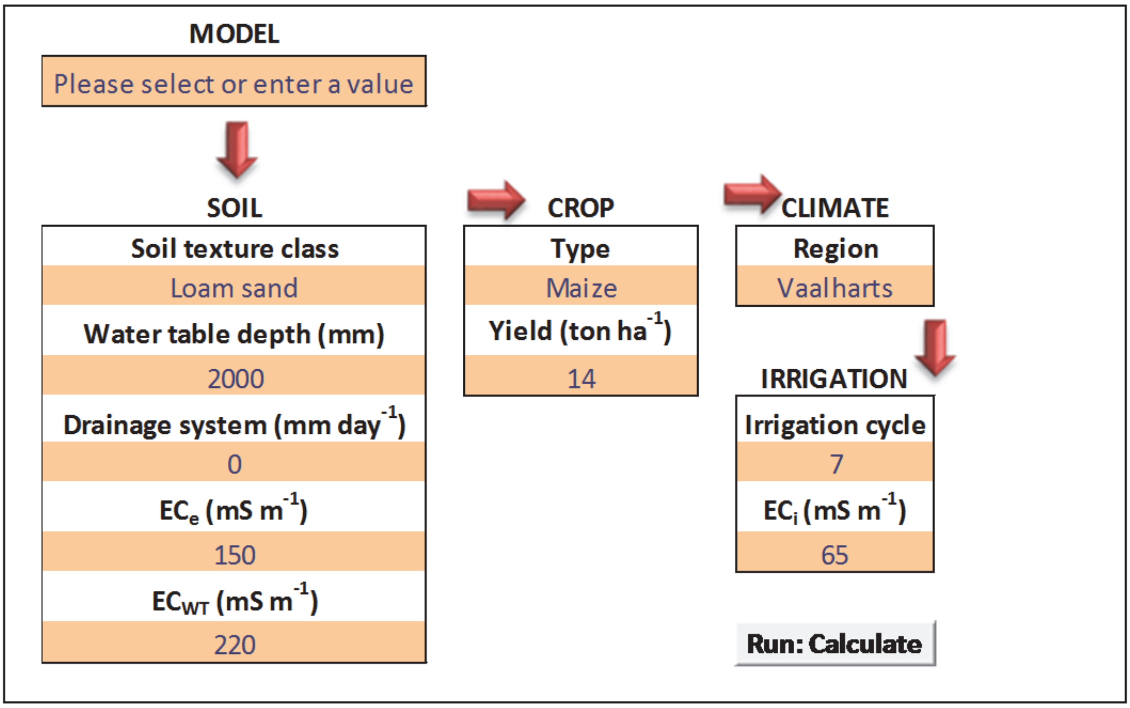


Figure 7-15 Modelling inputs to determine logging and salinity for maize

Figure 7-16 displays the measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (ECe) and water table salinity (ECWT) 20 years (approximately 7000 days) due to the inputs shown in Figure 7-15.

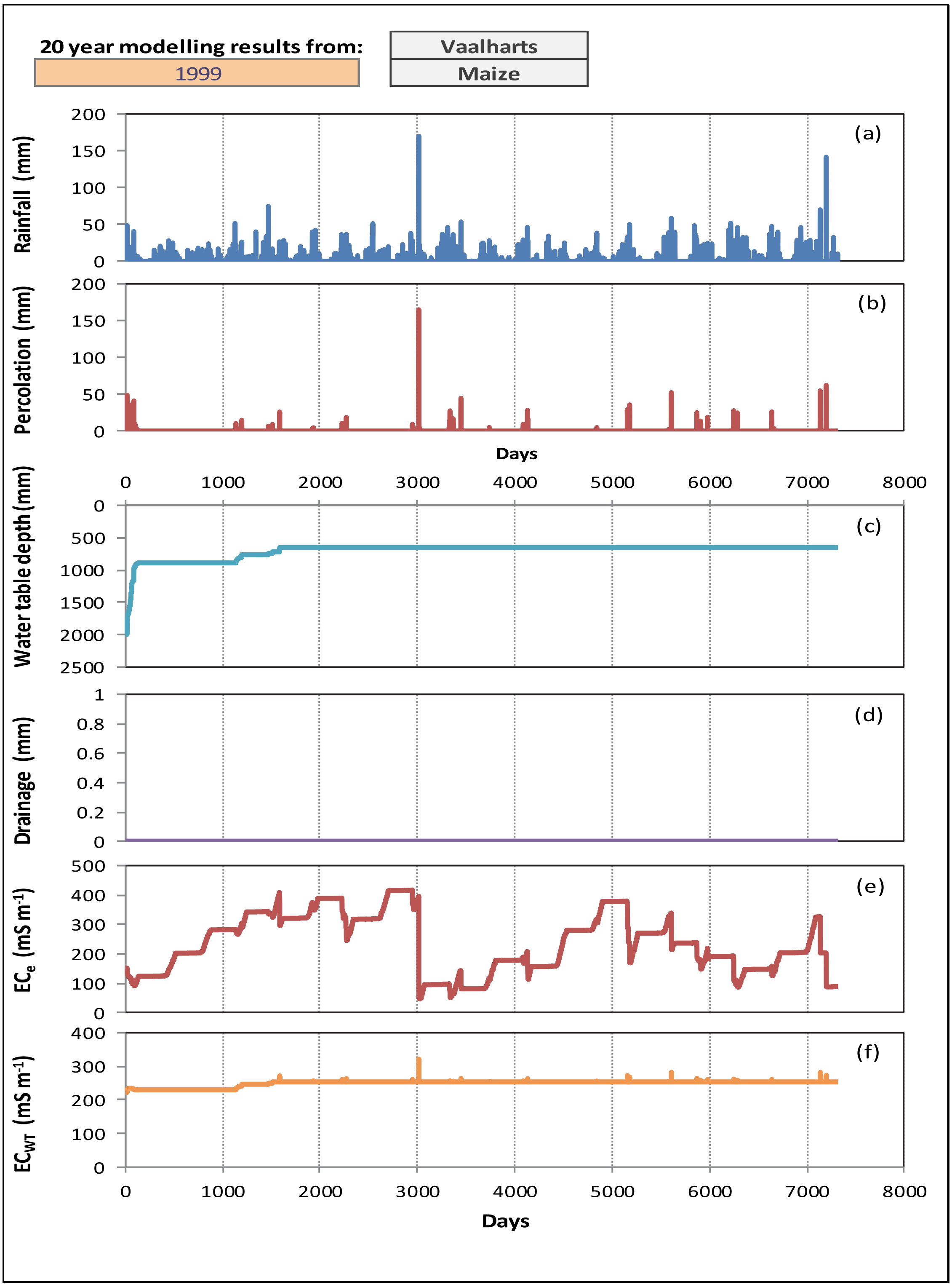


Figure 7-16 Measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (EC_e) and water table salinity (EC_{WT}) 20 years (approximately 7000 days).

Figure 7-17 shows the relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

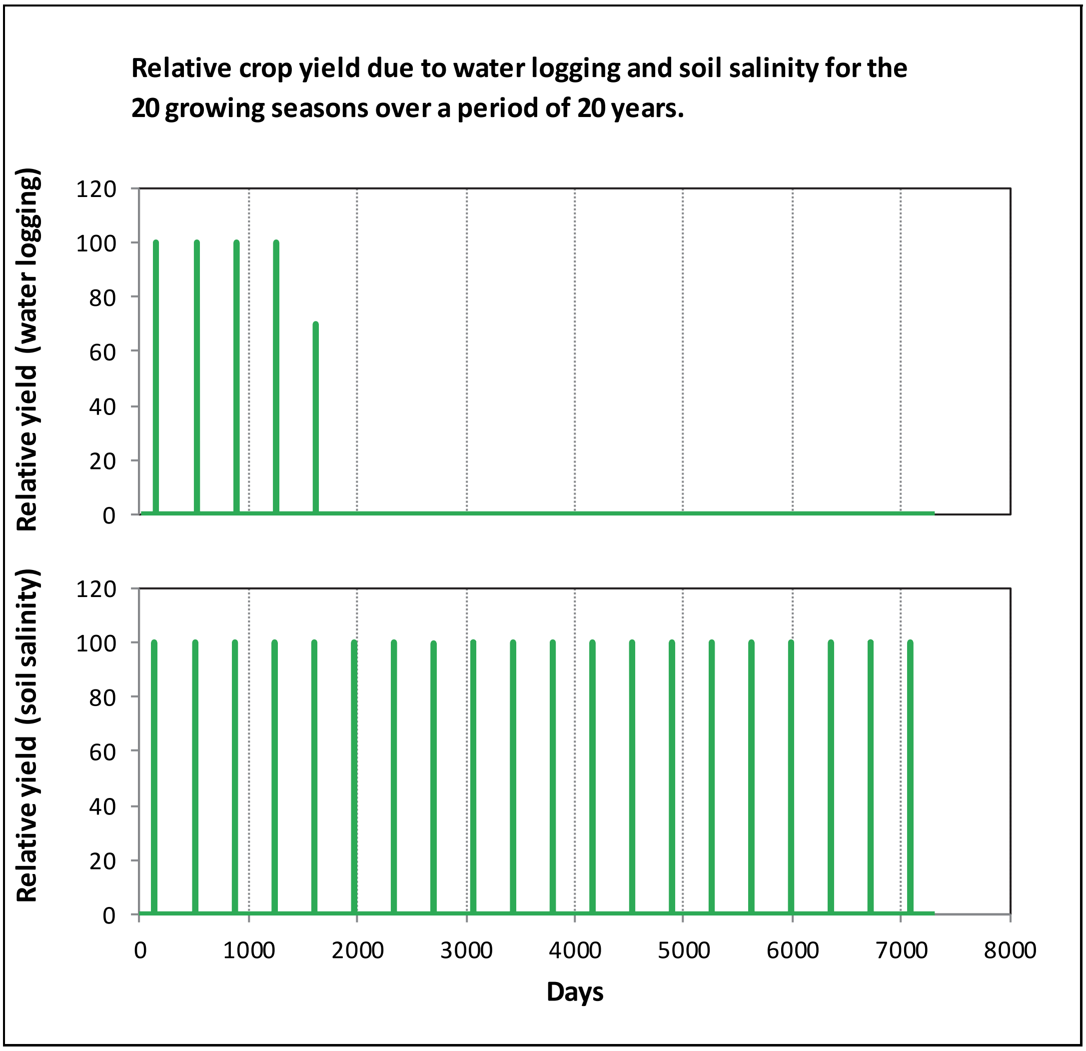


Figure 7-17 Relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

Figure 7-18 displays the mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

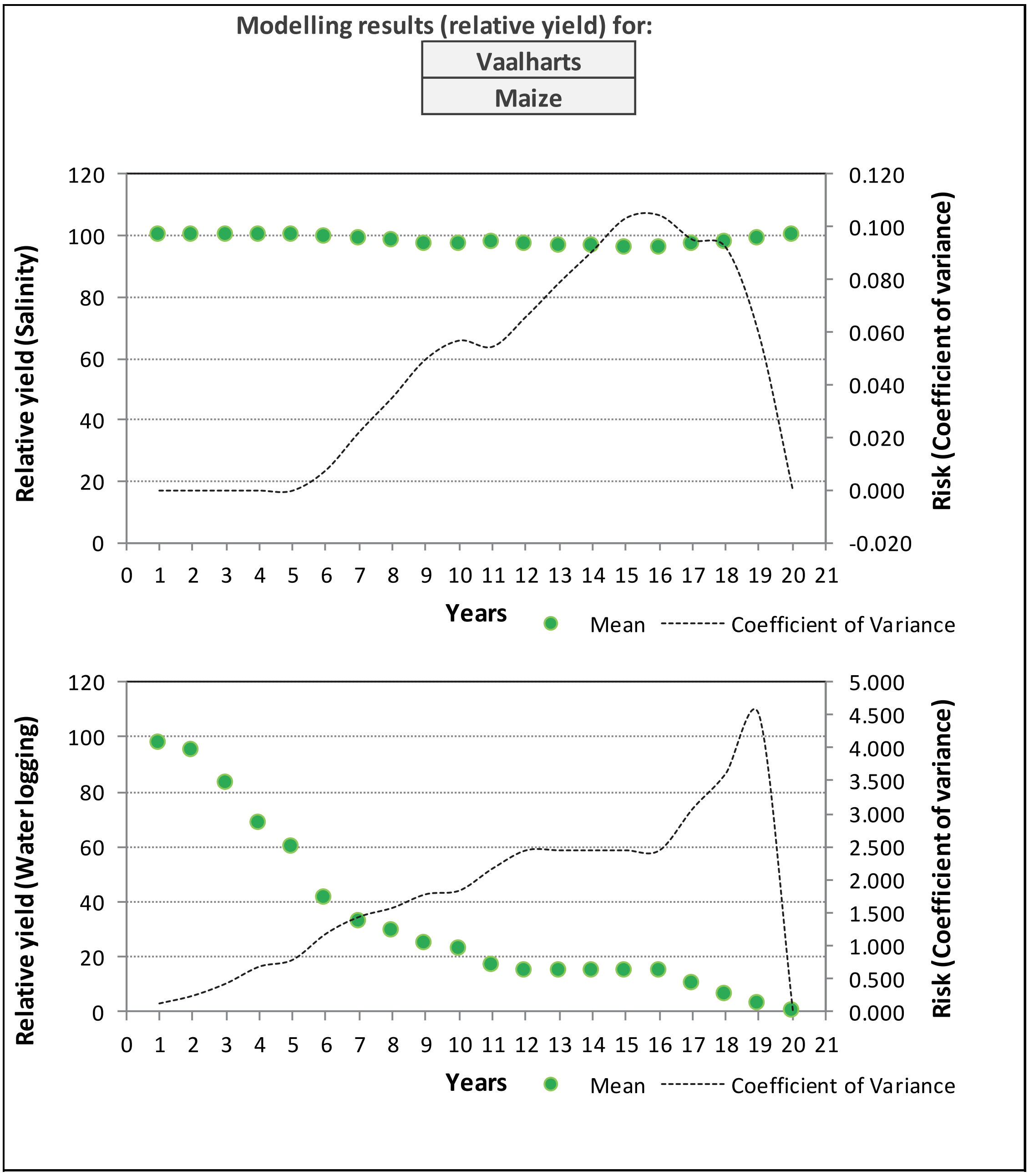


Figure 7-18 Mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

Table 7-10 displays the mean relative crop yield of the 20 repetitions in Figure 7-18 converted to ton ha-1 according to potential yield specified in Figure 7-15 together with the standard deviation and coefficient of variance.

Table 7-10 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance

Modelling results (ton ha^{-1}) for:	Vaalharts
0 (mm day-1) drain	Maize

	Water logging			Salinity		
Year	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	13.64	1.597	12	14.00	0.000	0
2	13.30	3.130	24	14.00	0.000	0
3	11.66	4.904	42	14.00	0.000	0
4	9.60	6.509	68	14.00	0.000	0
5	8.36	6.529	78	14.00	0.000	0
6	5.78	6.811	118	13.95	0.109	1
7	4.56	6.536	143	13.84	0.309	2
8	4.10	6.442	157	13.73	0.488	4
9	3.50	6.220	178	13.64	0.682	5
10	3.16	5.784	183	13.61	0.776	6
11	2.38	5.161	217	13.65	0.746	5
12	2.10	5.129	244	13.63	0.901	7
13	2.10	5.129	244	13.56	1.071	8
14	2.10	5.129	244	13.50	1.230	9
15	2.10	5.129	244	13.43	1.391	10
16	2.10	5.129	244	13.45	1.405	10
17	1.40	4.309	308	13.60	1.295	10
18	0.88	3.193	362	13.72	1.264	9
19	0.46	2.035	447	13.82	0.808	6
20	0.00	0.000	0	14.00	0.000	0

The modelling results shows that from a waterlogging and salinity point-of-view, waterlogging poses a bigger threat to potential yield than salinity. In the absence of subsurface drainage, sharp decreases in yield can be expected from year 3 as a result of waterlogging.

Table 7-11 shows the relative crop yield based on the same assumptions, but including a 1 mm day^{-1} drainage system.

Table 7-11 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance after introduction of 1 mm day^{-1} drainage system

Modelling results (ton ha^{-1}) for:	Vaalharts
1 (mm day-1) drain	Maize

	Water logging			Salinity		
Year	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	13.84	0.720	5	14.00	0.000	0
2	14.00	0.000	0	14.00	0.000	0
3	14.00	0.000	0	14.00	0.000	0
4	14.00	0.000	0	14.00	0.000	0
5	14.00	0.000	0	14.00	0.000	0
6	14.00	0.000	0	14.00	0.000	0
7	14.00	0.000	0	13.96	0.073	1
8	14.00	0.000	0	13.87	0.207	1
9	14.00	0.000	0	13.67	0.369	3
10	14.00	0.000	0	13.48	0.520	4
11	14.00	0.000	0	13.31	0.689	5
12	14.00	0.000	0	13.14	0.863	7
13	14.00	0.000	0	12.97	1.010	8
14	14.00	0.000	0	12.81	1.138	9
15	14.00	0.000	0	12.67	1.263	10
16	14.00	0.000	0	12.53	1.343	11
17	14.00	0.000	0	12.43	1.386	11
18	14.00	0.000	0	12.35	1.437	12
19	14.00	0.000	0	12.26	1.447	12
20	14.00	0.000	0	12.18	1.453	12

The results show that the drainage system resolves the waterlogging problem and at the same time reduces salinity. The remaining salinity impact can be managed by means of flushing the field.

- Barley

Figure 7-19 displays the assumptions on which the modelling to determine potential yield for barley in the Vaalharts case study, was based.

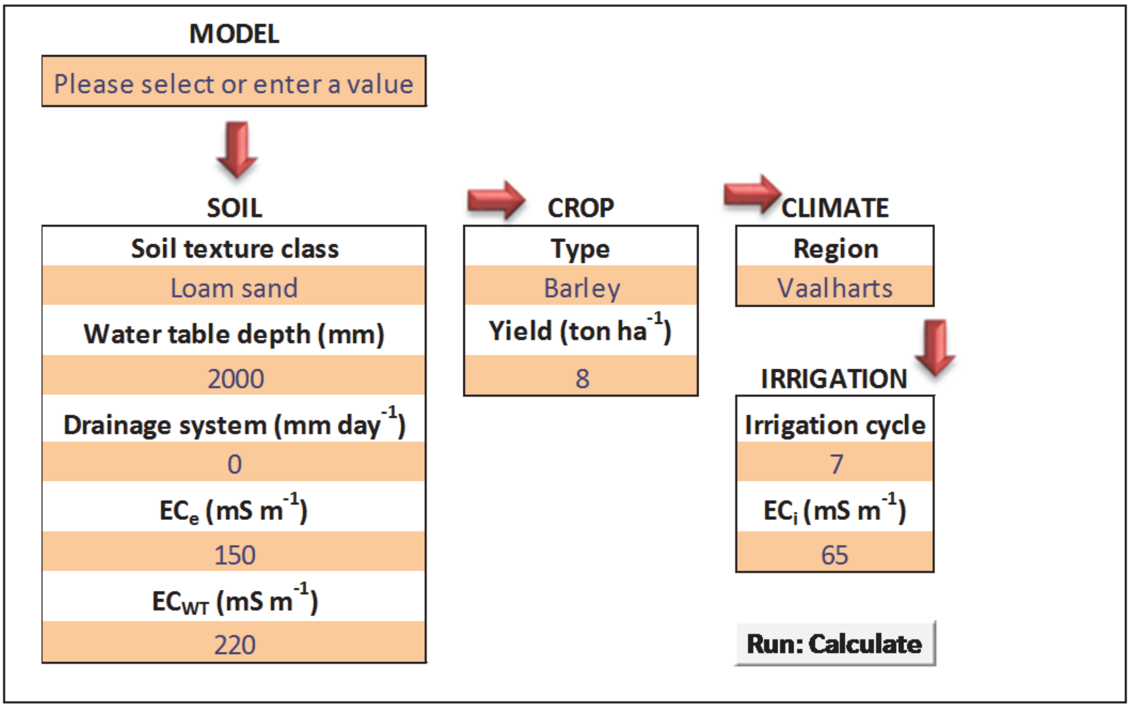


Figure 7-19 Modelling inputs to determine logging and salinity for barley

Figure 7-20 displays the measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (ECe) and water table salinity (ECWT) 20 years (approximately 7000 days) due to the inputs shown in Figure 7-19.

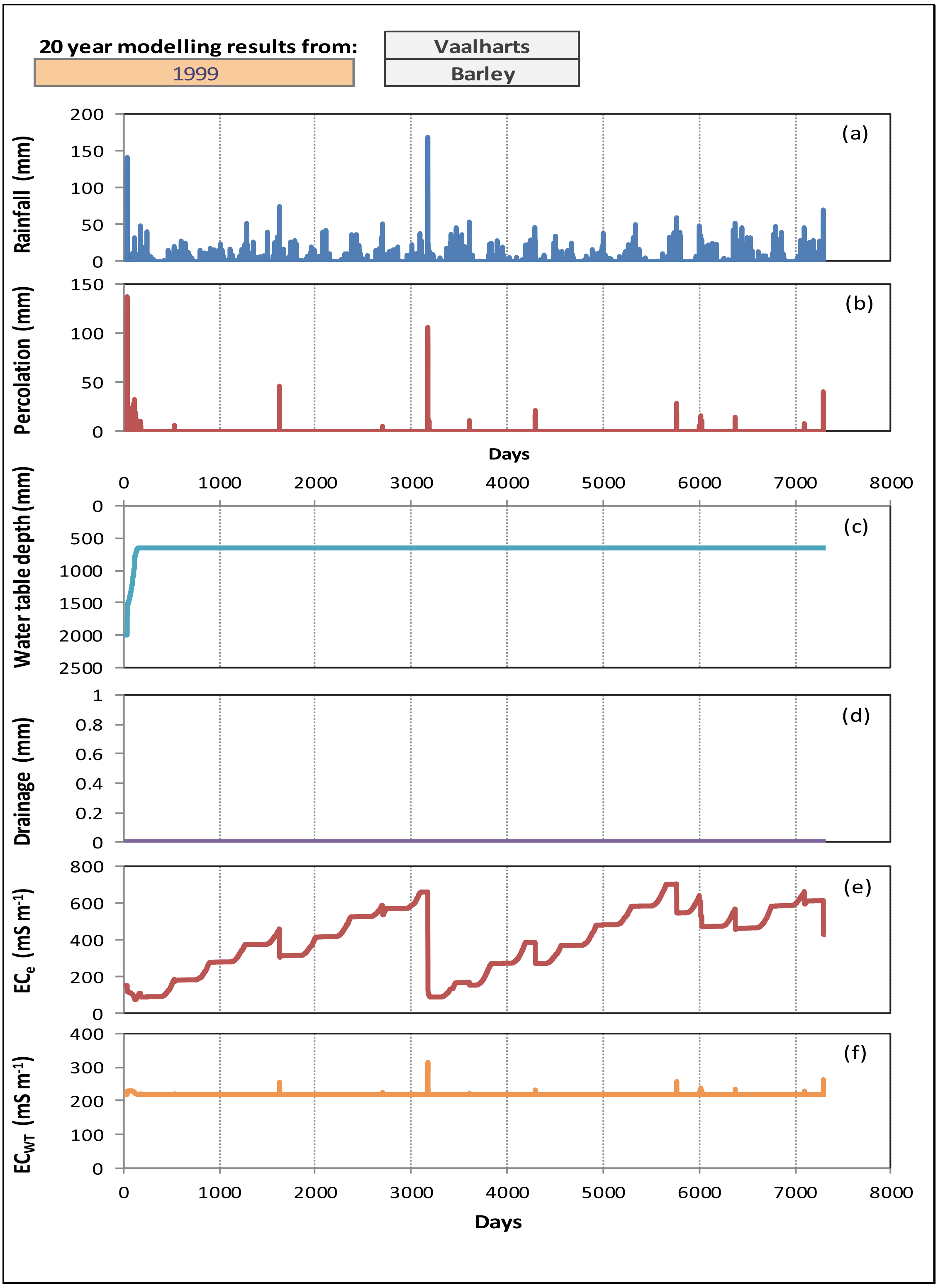


Figure 7-20 Measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (EC_e) and water table salinity (EC_{WT}) 20 years (approximately 7000 days).

Figure 7-21 shows the relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

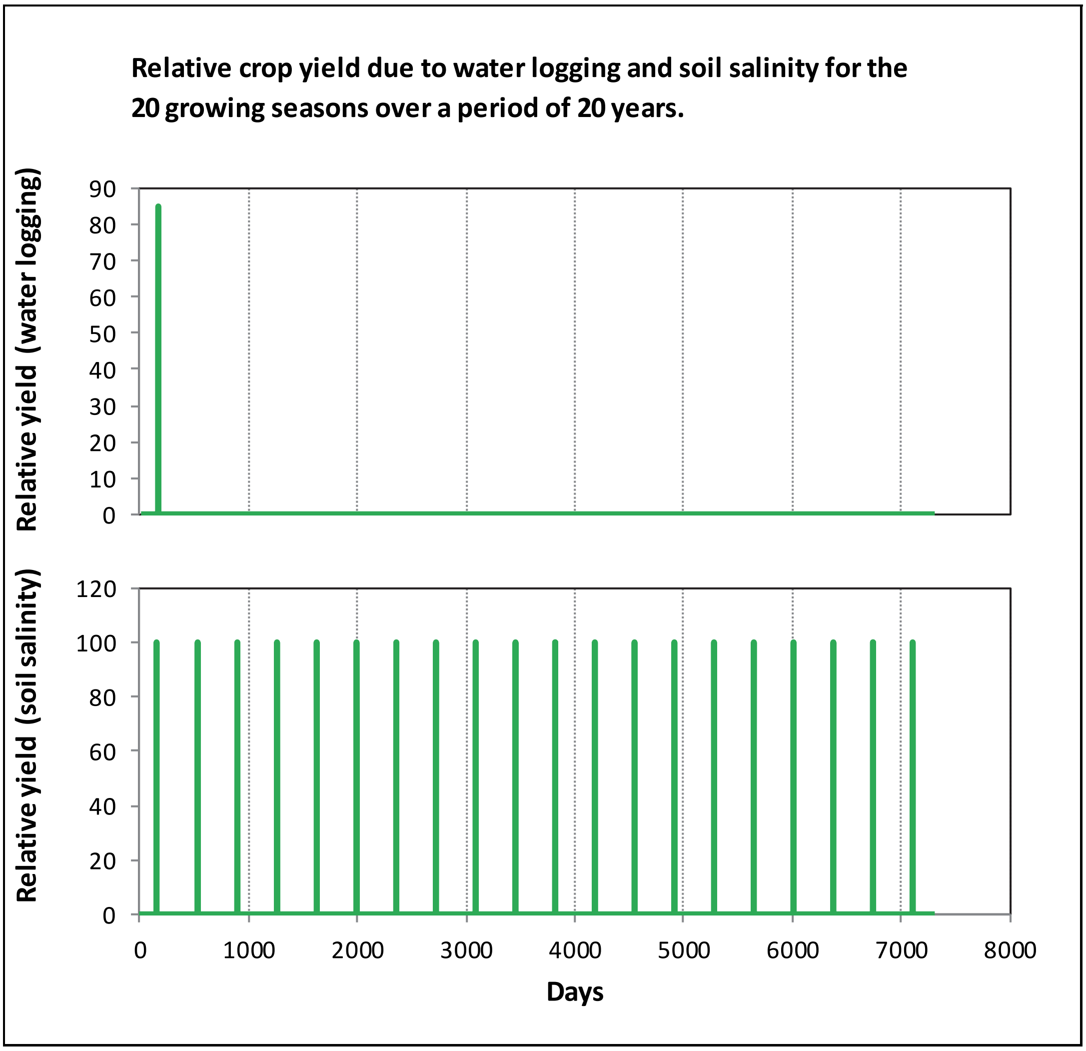


Figure 7-21 Relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

Figure 7-22 displays the mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

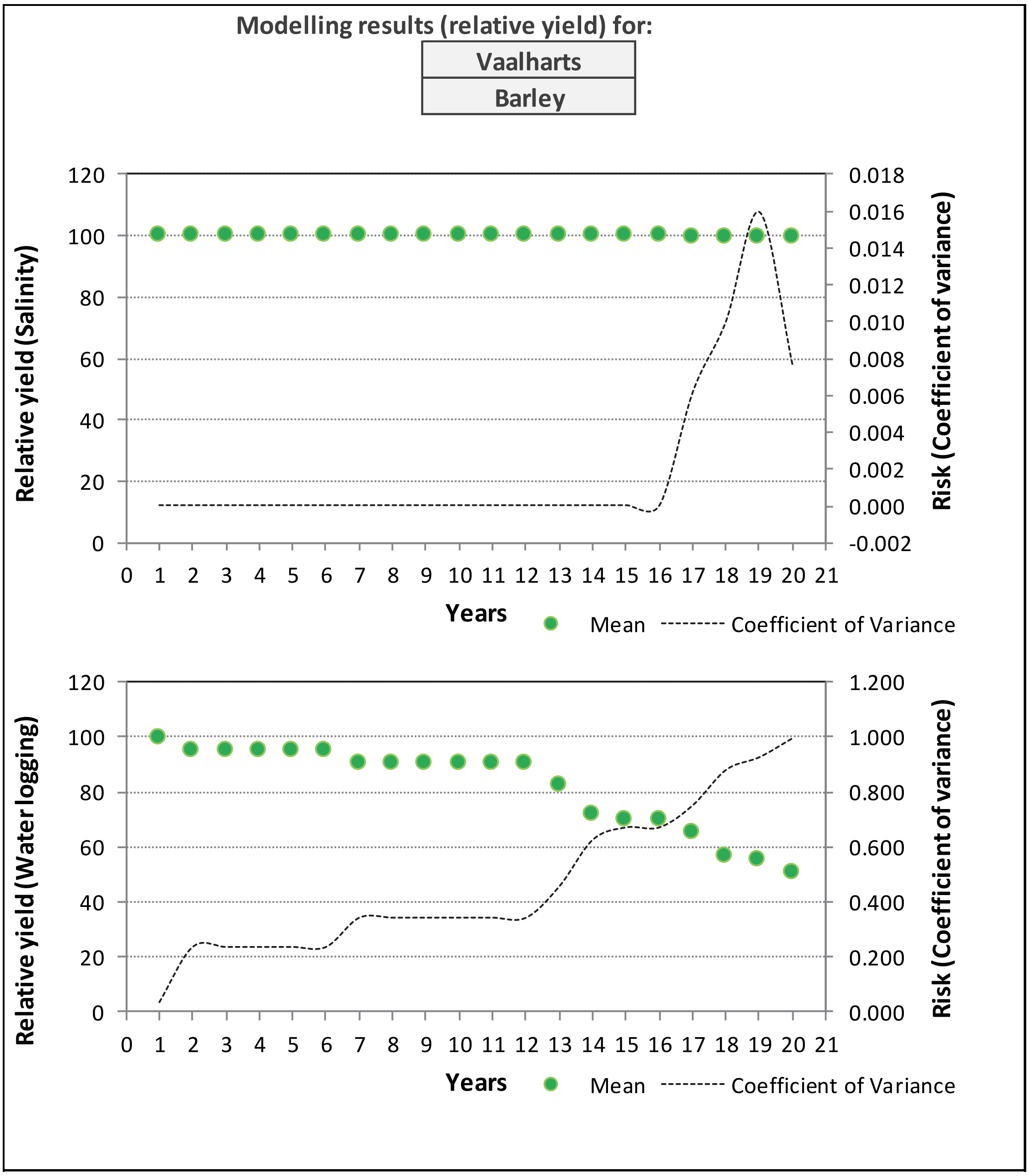


Figure 7-22 Mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

Table 7-12 displays the mean relative crop yield of the 20 repetitions in Figure 7-22 converted to ton ha-[1] according to potential yield specified in Figure 7-19 together with the standard deviation and coefficient of variance.

Table 7-12 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance

Modelling results (ton ha^{-1}) for:	Vaalharts
0 (mm day-1) drain	Barley

	Water logging			Salinity		
Year	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	7.94	0.268	3	8.00	0.000	0
2	7.60	1.789	24	8.00	0.000	0
3	7.60	1.789	24	8.00	0.000	0
4	7.60	1.789	24	8.00	0.000	0
5	7.60	1.789	24	8.00	0.000	0
6	7.60	1.789	24	8.00	0.000	0
7	7.20	2.462	34	8.00	0.000	0
8	7.20	2.462	34	8.00	0.000	0
9	7.20	2.462	34	8.00	0.000	0
10	7.20	2.462	34	8.00	0.000	0
11	7.20	2.462	34	8.00	0.000	0
12	7.20	2.462	34	8.00	0.000	0
13	6.58	3.005	46	8.00	0.000	0
14	5.74	3.594	63	8.00	0.000	0
15	5.60	3.761	67	8.00	0.000	0
16	5.60	3.761	67	8.00	0.000	0
17	5.20	3.915	75	7.98	0.049	1
18	4.52	3.984	88	7.97	0.080	1
19	4.40	4.083	93	7.97	0.127	2
20	4.06	4.051	100	7.98	0.060	1

The modelling results show that from a waterlogging and salinity point-of-view, waterlogging poses a bigger threat to potential yield than salinity. In the absence of subsurface drainage, sharp decreases in yield can be expected from year 13 as a result of waterlogging.

Table 7-13 shows the relative crop yield based on the same assumptions, but including a 1 mm day-^{1} drainage system.

Table 7-13 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance after introduction of 1 mm/day drainage system

Modelling results (ton ha^{-1}) for:	Vaalharts
1 (mm day-1) drain	Barley

	Water logging			Salinity		
Year	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	8.00	0.000	0	8.00	0.000	0
2	8.00	0.000	0	8.00	0.000	0
3	8.00	0.000	0	8.00	0.000	0
4	8.00	0.000	0	8.00	0.000	0
5	8.00	0.000	0	8.00	0.000	0
6	8.00	0.000	0	8.00	0.000	0
7	8.00	0.000	0	8.00	0.000	0
8	8.00	0.000	0	8.00	0.000	0
9	8.00	0.000	0	8.00	0.000	0
10	8.00	0.000	0	8.00	0.000	0
11	8.00	0.000	0	8.00	0.000	0
12	8.00	0.000	0	8.00	0.000	0
13	8.00	0.000	0	8.00	0.000	0
14	8.00	0.000	0	8.00	0.000	0
15	8.00	0.000	0	8.00	0.000	0
16	8.00	0.000	0	8.00	0.000	0
17	8.00	0.000	0	8.00	0.000	0
18	8.00	0.000	0	8.00	0.000	0
19	8.00	0.000	0	8.00	0.000	0
20	8.00	0.000	0	8.00	0.000	0

The results show that the drainage system resolves the waterlogging problem and at the same time reduces salinity.

7.4.2 **Economic and financial modelling results for the Vaalharts case study**

- Economic Benefit Cost analysis (per hectare)

Table 7-14 illustrates the Economic Benefit Cost analysis for Vaalharts case study crops.

Table 7-14 Economic Benefit Cost analysis – Vaalharts crops

Pecan nuts *(Per hectare drainage installation analysis)*		**Lucerne Sp** *(Per hectare drainage installation analysis)*	
Benefit-Cost Ratio	6.6 : 1	Benefit-Cost Ratio	1.4 : 1
Payback period (average)	0.9 years	Payback period (average)	11.4 years
Internal Rate of Return (IRR)	25.1%	Internal Rate of Return (IRR)	25.2%
Net Present Value (NPV)	451 256	Net Present Value (NPV)	103 027
Maize *(Per hectare drainage installation analysis)*		**Barley** *(Per hectare drainage installation analysis)*	
Benefit-Cost Ratio	2.7 : 1	Benefit-Cost Ratio	0.2 : 1
Payback period (average)	2.6 years	Payback period (average)	-7.0 years
Internal Rate of Return (IRR)	29.8%	Internal Rate of Return (IRR)	0.8%
Net Present Value (NPV)	234 020	Net Present Value (NPV)	-16 131

The Economic Benefit Cost analysis shows that installation of drainage for pecan nuts, lucerne and maize is economically viable.

- Financial Whole-farm analysis

For the Whole-farm analysis, five scenarios were modelled. These are:

  - Without drainage – 0% start-up debt ratio
  - Without drainage – 20% start-up debt ratio
  - With drainage – 20% start-up debt ratio
  - With drainage – 35% start-up debt ratio
  - With drainage – 35% start-up debt ratio – 50% subsidy

Table 7-15 reflects the production cost ratio, projected cash flow ratio, projected debt ratio and projected end bank balance of the different scenarios.

Table 7-15 Comparison of Financial Whole-farm analysis scenarios – Vaalharts

Scenario nr & description	Production cost ratio *	Projected cash flow ratio *	Highest Projected Debt ratio	End Bank balance
1 Without drainage	104%	101%	0%	4 638 190
2 Without drainage - 20% debt ratio	104%	86%	81%	-35 690 809
3 With drainage - 20% debt ratio	60%	126%	38%	38 995 738
4 With drainage - 35% debt ratio	60%	101%	58%	-18 765 206
5 With drainage - 35% debt ratio - 50% subsidy	60%	126%	41%	31 663 823
* *20-year average*				

The modelling results can be interpreted as follows:

Without drainage – 0% start-up debt ratio

- Not financially feasible – projected cash flow ratio <115% and debt ratio exceeds acceptable financing norm (<50%).
-

Without drainage – 20% start-up debt ratio

- Not financially feasible – projected cash flow ratio <115% and debt ratio exceeds acceptable financing norm (<50%).
-

With drainage – 20% start-up debt ratio

- Financially feasible – projected cash flow ratio > 115%
- Highest projected debt ratio < 50%
-

With drainage – 35% start-up debt ratio

- Not financially feasible – projected cash flow ratio < 115%
- Highest projected debt ratio > 50%
-

With drainage – 35% start-up debt ratio – 50% subsidy

- Financially feasible – projected cash flow ratio > 115%
- Highest projected debt ratio > 50%

Without drainage the case study farm will not be financially viable over the long term. The farm will be financially viable with 20% start-up debt ratio with drainage installed. However, chances are slim that the operation will succeed with a start-up debt ratio in excess of 35%, unless drainage installation costs are partially financed through “green box” grants.

- Financing decision support tool

Table 7-16 summarises the financing decision support tool indicators for the different scenarios.

Table 7-16 Summarised financing decision support tool – Vaalharts

Scenario / Description	Norm	1 Without drainage	2 Without drainage - 20% debt ratio	3 With drainage - 20% debt ratio	4 With drainage - 35% debt ratio	5 With drainage - 35% debt ratio - 50% subsidy
Capacity						
Cash flow ratio	> 115%	No	No	Yes	No	Yes
Capital						
Debt ratio	< 50%	Yes	No	Yes	No	Yes
Collateral						
Sufficient available "yes" or "no"	yes	Yes	Yes	Yes	Yes	Yes
Conditions						
Benefit Cost ratio (B/C) : 1	> 1	Yes	Yes	Yes	Yes	Yes
Payback average	< 8	Yes	Yes	Yes	Yes	Yes
Internal Rate of Return (IRR)	> 8%	No	No	No	No	No
Net Present value (NPV)	0	Yes	Yes	Yes	Yes	Yes
Character						
Trustworthy "yes" or "no"	yes	Yes	Yes	Yes	Yes	Yes
Economic & Financially feasible		**No**	**No**	**Yes**	**No**	**Yes**

** Average 1st 20 years*

In the economic and financially feasible row the scenarios with a "yes" will most probably attract finance from commercial banks in the normal run of business. Scenarios with a "no" will most probably not qualify for commercial finance. Please note that this tool serves as an indicator only.

- Summary

This section summarises the modelling results for the Vaalharts case study. Several scenarios were run including "with" and "without" drainage for 0%, 20% and 35% start-up debt ratios. The 35% start-up debt ratio "with drainage and 50% subsidy"-scenario illustrates the impact of green box grants/subsidies on the economic viability and financial feasibility of sub-surface drainage. The results show that it will not be financially viable for a farming operation with a debt ratio in excess of 35% to install subsurface drainage without subsidy. Subsidies will ultimately assist the farming operation to stay financially viable while installing drainage. However, it will not be financially viable for farming operations with debt levels in excess of 45% to install drainage, even with a 50% subsidy. In order for farming operations with debt ratios of more than 45% to stay financially viable, the subsidy on installation of drainage should exceed 50% of drainage installation cost.

7.5 Breede River case study

7.5.1 Waterlogging and salinity modelling results for Breede River case study

The waterlogging and salinity modelling for the Breede River case study include four crops, i.e. wine grapes, plums, nectarines and peaches. The modelling results are presented in the sections below.

- Wine grapes

Figure 7-23 displays the assumptions on which the modelling to determine potential yield for wine grapes in the Breede River case study, was based.

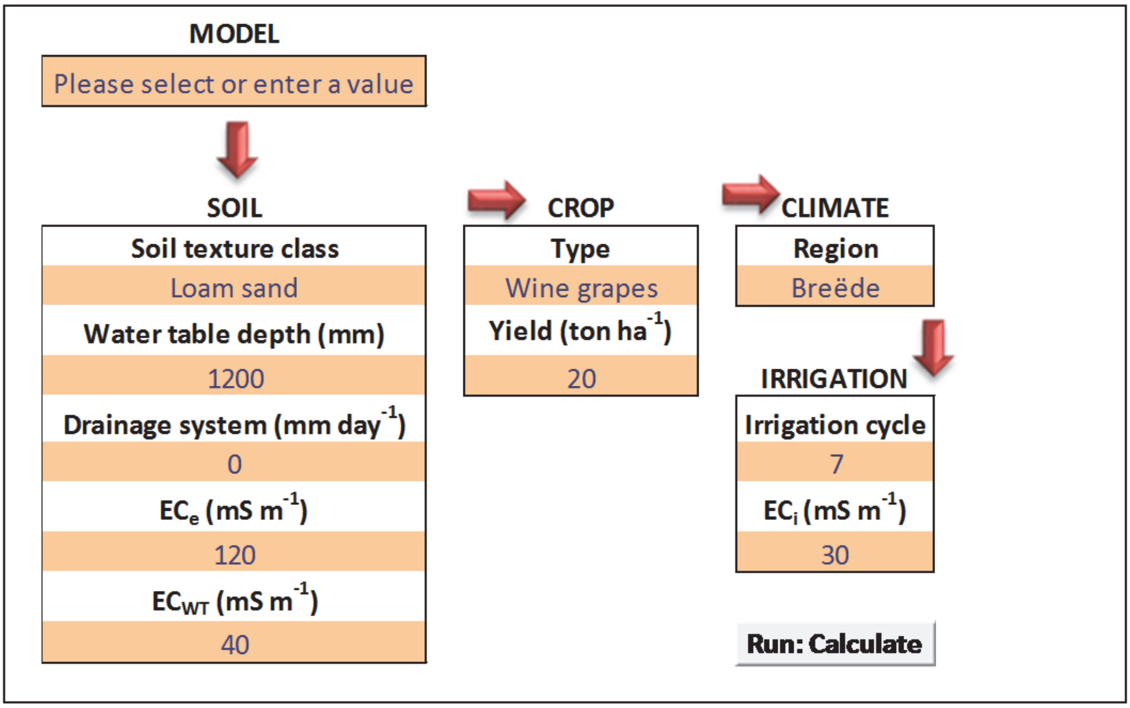


Figure 7-23 Modelling inputs to determine logging and salinity for wine grapes

Figure 7-24 displays the measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (ECe) and water table salinity (ECWT) 20 years (approximately 7000 days) due to the inputs shown in Figure 7-23.

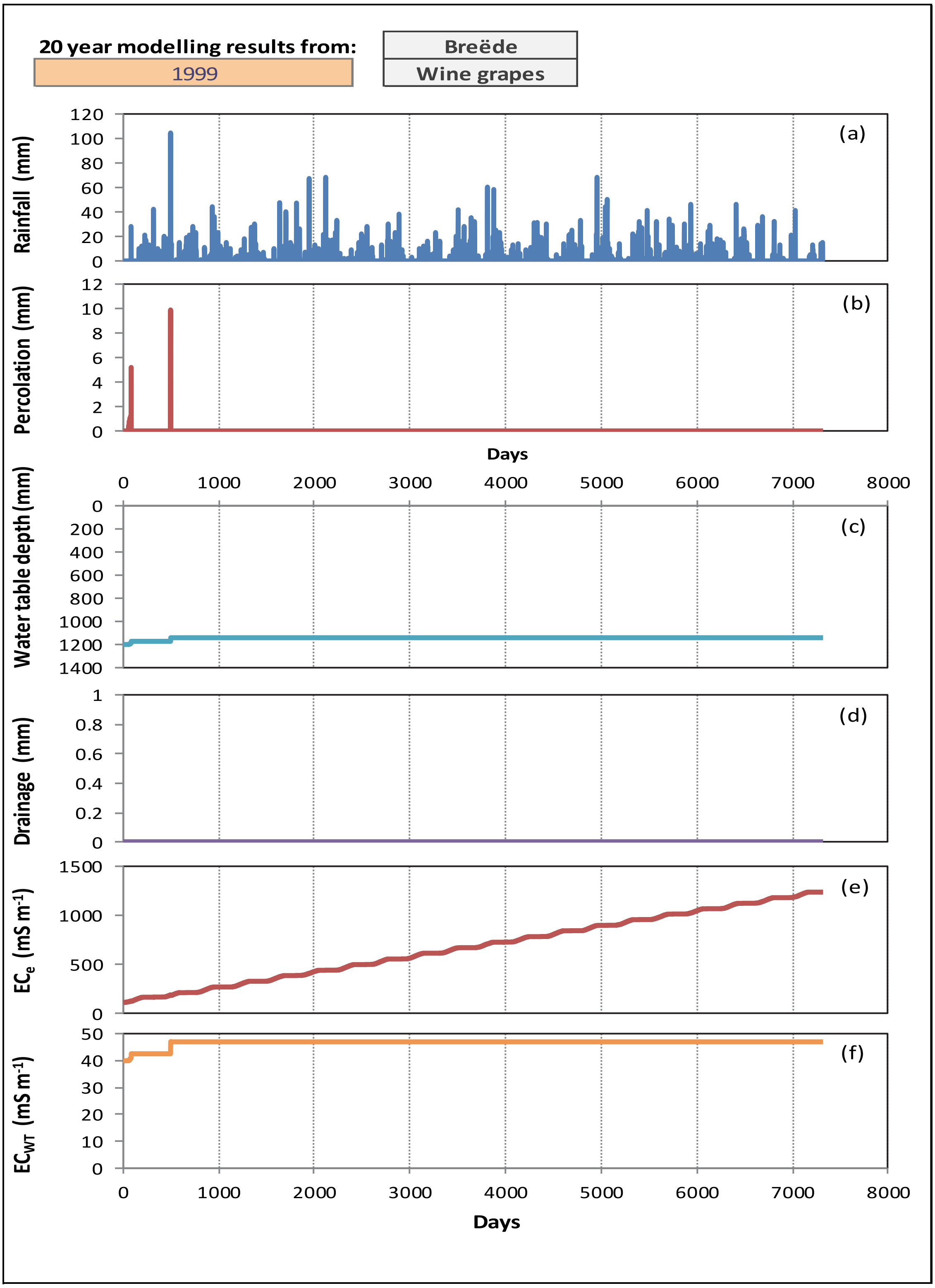


Figure 7-24 Measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (EC_e) and water table salinity (EC_{WT}) 20 years (approximately 7000 days).

Figure 7-25 shows the relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

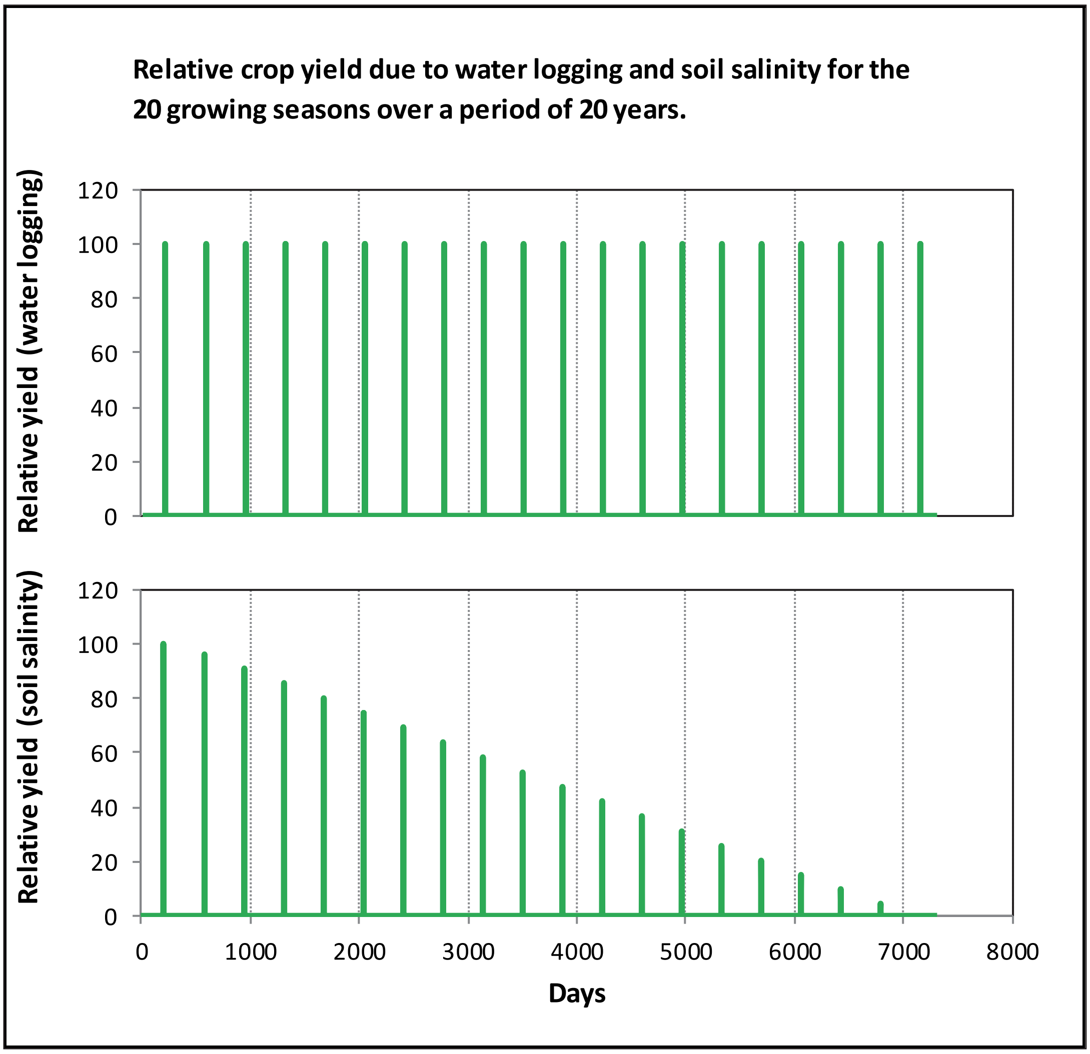


Figure 7-25 Relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

Figure 7-26 displays the mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

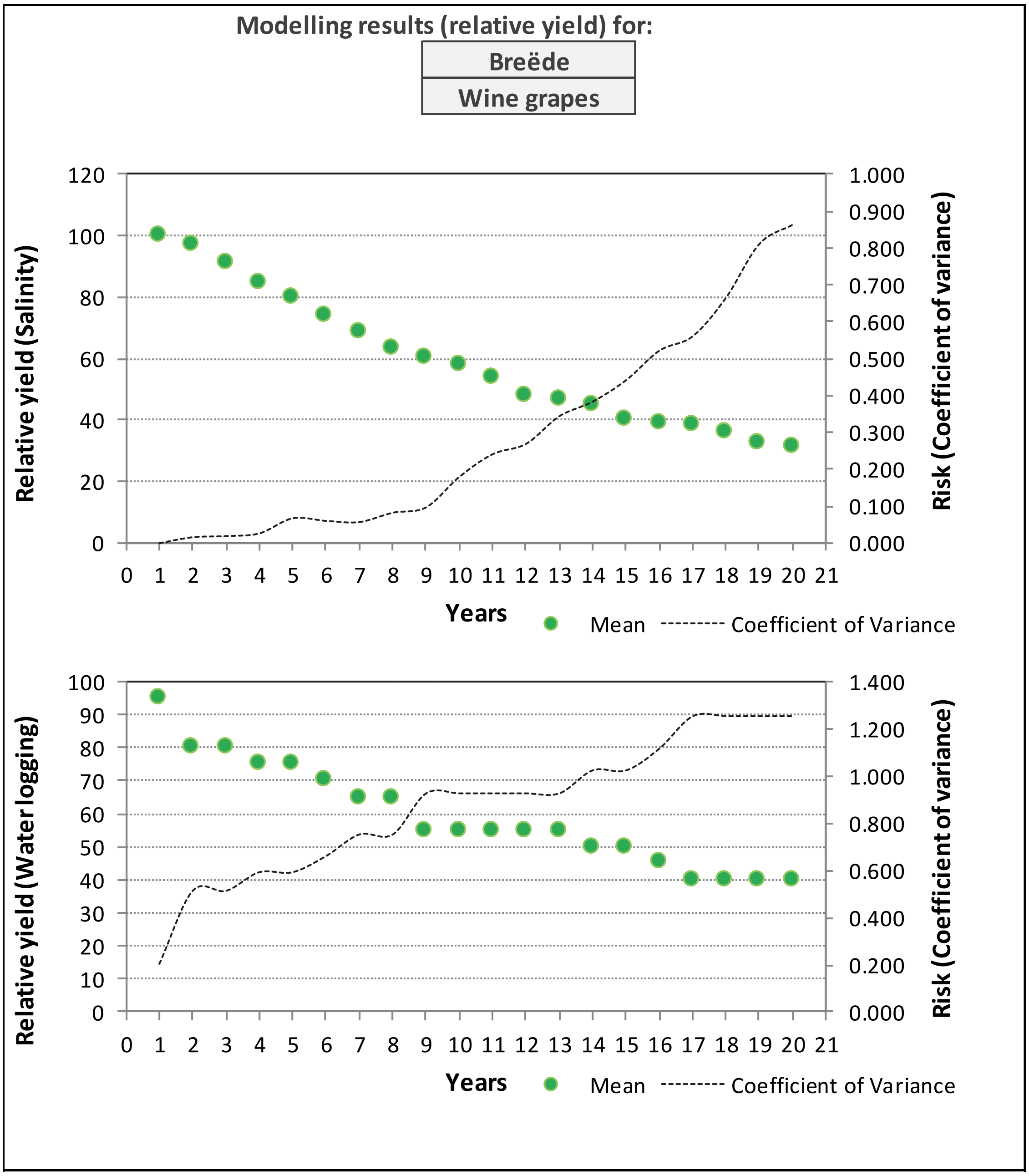


Figure 7-26 Mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

Table 7-17 displays the mean relative crop yield of the 20 repetitions in Figure 7-26 converted to ton ha-^{1} according to potential yield specified in Figure 7-23 together with the standard deviation and coefficient of variance.

Table 7-17 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance

Modelling results (ton ha^{-1}) for:	Breëde
0 (mm day-1) drain	Wine grapes

Year	Water logging			Salinity		
	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	18.98	3.837	20	20.00	0.000	0
2	16.00	8.208	51	19.45	0.316	2
3	16.00	8.208	51	18.20	0.349	2
4	15.00	8.885	59	16.94	0.449	3
5	15.00	8.885	59	15.94	1.077	7
6	14.00	9.256	66	14.80	0.896	6
7	13.00	9.787	75	13.73	0.787	6
8	13.00	9.787	75	12.69	1.045	8
9	11.00	10.208	93	12.01	1.169	10
10	11.00	10.208	93	11.58	2.086	18
11	11.00	10.208	93	10.74	2.591	24
12	11.00	10.208	93	9.63	2.595	27
13	11.00	10.208	93	9.33	3.210	34
14	10.00	10.260	103	8.94	3.430	38
15	10.00	10.260	103	8.06	3.562	44
16	9.07	10.148	112	7.78	4.059	52
17	8.00	10.052	126	7.63	4.279	56
18	8.00	10.052	126	7.22	4.809	67
19	8.00	10.052	126	6.50	5.277	81
20	8.00	10.052	126	6.25	5.398	86

The modelling results shows that from a waterlogging and salinity point-of-view, both waterlogging and salinity pose a threat to potential yield. In the absence of subsurface drainage, decreases in yield can be expected from year 2 as a result of waterlogging.

Table 7-18 shows the relative crop yield based on the same assumptions, but including a 1 mm day-^{1} drainage system.

Table 7-18 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance after introduction of 1 mm day-^{1} drainage system

Modelling results (ton ha^{-1}) for:	Breëde
2 (mm day-1) drain	Wine grapes

	Water logging			Salinity		
Year	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	20.00	0.000	0	20.00	0.000	0
2	20.00	0.000	0	20.00	0.000	0
3	20.00	0.000	0	19.73	0.095	0
4	20.00	0.000	0	19.04	0.090	0
5	20.00	0.000	0	18.36	0.090	0
6	20.00	0.000	0	17.67	0.097	1
7	20.00	0.000	0	16.98	0.103	1
8	20.00	0.000	0	16.30	0.100	1
9	20.00	0.000	0	15.61	0.099	1
10	20.00	0.000	0	14.92	0.099	1
11	20.00	0.000	0	14.24	0.100	1
12	20.00	0.000	0	13.55	0.103	1
13	20.00	0.000	0	12.86	0.103	1
14	20.00	0.000	0	12.18	0.105	1
15	20.00	0.000	0	11.49	0.099	1
16	20.00	0.000	0	10.80	0.097	1
17	20.00	0.000	0	10.12	0.101	1
18	20.00	0.000	0	9.43	0.098	1
19	20.00	0.000	0	8.75	0.098	1
20	20.00	0.000	0	8.06	0.087	1

The results show that the drainage system resolves the waterlogging problem and at the same time reduces salinity. The remaining salinity impact can be managed by means of flushing the field.

- Plums

Figure 7-27 displays the assumptions on which the modelling to determine potential yield for plums in the Breede River case study, was based.

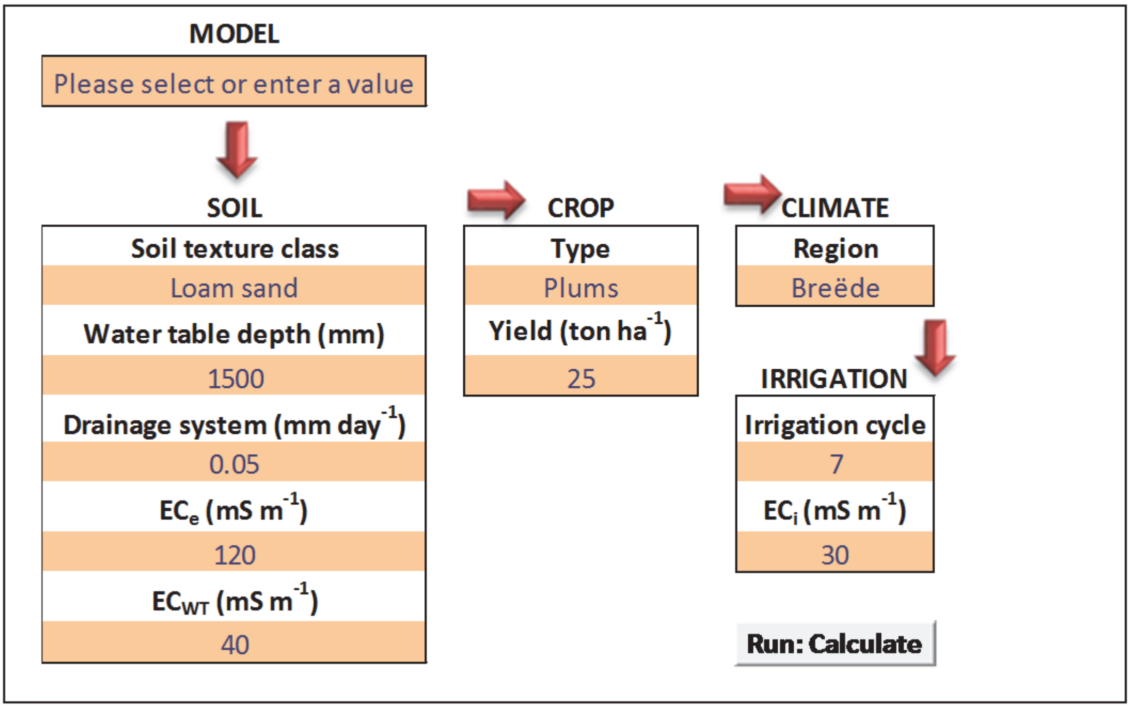


Figure 7-27 Modelling inputs to determine logging and salinity for plums

Figure 7-28 displays the measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (ECe) and water table salinity (ECWT) 20 years (approximately 7000 days) due to the inputs shown in Figure 7-27.

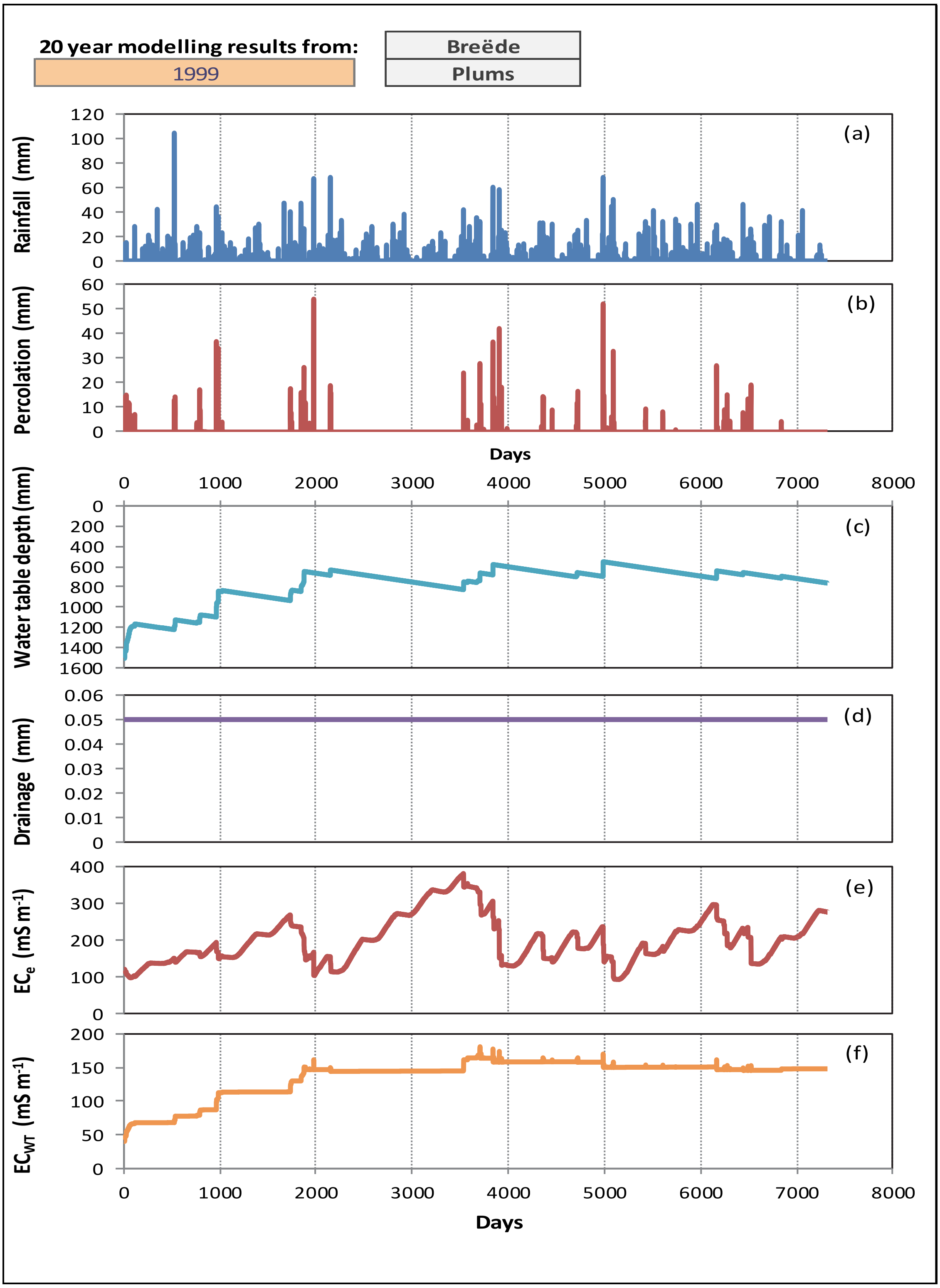


Figure 7-28 Measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (EC_e) and water table salinity (EC_{WT}) 20 years (approximately 7000 days).

Figure 7-29 shows the relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

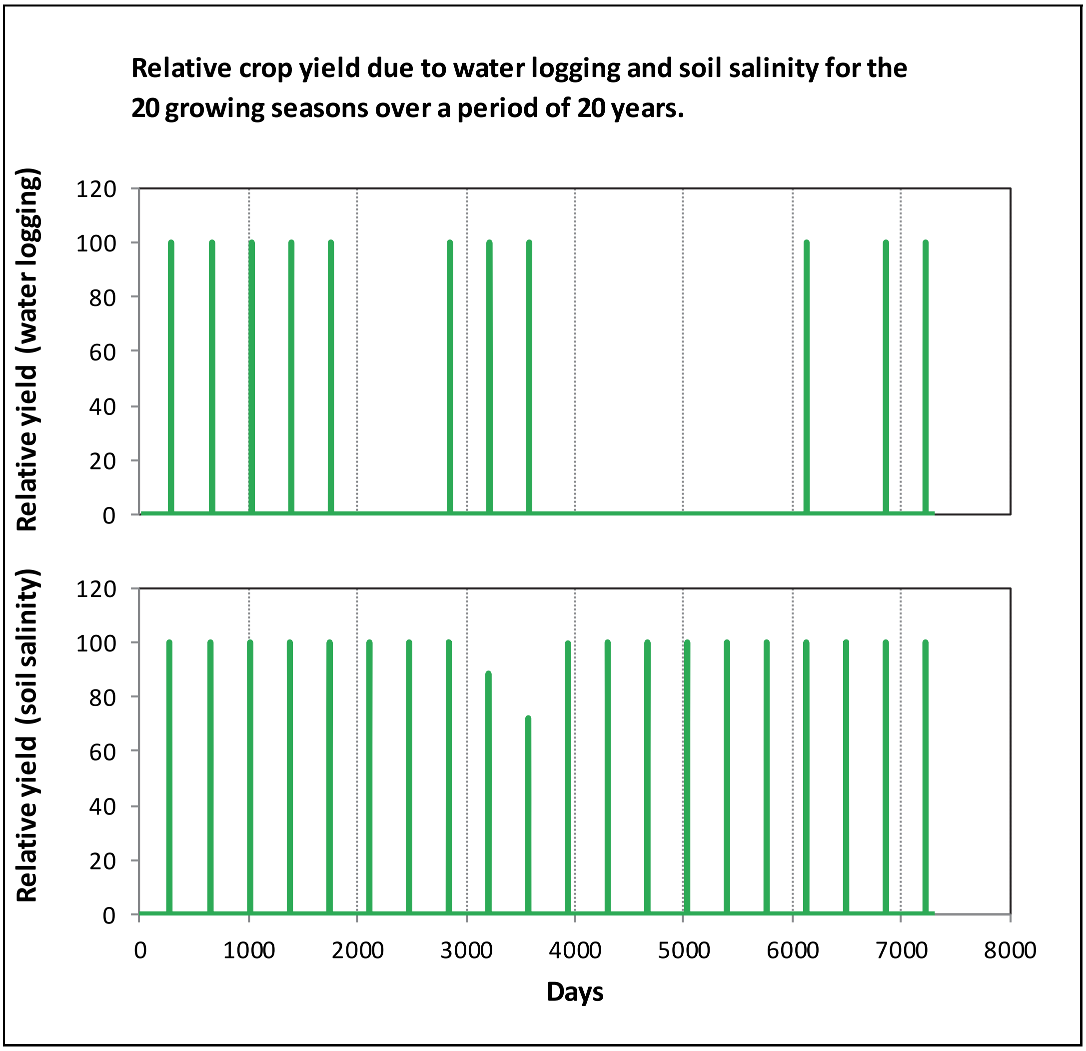


Figure 7-29 Relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

Figure 7-30 displays the mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

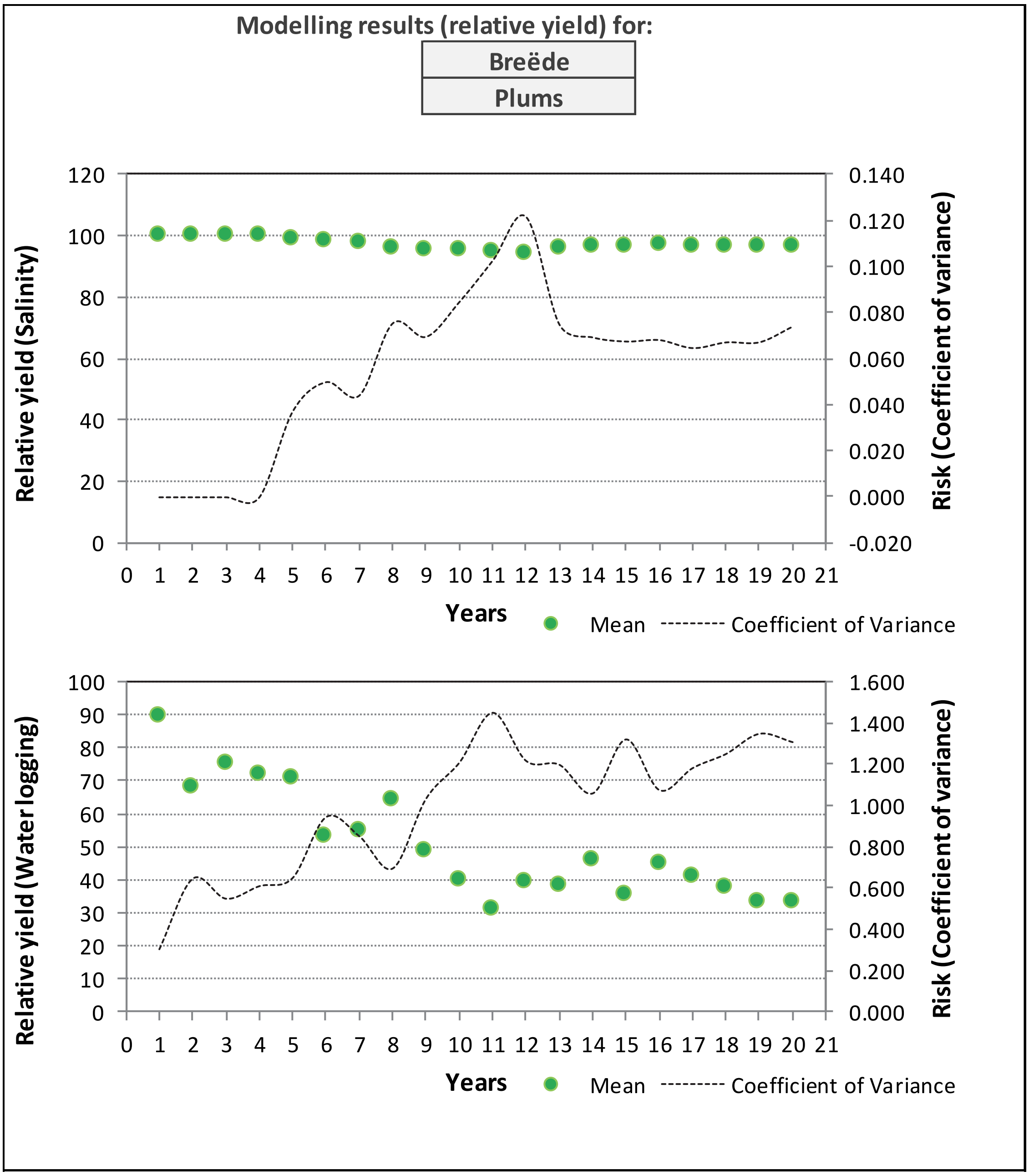


Figure 7-30 Mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

Table 7-19 displays the mean relative crop yield of the 20 repetitions in Figure 7-30 converted to ton ha-[1] according to potential yield specified in Figure 7-27 together with the standard deviation and coefficient of variance.

Table 7-19 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance

Modelling results (ton ha^{-1}) for:	Breëde
0.05 (mm day-1) drain	Plums

Year	Water logging			Salinity		
	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	22.40	6.788	30	25.00	0.000	0
2	16.99	10.954	64	25.00	0.000	0
3	18.80	10.309	55	25.00	0.000	0
4	17.95	10.934	61	25.00	0.000	0
5	17.69	11.487	65	24.73	0.919	4
6	13.23	12.486	94	24.60	1.226	5
7	13.68	11.636	85	24.36	1.075	4
8	16.04	11.146	69	23.99	1.808	8
9	12.15	12.558	103	23.86	1.658	7
10	9.93	12.000	121	23.88	2.022	8
11	7.84	11.363	145	23.73	2.433	10
12	9.90	12.045	122	23.58	2.864	12
13	9.56	11.450	120	24.00	1.795	7
14	11.46	12.141	106	24.12	1.670	7
15	8.89	11.740	132	24.13	1.628	7
16	11.26	12.106	107	24.24	1.650	7
17	10.21	12.073	118	24.18	1.562	6
18	9.40	11.759	125	24.19	1.624	7
19	8.40	11.326	135	24.21	1.626	7
20	8.35	10.917	131	24.14	1.786	7

The modelling results show that from a waterlogging and salinity point-of-view, waterlogging poses a bigger threat to potential yield than salinity. In the absence of subsurface drainage, sharp decreases in yield can be expected from year 2 as a result of waterlogging.

Table 7-20 shows the relative crop yield based on the same assumptions, but including a 1 mm day-^{1} drainage system.

Table 7-20 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance after introduction of 1 mm day^{-1} drainage system

Modelling results (ton ha^{-1}) for:	Breëde
1 (mm day-1) drain	Plums

Year	Water logging			Salinity		
	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	25.00	0.000	0	25.00	0.000	0
2	25.00	0.000	0	25.00	0.000	0
3	25.00	0.000	0	25.00	0.000	0
4	25.00	0.000	0	25.00	0.000	0
5	25.00	0.000	0	25.00	0.000	0
6	25.00	0.000	0	24.88	0.366	1
7	25.00	0.000	0	24.50	1.197	5
8	25.00	0.000	0	23.68	1.754	7
9	25.00	0.000	0	22.83	2.429	11
10	25.00	0.000	0	21.97	3.219	15
11	25.00	0.000	0	21.01	4.007	19
12	25.00	0.000	0	20.19	4.587	23
13	25.00	0.000	0	19.38	4.772	25
14	25.00	0.000	0	18.48	4.808	26
15	25.00	0.000	0	17.73	4.990	28
16	25.00	0.000	0	17.02	5.088	30
17	25.00	0.000	0	16.36	5.057	31
18	25.00	0.000	0	15.72	4.981	32
19	25.00	0.000	0	15.11	4.924	33
20	25.00	0.000	0	14.58	4.765	33

The results show that the drainage system resolves the waterlogging problem and at the same time reduces salinity. The remaining salinity impact can be managed by means of flushing the field.

- Nectarines

Figure 7-31 displays the assumptions on which the modelling to determine potential yield for nectarines in the Breede River case study, was based.

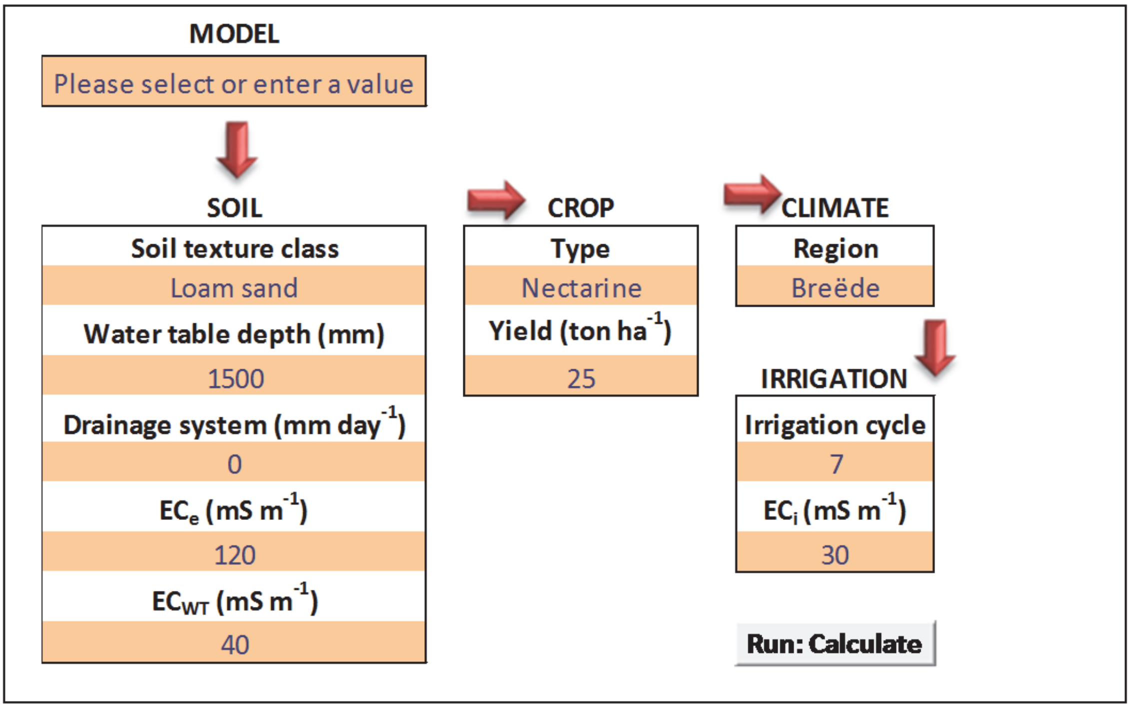


Figure 7-31 Modelling inputs to determine logging and salinity for nectarines

Figure 7-32 displays the measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (ECe) and water table salinity (ECWT) 20 years (approximately 7000 days) due to the inputs shown in Figure 7-31.

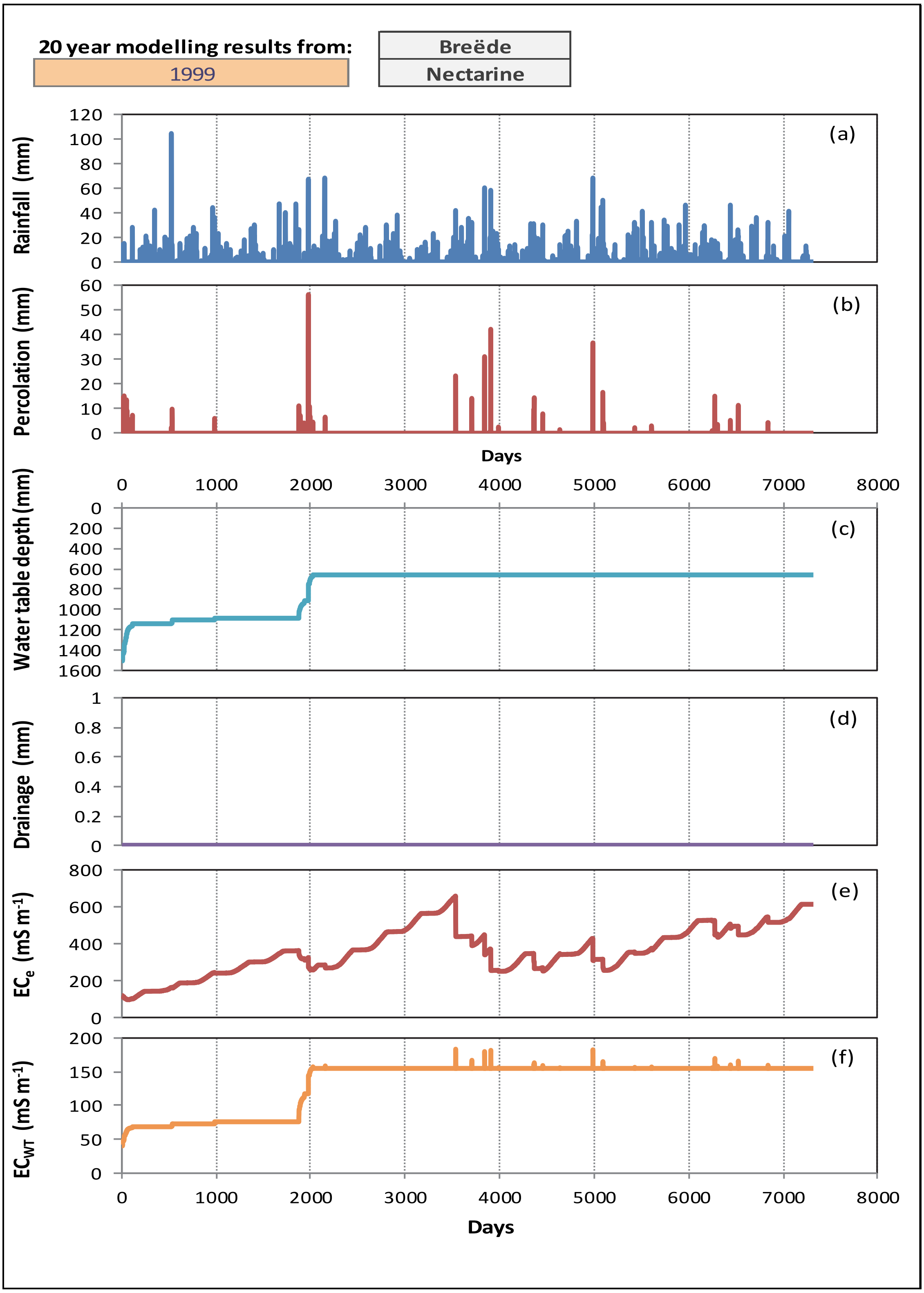


Figure 7-32 Measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (EC_e) and water table salinity (EC_{WT}) 20 years (approximately 7000 days).

Figure 7-33 shows the relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

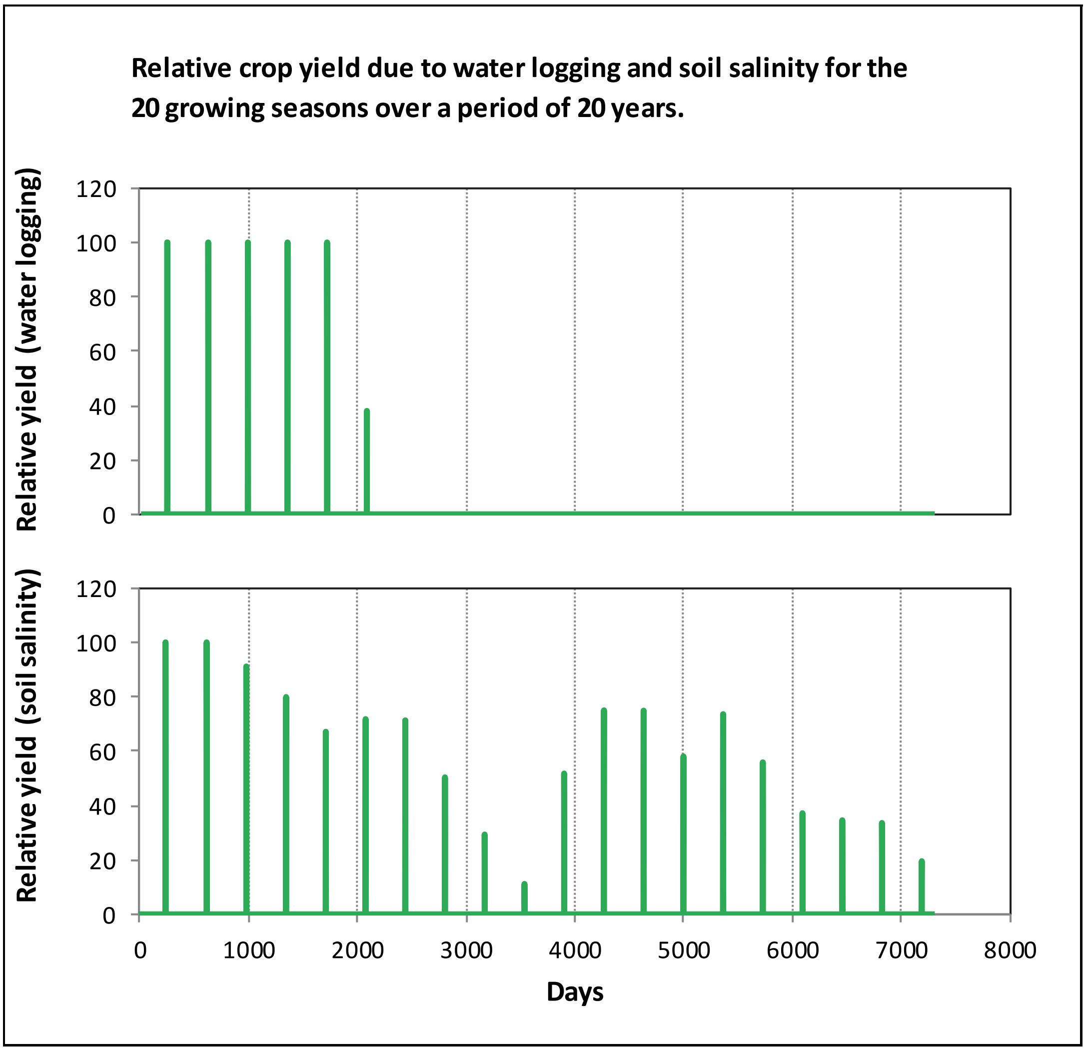


Figure 7-33 Relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years**.**

Figure 7-34 displays the mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

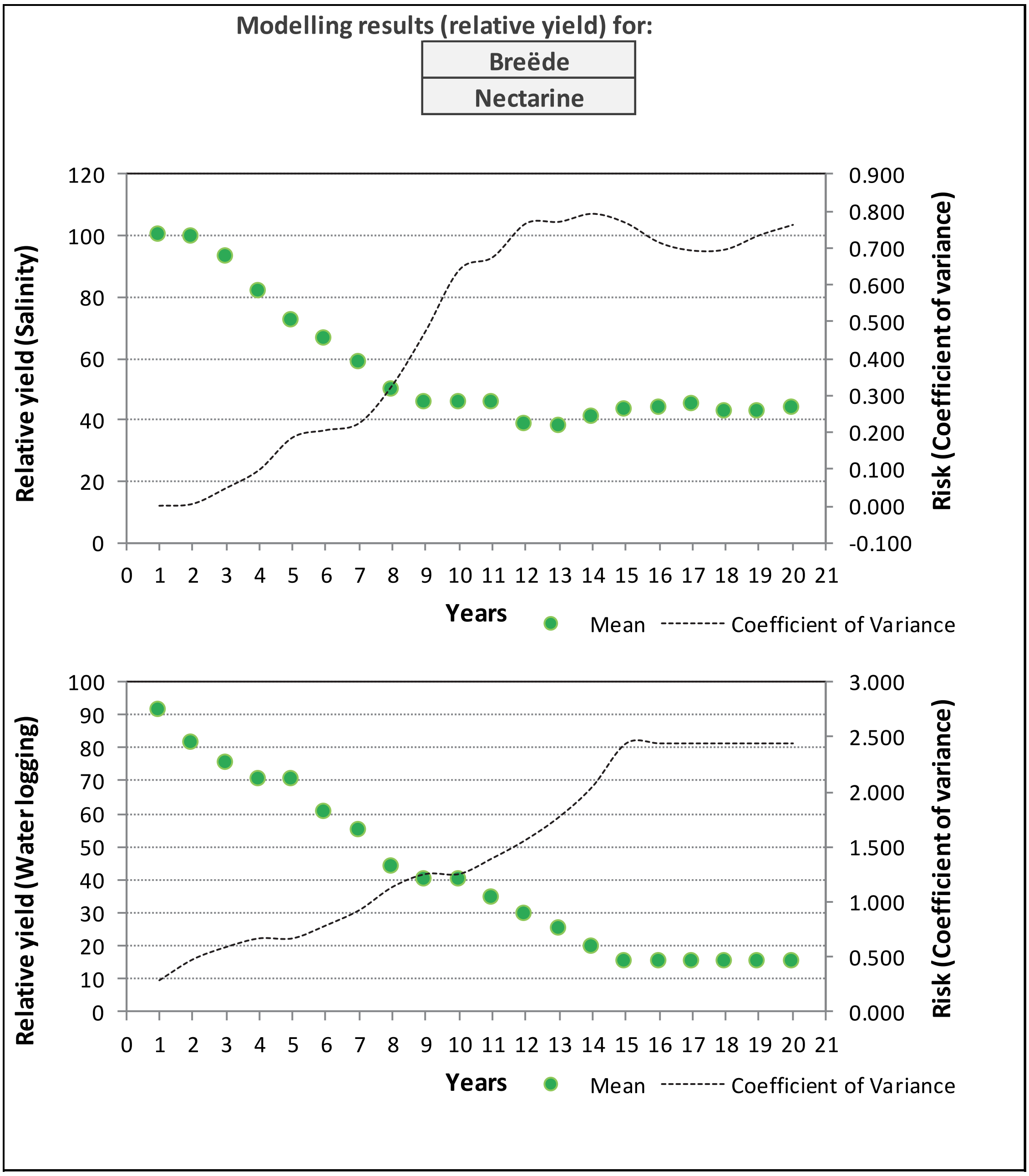


Figure 7-34 Mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

Table 7-21 displays the mean relative crop yield of the 20 repetitions in Figure 7-34 converted to ton ha-[1] according to potential yield specified in Figure 7-31 together with the standard deviation and coefficient of variance.

Table 7-21 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance

Modelling results (ton ha^{-1}) for:	Breëde
0 (mm day-1) drain	Nectarine

Year	Water logging			Salinity		
	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	22.80	6.636	29	25.00	0.000	0
2	20.29	9.737	48	24.95	0.129	1
3	18.75	11.107	59	23.20	1.109	5
4	17.50	11.754	67	20.42	1.993	10
5	17.50	11.754	67	18.10	3.352	19
6	15.14	11.955	79	16.52	3.380	20
7	13.68	12.695	93	14.68	3.292	22
8	10.98	12.505	114	12.45	4.081	33
9	10.00	12.566	126	11.43	5.433	48
10	10.00	12.566	126	11.31	7.232	64
11	8.58	12.012	140	11.32	7.622	67
12	7.43	11.641	157	9.63	7.366	76
13	6.25	11.107	178	9.51	7.319	77
14	4.94	10.135	205	10.13	8.007	79
15	3.75	9.159	244	10.75	8.227	77
16	3.75	9.159	244	10.95	7.800	71
17	3.75	9.159	244	11.28	7.795	69
18	3.75	9.159	244	10.58	7.348	69
19	3.75	9.159	244	10.69	7.835	73
20	3.75	9.159	244	10.91	8.301	76

The modelling results show that from a waterlogging and salinity point-of-view, waterlogging poses a bigger threat to potential yield than salinity. In the absence of subsurface drainage, sharp decreases in yield can be expected from year 3 as a result of waterlogging.

Table 7-22 shows the relative crop yield based on the same assumptions, but including a 1 mm day^{-1} drainage system.

Table 7-22 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance after introduction of 1 mm.day^{-1} drainage system

Modelling results (ton ha^{-1}) for:	Breëde
1 (mm day-1) drain	Nectarine

	Water logging			Salinity		
Year	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	25.00	0.000	0	25.00	0.000	0
2	25.00	0.000	0	25.00	0.000	0
3	25.00	0.000	0	24.73	0.356	1
4	25.00	0.000	0	23.37	0.808	3
5	25.00	0.000	0	21.60	1.008	5
6	25.00	0.000	0	19.76	1.024	5
7	25.00	0.000	0	17.91	1.033	6
8	25.00	0.000	0	16.07	1.019	6
9	25.00	0.000	0	14.22	1.005	7
10	25.00	0.000	0	12.38	1.012	8
11	25.00	0.000	0	10.53	1.014	10
12	25.00	0.000	0	8.69	1.018	12
13	25.00	0.000	0	6.85	1.028	15
14	25.00	0.000	0	5.00	1.032	21
15	25.00	0.000	0	3.16	1.027	33
16	25.00	0.000	0	1.31	1.018	77
17	25.00	0.000	0	0.20	0.597	294
18	25.00	0.000	0	0.04	0.181	447
19	25.00	0.000	0	0.00	0.000	0
20	25.00	0.000	0	0.00	0.000	0

The results show that the drainage system resolves the waterlogging problem although the salinity problem seems to worsen and should be managed.

- Peaches

Figure 7-35 displays the assumptions on which the modelling to determine potential yield for peaches in the Breede River case study, was based.

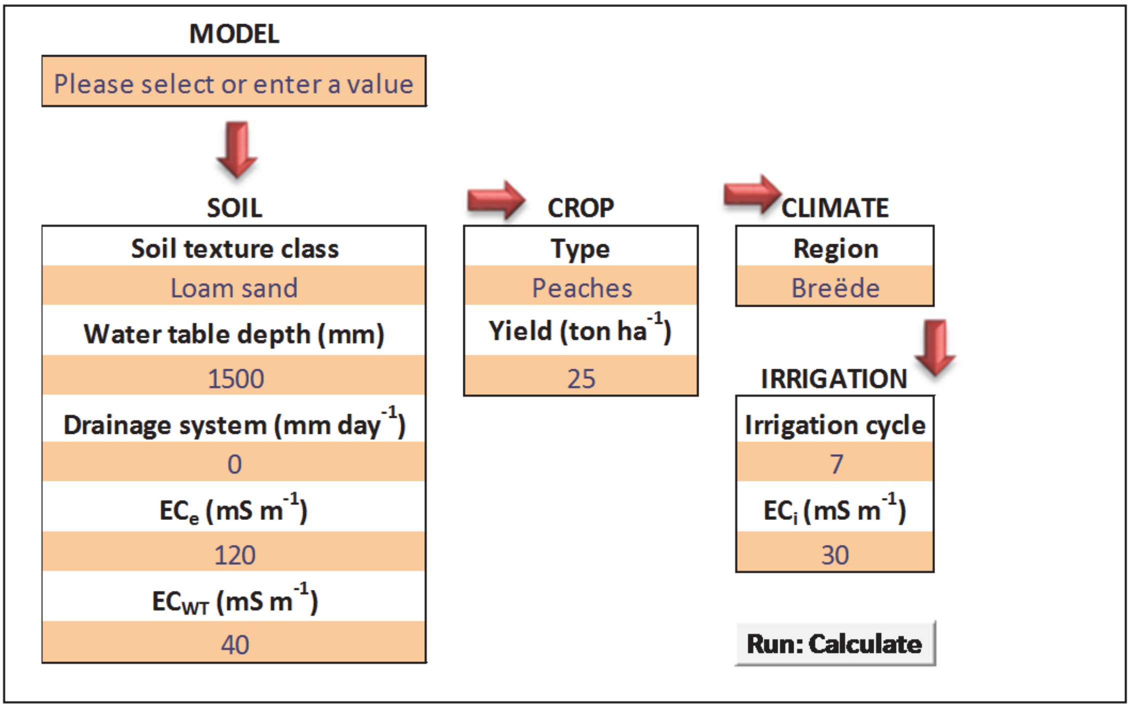


Figure 7-35 Modelling inputs to determine logging and salinity for peaches

Figure 7-36 displays the measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (ECe) and water table salinity (ECWT) 20 years (approximately 7000 days) due to the inputs shown in Figure 7-35.

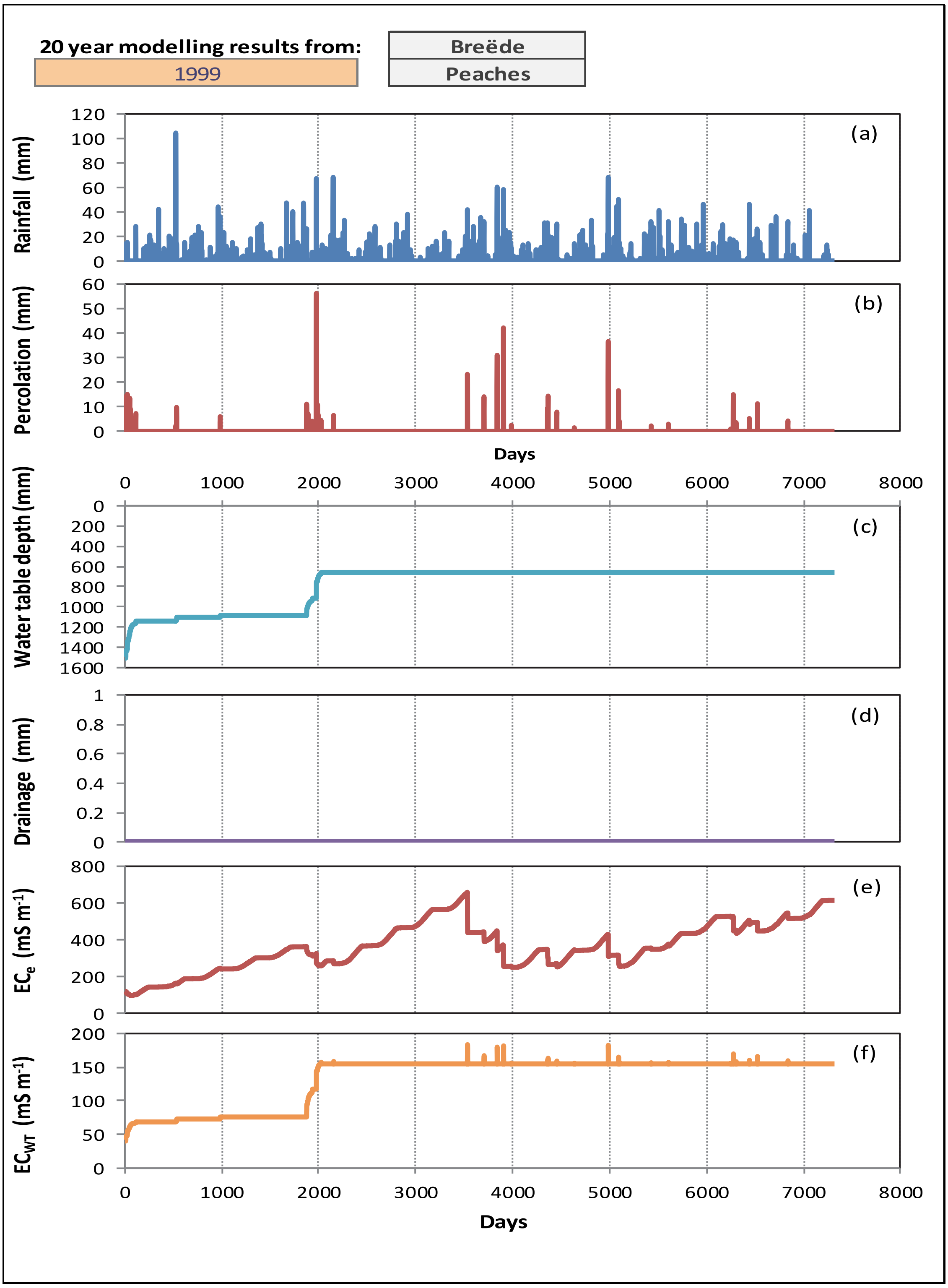


Figure 7-36 Measured rainfall and simulated percolation, water table depth, artificial drainage, soil salinity (EC_e) and water table salinity (EC_{WT}) 20 years (approximately 7000 days).

Figure 7-37 shows the relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

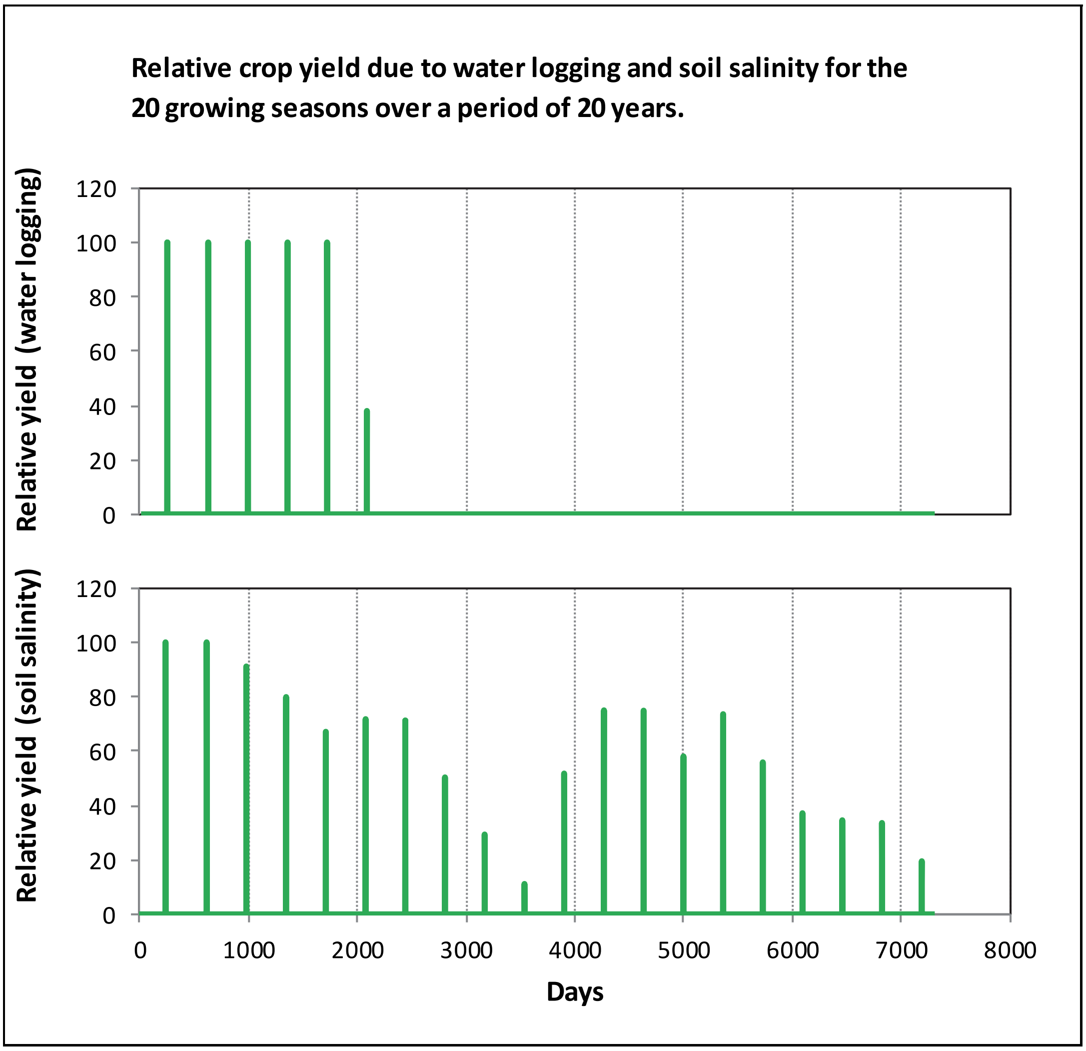


Figure 7-37 Relative crop yield due to water logging and soil salinity for the 20 growing seasons over a period of 20 years.

Figure 7-38 displays the mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

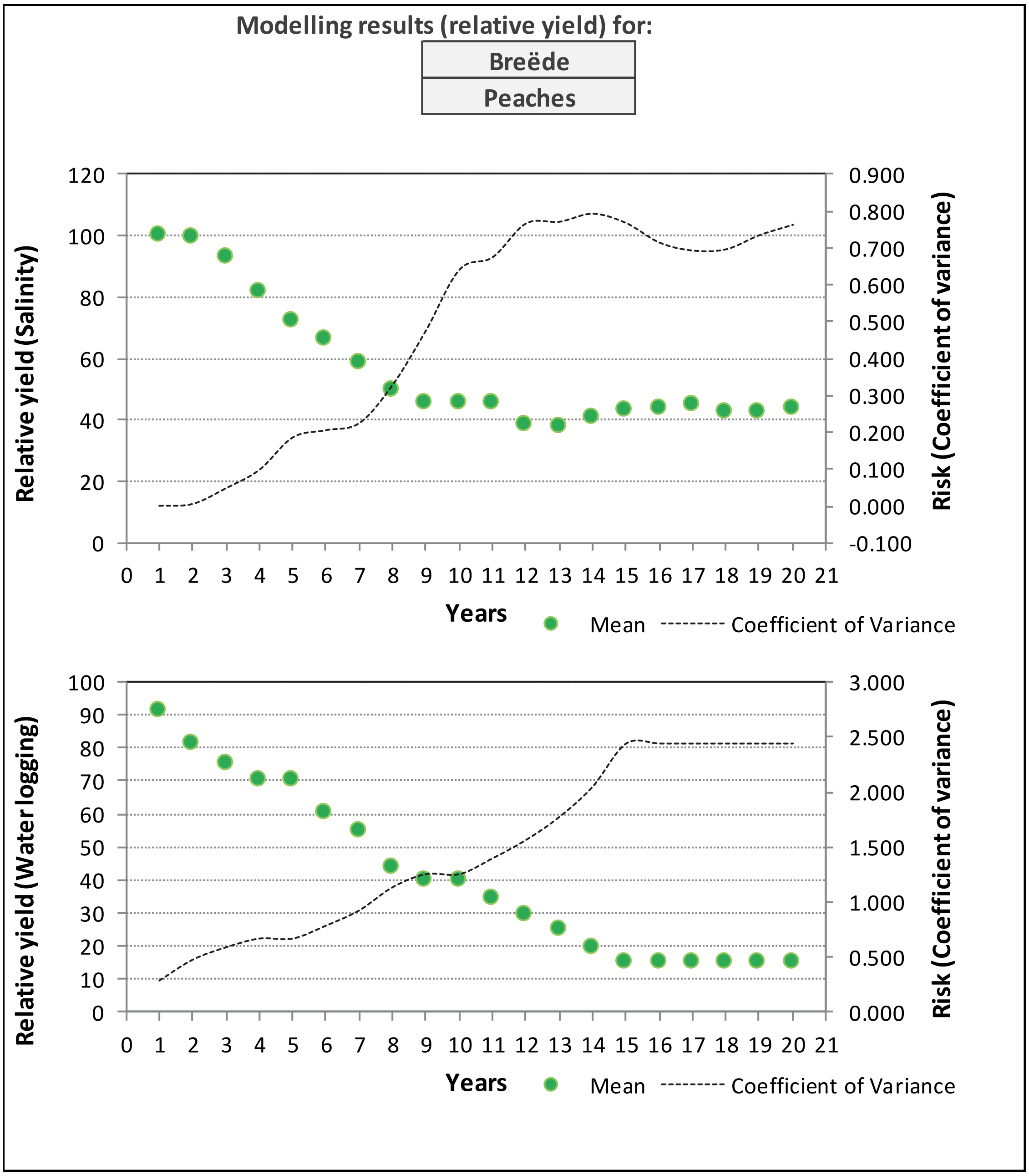


Figure 7-38 Mean relative crop yield due to water logging and soil salinity of 20 repetitions together with the coefficient of variance.

Table 7-23 displays the mean relative crop yield of the 20 repetitions in Figure 7-38 converted to ton ha-[1] according to potential yield specified in Figure 7-35 together with the standard deviation and coefficient of variance.

Table 7-23 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance

Modelling results (ton ha^{-1}) for:	Breëde
0 (mm day-1) drain	Peaches

	Water logging			Salinity		
Year	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	22.80	6.636	29	25.00	0.000	0
2	20.29	9.737	48	24.95	0.129	1
3	18.75	11.107	59	23.20	1.109	5
4	17.50	11.754	67	20.42	1.993	10
5	17.50	11.754	67	18.10	3.352	19
6	15.14	11.955	79	16.52	3.380	20
7	13.68	12.695	93	14.68	3.292	22
8	10.98	12.505	114	12.45	4.081	33
9	10.00	12.566	126	11.43	5.433	48
10	10.00	12.566	126	11.31	7.232	64
11	8.58	12.012	140	11.32	7.622	67
12	7.43	11.641	157	9.63	7.366	76
13	6.25	11.107	178	9.51	7.319	77
14	4.94	10.135	205	10.13	8.007	79
15	3.75	9.159	244	10.75	8.227	77
16	3.75	9.159	244	10.95	7.800	71
17	3.75	9.159	244	11.28	7.795	69
18	3.75	9.159	244	10.58	7.348	69
19	3.75	9.159	244	10.69	7.835	73
20	3.75	9.159	244	10.91	8.301	76

The modelling results shows that from a waterlogging and salinity point-of-view, waterlogging poses a bigger threat to potential yield than salinity. In the absence of subsurface drainage, decreases in yield can be expected from year 2 as a result of waterlogging.

Table 7-24 shows the relative crop yield based on the same assumptions, but including a 1 mm day-^{1} drainage system.

Table 7-24 Mean relative crop yield of the 20 repetitions converted to ton ha^{-1} together with the standard deviation and coefficient of variance after introduction of 1 mm day^{-1} drainage system

Modelling results (ton ha^{-1}) for:	Breëde
1 (mm day-1) drain	Peaches

	Water logging			Salinity		
Year	Mean	stdev	CV (%)	Mean	stdev	CV (%)
1	25.00	0.000	0	25.00	0.000	0
2	25.00	0.000	0	25.00	0.000	0
3	25.00	0.000	0	24.73	0.356	1
4	25.00	0.000	0	23.37	0.808	3
5	25.00	0.000	0	21.60	1.008	5
6	25.00	0.000	0	19.76	1.024	5
7	25.00	0.000	0	17.91	1.033	6
8	25.00	0.000	0	16.07	1.019	6
9	25.00	0.000	0	14.22	1.005	7
10	25.00	0.000	0	12.38	1.012	8
11	25.00	0.000	0	10.53	1.014	10
12	25.00	0.000	0	8.69	1.018	12
13	25.00	0.000	0	6.85	1.028	15
14	25.00	0.000	0	5.00	1.032	21
15	25.00	0.000	0	3.16	1.027	33
16	25.00	0.000	0	1.31	1.018	77
17	25.00	0.000	0	0.20	0.597	294
18	25.00	0.000	0	0.04	0.181	447
19	25.00	0.000	0	0.00	0.000	0
20	25.00	0.000	0	0.00	0.000	0

The results show that the drainage system resolves the waterlogging problem. It seems however that salinity poses a threat and should be carefully managed.

7.5.2 Economic and financial modelling results for the Breede River case study

- Economic Benefit Cost analysis (per hectare)

Table 7-25 illustrates the Economic Benefit Cost analysis for Breede River case study crops.

Table 7-25 Economic Benefit Cost analysis – Breede River crops

Wine grape *(Per hectare drainage installation analysis)*	
Benefit-Cost Ratio	2.6 : 1
Payback period (average)	3.2 years
Internal Rate of Return (IRR)	19.5%
Net Present Value (NPV)	141 142

Plums *(Per hectare drainage installation analysis)*	
Benefit-Cost Ratio	7.1 : 1
Payback period (average)	0.6 years
Internal Rate of Return (IRR)	31.2%
Net Present Value (NPV)	631 153

Nectarine *(Per hectare drainage installation analysis)*	
Benefit-Cost Ratio	6.7 : 1
Payback period (average)	0.7 years
Internal Rate of Return (IRR)	29.2%
Net Present Value (NPV)	589 076

Peaches *(Per hectare drainage installation analysis)*	
Benefit-Cost Ratio	7.0 : 1
Payback period (average)	0.6 years
Internal Rate of Return (IRR)	29.8%
Net Present Value (NPV)	619 273

The Economic Benefit Cost analysis shows that installation of drainage for wine grapes, plums, nectarines and peaches is economically viable.

- Financial Whole-farm analysis

For the Whole-farm analysis, five scenarios were modelled. These are:

- Without drainage – 0% start-up debt ratio
- With drainage – 0% start-up debt ratio
- With drainage – 20% start-up debt ratio
- With drainage – 25% start-up debt ratio
- With drainage – 25% start-up debt ratio – 50% subsidy

Table 7-26 reflects the production cost ratio, projected cash flow ratio, projected debt ratio and projected end bank balance of the different scenarios.

Table 7-26 Comparison of Financial Whole-farm analysis scenarios – Breede River

Scenario nr & description	Production cost ratio *	Projected cash flow ratio *	Highest Projected Debt ratio	End Bank balance
1 Without drainage - 0% debt ratio	113%	80%	110%	-24 030 498
2 With drainage - 0% debt ratio	73%	135%	6%	28 773 134
3 With drainage - 20% debt ratio	73%	121%	24%	10 798 644
4 With drainage - 25% debt ratio	73%	104%	29%	-5 011 068
5 With drainage - 25% debt ratio - 50% subsidy	73%	119%	26%	7 104 524
* *20-year average*				

The modelling results can be interpreted as follows:

Without drainage – 0% start-up debt ratio

- Not financially feasible – projected cash flow ratio <115% and debt ratio exceeds acceptable financing norm (<50%).

With drainage – 0% start-up debt ratio

- Financially feasible – projected cash flow ratio > 115%
- Highest projected debt ratio < 50%

With drainage – 20% start-up debt ratio

- Financially feasible – projected cash flow ratio > 115%
- Highest projected debt ratio < 50%

With drainage – 25% start-up debt ratio

- Not financially feasible – projected cash flow ratio < 115%
- Highest projected debt ratio > 50%

With drainage – 25% start-up debt ratio – 50% subsidy

- Financially feasible – projected cash flow ratio > 115%
- Highest projected debt ratio > 50%

Without drainage the case study farm will not be financially viable over the long term. The farm will be financially viable with 20% start-up debt ratio with drainage installed. However, chances are slim that the operation will succeed with a start-up debt ratio in excess of 25%, unless drainage installation costs are partially financed through “green box” grants.

- Financing decision support tool

Table 7-27 summarises the financing decision support tool indicators for the different scenarios.

Table 7-27 Summarised financing decision support tool – Breede River

Scenario / Description	Norm	1 Without drainage - 0% debt ratio	2 With drainage - 0% debt ratio	3 With drainage - 20% debt ratio	4 With drainage - 25% debt ratio	5 With drainage - 25% debt ratio - 50% subsidy
Capacity						
Cash flow ratio	> 115%	No	Yes	Yes	No	Yes
Capital						
Debt ratio	< 50%	No	Yes	Yes	Yes	Yes
Collateral						
Sufficient available "yes" or "no"	yes	Yes	Yes	Yes	Yes	Yes
Conditions						
Benefit Cost ratio (B/C) : 1	> 1	Yes	Yes	Yes	Yes	Yes
Payback average	< 8	Yes	Yes	Yes	Yes	Yes
Internal Rate of Return (IRR)	> 8%	No	No	No	No	No
Net Present value (NPV)	0	Yes	Yes	Yes	Yes	Yes
Character						
Trustworthy "yes" or "no"	yes	Yes	Yes	Yes	Yes	Yes
Economic & Financially feasible		**No**	**Yes**	**Yes**	**No**	**Yes**

** Average 1st 20 years*

In the economic and financially feasible row the scenarios with a "yes" will most probably attract finance from commercial banks in the normal run of business. Scenarios with a "no" will most probably not qualify for commercial finance. Please note that this tool serves as an indicator only.

- Summary

This section summarises the modelling results for the Breede River case study. Several scenarios were run including "with" and "without" drainage for 0%, 20% and 25% start-up debt ratios. The 25% start-up debt ratio "with drainage and 50% subsidy"-scenario illustrates the impact of green box grants/subsidies on the economic viability and financial feasibility of sub-surface drainage. The results show that it will not be financially viable for a farming operation with a debt ratio in excess of 25% to install subsurface drainage without subsidy. Subsidies will ultimately assist the farming operation to stay financially viable while installing drainage. However, it will not be financially viable for farming operations with debt levels in excess of 25% to install drainage, even with a 50% subsidy. In order for farming operations with debt ratios of more than 25% to stay financially viable, the subsidy on installation of drainage should exceed 50% of drainage installation cost.

8. SUMMARY AND CONCLUSION

Waterlogging and salinity management with and without drainage systems was measured and modelled for various crops in the three case study areas, viz. Pongola, Vaalharts and Breede River. Crops included in the modelling are: Sugar cane (Pongola), pecan nuts, lucerne, maize, barley (Vaalharts), wine grapes, plums, nectarines and peaches (Breede River). The projected modelling yields are presented in the various figures in Figure 8-1.

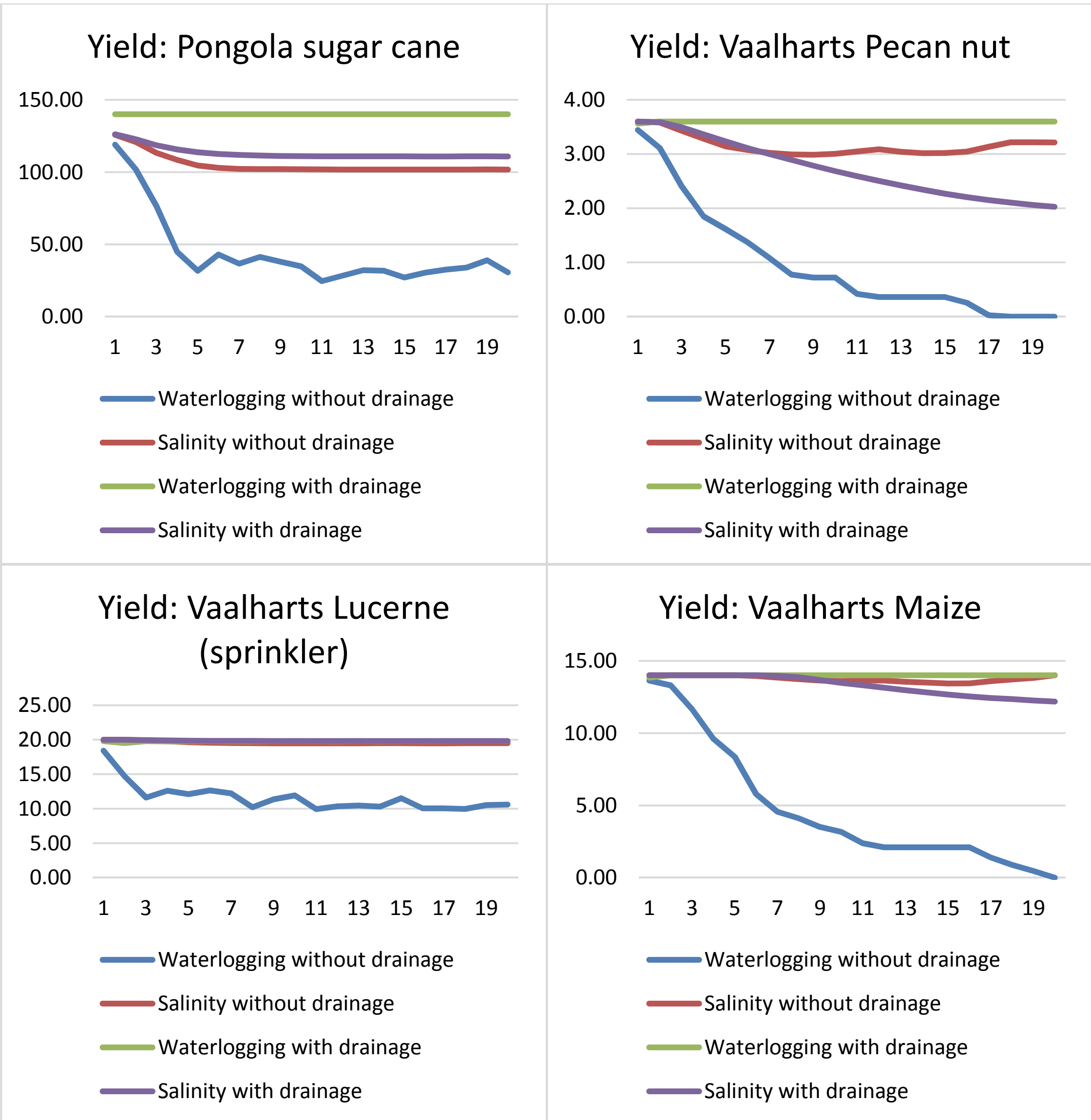


Figure 8-1 Projected modelling yields with waterlogging and salinity management

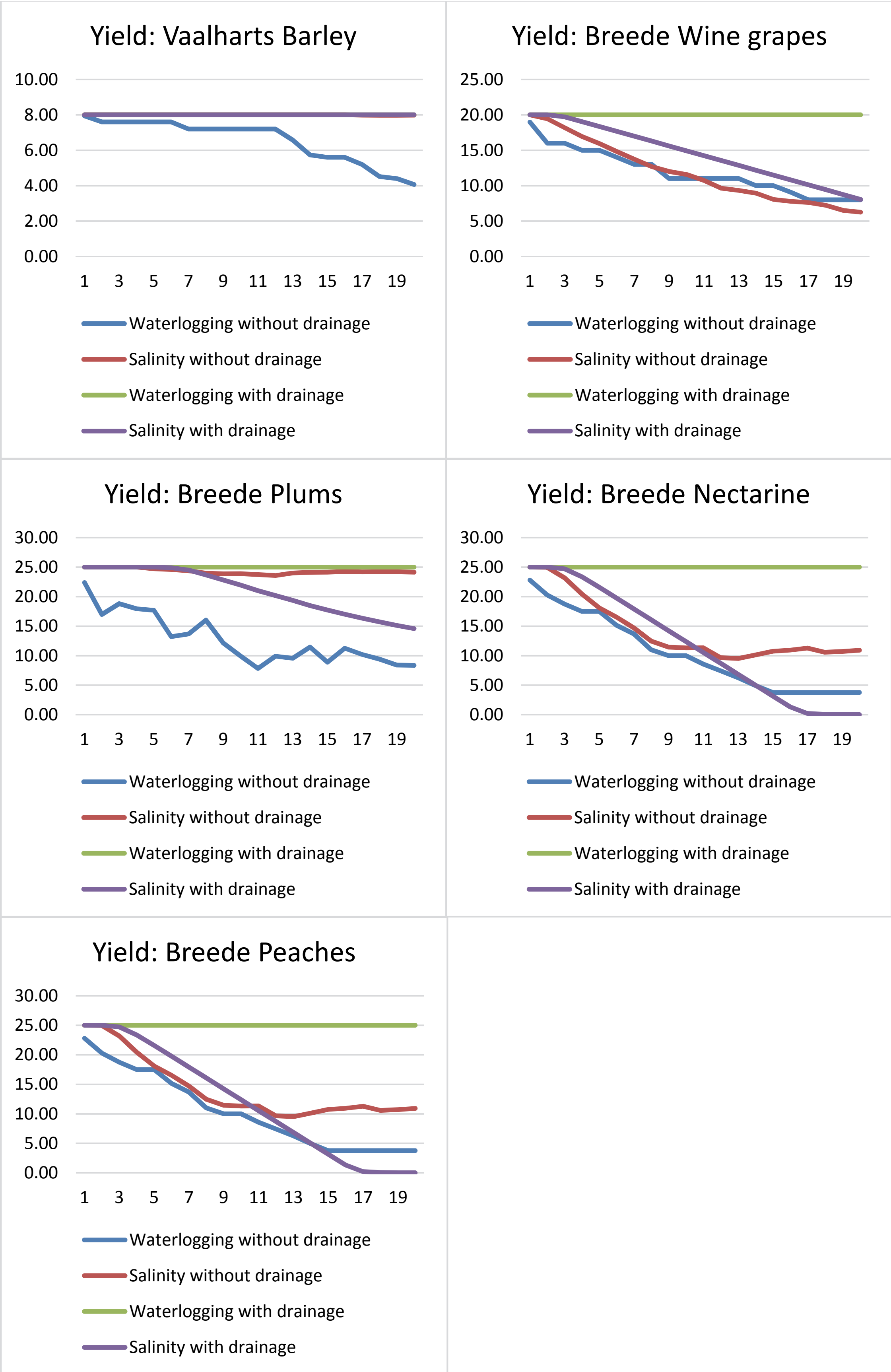


Figure 8-1 Projected modelling yields with waterlogging and salinity management (continued)

It is clear that subsurface drainage eliminates waterlogging and the negative impact thereof on potential yield. The negative effect of salinity is however for most crops not reduced to the optimal level. This is however a partly a function of the way in which the model is constructed. In simulating irrigation an attempt is made to minimize irrigation-induced leaching (percolation). This is done by irrigating the cumulative amount of water lost through evapotranspiration by the crop during the irrigation cycle (in this situation every 7 days) minus the cumulative rainfall. Irrigation amounts to 0 mm when cumulative rainfall during the irrigation cycle is more than cumulative crop evapotranspiration. The impact of salinity can however be reduced by flushing the field.

The installation of subsurface drainage seems economic viable for all crops with the exception of barley (Vaalharts). The economic viability of drainage refers to the per hectare ability of the direct increase in profitability as a result of drainage to repay the capital required to drain, whereas financial feasibility refers to the ability of the farming unit to access sufficient additional funds to pay for the drainage required and maintain an overall increasing cash flow in the long term or positive Net Present Value (NPV). Economic viability is a prerequisite for financial feasibility (Armour and Viljoen 2008). The Financial Whole-farm analysis is a more practical analysis to determine if drainage will be financial feasible.

The financial viability of installing drainage differs between the case studies. The results for **Pongola** case study show that it will not be financially viable for a farming operation with a debt ratio in excess of 30% to install subsurface drainage without subsidy. Subsidies will ultimately assist the farming operation to stay financially viable while installing drainage. It will also not be financially viable for farming operations with debt levels in excess of 40% to install drainage, even with a 50% subsidy. In order for farming operations with debt ratios of more than 40% to stay financially viable, the subsidy on installation of drainage should exceed 50% of drainage installation cost.

In the **Vaalharts** case study the results show that it will not be financially viable for a farming operation with a debt ratio in excess of 35% to install subsurface drainage without subsidy. Subsidies will ultimately assist the farming operation to stay financially viable while installing drainage. It will also not be financially viable for farming operations with debt levels in excess of 45% to install drainage, even with a 50% subsidy. In order for farming operations with debt ratios of more than 45% to stay financially viable, the subsidy on installation of drainage should exceed 50% of drainage installation cost.

For the **Breede River** case study the results show that it will not be financially viable for a farming operation with a debt ratio in excess of 25% to install subsurface drainage without subsidy. Subsidies will ultimately assist the farming operation to stay financially viable while installing drainage. It will also not be financially viable for farming operations with debt levels in excess of 25% to install drainage, even with a 50% subsidy. In order for farming operations with debt ratios of more than 25% to stay financially viable, the subsidy on installation of drainage should exceed 50% of drainage installation cost.

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APPENDIX:

APPENDIX A: QUESTIONNAIRE

DREINERING PROJEK

DRAINAGE PROJECT

"Development of technical and financial norms and standards for drainage of irrigated lands"

OPNAME/SURVEY

Doel: Om die inligting te gebruik ten einde gevallestudie plaasmodelle te ontwikkel om tegniese en finansiële norme vir dreinering te evalueer.

Objective: To use the information to construct "case study" farms to evaluate technical and financial norms for drainage.

Persoonlike vraelys: Feb/Maart 2013

Personal survey: Feb/March 2013

Navorsers/Researchers: Dr. Daan Louw – 082 857 3458

Hamman Oosthuizen – 082 783 6192

Vertroulikheidsverklaring

Hiermee verklaar OABS en sy medewerkers dat daar onder geen omstandighede individuele inligting, van watter aard hoegenaamd, aan 'n ander party beskikbaar gestel sal word sonder die skriftelike toestemming van die eienaar van die eiendom wie se inligting hier opgeneem word nie. Die enigste inligting wat bekend gemaak sal word is gemiddelde syfers van die hele gebied en/of van "gevalle studie plase".

We declare that OABS and its personnel will under no circumstances what so ever make individual information available to any other party without the written consent of the owner of the property of the information contained in this questionnaire. The only information which will be made available will be processed average information of the region and/or anonymous case-study farms.

Nota/Note:

U samewerking met die deeglike invul van hierdie vraelys word hoog op prys gestel deur die navorsers sowel as u mede produsente. Die kwaliteit van die navorsing sal direk hierdeur beïnvloed word.

Your cooperation with the proper completion of this questionnaire is appreciated by the researchers as well as the other participating farmers of this survey. The quality of the research will be affected by the way in which you complete the questionnaire.

Lees asseblief die instruksies by elke vraag voordat u dit invul. Indien u nie seker is wat om in te vul nie, kontak asseblief enige een van die navorsers. Vul asseblief al die vrae in.

We request you to read the instructions carefully before completing the questionnaire. If you are uncertain please contact any of the researchers. Please complete all questions where applicable.

1.REGISTRASIE/REGISTRATION

ITEM	BESONDERHEDE/DETAIL
Naam van eienaar/Name of owner	
Plaasnaam of naam van die boerdery/Farm or Business name	
GIS koördinate/GIS coordinates	
Adres/Address	
Telefoon/Telephone	
Selfoon/Cell phone	
Faks/Fax	
E-pos/E-mail	

- Jare ondervinding in landbousektor/Years of experience in agricultural sector: ……………………………………………….
- Wat is u hoogste kwalifikasie/Highest level of education: ……………………………………………………………………………………….
- Het die boerdery entiteit enige ander belange buite primêre landbou? Indien wel, noem:/Does this farming entity have any other running concerns outside primary agriculture? If yes, please provide details:

2. GEBRUIKSPATROON VAN GROND/LAND USE

ITEM	TOTALE OPPERVLAKTE (ha) TOTAL AREA (ha) <u>(Gehuurde grond ingesluit/including leased land)</u>
Totale besproeiingsgrond (reeds ontwikkel met infrastruktuur) (a+b+c)/Total irrigation land (land already developed with infrastructure)(a+b+c)	
- Hoë potensiaal/High potential (a)	
- Medium potensiaal/Medium potential (b)	
- Lae potensiaal /Low potential (c)	
Besproeibare grond (nog nie ontwikkel maar het water om te besproei)/Irrigable land (not developed yet but you do have water) (d)	
Totale droëland oppervlakte/Total dry land area (e)	
Veld/Veldt (f)	
Werf en uitval/Homestead and waste (g)	
Totale oppervlakte waarop geboer word/ Total Area farmed (a+b+c+d+e+f+g)	

3. GRONDGEBRUIK (MET HUIDIGE WATER) VIR DIE JAAR/LAND USE WITH EXISTING WATER

* Of die nuutste syfers wat u beskikbaar het vir 'n 12 maande periode/Or the latest figures available

3.1 Langtermyn gewasse/Long term crops

(om huidige grondgebruikspatrone te bepaal)/(to determine current land use pattern)

Nota: Dui asb. in die toepaslike blokkie die hektare aan by die besproeiingsintensiteit en stelsel. Onthou dat die totale aantal ha wat u aandui onder besproeiingsintensitiet moet ooreenstem met die wat u aangedui het by totale oppervlakte. Dieselfde geld vir die besproeiingsstelsels/Please indicate the area of irrigation intensity and irrigation system. Please ensure that these areas add up with those in the total area column.

GEWAS/CROP	**Totale oppervlak/Total area (ha)**	**Besproeiingsintensiteit/Irrigation intensity**			**Besproeiingstelsel/Irrigation system**			
		Permanent	Aanv/ Suppl	Geen/ None	Drup/ Drip	Mikro/ Micro	Sprinkel/Sprincle	Vloed/ Flood
Langtermyn gewasse/LT crops								
Wyndruiwe (volwasse)/Wine grapes (mature)								
Wyndruiwe (jong stokke)/Wine grapes (young vines)								
Wyndruiwe (nuut gevestig)/Wine grapes (newly								

established)								
Sitrus (volwasse)/Citrus (mature)								
Sitrus (jong bome)/Citrus (young trees)								
Sitrus (nuut gevestig)/Citrus (newly established)								
Tafeldruiwe (volwasse)/Table grapes (mature)								
Tafeldruiwe (jong stokke)/Table grapes (young vines)								
Tafeldruiwe (nuut gevestig)/Table grapes (newly established)								
Ander langtermyn weidings (spesifiseer)/Other long-term grazing (specify)................								

Ander langtermyn gewasse (spesifiseer)/Other long-term crops (specify)								
Lusern/Lucerne								

3.2 Korttermyn gewasse/Short-term crops

* Of die nuutste syfers wat u beskikbaar het vir 'n 12 maande periode/Or the latest available for a 12 month period.

3.2.1 Algemeen/General

GEWAS/CROP	**Oppervlakte/ Area (ha)**	**Besproeiingsintensiteit /Irrigation intensity**			**Besproeiingstelsel/Irrigation systems**			
		Permanent	Aanv/ Suppl	Geen	Drup/ Drip	Mikro/ Micro	Sprinkel/Sprincle	Vloed/ Flood
Graan/Grain								
Koring/Wheat								
Mielies/Maize								
Hawer/Oats								
Gars/Barley								
Korog/Triticale								
Saad/Seeds (tipe/type)								
Vegetables								
Aartappels/Potatoe								

s (summer)								
Aartappels/Potatoes (winter)								
Patats/Sweet potatoes								
Tamaties/Tomatoes								
Uie/Onions								
Groenbone/Green beans								
Kopkool/Cabbage								
Blomkool/Cauliflower								
Wortels/Carrots								
Ertjies/Peas								
Boerpampoen/Pumpkin								
Skorsies/Squash								
"Butternuts"								
Blaarslaai/Salad								
Ander groentes (spesifiseer)/Other (specify)								
Suikermielies/Sweet corn								
Ander weidings (behalwe lusern)/Other short term pastures (excluding lucerne)								

3.2.2 Wisselboustelsels – grondbesetting van korttermyn gewasse/Crop rotation of short-term crops

Dui asseblief die grondbesetting aan van gewasse wat u normaalweg produseer. Maak asb. 'n kruis in die maande waarin hierdie gewasse in die grond is vanaf grondvoorbereiding tot oestyd (sien voorbeeld)/Please indicate the growing period of short-term crops that you normally grow from land preparation to harvest (see example).

Gewas/Crop	**Jan**	**Feb**	**Mrt**	**April**	**Mei/ May**	**Jun**	**Julie/ July**	**Aug**	**Sept**	**Okt/ Oct**	**Nov**	**Des/ Dec**
Aartappels/ Potatoes	X	X	X	X							X	X

4. WATER HULPBRON/WATER RESOURCES

4.1 Damme en boorgate (nie water vanaf skemas nie-sien 4.2 vir skemas)/Dams and bore holes (not water from schemes – see 4.2 for schemes)

		Bron (% bydrae)/ Source (% contribution)		
Damkapasiteit (eie damme)/Dam capacity (own dams)	**Inhoudsmaat/Capacity (m^3)**	**Afloop/ Runoff**	**Rivier/ River**	**Skema/ Scheme**
1. bv/e.g. Langdam	2 Milj/Mill	20%		80%
2.				
3.				
4.				
5.				
6.				

		Kwaliteit (maak X in toepaslike blok)/Quality (please make a X)		
Ander waterbronne (boorgate, ens.)/ Other water sources (bore holes)	**Kapasiteit (m^3 per uur)/Capacity (m^3 per hour)**	**Goed/ High**	**Medium**	**Swak/ Low**
1.				
2.				
3.				
4.				
5.				

4.2 Inlysting uit skemas/riviere/Water rights from schemes/rivers

Verskaf asb. die volgende inligting met betrekking tot skemas en riviere waaruit u waterregte het wat geregistreer is by die Departement van Waterwese/Please supply the following information about your water rights as registered at the Department of Water Affairs

Skemas of riviere/Scheme or river	**Inlysting/ Entitlement (ha)**	**Volume per ha (m^3/ha)**	**Tarief/ Tariff (Rand per ha)**	**In hoeveel uit 10 jaar het u, die volle inlysting ontvang. bv. 5 uit 10/For how many years out of 10 did you receive your full entitlement, e.g. 5 out of 10**
1.				
2.				
3.				
4.				

5. WAARDASIE VAN BOERDERY/VALUATION OF THE FARM

(Berekening van opbrengs op kapitaalbelegging asook Rand waarde van bates wat jaarliks aangewend word om sekere inkomste te kan genereer)/(Calculation of return on capital and Rand value of assets applied to generate income)

Nota: Die waardasie van u eiendom word hier baie eenvoudig hanteer ten einde die vraelys te verkort. Slegs die totale waarde word gevra by die indelings. Maak asb. seker dat u alle bates waardeer. Gebruik asb. sover as moontlik die waarde waarteen die bates **verseker** is en/of veilingswaardes. /

The valuation of your property is treated simplistically here to shorten the questionnaire. Only the totals for each category are asked for. Please ensure that you value all your assets. Please use insurance values and/or auction values as far as possible.

Waarde van grond/Value of land (per ha)	**Waarde/ Value (per ha)**
- Besproeiingsgrond wat reeds ontwikkel is met boorde/wingerde/ - Irrigation land already developed with orchards/vines	
- Besproeiingsgrond wat reeds ontwikkel is met lusern/ - Irrigation land already developed with Lucerne	
- Besproeiingsgrond wat reeds ontwikkel is met kort-termyn gewasse of weidings/ - Irrigation land already developed with short-term crops or pastures	
- Grond wat nog ontwikkel kan word waarvoor water beskibaar is/ - Land that can be developed for which water is available	
- Droëland/ - Dry land	
- Werf en uitval/ - Homesteads and waste	
- Veld/Veldt	
Waarde van vaste verbeteringe (totaal per item)/ Value of fixed improvements (total per item)	
- Bestuurders se woonhuise/Managers homes	
- Arbeidershuise/Labourers houses	
- Ander plaasgeboue (nie store nie)/Other farm buildings (not sheds)	
- Pakstoor (slegs gebou, nie toerusting)/Pack house (only building not equipment)	
- Koelstoor (slegs gebou, nie toerusting)/Cold store (only building not equipment)	
- Ander store/Other sheds	
- Watervoorsiening (damme, veesuipings, reservoirs, boorgate,	

ens.)/ - Value of cement dams, reservoirs and bore holes	
Totaal/Total	
Waarde van voertuie, masjiene, implemente, vee en losgoed/ **Value of vehicles, machinery, implements, livestock and loose equipment**	
- Voertuie (motors, vragmotors, trekkers, stropers, ens.)/ - Vehicles (cars, trucks, tractors, harvesters, etc.)	
- Ander self aangedrewe masjiene/Other self propelled equipment	
- Implemente/Implements	
- Pakstoor toerusting/Pack house equipment	
- Koelstoor toerusting/Cold room equipment	
- Vee/Livestock	
- Voorrade/Stocks	
- Alle ander (kantoor toerusting, ens.)/All other (office, etc.)	
Totaal/Total	

*** Opmerking: Sluit gehuurde items se waardes in by al die bogenoemde/Please include values for all rented items in the above**

Wat is die totale realistiese markwaarde van u plaas (alle bates – eie en gehuurde)/

Please indicate the realistic market value of your farm (all assets – own and leased):

....

6. SKULDVERPLIGTINGE/LIABILITIES –

Nota: Vul asseblief volledig in indien u bereid is om hierdie inligting te verskaf/Please fill in as complete as possible if you are prepared to give us the information

(Om volledige prentjie te kry, maar besef dat skuld posisie oor tyd sal verander/To provide us with a clearer picture, knowing debt position will change over time)

* Of die nuutste syfers wat u beskikbaar het vir 'n 12 maande periode/Based on the latest figures available for a 12 month period

Korttermyn verpligtinge (een jaar en minder)/ Short term (one year or less)	**Limiet/Limit (R)**	**Rentekoers/Interest rate (%)**	**Rente per jaar/Interest per annum (R)**
1.			
2.			
3.			
4.			

Mediumtermyn (twee tot vyf jaar)/Medium term (two to five years)	**Oorspronklike bedrag/Original amount**	**Paaiement per jaar/Payment per annum (R)**	**Rentekoers/Interest rate (%)**	**Uitstaande bedrag/Outstanding amount**	**Oorspronklike termyn(maande)/Original period (months)**	**Uitstaande termyn (maande)/Outstanding term (months)**
1.						
2.						
3.						
4.						

Langtermyn(vyf jaar en langer)/Long-term (five years and longer)	**Oorspronklike bedrag/Original amount**	**Paaiement per jaar/Payment per annum (R)**	**Rentekoers/Interest rate (%)**	**Uitstaande bedrag/Outstanding amount**	**Oorspronklike Termyn (jare)/Original period (years)**	**Uitstaande termyn(jare)/Outstanding term (years)**
1.						
2.						
3.						
4.						

Nota: Vul asseblief volledig in indien u bereid is om hierdie inligting te verskaf/Please fill in as complete as possible if you are prepared to give us the information

7 OORHOOFSE UITGAWES (nie allokeerbaar nie)/OVERHEAD COSTS (not allocateable) –

* Of die nuutste finansiële syfers wat u beskikbaar het vir 'n 12 maande periode/Or alternatively the latest over a 12 month period

OORHOOFSE UITGAWES (per jaar)/OVERHEAD EXPENCES (per year)	**BEDRAG/AMOUNT** **(per jaar/per year)**
- Gehuurde bestuurskoste/Hired management	
- Waterbelasting/Water tax/tariff	
- Elektrisiteit/Electricity	
- Distrikraadbelasting/District council tax	
- Grondhuur/Land rent	
- Boekhoufooie/Accountant fees	
- Konsultasiefooie/Consulting fees	
- Kantooruitgawes (sekretaresse, skryfbehoeftes, ens.)/Office expenses (secretary, stationary, etc.)	
- Telefoon en posbus/Telephone and post office box	
- Selfoon/Cell phone	
- Lede- en intekengeld/Membership fees	
- Brandstof (slegs plaasbakkies en vragmotors, **nie trekkers**)/Fuel (only for farm LDV's and trucks, **not for tractors**)	
- Kort-termyn versekering op geboue, masjinerie, implemente en toerusting/Insurance on farm buildings, machinery, implements and equipment	
- Reparasies en onderhoud op vaste verbeterings/Repairs and maintenance on fixed improvements	

- Reparasies en onderhoud op masjinerie, implemente en toerusting/Repairs and maintenance on machinery, implements and equipment	
- Reparasies en onderhoud op besproeiingstoerusting/Repairs and maintenance on irrigation equipment	
- Bankkoste/Bank costs	
- Sekuriteit/Security	
- Advertensiekoste/Advertisement	
- Inkomstebelasting/Income tax	
- Ander (spesifiseer)......................../Other (specify).........................	
-	
Totaal/Total	

8. ANDER FINANSIëLE INLIGTING/OTHER FINANCIAL INFORMATION	**BEDRAG/AMOUNT** **(per jaar/per year)**
HUISHOUDELIKE UITGAWES PER JAAR (Alle afhanklikes)/Household expenses per annum (all dependents)	
EIE BEDRYFSKAPITAAL (Kontant op hande, begin van seisoen)/Own operating capital (Cash on hands in the beginning of the season)	
DEBITEURE (Hoeveel geld skuld ander mense jou soos op 28 Febr 2013)/Debtors (People owing you money as on 28 Feb 2013)	
NIE-BOERDERY INKOMSTE/NON-FARM INCOME	

9. HUIDIGE BOOM OF STOK SENSUS INLIGTING/TREE OR VINE CENSUS INFORMATION

VRA EERS VIR AFSKRIF VAN BOOMSENSUS – INDIEN NIE BESKIKBAAR VUL LYS IN!/ASK FOR A COPY OF TREE CENSUS – IF NOT AVAILABLE FILL OUT LIST BELOW

(Inligting is belangrik om langtermyn grondgebruikspatrone te bepaal. Ou boorde sal hervestig moet word aan einde van produktiewe leeftyd Hierdie inligting is ook belangrik vir opbrengs bepaling bv. jong boorde nog nie in drag, ens.)/(Info is important to determine land use patterns. Orchards needs to be re-established at the end of their lifecycle. Info is also important when calculating yield)

Vrugtipe/Fruit kind	**Kultivar/Cultivar**	**Jaar van aanplanting (dui asb. die aantal ha in die toepaslike spasie aan)/Year of planting (please indicate the hectares in the applicable block)**										
		2003 en ouer/and older	2004	2005	2006	2007	2008	2009	2010	2011	2012	**Totaal (ha)**
Bv. Wyndruiwe	Columbar	10	3	2	2							17

10. OPBRENGS EN PRYS INLIGTING VIR LANGTERMYN GEWASSE VIR DIE SEISOEN/YIELD AND PRICE INFORMATION FOR LONG- TERM CROPS FOR THE LATEST SEASON

NB. Dui asb. die plaashek prys minus alle bemarkingskoste aan/Please indicate the farm gate price minus all marketing costs

N.V.T = Nie van toepassing/NA = Not applicable

Gewas/ Crop	Kultivar/ Cultivar	Opbrengs/ eenheid (ton of kartonne/ha) Yield/Unit (Tons or Cartons/ha)	Uitpak %/Pack-out %					Prys (Rand/Eenheid)/Price (Rand/Unit)				
			Uitvoer 1/ Export 1	Uitvoer 2/ Export 2	Plaaslik/ Local	Kelder/ Cellar	Sap/Juice Verwerk/ Processed	Uitvoer 1/ Export 1	Uitvoer 2/ Export 2	Plaaslik/ Local	Kelder/ Cellar	Sap/Juice Verwerk/ Processed
Bv. Perskes	Keisie	25 ton/ha	60%		20%		20%	R5000/ton		R2500/ton		R1000/ton

11. OPBRENGS EN PRYS VAN KORTTERMYN GEWASSE/YIELD AND PRICE OF SHORT-TERM CROPS

NB: Vul asseblief volledig in. Alle opbrengste moet per hektaar en pryse per ton aangedui word/Please fill in as complete as possible. All yields must be per hectare and prices per ton

Voorbeeld/ Example

Gewas /Crop	Aartappels /Potatoes											
Droëland of besproeiing (D/B)/Dry land or Irrigation (D/I)	D											
Begrote opbrengs per ha/Estimated yield per ha (ton)												
- Klas 1/Class 1	15											
- Klas 2/Class 2	5											

- Klas 3/Class 3												
- Klas 4/Class 4												
Prys per ton (begrote prys)/Price per ton (budget price)												
- Klas 1/Class 1	1000											
- Klas 2/Class 2	800											
- Klas 3/Class 3												
- Klas 4/Class 4												

12. BESTUURSVERGOEDING/MANAGER REMUNARATION

(Indien nie reeds verdiskonteer onder par 5/If not already discounted in par. 5)

Wat is u jaarlikse bestuursvergoeding/trekking vanuit die boerdery?/What is your annual management remuneration /drawings from the farming enterprise ?

....
....

DANKIE VIR U SAMEWERKING!!!/THANK YOU FOR YOUR PARTICIPATION!!!

APPENDIX B: PROJECTED CASH FLOW STATEMENT – PONGOLA CASE STUDY

Projected cash flow statement

Crop production income	YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Permanent crops	Sugarcane		3,857,920	3,879,040	4,009,280	4,037,440	4,092,000	4,097,280	3,931,840	4,033,920	3,817,440	3,982,880	4,092,000	3,857,920	3,879,040	4,009,280	4,037,440	4,092,000	4,097,280	3,931,840	4,033,920	3,817,440
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cash crops	Maize		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	?		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	?		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	?		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	?		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	?		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Maize		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	?		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	?		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total crop incom			**3,857,920**	**3,879,040**	**4,009,280**	**4,037,440**	**4,092,000**	**4,097,280**	**3,931,840**	**4,033,920**	**3,817,440**	**3,982,880**	**4,092,000**	**3,857,920**	**3,879,040**	**4,009,280**	**4,037,440**	**4,092,000**	**4,097,280**	**3,931,840**	**4,033,920**	**3,817,440**
Livestock income	YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Total livestock income			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total production income			**3,857,920**	**3,879,040**	**4,009,280**	**4,037,440**	**4,092,000**	**4,097,280**	**3,931,840**	**4,033,920**	**3,817,440**	**3,982,880**	**4,092,000**	**3,857,920**	**3,879,040**	**4,009,280**	**4,037,440**	**4,092,000**	**4,097,280**	**3,931,840**	**4,033,920**	**3,817,440**
Capital income	Land sales																					
	Breeding stock																					
	Machinery & equipment																					
	Vehicles																					
Income from loan			2,850,320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-farm income																						
Total income			**6,708,240**	**3,879,040**	**4,009,280**	**4,037,440**	**4,092,000**	**4,097,280**	**3,931,840**	**4,033,920**	**3,817,440**	**3,982,880**	**4,092,000**	**3,857,920**	**3,879,040**	**4,009,280**	**4,037,440**	**4,092,000**	**4,097,280**	**3,931,840**	**4,033,920**	**3,817,440**

Fill in details and income per year

Projected cash flow statement (continue)

Direct Allocated costs as per crop budgets	YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Permanent crops	Sugarcane		1,807,850	2,128,456	1,903,323	1,958,267	1,898,180	1,973,387	2,256,369	1,949,187	2,313,076	1,890,565	1,819,494	2,307,368	2,128,456	1,903,323	1,958,267	1,898,180	1,973,387	2,256,369	1,949,187	2,313,076
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	citrus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cash crops	Maize		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	?		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	?		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	?		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	?		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	?		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Maize		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	?		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	?		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Maize		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total crop expenses			**1,807,850**	**2,128,456**	**1,903,323**	**1,958,267**	**1,898,180**	**1,973,387**	**2,256,369**	**1,949,187**	**2,313,076**	**1,890,565**	**1,819,494**	**2,307,368**	**2,128,456**	**1,903,323**	**1,958,267**	**1,898,180**	**1,973,387**	**2,256,369**	**1,949,187**	**2,313,076**
Livestock prod costs	YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Total livestock expenses			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total direct allocated costs			**1,807,850**	**2,128,456**	**1,903,323**	**1,958,267**	**1,898,180**	**1,973,387**	**2,256,369**	**1,949,187**	**2,313,076**	**1,890,565**	**1,819,494**	**2,307,368**	**2,128,456**	**1,903,323**	**1,958,267**	**1,898,180**	**1,973,387**	**2,256,369**	**1,949,187**	**2,313,076**
Non allocated costs	YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Fuel		30,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
	Maintenance/repairs/parts		77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000
	Contract work																					
Not discounted in crop budgets	Salaries																					
	Labour																					
	Insurance		122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000
	Licenses																					
	Telephone		48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000
	Electricity		20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
	Water																					
	Maintenance buildings																					
	Bank charges		37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000
	Professional fees		25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
	Other expenses		21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000
5%	Unforseen expenses		109,393	126,923	115,666	118,413	115,409	119,169	133,318	117,959	136,154	115,028	111,475	135,868	126,923	115,666	118,413	115,409	119,169	133,318	117,959	136,154
Total non allocatable costs			**489,393**	**536,923**	**525,666**	**528,413**	**525,409**	**529,169**	**543,318**	**527,959**	**546,154**	**525,028**	**521,475**	**545,868**	**536,923**	**525,666**	**528,413**	**525,409**	**529,169**	**543,318**	**527,959**	**546,154**

Projected cash flow statement (continue)

Capital expenditure	YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Drainage installation		1,425,160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Machinery & plant purchases																					
Medium term pmts Do not fill in here - see monthly accounts below	Vehicle purchases																					
	Livestock purchases																					
	Land purchases																					
	Developments (fixed)																					
	Investments																					
	Other																					
Total capital expenditure			**1,425,160**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Debt redemption	YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Short term payments	Monthly payments		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total short term payments			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Medium-term payments	YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Eg AVAF		94,641	94,641	94,641	94,641	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium term pmts Do not fill in here - see medium term debt below	Eg AVAF		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Eg AVAF		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Eg AVAF		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Eg AVAF		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Eg AVAF		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Eg AVAF		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Eg AVAF		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total medium-term payments			**94,641**	**94,641**	**94,641**	**94,641**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Long-term payments	YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		0	463,876	463,876	463,876	463,876	463,876	463,876	463,876	463,876	463,876	463,876	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Eg Nedbank		187,444	187,444	187,444	187,444	187,444	187,444	187,444	187,444	0	0	0	0	0	0	0	0	0	0	0	0
	Eg Nedbank		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Eg Nedbank		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Eg Nedbank		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total long-term payments			**651,320**	**651,320**	**651,320**	**651,320**	**651,320**	**651,320**	**651,320**	**651,320**	**463,876**	**463,876**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total debt redemption			**745,962**	**745,962**	**745,962**	**745,962**	**651,320**	**651,320**	**651,320**	**651,320**	**463,876**	**463,876**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Other expenditure	YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fill in - discounted from previous years financials	Private expenses		432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000
	Income tax		32,000	71,161	-6,692	107,604	114,125	162,856	196,708	81,621	214,952	64,647	247,846	339,636	138,672	201,894	312,545	313,818	356,129	345,472	224,313	350,816
	Life insurance, etc																					
	Medical																					
	Univ / school																					
	Other																					
Total Other expenditure			**464,000**	**503,161**	**425,308**	**539,604**	**546,125**	**594,856**	**628,708**	**513,621**	**646,952**	**496,647**	**679,846**	**771,636**	**570,672**	**633,894**	**744,545**	**745,818**	**788,129**	**777,472**	**656,313**	**782,816**
Total Expenditure			**4,932,364**	**3,914,501**	**3,600,258**	**3,772,246**	**3,621,034**	**3,748,732**	**4,079,716**	**3,642,088**	**3,970,058**	**3,376,116**	**3,020,814**	**3,624,872**	**3,236,051**	**3,062,883**	**3,231,226**	**3,169,407**	**3,290,685**	**3,577,160**	**3,133,460**	**3,642,046**
Excess / Defecit			1,775,876	-35,461	409,022	265,194	470,966	348,548	-147,876	391,832	-152,618	606,764	1,071,186	233,048	642,989	946,397	806,214	922,593	806,595	354,680	900,460	175,394
Bank balance : Initial (+ / -)			200,000	1,999,635	2,023,808	2,497,633	2,840,408	3,401,296	3,855,368	3,821,674	4,332,075	4,307,893	5,049,961	6,283,357	6,707,237	7,557,873	8,740,470	9,816,961	11,043,289	12,189,248	12,913,153	14,210,012
10%	Interest (Dt)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2%	Interest (Ct)		23,759	59,634	64,804	77,581	89,922	105,524	114,182	118,569	128,436	135,304	162,211	190,831	207,647	236,200	270,276	303,735	339,365	369,224	396,399	428,054
Bank balance : End			**1,999,635**	**2,023,808**	**2,497,633**	**2,840,408**	**3,401,296**	**3,855,368**	**3,821,674**	**4,332,075**	**4,307,893**	**5,049,961**	**6,283,357**	**6,707,237**	**7,557,873**	**8,740,470**	**9,816,961**	**11,043,289**	**12,189,248**	**12,913,153**	**14,210,012**	**14,813,461**
Production cost ratio		*64%*	*60%*	*69%*	*61%*	*62%*	*59%*	*61%*	*71%*	*61%*	*75%*	*61%*	*57%*	*74%*	*69%*	*61%*	*62%*	*59%*	*61%*	*71%*	*61%*	*75%*
Cash flow ratio		*121%*	*136%*	*101%*	*113%*	*109%*	*115%*	*112%*	*99%*	*114%*	*99%*	*122%*	*141%*	*112%*	*126%*	*139%*	*133%*	*139%*	*135%*	*120%*	*141%*	*117%*

Projected cash flow statement (continue)

Short term debt	YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Cooperatives																				
	Creditors																				
	Lease installments																				
	Other																				
Monthly purchases		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Balance short term debt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments																				
10%	Interest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Short term debt	Closing balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Instalment Sale agreement	YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Eg AVAF	300,000	235,359	164,253	86,037	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Plus New con	0																			
10%	Interest	30,000	23,536	16,425	8,604	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments	94,641	94,641	94,641	94,641																
	Balance	235,359	164,253	86,037	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Eg AVAF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Plus New contract	0																			
10%	Interest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments	0																			
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Eg AVAF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Plus New contract	0																			
10%	Interest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments	0																			
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Eg AVAF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Plus New contract	0																			
10%	Interest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments	0																			
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Eg AVAF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Plus New contract	0																			
10%	Interest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments	0																			
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Eg AVAF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Plus New contract	0																			
10%	Interest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments	0																			
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Eg AVAF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Plus New contract	0																			
10%	Interest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments	0																			
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Eg AVAF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Plus New contract	0																			
10%	Interest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments	0																			
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total interest		*30,000*	*23,536*	*16,425*	*8,604*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Total installments		**94,641**	**94,641**	**94,641**	**94,641**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total medium-term debt		**235,359**	**164,253**	**86,037**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Fill in normal monthly accounts - only items not discounted in crop budgets

From Balance sheet

Fill in outstanding capital amount

Fill in if any new contract

Fill in pmt

Projected cash flow statement (continue)

Long term debt	YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1			2,474,352	2,292,140	2,091,706	1,871,228	1,628,703	1,361,926	1,068,471	745,670	390,589	0	0	0	0	0	0	0	0	0	0
	Drainage loan 1	2,640,000																			
10%	Interest	264,000	247,435	229,214	209,171	187,123	162,870	136,193	106,847	74,567	39,059	0	0	0	0	0	0	0	0	0	0
	Less payments	429,648	429,648	429,648	429,648	429,648	429,648	429,648	429,648	429,648	429,648										
	Balance	2,474,352	2,292,140	2,091,706	1,871,228	1,628,703	1,361,926	1,068,471	745,670	390,589	0	0	0	0	0	0	0	0	0	0	0
2			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Drainage loan 2																				
9%	Interest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments																				
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Drainage loan 3																				
9%	Interest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments																				
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Drainage loan 4																				
9%	Interest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments																				
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Eg Nedbank	1,000,000	912,556	816,368	710,560	594,172	466,146	325,316	170,404	0	0	0	0	0	0	0	0	0	0	0	0
	Plus New loan																				
10%	Interest	100,000	91,256	81,637	71,056	59,417	46,615	32,532	17,040	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments	187,444	187,444	187,444	187,444	187,444	187,444	187,444	187,444												
	Balance	912,556	816,368	710,560	594,172	466,146	325,316	170,404	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Eg Nedbank		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Plus New loan																				
9%	Interest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments																				
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Eg Nedbank		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Plus New loan																				
9%	Interest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments																				
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Eg Nedbank		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Plus New loan																				
9%	Interest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Less payments																				
	Balance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total interest		*364,000*	*338,691*	*310,851*	*280,227*	*246,540*	*209,485*	*168,724*	*123,887*	*74,567*	*39,059*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Total installments		**617,092**	**617,092**	**617,092**	**617,092**	**617,092**	**617,092**	**617,092**	**617,092**	**429,648**	**429,648**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total long-term debt		**3,386,908**	**3,108,507**	**2,802,266**	**2,465,401**	**2,094,849**	**1,687,242**	**1,238,874**	**745,670**	**390,589**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Debt		**3,622,267**	**3,272,760**	**2,888,303**	**2,465,401**	**2,094,849**	**1,687,242**	**1,238,874**	**745,670**	**390,589**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total interest paid		377,393	323,871	279,387	216,428	150,435	86,024	27,176	-28,723	-96,642	-146,309	-225,200	-265,173	-286,606	-323,529	-370,751	-416,983	-465,795	-506,528	-541,839	-583,697

APPENDIX C: PROJECTED INCOME STATEMENT – PONGOLA CASE STUDY

Projected Income statement

Sales (Farming operation)	YEAR	1	2	3	4	5	6	7	8	9	10
	Crop production	3,734,720	3,618,560	3,775,200	3,870,240	3,907,200	3,930,080	3,769,920	3,775,200	3,659,040	3,706,560
	Livestock production	0	0	0	0	0	0	0	0	0	0
	Other										
TOTAL Sales		**3,734,720**	**3,618,560**	**3,775,200**	**3,870,240**	**3,907,200**	**3,930,080**	**3,769,920**	**3,775,200**	**3,659,040**	**3,706,560**
Consumption	Household										
	Labour										
	Internal										
TOTAL Consumption		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Stock adjustment	Closing stock										
Less:	Opening stock										
Less:	Purchases										
TOTAL stock adjustment		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
TOTAL GROSS PRODUCTION VALUE	**(GPV)**	**3,734,720**	**3,618,560**	**3,775,200**	**3,870,240**	**3,907,200**	**3,930,080**	**3,769,920**	**3,775,200**	**3,659,040**	**3,706,560**
Less: Costs	YEAR	1	2	3	4	5	6	7	8	9	10
Production inputs	Direct Allocated	1,236,510	1,805,010	1,376,985	1,469,260	1,375,060	1,469,260	1,990,935	1,472,835	2,085,685	1,378,635
Other	Fuel	30,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
	Maintenance/repairs/parts	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000	77,000
	Contract work	0	0	0	0	0	0	0	0	0	0
	Salaries	0	0	0	0	0	0	0	0	0	0
	Labour	0	0	0	0	0	0	0	0	0	0
	Insurance	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000	122,000
	Licenses	0	0	0	0	0	0	0	0	0	0
	Telephone	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000
	Electricity	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
	Water	0	0	0	0	0	0	0	0	0	0
	Maintenance buildings	0	0	0	0	0	0	0	0	0	0
	Bank charges	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000	37,000
	Professional fees	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
	Other expenses	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000	21,000
	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0
5%	Unforseen expenses	80,826	110,751	89,349	93,963	89,253	93,963	120,047	94,142	124,784	89,432
	Depreciation - Fixed improvements	197,000	197,000	197,000	197,000	197,000	197,000	197,000	197,000	197,000	197,000
	Depreciation - Drainage system	132,000	132,000	132,000	132,000	132,000	132,000	132,000	132,000	132,000	132,000
	Depreciation - Vehicles	140,000	140,000	140,000	140,000	140,000	0	0	0	0	0
	Depreciation - Machinery & equipment	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000
Total Production, Marketing & Admin costs		**2,241,336**	**2,869,761**	**2,420,334**	**2,517,223**	**2,418,313**	**2,377,223**	**2,924,982**	**2,380,977**	**3,024,469**	**2,282,067**
NET FARM INCOME	**(NFI)**	**1,493,385**	**748,800**	**1,354,866**	**1,353,017**	**1,488,887**	**1,552,857**	**844,938**	**1,394,223**	**634,571**	**1,424,493**

Projected Income statement (continue)

NET FARM INCOME	**(NFI)**	**1,493,385**	**748,800**	**1,354,866**	**1,353,017**	**1,488,887**	**1,552,857**	**844,938**	**1,394,223**
Less: Interest paid									
	Interest (interest earned -ve sign)	377,393	323,871	279,387	216,428	150,435	86,024	27,176	-28,723
FARM PROFIT	**(NFP)**	**1,115,991**	**424,929**	**1,075,479**	**1,136,589**	**1,338,452**	**1,466,833**	**817,762**	**1,422,946**
Plus:	Non-farming income	199,000	102,000	102,000	102,000	102,000	102,000	102,000	102,000
	Capital appreciation								
	Capital profits								
	Own capital inflow								
Less:	Capital loss								
	Own-capital outflow								
	Dividends / profits								
28%	Income tax provision	247,237	26,580	208,734	225,845	282,366	318,313	136,573	306,025
	Private & househ expenses	432,000	432,000	432,000	432,000	432,000	432,000	432,000	432,000
	Farm products consumed								
GROWTH IN NET WORTH	**(GNW)**	**635,754**	**68,349**	**536,745**	**580,744**	**726,085**	**818,520**	**351,189**	**786,921**

APPENDIX D: PROJECTED BALANCE SHEET – PONGOLA CASE STUDY

Projected Balance sheet

Fill in year 0 from previous year's balance sheet

ASSETS	0	1	2	3	4	5	6	7	8	9	10
Current assets											
Cash on hand / in bank	500,000	1,277,258	1,319,443	2,197,884	2,916,836	3,872,891	4,723,751	4,848,832	5,716,000	5,860,107	7,001,981
Debtors		0	0	0	0	0	0	0	0	0	0
Prepaid expenses		0	0	0	0	0	0	0	0	0	0
Life insurance		0	0	0	0	0	0	0	0	0	0
Negotiable securities		0	0	0	0	0	0	0	0	0	0
Stock:		0	0	0	0	0	0	0	0	0	0
Crops and crop products		0	0	0	0	0	0	0	0	0	0
Fruit products		0	0	0	0	0	0	0	0	0	0
Production inputs		0	0	0	0	0	0	0	0	0	0
Marketable livestock		0	0	0	0	0	0	0	0	0	0
Other		0	0	0	0	0	0	0	0	0	0
Short-term investment		0	0	0	0	0	0	0	0	0	0
Rotating fund		0	0	0	0	0	0	0	0	0	0
Co-op shares		0	0	0	0	0	0	0	0	0	0
Total current assets	**500,000**	**1,277,258**	**1,319,443**	**2,197,884**	**2,916,836**	**3,872,891**	**4,723,751**	**4,848,832**	**5,716,000**	**5,860,107**	**7,001,981**
Medium-term assets											
Breeding stock		0	0	0	0	0	0	0	0	0	0
Machinery & equipment, etc	750,000	675,000	600,000	525,000	450,000	375,000	300,000	225,000	150,000	75,000	0
Vehicles	700,000	560,000	420,000	280,000	140,000	0	0	0	0	0	0
Stock adjustment		0	0	0	0	0	0	0	0	0	0
Other											
Total medium-term assets	**1,450,000**	**1,235,000**	**1,020,000**	**805,000**	**590,000**	**375,000**	**300,000**	**225,000**	**150,000**	**75,000**	**0**
Fixed assets											
Fixed improvements	3,940,000	3,743,000	3,546,000	3,349,000	3,152,000	2,955,000	2,758,000	2,561,000	2,364,000	2,167,000	1,970,000
Drainage system			2,508,000	2,376,000	2,244,000	2,112,000	1,980,000	1,848,000	1,716,000	1,584,000	1,452,000
Land	10,470,000	10,470,000	10,470,000	10,470,000	10,470,000	10,470,000	10,470,000	10,470,000	10,470,000	10,470,000	10,470,000
Other		0	0	0	0	0	0	0	0	0	0
Increase in drained land value		2,640,000	0	0	0	0	0	0	0	0	0
Total Fixed assets	**14,410,000**	**16,853,000**	**16,524,000**	**16,195,000**	**15,866,000**	**15,537,000**	**15,208,000**	**14,879,000**	**14,550,000**	**14,221,000**	**13,892,000**
Total Assets	**16,360,000**	**19,365,258**	**18,863,443**	**19,197,884**	**19,372,836**	**19,784,891**	**20,231,751**	**19,952,832**	**20,416,000**	**20,156,107**	**20,893,981**
Value of hired land											
Total Capital employed	**16,360,000**	**19,365,258**	**18,863,443**	**19,197,884**	**19,372,836**	**19,784,891**	**20,231,751**	**19,952,832**	**20,416,000**	**20,156,107**	**20,893,981**

Projected Balance sheet (continue)

LIABILITIES YEAR	0	1	2	3	4	5	6	7	8	9	10
Current liabilities											
Banks		0	0	0	0	0	0	0	0	0	0
Cooperatives											
Creditors											
Lease installments											
Current portion of long term liabilities											
Medium term loans loan	94,641	94,641	94,641	94,641	0	0	0	0	0	0	0
Long-term loans	617,092	617,092	617,092	617,092	617,092	617,092	617,092	617,092	429,648	429,648	0
Other short term debt		0	0	0	0	0	0	0	0	0	0
Total current liabilities	**711,733**	**711,733**	**711,733**	**711,733**	**617,092**	**617,092**	**617,092**	**617,092**	**429,648**	**429,648**	**0**
Medium term liabilities											
Med Term loans	300,000	235,359	164,253	86,037	0	0	0	0	0	0	0
Other											
Total medium-term liabilities	**300,000**	**235,359**	**164,253**	**86,037**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Long-term liabilities											
Long-term loans	1,000,000	912,556	816,368	710,560	594,172	466,146	325,316	170,404	0	0	0
Drainage loan	0	2,474,352	2,292,140	2,091,706	1,871,228	1,628,703	1,361,926	1,068,471	745,670	390,589	0
Total long-term liabilities	**1,000,000**	**3,386,908**	**3,108,507**	**2,802,266**	**2,465,401**	**2,094,849**	**1,687,242**	**1,238,874**	**745,670**	**390,589**	**0**
Total liabilities	**2,011,733**	**4,334,000**	**3,984,494**	**3,600,037**	**3,082,493**	**2,711,941**	**2,304,334**	**1,855,966**	**1,175,318**	**820,237**	**0**
Net worth (from balance sheet)	14,348,267	15,031,258	14,878,949	15,597,848	16,290,344	17,072,950	17,927,417	18,096,865	19,240,682	19,335,870	20,893,981
Net worth (from income statement)		635,754	704,102	1,240,847	1,821,591	2,547,676	3,366,195	3,717,384	4,504,305	4,793,179	5,686,556
Total liabilities + Net Worth	**16,360,000**	**19,365,258**	**18,863,443**	**19,197,884**	**19,372,836**	**19,784,891**	**20,231,751**	**19,952,832**	**20,416,000**	**20,156,107**	**20,893,981**
Debt Ratio	**12%**	**22%**	**21%**	**19%**	**16%**	**14%**	**11%**	**9%**	**6%**	**4%**	**0%**

Total short term debt including cooperatives, creditors & lease installments

APPENDIX E: CROP ENTERPRISE BUDGET

Sugar cane enterprise budget

Year		1	2	3	4	5	6	7	8	9	10	11
Yield without drainage		90	90	90	90	90	90	90	90	90	90	90
Yield with drainage		105	115	120	125	130	135	140	140	140	140	140
Income per hectare (without drainage)		**31,650**	**31,650**	**31,650**	**31,650**	**31,650**	**31,650**	**31,650**	**31,650**	**31,650**	**31,650**	**31,650**
Income per hectare (with drainage)		**36,925**	**40,442**	**42,200**	**43,959**	**45,717**	**47,475**	**49,234**	**49,234**	**49,234**	**49,234**	**49,234**
Establishment cost												
Land preperation	2,800											
Seed cane	9,150											
Seed cane harvesting	2,615											
Seed cane transport	7,000											
Labour	6,530											
Water & pump	2,380											
Weed control	895											
Establishment cost	**31,370**											
Production cost												
Weed control		980	980	980	980	980	980	980	980	980	980	980
Fertilizer		5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600
Irrigation		3,760	3,760	3,760	3,760	3,760	3,760	3,760	3,760	3,760	3,760	3,760
Labour		1,480	1,480	1,480	1,480	1,480	1,480	1,480	1,480	1,480	1,480	1,480
Water cost		2,150	2,150	2,150	2,150	2,150	2,150	2,150	2,150	2,150	2,150	2,150
Yearly production cost		**13,970**	**13,970**	**13,970**	**13,970**	**13,970**	**13,970**	**13,970**	**13,970**	**13,970**	**13,970**	**13,970**
Harvest costs												
Harvest ("kap")		1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
Load		2,475	2,475	2,475	2,475	2,475	2,475	2,475	2,475	2,475	2,475	2,475
Transport		1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300
Yearly harvesting cost		**4,875**	**4,875**	**4,875**	**4,875**	**4,875**	**4,875**	**4,875**	**4,875**	**4,875**	**4,875**	**4,875**
Additional cost due to drainage												
Additional harvest load cost		413	688	825	963	1,100	1,238	1,375	1,375	1,375	1,375	1,375
Additional harvest transport cost		217	361	433	506	578	650	722	722	722	722	722
Drainage maintenance cost		300	25	25	25	25	25	25	25	25	25	25
"Gips toediening"			527			527			527			527
Total additional cost due to drainage		**929**	**1,601**	**1,283**	**1,493**	**2,230**	**1,913**	**2,122**	**2,649**	**2,122**	**2,122**	**2,649**
Gross margin / ha (without drainage)		**12,805**	**12,805**	**12,805**	**12,805**	**12,805**	**12,805**	**12,805**	**12,805**	**12,805**	**12,805**	**12,805**
Production cost %		*60%*	*60%*	*60%*	*60%*	*60%*	*60%*	*60%*	*60%*	*60%*	*60%*	*60%*
Gross margin / ha (with drainage)		**17,151**	**19,996**	**22,072**	**23,621**	**24,642**	**26,718**	**28,267**	**27,740**	**28,267**	**28,267**	**27,740**
Production cost %		*54%*	*51%*	*48%*	*46%*	*46%*	*44%*	*43%*	*44%*	*43%*	*43%*	*44%*

Price per tonne (sucrose)	3,197
Percentage (sucrose)	11.0%
Price per harvest tonne	352

APPENDIX F: CAPITAL BUDGET AND SUB-SURFACE DRAINAGE INSTALLATION PLAN – PONGOLA CASE STUDY

Sub-surface drainage cost calculation – Pongola case study

SUBSURFACE DRAINAGE COST PER METER			
PONGOLA		25.86 hectare	
SURVEY & DESIGN:	**Per Meter Cost**	**Length (m)**	**Total Cost**
Total length of drainage pipes m		4452	
Initial Investigation, Survey & Design costs R/Ha	17 days		N/C
Construction Surveys & Inspections	12 days		N/C
CONTRACTORS SITE ESTABLISHMENT:			
Transport of 2 excavators and other plant to site			R 15,000.00
2 x 20T Excavators on tracks			
1 x 10m³ Tipper truck			
1 x Payloader			
CONTRACTORS PRELIMANARY & GENERAL EXPENSIS:			
Labour protective clothing - Boots, Raincoats, Overalls	R 4.25		R 18,921.00
Transport of labour to site			
Tools - Shovels, Hammers, Wheelbarrows, Rake, Bowning Rods			
Survey marker pegs for construction leveling			
INSTALLATION OF SUBSURFACE DRAINAGE:			
Delivery of graded filter material to site - Stockpiled	R 37.50		R 166,950.00
Placement of filter material infield next to drainage lines	R 12.50		R 55,650.00
Supply 110mm diameter subsurface drainage pipe	R 12.50	3882	R 48,525.00
Supply 160mm diameter subsurface drainage pipe	R 27.00	570	R 15,390.00
Excavation of 1,9 meter trench on design grade, 0,6m wide			
Soft soil no collapsing	R 37.50		R 166,950.00
Soft soil muddy - collapsing trenches	R 70.00	503	R 35,210.00
Soft Rock	R 85.00	40	R 3,400.00
Fuel for all construction equipment on site	R 10.00		R 44,520.00
Backfil trenches - initial 500mm by hand, thereafter by machine	R 10.00		R 44,520.00
Labour cost			
Prep of bedding by hand to design grade, laying of pipes	R 15.00		R 66,780.00
Inspection manholes, supply & installation	R 22.50		R 100,170.00
Construction management & supervision	R 12.50		R 55,650.00
TOTAL TILE DRAIN INSTALLATION COST			**R 837,636.00**
PROJECT IMPLEMENTATION TIME		**68 days**	

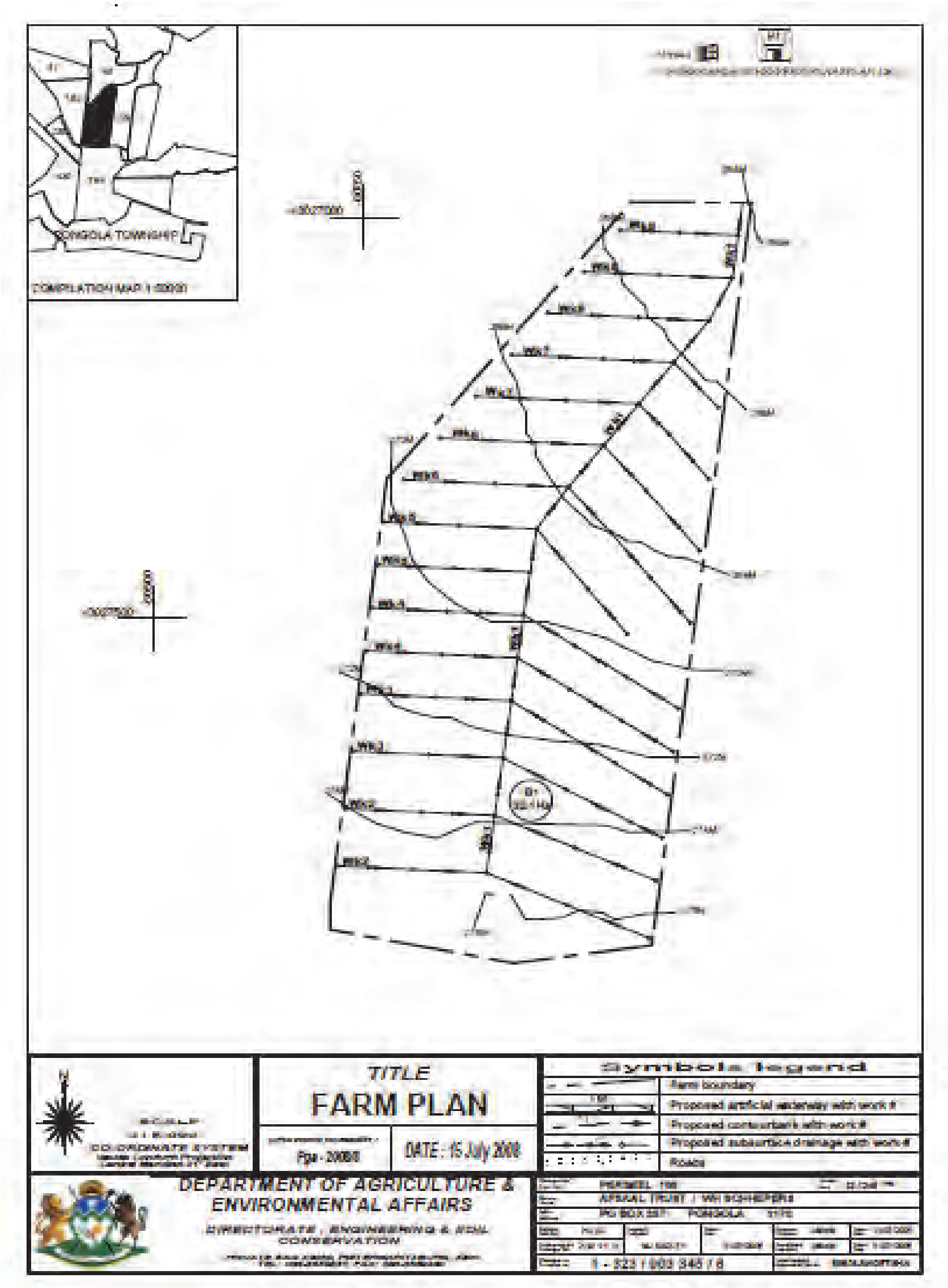
(Source: KZN Department of Agriculture and Environmental Affairs, Pongola office 2013)

Sub-surface drainage cost breakdown – Pongola case study

COST BREAKDOWN EXCLUDES DESIGN & INSPECTION FEES						
MAIN COLLECTOR DRAINS						
WORK #	**Length (m)**	**Pipe Diameter**	**Drain Spacing**	**Area Drained**	**Cost / Ha**	**Actual Cost**
13	411	160				R 87,176.25
14	354	110				R 61,684.50
	159	160				R 30,011.25
INFIELD SUBSURFACE DRAINS						
WORK #	**Length (m)**	**Pipe Diameter**	**Drain Spacing**	**Area Drained**	**Cost / Ha**	**Actual Cost**
15	437	110	90	4.34	R 19,938.19	R 86,531.75
16	486	110	72	3.76	R 21,990.82	R 82,685.50
17	234	110	72	1.94	R 20,502.32	R 39,774.50
18	107	110	72	1.03	R 16,451.21	R 16,944.75
19	151	110	72	1.35	R 18,008.70	R 24,311.75
20	98	110	54	0.68	R 33,730.15	R 22,936.50
21	205	110	54	1.25	R 37,657.00	R 47,071.25
22	200	110	54	1.23	R 37,276.42	R 45,850.00
23	162	110	72	1.43	R 19,740.21	R 28,228.50
24	192	110	72	1.64	R 20,400.00	R 33,456.00
25	190	110	54	1.17	R 29,151.71	R 34,107.50
26	196	110	54	1.20	R 28,460.83	R 34,153.00
27	288	110	54	1.70	R 29,837.65	R 50,724.00
28	198	110	54	1.22	R 28,279.92	R 34,501.50
29	180	110	54	1.12	R 28,245.54	R 31,635.00
30	204	110	36	0.80	R 57,283.75	R 45,827.00
TOTAL COST ANALYSIS MAIN COLLECTOR DRAINS						
	Length (m)			**Area Drained**	**Cost / Ha**	**Actual Cost**
	924			**25.86**	**R 6,916.94**	**R 178,872.00**
TOTAL COST ANALYSIS INFIELD LATERAL DRAINS						
	Length (m)			**Area Drained**	**Cost / Ha**	**Actual Cost**
	3528			**25.86**	**R 25,473.26**	**R 658,738.50**
TOTAL COST ANALYSIS						
	Length (m)			**Area Drained**	**Cost / Ha**	**Actual Cost**
	3939			**25.86**	**R 32,390.20**	**R 837,610.50**

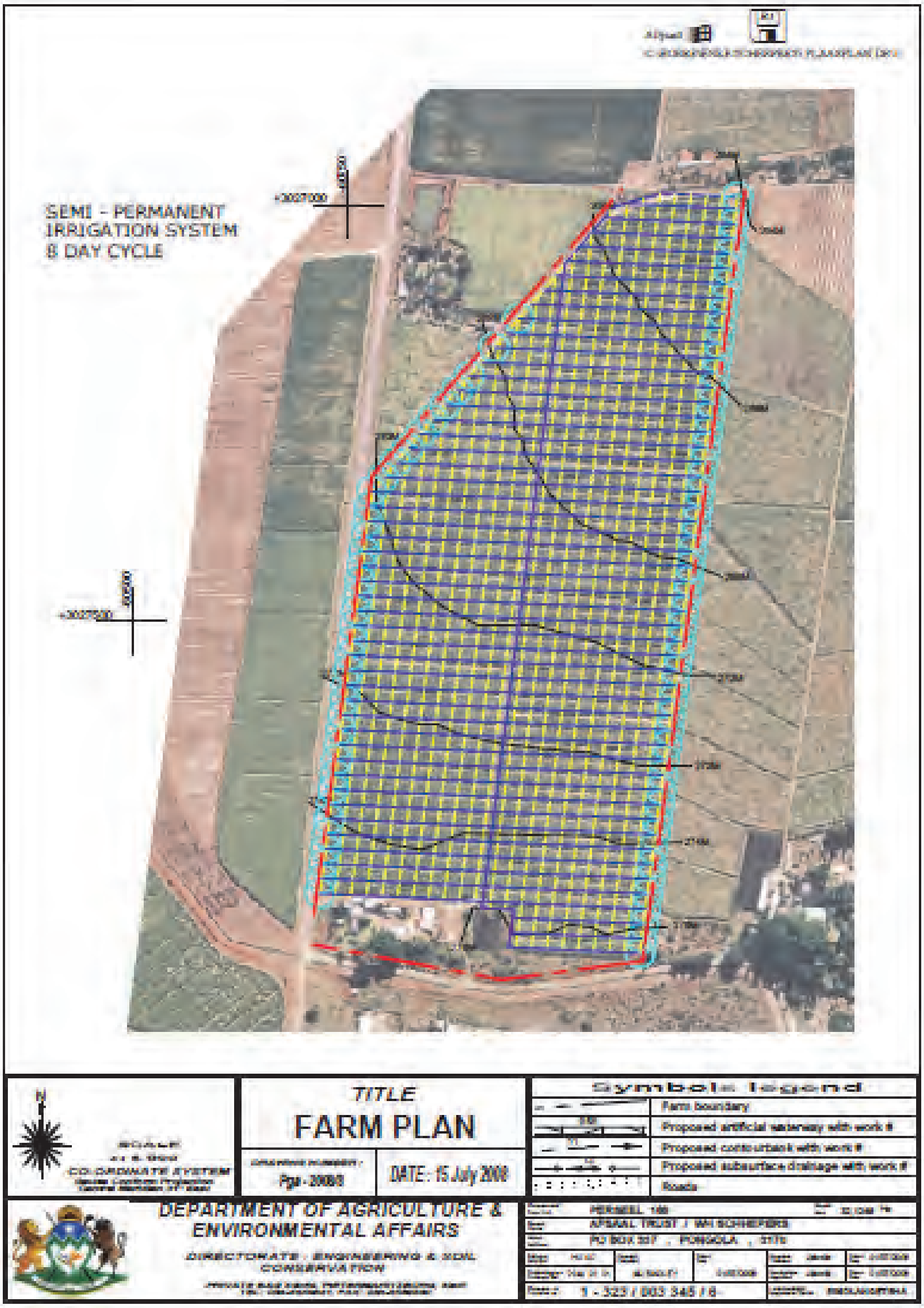
(Source: KZN Department of Agriculture and Environmental Affairs, Pongola office 2013)

Drainage plan – Pongola case study



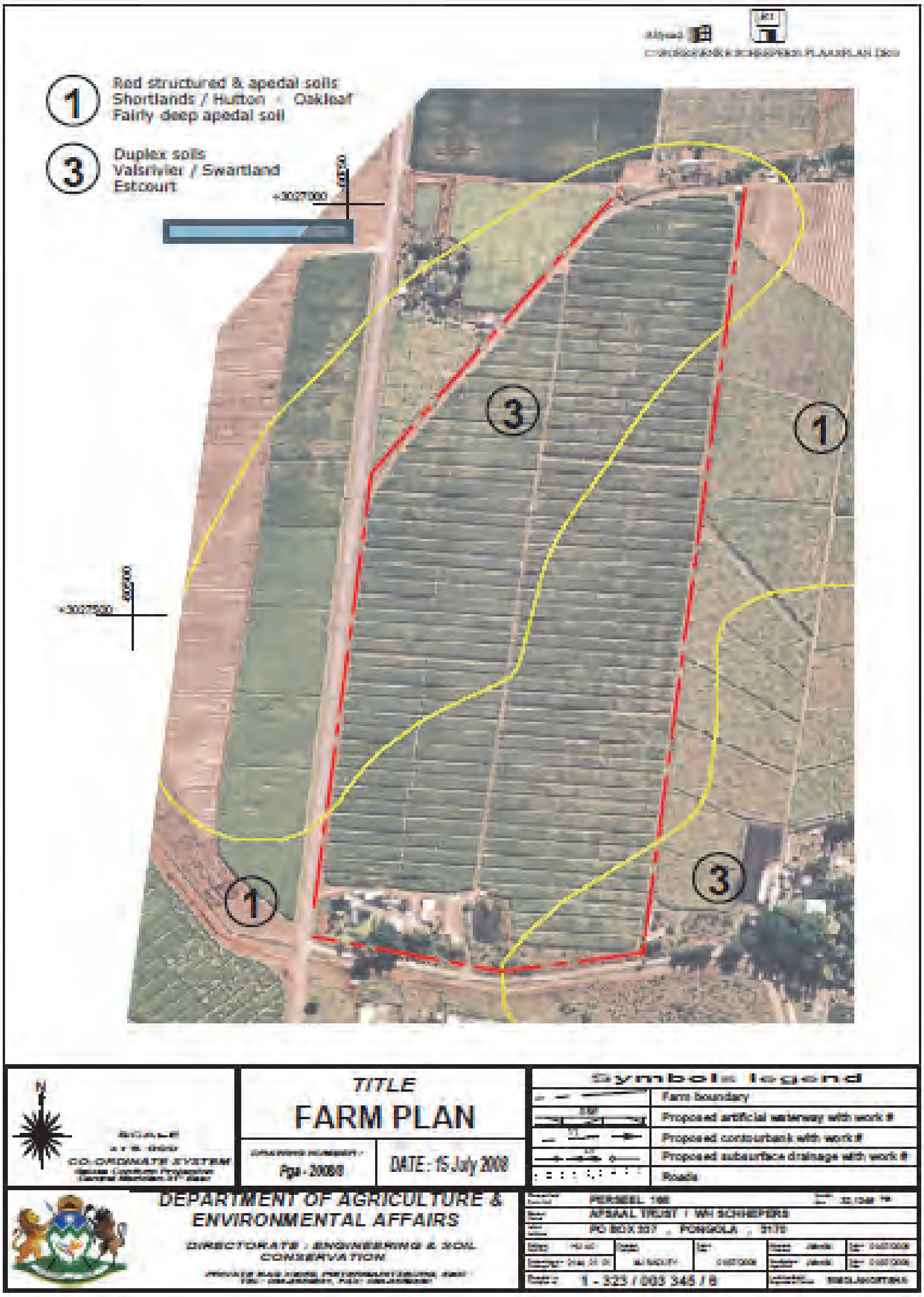
(Source: KZN Department of Agriculture and Environmental Affairs, Pongola office 2013)

Irrigation plan – Pongola case study



(Source: KZN Department of Agriculture and Environmental Affairs, Pongola office 2013)

Field chart – Pongola case study

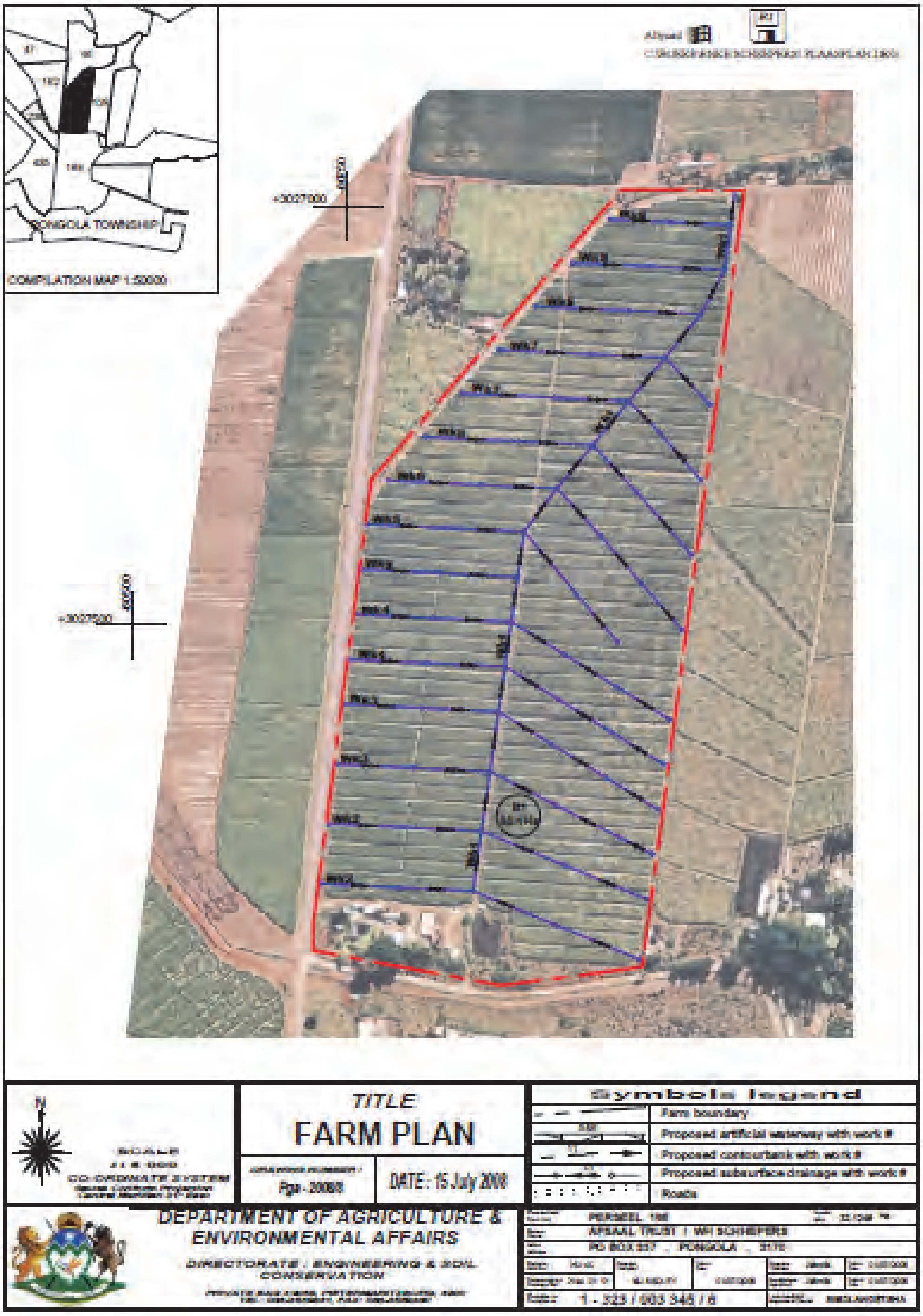


(Source: KZN Department of Agriculture and Environmental Affairs, Pongola office 2013)

Contour plan – Pongola case study

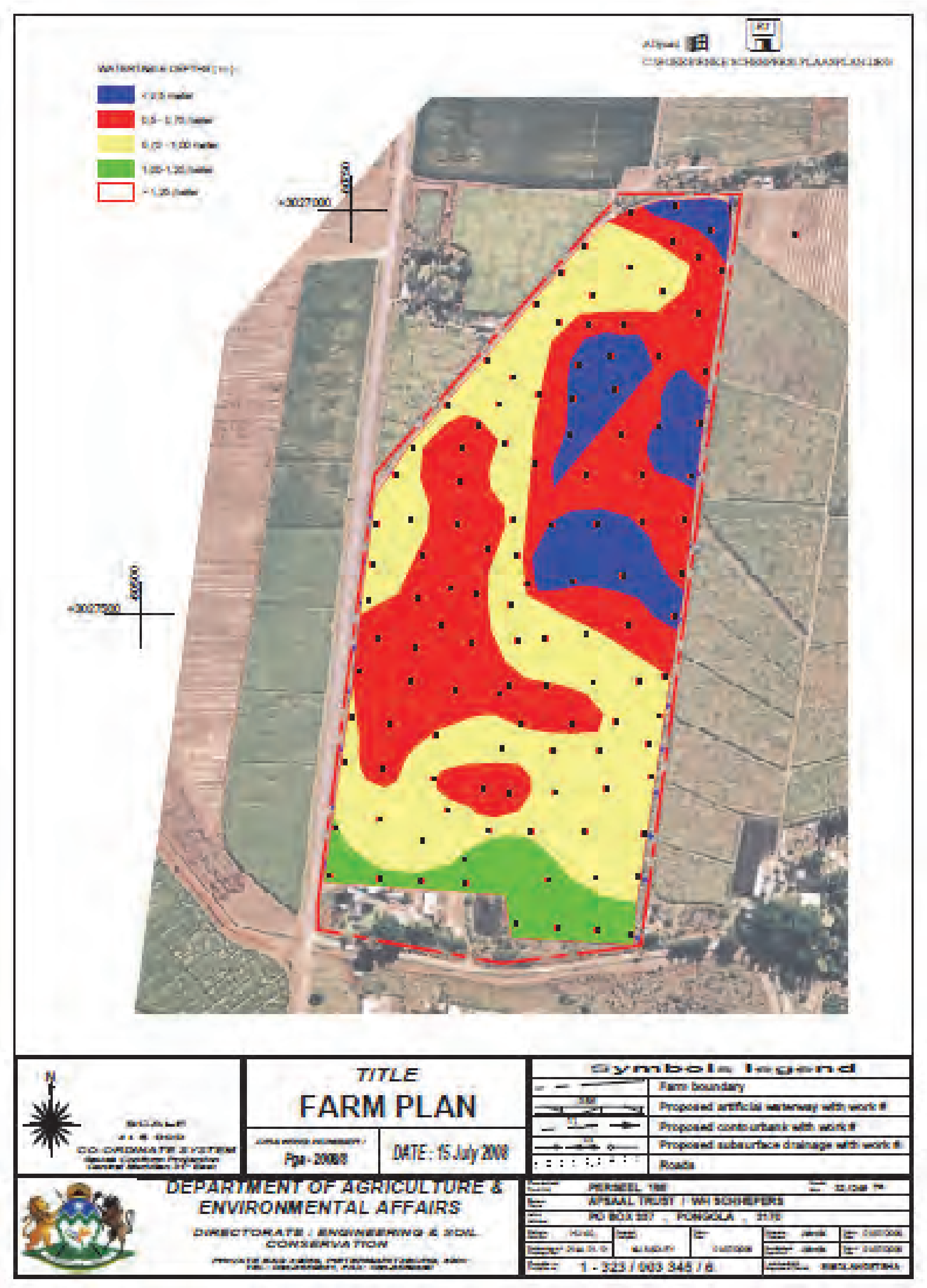
(Source: KZN Department of Agriculture and Environmental Affairs, Pongola office 2013)

Farm plan – Pongola case study



(Source: KZN Department of Agriculture and Environmental Affairs, Pongola office 2013)

Water table plan – Pongola case study



(Source: KZN Department of Agriculture and Environmental Affairs, Pongola office 2013)

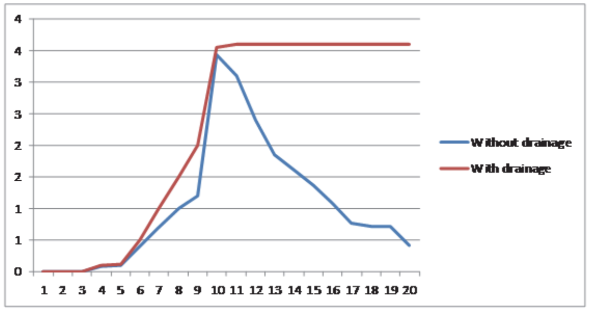
APPENDIX G: VAALHARTS CASE STUDY

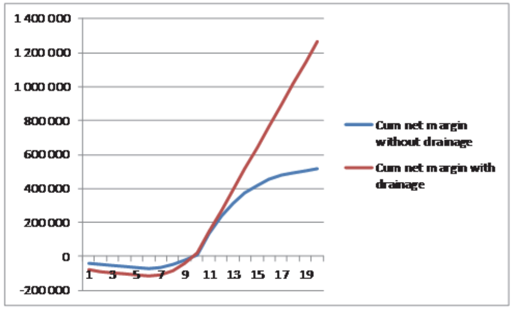
Crop Enterprise budgets – Vaalharts case study

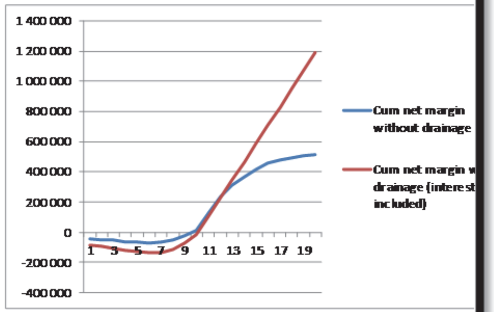
Summary crop budgets - Permanent crops																				
Pecan nuts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Yield t/ha (Without drainage)	0	0	0	0	0	0	1	1	1	3	3	2	2	2	1	1	1	1	1	0
Yield t/ha (With drainage)	0	0	0	0	0	1	1	2	2	4	4	4	4	4	4	4	4	4	4	4
Additional drainage cost	39 560	2 060	2 060	2 060	2 060	2060	2 060	2060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060
Cumulative net margin / ha (without drainage	-47 984	-53 886	-61 078	-64 250	-69 723	-64 143	-48 690	-23 110	9 342	129 404	236 146	314 735	370 933	417 915	455 177	480 702	494 060	505 186	516 312	515 341
Cumulative net margin / ha (with drainage)	-87 544	-95 506	-104 758	-109 190	-115 923	-108 403	-83 010	-39 490	22 902	145 656	269 922	394 187	518 453	642 719	766 985	891 250	1 015 516	1 139 782	1 264 048	1 388 313
Lucerne Sprinkle	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Yield t/ha (Without drainage)	18	15	12	13	12	13	12	10	11	12	10	10	10	10	12	10	10	10	11	11
Yield t/ha (With drainage)	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Additional drainage cost	39 560	2 060	2 060	2 060	2 060	2060	2 060	2060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060
Cumulative net margin / ha (without drainage	10 919	18 301	20 878	24 989	28 333	32 538	36054	36 409	36295	39 341	39 289	39 879	40 625	41 121	43 526	43 631	41 466	41 461	42 317	43 283
Cumulative net margin / ha (with drainage)	-26 466	-13 570	-251	12 990	26 262	39 566	52838	66 110	77128	90 463	103 782	117 038	130 373	143 629	156 948	170 236	181 286	194 620	207 955	221 258
Lucerne flood	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Yield t/ha (Without drainage)	14	11	9	9	9	9	9	8	9	9	7	8	8	8	9	8	8	7	8	8
Yield t/ha (With drainage)	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Additional drainage cost	39 560	2 060	2 060	2 060	2 060	2060	2 060	2060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060
Cumulative net margin / ha (without drainage	3 716	5 350	3 381	2 562	1 168	420	-845	-4 480	-9 040	-10 656	-16 882	-20 342	-25 969	-29500	-33 883	-37706	-43 803	-47 709	-53 254	-56 432
Cumulative net margin / ha (with drainage)	-26 153	-28 957	-23 385	-17 872	-12 335	-6 774	-1 237	4300	7 576	13 160	16 447	21 972	25 271	30 796	34 084	39 632	42 931	48 515	51 814	57375

Summary crop budgets - Cash crops																				
Maize	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Yield t/ha (Without drainage)	14	13	12	10	8	6	5	4	4	3	2	2	2	2	2	2	1	1	0	0
Yield t/ha (With drainage)	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Additional drainage cost	39 560	2 060	2 060	2 060	2 060	2060	2 060	2060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060	2 060
Cumulative net margin / ha (without drainage	18 545	36 198	49 574	57 617	62 421	60 527	55448	49 187	41 360	32 641	21 902	10 435	-1032	-12 499	-23 966	-35 433	-48 720	-63 354	-79 098	-96 025
Cumulative net margin / ha (with drainage)	-20 506	-3 093	14 320	31 733	49 146	66 559	83972	101 385	118 798	136 211	153 624	171 037	188 450	205 863	223 276	240 689	258 102	275 515	292 928	310 341
Barley	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Yield t/ha (Without drainage)	8	8	8	8	8	8	7	7	7	7	7	7	7	6	6	6	5	5	4	4
Yield t/ha (With drainage)	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Additional drainage cost	37 500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumulative net margin / ha (without drainage	942	20 270	29 912	39 554	49 196	58 838	67320	75 802	84284	92 766	101 248	109730	116 402	120639	124 481	128 323	131 005	131 703	132 065	131 441
Cumulative net margin / ha (with drainage)	-28 758	-20 016	-11274	-2 532	6 210	14 952	23694	32 436	41178	49 920	58 662	67 404	76 146	84 888	93 630	102 372	111 114	119 856	128 598	137 340

Pecan nuts																				
Yield	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Without drainage	0	0	0	0	0	0	1	1	1	3	3	2	2	2	1	1	1	1	1	0
With drainage	0	0	0	0	0	1	1	2	2	4	4	4	4	4	4	4	4	4	4	4
Cum net margin without	-42 082	-47 984	-53 886	-61 078	-64 250	-69 723	-64 143	-48 690	-23 110	9 342	129 404	236 146	314 735	370 933	417 915	455 177	480 702	494 060	505 186	516 312
Cum net margin with drai	-79 582	-87 544	-95 506	-104 758	-109 190	-115 923	-108 403	-83 010	-39 490	22 902	145 656	269 922	394 187	518 453	642 719	766 985	891 250	1 015 516	1 139 782	1 264 048







Cost Benefit analysis	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Net annual benefit	910 472	-2 060	-2 060	-2 060	-1 260	-1 260	1 940	9 940	17 940	29 940	2 692	17 524	45 676	68 068	77 284	87 004	98 740	110 908	113 140	113 140	125 236
Annual costs	108 750	5 438	5 438	5 438	5 438	5 438	5 438	5 438	5 438	5 438	5 438	5 438	5 438	5 438	5 438	5 438	5 438	5 438	5 438	5 438	5 438
Maintenance cost	*41 200*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*
Depreciation	*37500*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*
Interest	*71250*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*
Net incremental cash flow per ha		-39 560	-2 060	-2 060	-1 260	-1 260	1 940	9 940	17 940	29 940	2 692	17 524	45 676	68 068	77 284	87 004	98 740	110 908	113 140	113 140	125 236

Discounted Cost Benefit Analysis

Discount rate = 4%

Item	Total
Net annual benefit	487 314
Annual costs	73 897

Pecan nuts *(Per hectare drainage installation analysis)*

Benefit-Cost Ratio	6.6 : 1
Rate of return	55.1%
Payback period (average)	0.9 years
Internal Rate of Return (IRR)	25.1%
Net Present Value (NPV)	451 256

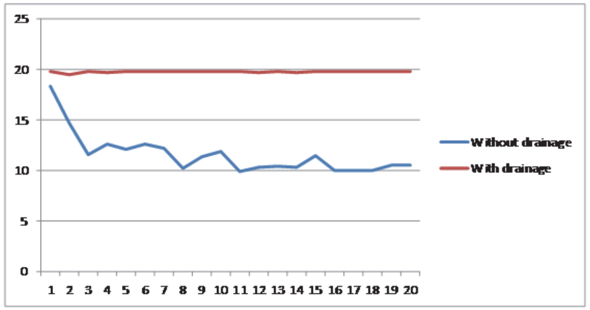
Cum net margin (Interest included)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cum interest	3 563	7 125	10 688	14 250	17 813	21 375	24 938	28 500	32 063	35 625	39 188	42 750	46 313	49 875	53 438	57 000	60 563	64 125	67 688	71 250
Cum net margin without drainage	-42 082	-47 984	-53 886	-61 078	-64 250	-69 723	-64 143	-48 690	-23 110	9 342	129 404	236 146	314 735	370 933	417 915	455 177	480 702	494 060	505 186	516 312
Cum net margin with drainage (intere	-83 145	-94 669	-106 194	-119 008	-127 003	-137 298	-133 341	-111 510	-71 553	-12 723	106 468	227 172	347 875	468 578	589 281	709 985	830 688	951 391	1 072 094	1 192 798

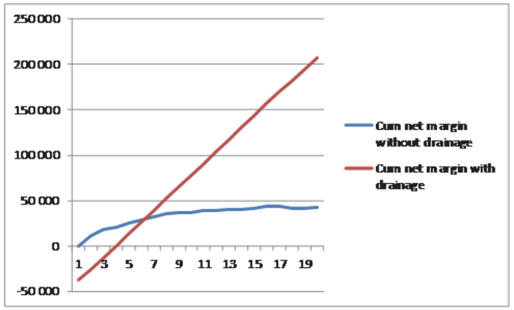
Lucerne Sprinkle

Yield	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Without drainage	18	15	12	13	12	13	12	10	11	12	10	10	10	10	12	10	10	10	11	11
With drainage	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Cum net margin without	0	10 919	18 301	20 878	24 989	28 333	32 538	36 054	36 409	36 295	39 341	39 289	39 879	40 625	41 121	43 526	43 631	41 466	41 461	42 317
Cum net margin with drai	-37 500	-26 466	-13 570	-251	12 990	26 262	39 566	52 838	66 110	77 128	90 463	103 782	117 038	130 373	143 629	156 948	170 236	181 286	194 620	207 955

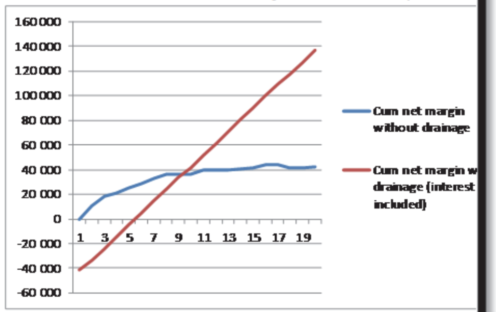
Yield Curve for Lucerne Sprinkle



Cumulative net margin for Lucerne Sprinkle



Cumulative net margin for Lucerne Sprinkle



Cost Benefit analysis	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Net annual benefit	215 476	115	5 515	10 742	9 130	9 928	9 098	9 756	12 917	11 133	10 288	13 371	12 667	12 588	12 761	10 914	13 183	13 214	13 340	12 479	12 338
Annual costs	149 950	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498
Maintenance cost	*41 200*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*
Depreciation	*37500*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*
Interest	*71250*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*
Net incremental cash flow per ha		-37 385	5 515	10 742	9 130	9 928	9 098	9 756	12 917	11 133	10 288	13 371	12 667	12 588	12 761	10 914	13 183	13 214	13 340	12 479	12 338

Discounted Cost Benefit Analysis

Item	Total
Net annual benefit	139 085
Annual costs	101 893

Discount rate = *4%*

Lucerne Sprinkle *(Per hectare drainage installation analysis)*

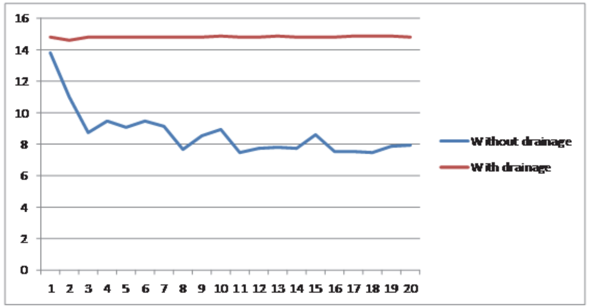
Benefit-Cost Ratio	1.4 : 1
Rate of return	5.0%
Payback period (average)	11.4 years
Internal Rate of Return (IRR)	25.2%
Net Present Value (NPV)	103 027

Cum net margin (Interest included)

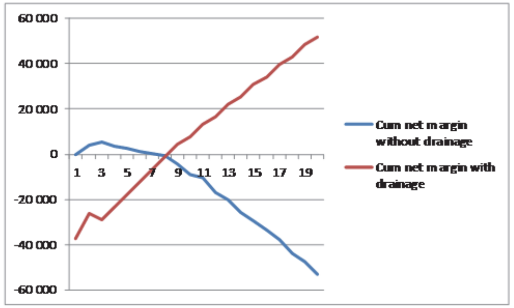
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cum interest	3 563	7 125	10 688	14 250	17 813	21 375	24 938	28 500	32 063	35 625	39 188	42 750	46 313	49 875	53 438	57 000	60 563	64 125	67 688	71 250
Cum net margin without drainage	0	10 919	18 301	20 878	24 989	28 333	32 538	36 054	36 409	36 295	39 341	39 289	39 879	40 625	41 121	43 526	43 631	41 466	41 461	42 317
Cum net margin with drainage (intere	-41 063	-33 591	-24 257	-14 501	-4 822	4 887	14 628	24 338	34 047	41 503	51 275	61 032	70 726	80 498	90 192	99 948	109 673	117 161	126 933	136 705

Lucerne flood																				
Yield	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Without drainage	14	11	9	9	9	9	9	8	9	9	7	8	8	8	9	8	8	7	8	8
With drainage	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Cum net margin without	0	3 716	5 350	3 381	2 562	1 168	420	-845	-4 480	-9 040	-10 656	-16 882	-20 342	-25 969	-29 500	-33 883	-37 706	-43 803	-47 709	-53 254
Cum net margin with drai	-37 500	-26 153	-28 957	-23 385	-17 872	-12 335	-6 774	-1 237	4 300	7 576	13 160	16 447	21 972	25 271	30 796	34 084	39 632	42 931	48 515	51 814

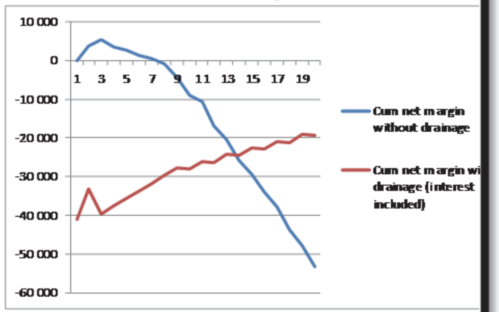
Yield Curve for Lucerne flood



Cumulative net margin for Lucerne flood



Cumulative net margin for Lucerne flood



Cost Benefit analysis	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Net annual benefit	159 366	7 631	3 621	7 541	6 332	6 931	6 309	6 802	9 173	7 835	7 201	9 513	8 985	8 926	9 055	7 670	9 372	9 396	9 490	8 844	8 739
Annual costs	149 950	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498
Maintenance cost	*41 200*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*
Depreciation	*37500*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*
Interest	*71250*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*
Net incremental cash flow per ha		-29 869	3 621	7 541	6 332	6 931	6 309	6 802	9 173	7 835	7 201	9 513	8 985	8 926	9 055	7 670	9 372	9 396	9 490	8 844	8 739

Discounted Cost Benefit Analysis

Item	Total
Net annual benefit	105 064
Annual costs	101 893

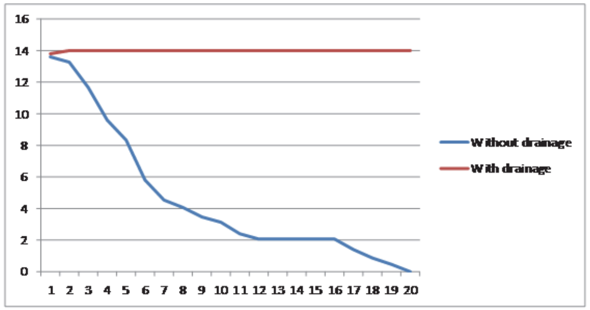
Discount rate = *4%*

Lucerne flood	*(Per hectare drainage installation analysis)*
Benefit-Cost Ratio	1.0 : 1
Rate of return	0.4%
Payback period (average)	79.6 years
Internal Rate of Return (IRR)	22.1%
Net Present Value (NPV)	69 007

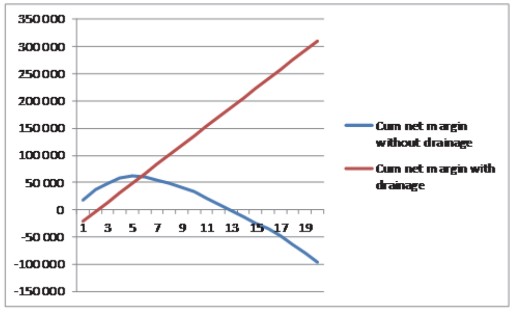
Cum net margin (Interest included)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cum interest	3 563	7 125	10 688	14 250	17 813	21 375	24 938	28 500	32 063	35 625	39 188	42 750	46 313	49 875	53 438	57 000	60 563	64 125	67 688	71 250
Cum net margin without drainage	0	3 716	5 350	3 381	2 562	1 168	420	-845	-4 480	-9 040	-10 656	-16 882	-20 342	-25 969	-29 500	-33 883	-37 706	-43 803	-47 709	-53 254
Cum net margin with drainage (intere	-41 063	-33 278	-39 645	-37 635	-35 684	-33 710	-31 712	-29 737	-27 762	-28 049	-26 028	-26 303	-24 340	-24 604	-22 641	-22 916	-20 930	-21 194	-19 172	-19 436

Maize																				
Yield	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Without drainage	14	13	12	10	8	6	5	4	4	3	2	2	2	2	2	2	1	1	0	0
With drainage	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Cum net margin without	18 545	36 198	49 574	57 617	62 421	60 527	55 448	49 187	41 360	32 641	21 902	10 435	-1 032	-12 499	-23 966	-35 433	-48 720	-63 354	-79 098	-96 025
Cum net margin with drai	-20 506	-3 093	14 320	31 733	49 146	66 559	83 972	101 385	118 798	136 211	153 624	171 037	188 450	205 863	223 276	240 689	258 102	275 515	292 928	310 341

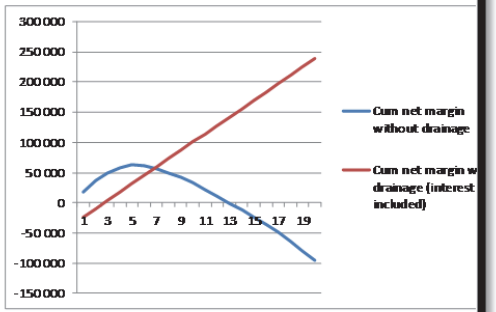
Yield Curve for Maize



Cumulative net margin for Maize



Cumulative net margin for Maize



Cost Benefit analysis	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Net annual benefit	443 866	-1 550	-240	4 037	9 370	12 609	19 307	22 492	23 675	25 240	26 132	28 152	28 880	28 880	28 880	28 880	28 880	30 700	32 047	33 157	34 340
Annual costs	149 950	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498
Maintenance cost	*41 200*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*
Depreciation	*37500*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*
Interest	*71250*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*
Net incremental cash flow per ha		-39 050	-240	4 037	9 370	12 609	19 307	22 492	23 675	25 240	26 132	28 152	28 880	28 880	28 880	28 880	28 880	30 700	32 047	33 157	34 340

Discounted Cost Benefit Analysis

Item	Total
Net annual benefit	270 078
Annual costs	101 893

Discount rate = *4%*

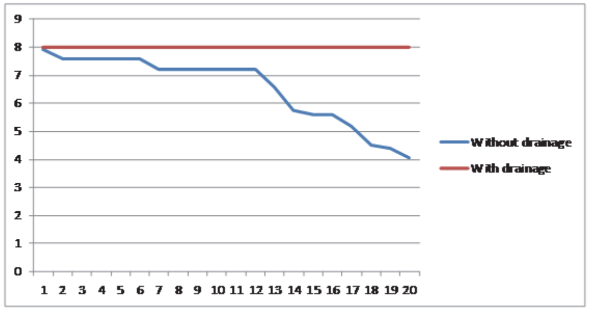
Maize	*(Per hectare drainage installation analysis)*
Benefit-Cost Ratio	2.7 : 0
Rate of return	22.4%
Payback period	2.6 years
Internal Rate of Return (IRR)	29.8%
Net Present Value (NPV)	234 020

Cum net margin (Interest included)

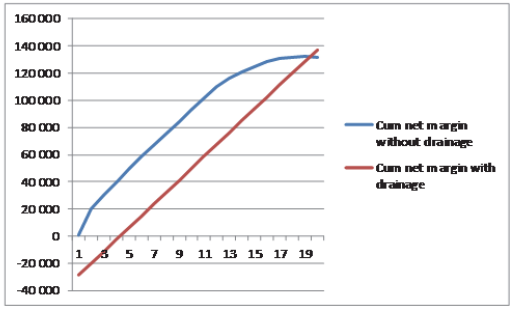
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cum interest	3 563	7 125	10 688	14 250	17 813	21 375	24 938	28 500	32 063	35 625	39 188	42 750	46 313	49 875	53 438	57 000	60 563	64 125	67 688	71 250
Cum net margin without drainage	18 545	36 198	49 574	57 617	62 421	60 527	55 448	49 187	41 360	32 641	21 902	10 435	-1 032	-12 499	-23 966	-35 433	-48 720	-63 354	-79 098	-96 025
Cum net margin with drainage (intere	-24 068	-10 218	3 633	17 483	31 334	45 184	59 035	72 885	86 736	100 586	114 437	128 287	142 138	155 988	169 839	183 689	197 540	211 390	225 241	239 091

Barley																				
Yield	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Without drainage	8	8	8	8	8	8	7	7	7	7	7	7	7	6	6	6	5	5	4	4
With drainage	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Cum net margin without	942	20 270	29 912	39 554	49 196	58 838	67 320	75 802	84 284	92 766	101 248	109 730	116 402	120 639	124 481	128 323	131 005	131 703	132 065	131 441
Cum net margin with drai	-28 758	-20 016	-11 274	-2 532	6 210	14 952	23 694	32 436	41 178	49 920	58 662	67 404	76 146	84 888	93 630	102 372	111 114	119 856	128 598	137 340

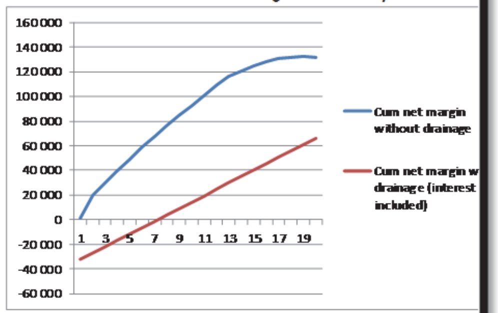
Yield Curve for Barley



Cumulative net margin for Barley



Cumulative net margin for Barley



Cost Benefit analysis	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Net annual benefit	43 399	-1 886	-900	-900	-900	-900	-900	260	260	260	260	260	260	2 070	4 506	4 900	4 900	6 060	8 044	8 380	9 366
Annual costs	149 950	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498	7 498
Maintenance cost	*41 200*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*	*2 060*
Depreciation	*37500*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*	*1875*
Interest	*71250*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*	*3562.5*
Net incremental cash flow per ha		-39 386	-900	-900	-900	-900	-900	260	260	260	260	260	260	2 070	4 506	4 900	4 900	6 060	8 044	8 380	9 366

Discounted Cost Benefit Analysis

Item	Total
Net annual benefit	19 927
Annual costs	101 893

Discount rate = *4%*

Barley	*(Per hectare drainage installation analysis)*
Benefit-Cost Ratio	0.2 : 0
Rate of return	-10.9%
Payback period	-7.0 years
Internal Rate of Return (IRR)	0.8%
Net Present Value (NPV)	-16 131

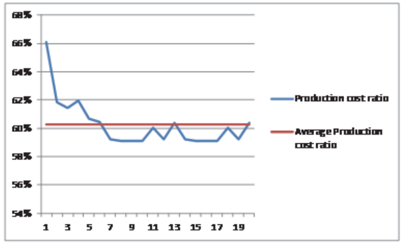
Cum net margin (Interest included)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cum interest	3 563	7 125	10 688	14 250	17 813	21 375	24 938	28 500	32 063	35 625	39 188	42 750	46 313	49 875	53 438	57 000	60 563	64 125	67 688	71 250
Cum net margin without drainage	942	20 270	29 912	39 554	49 196	58 838	67 320	75 802	84 284	92 766	101 248	109 730	116 402	120 639	124 481	128 323	131 005	131 703	132 065	131 441
Cum net margin with drainage (intere	-32 321	-27 141	-21 962	-16 782	-11 603	-6 423	-1 244	3 936	9 116	14 295	19 475	24 654	29 834	35 013	40 193	45 372	50 552	55 731	60 911	66 090

Summarised financial analyses for different scenarios – Vaalharts case study

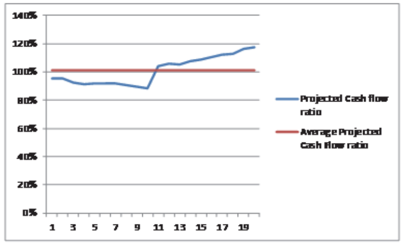
Scenario 4 — With drainage - 35% debt ratio

Production cost ratio



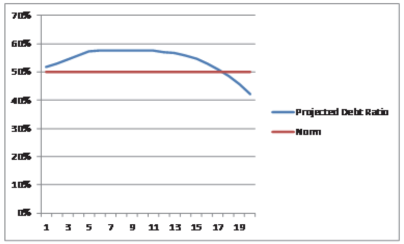
20-year average production cost ratio 60%

Projected cash flow ratio



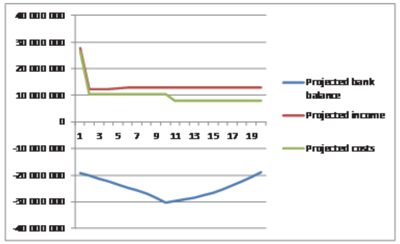
20-year average cash flow ratio 101%

Projected Debt ratio



Highest debt ratio 58%

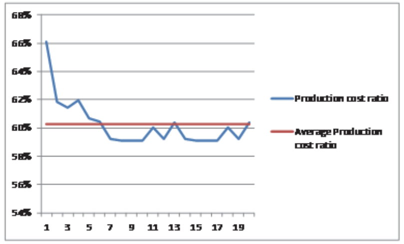
Projected income, cost & bank balance



End bank balance -18 765 206

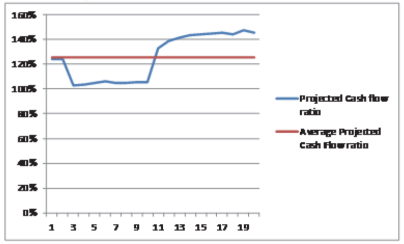
Scenario 5 — With drainage - 35% debt ratio - 50% subsidy

Production cost ratio



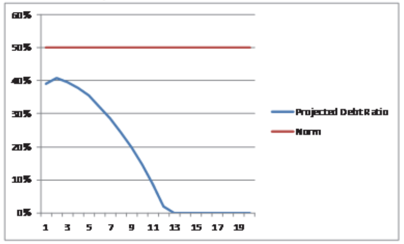
20-year average production cost ratio 60%

Projected cash flow ratio



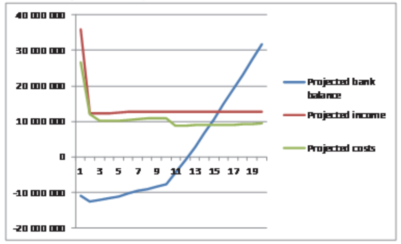
20-year average cash flow ratio 126%

Projected Debt ratio



Highest debt ratio 41%

Projected income, cost & bank balance



End bank balance 31 663 823

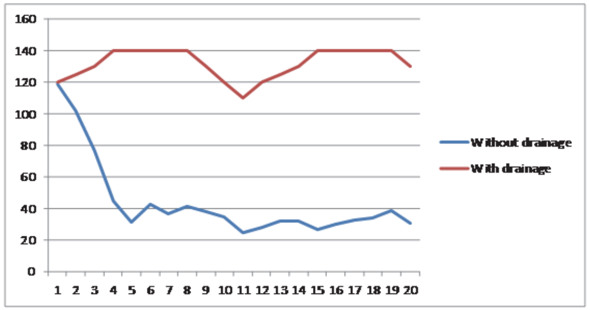
APPENDIX H: PONGOLA CASE STUDY

Crop enterprise budget – Pongola case study

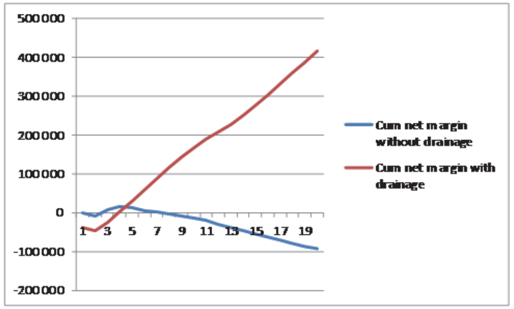
Sugarcane	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Yield t/ha (Without drainage)	119	102	77	45	32	43	37	41	38	35	25	28	32	32	27	30	33	34	39	31
Yield t/ha (With drainage)	120	125	130	140	140	140	140	140	130	120	110	120	125	130	140	140	140	140	140	130
Additional drainage cost	39 359	1 601	1 283	1 493	2 230	1 913	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649
Cumulative net margin / ha (without drainage	-8 327	8 679	16 766	13 690	6 007	2 291	-3 667	-7 974	-13 465	-20 064	-30 285	-39 150	-46 710	-54 369	-63 703	-71 854	-79 241	-86 136	-91 256	-99 334
Cumulative net margin / ha (with drainage)	-47 334	-23 780	1 852	30 794	58 999	87 521	115 834	143 620	168 413	189 686	206 912	228 185	251 218	275 484	303 797	332 110	359 896	388 209	416 522	440 788

Sugarcane																				
Yield	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Without drainage	119	102	77	45	32	43	37	41	38	35	25	28	32	32	27	30	33	34	39	31
With drainage	120	125	130	140	140	140	140	140	130	120	110	120	125	130	140	140	140	140	140	130
Cum net margin without	0	-8 327	8 679	16 766	13 690	6 007	2 291	-3 667	-7 974	-13 465	-20 064	-30 285	-39 150	-46 710	-54 369	-63 703	-71 854	-79 241	-86 136	-91 256
Cum net margin with drai	-38 390	-47 334	-23 780	1 852	30 794	58 999	87 521	115 834	143 620	168 413	189 686	206 912	228 185	251 218	275 484	303 797	332 110	359 896	388 209	416 522

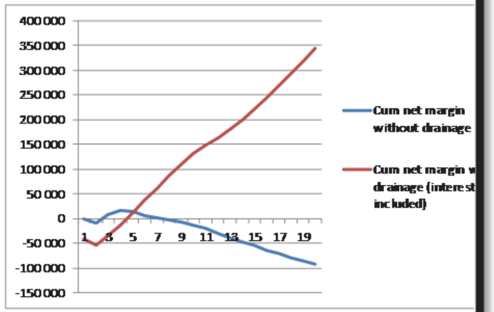
Yield Curve for Sugarcane



Cumulative net margin for Sugarcane



Cumulative net margin for Sugarcane



Cost Benefit analysis	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Net annual benefit	578 512	-617	6 548	17 545	32 017	35 888	32 238	34 271	32 093	30 283	27 872	27 447	30 139	30 593	31 924	37 647	36 464	35 173	35 208	33 434	32 343
Annual costs	111 331	5 567	5 567	5 567	5 567	5 567	5 567	5 567	5 567	5 567	5 567	5 567	5 567	5 567	5 567	5 567	5 567	5 567	5 567	5 567	5 567
Maintenance cost	*41 832*	*969*	*1 601*	*1 283*	*1 493*	*2 230*	*1 913*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*
Depreciation	*38390*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*	*1919.5*
Interest	*72941*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*	*3647.05*
Net incremental cash flow per ha		-39 007	6 548	17 545	32 017	35 888	32 238	34 271	32 093	30 283	27 872	27 447	30 139	30 593	31 924	37 647	36 464	35 173	35 208	33 434	32 343

Discounted Cost Benefit Analysis

Item	Total
Net annual benefit	372 904
Annual costs	75 651

Discount rate = 4%

Sugarcane *(Per hectare drainage installation analysis)*

Benefit-Cost Ratio	4.9 : 1
Rate of return	38.7%
Payback period (average)	1.6 years
Internal Rate of Return (IRR)	52.2%
Net Present Value (NPV)	335 990

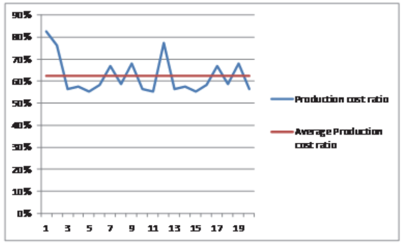
Cum net margin (Interest included)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cum interest	3 647	7 294	10 941	14 588	18 235	21 882	25 529	29 176	32 823	36 471	40 118	43 765	47 412	51 059	54 706	58 353	62 000	65 647	69 294	72 941
Cum net margin without drainage	0	-8 327	8 679	16 766	13 690	6 007	2 291	-3 667	-7 974	-13 465	-20 064	-30 285	-39 150	-46 710	-54 369	-63 703	-71 854	-79 241	-86 136	-91 256
Cum net margin with drainage (intere	-42 037	-54 628	-34 721	-12 736	12 559	37 117	61 992	86 658	110 797	131 943	149 568	163 147	180 773	200 159	220 778	245 444	270 110	294 249	318 915	343 581

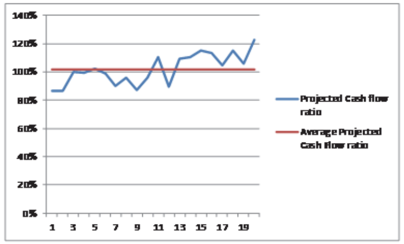
Summarised financial analysis of drainage scenarios for Pongola case study

Scenario	4	With drainage - 30% Debt ratio

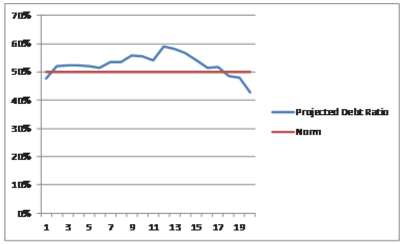
Production cost ratio



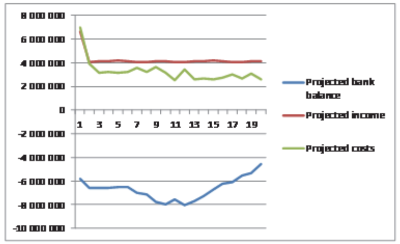
Projected cash flow ratio



Projected Debt ratio



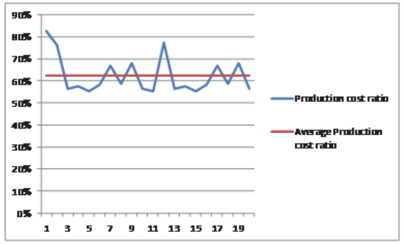
Projected income, cost & bank balance



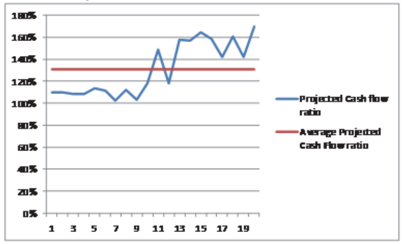
20-year average production cost ratio	62%	20-year average cash flow ratio	102%	Highest debt ratio	59%	End bank balance	-4 533 908

Scenario	5	With drainage - 30% Debt ratio - 50% subsidy

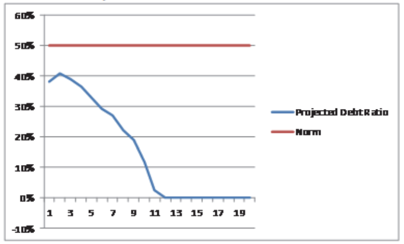
Production cost ratio



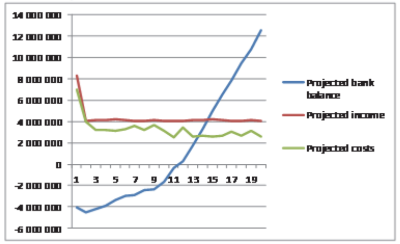
Projected cash flow ratio



Projected Debt ratio



Projected income, cost & bank balance



20-year average production cost ratio	62%	20-year average cash flow ratio	131%	Highest debt ratio	41%	End bank balance	12 568 586

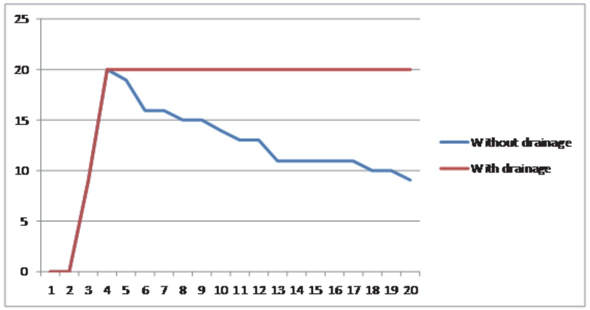
APPENDIX I: BREEDE RIVER CASE STUDY

Crop enterprise budgets – Breede River case study

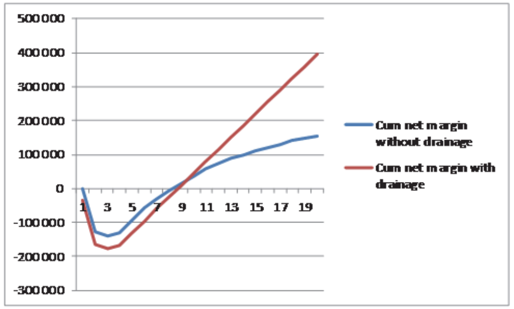
Summary crop budgets - Permanent crops																				
Wine grapes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Yield t/ha (Without drainage)	0	0	9	20	19	16	16	15	15	14	13	13	11	11	11	11	11	10	10	9
Yield t/ha (With drainage)	0	0	9	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Additional drainage cost	34 302	1 601	1 283	1 493	2 230	1 913	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649
Cumulative net margin / ha (without drainage	-129 078	-140 426	-131 582	-92 007	-57 762	-32 457	-7 152	15 153	37 458	56 763	73 068	89 373	99 678	109 983	120 288	130 593	140 898	148 203	155 508	160 023
Cumulative net margin / ha (with drainage)	-163 380	-176 329	-168 768	-130 686	-95 611	-60 219	-25 036	9 620	44 803	79 986	114 642	149 825	185 008	219 664	254 847	290 030	324 686	359 869	395 052	429 708
Plums	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Yield t/ha (Without drainage)	0	5	10	15	18	21	25	22	17	19	18	18	13	14	16	12	10	8	10	10
Yield t/ha (With drainage)	0	5	10	15	18	21	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Additional drainage cost	34 302	1 601	1 283	1 493	2 230	1 913	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649
Cumulative net margin / ha (without drainage	-188 309	-183 904	-134 499	-73 906	-23 516	16 670	55 653	71 236	38 107	21 290	-3 177	-30 007	-96 999	-159 941	-201 620	-278 287	-374 979	-490 459	-587 376	-687 330
Cumulative net margin / ha (with drainage)	-222 611	-219 807	-171 685	-112 585	-64 425	-26 152	10 709	47 043	83 904	120 765	157 099	193 960	230 821	267 155	304 016	340 877	377 211	414 072	450 933	487 267
Nectarine	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Yield t/ha (Without drainage)	0	0	4	8	12	18	21	25	23	20	19	18	18	15	14	11	10	10	9	7
Yield t/ha (With drainage)	0	0	5	8	12	18	21	25	25	25	25	25	25	25	25	25	25	25	25	25
Additional drainage cost	34 302	1 601	1 283	1 493	2 230	1 913	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649
Cumulative net margin / ha (without drainage	-150 498	-188 443	-188 932	-174 020	-131 455	-67 608	-10 570	49 022	88 013	103 477	104 544	93 906	83 268	50 508	4 052	-67 686	-148 554	-229 422	-323 634	-428 614
Cumulative net margin / ha (with drainage)	-184 800	-224 346	-216 754	-203 335	-163 000	-101 066	-46 150	10 793	68 263	125 733	182 676	240 146	297 616	354 559	412 029	469 499	526 442	583 912	641 382	698 325
Peaches	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Yield t/ha (Without drainage)	0	0	4	8	12	18	21	25	23	20	19	18	18	15	14	11	10	10	9	7
Yield t/ha (With drainage)	0	0	5	8	12	18	21	25	25	25	25	25	25	25	25	25	25	25	25	25
Additional drainage cost	34 302	1 601	1 283	1 493	2 230	1 913	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649	2 122	2 122	2 649
Cumulative net margin / ha (without drainage	-150 498	-188 443	-187 188	-168 788	-120 991	-49 296	16 898	87 390	136 322	160 631	169 873	166 865	163 857	137 697	97 204	30 251	-46 257	-122 765	-213 238	-314 981
Cumulative net margin / ha (with drainage)	-184 800	-224 346	-214 574	-197 667	-152 100	-82 318	-18 246	49 597	117 967	186 337	254 180	322 550	390 920	458 763	527 133	595 503	663 346	731 716	800 086	867 929

Wine grapes																				
Yield	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Without drainage	0	0	9	20	19	16	16	15	15	14	13	13	11	11	11	11	11	10	10	9
With drainage	0	0	9	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Cum net margin without	0	-129 078	-140 426	-131 582	-92 007	-57 762	-32 457	-7 152	15 153	37 458	56 763	73 068	89 373	99 678	109 983	120 288	130 593	140 898	148 203	155 508
Cum net margin with drai	-33 333	-163 380	-176 329	-168 768	-130 686	-95 611	-60 219	-25 036	9 620	44 803	79 986	114 642	149 825	185 008	219 664	254 847	290 030	324 686	359 869	395 052

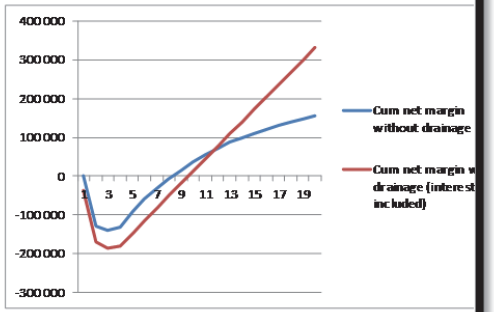
Yield Curve for Wine grapes



Cumulative net margin for Wine grapes



Cumulative net margin for Wine grapes



Cost Benefit analysis	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Net annual benefit	303 018	-969	-1 601	-1 283	-1 493	830	10 087	9 878	12 351	12 878	15 878	18 351	18 878	24 878	24 351	24 878	24 878	24 351	27 878	27 878	30 141
Annual costs	96 666	4 833	4 833	4 833	4 833	4 833	4 833	4 833	4 833	4 833	4 833	4 833	4 833	4 833	4 833	4 833	4 833	4 833	4 833	4 833	4 833
Maintenance cost	*41 832*	*969*	*1 601*	*1 283*	*1 493*	*2 230*	*1 913*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*
Depreciation	*33333*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*
Interest	*63332.7*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*
Net incremental cash flow per ha		-34 302	-1 601	-1 283	-1 493	830	10 087	9 878	12 351	12 878	15 878	18 351	18 878	24 878	24 351	24 878	24 878	24 351	27 878	27 878	30 141

Discounted Cost Benefit Analysis

Item	Total
Net annual benefit	173 193
Annual costs	65 686

Discount rate = *4%*

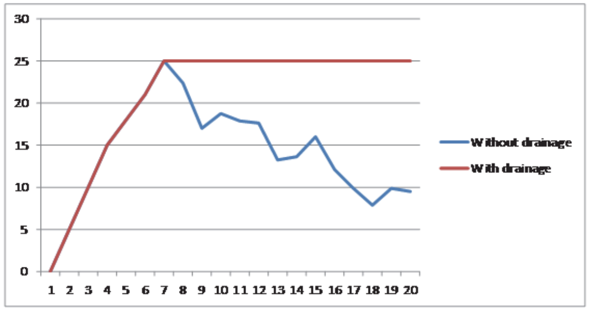
Wine grapes	*(Per hectare drainage installation analysis)*
Benefit-Cost Ratio	2.6 : 1
Rate of return	16.1%
Payback period (average)	3.2 years
Internal Rate of Return (IRR)	19.5%
Net Present Value (NPV)	141 142

Cum net margin (Interest included)

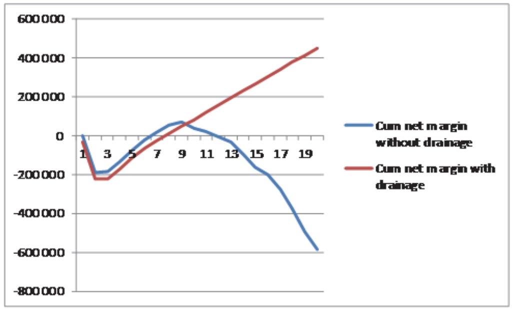
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cum interest	3 167	6 333	9 500	12 667	15 833	19 000	22 166	25 333	28 500	31 666	34 833	38 000	41 166	44 333	47 500	50 666	53 833	56 999	60 166	63 333
Cum net margin without drainage	0	-129 078	-140 426	-131 582	-92 007	-57 762	-32 457	-7 152	15 153	37 458	56 763	73 068	89 373	99 678	109 983	120 288	130 593	140 898	148 203	155 508
Cum net margin with drainage (intere	-36 500	-169 713	-185 828	-181 434	-146 519	-114 611	-82 385	-50 369	-18 880	13 137	45 153	76 642	108 659	140 675	172 164	204 181	236 197	267 687	299 703	331 719

Plums																				
Yield	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Without drainage	0	5	10	15	18	21	25	22	17	19	18	18	13	14	16	12	10	8	10	10
With drainage	0	5	10	15	18	21	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Cum net margin without	0	-188 309	-183 904	-134 499	-73 906	-23 516	16 670	55 653	71 236	38 107	21 290	-3 177	-30 007	-96 999	-159 941	-201 620	-278 287	-374 979	-490 459	-587 376
Cum net margin with drai	-33 333	-222 611	-219 807	-171 685	-112 585	-64 425	-26 152	10 709	47 043	83 904	120 765	157 099	193 960	230 821	267 155	304 016	340 877	377 211	414 072	450 933

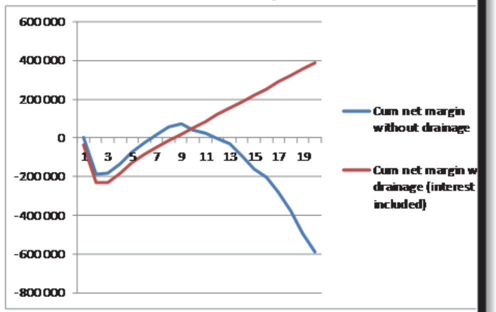
Yield Curve for Plums



Cumulative net margin for Plums



Cumulative net margin for Plums



Cost Benefit analysis	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Net annual benefit	1 207 931	-969	-1 601	-1 283	-1 493	-2 230	-1 913	-2 122	20 751	69 991	53 678	60 801	63 691	103 853	99 276	78 541	113 528	133 026	152 341	133 778	136 289
Annual costs	138 498	5 802	6 434	6 116	6 326	7 063	6 746	6 955	7 482	6 955	6 955	7 482	6 955	6 955	7 482	6 955	6 955	7 482	6 955	6 955	7 482
Maintenance cost	*41 832*	*969*	*1 601*	*1 283*	*1 493*	*2 230*	*1 913*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*
Depreciation	*33333*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*
Interest	*63332.7*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*
Net incremental cash flow per ha		-34 302	-1 601	-1 283	-1 493	-2 230	-1 913	-2 122	20 751	69 991	53 678	60 801	63 691	103 853	99 276	78 541	113 528	133 026	152 341	133 778	136 289

Discounted Cost Benefit Analysis

Item	Total
Net annual benefit	663 204
Annual costs	93 117

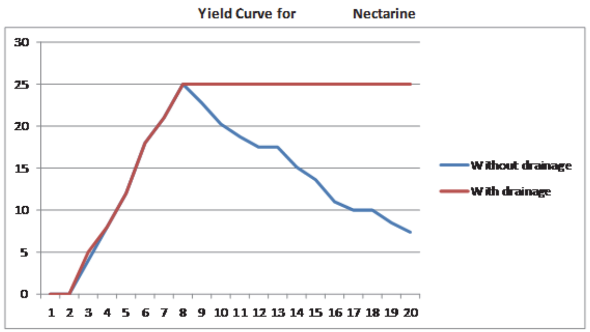
Discount rate = *4%*

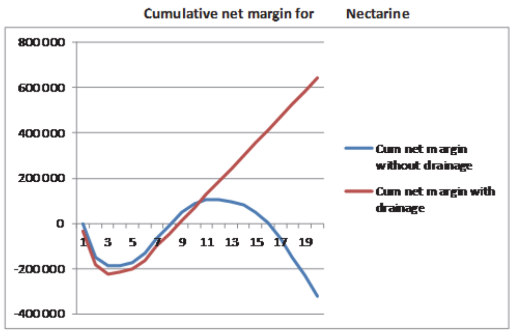
Plums	*(Per hectare drainage installation analysis)*
Benefit-Cost Ratio	7.1 : 1
Rate of return	85.5%
Payback period (average)	0.6 years
Internal Rate of Return (IRR)	31.2%
Net Present Value (NPV)	631 153

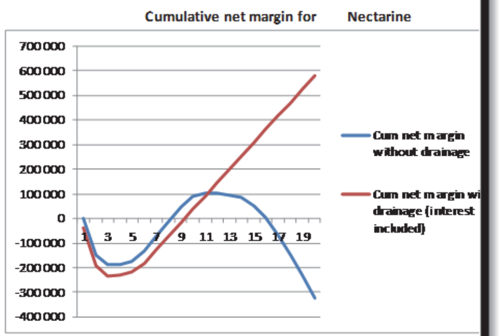
Cum net margin (Interest included)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cum interest	3 167	6 333	9 500	12 667	15 833	19 000	22 166	25 333	28 500	31 666	34 833	38 000	41 166	44 333	47 500	50 666	53 833	56 999	60 166	63 333
Cum net margin without drainage	0	-188 309	-183 904	-134 499	-73 906	-23 516	16 670	55 653	71 236	38 107	21 290	-3 177	-30 007	-96 999	-159 941	-201 620	-278 287	-374 979	-490 459	-587 376
Cum net margin with drainage (intere	-36 500	-228 944	-229 307	-184 352	-128 418	-83 425	-48 318	-14 624	18 544	52 238	85 932	119 100	152 794	186 489	219 656	253 350	287 045	320 212	353 906	387 601

Nectarine																				
Yield	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Without drainage	0	0	4	8	12	18	21	25	23	20	19	18	18	15	14	11	10	10	9	7
With drainage	0	0	5	8	12	18	21	25	25	25	25	25	25	25	25	25	25	25	25	25
Cum net margin without	0	-150 498	-188 443	-188 932	-174 020	-131 455	-67 608	-10 570	49 022	88 013	103 477	104 544	93 906	83 268	50 508	4 052	-67 686	-148 554	-229 422	-323 634
Cum net margin with drai	-33 333	-184 800	-224 346	-216 754	-203 335	-163 000	-101 066	-46 150	10 793	68 263	125 733	182 676	240 146	297 616	354 559	412 029	469 499	526 442	583 912	641 382







Cost Benefit analysis	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Net annual benefit	1 160 272	-969	-1 601	8 081	-1 493	-2 230	-1 913	-2 122	-2 649	18 479	42 006	55 876	68 108	68 108	89 703	103 925	129 208	137 811	138 338	151 682	161 923
Annual costs	138 498	5 802	6 434	6 116	6 326	7 063	6 746	6 955	7 482	6 955	6 955	7 482	6 955	6 955	7 482	6 955	6 955	7 482	6 955	6 955	7 482
Maintenance cost	*41 832*	*969*	*1 601*	*1 283*	*1 493*	*2 230*	*1 913*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*
Depreciation	*33333*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*
Interest	*63332.7*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*
Net incremental cash flow per ha		-34 302	-1 601	8 081	-1 493	-2 230	-1 913	-2 122	-2 649	18 479	42 006	55 876	68 108	68 108	89 703	103 925	129 208	137 811	138 338	151 682	161 923

Discounted Cost Benefit Analysis

Item	Total
Net annual benefit	621 127
Annual costs	93 117

Discount rate = *4%*

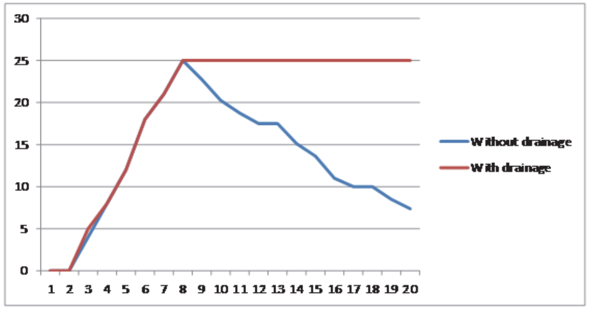
Nectarine	*(Per hectare drainage installation analysis)*
Benefit-Cost Ratio	6.7 : 1
Rate of return	79.2%
Payback period (average)	0.7 years
Internal Rate of Return (IRR)	29.2%
Net Present Value (NPV)	589 076

Cum net margin (Interest included)

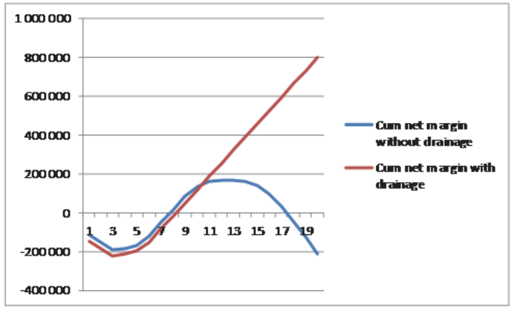
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cum interest	3 167	6 333	9 500	12 667	15 833	19 000	22 166	25 333	28 500	31 666	34 833	38 000	41 166	44 333	47 500	50 666	53 833	56 999	60 166	63 333
Cum net margin without drainage	0	-150 498	-188 443	-188 932	-174 020	-131 455	-67 608	-10 570	49 022	88 013	103 477	104 544	93 906	83 268	50 508	4 052	-67 686	-148 554	-229 422	-323 634
Cum net margin with drainage (intere	-36 500	-191 133	-233 846	-229 421	-219 168	-182 000	-123 232	-71 483	-17 707	36 596	90 900	144 676	198 979	253 283	307 059	361 362	415 666	469 442	523 746	578 049

Peaches																				
Yield	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Without drainage	0	0	4	8	12	18	21	25	23	20	19	18	18	15	14	11	10	10	9	7
With drainage	0	0	5	8	12	18	21	25	25	25	25	25	25	25	25	25	25	25	25	25
Cum net margin without	-112 553	-150 498	-188 443	-187 188	-168 788	-120 991	-49 296	16 898	87 390	136 322	160 631	169 873	166 865	163 857	137 697	97 204	30 251	-46 257	-122 765	-213 238
Cum net margin with drai	-145 886	-184 800	-224 346	-214 574	-197 667	-152 100	-82 318	-18 246	49 597	117 967	186 337	254 180	322 550	390 920	458 763	527 133	595 503	663 346	731 716	800 086

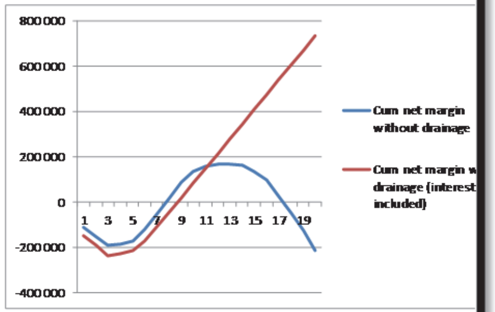
Yield Curve for Peaches



Cumulative net margin for Peaches



Cumulative net margin for Peaches



Cost Benefit analysis	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Net annual benefit	1 216 243	-969	-1 601	8 517	-1 493	-2 230	-1 913	-2 122	-2 649	19 438	44 061	58 601	71 378	71 378	94 004	108 863	135 323	144 351	144 878	158 843	169 586
Annual costs	138 498	5 802	6 434	6 116	6 326	7 063	6 746	6 955	7 482	6 955	6 955	7 482	6 955	6 955	7 482	6 955	6 955	7 482	6 955	6 955	7 482
Maintenance cost	*41 832*	*969*	*1 601*	*1 283*	*1 493*	*2 230*	*1 913*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*	*2 122*	*2 122*	*2 649*
Depreciation	*33333*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*	*1666.65*
Interest	*63332.7*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*	*3166.635*
Net incremental cash flow per ha		-34 302	-1 601	8 517	-1 493	-2 230	-1 913	-2 122	-2 649	19 438	44 061	58 601	71 378	71 378	94 004	108 863	135 323	144 351	144 878	158 843	169 586

Discounted Cost Benefit Analysis

Item	Total
Net annual benefit	651 324
Annual costs	93 117

Discount rate = *4%*

Peaches *(Per hectare drainage installation analysis)*

Benefit-Cost Ratio	7.0 : 1
Rate of return	83.7%
Payback period (average)	0.6 years
Internal Rate of Return (IRR)	29.8%
Net Present Value (NPV)	619 273

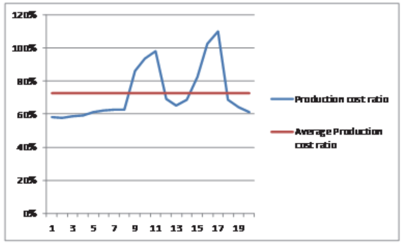
Cum net margin (Interest included)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cum interest	3 167	6 333	9 500	12 667	15 833	19 000	22 166	25 333	28 500	31 666	34 833	38 000	41 166	44 333	47 500	50 666	53 833	56 999	60 166	63 333
Cum net margin without drainage	-112 553	-150 498	-188 443	-187 188	-168 788	-120 991	-49 296	16 898	87 390	136 322	160 631	169 873	166 865	163 857	137 697	97 204	30 251	-46 257	-122 765	-213 238
Cum net margin with drainage (intere	-149 053	-191 133	-233 846	-227 241	-213 500	-171 100	-104 484	-43 579	21 097	86 300	151 504	216 180	281 383	346 587	411 263	476 466	541 670	606 346	671 550	736 753

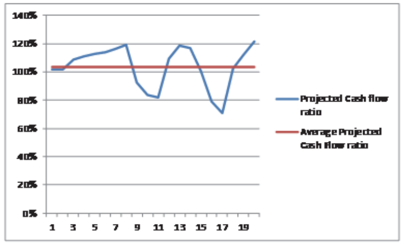
Summarised financial analysis for different drainage scenarios for Breede River case study

Scenario	4	With drainage - 25% debt ratio

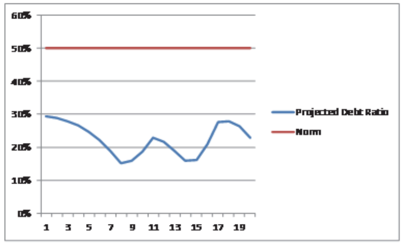
Production cost ratio



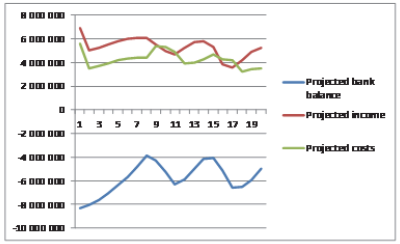
Projected cash flow ratio



Projected Debt ratio



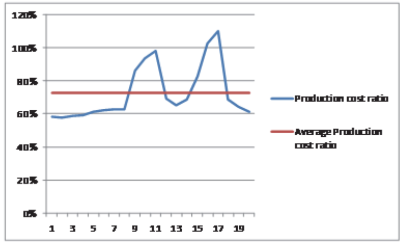
Projected income, cost & bank balance



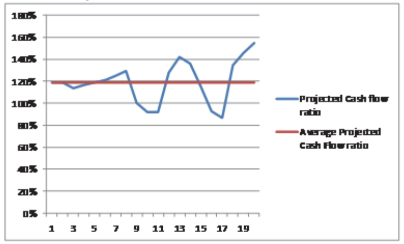
20-year average production cost ratio	73%	20-year average cash flow ratio	104%	Highest debt ratio	29%	End bank balance	-5 011 068

Scenario	5	With drainage - 25% debt ratio - 50% subsidy

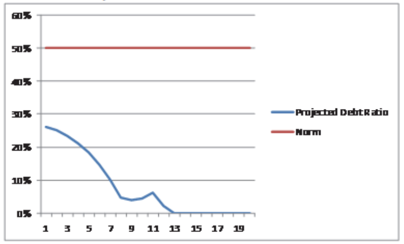
Production cost ratio



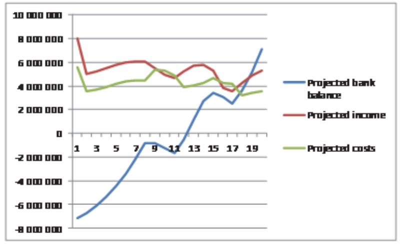
Projected cash flow ratio



Projected Debt ratio



Projected income, cost & bank balance



20-year average production cost ratio	73%	20-year average cash flow ratio	119%	Highest debt ratio	26%	End bank balance	7 104 524